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AEROSPACE
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Nuclear Rocket Redux

The U.S. has pulled nuclear propulsion from the dust bin of history. Can it succeed this time?

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AIAA
SHAPING THE FUTURE OF AEROSPACE

Recovery crews from NASA and the U.S. Navy approach the unoccupied Orion crew capsule that splashed down in the Pacific Ocean on Dec. 11, concluding the Artemis I test flight. During the 25.5-day mission, the Orion design's first in deep space, the capsule and its service module reached a distance of 434,000 kilometers from Earth, the farthest any human-rated spacecraft has traveled.

NASA

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IN THIS ISSUE

Keith Button

Keith has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns scandal that kicked off the global credit crisis. PAGE 20

Moriba Jah

Moriba is an associate professor at the University of Texas at Austin and chief scientist at Privateer. He helped navigate spacecraft at NASA's Jet Propulsion Lab and researched space situational awareness issues at the U.S. Air Force Research Laboratory. PAGE 64

Jon Kelvey

Jon previously covered space for The Independent in the U.K. His work has appeared in Air and Space Magazine, Slate, Smithsonian and the Washington Post. PAGE 30

Paul Marks

Paul is an award-winning journalist focused on technology, cybersecurity, aviation and spaceflight. A regular contributor to the BBC, New Scientist and The Economist, his current interests include eVTOL aircraft, new space and the history of notable inventors — especially the Wright brothers. PAGE 14

Debra Werner

A longtime contributor to Aerospace America, Debra is also a West Coast correspondent for Space News.
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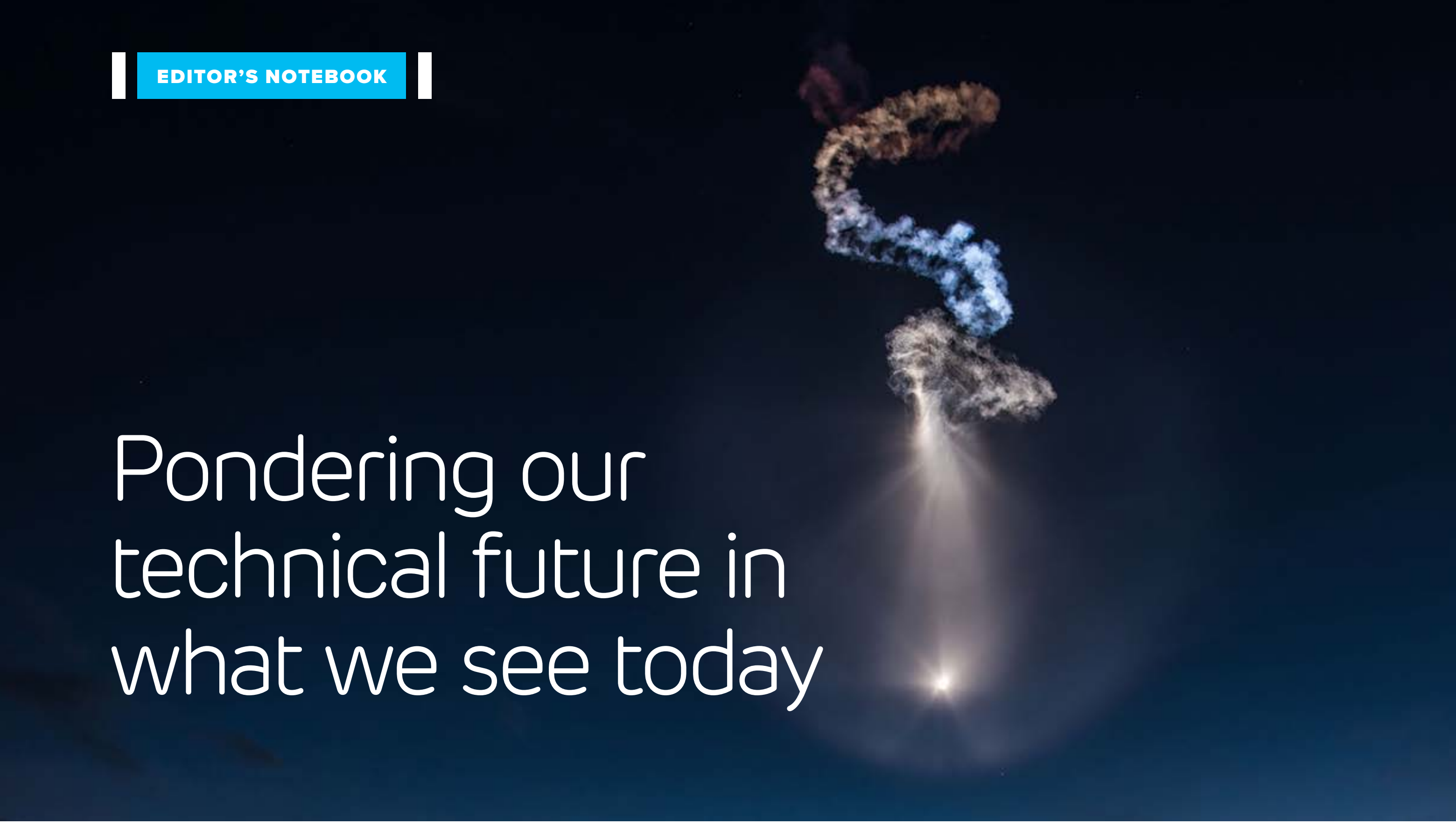
DEPARTMENTS

EDITOR'S NOTEBOOK



Pondering our technical future in what we see today

Most of us like nighttime space launches the best. Is that because of the light show? Maybe, but I suspect, or maybe hope, it's because that on the right night, we can literally watch a human machine pierce the cosmos. We have the sense at such moments that perhaps the best is yet to come for us Homo sapiens.

For me, a good space launch can spark a mental chain reaction. I wonder if out there somewhere other societies have lifted off. That makes me think about our technical progress and whether there is, in fact, only one optimal solution for each technical challenge and we are still a long way from finding them.

Since it's space launch that sparked this chain reaction, let's consider the challenge of getting people and equipment into space. Ironically, when I watch that exhaust plume, I somehow doubt that the most advanced societies out there are doing it like this: Sucking up ancient detritus, turning it into flammable liquid, lighting it and riding to space atop, potentially, dozens of the devices. Common sense but not a lot of evidence tells me that our heirs will look back on Starship and the other modern rockets as interesting steps in the right direction. Or maybe they'll just laugh. In any case, instinct tells me there must be a better way. The only question is which nation, corporation or university will find it.

Could nuclear fission be the answer? I want to say, "Now we're getting somewhere!" but the safety and environmental questions are enormous. As our cover story indicates, the focus right now is on nuclear fission for in-space propulsion. The idea is to turn the reactor on far from Earth, which might be safe, but of course won't work if your goal is to launch stuff from the surface. Perhaps the seeds of a more satisfying innovation lie somewhere in the U.S. Department of Energy's announcement last month about achieving fusion ignition as a step toward clean energy. Now we are getting somewhere.

So what about transportation from here to there on Earth? It might be silly, but I can imagine — and that's all it is — that out there somewhere, extraterrestrials are being whisked from point A to B in pneumatic tubes under their planet's surface. What about windows? Now that I'm in the aisle seat phase of life, this doesn't sound so crazy. Locally, though, I wouldn't be surprised if the extraterrestrials are bopping around in craft roughly like the electric-powered advanced air mobility designs we're beginning to see. These aircraft are a much greater departure from conventional aircraft than today's rockets are from their predecessors. Good for these pioneers. Best of all, even if only some of the promises come true, we won't have to be a lottery winner, billionaire or jauntily famous actor to fly in one.

Maybe when these innovators are done with advanced air mobility, they can take on space launch. ★

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

▲ Sunlight illuminates the exhaust of the Falcon 9 rocket that sent a Cargo Dragon to the International Space Station in 2018, creating a "jellyfish" plume for onlookers along the Florida Coast.

SpaceX

Busting the sonic boom

I wanted to comment on your article "Bye-bye boom" [November 2022, p. 22] regarding the NASA X-59 aircraft designed to reduce sonic boom. The author made this vehicle sound like it was completely revolutionary to have an aircraft designed to reduce the effects of sonic boom, when the Northrop/NASA SSBD [Shaped Sonic Boom Demonstration] program proved this capability back in 2003. I think a mention of this prior design and flight test success should have at least warranted a blurb in the article; credit where credit is due.

Michael Malone
AIAA member
Riverside, California

From the editors: *This is a good point. An article on the history of boom reduction would be interesting.*

CORRECTION

On page 29 of the December issue, we incorrectly identified the national affiliation of the Air Force Engineering University. It is Chinese.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The Power of Convening

Happy New Year! It certainly feels like 2023 is starting strong for the Institute. Our members and staff are planning our first event of the year – the 2023 AIAA SciTech Forum – when we'll gather in National Harbor, Maryland, 23–27 January, for what is proving to be the largest assembly of technical presentations we have ever offered. The Exposition Hall will be full of the leading companies in aerospace showcasing a range of transformative products and technologies, including some great new surprises. And we anticipate a crowd that rivals pre-pandemic levels. It's going to be an outstanding event!

The intensity of your energy and participation is exciting to witness. What is causing this renewed swell of activity? Most likely it's due to a combination of professional and human needs. As engineers and scientists, we need to move our community's interests forward. As human beings, we need to be with one another, having emerged from the pandemic when we had to refrain from gathering. We appreciate these chances to assemble now more than ever.

From the earliest days of our predecessor organizations more than 90 years ago, the convening of technical and scientific professionals to share knowledge and discovery has been one of our primary purposes. Back then we were establishing the foundation of our profession in aviation and space. Those who preceded us exchanged ideas, debated theories, and shared research results – always driving the profession forward. It is vital that the AIAA technical communities continue this in-person gathering for the personal feedback given and received from peers in our disciplines. We hone our craft with the input of others. It is the very lifeblood of AIAA events.

Today, AIAA convenes the international aeronautics and astronautics community frequently every year, with the same goals for our gatherings, while also offering the broadest combination of programs and opportunities for professional advancement than ever before. AIAA is continuing to deliver on our role – and our responsibility – to bring the community together.

One of the AIAA Core Values is resilience – we knew our in-person community gatherings would be coming back after the pandemic, although we didn't know the exact timing. Because human beings are social animals, we thrive on being together – whether we are introverts or extroverts. We depend on each other. Further, there is strength when we are together. As anthropologist Margaret Mead said, "Never underestimate the power of a small group of committed people to change the world. In fact, it is the only thing that ever has." Across the aerospace community, we have been changing society and the world, bringing benefits to everyone on Earth – and we must continue.

2022 ASCEND was a great example of the revived enthusiasm for in-person attendance at events. The crowd doubled from the previous year, to more than 1,100 people in Las Vegas. We heard from attendees that a few factors were key drivers for their in-person attendance: hearing from industry thought leaders, networking for collaboration, and holding business development conversations. Our first opportunity in the new year to gather with a focus on accelerating the space ecosystem will be at 2023 ASCENDxTexas in Houston, Texas, 29–30 March. We launched this in-person event during 2022 to a full crowd who were thrilled to assemble to drive momentum toward outcomes.

During the past year, we have been witnessing a shift in the meeting industry on the format of events, the specific content presented, and the overall curated experience. Meeting attendees are expecting a more immersive experience from events where they choose to invest their travel time and budget. AIAA's events are squarely in the midst of this transformational time, with the staff and volunteer members embracing the chance to invigorate our gatherings in dynamic ways. They continue to review forum and event attendee feedback after each one of our gatherings, focusing on continuous improvement to deliver the most meaningful experiences possible. You can count on AIAA events throughout the coming year to deliver the distinctive energy and experiences our members and our community need.

Consider this message a personal invitation on a professional scale. You are cordially invited to exchange ideas with one another, debate theories, and share your research results all year long. Bring your curiosity when you join your fellow AIAA members at forums and events. Dive into the awesome and awe-inspiring opportunities that are available to shape the future of aerospace. Let's start strong and finish stronger in 2023. ★

Dan Dumbacher
Executive Director
AIAA

AERO PUZZLER

Email us at aeropuzzler@aerospaceamerica.org

Napoleon in sunglasses

Q: A fantasy novel protagonist, who is fluent in French, has snapped back to modern times after carrying two polarized sunglasses on a trip to France in the early 1800s. The protagonist rushes into an art museum to see if the mischief during the trip worked. Sure enough, Napoleon on horseback is now wearing sunglasses. What French physicist, military officer and contemporary of Napoleon did the protagonist visit to help him scoop Edwin Land by over 100 years? What demonstration did the protagonist do with the sunglasses to show the physics at work? Answer in English. Googling is allowed.

SEND A RESPONSE OF UP TO 250 WORDS that someone in any field could understand to aeropuzzler@aerospaceamerica.org by noon Eastern Jan. 18 for a chance to have it published in the next issue.

Scan this QR code to get a head start on the February AeroPuzzler

FROM THE DECEMBER ISSUE

RUNAWAY PLANE: We asked you to review a fictional screenplay about a conventional airliner going supersonic. Your answers were reviewed by AIAA Fellow Jim Kuchar of MIT's Lincoln Laboratory, who provided the idea for this question.

WINNER Groundspeed is not airspeed. A sonic boom occurs when an object moves through the air faster than sound can. The ratio of the speed of an object through a fluid divided by the speed of sound in that fluid is known as the Mach number. Above Mach 1, pressure waves cannot move as fast as the object, build up like the bow wave of a fast-moving boat and reach the ground simultaneously as a "boom." Mach number ignores any velocity the object and fluid share. Therefore, it does not matter what the tailwind is for our fictional airliner. Unless the pilot changes his throttle or altitude, his Mach number is constant and there is no danger of a sonic boom, despite the tailwind giving him a large increase in groundspeed. In 2019, a Boeing 787 Dreamliner broke the airline groundspeed record at 801 mph [1,289 kph]. This may seem supersonic, given the speed of sound in ambient air is 740 mph [1,191 kph]. However, that plane had entered a similarly record-breaking 230-mph jet stream. To set that record, it would have only had to fly at 571 mph inside the jet stream (around Mach 0.8, or 80% of the speed of sound), which is only 10 mph above its cruising speed. With a top airspeed of 587 mph, it would be impossible for a Dreamliner — or any other current airliner — to go supersonic in level flight.

Jeffrey J. Mach, AIAA senior member
Santa Clara, California

Jeffrey works for Sierra Lobo Inc. as a site manager at the Thermophysics Facilities Branch of NASA's Ames Research Center.

Beta Technologies in December completed the second multileg journey of the year with its Alia SN1 electric aircraft. The six-day journey ended in Louisville, Kentucky, where U.S. Transportation Secretary Pete Buttigieg got an up-close look at the aircraft.

Beta Technologies

Buttigieg meets Beta Technologies' electric aircraft

BY PAUL BRINKMANN | paulb@aiaa.org

Beta Technologies' piloted test flight from upstate New York to a cargo warehouse in Louisville, Kentucky, that concluded in early December required minimal special accommodations or airspace clearances, prompting one of the pilots on the journey to say such flights have become routine.

Lochie Ferrier, a pilot and engineer with the Vermont-based company, was one of two flyers who alternated in the cockpit during the six-day journey that began in late November and covered 1,410 kilometers. Beta has a Special Airworthiness Certificate from FAA, which allows demonstrations and crew training.

"We were able to move it across the country in real winter weather, which is pretty brutal flying weather, in a fairly short time," Ferrier says.

The SN1, with an empty cargo hold, carried only its pilot.

The primary purpose of the flight was to position the aircraft at a United Parcel Service cargo facility so that UPS could show it to U.S. Transportation Secretary Pete Buttigieg, whose agency includes FAA, during his scheduled tour there on Dec. 6. UPS says it intends to purchase 150 Alia aircraft starting in 2024, but Beta has yet to receive FAA type certification.

Buttigieg viewed the aircraft at Louisville Muhammad Ali International Airport. Beta says he spoke with founder and CEO Kyle Clark about electric aviation, the journey to Louisville and the company's propulsion system and charging infrastructure.

A secondary purpose was to continue learning about Alia's systems, especially battery recharging during long flights. During the flight, a snow shower in New York grounded the flight for a day and a half.

"It's an experimental aircraft, so we treat these prototypes with kid gloves, and we eliminate as much weather risk as possible," Ferrier says.

The SN1, an electric vertical takeoff and landing aircraft, has a lift-plus-cruise configuration with four vertical lift rotors and a single rear propeller for forward motion. But Beta pilots flew the aircraft in conventional mode to Louisville, with the vertical lift rotors locked in aerodynamic position. Beta says that's because its current focus is proving battery performance and charging throughout longer-range flights.

Ferrier says the biggest lesson learned was how to smoothly recharge the plane, which was done by Beta pilots and other employees. Twice, batteries were recharged in less than an hour. The longest charge period was just over two hours. In most cases, charging was done at permanent stations established by Beta, although temporary charging stations were deployed three times.

As for the actual flight, Ferrier says the Alia is relatively easy to fly, compared to the Cessna Caravan chase plane that also made the journey.

"You basically take off and set the power for cruise, and then all we're doing is holding an altitude and navigating to where we want to go," he says. "We're not up there fiddling with how many electrons are flowing into the motor or something." ★

Meet your candidate for president-elect

MEMBERS VOTE
Feb. 1-17

DANIEL E. HASTINGS

CURRENTLY: Since 2021, associate dean of engineering for diversity, equity and inclusion; since 2019, head of MIT's AeroAstro Department; since 1993, a professor of aeronautics and astronautics.

NOTABLE: A plasma physicist-turned-college professor; has taught successful students, including former AIAA president Mark Lewis and current AIAA Board of Trustees member Annalisa Weigel; Born in Charnock, England, and grew up in Jamaica and England; Became a U.S. citizen in 1984 and joined the MIT faculty in 1985 as an assistant professor; In the 1980s and early 1990s, helped design the power system for what would become the International Space Station; Worked on the ion engine portion of the Hughes 702 satellite bus that became a Boeing product; Air Force chief scientist, 1997-1999; Investigated fusion technology at Oak Ridge National Laboratory in Tennessee.

AIAA RECORD: Became an AIAA Fellow in 1998 and an Honorary Fellow in 2021; Received AIAA's Losey Atmospheric Sciences Award in 2003 for studies on the interaction of space plasma with high-voltage solar arrays; Served on the Space Sciences and Astronomy; Space Systems; and Plasmadynamics and Lasers technical committees.

AGE: 67 on Jan. 14

RESIDENCE: Bedford, Massachusetts

EDUCATION: Bachelor of Science in mathematics, Oxford University, 1976. Master of Science in aeronautics and astronautics, 1978, MIT. Ph.D. from MIT in 1980.

FAVORITE SAYING: "We are what we repeatedly do. Excellence, then, is not an act, but a habit." — Aristotle

Ben Iannotta: Tell me about growing up in England and Jamaica and how you got into this line of work.

Dan Hastings: I actually grew up between England and Jamaica. When I was 10, my parents moved to Jamaica from England. My father was a dentist, so he went to set up a practice. So, I actually grew up in England and then Jamaica and then back to England. The way to understand me as a kid is that I was fascinated by space. I could see it in two different ways. One was Star Trek: The Original Series. I watched every new episode. And Neil Armstrong and Buzz Aldrin landed on the moon. Those were very motivating for me. I wanted to do something in space. At one point, I wanted to be an astronaut, and I knew I had to go and do something in the STEM area, so I ended up studying mathematics. When I finished undergraduate school, I applied to graduate school to do aeronautics and astronautics, with particular emphasis on astronautics. The trouble was it was 1976. As the former department head said to me, "You're six years too late." There wasn't much going on in the space business. Shuttle was being developed, but it hadn't flown. Space station was just a dream. I ended up working in the energy business, which is how I got into plasma physics associated with both magnetohydrodynamic power generation and also fusion. When I finished at graduate school with a Ph.D. in plasma physics, I went to work for a company called Physical Sciences which was then in Woburn, Massachusetts. I worked there for a while doing contract research. It was basically applied physics. And then I went to Oak Ridge National Lab, where I worked on the fusion energy program. In 1985, I decided I wanted to really focus on space, and I also wanted to teach and interact with students. MIT offered me a position as an assistant professor in the Department of Aeronautics and Astronautics, so back I came to MIT. And of course, what had happened was that the shuttle was flying, the space station had been announced and there was this Strategic Defense Initiative. That's when I joined AIAA, in 1985.

How was AIAA helpful to you?

It was the conferences and the technical committees. What's now called SciTech, and what's now called ASCEND, going to those conferences is where you heard interesting work in the space business. You met interesting people, particularly at NASA and the Department of Defense, the Air Force. There was no Space Force then. The conferences were mechanisms to hear interesting ideas, as well as to present your own ideas.

Did you do research as well as teach?

Yes, I got NASA funding initially. Some of the NASA funding came from the Strategic Defense Initiative. They funneled it through NASA. But it was all initially NASA funding, and a few years later, I got some Air Force funding. All associated with looking at issues in space: I looked at plasma interactions with satellite surfaces. I looked at electric propulsion issues for satellites. I was doing lots of research.

Each AIAA president-elect helps guide the institute, first as a member of the Board of Trustees and then as president beginning a year later. During this round of elections, Dan Hastings of MIT is running unopposed and in May is due to become the first Black president of AIAA. I spoke to Hastings about the importance of diversity, his personal experience with racism and his vision for AIAA. As for how AIAA can achieve growth, this teacher says he has come ready to learn before making recommendations. — *Ben Iannotta*

THE ROLE: In May, Hastings begins a one-year term and becomes a member of the Board of Trustees, followed by two years as president starting in May 2024.

In your statement of goals, you talked about engaging with youth as a top priority. How does one do that now? I don't remember how old you were in 1985, but you were probably a young professional.

I was 29. One of the things that's substantially different today than when I was starting out was that the aerospace business was dominated by the big primes, the Boeings of the world, dominated by the government. It's hugely different today. What has happened is this enormous burst of entrepreneurial energy. You still see the big primes — and of course many of them merged — but you see the growth of all of these companies, many of which are small, but some of which are very well resourced, like SpaceX and Blue Origin. And you see the growth of lots and lots and lots of small companies. That's the first thing. The second thing is that across government, there's a much broader understanding of what aerospace brings. Even beyond the government, you see a much broader understanding. It's just hugely different in that sense. You see people doing interesting things with UAVs, some positive and some negative. It's a much broader environment than when I started.

What does that drive AIAA to do?

First of all, recognize that. But secondly, AIAA has to be able to articulate its value proposition to the engineers in a 40-person company that is starting up to build a rocket, not at a 10,000-person major prime or whatever the numbers are. Boeing has many more than that — over 100,000 people. The other thing, of course, is that even across the government, the range is much larger now. So AIAA has to recognize its much broader framework and then ask the question for each of the different demographic segments: What's the message that resonates? What's the value that AIAA brings? I think you see that very clearly in ASCEND, which is doing a good job of being much broader than the thing it replaced. It's attracting startups. It's attracting people with MBAs as opposed to technical degrees. It's attracting a much broader spread in the government, as well as the big primes and the traditional people. So, that's the sort of thing that needs to happen right now. Another thing that has changed very dramatically since I started is a much broader recognition of the value of STEM degrees. It's kind of exciting, especially with all this entrepreneurial energy. AIAA has to articulate its value proposition to K-12, undergraduates, graduate students, people who go work at startups, people who work for the primes, people who work for the different parts of the government that are now interested in aerospace.

You should know how to do that, being a teacher.

I have some understanding about how to do that.

I want to talk a little bit about diversity. I'm curious what you know about your family history, how your ancestors came to England.

My father was actually born in Angola. His parents were missionaries in Angola, so he was born there. His parents were from Jamaica, so as a young man, after he finished his dental studies, my father returned to Jamaica and met my mother. At some point, they decided to return to England, which is why I was born in England. You know, in my family, my father was a dentist, my uncle was a surgeon, my aunt was a general practitioner, my grandfather was a missionary, but he was trained in anthropology. He actually had a Ph.D. in anthropology. For me, when I was growing up, there was simply no question that I would go to college, or certainly undergraduate school. Within the context of my family, I think I was expected to go more the doctor, minister route, but I decided I didn't want to go that route. I was interested in space. I had to go the route of doing a STEM degree.

Have you researched your heritage? Do you know when your relatives left Africa or how?

Oh, my son has, and he's constructed a fairly substantial genealogy, which I've looked at on occasions.

So flashing forward, in the United States, former NASA Administrator Charlie Bolden has talked openly about how hard it was for him to get an appointment to the Naval Academy from South Carolina in the '60s. What was it like for you entering this field as a Black man in England and Jamaica?

Certainly, as a kid growing up in England, I heard all the usual stuff — about being called various names. And people are just surprised that I did as well as I did. There's no point in repeating some of the names, but you could probably guess what some of them were, right?

The worst ones I could think of?

Yeah, exactly. So you know, I had all that in England growing up. But I ended up doing well at school, and I was actually able to get into Oxford. And actually, when I went to Oxford as an undergraduate, I was one of the very few what today you call an African American, but in England they called it something different. That was actually, as you can guess, very isolating and lonely. Then I decided when I finished

"I have a certain lens on AIAA, … it's a traditional lens, and it's kind of the lens of somebody who has benefited as a professor working with students. There's nothing wrong with that, but I appreciate there's a broader perspective."

my undergraduate degree that I wanted to get into the space business, and at that time in England there was not much going on in the space business. There's a lot more now, but there wasn't very much then. That's why I decided to leave England and come to America to — seek my fortune [laughs] — at MIT as a graduate student. I would say MIT is the kind of place where you make do on the quality of your intellect. So actually, MIT as a graduate student was a great place to be. I ended up making some very good friends over the years, some of them I'm still in touch with, actually, and I had a very good, supportive experience. I can't say I believe I experienced any kind of discrimination as a graduate student. And it wasn't as isolating as it was as an undergraduate, because there were many more Black people around, both in the town of Cambridge and also at MIT.

You will be AIAA's first Black president. What's the meaning of that for you?

Well, for all the people like myself who do that kind of thing, I understand and appreciate that people will look to me as a role model, and I'm glad about that. I will do my best. My colleague, Sheila Widnall, who was also an AIAA president, is in my department at MIT.

I saw she nominated you.

She did. She was also the first woman president of AIAA and, of course, she was the first [woman] secretary of the Air Force, and so on. So she had to do a lot with being the first. In that sense, I understand that being the first has meaning, and I will do my best to attract young people to consider joining the AIAA and contributing to its mission.

When you talk, about diversity, equity, and inclusion. What are you talking about there? Ethnicity? Gender?

Well, that of course is one of my jobs. I'm the associate dean for D-E-I. What it means is we want everybody who is capable of contributing to — in this case engineering — be able to achieve whatever level they want to achieve based upon their talents, not based upon anything else. We want people to feel that they belong in engineering. You have to make sure you remove all the barriers that have hindered people from moving forward to the level they want to. So what are some of the barriers? Certainly, if you look at aerospace engineering and you talk to enough women, you'll discover that over the years, women were often excluded from being in aerospace engineering. You just have to go look at the movie "Hidden Figures." You see it very, very clearly there, some one of them being told, "You can't be an engineer because you're a woman." That's the kind of thing we have to get rid of.

Is it just an ethical issue, or is it beyond that?

I first of all think it's an ethical issue. We want people to contribute as much as they can wherever their talents take them. That's also true of African Americans and Latinos, women and people with diverse sexual orientations. All those barriers need to go away. All those biases need to go away. That's an ethical issue. It's getting rid of those barriers, which only exist because of people's prejudices. Now, it is also the case, and I see this very clearly since I'm in a university, that the demographics of the population in the United States is shifting. You see much larger ethnic diversity in the 18-year-old population than you see in the 70-year-old

population. You see many more women now going to college — actually, women are now the majority of people who go to college as compared to when I started. So in addition to being an ethical issue, it's also a question of: We want to get the best talents to work on the problems of aerospace, both the issues of national defense, national security, but also the issues of how we treat this planet and sustainability and all of those things. There's lots of studies which have shown that having diverse groups address all of those problems will, many times, lead to better solutions than not. So it's an ethical issue to start with. I think of it that way. But at the end of the day, it's people who come up with solutions. Let's make sure we're pulling in the best people to come up with those solutions.

In your role as associate dean of engineering for DEI, what are some of the things you've done?
I'm very proud of the fact that we created a postdoc program in the School of Engineering to attract outstanding postdocs who were underrepresented. We have attracted a good group of those people, and they're working away and doing their postdocs at MIT. Some of them will go out to do startups and that's great. We're seeding those populations with the talent that's out there.

Do any of your experiences as the associate dean apply to your coming role at AIAA?
Yes. So, the reason we created a program was because the dean and I took a look at both gender and ethnic diversity of the postdocs in the School of Engineering, and it was terrible. The reason it's terrible is because the decisions on whom to bring in — there was nothing strategic about them. They're all decisions made individually at the tactical level. So, just being strategic about it, we've managed to make changes. The AIAA is a big organization, but you can't do everything. Whatever you do, you've got to do with quality, but what I would like to do is take a big-picture view and focus on a few things. When I went to be chief scientist of the Air Force, one of the previous chief scientists said to me, "Focus on no more than three things. In an organization that big, if you try to do too many things, you'll get nothing done. If you get two of them done, you've done well." That's what I did.

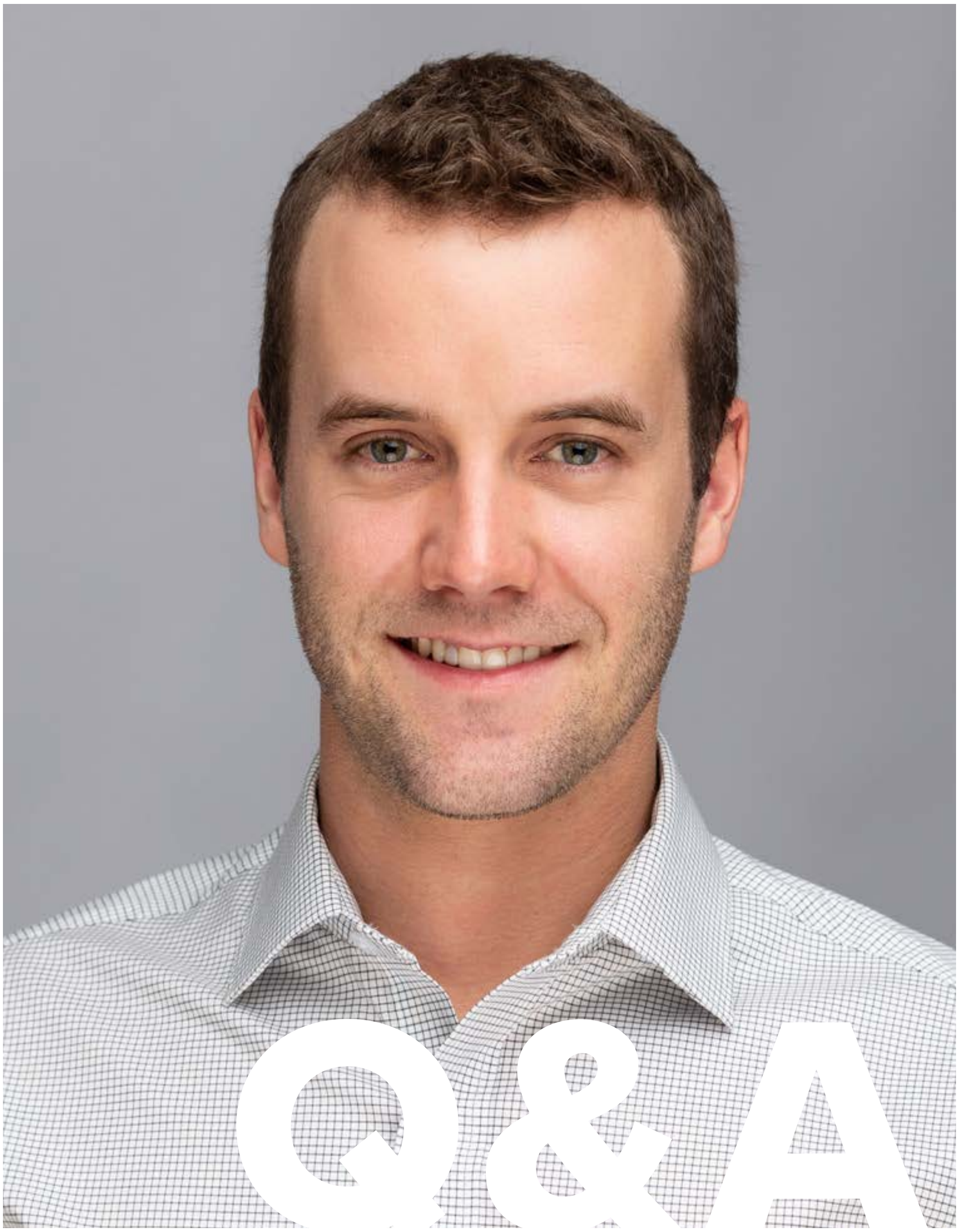
So you're going to be highly focused at AIAA.
Yeah, I got to figure out what the three things are, though, right? When I went to be chief scientist of the Air Force, I was able to figure it out because I was talking to the chief of staff and the secretary of the Air Force. So we figured out the three things, and I actually got two of them done.

Is there anything that you're surprised I haven't asked, or that you want to circle back on?
I will have to find out, or sort out, what did the previous presidents do right and what did they not do right. Learning that will be instrumental.

There may not be one opinion on all those.
I understand. I've talked to several of the previous presidents, because I know some of them pretty well, actually. I know Sheila [Widnall] well. I know Mark Lewis well.

What do you think would mark a successful presidential tenure?
For any organization, you have to understand the tenor of the times. As you yourself pointed out, my entrance into AIAA was kind of the traditional way, so I would say I can help the organization understand the current tenor of the times and be reflective.

AIAA, like many institutes, faces declining membership and financial challenges coming out of covid-19. Can you help make a dent in that?
That's why I keep emphasizing the articulation of the value proposition. You want to get people wherever they are to say, "Yes, joining this professional organization is something that will help my career, and I can contribute." ★



AeroVironment

Martian aviator

Even before the now-famous Ingenuity helicopter made its first flight on Mars in 2021, Ben Pipenberg and his colleagues at drone maker AeroVironment began thinking about the next iteration of the aircraft whose airframe and rotor system they built. Knowing about the plan to bring samples of Mars back to Earth, they conceptualized and prototyped a helo with a gripper capable of grasping sample tubes, and demonstrated a model of this "advanced Mars Sample Fetch helicopter" to the NASA-funded Jet Propulsion Laboratory. The name was an obvious play on the NASA-European plan to send a Sample Fetch Rover to Mars, a plan that was abandoned last year in favor of sending two helos to Mars to retrieve the samples not collected by Perseverance. As of mid-December, NASA was assessing proposals. I reached Pipenberg by Zoom to discuss the company's concept. — *Paul Marks*

BEN PIPENBERG

POSITIONS: Since June, program chief engineer of AeroVironment's effort to create potentially multiple helos to retrieve some of the samples left on the surface of Mars by NASA's Perseverance rover; 2019-August 2022, chief engineer of a military drone program AeroVironment isn't permitted to name; 2017-October 2022, design lead and chief engineer for AeroVironment's fabrication of the rotor system and primary airframe structure for NASA's Ingenuity Mars Helicopter; 2014-2017, aeromechanical engineer at AeroVironment.

NOTABLE: Started his career at AeroVironment in 2009 as an engineering intern working on the Nano Hummingbird, later named one of TIME Magazine's 50 best inventions of 2011. Part of the NASA and Jet Propulsion Laboratory Ingenuity team that was awarded the 2021 Collier Trophy for demonstrating the first powered flight on Mars.

RESIDES: Los Angeles area

AGE: 33

EDUCATION: Bachelor of Science degree in aerospace engineering, Pennsylvania State University, 2011

Q: How long has AeroVironment been working on NASA's Mars helicopter program?

A: On Ingenuity, we started working with JPL very early on, initially in the late 1990s, early 2000s. There was some very initial, conceptual work that ended up not really going anywhere, but AeroVironment was involved in putting together some of the concepts for very early rotorcraft designs. And then, around 2012 or 2013, Bob Balaram, chief engineer for JPL's Ingenuity program, approached AeroVironment about starting work again on a small rotorcraft to demonstrate the utility of aerial robotics on Mars. And so, from pretty early on AeroVironment was doing the design and conceptual work on what would eventually become Ingenuity. After the early conceptual design work, AeroVironment was involved all the way through, designing, developing and building basically what we would call the airframe, the rotor system and the propulsion systems. That's Ingenuity's primary structure, the rotor blades, the landing gear system and the box on the bottom — that we call the helicopter's warm electronics box — plus the structure for the solar array, the propulsion motor, the servos and all the linkages and swash plates that control the rotors.

Q: What was it like to see the aircraft you built placed on the surface of Mars by the Perseverance rover in 2021?

A: It's pretty incredible. You go outside at night and you look up in the sky and you can see Mars, and you know, conceptually, that's a couple hundred million miles away. And then you go inside and you look at the images that are coming down from Ingenuity or of Ingenuity being taken by Perseverance, and it's really hard to wrap your brain around just how far away it is. We were working on the helicopter for years — we were all handling all of these pieces that have been in our labs, on our benches, so we're very familiar with it. Seeing it on the surface of Mars in this very, very alien environment is absolutely amazing.

Q: And what about when it spun up its rotors and flew on Mars for the first time?

A: In some ways, we had a lot of confidence. We had done an enormous amount of testing on this thing. This was basically the fourth helicopter that had flown in a Mars-like environment in the space simulator at JPL. So in some ways, it was completely unremarkable to us: It looked just like what we had been seeing. Except, of course, it's on Mars! It was pretty surreal, I think, for everybody. It was the culmination of years and years of work, and a lot of overtime, a lot of nights and weekends for everybody. So yeah, there were a lot of happy tears about that.

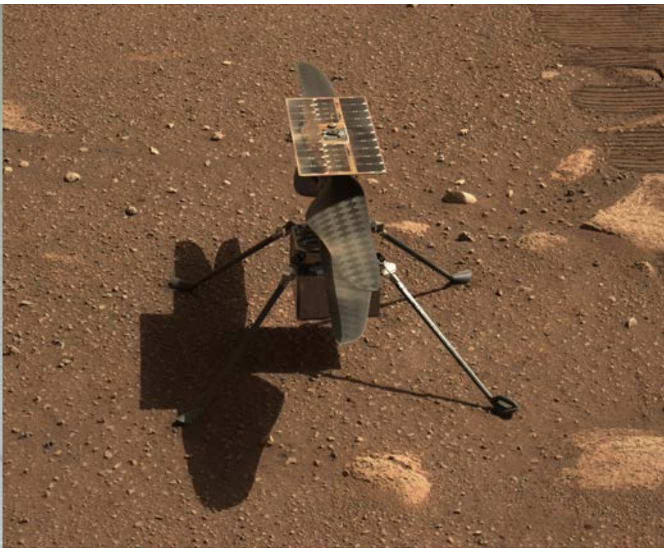
Q: What motivated your team to hatch the idea of the upgraded Ingenuity-class Mars helicopters for Mars Sample Return?

A: That concept was developed as a sort of tertiary backup. Perseverance, of course, is the primary means of getting samples to the Sample Retrieval Lander.

Plans call for Perseverance to backtrack to collect samples and deliver them to the Sample Retrieval Lander after its arrival in 2030 along with a Mars Ascent Vehicle. That rocket would boost the samples into orbit to rendezvous with the planned Earth Return Orbiter. The samples would land in Utah in 2033 (subject to ongoing back-contamination and environmental risk assessments). — PM

The backup to that was the Sample Fetch Rover, the small European rover. And then we were looking at the recovery helicopter as sort of a tertiary backup, either deployed from the backshell [of the Retrieval Lander] during entry, or maybe stowed on the lander somewhere. Of course, the last eight months or so have kind of reordered things significantly. It's a single lander solution now when it had previously been two landers.

"Precise positioning with just the aerial mobility system is likely possible, but it's pretty difficult. It's easier to develop a system which can very precisely position the vehicle down to millimeter kind of resolution on the surface, using a wheeled mobility system."



▲ In designing its sample recovery helicopter (an early model is shown at left), AeroVironment kept many of the design elements from the 1.8-kilogram Ingenuity helicopter, pictured at right on the surface of Mars days before its first flight in April 2021. The biggest changes are the addition of wheels for precise maneuvering up to caches of samples stowed on the Martian surface, and a robotic arm for retrieving multiple sample tubes, shown here stowed horizontally along the model.

AeroVironment

Q: What's the idea in giving the new helicopters motor-driven wheels?

A: Precise positioning with just the aerial mobility system is likely possible, but it's pretty difficult. It's easier to develop a system which can very precisely position the vehicle down to millimeter kind of resolution on the surface, using a wheeled mobility system. You can move much slower — and you can take your time to do that.

Q: What kind of sample tube pickup scenarios will that be useful for?

A: It's really just for the last meter or 2 meters — so in this case, you land near your sample, and then you drive right up to it. The other reason is so that we don't need to fly near the landed asset: the Sample Retrieval Lander with the MAV on it. We can land a couple of meters away and then drive up, which obviously is a much lower kinetic energy approach.

Q: Why stand off from those assets? Worried about damage to the MAV?

A: With Perseverance in particular, there's no good scientific reason for Ingenuity to ever come close to it. It's an unnecessary risk. And so with the Sample Retrieval Lander, that's not necessarily the case: We have to get the sample tubes right up to the lander so that the [lander's] sample transfer arm is able to pick those samples up off the ground and put them into the MAV. And so we do need to interact with the lander, but doing that in the safest way possible, of course, is desirable. And if we're on wheels, rather than spinning our rotor blades at 2,800 rpm, that's seen as a safer approach.

Q: It can be minus 60 degrees Celsius on Mars. What stops the motors from simply freezing up?

A: On Ingenuity, the primary propulsion motors were designed, developed and built at AeroVironment. The materials and the thermal design of the motor are pretty unusual. We use some exotic alloys in there, such as AlBeMet — an aluminum beryllium metal matrix — for the heatsink. The lubricants used are designed for very low temperature operation, with very low outgassing, which is really important for operation in a vacuum.

Q: That's way beyond conditions for unoccupied aerial vehicles on Earth. How did you predict what you'd need?

A: The motor design was pulled, indirectly, from AeroVironment's experience with very-high-altitude pseudo satellites — the HAPS programs everyone's working on. The atmospheric temperature on Mars is actually pretty similar to where, for example, Helios, an AeroVironment-designed aircraft, flew.

Helios was a remotely controlled, ultra-lightweight solar-electric flying wing built for NASA. Driven by 10 electric propellors, Helios was flown at high altitudes to test the use of unoccupied aircraft as communications platforms, and in one record-breaking flight in 2001 reached an altitude of 96,863 feet. Helios broke apart and crashed into the Pacific Ocean during a 2003 test flight due to turbulence. — PM

That flew at 99,000 feet above ground, and the atmospheric temperatures there are very similar to where Ingenuity actually operates on Mars. We fly at about minus 40 degrees C, and it's about one one-hundredth of the atmospheric density at sea level here. And so that's a pretty similar environment, actually, and we were able to pull lessons learned from the HAPS and Helios programs into the design of those motors.

AeroVironment built this full-scale test article of its sample recovery helicopter and drove it over a sandbox filled with different sized rocks and dirt to help determine the best wheel design for maneuvering the Martian terrain. The company also prototyped various versions of a robotic arm, shown here clutching a representative sample tube. AeroVironment is designing the helicopter to carry up to four 70-gram sample tubes.

AeroVironment

Q: What do you need to do to keep Martian dust out of the wheel-drive motor at ground level?

A: All of the motor systems are either sealed or shielded. The primary propulsion motors have Teflon seals, the servo actuators that drive the swash plates have spring-energized Teflon seals. And those go through quite a bit of testing to make sure that they're robust to the dust environment.

Q: Moving on to the next amazing thing about the new helos: your addition of a robot arm and gripper to the helicopter. What engineering issues does this present?

A: First of all, AeroVironment has been working on this on our own internal research and development funding. But what that arm is going to look like, and who's going to be developing it for the Sample Recovery Helicopter, is still very much in the works.

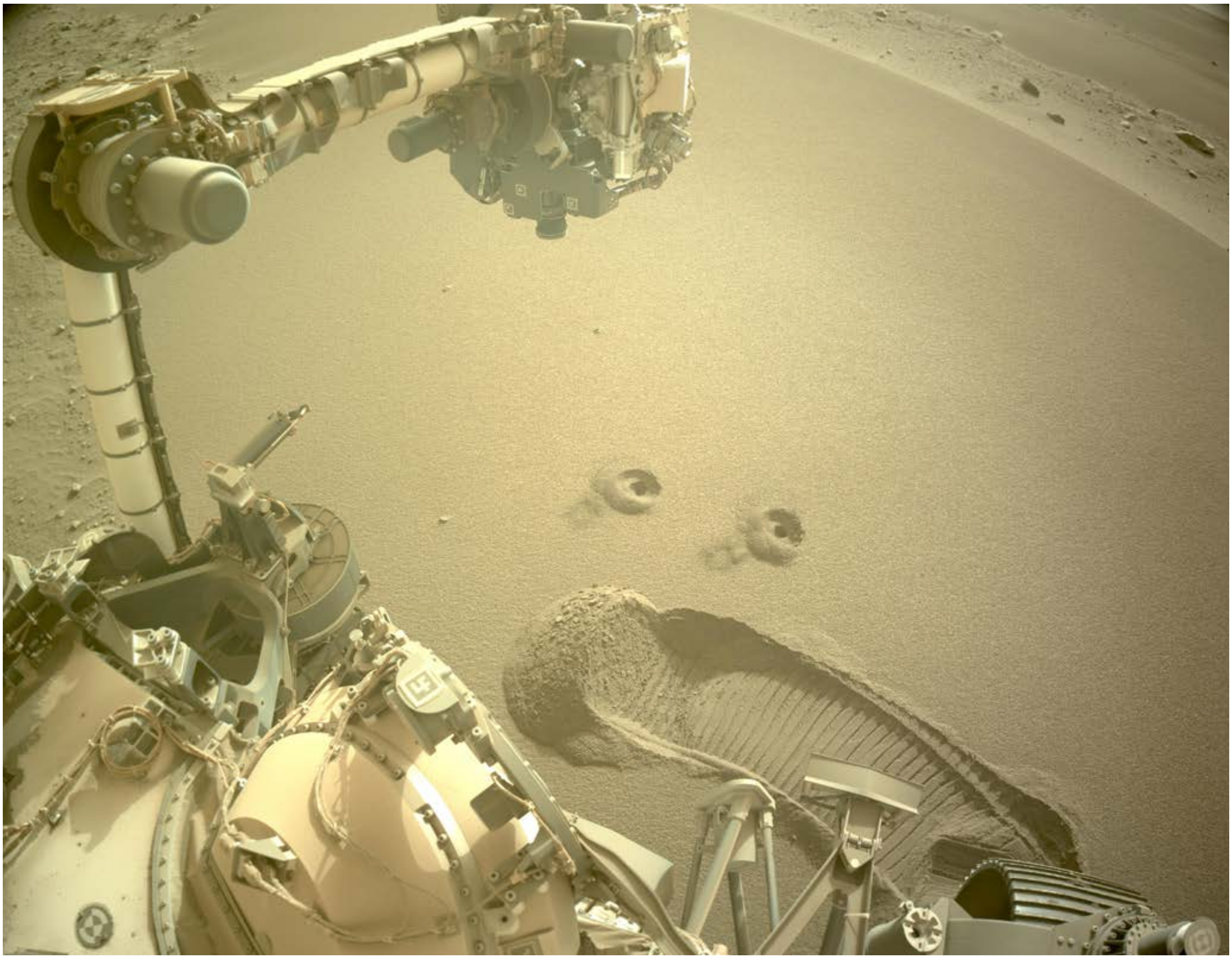
Q: So the robotic arm work could be performed by another contractor?

A: It could, right. JPL is going to be leading the integration on that. We do not have a contract for that. But what I can say from our work on it over the last year and a half is that mass is always at a premium with these helicopters. They're extremely sensitive to carrying any dead weight, so they really need to be optimized for mass. And so these manipulators and the arms — what JPL is calling the placement mechanisms — are going to have to be extremely highly optimized. And in particular, the loads these things see are really pretty high due to launch on a rocket, something that you really don't think about.

Q: By "loads" do you mean pulling Gs on liftoff?

A: Yes, exactly. The loads that these [robotic arm] mechanisms see when the engines initially ignite. And the first couple of seconds when they're coming off of the pad are very, very high. Those are by far the highest loads that the gearboxes and actuators ever see. So it's kind of an unusual design for an arm: Not only does it need to work in the very austere Martian environment, but it needs to take these very rough loads during launch.

Q: Why is it such a complex arm? In your paper presented at the 2022 IEEE conference, it is shown with two elbow joints.



▲ NASA's Perseverance rover collects two samples of Martian rock and regolith in early December in this photo taken by one of the navigation cameras on the rover's mast. One of those samples, encased in a tube, may be left in a cache near the delta of Jezero Crater for retrieval later this decade by Perseverance or one of the Sample Recovery Helicopters NASA's Jet Propulsion Laboratory is developing.

NASA/JPL-Caltech

A: We worked on a handful of different versions of that arm. I believe the one that we showed there has two joints up at the shoulder. So there's kind of a rotation about the vertical axis of the helicopter, there's the up and down, and then there's the elbow, and then there's actually a wrist mode as well, so it can rotate down. So that one's a four-degree-of-freedom arm, and then the gripper is on the end of it. So this is picking up just the tubes that Perseverance drops onto the surface. In the IEEE paper, I showed a few pictures of it kind of putting the tube into a docking mechanism, where it can hold it securely during flight. And then the helicopter basically drives up to the lander, releases the tubes and places them on the ground in front of the lander.

Q: I understand the new helos will have different batteries. Was there something wrong with the one on Ingenuity?

A: It's kind of funny, but these science programs that we send to space, we have to baseline the technologies really pretty early on so they can go through the test campaigns, actually get fabricated into the helicopter, go through all of the integrated tests with the rest of the spacecraft system, and then actually launch to Mars. And so by the time it is actually operating on Mars, it's well out of date. And Ingenuity is using battery technology from almost 10 years ago. There have been significant advances in lithium batteries since.

Q: I'm surprised that you can use off-the-shelf technology at those super-frigid temperatures.

A: That whole box on the bottom of Ingenuity is heated with conventional Kapton resistive heaters at all times. A lot of the energy from the battery is actually just used to keep itself warm, overnight and during the day. That strange color on the box, that kind of grayish color, that's a very specifically tuned optical surface to collect solar energy to warm that battery and to prevent it from radiating heat. It's called a selective surface. So quite a bit of effort goes into making sure that we can keep those batteries warm at all times.

Q: Have the seasons on Mars affected Ingenuity's ability to keep its electronics warm enough?

A: What's been happening is that because it's winter and there's a lot of dust in the atmosphere, the [solar] energy on Mars has been so low and the temperatures have been so cold at night that we are not able to keep Ingenuity warm overnight. It actually does get cold and so cold that the helicopter shuts down every single night and then restarts the next morning. And we've been operating like that continuously now since early May.

Q: How long does the solar-powered restart take?

A: It's a couple of hours. By about noon, things are warm enough that we can communicate with the helicopter, and it wakes up again. But that is not standard operation, right? We never intended for Ingenuity to operate in winter; it was originally designed for 30 days of operation from April 2021. And so we're kind of as shocked as anybody that it's been able to survive in this in this very, very low power state and that it's still able to operate.

Q: Ingenuity is called a helicopter and not a drone because it has rotors with both collective and cyclic control. Will the Sample Recovery Helicopters operate similarly?

A: Yes, that is likely going to be the case. In the IEEE paper, we were proposing putting just collective on one of the two rotors and cyclic on only one.

Collective pitch control means the rotor blades can be angled equally and simultaneously to produce vertical up/down motion; cyclic blade pitch control angles blades individually for forward/backward, nose up/down and roll control. — PM

Actually, the first full-sized helicopter that we flew in May 2016 in the space simulator at JPL only had collective on one rotor and collective and cyclic on the other. It was being proposed in that paper as a mass saving.

Q: Because you'd need less metal to manipulate the rotors?

A: Yeah. Basically, we now have a lot of information about flying on Mars. And so that was one of the things that we're proposing, but it's not clear whether or not that's going to happen. There's a bit of an argument, at all times, between control margin and mass: If you can reduce mass, you can carry more other stuff, like make the [robot] arm heavier or whatever. But of course, control margin is important for just the basic stability when you have any kind of a disturbance, like wind or anything like that. And so what we're saying is that we only need collective on the upper rotor, we don't need cyclic, but that's TBD.

Q: Whatever happens, will the motors spinning those rotors be any different on the new helos?

A: Absolutely. These motors are a little bit unusual. Our flight time is relatively short: Three minutes lets us do what we need to do. But the environment on Mars, that very low atmospheric density, means that we don't get very effective cooling. In fact, we're assuming that we don't get any cooling at all, because we have these motors sealed against dust. It's a very strange operating condition because with Ingenuity, the maximum flight time was actually limited by overheating the motors. We're starting with these motors very cold, well below freezing. But by the end of the flight, they're hotter than 100 degrees C. And so in the case of the Sample Recovery Helicopter, the motors are being redesigned to accommodate that higher mass [of wheels and a robot arm] and still maintain about a three-minute flight time. So the motors are larger, the motors are slightly heavier, they're going to be more efficient and we're likely going to be using some different materials to improve the thermal properties.

Q: What kind of materials might you change?

A: In particular, we're going to be looking at higher thermal conductivity in the adhesives. We know that was one of the limiting issues for us with Ingenuity. Otherwise, they're going to be very similar. We're trying to maintain flight heritage from Ingenuity so that we aren't going way outside of our current experience with flight on Mars.

Q: What about the composite rotors? Is there anything different you'll do there?

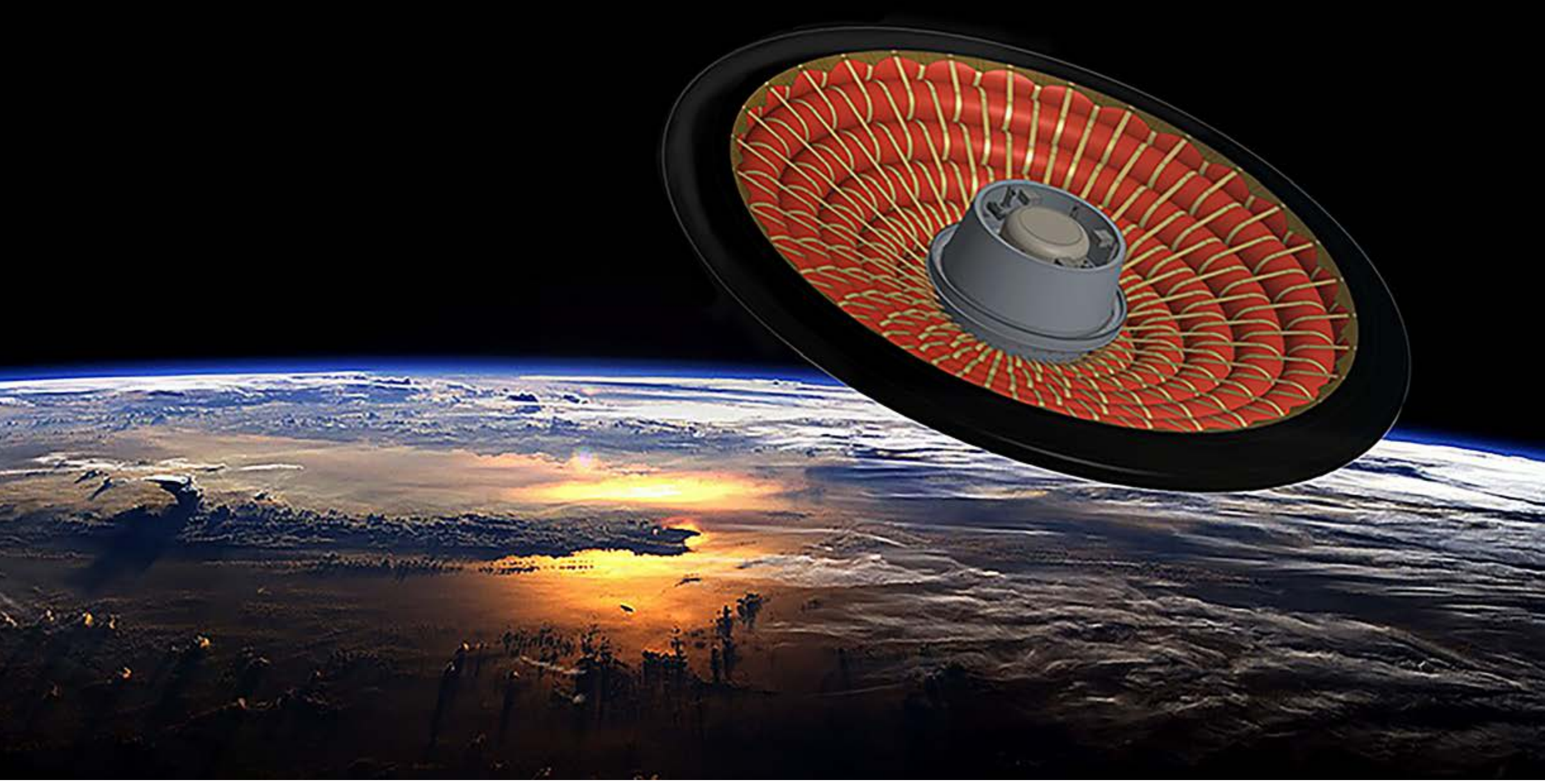
A: We're potentially going to be trying to make those lighter. One of the limiting issues with those rotors is how much we can lift with them and how fast we can spin them. We have a fundamental limit just due to the speed of sound. We don't want to get too close to supersonic at the rotor tips. If it did, it'd create quite a bit of drag and vibration and pretty negative structural impacts on the system. Wave drag [an opposing force caused by shockwaves] is a big one as well. And so in the case of Ingenuity, we kind of limit the rpm to about 2,800 — we've never actually needed to fly at that full 2,800 rpm. But as we make the helicopter heavier, we think that we can increase the rpm somewhat without having a significant performance hit. We think that we can go to a slightly higher tip Mach number. But to do that, if you spin those blades faster, the centrifugal forces go up, of course. And so all of the loads on the structure go up, unless you make the blades lighter. We think that we can take just a couple of grams more out of those rotor blades. They already only weigh 1 ounce each. ★

Inflatable heat shields

HOW TO GENERATE THE NEEDED GAS

Today, returning payloads to Earth or delivering them to Mars means facing the tyranny of the rocket shroud. Payloads must be protected by rigid heat shields, and this reality limits their mass, since heavier payloads need wider shields, but the shield must fit in the shroud. What if a shield could be inflated in space? A November test by NASA pointed the way, but the mission left a key challenge to be addressed. Keith Button tells the story.

BY KEITH BUTTON | buttonkeith@gmail.com



In a gravel lot outside of Bozeman, Montana, a handful of space wonks peered from a safe distance at a long, empty plastic bag attached to a metal pipe jutting horizontally from a stack of sandbags. Among them was John Bognar, who later explained the experiment to me over the phone. Bognar is a chemist and owner of Anasphere, a three-person space technology company in nearby Logan. He counted "three, two, one" and hit a red button on a black box. Behind the sandbags, a loud "pop" emanated from a metal drum, followed by a "whoosh." The pop was the sound of an electric charge igniting small discs of thermite, a pyrotechnic substance commonly employed by welders. This ignition produced heat that triggered a chemical reaction in which hydrogen molecules were dislodged from granules of a metal hydride in the drum to form hydrogen gas. The whoosh was the sound of gas slowly inflating the plastic bag, a successful result that was met with a subdued reaction from the NASA managers in the group.

"We always have very serious audiences," Bognar notes. "They're really trying to take in a lot."

This 2021 experiment demonstrated a simple gas generator: a device that turns a solid into a gas. The technology is a key missing ingredient in an initiative by NASA and industry players to liberate themselves from the need to squeeze a rigid, dome-shaped heat shield into a rocket shroud every time they want to deliver a payload to the surface of Mars or back to Earth. What if a fabric heat shield could be packaged in the shroud and inflated in space? NASA took a step toward that vision in November with LOFTID, the Low-Earth Orbit Flight Test of an Inflatable Decelerator. NASA's early analysis of this test suggests that the 6-meter-diameter shield indeed kept the temperatures on its aft side at acceptable levels as it plowed back into the atmosphere at 8.1 kilometers per second (nearly Mach 24) over the Pacific Ocean, following its release from a United Launch Alliance Atlas V rocket.

LOFTID was a breakthrough in the field of HIADs, short for hypersonic inflatable aerodynamic decelerators, but the inflation technique, though potentially useful for returning equipment to Earth, was not what NASA wants for deep space. This handmade fabric shield was inflated by high-pressure nitrogen gas released from "a glorified scuba tank" on the Atlas V upper stage, says Neal Cheatwood, NASA's senior technologist for planetary entry, descent and landing, and one of those on hand for Anasphere's demonstration.

The mass and volume of this inflation system were too high for a Mars mission. The tank, the gas and the series of regulators that lowered the pressure before inflation weighed about 135 kilograms. As for the nitrogen, that would be "a lot of volume of gas that you'd have to store for a very long time," says Cheatwood. "To go to Mars, even if we did a fast trajectory, you're talking about storing it for three months." Hence the desire to turn a solid into a gas, despite the hurdles.

"One of the biggest engineering challenges to using gas generators for space applications is that, quite frankly, no one is doing that yet," says Hillary Blakeley, who was NASA's inflation system lead for LOFTID.

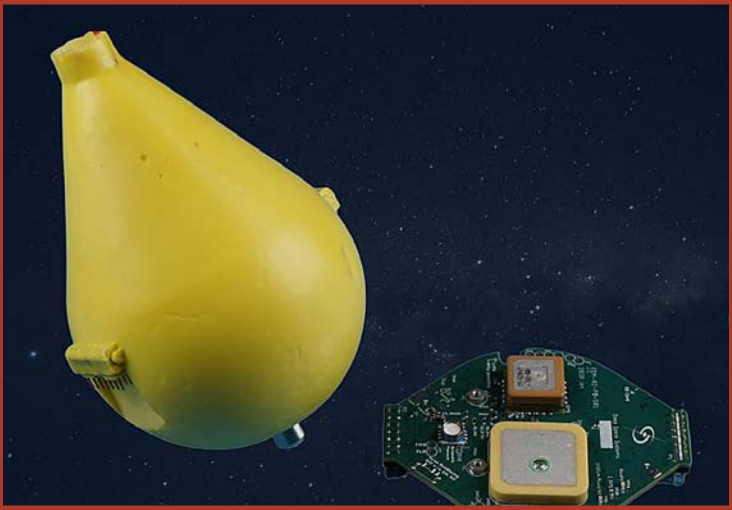
So far, only modest funding has been spent toward a better inflation system. Most recently, NASA's Small Business Innovative Research program awarded a combined $1.05 million to Anasphere and two other companies: Outpost Technologies of Santa Monica, California, which plans to return satellites to Earth for reuse, and Storm Castle Technical Products, a Montana company that is developing lightweight housings for Anasphere's hydrogen gas generator cores. Because hydrogen might not be needed for Earth applications, the other companies are looking at lower-cost generators that would rely on carbon monoxide, carbon dioxide or nitrogen, Cheatwood says.

On to Mars

The payload demands for a human mission to Mars

▲ NASA's Low-Earth Orbit Flight Test of an Inflatable Decelerator relied on a canister of nitrogen gas to inflate the flexible aeroshell in Earth orbit, but future inflatable heat shields will need to turn a solid into gas to save room. This 2021 test near Anasphere's offices in Montana demonstrated one such approach. The long plastic bag was inflated with hydrogen gas (at right) generated by heating granules of metal hydride.

Anasphere


Redwire Space

LOFTID's ejectable data recorder

What could be more awesome? A yellow, teardrop-shaped device about the size of a softball that can survive an impact with Earth at a hypersonic speed and 325 Gs while safely containing 1 terabyte of data stored on its memory card.

In November, one of Redwire Space's Data Acquisition and Recovery Systems, or DARS, devices safeguarded digital video and other data collected during NASA's Low-Earth Orbit Flight Test of an Inflatable Decelerator, or LOFTID, mission. Nestled in the center of the cold side of the heat shield, its role was to backup another recorder that rode all the way to the surface with the LOFTID shield. DARS collected test data until an altitude of 50,000 feet, when a spring ejected it from the shield, and it fell into the Pacific Ocean at a velocity of about 160 kilometers per hour. Made mainly of polyurethane foam, it could have floated for a month, but that did not turn out to be necessary. It made a satellite phone call to signal its arrival and sent out GPS pings to a NASA team that recovered it.

Notably, its cheery yellow ablative coating did not burn off because, as planned, DARS was ejected after the worst of the atmospheric heating.

To prepare DARS for the November demonstration, designer Redwire Space of Florida put multiple test articles through drop tests, releasing one from an airplane flying 4,000 feet above a reservoir in Colorado and dropping several more from high-altitude balloons into the ocean, says Al Tadros, Redwire's chief technology officer. A DARS test article also underwent shock testing that included striking it with a large hammer on a pendulum, imparting the force equivalent to a brick dropped from a five-story window.

Besides collecting data from flight tests, future versions of DARS could bring back samples of micrometeorites, research materials or items manufactured on-orbit, Tadros says. — *Keith Button*

would be enormous. Today, the largest rocket fairings are about 5 meters in diameter, so Cheatwood estimates a rigid aeroshell could be, at most, 4.7 meters wide. If a crew landed on Mars protected by such an aeroshell, "I don't know what they would do when they got there, or how long they would last," Cheatwood says. There would be little room or mass allocation for supplies. In fact, a crew of four would require 80 metric tons of equipment — the landing craft, food, water, oxygen, habitat, other gear and launch vehicle to leave Mars. This would need to be delivered in multiple batches of 20 to 25 metric tons each, one of those missions carrying the crew as well.

Delivering a payload of that mass isn't possible with a 4.7-meter heat shield because it's too small to create enough drag to slow down the craft quickly enough as it enters the atmosphere, which in turn means the payload would be subject to higher temperatures. To guide a single 20-ton payload through the Martian atmosphere, a 16- to 20-meter heat shield is required. (SpaceX is proposing to deliver humans and their equipment to Mars with a single Starship upper stage that would land vertically on the surface with retrorockets and then take off when the time came to depart, but that idea relies on refueling with carbon dioxide and water from the Martian environment.)

To inflate a HIAD for a Mars mission, the most promising concept involves powdered metal hydrides like those in the Anasphere experiment. Unlike the explosive chemical reaction that inflates a car's airbags with nitrogen in a split second, the space version would need to fill up much more slowly so that the inflatable structure can get by with thin, light walls. Hydrogen gas derived this way provides the largest volume of gas per kilogram of solid, Cheatwood explains.

The structure of the heat shield needs to be lightweight enough that it can be folded compactly into a rocket fairing but also be arranged in such a way that when inflated, it withstands the heat and pressures of reentry. So for LOFTID, NASA covered the downward-facing side of the HIAD with a ceramic-fiber-cloth-and-insulation blanket capable of withstanding 1,600 degrees Celsius. This blanket covered concentric rings of textiles, each ring with an inflatable fluoropolymer liner (think the inner tube in a bicycle tire) encased by a layer of braided nylon or Kevlar — the tire, in this analogy. Once inflated, the rings acted as a blunt cone-shaped brake, slowing LOFTID as it plowed through the atmosphere.

For inflation, NASA needs the gas temperature to be lower than 200 degrees Celsius so it won't melt the liner, and the gas must be nearly free of contaminants that could damage the liner, such as metal particles or chemicals that react with the material, or water vapor that could cause the inflatable shield to lose too much pressure as the water cools.

Cookies and cans

As Bognar developed his hydrogen gas generator, he knew he needed to create a controlled chemical reaction so the gas wouldn't release suddenly but rather over 30 seconds to 2 minutes. This required keeping the thermite-triggering material separate, so the pace of the reaction could be controlled.

For the demonstration in Montana, Bognar designed an Oreo cookie-like stack of alternating layers of solid thermite and powdered hydride. The thermite was ignited by a NASA Standard Initiator, a pyrotechnic device that's "like a bottle rocket ignitor on steroids," Bognar says.

"We very much rely on this principle of transferring heat from one to the other so that we can control reaction rates," he says.

Because the pressure created by the controlled reaction isn't extreme, the gas generation chamber can be designed in almost any shape necessary to fit it aboard a spacecraft.

Prior to selecting the metal drum employed for the 2021 test, Bognar chose a standard steel coffee can for the chamber that houses the cookies and sealed the lid on with a hand-cranked canning machine. He then drilled holes for ignition wires and for the gas to escape.

"We literally are doing nothing different than people who do home canning," he says.

When Anasphere began its research for NASA four years ago, it started with hydrogen generators that produced 250 liters of gas. Now, the company is building generators that can produce 1,000 liters of hydrogen. Over the next year and a half, it plans to develop cooling pipes and air filters for even more powerful gas generators. The end goal for the largest HIAD-inflating gas generators is about 70,000 liters, Cheatwood says.

Launching inflatables

As NASA and its contractors continue this work on generators, they might soon have a wealth of test flight data to refer to. The agency has agreements to share HIAD technology with Outpost and with ULA. Each company needs something smaller than the 16- to 20-meter shields NASA is developing for Mars missions. Outpost intends to return smaller payloads to Earth from satellites, such as science experiments or space-manufactured alloys and optical fiber, for which it would need 2- to 3-meter inflatable shields. As for ULA, the company requires heat shields about 10 meters in diameter to recover booster engines from its Vulcan Centaur rockets.

NASA says ULA plans to begin launching its HIADs in about four years, and Outpost in about two years. With each launch, NASA can apply the results to its own HIAD designs, Cheatwood says.

"You can imagine each time they launch one of those, if we can learn things that let us reduce the mass of the inflatable or the mass of the heat shield or the mass of the inflation system, that frees up more mass for payload," he says. "I imagine their design will evolve over at least the first few flights as we learn, say, 'Well, you could take out this layer of insulator or get by with one less gas generator.'" ★

▲ For the November demonstration of NASA's inflatable heat shield, a canister of nitrogen on an Atlas V upper stage inflated the heat shield before its separation, a process shown in this illustration and in the photo (see inset) taken shortly before the shield began its entry, building up to a maximum speed of Mach 24.

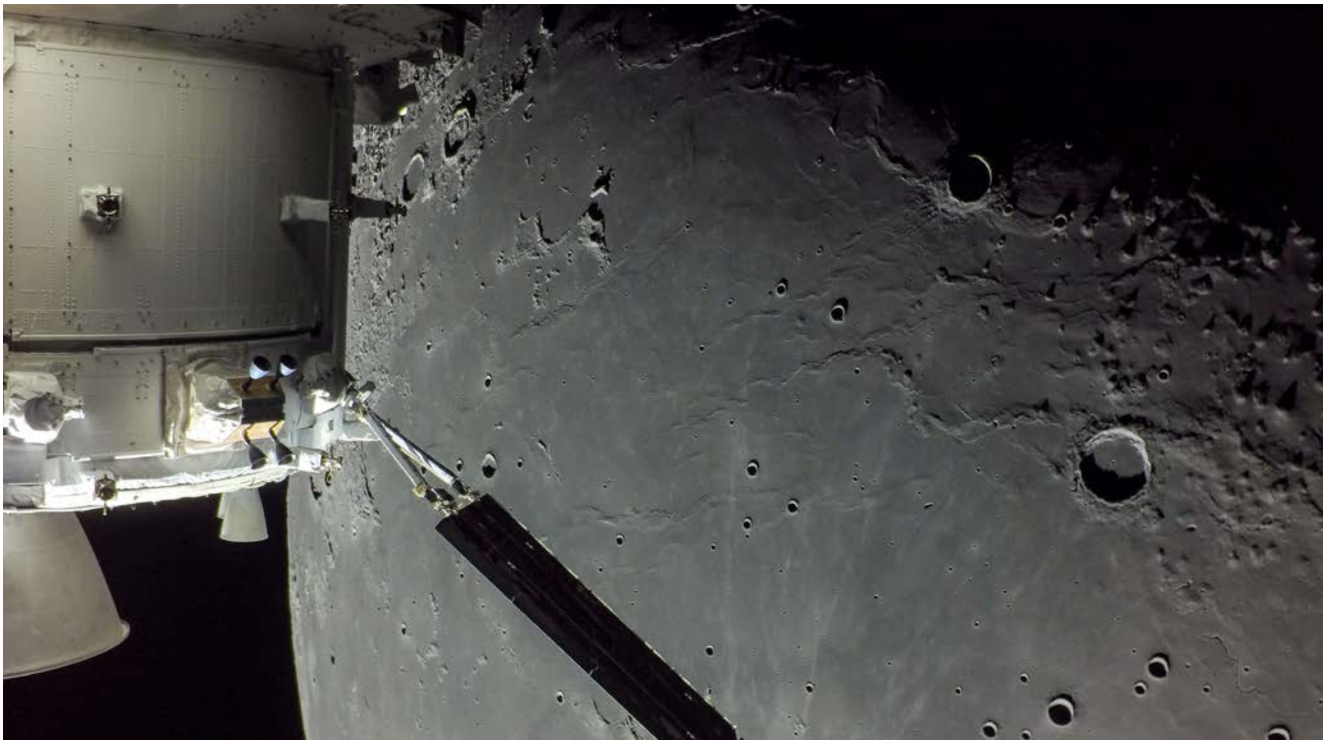
United Launch Alliance


NASA
esa

TRAIN 'EM. TRUST 'EM.
TURN 'EM LOOSE.

Since the Apollo program concluded 50 years ago, NASA's astronaut corps has accumulated thousands of hours of flight time in low-Earth orbit. As the agency now prepares to send astronauts back to the moon under the Artemis program, Apollo veterans told Debra Werner that a new set of skills — and a new mindset — may be needed.

BY DEBRA WERNER | dplwerner@gmail.com



▲ NASA's unoccupied Orion spacecraft approaches the moon on Dec. 5, the 20th day of the Artemis I test flight. Orion flew 129.7 kilometers above the lunar surface and fired its main engine for about three and a half minutes to accelerate and put it on a course toward Earth. There are no photos of the moment of closest approach because the moon blocked signal transmission to the Deep Space Network.

NASA

In the five decades since the last Apollo mission, NASA astronauts have performed impressive feats. In the 1970s aboard Skylab, NASA's first space station, they conducted scientific research in low-Earth orbit at altitudes of 400 kilometers. Over 30 years of space shuttle flights, astronauts repaired and upgraded the Hubble Space Telescope, constructed the International Space Station and showed the promise of microgravity for making materials and conducting research in the biological and physical sciences. In fact, since ISS was completed in 2000, astronauts have continuously inhabited the football-field-size structure, all while launching dozens of satellites from the station, bolstering knowledge of Earth and the solar system, and demonstrating the promise and downside of long-term human spaceflight.

Despite the successes, those LEO spaceflights are very different than operating on the lunar surface some 384,000 kilometers away, as new astronauts and veterans of ISS must do under the Artemis moon program.

"By the time you get to the moon, the quickest you could get home is three to four days," says Gerald D. Griffin, lead flight director for Apollo 17. "To put that in context, at the ISS in low-Earth orbit, you can be home in a matter of hours if you have a big issue."

When I contacted Griffin and other veterans involved in Apollo 17 earlier this year, it was to discuss the upcoming anniversary of NASA's last lunar landing and the half-century hiatus that followed. **[See the November 2022 issue for that story.]** But they also described how they believe NASA should prepare its managers and astronauts for the lunar landings scheduled for later this decade.

The bottom line? Crewed lunar missions require different styles of management and training than those NASA has leaned on to prepare astronauts for LEO operations. The risks involved are different too.

"We're not going to do Apollo over again," says James W. Head, Apollo lunar exploration missions program geologist. "But there are some really important lessons from Apollo."

A "gulp moment"

On Dec. 11, NASA took its biggest step yet toward returning humans to the moon, when an unoccupied Orion crew capsule returned to Earth 25.5 days after the first Space Launch System rocket sent the capsule and its service module to lunar orbit. This Artemis I test flight, which NASA Administrator Bill Nelson declared "extraordinarily successful" in a post-splashdown news conference, was the first in a series of missions aimed at establishing the Gateway outpost in lunar orbit and eventually a lunar base camp for astronauts. The Artemis II flight that will send two astronauts into lunar orbit is currently scheduled for 2024, setting up an Artemis III landing in the south pole with two astronauts in 2025 at the earliest.

That may seem like the distant future for people tracking the frenetic pace of commercial space launches and the growth of satellite constellations, but the clock is ticking for NASA to train astronauts and other personnel for these missions.

"One of the things I tell the younger flight directors

◀ Apollo 17 astronauts Gene Cernan and Jack Schmitt collected 110.5 kilograms of lunar regolith during their three spacewalks. In this photo taken by Cernan, Schmitt drags a rake through lunar soil and shakes it to dislodge small rocks.

NASA

now when I get a chance to talk to them is deep space is a lot different than low-Earth orbit," Griffin says. "As soon as you do translunar injection, the burn that sends you on the way to the moon, it is a bit of a gulp moment because you've got them now on a trajectory that is going to take them far, far away. And it feels different from the beginning."

The differences won't end there. The Artemis III crew will touch down in more rugged terrain than the sunny, flat equatorial plains the Apollo astronauts explored. NASA plans to conduct detailed studies of the possible landing sites ahead of time via sources including images taken by the Lunar Reconnaissance Orbiter, but Artemis crews will still likely encounter some unknowns that will require instantaneous decision making.

This would be a big shift for today's astronauts, who are accustomed to having their schedules planned in five-minute increments on ISS.

"This is the space station generation," Head says. "Astronauts work extremely closely with mission control in Houston, getting advice all the way along."

Instead, NASA's training curriculum should emphasize independence and creativity.

"When they're on the surface of the moon, they can't hold up a rock and say, 'Houston, do you want this one?' That's ridiculous," Head says. "At Apollo, we had this strategy we called T-cubed: Train 'em. Trust 'em. Turn 'em loose. Our job was to train them. If they weren't ready, that was our problem. We trusted them, and they were turned loose to explore."

Nor can NASA create checklists for every single scenario that astronauts might encounter during surface missions. Like geologists exploring terrestrial sites, "you make the best plans you can based on the information available before you go in the field, but there are always new things that you didn't know about," says Harrison "Jack" Schmitt, Apollo 17 lunar module pilot.

"You have to decide whether they are significant enough to sample, photograph or spend some time on. I was fortunate enough to have experience in field geology for the Apollo 17 mission. In the future, with good training as we also had for Apollo, I think that kind of experience and training is going to pay off."

To illustrate this point, Head pointed me to a 2009 paper by Sergey Krikalev, the former cosmonaut who heads human spaceflight programs at Roscosmos. He made the case for giving astronauts more authority and flexibility. Supplying too many instructions risks "turning a human being into a robot and subsequently, to the loss of his advantages as a 'thinking being' compared to the robot," Krikalev wrote with fellow cosmonaut Alexander Kalery and Igor Sorokin, deputy head of space station utilization center for RSC Energia, the prime contractor for Russia's human spaceflight program. Exploration of the moon, Mars and asteroids will require crews to be independent and creative, according to the paper, "Crew on the ISS: Creativity or determinism?"

The current astronaut operations in low-Earth orbit "tend to be dominated by determinism," Head says. "You're in the space station. You have tasks to do. The creativity, which is required for exploration of the unknown, like getting out of the lunar module

▲ Since the Apollo program concluded in 1972, NASA astronauts have logged tens of thousands of hours in low-Earth orbit. Mark Vande Hei, pictured here setting up an experiment in the U.S. Destiny Laboratory on the International Space Station in 2021, logged 8,520 hours on the station.

NASA/Kayla Barron

on the moon and figuring out what to do, is less important. Make no mistake, these are incredibly brave and talented individuals, but the ISS environment doesn't call on their native creativity as much as exploring the lunar surface will."

Bureaucratic hurdles

As the Artemis program gets underway, another area where NASA might want to take a cue from Apollo is management structure.

"Look at your organization, the program management, from headquarters on down and how you've partitioned things out to the various NASA centers," says Robert B. Sieck, a command and service module test engineer throughout the Apollo program and a space shuttle launch director. "See if the management structure you've got in place is really the most efficient structure. Does it facilitate responsibility?"

The U.S. Aerospace Safety Advisory Panel, which submits an annual report to NASA and Congress, has raised similar concerns about Artemis program management. Unlike the unified program office located at NASA Headquarters in Washington, D.C., that oversaw all aspects of Apollo, no single entity directs the various components for Artemis "in a cohesive manner to manage the overall risk," according to the safety panel's 2021 annual report, released in early 2022. Instead, SLS, Orion and Exploration Ground Systems, to name a few, "were set up as three individual programs." The report noted that NASA had begun "a number of integrating efforts" to address this. During the panel's latest public meeting, held in October, member William Bray said he was "very satisfied" with the progress NASA has made so far.

Another strength of Apollo that Artemis may want to replicate was pushing "decisions down to the level where the expertise was located," Griffin says. "We had many occasions where the leadership of the agency and the leadership of the flight operations left it up to us to make the decision."

Part of that may have been due to the relative youth of the space agency, established just three years before then-President John F. Kennedy made his 1961 address to Congress about landing humans on the moon.

"One of the things that I preach, even to corporations when I speak to them, is that as organizations get larger and older, they tend to drag decisions up, as if somebody at a higher level can make a better decision," Griffin says.

A management structure like Apollo's "makes it absolutely clear who is responsible for what," Sieck says. "If it takes 10 approvals to do something and then something goes wrong, you don't want to play this finger-pointing game as to who's responsible. Responsibility is key, and it has to filter down to each organization and each individual."

Since responsibility was clear in Apollo, managers knew when an individual engineer made a mistake.

"Assuming it wasn't something irresponsible, the bosses would sit down with us and say, 'We want to understand what we did wrong to not set you up to succeed,'" Sieck says. "'Is it the tools, the training, the procedures? What is it that we need to do so that as a team we can accomplish these objectives?' It was a great environment to work in."

Risk aversion

Societal and political changes outside NASA could pose challenges for Artemis as well.

During the Apollo program, when something like an engine test did not go as planned or someone bought the wrong part from a vendor, "it was not looked upon as a failure," Sieck says. Today, any anomaly — a rocket explosion or a defective heat shield on an uncrewed capsule, for instance — could trigger multiple investigations from outside organizations and recommendations for changes in policies and procedures that may or may not have led to the original incident.

"You end up overreacting and modifying things that you didn't have to modify to satisfy all of these criticisms," Sieck says. "Don't get me wrong, I'm fine with having independent people look at what you're doing. Some of that is good, but I think we have too much of it, particularly for an agency like NASA."

In recent decades, there has been a steady reduction of how much risk society at large is willing to accept, Griffin says, a view that poses a challenge for NASA, given the inherently risky nature of human spaceflight.

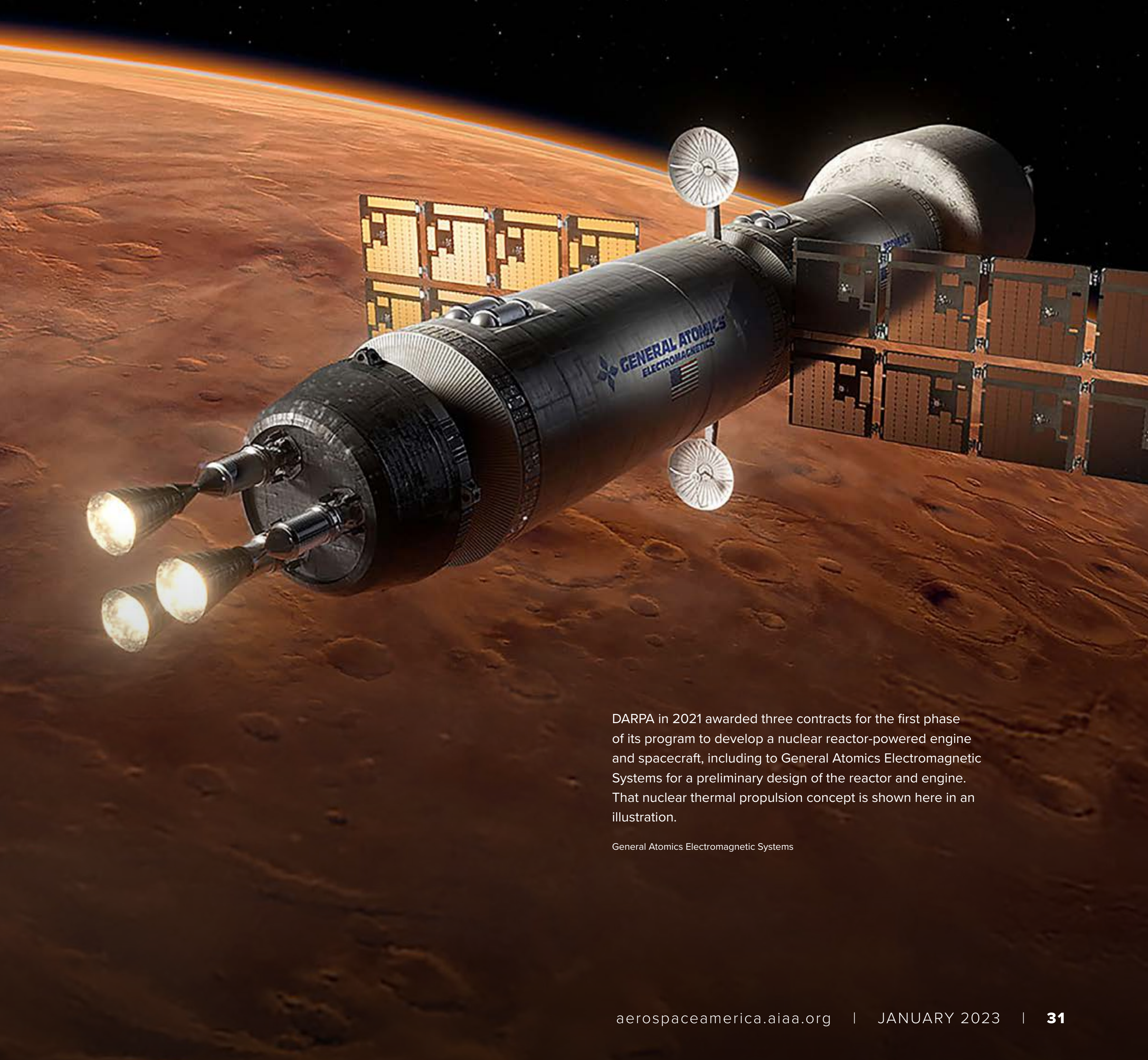
"People will get on an airplane and go from Chicago to Houston because the risk involved is small, but it's not zero," he says. "What we're doing in space is quite a bit more risky because we're working with higher energies and higher speeds and in bad environments for human life. That's what makes the country great, solving those problems." ★

COVER STORY

Nuclear Rocket Redux

The United States has had multiple dalliances over the decades with in-space nuclear propulsion. The latest resurgence of interest is happening right now, driven by the desire to settle the moon and get humans to Mars. Jon Kelvey looks at the odds of success this time around.

BY JON KELVEY | kelvey@gmail.com



DARPA in 2021 awarded three contracts for the first phase of its program to develop a nuclear reactor-powered engine and spacecraft, including to General Atomics Electromagnetic Systems for a preliminary design of the reactor and engine. That nuclear thermal propulsion concept is shown here in an illustration.

General Atomics Electromagnetic Systems

Progress on space technology has often begun with grandiose visions unrestrained by the realities of budgets and environmental and regulatory reviews. So imagine: It's 2028 and the crew of NASA's Artemis V moon mission is stuck on the lunar Gateway space station in orbit around the moon — and the power just went out. The space agency desperately needs to get another power and propulsion unit to the Gateway immediately, but the Advanced Electric Propulsion System spacecraft that ferried the original PPE to the station will take weeks to arrive, and the space agency can't stand up another of its massive Space Launch System rockets fast enough either.

If Tabitha Dodson has her way, the U.S. Space Force could come to the rescue, propelling the PPE there from Earth orbit with the next generation of atomic age technology, as envisioned by DARPA. "And it wouldn't take a third of the year to get it there. It would take a day or so," she says.

Very rapid delivery of large cargo over long distances: That's the tagline for nuclear thermal propulsion, or NTP. A screaming hot nuclear fission reactor would heat liquid hydrogen propellant into a gas and accelerate it out a nozzle. The result would be high thrust and fuel efficiency that, at least in theory, outclasses chemical rockets and electric thrusters alike. The U.S. has never launched a nuclear reactor into space for the purposes of propelling a spacecraft, but it's not for lack of trying. It's on old idea, explored by NASA and the Atomic Energy Commission beginning in 1958 after the two agencies inherited a research program from the U.S. Air Force. Dodson, a DARPA nuclear physicist, is helping to lead that rebirth as the chief engineer and manager of the Demonstration Rocket for Agile Cislunar Operations, or DRACO, program. NASA is also rekindling research into nuclear propulsion, with plans to demonstrate a fission reactor-powered NTP system in space by the early 2030s.

With DRACO, DARPA aims to design, build and fly an NTP-powered spacecraft in orbit by fiscal 2026.

A Kiwi-B nuclear engine is lowered onto a test stand at NASA's Armstrong Test Facility in Ohio. Under Project Rover, NASA and the Atomic Energy Commission ground tested multiple variants of reactors between 1959 and 1964 as preparation for building a planned flight version in the next phase of the program, NERVA, or Nuclear Engine for Rocket Vehicle Application. An engine was never flown.

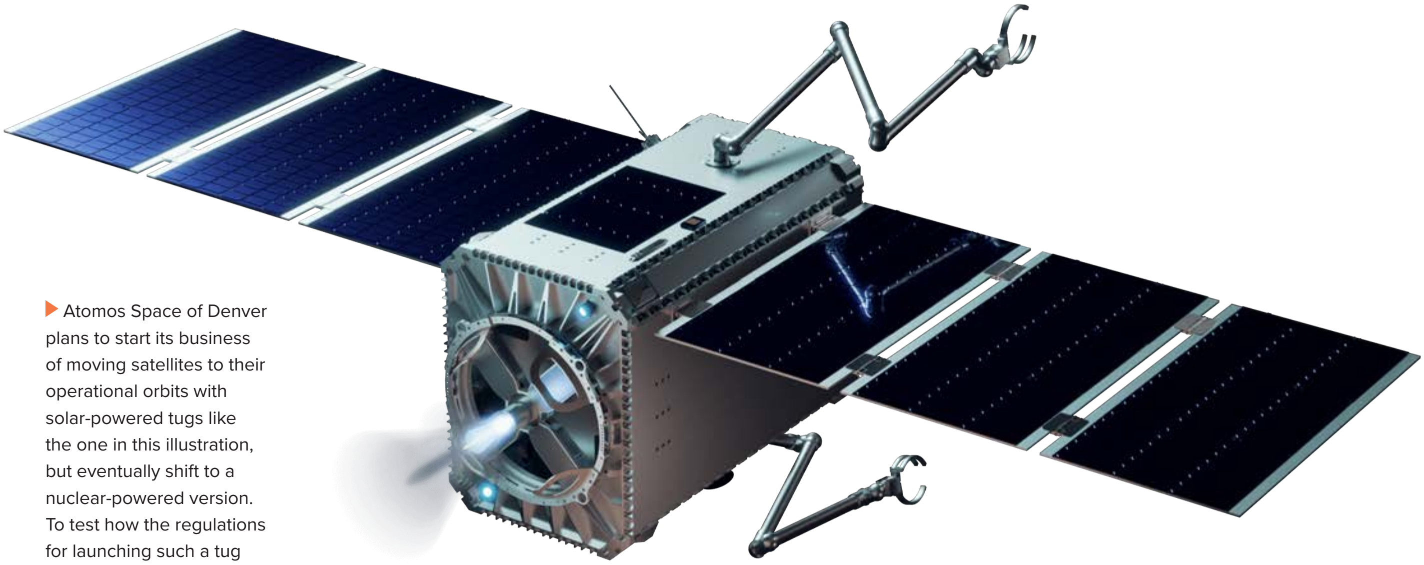
NASA's Glenn Research Center

The 1965 launch of NASA's SNAP-10A satellite marks the only time the U.S. has sent a nuclear reactor to space. But instead of propelling the satellite, the reactor, an earlier version of which is pictured here, generated electricity by converting heat from a compact nuclear reactor.

U.S. Department of Energy

About four months after its launch in September 1977, the Soviet Union's nuclear reactor-powered Cosmos 954 satellite crashed in northern Canada. The U.S. and Canada spent several months retrieving and disposing of the debris, due to the high radiation level of the fragments from the spacecraft's uranium reactor.

National Nuclear Security Administration, U.S. Department of Energy

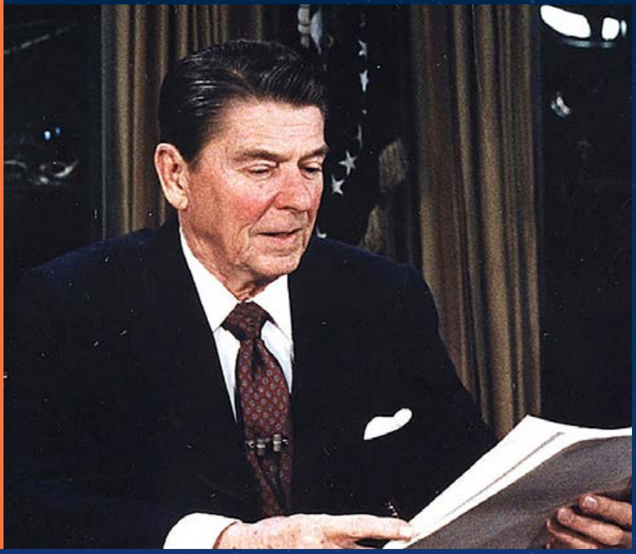


Atomos Space of Denver plans to start its business of moving satellites to their operational orbits with solar-powered tugs like the one in this illustration, but eventually shift to a nuclear-powered version. To test how the regulations for launching such a tug work, the company plans to launch a test reactor in the mid-2020s.

Atomos Space

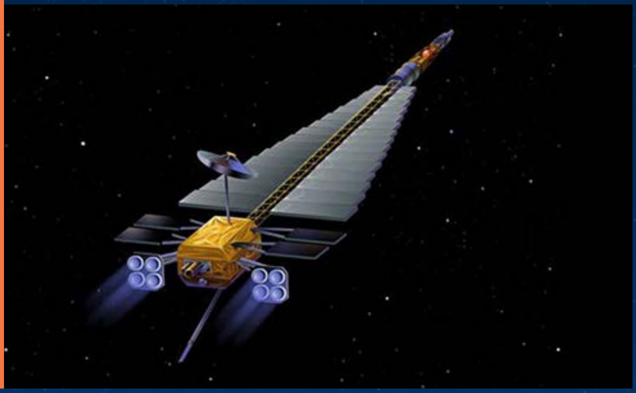
U.S. President Ronald Reagan announced the Strategic Defense Initiative during a televised speech in March 1983. Research was conducted on a variety of weapons concepts, including a nuclear thermal rocket.

Ronald Reagan Presidential Library

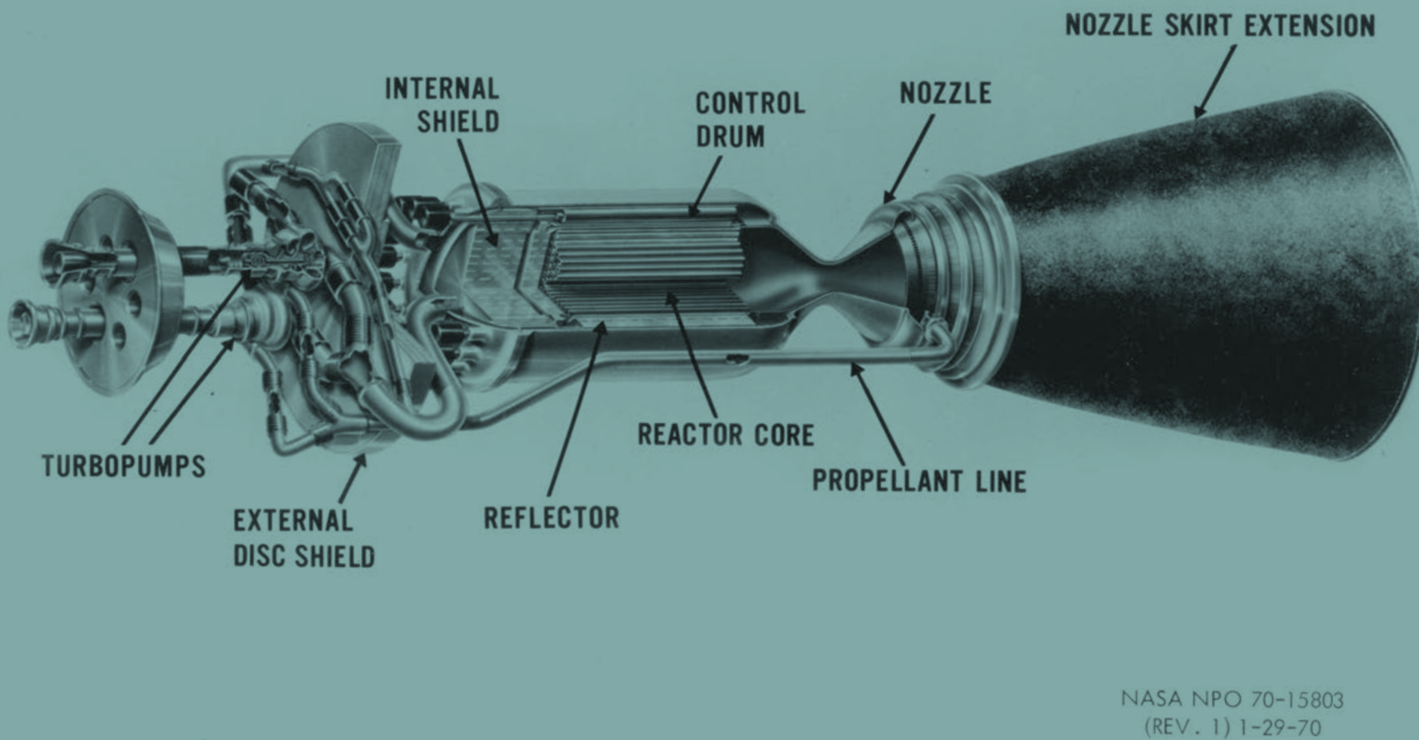


NASA In the early 2000s proposed a spacecraft that would orbit three of Jupiter's moons thought to contain subsurface oceans, as indicated by images taken by the Galileo spacecraft. The Jupiter Icy Moon Orbiter, or JIMO, was to be powered by a nuclear fission reactor, depicted in this illustration as a thin rod (at right). The mission was canceled in 2005.

NASA/Jet Propulsion Laboratory



NERVA ENGINE



▲ A drawing of the nuclear rocket engine developed under NERVA, or Nuclear Engine for Rocket Vehicle Application, program. NASA and the Atomic Energy Commission ground tested multiple designs, but the program was canceled in 1973 before an engine was ever flown.

NASA's Glenn Research Center

If all goes as planned, it could serve as the basis of a Space Force fleet of NTP rocket upper stages that could push big satellites around.

"Our missions are looking at going into the cislunar volume beyond Earth orbit," says Dodson.

So nuclear is in the air, so to speak, but not literally. In fact, that's one of the challenges to wider adoption: Experts and the public alike must be convinced that putting nuclear reactors on rockets will be safe. Combine safety concerns, real and perceived, with the remaining technical challenges to building a functional NTP system, and the task before DARPA and NASA looms large. Add to that a third challenge, the federal regulatory and budget landscape, and you start to get a sense of why NTP never took off in the 1970s and why questions remain about whether matters will unfold differently this time.

Why go nuclear?

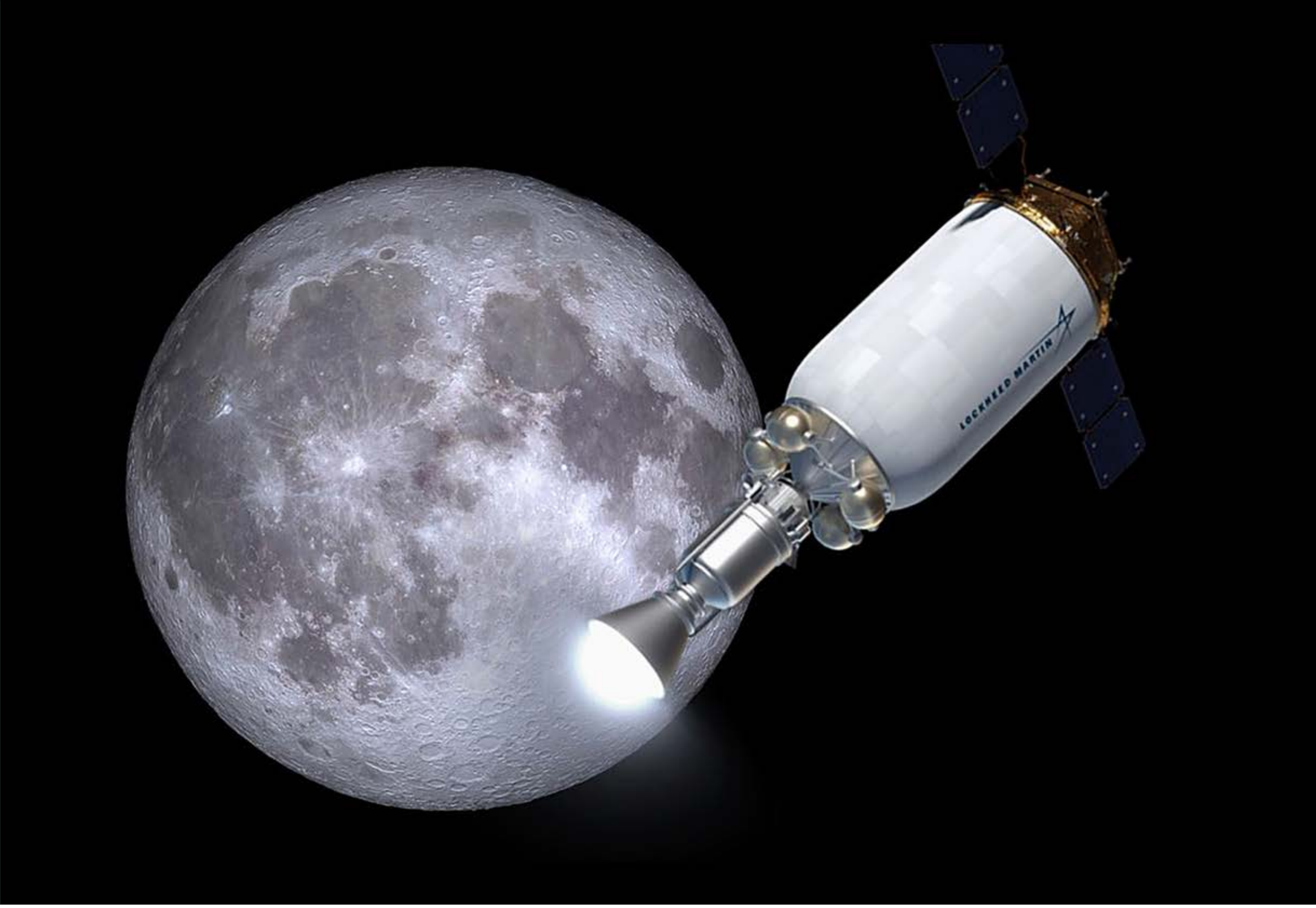
Each year, MIT professor of aeronautics and astronautics Paulo Lozano teaches a rocket propulsion class. "Recently, I have been adding a few lectures on nuclear, precisely because I think it's kind of coming back," he says.

It's not just that NASA and DARPA are researching NTP. It's what they are researching those systems for — pushing big payloads to geosynchronous orbit and beyond quickly, building moon bases and going to Mars. You don't need NTP to do those things, Lozano says, but it's a much more flexible option.

"I think nuclear propulsion has its niche application, which is fast transport to deep space destinations," he says. "That is something that very likely nuclear can do better than any other technology."

For NASA, an uncrewed space demonstration of an NTP system by the early 2030s could open the door to an alternative way of propelling human missions to Mars, says Anthony Calomino, who manages the Space Nuclear Technology Portfolio within NASA's Space Technology Mission Directorate. With NTP, a spacecraft could make the journey in four to six months, rather than the nine months typically required when using chemical propulsion.

Getting to Mars faster isn't just a matter of convenience — It could be a survival measure. Astronauts spending long durations outside the protective shield of Earth's magnetosphere will be exposed to high-energy galactic cosmic radiation that could irreparably damage their DNA. Historically, there's been a few ways of thinking about that problem, according to Michael Neufeld, a senior curator at the Smithsonian's National Air and Space Museum.



"Either we have to have much better radiation protection," he says (which costs mass and material), or accept the heightened health risks or "we need to have a nuclear rocket so that we're not spending so many months in transit."

Closer to home, Denver-based Atomos Space is developing an NTP space tug for delivering satellites to higher orbits after launch, though the company will likely use solar-electric propulsion in the short term.

"The long-term vision of that is fielding space nuclear technologies because it is the best way to move around in both near-Earth orbit and beyond," Atomos co-founder and CEO William Kowalski says. "It's really how we make solar systems small."

The main advantages of NTP over conventional chemical rockets stem from the basic physics of space propulsion. Any engine will provide some amount of thrust, and do so by expelling propellant with a degree of efficiency, the engine's specific impulse, measured in seconds. A chemical rocket engine, such as each of the RS-25s that powered the space shuttle orbiters and that power the core stage of NASA's Space Launch System rockets, generates a large amount of thrust, around 2,277,489 newtons, with a fairly modest specific impulse of 452 seconds in space. That's about as efficient a chemical rocket engine can be made, according to Lozano.

Electric propulsion engines, such as the Hall thrusters on SpaceX Starlink satellites, generate around 1 newton of thrust or less, but do so with great efficiency, scoring specific impulses of thousands of seconds.

NTP systems can produce both higher thrust and higher specific impulse than chemical rockets. The Nuclear Engine for Rocket Vehicle Application, or NERVA, engine developed in the United States in the 1950s, '60s and '70s was never launched, but in ground testing produced 246,662 newtons of force with a specific impulse of around 841 seconds.

"Specific impulse scales approximately as the square root of the exhaust temperature of the propellant divided by the molecular weight of the propellant," Dodson says. Use hydrogen for the lowest atomic weight possible, then "get the reactor to be very hot, and you can drive up this specific impulse."

Crucially, there is no combustion involved in NTP. Cryogenic hydrogen is superheated by the reactor but doesn't burn, removing the need for carrying the extra mass of an oxidizer. "So the initial mass of the spacecraft is not as large as what it would be if it were a chemical-based system," Lozano says.

You could therefore launch a powerful NTP upper stage on a smaller conventional rocket — which is just

▲ Lockheed Martin last year submitted to DARPA its concept for a nuclear-powered spacecraft for the agency's Demonstration Rocket for Agile Cislunar Operations, shown here in an illustration. The deliverables of Lockheed Martin's Phase 1 contract included performance requirements for a nuclear thermal propulsion reactor. DARPA also awarded Blue Origin a Phase 1 contract for a spacecraft design, and a contract to General Atomics Electromagnetic Systems for the preliminary design of a reactor and engine.

Lockheed Martin

what NERVA was supposed to accomplish more than 50 years ago.

Moon shots and nuclear rockets

In May 1961, then-U.S. President John F. Kennedy gave a speech to Congress that has since become for famous pointing America toward the moon. But as Dodson notes, Kennedy didn't just shoot for the moon. He went on to say the nation should "accelerate development of the Rover nuclear rocket. This gives promise of some day providing a means for even more exciting and ambitious exploration of space, perhaps beyond the moon, perhaps to the very end of the solar system itself."

Project Rover was the U.S. effort to design a nuclear-powered rocket engine, originally for the upper stage of an intercontinental ballistic missile. When the Air Force transferred the program to NASA, it was incorporated into NERVA and the focus became propulsion for long-duration spaceflights. Based at Los Alamos National Laboratory in New Mexico, Project Rover began in 1955 and lasted until 1973, when NASA and national priorities changed.

"It grew out of a combination of the atomic enthusiasm of the 1950s combined with the space enthusiasm of the 1960s," Neufeld says. NASA had plenty of money at the time, "so it was easy to imagine that NASA could incorporate a nuclear thermal rocket into post Apollo planning."

With an NTP rocket, Dodson says, NASA could move big cargo to the moon and beyond, but with much smaller propellant tanks. "So even bigger cargo to the moon, or more cargo faster," she says.

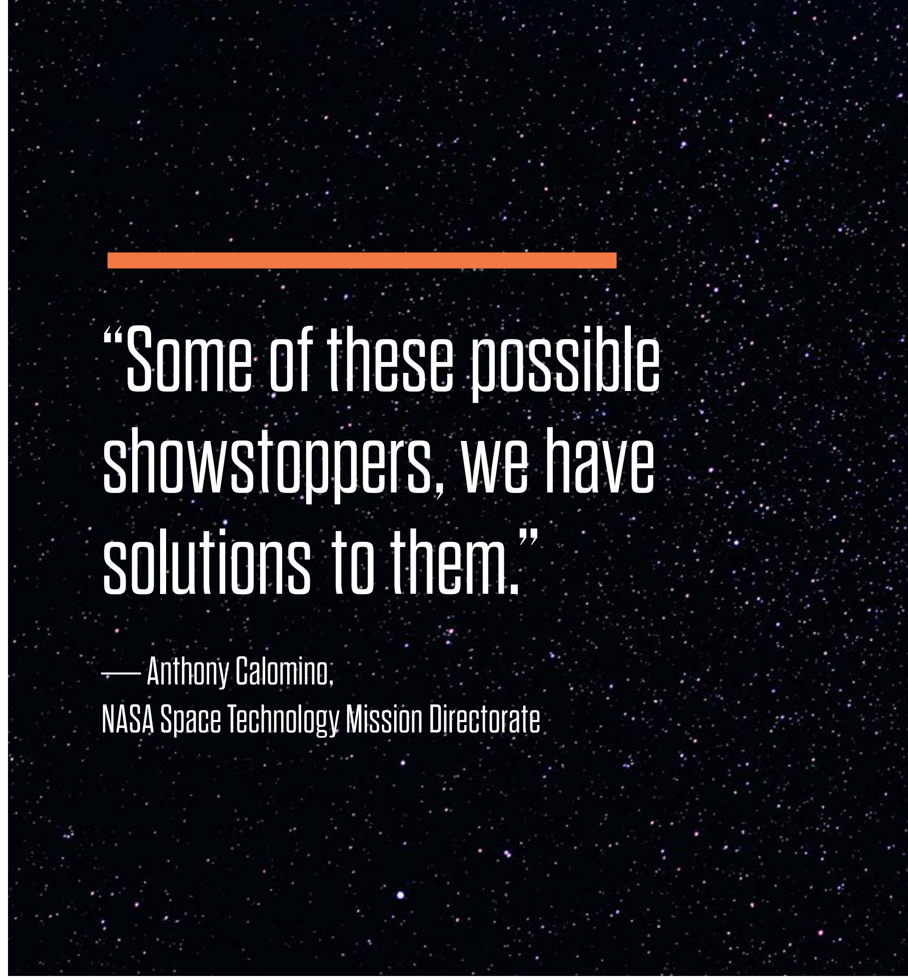
Engineers at the time designed the NERVA engine around a graphite core reactor fueled by highly enriched, or "weapons grade," uranium. The reactor and engine functioned well in at least six ground tests between 1964 and 1969, producing around 1,100 megawatts of power on average.

But NERVA eventually fell victim to the same post-moon-landing malaise that would lead to curtailment of the Apollo program after the Apollo 17 landing in 1972.

"NASA's budget effectively was halved between 1966 and the mid '70s," Neufeld says. "It just wasn't sustainable to say, 'We still need a nuclear thermal program.'" The program was canceled in 1973.

NERVA never would fly in space. The only U.S. nuclear fission reactor to do so was on the SNAP-10A satellite launched in April 1965, but that reactor was not for propulsion, but rather intended as a test case for generating electricity for satellites as part of NASA's System for Nuclear Auxiliary Power program.

Interest in nuclear propulsion continued to simmer, however. The late 1980s and early 1990s saw research into a new NTP rocket design funded by the Strategic Defense Initiative and further developed as the Air Force Space Nuclear Thermal Propulsion program, but that effort was canceled in 1994. NASA's ambitious Jupiter Icy Moons Orbiter, JIMO, mission of the early 2000s would have used nuclear electric propulsion with a fission reactor powering ion thrusters, but the mission was canceled in 2005.



> "Some of these possible showstoppers, we have solutions to them."
>
> — Anthony Calomino,
> NASA Space Technology Mission Directorate

None of those projects got as far as NERVA did in terms of testing a working engine. "Now we're sort of picking the NERVA back up off the shelf," Dodson says.

Engineering a modern nuclear rocket

But picking NERVA up off the shelf isn't just a matter of building a new engine to the specifications of the older system. NERVA never flew, and there remain a number of challenges — technical and political — to making NTP an operational reality.

For one thing, it's not clear that everything worked on NERVA as well as NASA would demand today, says Calomino.

"They didn't necessarily know the amount of damage that was being done to the material," he says. "How long can that engine work? Can you man rate that engine? Can you use it in an application with the reliability that you need?"

Handling heat is the key challenge for NTP. Higher heat provides higher specific impulse but also degrades the engine components, limiting their operational lifespan. This is especially true of the nuclear fuel in the reactor core, according to Paolo Venneri, who manages the advanced technologies division at Ultra Safe

Nuclear Corp. The Seattle-based company was a supporting contractor to two of the primes awarded Phase 1 contracts, Blue Origin and General Atomics.

For an NTP engine, "the outlet temperature of the reactor is something on the order of 3,000 Kelvin, or 2,700 Celsius," Venneri says. "Today, there's no nuclear fuel that can operate at that temperature for the desired period of time."

And about that fuel: NERVA used weapons grade uranium, meaning ore that's enriched to consist of at least 85% uranium 235, an isotope that's more amenable to fission than the uranium 238 also found in ore. Use of such fuel is highly restricted because of nuclear proliferation concerns, so all the current NTP research programs focus on the use of high-assay low-enriched uranium, or HALEU, which is enriched to levels of about 20% — lower than weapons grade, but higher than the 5% enrichment levels used in traditional nuclear reactor power plants.

But using HALEU introduces material design challenges too, says Dodson. With less fissionable material in the core, reactor designs must introduce moderating materials to slow down high-energy neutrons enough that they strike and split additional uranium atoms and keep the nuclear chain reaction going.

These are really challenges of materials science, according to Calomino, who came to NASA with a materials science background. Those materials science research techniques have come a long way in half a century.

"Our [abilities] to model these systems have advanced in the last 50 years," he says. "Some of these possible showstoppers, we have solutions to them."

Modeling can help identify hot spots in a reactor core where damage could occur, Calomino says, while advanced moderating materials — including beryllium and metal hydrides — can slow neutrons down enough to allow fission with HALEU fuel.

"These moderators are actually an enabling capability for space reactors," he says, "to get low enriched uranium space reactors into the volume and mass bucket that we need them in to actually make them practical systems."

Nuclear rocket safety

Because you're talking about putting a nuclear reactor on a rocket, safety is a challenge to the future of NTP, and it's both an engineering problem and a public relations problem.

"The public takes a lot of convincing when you're launching uranium on a spacecraft," Neufeld says, noting that there were protests in 1997 around the launch of NASA's Cassini probe due to the spacecraft carrying plutonium in its Radioisotope Thermoelectric Generator.

While the idea of splitting atoms rather than simply housing pellets of plutonium, as an RTG does,

DARPA

Building DRACO

To demonstrate in-space nuclear propulsion, DARPA has divided its Demonstration Rocket for Agile Cislunar Operations program into three stages, with Phase 3 culminating in an uncrewed flight test by fiscal 2026 of the DRACO spacecraft propelled by its nuclear thermal reactor.

"This is in line with the other big space missions — the ones that go to Mars, or Jupiter asteroids," says program manager Tabitha Dodson. "Those programs last four or five years."

After that point, NASA, the U.S. Space Force or both could become "transition partners," using the DRACO technology for moving cargo or big military satellites.

"I would hope that the nuclear rocket could serve as an option for them to deliver large cargo to the moon, in particular," Dodson says. "It would be a better option for the astronauts, in my opinion."

Phase 1: Research and development in two tracks

Duration: 18 months

Contracts: Awarded in April 2021

Contractors:

- Track A: General Atomics Electromagnetic Systems — nuclear reactor preliminary design, with support from Ultra Safe Nuclear
- Track B: Blue Origin and Lockheed Martin — spacecraft concepts and preliminary designs, with Ultra Safe Nuclear supporting the Blue Origin contract

Phase 2: Hardware construction and engine tests

Planned duration: 24 months

Contracts: Pending as of mid-December for the construction of one engine and one spacecraft

Phase 3: Integrated testing of the reactor and spacecraft

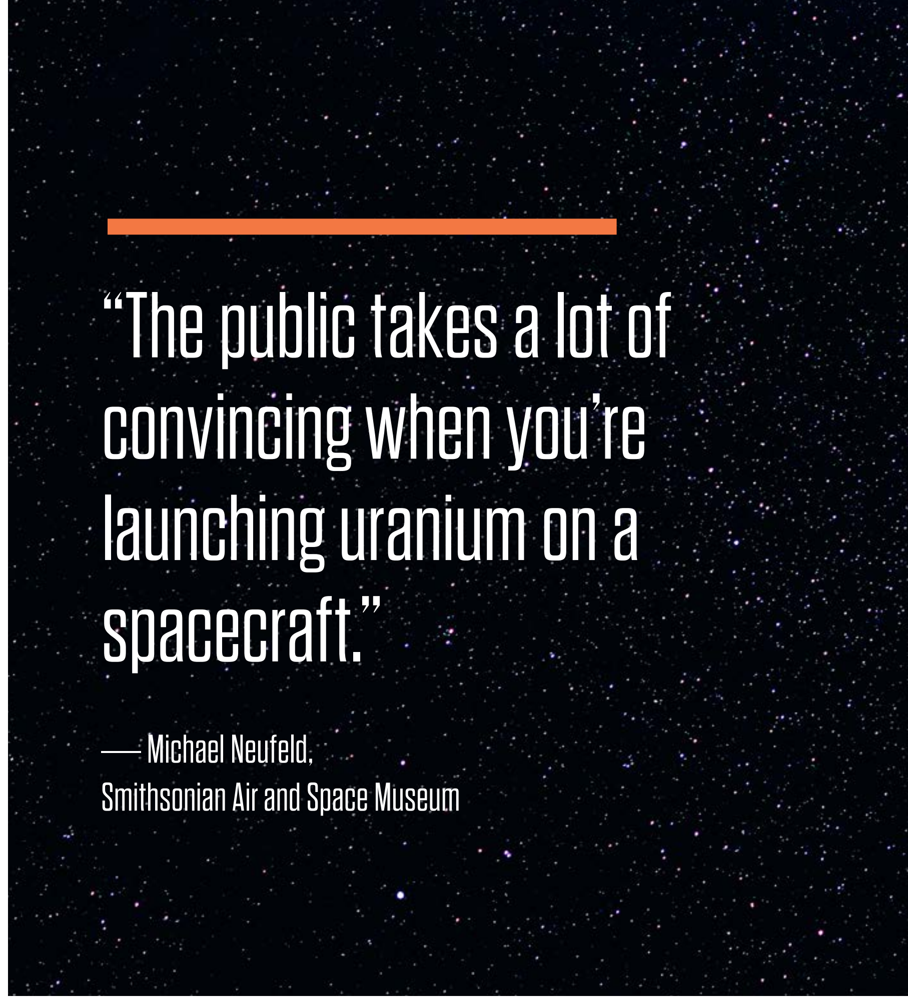
Planned duration: 18 months

Contracts: To be awarded to the Phase 2 winners after engine tests are completed might sound scarier, in Venneri's view, uranium fission reactors actually pose less of a risk should something go wrong on the launchpad.

"Until you turn them on, they're not radioactive," he says. By contrast, the plutonium in an RTG is always shedding dangerous radiation as it undergoes natural nuclear decay, a process that releases the heat that's used to generate electricity.

Safety mechanisms then must center around ensuring the reactor cannot turn on before reaching a safe orbit, even under emergency conditions, such as fission-enhancing water infiltrating the reactor core, Venneri says.

"It's a matter of putting poisons inside of the reactor that prevent it from turning on in case of an accident," he says — "poisons" like a neutron-absorbing rod of boron carbide. "If you just insert one of these inside of the reactor, that's just about the most effective way of killing it that there is."



Rules and costs

Not surprisingly, where there are safety questions, the government is never far behind. "Truly, what would squash the idea of a nuclear-powered OTV, or orbital transfer vehicle, would be regulation," says Atomos Space's Kowalski.

The past few years have generally been favorable to proponents of space nuclear, in terms of movements in government. In August 2019, for instance, then-President Donald Trump issued National Security Memorandum 20, which gave sponsoring agencies authority to launch NTP engines fueled by HALEU.

"In the prior framework, to prepare for launch approval, analysts would get stuck in 'analysis paralysis' and years of back-and-forth," Dodson says. With the memorandum, in the case of DRACO, the Defense Department will be able to make the final call to launch the NTP flight demonstration rather than needing the thumbs up from the Executive Office of the President.

Also, Trump's Space Policy Directive-6, issued in December 2020, discourages the use of weapons-grade uranium except in cases where HALEU fuel is not feasible, and encourages private sector involvement developing NTP systems and setting up separate launch oversight for private enterprises.

"It laid out the different launch processes for government and commercial launches, and then directed that any launch by a commercial company will be regulated by the FAA," Venneri says. "The FAA now is figuring out how to do this."

FAA declined to comment on its efforts regarding Space Policy Directive-6.

To test the regulatory framework, Atomos Space hopes to launch a reactor into space sometime in the mid-2020s. The fission reactor would generate electric power, rather than thrust for propulsion, since the main purpose is to test how the incipient regulatory and licensing processing actually plays out for a private company.

But all the supportive regulations and executive memos in the world might not be enough to get these new systems off the ground if Congress loses interest in missions that require NTP. If Congress chokes off funding, DRACO might well produce another NERVA — a proof of concept that immediately gets mothballed.

"What it really amounts to at the core is, 'Is there money for an ambitious human spaceflight program beyond the moon?'" Neufeld says. "My personal opinion about Artemis and so forth is that it'll turn out to be pretty expensive to try to develop a permanent base on the moon. And I'm not expecting Mars to be happening anytime soon."

But unlike during the Apollo era, today's NTP isn't just for Mars missions and moon bases. The rapid proliferation of satellites at all altitudes, international competition and the founding of the Space Force all point to military and civilian cases for the development of these systems.

At least, that's what Kowalski and Atomos Space are counting on.

"I think what was lacking before that has really changed now is more of a mission need," he says. "We have a true mission need. This solves a business case." ★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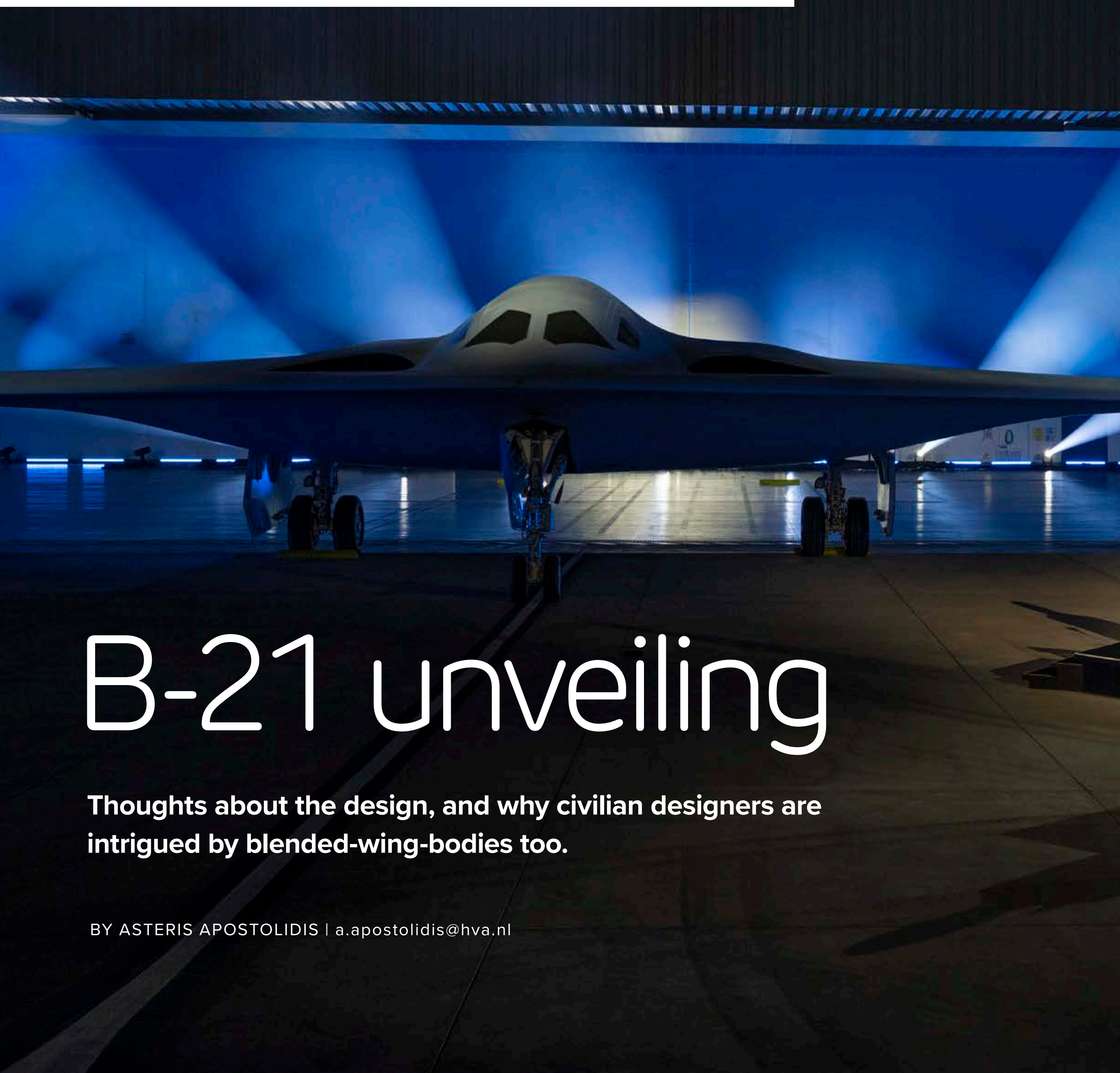
The first B-21 test aircraft was rolled out of a han
California, on a Friday night in early December, c
and blue lighting (above). Northrop Grumman en
back the cover to reveal the the sixth-generation
wing-body design.

Northrop Grumman/Chad McNeeley, U.S. Department of Defense



B-21 unveiling

Thoughts about the design, and why civilian designers are intrigued by blended-wing-bodies too.

BY ASTERIS APOSTOLIDIS | a.apostolidis@hva.nl

gar in Palmdale,
cloaked in a shroud
mployees then pulled
n bomber, a blended-

Now that the public has had its first glimpse of the B-21 Raider, let's do some comparing and contrasting to civil concepts.

Not much can be said with certainty about the B-21, which is still at least four years from being introduced into service by the U.S. Air Force, with the first test flight scheduled sometime this year. The media was only allowed to view and photograph the test aircraft from the front during the Dec. 2 unveiling at Northrop Grumman's plant in Palmdale, California.

But we know for sure that B-21 is a blended-wing-body, or BWB, meaning the wings and the main body of the aircraft are not clearly divided. We can easily see that in head-on shots of the B-21 and in the ample photos of its precursor, today's B-2s. Both configurations resemble recent civil BWB designs, including Airbus' MAVERIC*, a subscale flying model unveiled in 2020 at the Singapore Airshow, and the NASA-Boeing X-48B and C research aircraft. As similar as the military and civil concepts might look, their starting design principles are very different. B-21's sleek shape is dictated by the need for minimal infrared and radar signatures. From the front view, one can tell that the engines are buried deeply in the fuselage. This conceals the motion of their fans and minimizes their exhaust signatures. The need to minimize the aircraft's radar signature likely results in complex intake and exhaust designs, which at least partly explains why the Air Force and Northrop Grumman were so protective of the aft view during the unveiling. Burying the engines this way likely makes maintenance more of a chore, but stealth and survivability outweigh that consideration. Aerodynamic considerations are secondary but surely not neglected given that the B-21 must have a high combat radius, meaning the ability to fly far from its base in any direction. That spells a need for high fuel efficiency, and that comes from minimizing airframe drag, something a BWB shape does well.

Civil designers, by contrast, are attracted to BWB designs mainly for their interior roominess and the exterior real estate they provide for propulsion innovations. Without a need for stealth, engines can be mounted externally to improve their intake aerodynamics and simplify the maintenance. We see designs such as the European Union-funded AHEAD** concept that incorporates boundary layer ingestion technologies and NASA's N3-X concept that distributes the propulsion around the airframe, including small electric fans positioned very close to the airframe, to draw in the slow-moving boundary layer air and improve propulsive efficiency. For a commercial aircraft, the fuel, passenger and cargo capacities amount to a crucial parameter. With the engines mounted externally, this parameter can be maximized. As for innovations, in announcing its plan to introduce hydrogen aircraft by 2035, Airbus two years ago presented a BWB concept as one of the candidates under its ZEROe design campaign. Will this be the way of the future? Probably not any time soon. During the 2022 Singapore Airshow, Chief Technical Officer Sabine Klauke called the concept "most futuristic" and said a more "classical" configuration would likely be the first hydrogen aircraft to market, according to Aviation Week. ★

Asteris Apostolidis is an associate professor at Amsterdam University of Applied Sciences.

* **MAVERIC** stands for Model Aircraft for Validation and Experimentation of Robust Innovative Controls.

** **AHEAD** stands for Advanced Hybrid Engines for Aircraft Development.

AIAA Bulletin

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Addresses for Technical Committees and Section Chairs can be found on the AIAA website at aiaa.org.

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Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2023			
15–19 Jan*	33rd AAS/AIAA Space Flight Mechanics Meeting	Austin, TX (space-flight.org)	
21–22 Jan	6th AIAA Propulsion Aerodynamics Workshop (PAW06)	National Harbor, MD	
21–22 Jan	3rd AIAA Aeroelastic Prediction Workshop (AePW-3)	National Harbor, MD	
23–27 Jan	AIAA SciTech Forum	National Harbor, MD	1 Jun 22
30 Jan–2 Feb	Space Mission Operations Course	ONLINE (learning.aiaa.org)	
7 Feb–2 Mar	AI for Air Traffic Safety Enhancement Course	ONLINE (learning.aiaa.org)	
15–24 Feb	Complex Systems Competency Course	ONLINE (learning.aiaa.org)	
21 Feb–2 Mar	Technical Writing Essentials for Engineers	ONLINE (learning.aiaa.org)	
28 Feb–30 Mar	Electric VTOL Aircraft Design: Theory and Practice Course	ONLINE (learning.aiaa.org)	
4–11 Mar*	IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
6 Mar–12 Apr	Design of Space Launch Vehicles Course	ONLINE (learning.aiaa.org)	
13 Mar–5 Apr	Agile Systems Engineering Course	ONLINE (learning.aiaa.org)	
21 Mar–20 Apr	Design of Modern Aircraft Structures Course	ONLINE (learning.aiaa.org)	
24–25 Mar	AIAA Region III Student Conference	Dayton, OH	3 Feb 23
25–26 Mar	AIAA Region VI Student Conference	Davis, CA	5 Feb 23
27–28 Mar	AIAA Region II Student Conference	Knoxville, TN	27 Jan 23
28 Mar–6 Apr	Introduction to Propellant Gauging Course	ONLINE (learning.aiaa.org)	
29–30 Mar	ASCENDxTexas	Houston, TX	
31 Mar–1 Apr	AIAA Region I Student Conference	Buffalo, NY	27 Jan 23
31 Mar–1 Apr	AIAA Region IV Student Conference	Las Cruces, NM	31 Jan 23
5–26 Apr	Optimal Control for Unpiloted Aerial Vehicles (UAVs) – Online Guided Short Course	ONLINE (learning.aiaa.org)	
11–13 Apr	AIAA DEFENSE Forum	Laurel, MD	18 Aug 22
11–27 Apr	Overview of Python for Engineering Programming Course	ONLINE (learning.aiaa.org)	
13–16 Apr	AIAA Design/Build/Fly Competition	Tucson, AZ	

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
2023			
17 Apr–17 May	Hypersonic Flight Vehicle Design and Performance Analysis Course	ONLINE (learning.aiaa.org)	
19 Apr–9 Jun	Design of Gas Turbine Engines: From Concept to Details Course	ONLINE (learning.aiaa.org)	
19 Apr–12 May	Electrochemical Energy Systems for Electrified Aircraft Propulsion Course	ONLINE (learning.aiaa.org)	
21–22 Apr	AIAA Region V Student Conference	Kansas City, MO	11 Feb 23
25 Apr–11 May	Understanding Aircraft Noise: From Fundamentals to Design Impacts & Simulations Course	ONLINE (learning.aiaa.org)	
25–26 Apr	OpenFOAM® CFD Foundations Course	ONLINE (learning.aiaa.org)	
2–11 May	Digital Engineering Fundamentals Course	ONLINE (learning.aiaa.org)	
8, 15 May	Essential Model-Based Systems Engineering Course	ONLINE (learning.aiaa.org)	
9–11 May	Launch Vehicle Coupled Loads Analysis: Theory and Approaches Course	ONLINE (learning.aiaa.org)	
16 May–8 Jun	Introduction to Aeroelasticity: From Basics to Application Course	ONLINE (learning.aiaa.org)	
16–17 May	OpenFOAM® External Aerodynamics Course	ONLINE (learning.aiaa.org)	
16–25 May	Aircraft Reliability & Reliability Centered Maintenance Course	ONLINE (learning.aiaa.org)	
18 May	AIAA Awards Gala	Washington, DC (aiaa.org/gala)	
22–25 May	Understanding Space: An Introduction to Astronautics & Space Systems Engineering Course	ONLINE (learning.aiaa.org)	
23 May–6 Jun	Sustainable Aviation Course	ONLINE (learning.aiaa.org)	
28 May–1 Jun	25th AIAA International Space Planes and Hypersonic Systems and Technologies Conference	Bengaluru, Karnataka, India	6 Dec 22
7–9 Jun*	10th International Conference on Recent Advances in Air and Space Technologies (RAST 2023)	Istanbul, Turkey	20 Mar 23
12–16 Jun	AIAA AVIATION Forum	San Diego, CA	10 Nov 22
19–23 Jun*	International Conference on Icing of Aircraft, Engines, and Structures 2023	Vienna, Austria (https://www.sae.org/attend/icing)	
27–30 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
13–17 Aug*	2023 AAS/AIAA Astrodynamics Specialist Conference	Big Sky, MT (https://space-flight.org)	
2–6 Oct*	74th International Astronautical Congress	Baku, Azerbaijan (iac2023.org)	
23–25 Oct	ASCEND Powered by AIAA	Las Vegas, NV	

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

AIAA Continuing Education offerings (green rows)

AIAA Announces Its Class of 2023 Associate Fellows

AIAA is pleased to announce its newly elected Class of 2023 Associate Fellows. The grade of Associate Fellow recognizes individuals "who have accomplished or been in charge of important engineering or scientific work, or who have done original work of outstanding merit, or who have otherwise made outstanding contributions to the arts, sciences, or technology of aeronautics or astronautics." To be selected as an Associate Fellow an individual must be an AIAA Senior Member in good standing, with at least 12 years of professional experience, and be recommended by three current Associate Fellows.

The Institute is hosting a Class of 2023 Associate Fellows Meet and Greet on Tuesday, 24 January, during the 2023 AIAA SciTech Forum, National Harbor, Maryland, 23–27 January.

Class of 2023 AIAA Associate Fellows

Tarek Abdel-Salam
East Carolina University

Vishal Acharya
Georgia Institute of Technology

W. Nathan Alexander
Virginia Polytechnic Institute and State University

Eric Andrews
Boeing Commercial Airplanes

Selin Aradag
TED University

Emily Arnold
University of Kansas

H. Pat Artis
Virginia Polytechnic Institute and State University

Turaj Ashuri
Kennesaw State University

Mario Asselin
Asselin Inc.

Benjamin L. Austin Jr.
IN Space LLC

Steven Barrett
Massachusetts Institute of Technology

Steven Beard
NASA/ARC-AFS Aerospace Simulation R&D

Stuart Benton
Air Force Research Laboratory

Samuel Case Bradford
Jet Propulsion Laboratory, California Institute of Technology

Justin Bradley
University of Nebraska

Luca Carlone
Massachusetts Institute of Technology

Imon Chakraborty
Auburn University

Jeffrey T. Chambers
Aurora Flight Sciences, A Boeing Company

Haiyang Chao
University of Kansas

Melissa Choi
MIT Lincoln Laboratory

Tammy L. Choy
The Aerospace Corporation

Clinton Church
Aurora Flight Sciences, A Boeing Company

Joshua W. Clemens
Lockheed Martin Corporation

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Novespace SA

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Purdue University

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Raytheon Technologies

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Jet Propulsion Laboratory, California Institute of Technology

Michael Drews
Lockheed Martin Space


Kiran D'Souza
Ohio State University


Aaron Dufrene
CUBRC


Alexander Edsall
Charles Stark Draper Laboratory, Inc.


Kivanc Ekici
University of Tennessee


Dean Eklund
Air Force Research Laboratory


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University of Colorado Boulder


Edward J. Feltrop
Textron Aviation


Kent Gee
Brigham Young University


Andrew Gibson
Empirical Systems Aerospace, Inc. (ESAero)


Kandyce Goodliff
NASA Langley Research Center


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Digital Twin Institute


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Rolls-Royce PLC


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Lockheed Martin Corporation


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NASA Ames Research Center


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Teknicare, Inc.


Graeme Kennedy
Georgia Institute of Technology


Bhupendra Khandelwal
University of Alabama, Tuscaloosa


Steve Klausmeyer
Textron Aviation


Ashley Korzun
NASA Langley Research Center


Scott Kowalchuk
Sandia National Laboratories


Seth Lacy
U.S. Air Force


Vaios Lappas
National and Kapodistrian University of Athens/ Cranfield University


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Boeing Defense, Space & Security


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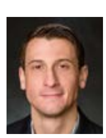
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Matthew Ringuette
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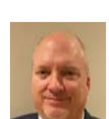
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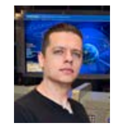


Tansel Yucelen
University of South Florida

Brian Yutko
The Boeing Company

For more information on the AIAA Honors Program or AIAA Associate Fellows, contact Patricia A. Carr at patriciac@aiaa.org.

AIAA Announces 2023 Sustained Service Award Winners

AIAA has announced the winners of the 2023 Sustained Service Awards. The award recognizes "sustained, significant service and contributions to AIAA by members of the Institute." Recipients must be AIAA members in good standing who have shown continuing dedication to the interests of the Institute by making significant and sustained contributions over a period of time, typically 10 years or more. Active participation and service at the local section/regional level, and/or the national level is a potential discriminator in the evaluation of candidates.

The **2023 Sustained Service Award** winners are:

David L. Carroll

CU Aerospace LLC

For distinguished and sustained service to AIAA; the enhancement of science, innovation, and entrepreneurial leadership in aerospace engineering; and education of scientist engineers.

Carroll co-founded CU Aerospace in 1998 and has served as its president since 2011. The company's focus is engineering innovation for new aerospace technology products. He received his Ph.D. in Aerospace Engineering from the University of Illinois in 1992. He was inducted as an AIAA Fellow in 2011.

John W. Daily

University of Colorado Boulder

In recognition of sustained contributions to the Institute's technical services, publications, and education committees.

Daily is Emeritus Professor of Mechanical Engineering at the University of Colorado Boulder. He received his Ph.D. from Stanford University in 1975. He works in the field of combustion and fire. He has served AIAA in numerous positions and is a Fellow of the Institute.

Luisella Giulicchi

European Space Agency

For over two decades of service to the Institute's governance, regional organization, and technical activities, and for being the advocate of international cooperation and AIAA engagement worldwide.

Giulicchi is a system manager at the European Space Agency (ESA), The Netherlands, for the Copernicus Program: the largest operational Earth observation program in the world.Her technical and programmatic management contributions include Bepi Colombo, SMART-1, LISA Pathfinder, Copernicus Sentinel-1, and Copernicus Sentinel-6. She is an RAeS Fellow; AIAA Associate Fellow, WIA-Europe President, and past AIAA Board of Directors member.

Walter O. Gordon

Moog Inc. (retired); Colonel, U.S. Air Force (retired)

For exceptional service to AIAA and for significant advancement of aerospace activities.

Gordon worked as an engineer in Western New York for 41 years before retiring recently to devote his time to the AIAA Niagara Frontier Section and local aerospace history. He also flew C130s in the Air Force Reserve, retiring in 2014 as the commander of the 914th Airlift Wing.

Dawn Phillips

NASA Marshall Space Flight Center

In honor of 20 years of dedicated service, leadership, and tireless work on behalf of AIAA, the AIAA Structures Technical Committee, and AIAA members.

With NASA, Phillips has supported the Space Shuttle, Ares, and SLS programs as a stress analyst and member of the NESC Structures Team. She is currently in Huntsville, AL, as the MSFC Assistant Chief Engineer for the International Space Station.

Sidra Silton

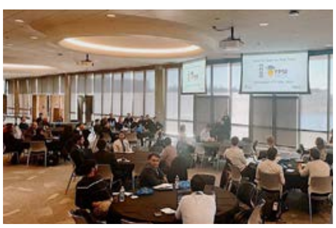
U.S. Army DEVCOM Army Research Laboratory

For two decades of dedicated service to the applied aerodynamics and fluid dynamics technical communities.

Silton received her Ph.D. in Aerospace Engineering from the University of Texas at Austin in 2001. Upon graduation she began working for the Army Research Laboratory where she now serves as Chief of the Mechanical Sciences Division. She is an AIAA Associate Fellow.

MAKING AN IMPACT

Students Present Research at Annual YPSE Conference



The AIAA Mid-Atlantic Section held their annual Young Professionals, Students, and Educators (YPSE) Conference in November. University and high school students presented their research at the event, with the addition of young professionals and educators also in attendance at the Johns Hopkins University Applied Physics Laboratory in Laurel, MD.

The conference was an incredible experience that brought together students, educators, and young professionals from all around the country to share their work and make connections within the broader aerospace industry. In addition to the presentations, the conference provided an opportunity for attendees to network and learn about various aspects of the aerospace industry and academia. AIAA Headquarters also hosted an exhibitor table where staff talked to attendees about upcoming events, programming, and AIAA membership.

The winning presentations included:

High School Category:

Honorable Mention – Logan SmithPerkins, The Effect of High Forces at Launch on the Deformations of a Protected Object

Top Presentation – Khoi Dinh and Alan Hsu, TJREVERB: Novel Communications and Radio Configuration for Educational CubeSat Missions

Undergraduate:

Honorable Mention – Jerry Liu and Kaylyn Song, Finding the Scaling Law for Pulsejet Engines

Top Presentation – Matteo Cerasoli, Ionospheric Propagation Measurement Through the Use of Sounding Rockets

Graduate:

Honorable Mention – Abenezer Taye and Peng Wei, Scalable Real-Time Trajectory Planning Framework for Urban Air Mobility

Top Presentation – Jorge Ahumada Lazo, Characterization of Recirculating Structures in the Near Field of Underexpanded Swirling Jets

Young Professional:

Honorable Mention – Erin Sutton, Preliminary Use for System Identification to Validate Models of Dragonfly's Octocopter

Top Presentation – Georgios Kyriakou, Additively Manufacturing Electronics: From Lab to Outer Space

Educator:

Top Presentation – Michelle Ming, Exposure Deficit

Don't Miss "Teacher Friday" on 27 January

Are you a K-12 educator near the DC/Maryland/Virginia area? You are invited to a free professional development workshop taking place at AIAA SciTech Forum!

When: Friday, 27 January 2023, 0800–1630 hrs ET USA

Where: Gaylord National Resort and Convention Center, National Harbor, Maryland

Meet educators and engineers and learn about the aerospace challenges of the 21st century. Dive into STEM concepts for your classroom or afterschool club/organization. Attendees will discover newly developed standards-based curriculum and integrated projects that can be used in the classroom. Topics include:

- Cutting-edge rocketry curriculum introduction (for students of all ages)
- An insider's look at NASA's Artemis program
- Aircraft Design Challenges
- DEI considerations for STEM programs
- High school CubeSats
- The value of communication and teamwork in STEM
- The Martian Greenhouse Program
- And more

Register at **aiaa.org/scitech/registration**. Select one-day registration for Friday, 27 January, at checkout and use code ST23TF for free* registration.

**Please note: This registration code may only be used by K-12 educators.*

This event is organized and hosted by the AIAA STEM K–12 Outreach Committee.

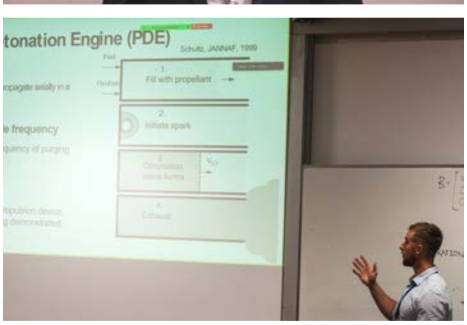
University of Adelaide Hosts 2022 AIAA Region VII Student Conference

To wrap up the 2022 Regional Student Conferences, the University of Adelaide hosted the 2022 Region VII Student Conference, 29–30 November 2022, both in person and virtually.

There were 34 papers presented, representing 23 universities. The conference had a strong international presence with students from 12 countries, including Australia, Bangladesh, China, Germany, India, Italy, Japan, Netherlands, New Zealand, Paraguay, the United Arab Emirates, and the United Kingdom.

Students presented in three categories: High School, Undergraduate, and Masters. Their presentations were evaluated by industry peers with many years of experience in the aerospace sector.

First-place winners in the Undergraduate and Masters categories received a cash prize of $500 and an invitation to participate in the International Student Conference at the 2023 AIAA SciTech Forum, 23–27 January, National Harbor, Maryland. Second-place winners received a cash prize of $300, third-place winner received $250, and the high school winner received $100.



High School Category

ShivNaveed Raina, Scholars International Academy, United Arab Emirates, “Exploring How the Hybridisation of Laser-Microwave Hybrid Wireless Power Transfer System (LMHWPTS) has Increased Efficiency in Comparison to the Two Commonly Established Traditional Models”

Undergraduate Category

1st: Daniel Smith, Monash University, Australia, “Symmetry-Enforced Coherent Structure Background Oriented Schlieren”

2nd: Omar Mourad, University of Stuttgart, Germany, “Neural Network based Model-Predictive Upset Recovery Control in Real-Time”

3rd Tie: Michael Pangestu, Monash University, Australia, “Enhancing 2-Component – 2-Diminsional Particle Image Velocimetry Using Physics-Informed Deep Learning”

3rd Tie: Kevin Liu, Monash University, Australia, “Enhancing Large Eddy Simulation Sub-grid Scale Closure Model Estimation Using Convolutional Neural Networks”

Masters Category

1st: Vishal Kashyap, Queen Mary University of London, United Kingdom, “Reinforcement Learning Based Linear Quadratic Regulator for the Control of a Quadcopter”

2nd: Celine Jane, Victoria University of Wellington, New Zealand, “Magnetic Disturbance Analysis of Spacecraft using Electromagnetic Thrusters”

3rd: Aaron Sew, Royal Melbourne Institute of Technology, Australia, “Designing an Automated Barking Drone to Detect and Repulse Cattle in Real World”

AIAA’s student conferences are a way for students to present their work in front of their peers and members of the industry. The Regional Student Conferences for Regions I-VI take place annually in the spring.

AIAA would like to thank Lockheed Martin for supporting the program. Additionally, special thanks to the University of Adelaide, the Adelaide Section, the judges, Rey Chin, Patrick Neumann, and Region VII Director Cees Bil for coordinating the conference.

SAT OC's Successful Year

By Amir S. Gohardani, SAT OC Chair

The AIAA Society and Aerospace Technology Outreach Committee (SAT OC) had a very productive year, seeing its largest membership in the past 7 years with a 32% growth of committee members since 2021. Based on the shown interest in the committee and the number of membership applications submitted for 2023, this year will be an even better year with an increasingly diverse membership active in both for-profit and nonprofit organizations, as well as government agencies. The successful launch of the *Diversity Corner* in collaboration with the AIAA Diversity and Inclusion Working Group, SAT OC also has paved the way for the committee to take new steps in its commitment to become more inclusive. Continuing its tradition of exploring a myriad of topics related to aerospace technology and society, the SAT OC will host three sessions during the 2023 AIAA SciTech Forum. We invite you to join these sessions and assist us in advancing the discussions on society and aerospace technology.

SAT OC Spotlight


Elizabeth Rieken

This month, we are spotlighting **Elizabeth Rieken** who joined the committee in April. Rieken is an aerospace engineer in the Engineering Integration Branch at NASA Langley Research Center. She holds a B.S. in Aerospace Engineering from the University of Virginia and an M.S. and Ph.D. in Mechanical Engineering from Stanford University. Rieken conducted graduate research in the field of laser diagnostics prior to completing her dissertation work focused on increasing innovation in engineering design through mindfulness and divergent thinking. Her training and experience span the disciplines of engineering, design, education, and social science. She joined NASA Langley in 2018 as a researcher in the Aerothermodynamics Branch. Her work focused on aeroheating and aerodynamic force and moment wind tunnel testing for hypersonic vehicles. In 2021, Rieken joined the Convergent Aeronautics Solutions (CAS) project as a complex systems design engineer. CAS explores pressing sociotechnical problems and imagines desirable aviation futures to illuminate high-value opportunities for NASA aeronautics and beyond. She leads the Synthesis element of the CAS lifecycle where teams focus on problem exploration and problem framing with a systems-level lens. She is thrilled to exercise the breadth of her training and expertise in aerospace engineering, design, and social science to think differently about framing problems for aviation concepts.

Upon joining SAT OC, she is equally excited to expand her community of students and professionals who conduct and promote work at the intersection of aerospace technology and complex societal challenges.

Diversity Corner


Maruthi Akella

NAME: Maruthi Akella

NOTABLE CONTRIBUTIONS:
Akella holds the Ashley H. Priddey Centennial Professorship, at the University of Texas at Austin and is director of the Center for Autonomous Air Mobility. An expert in space robotics, autonomy, learning, and control theory, Akella was elected to the 2022 AIAA Fellow class "for sustained outstanding scholarship, leadership, and high-impact contributions in the field of aerospace guidance and control."

Akella is also a Fellow of the IEEE and the American Astronautical Society (AAS) and holds the Academian rank with the International Academy of Astronautics. His major research contributions have been recognized through the AIAA Mechanics and Control of Flight Award (2014); IEEE AESS Judith A. Resnik Space Award (2015); IEEE Control Systems Society Award for Technical Excellence in Aerospace Control (2020); academician, International Academy for Astronautics (2020); and AAS Dirk Brouwer Award (2020). Akella is currently the Editor-in-Chief of *The Journal of the Astronautical Sciences* and an Associate Editor for the AIAA *Journal of Guidance, Control, and Dynamics*. He is the Technology area coordinator for the State of Texas Urban Air Mobility Advisory Committee. He also serves on the AIAA Guidance, Navigation, and Control Technical Committee and the AAS Board of Directors.

POTENTIAL SOCIETAL IMPACT OF CONTRIBUTIONS:
Along with his many impressive contributions to the aerospace controls field, Akella made many enduring educational contributions as an academic advisor and mentor. With a classroom philosophy of fostering open discussion and embracing ambiguity, he encourages his students to be curious and embrace the lessons learned from both successes and failures.

*In collaboration with the AIAA Diversity and Inclusion Working Group and Claudine Phaire, SAT OC is highlighting prominent members of the wider aerospace community in the Diversity Corner.

Integrating Mission Objectives, Capabilities, and Technologies — 2022 SSTC Essay Contest Winners Announced

The AIAA Space Systems Technical Committee's (SSTC) annual middle school essay contest continues to advance the committee's commitment to directly inspire students and to involve local AIAA sections in educational pursuits. Each year, local sections sponsor parallel contests to feed into selection of national award winners recognized by the SSTC.

Seventh and eighth grade students were invited to participate. This year, AIAA local sections from across the country submitted entries to the contest. Participating sections included Cape Canaveral, Connecticut, Long Island, Los Angeles/Las Vegas, Palm Beach, Rocky Mountain, and Southwest Texas. For each grade, there were first-, second-, and third-place winners, which included $125, $75, and $50 awards for the students, respectively. The six students also received a one-year student membership with AIAA. The 2022 essay topic was "Describe a space mission that integrates at least three of the following system capabilities: autonomous systems; disaggregated satellites or platforms; on-orbit servicing, assembly, and manufacturing; in-situ resource utilization; small satellites; data analytics; optical and radio communications; advanced propulsion, advanced sensors (low mass, high-sensitivity, quantum, etc.). What is the objective of this mission, and how will the mission achieve the objective?"

The first-place winner for 8th grade is **Lea Segal** of Rancho Palos Verdes, CA (Los Angeles-Las Vegas Section). The second-place winner for 8th grade is **Michael Mikati** of Stuart, FL (Palm Beach Section). The third-place winner for 8th grade is **Alayna Garrett** of Colorado Springs, CO (Rocky Mountain Section)

The first-place winner for 7th grade is **Axel Anderson** of Colorado Springs, CO (Rocky Mountain Section). The second-place winner for 7th grade is **Santiago Gollarza** of Palm Beach Gardens, FL (Palm Beach Section). The third-place winner for 7th grade is **Sid Patsamatla** of Merritt Island, FL (Cape Canaveral Section)

All 2022 winning essays can be found on the Aerospace America website (**aerospaceamerica.aiaa.org/bulletin/january-2023-aiaa-bulletin**). The topic for 2023 is "Choose one aspect of the James Webb Space Telescope, describe how it works, and explain why it leads us to new discoveries and to answer important questions about the universe." If you, your school, or your section would be interested in participating in the 2023 contest, please contact Anthony Shao-Berkery (ant.shao@gmail.com), Erica Rodgers (erica.rodgers@nasa.gov), or your local section for more details.

Obituaries

AIAA Fellow Gasich Died in January 2022

Welko E. Gasich died on 14 January 2022. He was 99 years old.

Gasich's interest in aircraft was sparked at age 10 when his uncle gave him a flight in his airplane. He received his B.A. degree in Mechanical Engineering from Stanford University in 1943. His graduate studies were interrupted by World War II when he served in the United States Navy as a flight test engineer achieving the rank of Lieutenant. As an officer on detached duty with NACA, he was placed at Moffett Field to correlate the P-39 flight test results of drag divergence Mach number with wind tunnel tests. He also was the project engineer in charge of propeller tests on the XSB2D-1 single-engine airplane that eventually crashed due to engine failure. Both he and the pilot survived, but the airplane was destroyed. After his active duty in the U.S. Navy (1944–1946), he continued in the U.S. Naval Reserve until April1954, at which time he was honorably discharged.

Returning to Stanford University, he received his M.S. in Aeronautical Engineering in Aeronautical Engineering in 1948. Gasich also received a Professional Degree of Engineering from California Institute of Technology, and he was a graduate of the Sloan Executive Program, Graduate School of Business, Stanford University (1967). Gasich began his professional career with Douglas Aircraft Company, El Segundo Division, where he worked in the fields of aerodynamics and aeroelasticity on a variety of aircraft. He also worked at the Rand Corporation, as Chief of Aircraft Design on various aircraft programs in support of the U.S. Air Force. Gasich was asked to join the Northrop Corporation as Chief of Preliminary Design in 1953. He had a major role in Northrop's conception and development of the U.S. Air Force's lightweight supersonic jet trainer, the T-38 Talon, of which he was a co-patentee. The T-38 entered service with the USAF. He was also intimately involved in the design of the F-5 (co-patentee) as well as the F-5A, and the F-5E supersonic fighters. In 1956 he was promoted to Director of Advanced Systems and in 1961 to Vice President of Engineering and Assistant General - Manager Technical.

Following his return to Northrop from the Sloan Executive Program at Stanford University, he was General Manager of Ventura Division. While there he managed subsystems such as the parachute recovery system for Mercury, Gemini, and Apollo space vehicles. In 1971 he returned to the Aircraft Division of Northrop as General Manager. He worked on the NASA M-2 and HL-10 space recovery vehicles as well as the A-9, YF-17, F-18 fighters and the early work of the B-2 bomber. Thereafter, he was appointed a Corporate Officer and Senior Vice President of Advanced Projects. In 1985 he was elected Executive Vice President of Programs until his retirement in 1988.

Gasich was elected to the National Academy of Engineering for his work on supersonic aircraft design and leadership in the engineering field. He was a member of the Joint Strategic Target Planning Staff (JSTPS) Scientific Advisory Group. He was also elected a Fellow of AIAA and SAE. He served as a member of the SAE Board of Directors and on various university engineering advisory boards. He was the author of various articles on technical subjects and engineering management. Upon his retirement from aerospace, he studied the key factor in determining the horsepower output of racing engines. After two years of research on Ferrari engines, he determined that bore/stroke ratio was a powerful index of engine performance, and he authored the book, *Forty Years of Ferrari V-12 Engines*, published by the Society of Automotive Engineers.

AIAA Fellow Boehm Died in August


John Vidar

Barry Boehm, a pioneer in the fields of computer science and software engineering, died 20 August. He was 87.

Boehm earned his bachelor's and master's degrees from Harvard University and his Ph.D. in mathematics from the University of California, Los Angeles. He worked at the RAND Corporation, TRW Inc., and DARPA over the course of his career before joining the University of Southern California's faculty in 1992. He served as a USC distinguished professor of computer science, industrial and systems engineering, and astronautics until he retired in May 2022.

He is best known for the invention of a software cost estimation model that transformed the discipline. This model allowed software engineers and project managers to gain control of projects that were increasingly behind schedule, over budget, and low quality, saving companies and government agencies untold billions of dollars. He described this Constructive Cost Model in the 1981 book, *Software Engineering Economics*.

Boehm also developed the spiral software lifecycle model, which recognized that large, expensive, and complicated projects require an iterative development process with gradual releases and refinement of a product through each phase.

Boehm was the author of more than 900 publications, including nearly 200 journal

AIAA Standards Under Revision

The following AIAA Standards are under revision: AIAA S-111 (Qualification and Quality Requirements for Space Solar Cells), AIAA S-112 (Qualification and Quality Requirements for Electrical Components on Space Solar Panels) and S-113 (Criteria for Explosive Systems and Devices on Space and Launch Vehicles). If you are interested in any of these revision projects, please contact Nick Tongson (nickt@aiaa.org).

articles, 6 textbooks, and hundreds of conference papers, as well as presentations, keynotes, and webinars. He also helped guide more than 30 Ph.D. students at USC. In 2007, the International Conference on Software Engineering held a symposium to honor Boehm ("Software Engineering: The Legacy of Barry W. Boehm"), which highlighted his legacy by gathering colleagues and members of the software engineering community. The symposium also published a book that contained reprints of his 42 most influential papers. In 2014, his work was further discussed in the *Journal of Cost Analysis and Parametrics* article, "On the Shoulders of Giants: A Tribute to Professor Barry Boehm."

Boehm received many awards and recognitions, including the 2018 SERC Founders Award and the 2019 INCOSE Pioneer Award "for his work as a systems pioneer uniquely contributing to the advancement of systems engineering through extensive research, education and the application thereof in industry." He also received the 1979 AIAA Information Systems Award and the 2013 AIAA Aerospace Software Engineering Award. He was a fellow of the International Council on Systems Engineering (INCOSE), AIAA, the Association of Computing Machinery (ACM), and IEEE, and was elected as a member of the National Academy of Engineering in 1996.

AIAA Associate Fellow Tauber Died in October

Michael E. Tauber died on 17 October 2022.

A survivor the Holocaust, Tauber was educated in Aeronautical Engineering at the University of Washington and Stanford University (1959). The majority of Tauber's career was devoted to NASA's programs as a civil servant starting at NASA Ames Research Center in 1962, until he retired from Analytical Mechanics Associated, Inc. in 2016.

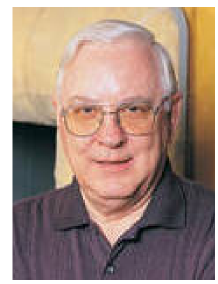
One of Tauber's most important works in space exploration was on the Jupiter Probe, which began in 1966. His study demonstrated that a human-made object could survive entry into the giant planet's atmosphere and return data to Earth revealing information regarding its structure and composition down to about 100 bars. Features of the probe and its trajectory included the use of a carbon phenolic heat shield and a shallow entry angle in the direction of the planets' equatorial rotation. The final results of Tauber's feasibility study were presented at an AIAA meeting in fall 1970 and published in the *Journal of Spacecraft and Rockets* in 1971. On 7 December 1995, Tauber was able to see his findings successfully applied when Galileo's entry took place on at a speed of 47.41 km/s; its entry is considered the most severe in the history of the space program. Recession sensors on board the probe showed that the thickness of the forebody heat shield was overestimated in the nose region and underestimated on the flank. Design tools used for the Galileo probe heat shield are primitive compared to those used by today's entry technologists, but because of the complicated flow physics and ablation processes involved the entry remains a focus of study to completely understand the observed heat shield recession. Tauber was involved with the design and understanding of the Galileo probe's entry performance, even in the latter stages of his career.

Tauber's research relating to atmospheric entry included analysis of important Mars missions including Pathfinder, Mars Exploration Rover (MER), Phoenix, and Insight. He was also heavily involved in the development of the design of the Stardust Comet Sample Return heat shield. He developed tools such as the Tauber-Sutton correlation for entry heating and explanations of why probe designs depend upon the composition of the planetary atmosphere under consideration. Tauber was the 2010 winner of the coveted International Planetary Probe Workshop's Alvin Seiff Award "In recognition of his contributions over the past fifty years as an Entry System Engineer, as a teacher and in developing concepts and successfully leading thermal protection systems (TPS) and entry system design of such missions as Galileo and Mars Pathfinder." Tauber is one of the greatest contributors to NASA's planetary missions, aerothermodynamics, and applications of thermal protection systems.

He was asked to contribute to NASA's program in rotorcraft from 1971 to 1985. He also excelled in this area, winning the 1985 Howard Hughes Award, "For his contributions to the development and application of ROT22, the first three-dimensional full potential computer code capable of predicting the transonic flow around helicopter rotor blades."

In addition to his contributions as a NASA researcher, Tauber also devoted considerable time as a teacher and a mentor to two generations of aerospace engineers. He taught courses in engineering at Stanford University, Santa Clara University, North Carolina University, and the University of Tennessee.

AIAA Fellow Mueller Died in December



Thomas J. Mueller, professor emeritus of aerospace and mechanical engineering at the University of Notre Dame and a leading authority on aerodynamics, died on 4 December. He was 88.

After earning his bachelor's degree in mechanical engineering from the Illinois Institute of Technology and a doctorate from the University of Illinois, Mueller joined Notre Dame's Department of Aerospace and Mechanical Engineering in 1965. He was named the Roth-Gibson Professor of Aerospace Engineering in 1989.

Mueller significantly enhanced Notre Dame's reputation in aeronautical research. In the 1970s, after making contributions to the understanding of blood flow in artificial heart valves, he began investigating new problem areas in aerodynamics. He was particularly interested in the complex movement of air around different airfoils, and his work in this area brought him international recognition from researchers in fluid dynamics. Mueller also made pivotal contributions to his department's graduate program. He served as director of engineering research and graduate studies from 1985 to 1989 and as department chair from 1988 to 1996.

Mueller published several books and many articles in scholarly journals, including the AIAA *Journal of Spacecraft and Rockets* and the *ASME Journal of Biomechanical Engineering*. He was a Fellow of the American Society of Mechanical Engineers, AIAA, and the Royal Aeronautical Society. He was recognized by AIAA with the 1980 J. Leland Atwood Award and the 2003 Aerodynamics Award.

AIAA Student Branches, 2022–2023

AIAA has more than 240 student branches around the world. Each branch has a chair elected each year, and a faculty advisor who serves long term to support that branch's activities. Like the professionals, the student branches invite speakers, take field trips, promote career development, and participate in projects that introduce students to membership with AIAA and their professional futures. The branches, and their officers in particular, organize branch activities in addition to their full-time schoolwork, and their advisors clearly care deeply about their students' futures. Please join us in acknowledging the time and effort that all of them take to make their programs successful.

FA = Faculty Advisor
SBC: Student Branch Chair

Region I

American Public University System
SBC: Cameron Nardini
FA: Kristen Miller

Boston University
FA: Sheryl Grace
SBC: Hannah Rafferty

Carleton University
FA: Steve Ulrich

Catholic University of America
FA: Diego Turo
SBC: Halle Green

City College of New York
SBC: Michael Jacobson
FA: Prathap Ramamurthy

Clarkson University
FA: Kenneth Visser
SBC: Melanie Orzechowski

Columbia University
SBC: Nathan Coulibaly
FA: Robert Stark

Concordia University
FA: Hoi Dick Ng

Cornell University
FA: Dmitry Savransky
SBC: Christopher Chan

Drexel University
FA: Ajmal Yousuff
SBC: Joseph Fasso

École de Technologie Supérieure
SBC: Elias Nejad
FA: Ruxandra Botez

George Washington University
FA: Peng Wei
SBC: Yazan Sawalhi

Hofstra University
FA: John Vaccaro

Howard University
FA: Nadir Yilmaz

Lehigh University
FA: Terry Hart
SBC: Kevin Jun

Massachusetts Institute of Technology
FA: David Darmofal

Manhattan College
SBC: Melissa Feliciano FA: John Leylegian

New York Institute of Technology
FA: James Scire

Northeastern University
SBC: Cameron Bracco
FA: Andrew Gouldstone

NYU Tandon School of Engineering
FA: Nick DiZinno

Old Dominion University
SBC: Cole Burnette
FA: Colin Britcher

Pennsylvania State University
FA: Robert Melton
SBC: Graeme Sutterlin

Princeton University
FA: Michael Mueller

Renssalaer Polytechnic Institute
SBC: Alex Stillman
FA: Farhan Gandhi

Rochester Institute of Technology
FA: Agamemnon Crassidis
SBC: Jacob Plato

Rowan University
SBC: Nicholas Gushue
FA: John Schmalzel

Rutgers University
FA: Francisco Diez
SBC: Noah McAllister

Ryerson University
Southern New Hampshire University
FA: Xinyun Guo
SBC: Kerry McNally

Stevens Institute of Technology
FA: Siva Thangam
SBC: Amir Choudhury

Stony Brook University
SBC: Alexis Herrera
FA: Foluso Ladeinde

SUNY/Buffalo
FA: Paul Schifferle
SBC: Aayush Kumar

Syracuse University
SBC: Sasha Valitutti
FA: John Dannenhoffer

United States Military Academy-West Point
FA: Nathan Humbert
FA: Chalie Galliand

United States Naval Academy
SBC: Oleksiy Lakei
FA: Eric Brogmus

University of Massachusetts-Lowell
SBC: Kyle Fielder
FA: Marianna Maiaru

University of Maryland, College Park
SBC: Allen Schnaitmann
FA: Norman Wereley

University of Connecticut
SBC: Hunter Lyman
FA: Sung Chih-Jen

University of Maine
SBC: Katie Holmes
FA: Alexander Friess

University of Maryland, Baltimore County
SBC: Anthony Lavezza
FA: Charles Eggleton

University of Pittsburgh
FA: Matthew Barry
SBC: Cara Rossetti

University of Toronto
University of Vermont
SBC: Dylan Baker
FA: William Louisos

University of Virginia
FA: Christopher Goyne

Vaughn College of Aeronautics and Technology
FA: Amir Elzawawy

Virginia Commonwealth University
FA: Bradley Nichols
SBC: Brenden Chaulklin

Virginia Polytechnic Institute and State University
SBC: Johana Aguero-Fischer
FA: Greg Young

Villanova University
SBC: Patrick Kumer
FA: Sergey Nersesov

Wentworth Institute of Technology
SBC: Sean Perkins
FA: Haifa El-Sadi

West Virginia University
SBC: Charles Harmison
FA: Christopher Griffin

Worcester Polytechnic Institute
SBC: Paul Coccomo
FA: Zachary Taillefer

Yale University
FA: Mitchell Smooke

Region II

Alabama A&M University
FA: Zhengtao Deng

Athens State University
FA: J Wayne Mc Cain
SBC: Michelle Allen

Auburn University
SBC: Olivia Smith
FA: Norman Speakman

Duke University
SBC: TBD
FA: Kenneth Hall

East Carolina University
SBC: Jacob Rose
FA: Tarek Abdel-Salam

Embry-Riddle Aeronautical University Worldwide
SBC: Jamarius Reid
FA: Robert Deters

Embry-Riddle Aero University-Daytona Beach
SBC: Daniel Garlock
FA: Habib Eslami

Florida A&M University
FA: Chiang Shih
SBC: Zachary Isriel

Florida Atlantic University
FA: Stewart Glegg
SBC: Jake Pearman

Florida Institute of Technology
FA: David Fleming
SBC: Ashley Rivkin

Florida International University
FA: George Dulikravich
SBC: Gabriel Herrera

Florida State University
SBC: Tripp Lappalainen
FA: Chiang Shih

Georgia Institute of Technology
FA: Dimitri Mavris
SBC: Satvik Kumar
SBC: Claire Keller

Kennesaw State University
SBC: Cindy Vo
FA: Adeel Khalid

Louisiana State University
FA: Keith Gonthier

Miami University, OH
SBC: Aayush Gadal
FA: James Van Kuren

Mississippi State University
FA: Robert Wolz
SBC: Joseph Mays

North Carolina State University
SBC: Holly Huffine
FA: Jack Edwards

North Carolina A&T State University
FA: Michael Atkinson
SBC: Christopher Manda

Polytechnic University of Puerto Rico
SBC: Yan Casanova
FA: Jose Pertierra

Tennessee Technological University
FA: Rory Roberts
SBC: Etehan Pesterfield

Tuskegee University
SBC: Brandon Guiseppi
FA: Mohammad Khan

University of Alabama-Huntsville
SBC: Alex Denson
FA: Kunning Xu

University of Central Florida
FA: Seetha Raghavan
SBC: Joey Barr

University of Florida
SBC: Esha Shah
FA: Richard Lind

University of Memphis
SBC: James Mathis
FA: Jeff Marchetta

University of Miami
SBC: Tristan Peterson
FA: Giacomo Po

University of Alabama at Birmingham
FA: Roy Koomullil
SBC: Stephen Bush

University of Alabama-Tuscaloosa
FA: Weihua Su
SBC: Adam Kempf

University of Georgia
FA: Ramana Pidaparti
SBC: Hunter Haskins

University of Mississippi
FA: Jeff Rish

University of North Carolina at Charlotte
FA: Artur Wolek
SBC: Kyle Vanhorn

University of Puerto Rico
SBC: Ernesto Forteza
FA: Sergio Preidikman

University of South Alabama
FA: Carlos Montalvo
SBC: Coleman Davis

University of South Carolina
SBC: Patrick Bailey
FA: Wout De Backer

University of Tennessee Knoxville
SBC: Chad Bolding
FA: James Coder

University of Tennessee Space Institute
FA: Phillip Kreth
FA: Jacob Butera

University of Tennessee-Chattanooga
FA: Kidambi Sreenivas

University of West Florida
SBC: Odalys Rodriguez
FA: Carolyn Mattick

Vanderbilt University
SBC: Zachary Friedman
FA: Amrutur Anilkumar

Region III

Air Force Institute of TechnologyFA: Marc Polanka
SBC: Matthew Gazella

Case Western Reserve University
SBC: Eduardo Valenzuela
FA: Paul Barnhart

Cedarville University
FA: Thomas Ward
SBC: Joel Stahr

Cleveland State University
SBC: Concetta Salvia
FA: Nicole Strah

Illinois Institute of Technology
SBC: Connie McNulty
FA: Boris Pervan

Indiana University:Purdue Univ Indianapolis
FA: Hamid Dalir
SBC: Peter Oluwaseun

Kettering University
FA: Ahmed Mekky

Lawrence Technological University
FA: Andrew Gerhart
SBC: Rose Gebara

Miami University Ohio

Michigan State University
SBC: Jake Rutkowski
FA: Patton Allison

Milwaukee School of Engineering
FA: William Farrow
SBC: Aaron Saef

Ohio Northern University
SBC: Olivia Galigher
FA: Jed Marquart

Ohio State University
SBC: Maya Sivakumaran
FA: Ali Jhemi

Ohio University
FA: Jay Wilhelm
SBC: Michael Variny

Purdue University
FA: Li Qiao
SBC: Haley Scott

Rose Hulman Institute of Technology
SBC: Jordan Massey
FA: Matthew Riley

Trine University
FA: James Canino
SBC: Ismar Chew

University of Akron
SBC: Jonathan Davis
FA: Alexander Povitsky

University of Dayton
SBC: Scott Chriss
FA: Sidaard Gunase-karan

University of Kentucky-Lexington
SBC: Kyle Hampton
FA: Alexandre Martin

University of Kentucky-Paducah
SBC: Joshua Hagan
FA: Sergiy Markutsya

University of Notre Dame
SBC: Keegan Tran
FA: Thomas Juliano

University of Wisconsin-Madison
SBC: Kyle Adler
FA: Riccardo Bonazza

University of Wisconsin-Milwaukee
SBC: Omar Habash
FA: Ryoichi Amano

University of Cincinnati
FA: Bryan Kowalczyk
SBC: Garrison Wettengel

University of Illinois at Chicago
SBC: Stevenson Durning
FA: Kenneth Brezinsky

University of Illinois at Urbana-Champaign
SBC: Noah Jon
FA: Laura Villafañe Roca

University of Michigan Ann Arbor
FA: Benjamin Jorns
SBC: Delenn Bauer

Western Michigan University
SBC: Ryan Dull
FA: Kapseong Ro

Wright State University
SBC: Caleb Wasserbeck
FA: Mitch Wolff

Region IV

Lamar University
FA: Mason Li

New Mexico Institute of Mining and Technology
SBC: James Montoya
FA: Mostafa Hassanalian

New Mexico State University
FA: Andreas Gross
SBC: Addison Miller

Oklahoma State University
SBC: Austin Rouser
FA: Andrew Arena

Rice University
SBC: Warren Rose
FA: Andrew Meade

Texas A&M University
FA: Bonnie Dunbar
SBC: Alexander Gross

University of Texas/Dallas
SBC: Kevin Debord
FA: Arif Malik

University of Arkansas
SBC: Chandler Dye
FA: Po-Hao Huang

Universidad Autonoma de Baja California
SBC: Christian Sanchez
FA: Paz Juan Antonio

Universidad Autonoma de Chihuahua
FA: Carlos Sanchez
SBC: Oscar Garcia

University of Houston
FA: Marzia Cescon
SBC: Hailey Stafford

University of New Mexico
SBC: Collin Nesbit
FA: Daniel Banuti

University of Oklahoma
FA: Thomas Hays

University of Texas at San Antonio
SBC: Monique Vasquez
FA: Christopher Combs

University of Texas/Arlington
SBC: Alan Montemayor
FA: Zhen-Xue Han

University of Texas-Austin
FA: Renato Zanetti
SBC: Lauren Rodriguez

University of Texas-El Paso
FA: Jack Chessa
SBC: Rene Aguilar

Region V

Colorado School of Mines
FA: Angel Abbud-Madrid
SBC: Nicole Bernuy-Her-quinigo

Colorado State University
FA: Karen Thorsett-Hill
SBC: Daniel Zhou

Iowa State University
SBC: Michael Weber
FA: Shahram Pouya

Kansas State University
SBC: Bolun Xu
FA: Scott Thompson

Metropolitan State University of Denver
SBC: Tiffany Jewell
FA: Jose Lopez

Missouri University of Science and Technology
FA: Kakkattukuzhy Isaac
SBC: Austin Sanders

Saint Louis University
FA: Michael Swartwout
SBC: Julia Maxwell

United States Air Force Academy
FA: Barrett McCann

University of Calgary
SBC: Raleigh Nolan
FA: Craig Johansen

University of Colorado Boulder
SBC: Matthew Davis
FA: Donna Gerren

University of Colorado Colorado Springs
SBC: Rebekah Shepard
FA: Lynnane George

University of Kansas
FA: Ronald Barrett-Gon-zalez
SBC: Carson Richardson

University of Minnesota
SBC: Claire Graney-Dolan
FA: Yohannes Ketema

University of Iowa
SBC: Sam Witte
FA: Kamran Samani

University of Missouri Columbia
SBC: Christopher Hammon
FA: Craig Kluever

University of Missouri-Kansas City
FA: Seth Seagraves
SBC: Austin Stark

Washington University in St Louis
SBC: Jonathan Richter
FA: Swami Karuna-moorthy

Wichita State University
SBC: Megan Drake
FA: Linda Kliment

Region VI

Arizona State University
SBC: Zach Norris
SBC: Lucas Guaglardi
FA: Timothy Takahashi

Brigham Young University
SBC: Max Wirz
FA: Steven Gorrell

California Institute of Technology
SBC: Malcolm Tisdale
FA: Soon-Jo Chung

California Poly State Univ:San Luis Obispo
FA: Aaron Drake
SBC: Elena Felix

California Polytechnic State University-Pomona
FA: Subodh Bhandari
SBC: Amber Leather-wood

California State University, Fresno
FA: Deify Law
SBC: Russell Gee

California State University-Long Beach
FA: Eun Jung Chae

California State University-Northridge
FA: Peter Bishay
SBC: Dylan Lyon

California State University-Sacramento
FA: Ilhan Tuzcu

Embry-Riddle Aero University Prescott/AZ
FA: David Lanning
SBC: Michael Finnigan

Oregon State University
SBC: James Shea
FA: Roberto Albertani

Portland State University
SBC: Rose Jardine
SBC: Danaya Murphy
FA: Andrew Greenberg

San Diego State University
SBC: Emma Topolcsik
FA: Pavel Popov

San Jose State University
SBC: Svitlana Kuklensko
FA: Periklis Papado-poulos

Santa Clara University
FA: Mohammad Ayoubi
SBC: Brian Puskarczyk

Stanford University
SBC: Walter Manuel
FA: Stephen Rock

University of Arizona
FA: Jekan Thangavel-autham
SBC: Matthew Banko

University of California/Los Angeles
SBC: Zehao Rong
FA: Jeff Eldredge

University of California/San Diego
FA: Mark Anderson
SBC: Carissa Yao

University of Alaska Fairbanks
SBC: Seth Thomas
FA: Michael Hatfield

University of California/Davis
SBC: Duha Bader
FA: Zhaodan Kong

University of California/Irvine
SBC: Rendell Miguel
FA: Jacqueline Huynh

University of California/Merced
SBC: Antonio Garcia
FA: YangQuan Chen

University of California-Berkeley
FA: Panos Papado-poulos
SBC: Yamilex Ramirez

University of Nevada, Reno
SBC: Kenneth Pi
FA: Jeffrey LaCombe

University of Nevada/ Las Vegas
SBC: Jacqueline Gonza-lez Blanco
FA: Matthew Pusko

University of Southern California
SBC: Mezie Nwizugbo
FA: Geoffrey Spedding

University of Washington
FA: Behcet Acikmese

University of Utah
FA: Jacob Hochhalter
SBC: Kian Ben-Jacob
SBC: Asael Horne

Utah State University
SBC: Joel Ellsworth
FA: Stephen Whitmore

Washington State University
FA: Jin Liu

Region VII

Beihang University
SBC: Longfei He
FA: Zhiqiang Wan

Chulalongkorn University
SBC: Supakorn Sut-tiruang
FA: Joshua Staubs

Hong Kong University of Science and Technology
FA: Larry Li
SBC: Thomas Kan

Institute of Space Technology, Pakistan
FA: Abid Khan
SBC: Muhammad Farhan

Istanbul Technical University
FA: Bariş Başpinar

Khalifa University of Science Technology
FA: Ashraf Al-khateeb
SBC: Fatma Almarzooqi

Korea Advanced Institute of Science and Technology
FA: Jiyun Lee
SBC: You Hwankyun

Monash University
SBC: Sweta Balakrishna
FA: Daniel Edging-ton-Mitchell

Royal Melbourne Institute of Technology
FA: Cees Bil
SBC: Nick Vrazas

Sapienza Universita di Roma
SBC: Alessandro Cervelli
FA: Giuliano Coppotelli

University of Adelaide
FA: Rey Chin
SBC: Harry Rowton

Universidad Pontificia Bolivariana
SBC: Stefania Villa Avila
FA: Juan Alvarado Perilla

Universita di Naples Federico II
FA: Francesco Marulo

University of Canterbury
SBC: Kieran Williams
FA: Dan Zhao

University of New South Wales
SBC: Ravijay Gampala
FA: Sonya Brown

University of Sydney
FA: Gareth Vio
SBC: Ethan Englund

AUBURN UNIVERSITY
SAMUEL GINN
COLLEGE OF ENGINEERING

Multiple Open Rank Tenure-Track Faculty Positions

The Department of Aerospace Engineering at Auburn University invites applications for multiple **open rank tenure-track faculty positions (Assistant, Associate or Full Professor)**. Applications are invited in all areas related to aerospace engineering. Candidates are especially encouraged to apply with expertise in: flight dynamics; aerospace structures and mechanics of materials in extreme environments; aerodynamics and propulsion; and space systems and hardware. Candidates will be expected to fully contribute to the department's mission through (i) the development of a strong, nationally recognized, funded research program, (ii) teaching aerospace engineering related courses at both the undergraduate and graduate level, and (iii) professional service. Successful candidates will have a demonstrated track record of scholarship, a creative vision for research, an active interest in engineering education, and strong communication skills. For applications at the rank of Associate or Full Professor, an emphasis will be placed on the strength and caliber of the candidate's existing research program and the candidate's ability and desire to provide mentorship and leadership to junior faculty members in a rapidly growing department. Candidates must have an earned Ph.D. in aerospace, mechanical, electrical engineering, or a closely related field at the time of employment.

The Department of Aerospace Engineering at Auburn University is in the midst of unprecedented growth with overall enrollment increasing by over 70% in last eight years to 662 students. This growth has been complemented by aggressive faculty hiring with the department now consisting of four full professors, two associate professors, nine assistant professors and two lecturers. Our current focus is on the development of world-class research programs and growth of the graduate program. The department is part of the Samuel Ginn College of Engineering, which has a total enrollment of over 6,200 students and is home to several nationally recognized research centers, which includes the National Center for Additive Manufacturing Excellence (NCAME), Center for Polymer, Advanced Composites (CPAC), Center for Advanced Vehicle and Extreme Environment Electronics (CAVE3), Auburn University Small Satellite Program, and Cyber Research Center. Auburn University's proximity to the aerospace, defense, and government enterprises located from Huntsville, AL down to the Florida Space Coast presents a unique opportunity for the department to emerge from this growth phase as one of the premier aerospace engineering departments in the country. Additional information about the department may be found at: **www.eng.auburn.edu/aero/.**

Auburn University (**www.auburn.edu/**) is one of the nation's premier public land-grant institutions. In 2022, the college of engineering was ranked in the Top 35 of public universities by U.S. News and World Report. Auburn maintains high levels of research activity and high standards for teaching excellence, offering Bachelor's, Master's, Educational Specialist, and Doctor's degrees in engineering and agriculture, the professions, and the arts and sciences. Its 2022 enrollment of 31,764 students includes 25,379 undergraduates and 6,385 graduate and professional students. Organized into twelve academic colleges and schools, Auburn's 1,443 faculty members offer more than 200 educational programs. The University is nationally recognized for its commitment to academic excellence, its positive work environment, its student engagement, and its beautiful campus. Auburn (**www.auburnalabama.org**) residents enjoy a thriving community, recognized as one of the "best small towns in America," with moderate climate and easy access to major cities or to beach and mountain recreational facilities. Situated along the rapidly developing I-85 corridor between Atlanta, Georgia, and Montgomery, Alabama, the combined Auburn-Opelika-Columbus statistical area has a population of over 500,000 with excellent public school systems and regional medical centers.

Candidates should log in and submit a cover letter, CV, research vision, teaching philosophy, statement on diversity, equity and inclusion, and three references at **www.auemployment.com/postings/32330**. Cover letters may be addressed to: Dr. Brian Thurow, Search Committee Chair, 211 Davis Hall, Auburn University, AL 36849. To ensure full consideration, candidates are encouraged to apply before December 1, 2022 **although applications will be accepted until the positions are filled.** The successful candidate must meet eligibility requirements to work in the U.S. at the time the appointment begins and continue working legally for the proposed term of employment.

Auburn University is understanding of and sensitive to the family needs of faculty, including career couples. See "Guidelines for Dual Career Services" **www.auburn.edu/academic/provost/policies-guidelines/#guidelines**

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USC University of Southern California

The Department of Aerospace and Mechanical Engineering (**https://ame.usc.edu**) in the USC Viterbi School of Engineering invites applications for tenure-track or tenured faculty positions at all levels in all disciplines of Aerospace or Mechanical Engineering with particular interests in *Energy and Sustainability and Advanced Manufacturing* including candidates whose research integrates Artificial Intelligence / Machine Learning into these disciplines. The USC Viterbi School of Engineering is committed to increasing the diversity of its faculty and welcomes applications from women; individuals of African, Hispanic and Native American descent; veterans; and individuals with disabilities.

Successful candidates are expected to develop a world-class research program within a stimulating interdisciplinary environment and demonstrate a strong commitment to teaching at both the graduate and undergraduate levels. Priority will be given to the overall originality and promise of the candidate's research work.

Positions are available starting August 16, 2023. Applicants must have earned a Ph.D., or equivalent, degree in Aerospace or Mechanical Engineering or a related field by the beginning of the appointment. Applications must include: a cover letter; curriculum vitae detailing educational background, research accomplishments, and work experience; a research plan; a teaching and service plan; and contact information of at least four professional references. Applicants are also required to include a succinct statement on fostering an environment of diversity and inclusion. In order to receive full consideration, candidates should apply on-line at **https://ame.usc.edu/facultypositions**, and all materials should be received by January 15, 2023, although earlier application is encouraged; applications received after this deadline might not be considered.

The USC Viterbi School of Engineering is committed to enabling the success of dual career families and fosters a family-friendly environment. USC is an equal opportunity, affirmative action employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, protected veteran status, disability, or any other characteristic protected by law or USC policy. USC will consider for employment all qualified applicants with criminal histories in a manner consistent with the requirements of the Los Angeles Fair Chance Initiative for Hiring ordinance.

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own. This pollution, namely space debris, poses real and burdensome operational costs and hazards to working satellites, which provide critical services and capabilities, not the least of which is climate change monitoring, assessment and verification. For example, a country like Kenya could receive some form of compensation allowing it to improve its own satellite operations capabilities and even purchase some commercial satellite tracking services, enabling it to operate more safely and sustainably, which in turn would help all other operators in the orbital neighborhood. Perhaps the fund could be used to pay third-party organizations to remove debris, like a salvage operation from a specific orbital highway, and thus remove known space traffic hazards to working satellites.

One metric that should be used in space environmentalism and sustainability is orbital carrying capacity, which is finite for any given orbital highway. Based on the purpose or mission of a given satellite, there are natural orbital paths that are better suited or optimal for that spacecraft. These are what I call orbital highways. So, in brief terms, orbital carrying capacity is the ability for any given orbital highway to sustain unencumbered space operations and activities and deliver services. As such, most of this capacity is currently being consumed, or made unavailable, by space debris. Exceeding the orbital carrying capacity results in a space operator's inability to operate in that given orbital highway while avoiding undesired consequences, including expending additional fuel to maneuver out of the way of predicted hazards. This saturation of orbital carrying capacity also results in a degradation of services and capabilities. Pragmatically, a non-G20 country has a higher operational cost and risk in orbital space due to space debris and may not even be able to operate in certain orbits.

In terms of the space pollution crisis humanity faces, the top three countries responsible for most of it are the United States, Russia and China. To be sure, I'm not demanding that these three countries solely pay into this loss and damage fund, but I am requesting that they lead the effort in getting this funded so that non-G20 countries can be compensated for a burden they're carrying — namely, operating in a congested environment absent resources to accurately and precisely avoid the traffic hazards, a result of activities by the dominant G20 countries in space. We don't need to give people Lamborghinis to go to orbit, but we should provide them with the basic resources to drive safely. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1923

Jan. 24 M. Bossoutrot sets a gliding record of 3 hours and 31 minutes in a Farman glider near Boulogne, France, beating the record made at Itford, England, by M. Maneyrol. **The Aeroplane**, Jan. 31, 1923, p. 84.

Also in January Juan de la Cierva makes his first successful flight in his autogiro, a gyroplane. The machine has two contrarotating rotors, later replaced by a single-rotor configuration in more developed designs. The historic flight takes place at Getafe, Spain. Three weeks later, Cierva flies a 4-kilometer circuit in Madrid with this aircraft. **The Aeroplane**, Jan. 9, 1947, p. 36.

1 **Also in January** Curtiss completes the first test flight with a prototype of its XPW-8 biplane fighter. The aircraft is powered by a single 440-horsepower Curtiss D-12 water-cooled engine that gives the new aircraft a top speed of 257 miles per hour. Curtiss will initially build a total of 25 machines for the U.S. Army, the first in a long line of famous Curtiss "Hawk" fighters. Peter Bowers, **Curtiss Aircraft: 1907-1947**, p. 241.

1948

Jan. 10 Reginald Kirshaw "Rex" Pierson dies. He designed the Vickers Vimy bomber in which John Alcock and Arthur Brown made the first nonstop transatlantic flight in 1919. Pierson joined Vickers as an apprentice in 1908; he joined the company's newly formed aviation section in 1911. He later became chief designer. During his career, Pierson also designed the Wellesley that set a distance record of 11,519 kilometers and the famous Vickers Wellington medium bomber of World War II that used Barnes Wallis' geodetic construction. **Flight**, Jan. 15, 1948, p. 57.

2 **Jan. 30** Orville Wright, the first person to make a controlled, heavier-than-air powered flight, dies at the age of 76. Orville and his brother Wilbur, who died in 1912, flew their Wright Flyer four times on Dec. 17, 1903, over the sand dunes of Kill Devil Hills near Kitty Hawk, North Carolina. The first flight lasted 12 seconds and traveled 120 feet. The Wright brothers designed and built all of their aircraft and gliders and incorporated data they gathered in their own wind tunnel. They were the first to recognize the need for control on all three axes of flight. **Aviation Week**, Feb. 9, 1948, p. 13.

2 **Jan. 31** Retired U.S. Coast Guard Capt. John T. Daniels dies. He is the last of the three Coast Guardsmen who assisted the Wright brothers with their Dec. 17, 1903, flights. Daniels took the photograph of that first historic flight. **Aviation Week**, Feb. 9, 1948, p. 13.

1973

Jan. 3 The sky show "When Earth Became a Planet" opens at the Hayden Planetarium in New York City to mark the 500th anniversary of the birth of Polish astronomer Nicolas Copernicus. Born in 1473, Copernicus taught that the sun was the center of the solar system. Prior to this time, it was widely believed that the planets orbited Earth. **American Museum-Hayden Planetarium Release**, 1973.

Jan. 4 U.S. Sen. Edward M. Kennedy (D-Mass.) introduces Bill. S 60 to authorize the National Park Service to acquire and maintain American rocket pioneer Robert H. Goddard's launching site in Auburn, Massachusetts. It was there in March 1926 that Goddard launched the first liquid-propellant rocket. NASA, **Aeronautics and Astronautics, 1973**, p. 5.

Jan. 4 The U.S. Federal Communications Commission authorizes Western Union Telegraph Co. to construct the country's first domestic satellite communications system. **Wall Street Journal**, Jan. 31, 1973, p. 1; **New York Times**, Jan. 13, 1973, p. 72.

3 **Jan. 6** In an Apollo 17 post-mission press conference, lunar module pilot Harrison "Jack" Schmitt says that the orange soil discovered at Shorty Crater on the moon's Taurus-Littrow valley is "extremely young material," less than 10 million years old that likely had been formed by a volcanic vent. This meant that "the moon is still active enough to produce volcanic rock." **Washington Post**, Jan. 6, 1973.

Jan. 8 The Soviet Union launches its Luna 21 robotic probe from Baikonur. After entering an elliptical lunar orbit on Jan. 12, the craft lands near the moon's Sea of Serenity on Jan. 16 and releases its self-propelled Lunokhod 2 rover to conduct scientific investigations of the surface. These include the use of a French-made laser reflector designed to more accurately measure the distance between Earth and the moon to within 20-30 centimeters. Prior to the last contact with mission controllers on May 9, the rover takes 80,000 TV pictures and 86 panoramic photos. **New York Times**, Jan. 17, 1973, p. C14.

Jan. 9 A Saturn IB rocket with a "boilerplate" version of an Apollo Command and Service Module is rolled out from the Vertical Assembly Building at NASA's Kennedy Space Center for fit checks and fueling tests ahead of the inaugural launch of the Skylab program. The space station is scheduled to launch aboard a Saturn V on April 30, and an Apollo spacecraft carrying Skylab's first three-astronaut crew is to be launched 24 hours later on the Saturn IB to rendezvous with the station in orbit. **Kennedy Space Center Release** 6-73.

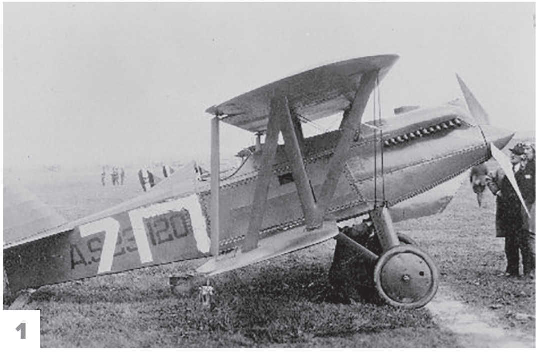
Jan. 10-13 During a meeting of the American Astronomical Society at Las Cruces, New Mexico, John C. Brandt, chief of the Solar Physics Laboratory at NASA's Goddard Space Flight Center, tells reporters that Native Americans in New Mexico and California nine centuries earlier may have recorded a star explosion. This is based on drawings on the walls and ceilings of a cave at Chaco Canyon National Monument, New Mexico, and in California, which closely resemble an explosion on July 4, 1054, recorded by the Chinese. **Washington Post**, Jan. 14, 1973, p. A13.

Jan. 16 NASA announces the appointment of retired U.S. Navy Capt. Chester M. Lee as program director of the Apollo-Soyuz Test Project. **NASA Release** 73-6.

Jan. 29 U.S. Rep. Wright Patman (D-Texas) introduces H.J.R. 255 to change the name of NASA's Manned Spacecraft Center to the Lyndon B. Johnson Space Center in honor of the late president, who died on Jan. 22. Throughout his career, Johnson supported the U.S. space program in many ways. As Senate majority leader, he played an important role in gathering support for the National Aeronautics and Space Act of 1958 that created NASA and the National Aeronautics and Space Council. He later chaired the council during his tenure as U.S. vice president and helped persuade President John F. Kennedy to set the national goal of achieving a crewed lunar landing within the decade. **Congressional Record**, Jan. 16, 1973, p. S1344; **Washington Post**, Jan. 23, 1973, p. A1.

4 **Jan. 31** This date marks the 15th anniversary of the launch of Explorer 1, the first U.S. satellite, by the U.S. Army Ballistic Missile Agency and Jet Propulsion Laboratory. With instruments aboard the 14-kg cylindrical satellite, scientists first detected the rings of charged particles surrounding Earth that would later be named the Van Allen Belts. **Kennedy Space Center Release** 17-73.

Jan. 31 The U.S. Air Force's last C-5A Galaxy aircraft rolls off Lockheed Aircraft Corp.'s assembly line. At this time, the C-5A is the world's largest subsonic jet transport. Other variations of the aircraft remain in production and operation. **Atlanta Journal Constitution**, Feb. 1, 1973, p. 8.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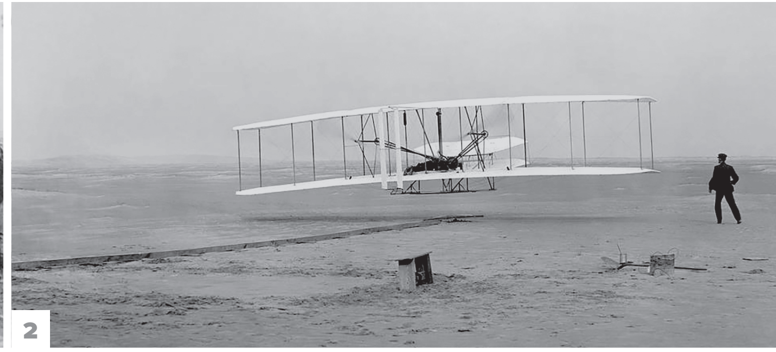
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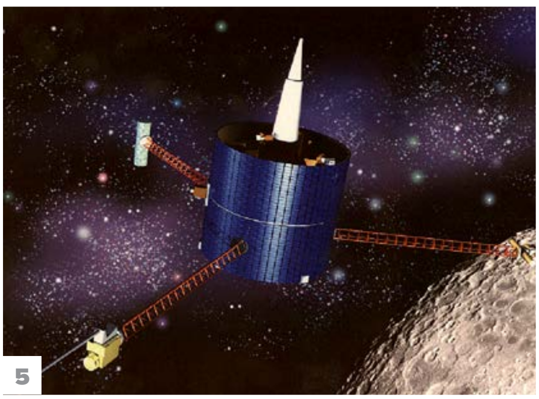
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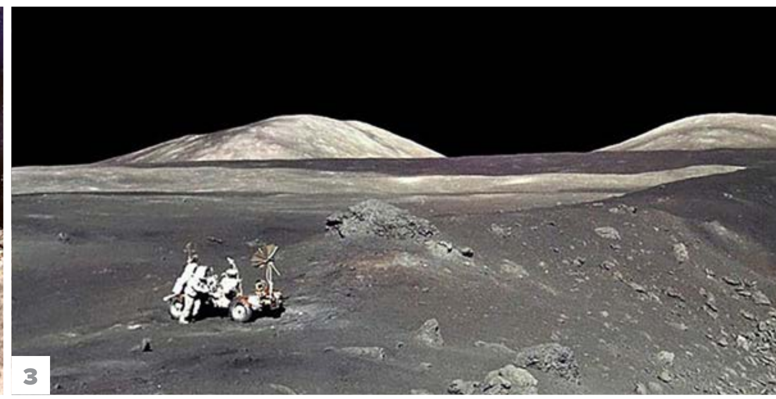
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Jan. 31 The U.S. Air Force orders its last F-111 Aardvark swing-wing fighter from General Dynamics. The F-111 pioneered several technologies for production aircraft, including variable-sweep wings, afterburning turbofan engines and automatic terrain-following radar. **Washington Post**, Jan. 31, 1973, p. A16.

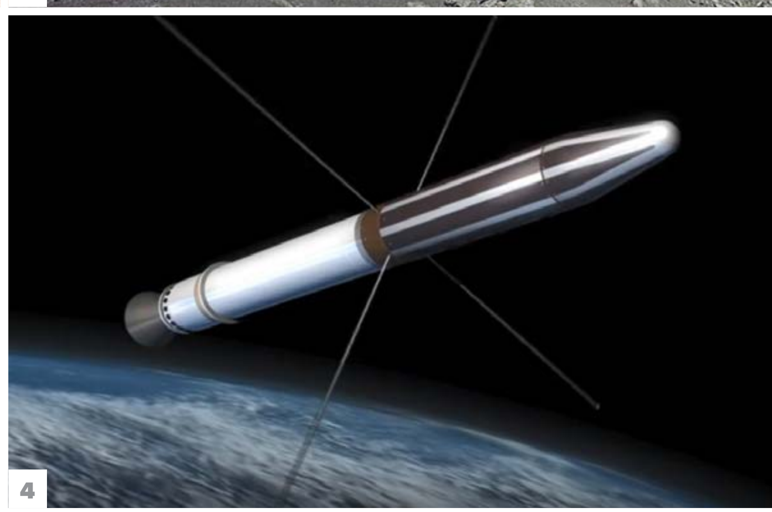
1998

5 **Jan. 6** NASA's 300-kg Lunar Prospector spacecraft launches. After entering a 100-kilometer-high lunar orbit, the craft begins an intensive 19-month survey of the moon, conducting basic research on its origin, evolution and composition. This mission differs from the Apollo expeditions 25 years earlier in that it is the closest and longest observation of Earth's neighbor. Among its finds, Prospector confirms the presence of ice at both poles, first indicated by NASA's Clementine spacecraft. **Flight International**, March 18, 1998, p. 25; **Aviation Week**, Jan. 5, 1998, pp. 50-52.

6 **Jan. 16** Former NASA astronaut and current U.S. Sen. John H. Glenn Jr. (D-OH) is named a crew member for STS-95. The first American to orbit the Earth, Glenn also becomes the oldest person to fly in space when Space Shuttle Discovery launches in October. Glenn will be the subject of testing of the biomedical effects of spaceflight on astronauts. David Baker, **Astronautics and Aeronautics: A Chronology, 1996-2000**, p. 111.

Jan. 22 Space Shuttle Endeavor launches from NASA's Kennedy Space Center for STS-89. The orbiter docks with Russia's Mir space station two days later. David Baker, **Astronautics and Aeronautics: A Chronology, 1996-2000**, p. 111.

Also in January The de Havilland Canada Dash 8-400 twin-engine turboprop airliner flies for the first time at the company's plant at Downsview, Toronto, Canada. **Flight International**, Feb. 11, 1998, p. 4.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6

UN's "loss and damage" fund should compensate newcomers to space

BY MORIBA JAH | moriba@utexas.edu

Over the next year, 24 countries will have the task of deciding who should pay into the climate change "loss and damage" fund established in November by the nations of the world, the forms those funds should take and how they should be distributed.

As important as climate change is, the nations that created this fund should also consider broadening the fund's mission by folding in space environmentalism and sustainability. Here's my reasoning.

The rationale for establishing the loss and damage fund was that those countries that are not members of the Group of 20 leading economic powers did little to contribute to the climate crisis, and yet they now bear some of its gravest consequences. "The African continent for example, contributes the least to climate change yet is the most vulnerable to its impacts," the United Nations Environment Programme noted on its website following COP27, the 27th session of the Conference of the Parties, the annual gathering of nations to assess progress toward solving the climate crisis.

A parallel rationale exists in space, where a handful of spacefaring nations have, in little over half a century, polluted orbits with debris and are loading the most desirable orbits with so many satellites that few others will be able to access them.

It turns out that many of these new spacefaring countries desire to establish persistent access and use of outer space for a variety of purposes, such as those related to communications and Earth observation. Their resources for maximizing space safety, security and sustainability are eclipsed by G20 countries that have been operating in space almost since the launch of Sputnik in 1957. For example, a country like Kenya that is new to the space domain lacks a global network of satellite tracking stations and workers skilled in the tradecraft of space operations. Established spacefarers have long since achieved these effective practices, while new spacefaring countries rely almost exclusively on orbital safety products provided to them freely by the United States.

To that end, I propose that space environmentalism and sustainability should be folded into this loss and damage fund because new entrants to the spacefaring community are already hindered in their use of orbital space due to the growing amount of pollution, to no fault of their

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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, he's also chief scientist of startup Privateer and hosts the monthly webcast "Moriba's Vox Populi" on SpaceWatch.global.