AEROSPACE

★ ★ ★ AMERICA ★ ★ ★

MH370

Ten years later PAGE 32

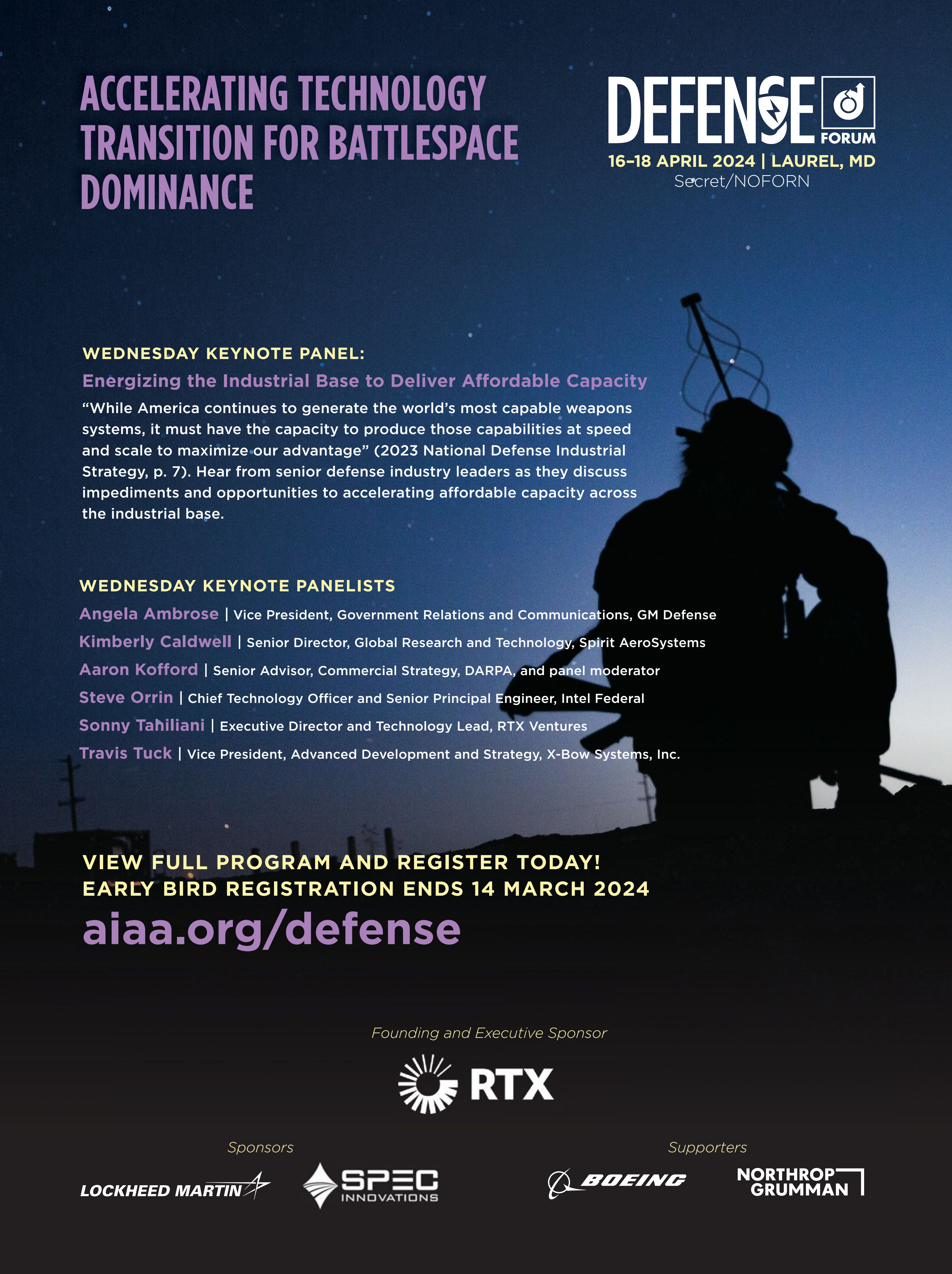
SPECIAL SPACE REPORT

MARCH 2024 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

AIAA
SHAPING THE FUTURE OF AEROSPACE

Investigators know what happened to Air France 447 because the black boxes were recovered two years after the crash. (The flight data recorder is shown here.) By contrast, the events aboard Malaysia Airlines 370 remain a mystery, largely because neither the flight data recorder nor the cockpit voice recorder were recovered.

Bureau of Enquiry and Analysis for Civil Aviation Safety


ACCELERATING TECHNOLOGY TRANSITION FOR BATTLESPACE DOMINANCE
DEFENSE FORUM
16–18 APRIL 2024 | LAUREL, MD
Secret/NOFORN
WEDNESDAY KEYNOTE PANEL:
Energizing the Industrial Base to Deliver Affordable Capacity
"While America continues to generate the world's most capable weapons systems, it must have the capacity to produce those capabilities at speed and scale to maximize our advantage" (2023 National Defense Industrial Strategy, p. 7). Hear from senior defense industry leaders as they discuss impediments and opportunities to accelerating affordable capacity across the industrial base.
WEDNESDAY KEYNOTE PANELISTS
Angela Ambrose | Vice President, Government Relations and Communications, GM Defense
Kimberly Caldwell | Senior Director, Global Research and Technology, Spirit AeroSystems
Aaron Kofford | Senior Advisor, Commercial Strategy, DARPA, and panel moderator
Steve Orrin | Chief Technology Officer and Senior Principal Engineer, Intel Federal
Sonny Tahiliani | Executive Director and Technology Lead, RTX Ventures
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AIAA
SHAPING THE FUTURE OF AEROSPACE

IN THIS ISSUE

Keith Button

Keith has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns hedge fund blowup that kicked off the global credit crisis. He is based in New York. PAGES 9, 16, 32

Moriba Jah

Moriba is a space environmentalist, 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 Smithsonian, Slate and The Washington Post. He is based in Maryland. PAGE 40

Paul Marks

Paul is a London journalist focused on technology, cybersecurity, aviation and spaceflight. A regular contributor to the BBC, New Scientist and The Economist, his current interests include electric aviation and innovation in new space. PAGE 24

DEPARTMENTS

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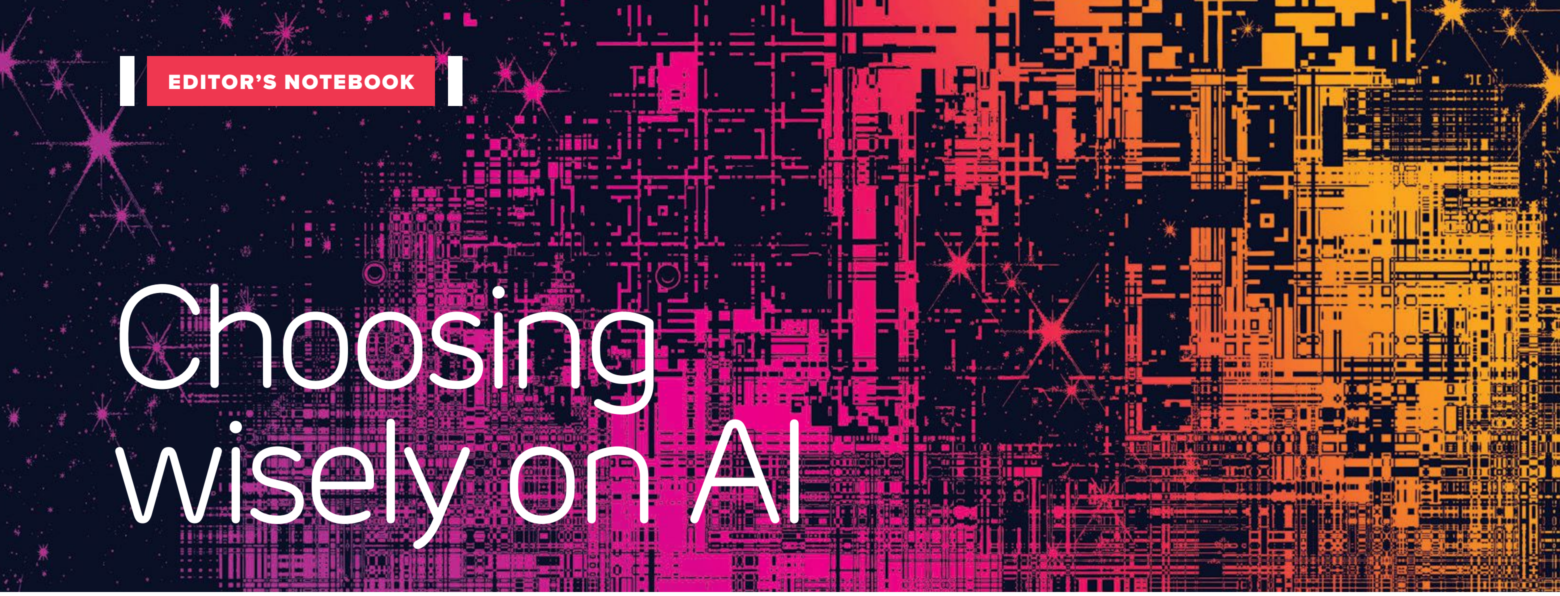


Choosing wisely on AI

We've been thinking a lot about appropriate uses of artificial intelligence in our research and reporting. Cat Hofacker, our associate editor, raised some especially strong points, so I invited her to provide this issue's editor's notebook. — Ben Iannotta, editor-in-chief

In the second book of "The Inheritance Cycle" saga, an immortal being with magical powers, an elf, explains why she doesn't rely on her magic for everything: "When you can have anything you want by uttering a few words, the goal matters not, only the journey to it," she says.

Artificial intelligence, of course, is not magic, but it's the closest thing we have in the real world. As we each consider how to incorporate these tools into our professional lives, it seems to me that we'll need to be like the elf: give careful thought about when and how we use them.

In the journalism world, these tools can be powerful assistants to reporters, editors and graphic artists. We'd love to receive completely accurate transcriptions in real time so that we can focus on considering the substance of the interviews and finding the most interesting way to tell the story. On the visual side, perhaps we should explore whether OpenAI's Sora or other text-to-video tools could help us brainstorm or generate early versions of infographics, which we'd then refine by applying our creativity and fact checking. As welcome as the efficiency would be, it will always be our responsibility as journalists to make sure that any use of AI is properly disclosed and that the products are accurate.

This concept of accountability is a core tenant of journalism. All Aerospace America stories must contain original interviews and wording — and not just because talking to smart people and figuring out how to describe their innovations is one of the most fun parts of the job. When I put my name on a piece, I am promising readers that this is my work. If this column were the result of me typing "write 500 words about AI and ethics" into ChatGPT, that promise would be broken.

Whether you are an engineer, researcher or student, I'm sure you're also considering how to employ these new tools wisely. In your world, as in ours, that will require recognizing the performance limitations of AI. The transcripts I mentioned are nowhere close to 100% accurate today, and generative AI can sometimes spit out absolute gibberish. We don't know yet if Sora will get things right either. Fundamentally, I'm betting that humans will always be needed to provide the creative spark in both of our worlds. Could AI have thought to propose the Ingenuity helicopter that made 72 flights on Mars? I suspect not.

But let's suppose that AI does eventually acquire human-level creativity. An accomplishment like Ingenuity would be less satisfying because we wouldn't have the inspiring story of the intrepid engineers who persevered even when they had to convince the doubters that this was a valuable addition to the mission.

I'd venture that I'm not the only person who doesn't want to live in a world in which all the innovations come from AI. Most aerospace professionals are drawn to this field not in spite of the wicked problems, but because of them. Incorporating new technologies is important for any successful organization, so leaders should proactively develop specific policies telling their employees how to leverage AI tools in appropriate ways. That means, in part, enhancing, not co-opting, human creativity.

To put my own spin on the elf's quote: The destination matters a great deal, but how we choose to get there should never be overlooked. ★

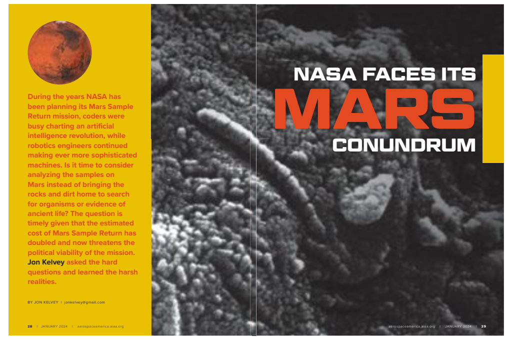
Cat Hofacker

Cat Hofacker, associate editor
catherineh@aiaa.org

For Mars Sample Return, a small rocket poses a big challenge

The Mars article in the January issue ["NASA faces its Mars conundrum"] referred to "a small U.S.-built rocket" for lifting geology samples to Mars orbit. The Mars Ascent Vehicle (MAV) will be the most amazing little rocket ever built, because it needs capability beyond the state of the art for its small size (4 km/s in a few minutes). Fifty years ago, a NASA study published by AIAA noted that the mass of this launch vehicle would drive mission scale (Weaver, 1974, Journal of Spacecraft and Rockets, 11(6), p. 426). In recent years the MAV design became much heavier than hoped for, now roughly half a metric ton. Despite the lightweight helicopters to be sent with it instead of the previously planned fetch rover, delivering the MAV still needs a larger-than-ever Mars lander, a major reason for the high mission cost.

The January editorial ["Sparking your imagination to start 2024] referred to "no shortage of innovation" for Mars missions. Yes, iterative building and testing can make the MAV smaller to reduce mission cost. SpaceX and others have shown what innovation can do for larger launch vehicles. Unfortunately, the MAV



During the years NASA has been planning its Mars Sample Return mission, coders were busy charting an artificial intelligence revolution, while robotics engineers continued making ever more sophisticated machines. Is it time to consider analyzing the samples on Mars instead of bringing the rocks and dirt home to search for organisms or evidence of ancient life? The question is timely given that the estimated cost of Mars Sample Return has doubled and now threatens the political viability of the mission. **Jon Kelvey** asked the hard questions and learned the harsh realities.

BY JON KELVEY | jonkelvey@gmail.com

28 | JANUARY 2024 | aerospaceamerica.aiaa.org

NASA FACES ITS MARS CONUNDRUM

challenge has been widely underestimated and the need for something new remains unappreciated. It is easy to take the MAV for granted, because all other planetary science maneuvers have been within the realm of satellite propulsion technology. This situation was summarized at the AIAA Space 2008 Conference by one of my papers, "Defining the Mars Ascent Problem for Sample Return."

John Whitehead, AIAA senior member
Davis, California | jcw@dcn.org

CLARIFICATION

An article in the February issue, "Collision avoidance for air taxis," contained an incomplete accounting of the entities that led development of the ACAS Xr (Airborne Collision Avoidance System for small rotorcraft) software. ACAS Xr was designed by the Johns Hopkins University Applied Physics Laboratory and MIT Lincoln Laboratory under sponsorship of FAA.

FLIGHT PATH

Strengthening Aerospace

Toward Ecosystems and Solutions That Help Meet Global Challenges

At the 2024 AIAA SciTech Forum, AIAA's new Domain Leads discussed how they plan to build and implement strategies to help the Institute accelerate aerospace innovation to meet global challenges. AIAA's new Domain Leads – Russell Boyce, Aeronautics; Greg Zacharias, Aerospace R&D; and Brent Sherwood, Space – all have extensive backgrounds in their respective domains and have demonstrated a deep commitment to the aerospace community over the course of their careers. They are well respected for their ability to set a coherent vision, develop strategy that incorporates both innovation and high-performance culture at its heart, and drive that strategy to take organizations to – and even beyond – the vision.

This article expands on their comments during the discussion at the HUB during AIAA SciTech Forum, where they shared their visions for the future of their respective Domains, outlined issues they will address, and priorities they will embrace.

The Why

As the new AIAA Domain Leads, Russ, Greg, and Brent see their principal role as providing strategic thought leadership that assists AIAA, the aerospace community, and broader society across the globe. Why? The world is facing generational-scale challenges – societal, economic, environmental, security – in the context of rapidly evolving technical capabilities. Technology advances rapidly, and so do other disruptive changes. The aerospace sector can contribute important solutions to significant issues, but not just via the application of science and technology. Our community must embrace system-of-systems thinking, build understanding and collaboration across the whole ecosystem of stakeholders, and integrate efforts to solve our biggest challenges. To this end, AIAA has adopted the Domain approach: the Domain Leads are charged to work across our whole community to develop, articulate, and coordinate actionable strategies, whose implementation will rely on the leadership and contributions of our large community of global, multidisciplinary experts.

- In **Aeronautics**, a major challenge is helping achieve net zero greenhouse gas emissions by 2050 as we address the sustainability of planet Earth, while simultaneously advancing mobility solutions that take the world forward.
- In **Aerospace R&D**, a critical challenge is integrating and accelerating digital design, development, test, and operations, while leveraging non-traditional emerging and enabling technologies.
- In **Space**, the fundamental challenge is adapting to the rapidly evolving landscape of proliferated systems, new operating regimes, and independent actors.

Working on Technical *and* Beyond-Technical Priorities

Key topics that have been addressed to date in the Aeronautics Domain include advanced air mobility, sustainability, certification, and most recently, high-speed flight. These are all critical areas that span the domain, according to Russ. "They're all very important, in different ways. Sustainability is a core challenge facing humanity. Advanced air mobility and high-speed flight are solutions built on disruptive technologies that can grow our economies and societies. Progress in certification – for example, certification approaches for new transformational systems – is a fundamental enabler for the industry. The important thing about those topic areas that I see is that they're not just technical stovepipes. They include the customer, the user, the investor, the regulatory regime, ethical considerations, etc.

"To continue to mature the Aeronautics Domain we need to ask two questions: What are the global challenges and opportunities that aeronautics can help address? And how can we grow and combine various elements of technical and non-technical talent and approaches into the ecosystems that will help meet those challenges? Building the talent pool and bringing all these elements together so they inform and guide each other is an overarching goal for this and indeed all of the domains."

Greg observed there is a wealth of emerging technology being developed and applied outside of our traditional aerospace focus areas, technology that could have a significant impact on how we do business in the future. On the "product" side, this might include bioinspired neuromorphic computing for better sensor systems and real-time situation assessment; cognitive state estimators for improved human-machine interactions; and post-lithium battery technologies for next-generation electric aircraft. On the "process" side, this will likely encompass fully threaded digital engineering, from concept exploration to operational monitoring; generative artificial intelligence (AI) for aiding design and testing; and full-stack AI-enabled modeling and simulation that embodies the detailed physics of the systems we develop. Machine learning-enabled tools will be crucial.

"What the Domain construct helps with is in combining technologies," Greg noted. "We need to think beyond simply bringing on one technology to fill a process or performance gap, but think more broadly, and consider how multiple technologies can yield not just additive returns, but multiplicative ones. And to do this, we need to look for innovators inside and outside of the AIAA community, expanding our collective envelope of understanding and expertise."

Brent sees three fundamental changes in the Space Domain that the Institute must address: 1) Rapid proliferation of simultaneously

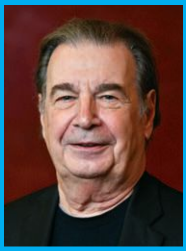
ACTION ITEM: Do you have a good idea that one of the Domain leads should hear about? Get in touch to discuss:

AERONAUTICS: russellb@aiaa.org
AEROSPACE R&D: gregz@aiaa.org
SPACE: brents@aiaa.org

RUSSELL BOYCE, AERONAUTICS

"I built a team that pushed hypersonics flight experiment boundaries, then built the first end-to-end (and successful) domestic space program in Australia, and was instrumental in translating those efforts into the establishment and success of three spin-off companies. It's the building of people and organizations, as fundamental building blocks of approaches to solve global problems, that gets me fired up. In aerospace, the Domain construct helps provide the 'why.' Why is it that we are doing what we're doing?"

GREG ZACHARIAS, AEROSPACE R&D



"I got my start with NASA, designing the Space Shuttle re-entry flight control system back when it was a paper airplane. That led to a start-up, which let me build a 30+ year career focused on human-system R&D for NASA and DOD. I returned to government to serve as the Chief Scientist for the Air Force, then for the OSD Office of Test and Evaluation. Both positions put me at the nexus of the R&D and mission-focused communities, experience that I hope to bring to bear in this new position with AIAA."

BRENT SHERWOOD, SPACE

"I'm a space architect by passion, training, and experience: space futures systems configuration design and business development at Boeing, retooling formulation and winning multiple planetary science missions at JPL, and building teams for lunar return, lunar resource technologies, cislunar mobility, and commercial LEO development at Blue Origin. Space holds the key to the unlimited future of human civilization in the cosmos. Humility, ambition, and collaboration should motivate everything we do."

operating assets, such as constellations in low Earth orbit; 2) Opening new regions of space to routine operations by multiple actors, especially cislunar space and the lunar surface; and 3) Emergence of the independent space sector and implementation of new public-private partnership models. Two task forces are already at work addressing Space Traffic Coordination and development of the Cislunar Ecosystem. Brent added that new synergies will be essential to rapidly evolve the space industry. "We've always had academia, government, and industry active within AIAA," he said, "And they were all tied together. But the emergence of the independent space sector, which brings its own resources, capabilities, and goals, changes this landscape. It's important that AIAA surf this wave, rather than being overtaken by it, because adaptation is key to relevance."

Disruptive Transformation

Russ commented on how AIAA forums are advancing the Domain transformation. "I believe the 2024 AIAA SciTech Forum enabled a very large collection of smart people who can do some horizon scanning and look forward and see what technologies, indeed what transformational disruptions, are coming over the horizon and how might they affect aeronautics and space, and the crossover between the two. That's where we get to think about those transformational technologies and try to ask: How is that going to affect the customer? How is that going to affect the application? What should the industry be worried about? How are we going to bring those together and not be disrupted by them but use them to be the disruptor? How do we prepare young professionals for this dynamic future?"

Domain Synergy is Moving Priorities Forward

Domain synergy is critical. Solutions implemented in the Aeronautics and Space Domains will both complement each other and depend upon and motivate the Aerospace R&D Domain for their transformational underpinnings. The Domain leads will help focus all of AIAA's capabilities – committees, sections, task forces, and other tactical initiatives – so the Institute can address today's and tomorrow's key challenges. Going forward, all of the Institute's infrastructure (e.g., our almost 100 Technical Committees and Integration/Outreach Committees, and all the sections worldwide) will be vital to success. AIAA is a unique global resource that can serve as an honest broker across the community, including all stakeholders, to articulate unbiased findings and recommendations that shape the future of aerospace.

Brent summed it up: "Because many of our existing committees cross Domains already, some critical intersections are already built into the technical fabric of AIAA. We have talked a lot about how the changes we see in each of our Domains affect the others. We're excited about synergy going forward." ★

Material riddle

Q: In the video game you're creating, the avatar is a materials scientist and action hero. A villain known for creating the world's most powerful microscope has snatched the avatar's autographed copy of "Materials Science and Engineering" and has lit a match. To prevent the villain from burning the book, the avatar must identify whether a sample of stainless steel under the microscope is magnetic and provide a satisfactory explanation. "One word of jargon, and I burn your little keepsake," the villain says. What should the avatar look for that indicates whether the steel is magnetic or nonmagnetic, and what should the avatar say?

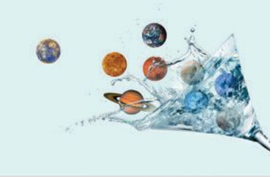
SEND A RESPONSE OF UP TO 250 WORDS that someone in any field could understand to aeropuzzler@aerospaceamerica.org by noon Eastern March 14 for a chance to have it published in the next issue.

Scan to get a headstart on the April AeroPuzzler

FROM THE FEBRUARY ISSUE

BOTTOMS UP:

We asked you to explain the joke and underlying physics of a bar named "The Libation Point" that serves an IPA called "Lisa's Juice."



WINNER The astrodynamicists' wordplay on "The Libation Point" is on the term "libration point," which is a point in space where the gravitational forces of two large mass objects create a balanced, stable environment for a smaller mass object. Historically, "libation" is also referred to as a ritualistic pouring of a liquid for a deity or religious ceremony but has since evolved to be a more common act of pouring a drink. The joke here is that the bar represents the idea of a stable point in space where the "libations" are the drinks served in the bar. Regarding "Lisa's Juice," this wordplay revolves around "Lissajous Orbit," a type of orbit where a small object can follow around a libration point, forming a complex, repeating pattern. The pronunciation breakdown of "Lissajous" into "Lis au jus," where "au jus" translates from French to English as "juice," adds to the humor. The joke lies in the repeated pattern of ordering a round of "Lisa's 'juice'" being served at the "Libation Point." The physics used in this joke pulls from both celestial and orbital mechanics, giving those in the profession a laugh.

Isabella Allen
AIAA student member
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Isabella is in her final semester of the master's of aerospace engineering program at the University of Cincinnati.

To prepare for contrail-measuring flights planned for later this year, Airbus in November flew this glider powered by a hydrogen combustion engine (right) over Nevada. For this Blue Condor initiative, an instrumented turboprop will fly behind this glider and an identical one with a kerosene engine, measuring the contrails that each produces. Airbus

How to probe a hydrogen contrail

BY KEITH BUTTON | buttonkeith@gmail.com

Airbus' initiative to build hydrogen-powered passengers planes is supposed to help meet the air transportation sector's goal of achieving carbon neutrality by 2050. But no one knows what effect contrails from hydrogen combustion might have on the climate compared to burning kerosene jet fuel. Studies have shown that the contrails left by the exhaust of conventional jets have a greater warming effect than carbon dioxide emissions.

Enter Blue Condor, an experiment by Airbus and DLR, the German Aerospace Center. Scientists later this year plan to measure the composition, including the size of the ice crystals, of the contrails left by hydrogen combustion. They could then compare any warming influence to that of conventional contrails. In flight trials scheduled to begin before the end of June at 30,000 feet over the Nevada desert, a turboprop will steer into the contrails created by one glider outfitted with a hydrogen combustion engine and another with a conventional jet engine burning kerosene. On each flight, "the snorkel," a 2-meter-long tubular appendage atop the turboprop's fuselage, will suck in air to measure trace gases, aerosols, nitrogen oxide and water vapor, while a torpedo-shaped spectrometer under its wing measures the size and number of ice crystals in the contrails.

"There are no contrail data available from hydrogen combustion, so this is really a first, and therefore it's extremely exciting for us," says Tina Jurkat-Witschas, head of the DLR team that will monitor the instruments from the ground and then analyze the contrails.

Flights of the hydrogen-powered glider began in November, but for the full campaign, the teams must wait for the right humidity and temperature for contrails to form — around minus 40 degrees Celsius.

The results could tell Airbus whether the climate-friendly aircraft it wants to have ready for customers by 2035 should be powered by hydrogen-combustion jet engines, turboprops powered by hydrogen fuel cells or a hybrid approach.

Airbus later plans to test hydrogen fuel cell and combustion engines by attaching them to the fuselage of a conventionally powered A380. This aircraft wasn't right for the contrail experiment, though, because a pristine sky is needed. Modified Arcus-J gliders were chosen because one can be easily propelled by a single engine at contrail-forming altitudes, and because the turboprop can fly close behind without turbulence.

Most of aviation's global warming effect comes from contrails, which consist of ice crystals that form mainly around soot from kerosene combustion. Hydrogen combustion doesn't create soot, but scientists nevertheless expect that ice crystals would be formed by water vapor in the exhaust coalescing around dust and other naturally occurring aerosol particles. The question is how big and numerous these crystals would be compared to those that form around soot, though current models suggest that the crystals will be larger and fewer.

If the crystals are large enough, they will quickly drop out of the atmosphere, and their climate warming effect will be less than crystals from kerosene combustion. However, there's a possibility that hydrogen combustion could form contrails at lower altitudes where kerosene combustion cannot, creating more overall contrail coverage. The Blue Condor results will help DLR researchers model whether this is the case. That analysis should be publicly available about six months after the tests, Jurkat-Witschas says. ★

DARPA

Innovation machine

At most jobs, employees are judged by their successes. But at DARPA, the Pentagon's technology incubator, "I actually get yelled at if my programs don't fail enough," says Ken Plaks, director of the agency's Tactical Technology Office. If the agency's programs succeed too often, the thinking goes, that means the challenges aren't hard enough. "It's a high bar," he says, considering that the agency created the networking concept that became the public internet. So Plaks has a sizable list of potentially groundbreaking innovations that are receiving funds: The current portfolio includes a joint undertaking with NASA to demonstrate a nuclear thermal rocket and an effort to build a drastically cheaper seaplane the size of a C-130 for cargo flights in the Pacific. I visited Plaks at DARPA Headquarters in Northern Virginia to discuss these programs and how the agency stays at the cutting edge of technology. Here are lightly edited excerpts of our discussion, organized by topics. — *Cat Hofacker*

KEN PLAKS

POSITIONS: Since June, director of DARPA's Tactical Technology Office, one of the agency's six program offices; (TTO aims to develop "revolutionary new platforms" for ground, sea, air and space). 2015-2020, manager of various DARPA programs in the Microsystems Technology Office, which develops next-generation components for electronic warfare and other applications. In 2014, retired from the U.S. Air Force as a colonel after 30 years; his last assignment was as director of special programs, where he advised the Air Force secretary and chief of staff about special access programs, including budgeting and research and development.

NOTABLE: Ranked the top academic graduate of the U.S. Air Force Academy in 1989, after which he completed test pilot school at Edwards Air Force Base in California. At Eglin Air Force Base in Florida, he oversaw a team of Air Force, Navy, Marine Corps and industry personnel that in 2007 established the first joint F-35 training base, three years ahead of schedule.

AGE: 58

RESIDES: Falls Church, Virginia

EDUCATION: Bachelor of Science in math and physics, U.S. Air Force Academy, Colorado, 1989; Master of Science in physics from MIT, 1991; Ph.D. in physics, University of Nevada-Las Vegas, 2004.

On the 'done' pile

From a technology perspective, certainly space has moved from mostly governments to mostly commercial. That's happened really only in the last couple of years, and DARPA kind of saw some of that coming. We had a program to do megaconstellations before megaconstellations, were a thing. And then Starlink passed us, right, which is fine. So we did our DARPA thing and said, "OK, cool. Put that in the done pile," and we're gracefully shutting down the program that we were trying to tease out.

He's referring to Blackjack, an "architecture demonstration" in which DARPA has been operating a constellation of small commercially built satellites to determine whether they could be a lower-cost alternative to geosynchronous spacecraft. Plans had called for 20 satellites, but DARPA decided to conduct the demo with just the first four satellites, launched in June by a SpaceX Falcon 9. — CH

And it influenced the NRO [National Reconnaissance Office] and Space Force's future architectures. Before, the idea was "We have to have the Battlestar Galactica satellite that does everything." Now, we're disaggregating into a bunch of small satellites that work together. It has been such a change that it went from "That's impossible," even as recently as five or six years ago, to "Of course, that's how you do it." And a lot of that's just with how cheap it's gotten to get to LEO in particular. On the engine side, we're getting back into hypersonics, but that's kind of back to the future. Most cargo or transport airplanes are still tubes with wings; we've talked about flying wings and stuff, but that really hasn't happened. Our X-65 CRANE program has the potential in future generations to change how we do aircraft.

The CRANE demonstrator, short for Control of Revolutionary Aircraft with Novel Effectors, is being built by Boeing subsidiary Aurora Flight Sciences to test active flow control, in which flight control would be maintained via jets of pressurized air instead of external control surfaces. Plans call for remotely piloted test flights to begin in 2025. — CH

On the drone side, small, unmanned things are now doing missions that we never even contemplated — except, there were a couple of DARPA programs for the last couple of years that were looking at "How would I use small drones to go after armor and to go after an integrated air defense system and take it down?" So it's interesting that if you look back four or five years, you can see the threads of the things that are actually emerging are things from DARPA programs.

Personal interests

A couple of things I'm noodling on and trying to push: Probably the biggest is how we deal with complexity and cost. We can build these really exquisite systems, but if I only have 10 of them against thousands, you know, eventually that breaks down. If you look at pLEO — proliferated low-Earth orbit — that is largely a way of dealing with complexity by doing simpler things. Pick one thing and be good at it and let someone else handle the other part, rather than putting it all together. Because as I start to get into all the size, weight, power-constrained volumes, one plus one frequently doesn't equal two; it's four, because there are all these interactions between the parts in nonobvious ways. The way we deal with that is systems engineering, which is necessary but kind of not sufficient. There's all these stories of unintended consequences and problems — "We put the brake

> "The DARPA mission is to prevent strategic surprise. How do you prevent surprise? Our solution is to make our own surprises and figure out what's coming next."

▲ NASA last year joined DARPA's planned 2027 on-orbit demonstration of a nuclear thermal rocket. The agencies selected Lockheed Martin to build the DRACO spacecraft and Virginia-based BWXT Technologies to develop the nuclear reactor.

Lockheed Martin

computer in the avionics computer, and now when your avionics crashes, you don't have brakes," or whatever. If it's simpler, then I can buy more of them, and it's cheaper and I can do it faster. And you get in this virtuous cycle. We also need to do a better job of dealing with the complexity. At some point there's a finite limit, and you can only make it so simple, right? So if I've got to have a system that slices, dices and makes julienne fries, for whatever reason, then how do I deal with all that complexity? How do I manage it? I don't want to sprinkle AI pixie dust on this, but it is kind of a big data problem. The ability to bring thousands and thousands of cores online to work on a problem without having to actually own thousands, for instance, may give you a computational way out of the wilderness.

Defining 'DARPA hard'

The first big thing is it's got to have an outsized impact. When they hire you, the director shakes your hand and says, "Go change the world." Stealth is a great example. The Air Force actually didn't want stealth at first; they just wanted bigger jammers. The joke at DARPA is if you don't invent the internet, you get a B. It's a high bar, and we're all A-plus students. The other big characteristic is our saying that there's hard, and then there's DARPA hard. When I first came here — I had been a colonel in the Air Force, and I had been in the acquisition community — I was pitching my first project, and I was like, "Well, this is low risk," to illustrate that we could do this. And my boss said, "Well, if you're sure you can do it, why are we doing it? The Air Force can do that." You know, it's not hard enough. I actually get yelled at if my programs don't fail enough — which I'm pretty sure is not common in the rest of the government — the idea being that if I'm achieving my goals routinely, then I'm not setting hard enough goals. We run this whole building like "Shark Tank." You go upstairs, and you get an hour to tell the big boss how you want to change the world with $50 million to build an airplane that has active flow controls or whatever. If she likes it, she writes the check, and then you go do your thing. Frequently, the result of the "Shark Tank" is homework — "Go make it bigger impact" or "You said you can make it twice as good; I want it 10 times as good." And we even say in our solicitations, I'm not interested in things that are evolutionary. It's got to be revolutionary. The other interesting thing about DARPA is that everybody's temporary. If you're doing a great job, after four years, they say, "Have a nice life." And unlike the rest of the federal government, there's really not any empires. We don't have any X amount of money set aside for AI. The NSF [National Science Foundation] does that, partly so you can have the continuity with the grad students. But DARPA can turn on a dime. It increases our agility, and it makes it a little idiosyncratic. A quarter of our workforce changes every year. After two years, DARPA is almost a completely different place, and the things we're working on are almost completely different. The other big thing

"The joke at DARPA is if you don't invent the internet, you get a B. It's a high bar, and we're all A-plus students."

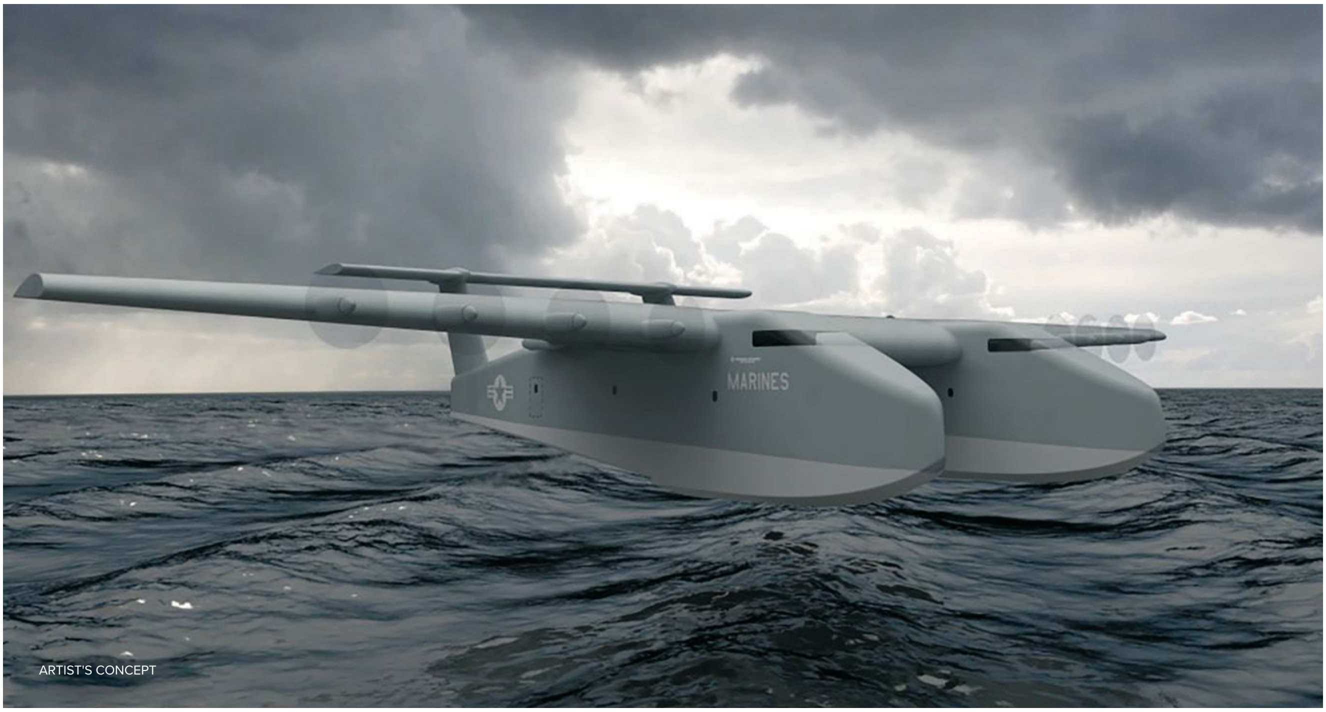
is all our programs are finite — typically three or four years, then it's over. We only do three- or four-year bites at the apple.

Handing off the tech

It's easier to get it into the commercial side than the military, because they're on two-year budget cycles. So even if it's the best thing, a service can't even begin to buy it for another two years. Whereas the commercial world can actually move quicker. It is a continual challenge. The DARPA mission is to prevent strategic surprise. How do you prevent surprise? Our solution is to make our own surprises and figure out what's coming next. That way, the services or the government may make a decision not to invest in hypersonics or whatever, but at least they know it's a possibility or that it's not a possibility and we don't need to worry about this. So while it would be tempting to go, "We have this fantastic missile and for another $100 million, we could get it to the point where it's ready for the Air Force to buy," that's $100 million I'm not spending on inventing an internet, or whatever else. So it's a balance. We do sometimes work with the services when they're really interested to go halfsies on the funding and we'll do an extra phase. We had a program here called the LRASM, Long Range Anti-Ship Missile, that the Navy was really interested in, but they just couldn't get started on their own. So DARPA actually started the acquisition, and now the Navy is buying them, but they had some skin in the game too. Another DARPA saying is that transition is a full contact sport, and it's super hard. We recently stood up a unit in one of our offices whose whole job is to help people transition [out of DARPA to the military or commercial applications] better. And again, part of that is understanding the landscape in the services. Because a lot of DARPA PMs [program managers] are from the military, they're university professors and industry, so some of that is just connecting. There's also a separate transition problem: Frequently, some university professor starts a company, that company performs on our contract and does a great job, has made a great piece of technology. What we were seeing was the Chinese were then coming in with a ton of venture capital — and sometimes it's not even obvious that it's a Chinese company or Chinese sponsorship. So we actually stood up a bunch of American venture capitalists.

He's referring to DARPA's Embedded Entrepreneurship Initiative, established in 2019. — CH

Having the DARPA stamp of approval is a pretty good thing for a startup, so we were doing a little bit of matchmaking of getting the venture folks together with the startups that are coming off a DARPA contract to try to get them capital without foreign entanglements. That's a bit far from defense, but it's critically important to the health of the defense industrial base, right?

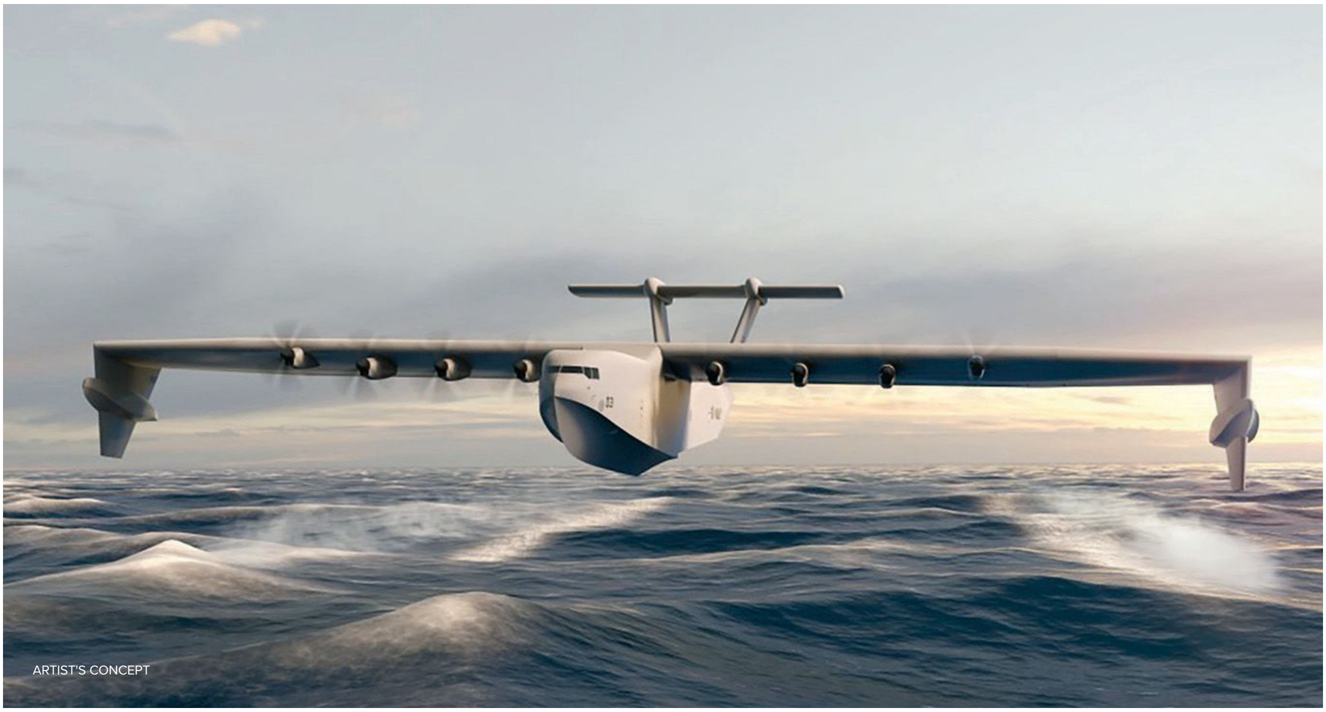


Lessons from Ukraine

What you're seeing is that anti-access/area denial really works good on both sides. Anything bigger than a quadcopter pretty much dies; they shoot down 30, 40 missiles and drones a night. If those were manned aircraft, those would be like World War II numbers. Part of managing complexity is I can do things faster and do it quicker, and you're seeing the Ukrainians adapting very rapidly, and the Russians to a certain extent too. We have programs that are looking at how we do that; we have a program called REMA [Rapid Experimental Missionized Autonomy] that is looking at how to rapidly adapt a drone for a different mission. How do I rapidly add autonomy and other things to a drone at the speed of relevance, like a couple months. We actually turned the engines of innovation on ourselves. It was 70 business days from the "Shark Tank" pitch to on-contract performing, which is a land-speed record in the federal government and certainly fast by DARPA standards. Also, the United States as a nation is pretty good at stealth, and while we have things that we're looking at doing better — and I'm not really going to go into that here — stealth only buys you so much speed, maneuverability and autonomy. It all really comes back to the complexity. Nobody says "I'd really like to go slow and take my time and do something in three years that I could do in a month," but we're driven there, by and large, by this vicious circle: It's complicated, therefore it takes longer, which means I got to think about it more before I get started, which means it takes longer, which slows me down. So you're trapped and it's the F-35; you're doing first flight in the '90s and we're still working on it. And the F-35 is a great airplane; I'm not throwing rocks at it; it's super, super complicated. What I want to do is to the extent you can disaggregate, knock the complexity down by making simpler things great. And then I want to overtly design things so that they can be produced. If you told me I could go from making 20 F-35s a year to making 200 F-35s a year by a 5% decrease in the signature, that might be a trade that's worth making. Those are all made up numbers, but nobody is actually talking that way.

Inspired by boat building

For our Liberty Lifter program, I have a naval architect building an airplane. A C-130's cost per pound is something like $550. You buy airplanes by the pound. We're looking at being $200-something per pound. It turns out there's a couple ways you could cut down $300. One is we're making a wing-in ground effect airplane — so very heavy lift, but it can still get up and away to 10,000 feet. That gets you over maritime obstacles, small islands and stuff like that. That also means I don't have to pressurize the cabin, which implies a certain level of fit and finish on a cargo airplane. So a C-130-sized airplane, that gets expensive. For Liberty Lifter, we're probably using marine grade composites — they're still in the trades phase — which are significantly cheaper than aviation composites. We're looking at using marine aluminum, which you can weld, versus aircraft aluminum that you have to rivet, which is a lot of touch labor. It's like 50 times more per pound just to use. The other thing is I want to be able to build large portions of this seaplane at boat yards — not like Huntington Ingalls,



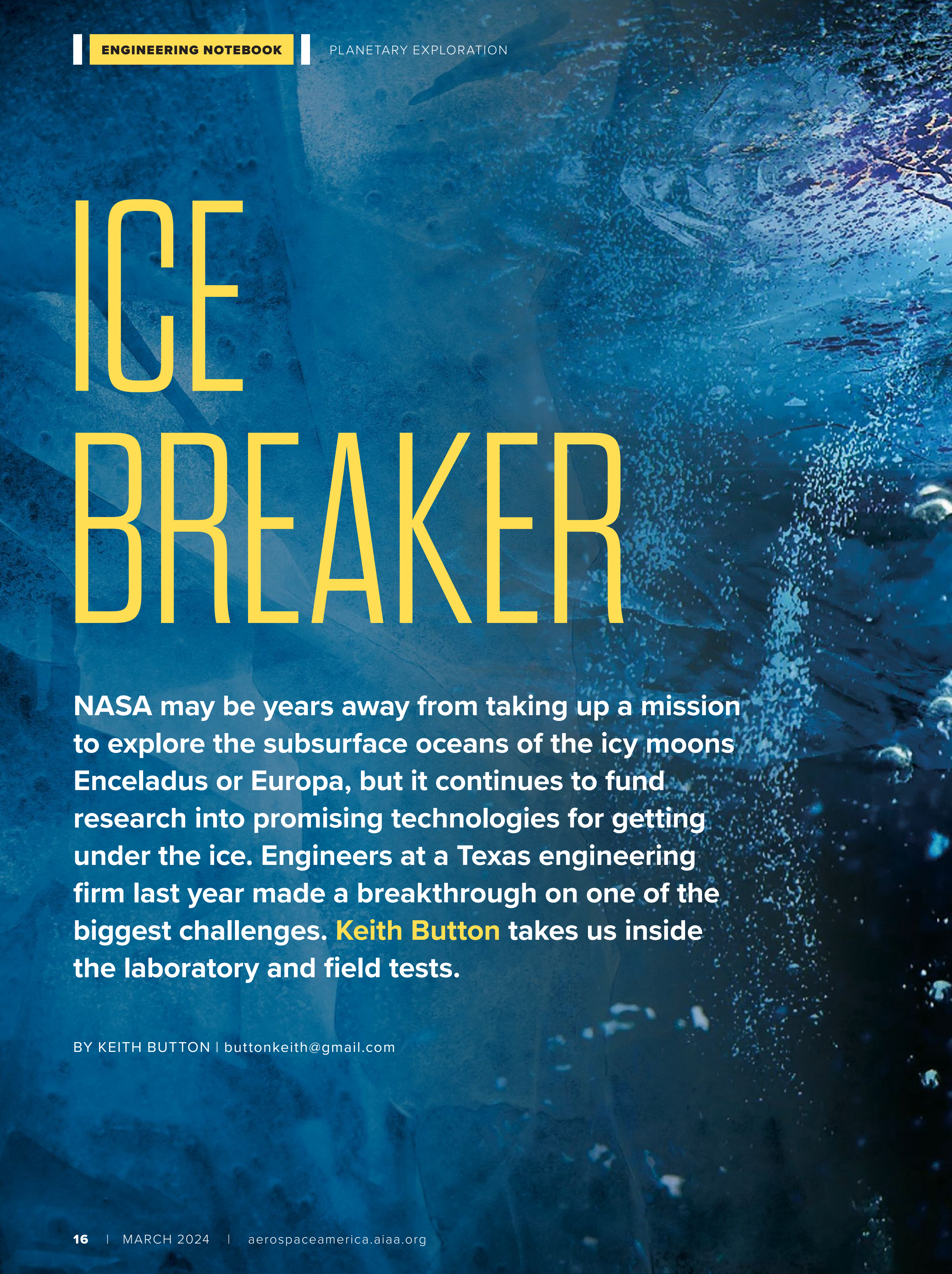
▲ DARPA's Tactical Technology Office aims to apply manufacturing techniques for naval ships in its Liberty Lifter demonstrator, targeted to fly in 2027 or 2028. DARPA this year plans to choose between a concept (left) proposed by General Atomic Aeronautical Systems and one proposed by Aurora Flight Sciences (above).

General Atomics/Aurora Flight Sciences

but Billy Bob's Boat Emporium. I want him to be able to make the wingbox because it's just aluminum and steel and maritime composites that he's used to using. It's a different shape, but he's got all the tooling and everything he needs. As we look at going to the Pacific, the Army and the Air Force and the Marines are talking about hiding on islands and playing a shell game. And that's great, except if everything's flying into a runway or a port, if I blow that up, you can't get supplies and you're going to be combat ineffective. But if I could bring in a C-130-sized seaplane or maybe even a C-17 to land anywhere on the coast or in the water, that changes the terms of the engagement. It's the transportation factor: how efficiently I can transport stuff, comparable to a ship but speeds comparable to an airplane. When you airmail or FedEx something, it's really fast, but it's also really inefficient in terms of price per pound. When I send something on a cargo ship, it's super efficient, but it would take a month to send a letter to Asia. Liberty Lifter is kind of in the middle, so it's almost as fast as a jetliner, but not quite, and it's almost as efficient as a cargo ship, but not quite. I don't know that there would be necessarily a civilian market for this, but from a military perspective, it solves a lot of problems in an innovative way — if we can build it.

The right time for a nuclear-thermal rocket demonstration

Space from a military perspective is more contested; it used to be kind of rainbows and unicorns out there. We are not expecting that to be quite the same in the future, particularly in cislunar beyond geosynchronous orbit. There's commercial interest in a way that there wasn't previously, and NASA, our partner on DRACO [Demonstration Rocket for Agile Cislunar Operations], wants to go to Mars. This is similar to the seaplane: Right now, your choices are chemical rockets — which give tens of thousands of pounds of thrust but are inefficient — and you've got ion drives that are super efficient and give much less thrust. DRACO is in that middle region where I get thrust like a chemical rocket but two to three times more efficiently. And there's a couple different flavors of nuclear propulsion. In the long term, if I've got a nuclear reactor up there, I think you want nuclear thermal, which gives you the magnitude of the thrust. For station-keeping, I'd rather use ions and be super efficient. And so it's not an either; it's a yes, both. And once I've got the nuclear reactor, I can decide how to use that power — an open loop as a thruster, or closed loop as an electricity source for an ion thrust. I think you would want both for a real mission. We know how to build closed-loop nuclear reactors; we've been doing that for years. Moving into space, there's all sorts of challenges. We're focusing on the nuclear thermal side of it, which is, to a certain extent, the thing with more uncertainty. There's nowhere on Earth where you can test those things, and so we're never turning the reactor on till we get into space. That solves the problem of "What if the rocket blows up?" Well, OK, fine; we're using high-assay, low-enriched uranium. It's not an innate radiation hazard in the way that the highly enriched, weapons-grade stuff is. So even if the rocket blew up on the pad, we're not going to have like a Chernobyl-type disaster. ★



ICE BREAKER

NASA may be years away from taking up a mission to explore the subsurface oceans of the icy moons Enceladus or Europa, but it continues to fund research into promising technologies for getting under the ice. Engineers at a Texas engineering firm last year made a breakthrough on one of the biggest challenges. Keith Button takes us inside the laboratory and field tests.

BY KEITH BUTTON | buttonkeith@gmail.com

In this artist concept, a cryobot breaches the ice of the Jovian moon Europa and reaches its subsurface ocean. The yellow beam represents the notional field of view of a camera. Cyrobots could be equipped with cameras and other instruments to navigate and record their surroundings. NASA/JPL-Caltech

When it comes to the search for extraterrestrial life, astrobiologists consider any planetary body with liquid water the Holy Grail. As luck would have it, there are two such destinations relatively close by: Saturn's Enceladus and Jupiter's Europa, both of which are believed to host subsurface oceans. These icy moons are within 1 billion kilometers of Earth, reachable within several years by robotic landers, depending on the route.

So why isn't NASA developing such a lander? Among the reasons is that any microbes or other primitive lifeforms in the oceans are likely to be ensconced under sheets of ice up to 34 kilometers thick, equivalent to the height of nearly four Mount Everests. So for the past decade, the agency has funded preliminary research into different technologies for breaching the ice. One of the leading proposals is to equip a lander with one or multiple cryobots, cigar-shaped robots that would tunnel through the ice, perhaps by squirting jets of hot water from their nose cones to melt a path down to the liquid center of the ocean.

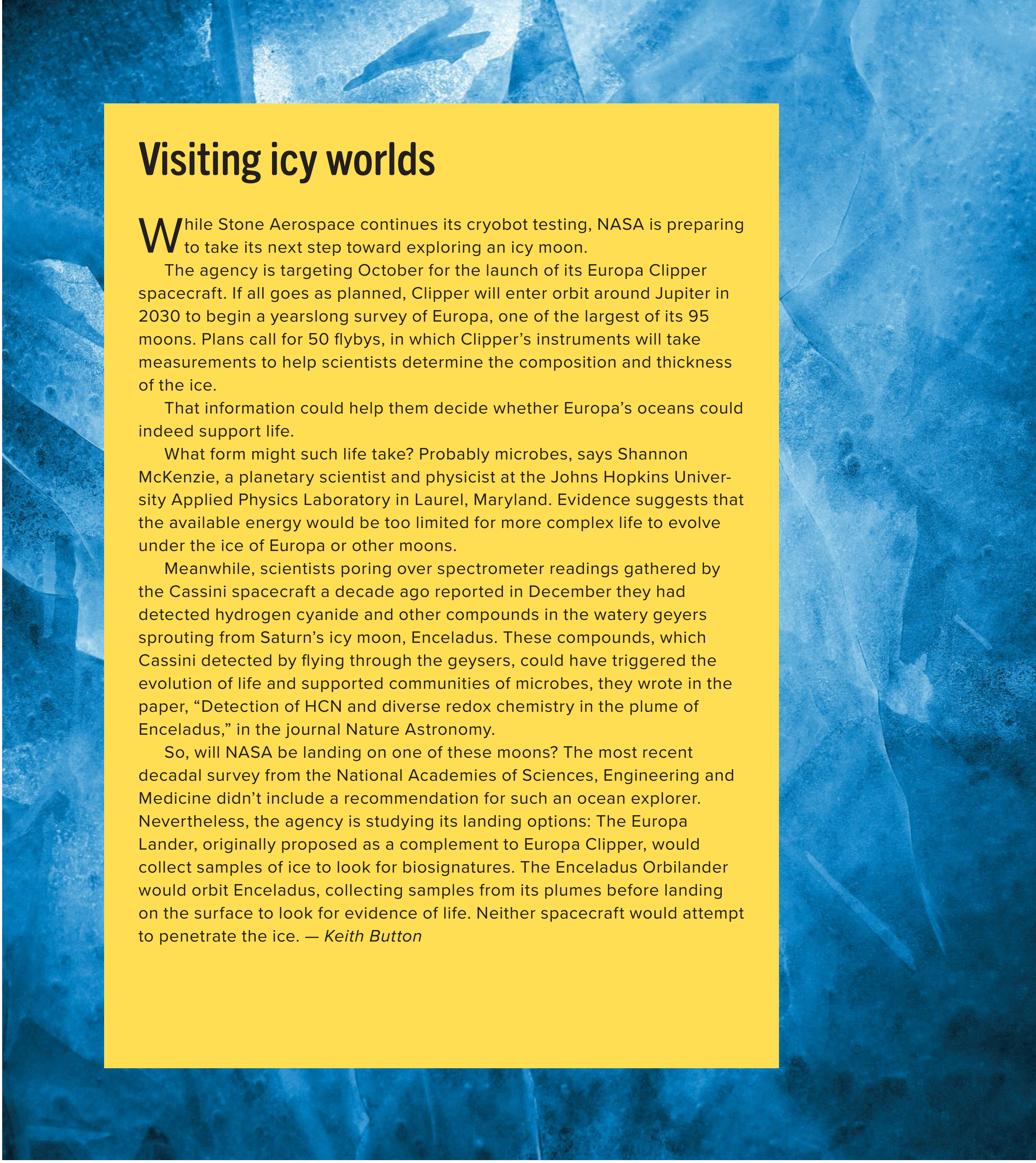
Technicians at Stone Aerospace, a small robotics company in Austin, Texas, are now working on one of the challenges such a future cryobot could encounter: descending through layers of asteroid gravel or other impurities in the ice.

"The hope is that by developing this technology and showing that it's sufficiently mature, it could be considered as part of an ocean worlds lander in the next decade," says Benjamin Hockman, a robotics technologist at the NASA-funded Jet Propulsion Laboratory and the agency's liaison for Stone Aerospace's cryobot research projects.

For its proposed solution, Stone Aerospace returned to a discovery made a decade ago on Alaska's Matanuska Glacier. The company is one of about a dozen teams funded by NASA to examine aspects of cryobot technology, and under one such grant in 2014 and 2015, technicians were testing their Valkyrie cryobot, a hot-dog-shaped, 3.5-meter-long prototype built to demonstrate one method for drilling through ice. To

▲ Another option NASA is studying for exploring subsurface oceans is EELS, the Exobiology Exant Life Surveyor. Instead of tunneling through ice like a cryobot, this snake-like autonomous robot would burrow into existing crevices. In September, researchers from NASA's Jet Propulsion Laboratory conducted field tests with an EELS prototype at Athabasca Glacier in Alberta, Canada.

NASA/JPL-Caltech



Visiting icy worlds

While Stone Aerospace continues its cryobot testing, NASA is preparing to take its next step toward exploring an icy moon.

The agency is targeting October for the launch of its Europa Clipper spacecraft. If all goes as planned, Clipper will enter orbit around Jupiter in 2030 to begin a yearslong survey of Europa, one of the largest of its 95 moons. Plans call for 50 flybys, in which Clipper's instruments will take measurements to help scientists determine the composition and thickness of the ice.

That information could help them decide whether Europa's oceans could indeed support life.

What form might such life take? Probably microbes, says Shannon McKenzie, a planetary scientist and physicist at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. Evidence suggests that the available energy would be too limited for more complex life to evolve under the ice of Europa or other moons.

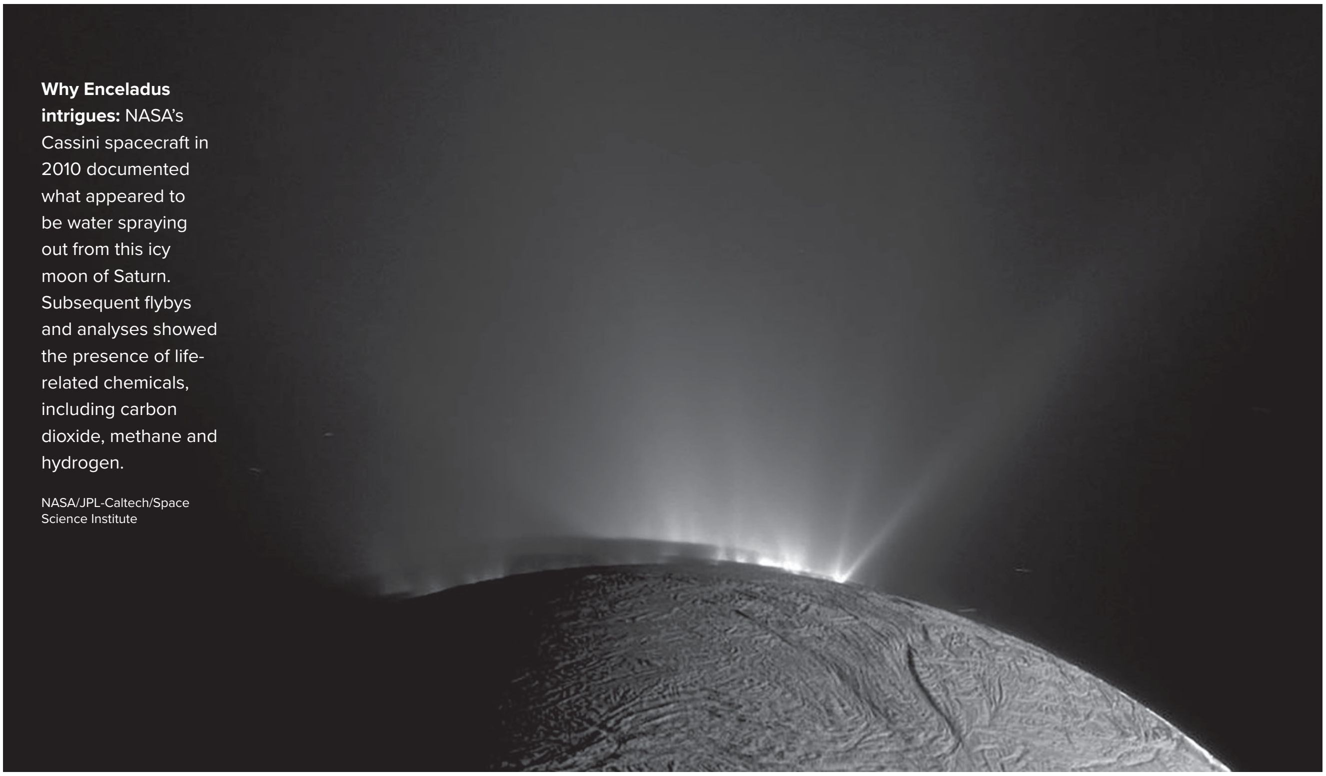
Meanwhile, scientists poring over spectrometer readings gathered by the Cassini spacecraft a decade ago reported in December they had detected hydrogen cyanide and other compounds in the watery geyers sprouting from Saturn's icy moon, Enceladus. These compounds, which Cassini detected by flying through the geysers, could have triggered the evolution of life and supported communities of microbes, they wrote in the paper, "Detection of HCN and diverse redox chemistry in the plume of Enceladus," in the journal Nature Astronomy.

So, will NASA be landing on one of these moons? The most recent decadal survey from the National Academies of Sciences, Engineering and Medicine didn't include a recommendation for such an ocean explorer. Nevertheless, the agency is studying its landing options: The Europa Lander, originally proposed as a complement to Europa Clipper, would collect samples of ice to look for biosignatures. The Enceladus Orbilander would orbit Enceladus, collecting samples from its plumes before landing on the surface to look for evidence of life. Neither spacecraft would attempt to penetrate the ice. — *Keith Button*

descend into the glacier, Valkyrie sprayed hot water through nozzles in its nose cone to melt the ice and then recirculated the meltwater into the cone to be heated and sprayed again.

On the glacier, they learned how they could maneuver Valkyrie as it descended to avoid potential obstacles farther down in the ice, like rocks detected via synthetic aperture radar, says Bill Stone, Stone Aerospace's founder and CEO.

"We said, 'Can we steer the vehicle as it goes down?' Because we had a hot water drill, and we had pressurized jets," Stone says. "And the answer is, 'Yes, you can.'" To do so, they added some jets on the nose cone that pointed laterally. When the lateral jets were turned on in one direction, they would cut a pocket in the ice — a cavity larger in diameter than the cryobot to the side and just below its nose — that the cryobot would then fall into. Repeating this process



Why Enceladus intrigues: NASA's Cassini spacecraft in 2010 documented what appeared to be water spraying out from this icy moon of Saturn. Subsequent flybys and analyses showed the presence of life-related chemicals, including carbon dioxide, methane and hydrogen.

NASA/JPL-Caltech/Space Science Institute

created cavities in a descending stairlike pattern through the ice, through which Valkyrie progressed deeper into the glacier.

This steering technique led to another discovery, Stone says. "We were seeing insoluble glacier material collecting at the bottom of the hole. But when we did these lateral cuts, it disappeared." They found that the sediment was falling into the lateral pockets they were creating for steering.

"That was the experimental kind of 'aha,'" he says. If a cryobot could sense that its rate of descent was slowing because of sediment building up in front of it, it could create a side pocket in the ice to move the sediment out of the way. Then, the cryobot could direct its nozzle downward to continue the path straight down into the ice.

Shortly after these tests, Stone put the side-pocket technique for removing sediment on hold for eight years as the team built and experimented with a series of cryobot prototypes in the lab to test for other icy moon challenges. They built and tested the full-scale, 4-meter-long Thor — large enough to carry a miniature nuclear reactor or decaying plutonium device to power a cryobot. They also tested 30-centimeter-long cryobots in a cryovacuum chamber to simulate the temperatures on the icy surfaces of Enceladus and Europa — promising targets not only for their oceans but also because they likely have rocky seabeds with the chemicals and energy to foster life.

In July, the Stone team received an additional Small Business Innovation Research grant from NASA to revisit the side-pocket sediment removal concept. They named the project Mjolnir, after the hammer of Thor, the Norse god of thunder.

As a starting point, they estimated that a cryobot equipped with a miniature nuclear reactor could cut through a 24-km ice shelf in about 300 days. If the cryobot were to encounter sediment in the ice — from asteroids or accumulations of insoluble salts, for instance — more and more detritus would accumulate in the pocket of meltwater below the nose as the bot descended.

▶▶ To observe how a cryobot might burrow its way through ice on frozen moons, researchers from Stone Aerospace tunneled into the clear block of ice shown on the next page with a model cryobot nose cone. They then filled the hole with plaster of Paris (the white cast at center) to document the size and shape of the pocket created.

Stone Aerospace

◀ Jets of hot water would be sprayed through the holes of a cryobot's nose cone (left) to descend through solid ice.

Stone Aerospace

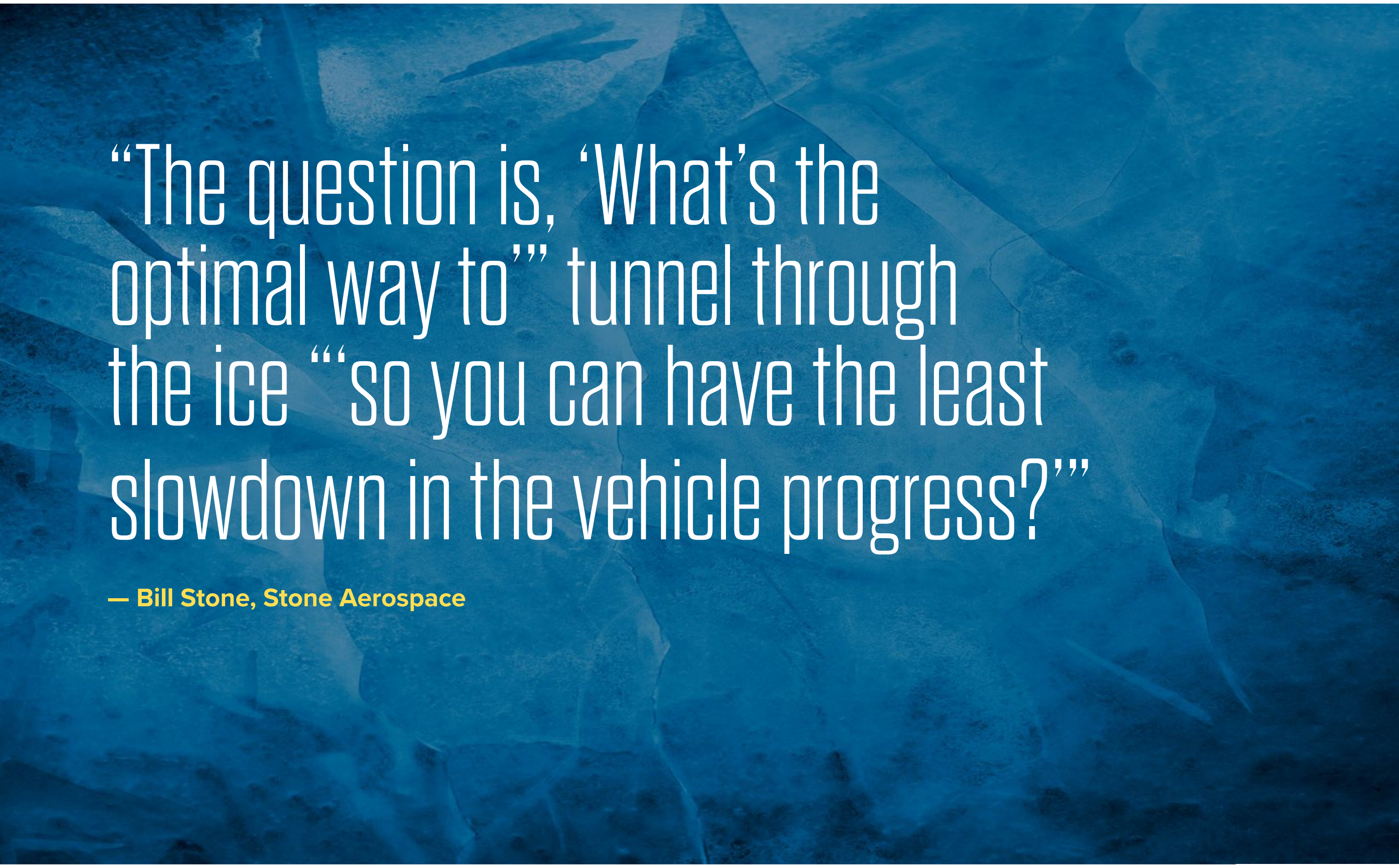
NASA is preparing to launch its Europa Clipper spacecraft in October. Pictured here being assembled at the Jet Propulsion Laboratory in late 2023, Clipper is to fly past Europa, one of Jupiter's 95 moons, dozens of times to help scientists determine whether the moon's icy subsurface ocean has the conditions to support life.

NASA/JPL-Caltech

"As it collects, it becomes an insulator, and it will stall out your forward progress," Stone says.

To advance the side-pocket concept so it could be applied to an icy moon cryobot, they needed to determine the most efficient way of creating the ice pockets for the sediment to fall into or be pushed into. How should the lateral cutting water jets be shaped? What angle, temperature and pressure should they operate at, and for how long?

"The question is, 'What's the optimal way to do it so you can have the least slowdown in the vehicle progress?'" Stone says. "It's going to take almost a year to get through [the ice]; you don't want to be doubling that because you've got this problem that's recurrent."



> “The question is, ‘What’s the optimal way to’” tunnel through the ice “‘so you can have the least slowdown in the vehicle progress?’”
>
> **— Bill Stone, Stone Aerospace**

First, they modeled on a computer how the ice-cutting hot water flows would interact with sediment particles and how that would change with variable levels of gravity. Europa’s gravity is about one-sixth that of Earth’s; Enceladus’ gravity is even less.

Next, they needed to test the water-cutting parameters in the lab, including the side angle, temperature, pressure and length of time to create a pocket. Plans called for running the initial tests with 1-meter-tall slabs of ice at minus 30 degrees Celsius, close to the estimated temperatures deep in Europa’s ice.

They needed clear ice without any bubbles so they could observe and record video of the ice-cutting and sediment movement, so they made their 1-meter-tall block in a machine that froze the ice from the bottom up while vibrating the water to eliminate any bubbles, similar to the “shot block” machines used by bars to make clear ice for cocktails. Each block took about two days to make in a walk-in freezer at Stone’s Austin lab. They also had to transfer the ice slowly from the machine to the lab, allowing the exterior to slowly warm to the ambient temperature of the lab before moving the block so it wouldn’t crack.

The next step was 3D printing a 7-cm-diameter scale model of the cryobot nose cone — one-fifth the expected size of the notional operational cryobot nose. They drilled a hole vertically down into the ice bock, filled it with water and dropped in the scale-model cryobot nose cone.

Then they started the experiment, turning on the water-cutting jet in the nose cone for the predetermined angle and other characteristics to be tested. Instead of recirculating the water, as a cryobot would do on Enceladus or Europa, they simplified the lab setup: A collar sealed the top of the hole, and the excess water was drawn off through the top. For each test, the cutting jet was turned on for up to 10 minutes.

Another problem they encountered was how to document the size and shape of the pocket to correlate with the water jet characteristics tested on the block. For about a month, they tried pouring in various types of epoxies and plasters to create casts of the cavity after the water jet was turned off. In the end, plaster of Paris was the best option.

“We went through a long road of trying everything under the sun, but the kindergarten solution won out,” says Vickie Siegel, chief operating officer of Stone Aerospace.

But there was another obstacle: Each time they tried to make a cast, the pocket would continue to melt

▲ Stone Aerospace's Valkyrie prototype burrowed its way through layers of ice in 2014 and 2015 at the Matanuska Glacier in Alaska. Valkyrie traveled about 30 meters, melting the ice with hot water jets in its nose. The engineers observed that sediment often fell into the lateral holes that Valkyrie created for steering through the ice.

Stone Aerospace

before the cast could set up.

"This was a big issue until one of our lab techs came up with a super clever idea," Stone says: After the pocket was formed, they pulled out the nose cone and dumped the water. Instead of trying to make a cast in the lab, they immediately placed the ice block in their industrial freezer at minus 30 Celsius to prevent any further melting. Then, in the freezer, they filled the pocket with plaster of Paris. Once the material hardened, they took the block outside to melt in the Texas sun. They 3D-scanned the solid shape left behind and logged the shape into their digital archives.

From this testing, Stone will have a catalog of results showing how altering the angle and other characteristics of the water-cutting jet affected the size and shape of the side pocket. Next, they plan to test and catalog how much sediment the water jet can push into the pockets by employing blocks of ice with various types of sediment frozen in them. From these results, they want to narrow in on the sediment removal techniques that are fastest and that require the least energy to execute. The next slate of activity is scheduled for July, when they plan to test techniques on ice frozen to minus 190 C — roughly the equivalent of the surface temperatures of the icy moons.

"It'll be incredibly valuable to analytical models for predicting how to come up with the best design for a cryobot," Stone says.

For now, preliminary results from the ice block tests indicate that the best technique is to cut a side pocket at least twice the width of the cryobot with jets of hot water that also push the sediment over. Then, by turning off the jets and letting the cryobot simply melt its way downward via the heat of the nose cone, the cryobot would avoid the risk of slicing a hole in the pocket, which could let sediment fall into the cavity in front of the nose cone again.

The discovery of that technique a decade ago on Matanuska Glacier illustrates the importance of field work, Siegel says. In the lab, a researcher can get tunnel vision trying to solve for the daunting task of drilling through a massive ice shelf, but the natural world reveals challenges that the researcher might not consider, she says.

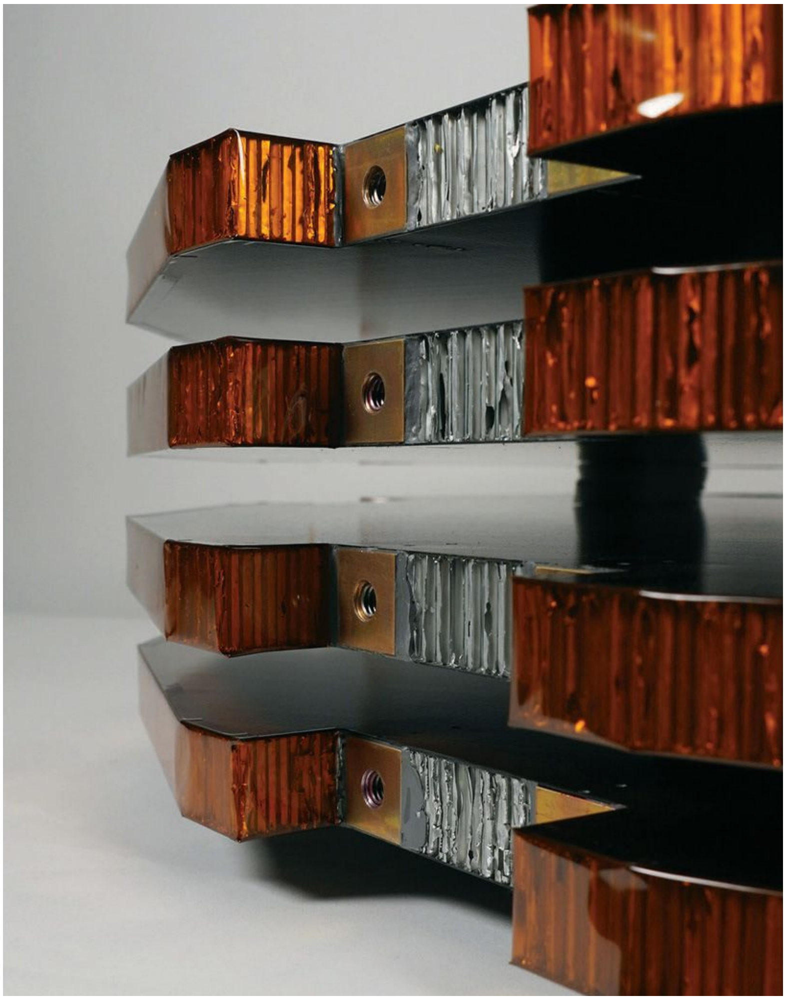
"You're so focused on the ice, and maybe you don't think about it when you go out onto an actual glacier," Siegel says. "Getting out in the field and watching these things occur in nature really kind of highlights elements that you wouldn't even have thought you needed to design to." ★

A NEW SHAPE

FOR SMALL SPACECRAFT

Paul Marks looks at the origin and promise of DiskSats, the flat, circular satellite format that's edging its way toward reality.

BY PAUL MARKS | paulmarksnews@protonmail.com



In 2025, the payload fairing of a small launch vehicle is scheduled to be jettisoned in low-Earth orbit to reveal a curious-looking cylinder. Inside that aluminum can, four flat, circular satellites — each a meter in diameter and only 2.5 centimeters thick — will be stacked like pancakes, separated by contact points between them. If all goes as planned, a geared mechanism will elevate each satellite to the top of the can and hurl it out into orbit.

This won't be some orbital publicity stunt by the International House of Pancakes but the first demonstration of the DiskSat concept — small, flat, meter-wide satellites built to a format that could soon join cubesats among the leaders in the small satellite field. The carbon composite and aluminum chassis structures of the four that are planned for the test launch next year arrived in January at the Aerospace Corp., the federally funded research center in El Segundo, California, that investigates new technologies mainly for the U.S. military and intelligence community.

There, in 2020, senior scientist Richard Welle had something of a Eureka moment when trying to figure out how to squeeze much more power out of small

◀ These are the chassis structures for the four DiskSats that were delivered to Aerospace Corp. in January in preparation for a planned launch next year. By covering aluminum honeycomb in carbon fiber composite panels, the weight of each satellite can be kept to about 3 kilograms — the equivalent of a 3-unit cubesat.

Rock West Composites

satellites, and perhaps launch many of them at the same time. Welle — whose specialisms include microsatellite solar power, advanced materials and propulsion — happened to be looking at some samples of rectangular composite material on a table in his office when, he says, it dawned on him that a flat circular satellite could be a great way to achieve much larger solar panel surface area.

"Sometimes it pays to just sit in a quiet office and think," he told me by email.

Welle dubbed the envisioned satellites "DiskSats." Weight would be kept down by starting with an aluminum honeycomb core, and laying down carbon-fiber-reinforced plastic composite over it. This composite would create a substrate for the solar panels and protect the payload circuitry inside the satellite.

Further advantages would come from this geometry: Constellations of disk-shaped satellites could be stacked snugly inside rocket fairings (with or without dispensers) to use volume that today is wasted when cubesat dispensers of various sizes must be squeezed inside these cylindrical fairings. Also, the solar panels could be installed on the surface on each side of the disk, therefore generating more power for a greater variety and size of payloads, including those that need a direct view of space or exposure to it.

As valuable as cubesats have proven to be, "Due to their small size, there's certain applications where the laws of physics mean you can't necessarily perform a particular mission," says smallsat architect Catherine Venturini, a collaborator of Welle's at Aerospace Corp.

The Eureka moment for Welle, who's since retired and moved into consulting, came when he was tasked with investigating the potential for a mission concept involving designing and deploying large numbers of cubesats in LEO. He quickly realized the spacecraft would not have enough power or enough surface area to host the antennas and equipment that needed exposure to space.

"We needed a satellite with a low mass, a large surface area for power and radio frequency aperture, and capable of being launched in large numbers from a small launch vehicle – such as the Rocket Lab Electron," Welle says. "It was obvious to me that the mission could not be done with cubesats, and the disk seemed like a good alternative. Once the idea was in place, it became obvious that the disk had advantages for many missions beyond the original study objective."

It was not immediately obvious to everybody, however.

"As with any new idea, the reaction was mixed - some thought it couldn't be done, some thought it provided no value. But fortunately there were enough people who thought it both workable and useful, so we got the support we needed to put together a demonstration mission," he says.

Satellites, like the 50 or so that were launched on SpaceX's Transporter-7 rideshare flight last year, tend to be variations on cube shapes. This leaves a lot of unused space inside conical fairings, as seen here.

SpaceX

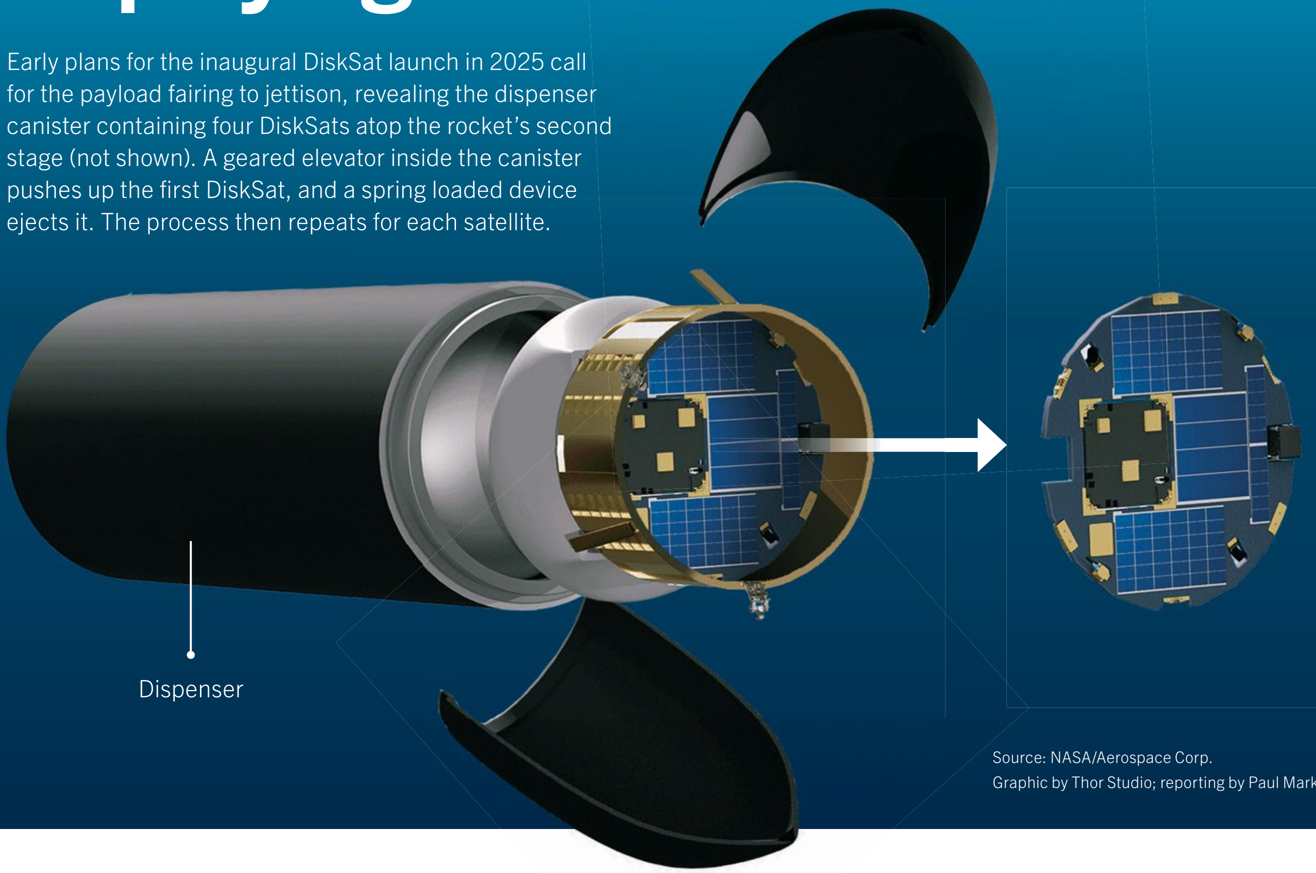
The four prototype DiskSats are to be dispensed from an as-yet-undecided launcher, but possibly a Rocket Lab Electron, for the U.S. Space Force, no earlier than April 2025. The project is run by Aerospace Corp. in collaboration with NASA's Space Technology Mission Directorate, with Space Force planning to run the launch and orbital operations under an agreement with NASA.

The impetus for that mission stems in no small measure from the sheer enthusiasm for it from Roger Hunter, program manager for the Small Spacecraft Technology Program at NASA's Ames Research Center in California.

"I was intrigued," Hunter recalls of first hearing about the DiskSat concept from Welle. "Some people come up with crazy ideas, and a lot of people are dismissive because they're hampered by culture. In

Deploying DiskSats

Early plans for the inaugural DiskSat launch in 2025 call for the payload fairing to jettison, revealing the dispenser canister containing four DiskSats atop the rocket's second stage (not shown). A geared elevator inside the canister pushes up the first DiskSat, and a spring loaded device ejects it. The process then repeats for each satellite.



Source: NASA/Aerospace Corp.
Graphic by Thor Studio; reporting by Paul Marks

many cases, change is hard for some people to embrace. But when Rich Welle came to my office and he got his DiskSat idea up on the whiteboard, I could see a lot of applications for it. And I have a lot of students right now who want to get their hands on a DiskSat as soon as possible to see if they can enable some of their ideas on orbit, too."

(And he has, he says, further "hare-brained ideas" to discuss with Welle.)

DiskSats could prove attractive to mission planners currently wrestling with the limits of cubesats. A single unit, or 1U, cubesat measures 10 centimeters x 10 cm x 10 cm. A 6U cubesat, a popular size, is about the size of a shoe box, at 30 cm long, 20 cm wide and 10 cm high.

"Very few CubeSats larger than 6U have flown, and none have been larger than 16U," Welle and colleagues wrote in their 2021 paper, "The DiskSat: A Two-Dimensional Containerized Satellite" at the Small Satellite Conference in Logan, Utah. But a 1-m-diameter, 2.5-cm deep DiskSat instantly gives users a super-sized smallsat volume — equivalent to a 20U cubesat, yet with a structural mass of only 3 kilograms. The reason it's so light? The interior chassis structure is lightweight anodized aluminum honeycomb, sandwiched between carbon fiber panels made from a space-proven, low-outgassing composite and epoxy formulation.

And because the spacecraft is a flat disk, readily available cubesat subsystems can be installed around its surface wherever the operator does not need a solar panel or antenna, Welle says. At least initially, Aerospace Corp. plans to install the avionics in a set-aside 25 x 25 cm square area, with mission-specific applications dotted around the disk as and where they are needed. Having those components distributed around the disk presents another major benefit: Troubleshooting before launch is easier.

"When you have a cubesat with its small volume, all your circuit boards and subsystems are stacked up inside it, so it's hard to get in to replace a board or do testing," says Venturini. "But with a DiskSat, you've got this large disk, and you can lay out your circuit boards and everything kind of flat. So it's also really great for testing and integration."

Or as NASA's Hunter puts it: "When you're engineering a cubesat, if you have it on the ground and something goes wrong, you'd say, 'Oh, God, I gotta pull all my cables and all the wires out.' You just won't have to do that with a DiskSat. It's like plug-and-play with Legos on top of the spacecraft; it's all much more accessible."

A further benefit of this distributed approach is the increased ease of thermally balancing the spacecraft — an important factor with the Enpulsion Nano indium-ion electric thruster, developed by the European Space Agency, that will propel the DiskSats, melting indium at 170 degrees Celsius on one edge of the ship's circumference.

"There's a lot of heat," Venturini says. "We've added some passive thermal techniques to the DiskSat to compensate for flying that unit. So we took that into consideration for our thermal design."

But that design is not set in stone, she cautions. The next one could have a different design, depending on the mission "or what we're trying to demonstrate."

Beyond the benefits of more real estate, "DiskSat immediately addresses one of the issues we're trying to improve upon, and that is power," says Hunter. Venturini says more typical power levels for a 6U cubesat range between 20 to 50 watts, whereas a DiskSat can carry enough solar panels on both sides to generate 200 watts — about double the power of most cubesats.

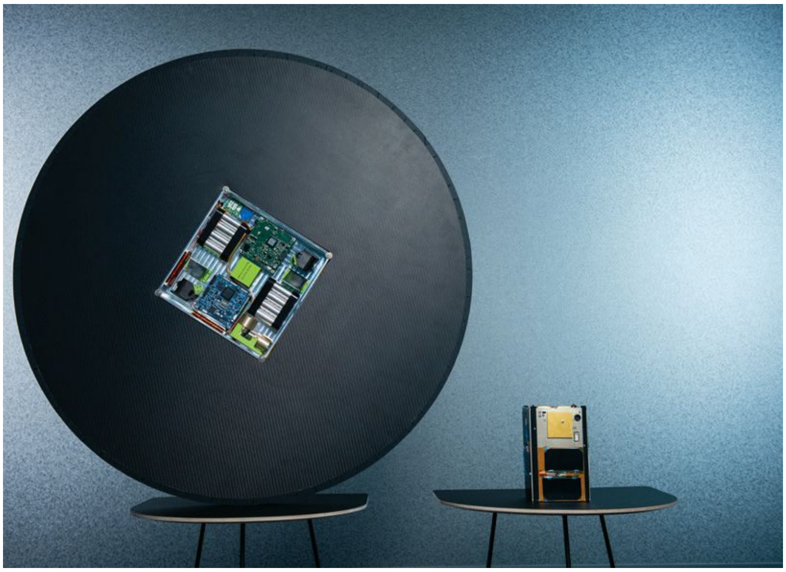
No one plans to demonstrate all that on the 2025 mission. Hunter wants to prove that what he calls the DiskSat "bus" works well, more than anything else. It's important, he says, that any other payloads NASA Ames or Aerospace Corp. run on the DiskSats do not interfere with that central aim.

"After we prove DiskSats work, we want to build a spacecraft that dispenses a huge array. So you can have a communications relay station with the moon or interplanetary space, or this could be a fundamental aperture that you would use as a large telescope," says Hunter.

He also envisages a curious type of cosmic "whip aerial" being possible for some communications applications: Wrap it around the edges of the DiskSat a few times, he says, and it can ping out a self-unfurling lengthy antenna once on orbit.

On the topic of debris, the NASA team plans to find out through the 2025 demo how quickly a DiskSat might be deorbitable by flying it "face-on" into the draggy, ultra-low-density air in LEO. This could involve flying two DiskSats edge-on and two face-on, then comparing their velocities. The maneuvers could determine whether flying the spacecraft edge-on is the best way to keep them on orbit longer, Hunter says.

Even without attitude control, a DiskSat might not constitute debris for long, says Venturini. "We've done some analysis that if it's just tumbling, it'll deorbit very, very quickly. So even tumbling can have a significant impact on deorbiting" — probably, she says, because the spacecraft would intercept a lot of draggy molecules once per turn of the tumble.



▲ At 1 meter in diameter, this early model of a DiskSat (left) dwarfs this 20-centimeter-tall 2-unit cubesat.

Aerospace Corp.

But talking about orbital demos is academic unless the DiskSat dispensing system can be perfected and made reliable enough for the rigors of orbital flight. "We have to flight qualify the dispenser, and the engineering model is looking pretty good. We're making some good progress on the dispenser," says Hunter.

The spacecraft are coming together fast, too, after the January delivery to Aerospace Corp. of the first four DiskSat carbon fiber and aluminum chassis structures from its contractor, Rock West Composites of San Diego.

Ultimately, shapes other than disks could emerge to satisfy the same basic idea of using up available space aboard rockets and maximizing area and power. Welle's patent on the idea (US 11,492,147) reveals hexagonal and square "DiskSats" as among the options, as well as larger diameter circular ones.

Though Rocket Lab's Electron, with its 1.2-meter payload bay, is in the running as a possible launcher for the first four DiskSats, the idea is far from tied to Electron-sized rockets. "The concept is extendable to other vehicles. For example, a disk two meters in diameter could fly on the Firefly Alpha," says Welle, adding that a "disk" that's actually a 1-m square could fly on a conventional secondary payload adapter that smallsats rideshare on today.

Essentially, large flat surfaces of many shapes and sizes could be leveraged to boost satellite solar power and aperture. "Just as most CubeSats are not actually geometric cubes, a DiskSat does not have to be a geometric disk," Welle says. "The final shape will depend on the mission needs and the launch vehicle constraints." ★

Could it happen again?

MH370

Ten years later

A decade ago this month, a Malaysia Airlines jet took off into the night with 239 aboard, and neither the plane nor those on it were ever seen again. MH370 remains the greatest mystery in the history of civil air transportation. Could a modern jet vanish today without explanation? Keith Button investigates.

KEITH BUTTON | BUTTONKEITH@GMAIL.COM

01:07:55 Flight 370
Malaysian…Three Seven Zero maintaining level three five zero.

01:08:00 Kuala Lumpur
Malaysian Three Seven Zero

01:19:24 Kuala Lumpur
Malaysian Three Seven Zero contact Ho Chi Minh 120 decimal 9. Good night.

01:19:29 Flight 370
Good night, Malaysian Three Seven Zero.

A sign-off came into Kuala Lumpur air traffic controllers from a Boeing 777 that had taken off a half hour earlier, bound for Beijing: "Good night, Malaysian Three Seven Zero." Controllers in Vietnam were supposed to hear from the crew next, but that radio call never came.

Malaysia Airlines Flight 370 and its 239 passengers and crew were gone.

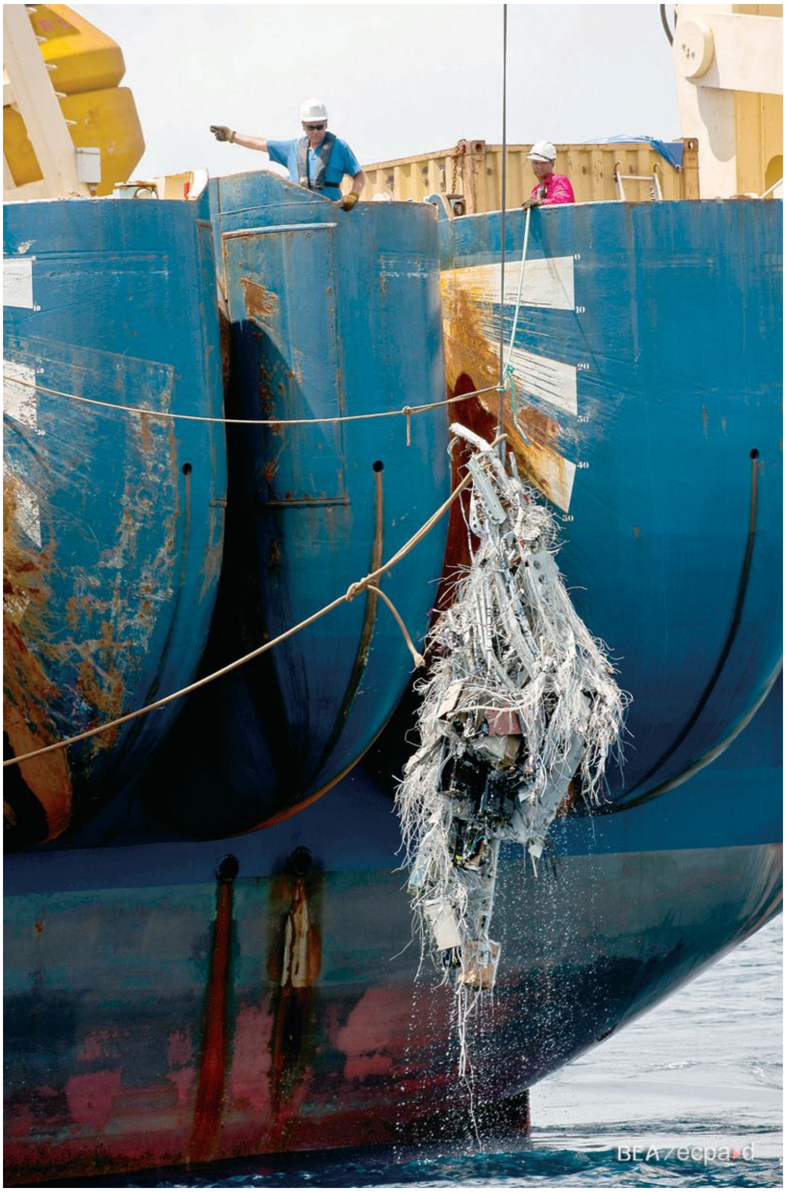
What came next was a fruitless 33-month search that remains the largest and most expensive in aviation history, exceeding $44 million in its first month alone, according to a Reuters estimate. What happened aboard the plane? Now, 10 years after MH370 disappeared, the only clues have been thinly sourced suspicions about actions of the pilot in the weeks before the flight and a dozen or so pieces of debris that washed up on shores in the years after the jet vanished.

Could an airliner suffer the same fate today, flying off into the darkness never to be seen again, with the cause becoming a global mystery? To find out, I examined investigative reports and analyses produced by agencies in Australia and Malaysia, plus media reports, an influential industry safety study and safety standard recommendations from various agencies. I also interviewed five industry safety technologists, a professor who specializes in crash investigations and a seasoned accident investigator.

A clue as to what might have happened aboard MH370 came about two minutes after the "good night" call: The plane's symbol disappeared from controller screens in Kuala Lumpur, Thailand and Vietnam. That meant the aircraft's Automatic Dependent Surveillance-Broadcast (ADS-B) transponder, that had been sending the GPS location and heading, was no longer doing so — either because a rogue pilot turned a knob in the cockpit or because of a loss of power or damage to the device.

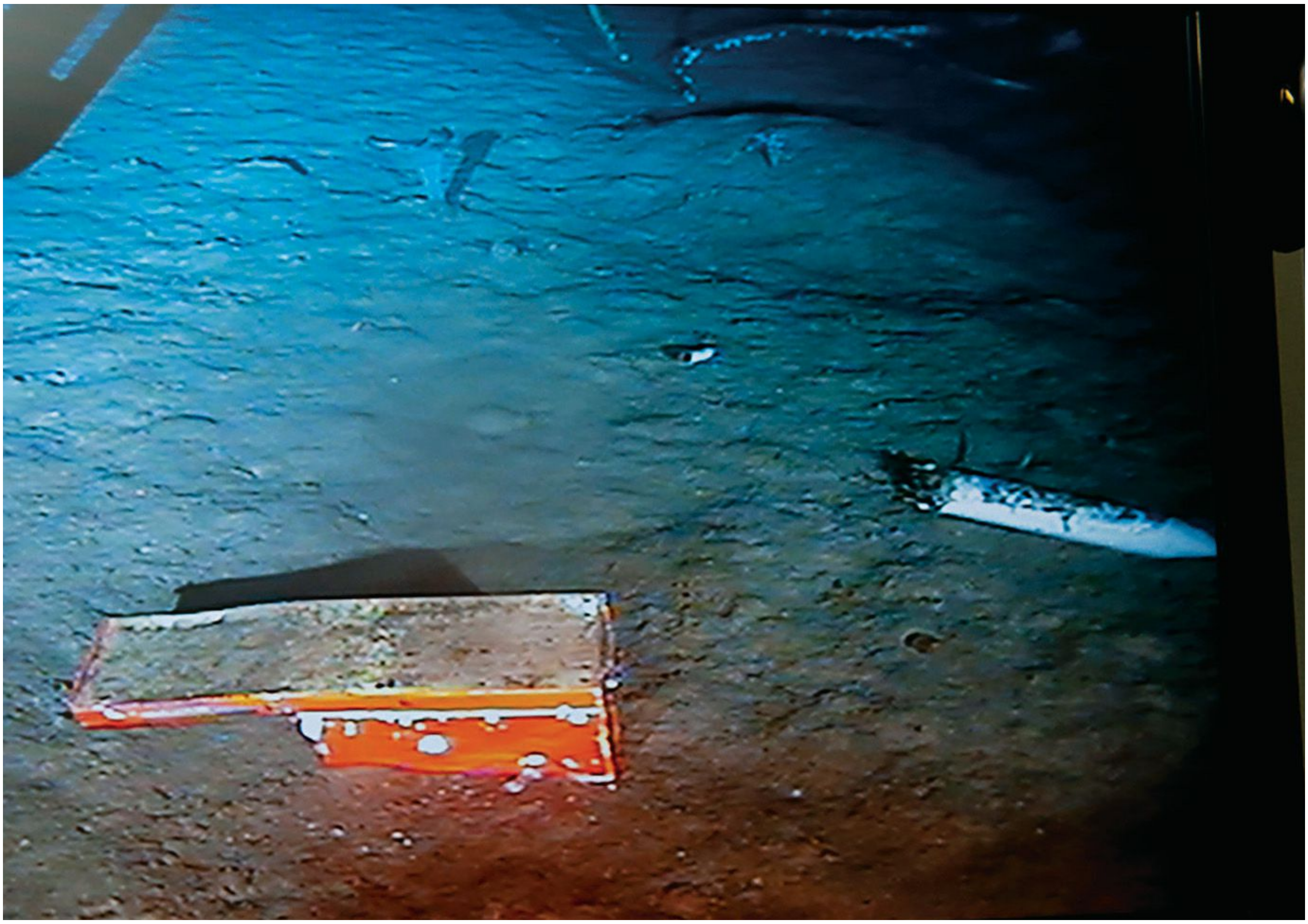
In 2014, ADS-B radio signals could be picked up only by ground stations when the plane was in range, and MH370 was well within that range when its symbol disappeared. Today, the Virginia-based Aireon service tracks aircraft globally by collecting ADS-B transmissions with Iridium satellites. Other providers offer regional tracking services. All told, an airliner flying an unplanned route over the Indian Ocean today could be tracked via ADS-B, provided its transponder was still transmitting.

Also, starting next year, newly constructed Airbus planes and new planes flown by European airlines will have a backup to ADS-B that would be automatically triggered in an in-flight emergency. It will be an upgrade of today's emergency locator transmitters, or ELTs, that are triggered only on impact so that a plane and any survivors can be found in a remote area. Now, a "distress tracking" capability will be added so that if a plane rolls or pitches at extreme angles, or drops quickly, it begins transmitting during the flight. Another trigger would be if the avionics that detect whether a plane is in distress stop operating, perhaps suggesting that a rogue pilot turned them off. This emergency locator transmitter with distress tracking, or ELT(DT), technology was a recommendation that predated the MH370 disappearance. A multinational working group had called for it following the 2009 crash of Air France 447 in the Atlantic Ocean that killed 228.



▲▶ The investigation into the Air France 447 crash, the Airbus 330 that disappeared in 2009 over the Atlantic Ocean, lasted nearly three years, due to the missing cockpit voice and flight data recorders. After numerous searches, investigators in 2011 recovered the wreckage including the avionics bay (above) and the flight data recorder (right). The cockpit voice recoder was also recovered.

Bureau of Enquiry and Analysis for Civil Aviation Safety



As MH370 flew into the night, hours went by with no word from the plane, and it became apparent that it must have crashed. But where? Military radar showed that it made a series of curious turns before vanishing from radar. Inmarsat, the London-based communications satellite operator, alerted Malaysian authorities of seven automated log-on attempts to establish links between the plane and a geosynchronous satellite over the Indian Ocean. Two of those attempts were initiated by the plane and five by an Inmarsat ground station in Australia. Timestamps for each attempt showed the send and receive times. From these signal transit times, the distance between the satellite and the plane at each attempt was deduced and represented as a series of circles on the globe with the satellite in the middle of each. Based in part on the aircraft's likely speed and previous estimated location, each circle was narrowed to an arc of possible locations that in turn helped narrow the next circle to an arc, and so on. The final arc represented the points at which the plane likely crossed just before impact when it ran out of fuel. Based on that arc, the Australian Transport Safety Bureau defined an underwater search area in the southeast Indian Ocean.

The task was then to locate the wreckage and the black boxes, meaning the cockpit voice recorder and flight data recorder. The flight data recorder would be most helpful because it was equipped to record up to 25 hours of data, including the readings the crew would have seen on their instrument panel and the settings of the flight control surfaces. Given that MH370 flew for an estimated seven and a half hours, there would be a record of the entire flight. The cockpit voice recorder, on the other hand, could well have proved to be useless given that it would have recorded only the final two hours of the flight, meaning any conversation early in the flight when the plane made the curious maneuver and the ADS-B stopped transmitting would have been overwritten.

Today, a solution for the voice recorder time limitation is being rolled out. The European Union Aviation Safety Agency in 2021 required all new large passenger planes to be equipped with voice recorders capable of collecting 25 hours of sound. FAA in December proposed to follow suit for new aircraft but resisted calls from the National Transportation Safety Board to extend the rule to existing aircraft, citing a need for "the lowest economic impact on operators." FAA estimates that retrofitting would cost $25,000 per plane. NTSB last month said the two-hour limit had "hampered" its investigation of two near collisions at U.S. airports in 2023 and other runway "incursions."

It also cited the case of the door plug that was blown off a Boeing 737 MAX 9 in early January. NTSB first broached the extension in 2018, citing a long list of investigations it says were hampered.

Even with the limitation of the voice recorder, investigators in 2014 were determined to find the boxes. Doing so required dragging hydrophones to listen for the acoustic pings from the underwater locator beacon on each box, a device that doubles as a handle on the exterior of each. Malaysian investigators enlisted ships, helicopters, underwater drones and fixed-wing planes from a dozen nations including Australia, China, the United Kingdom (which also contributed a nuclear-powered submarine) and the United States. Some of the vessels searched for the black boxes, and others looked for bodies or floating wreckage. By the time the search was called off in early 2017, some 710,000 square kilometers of the floor of the Indian Ocean — an area a little larger than Texas — had been scoured. A smaller privately funded search followed in 2018. Neither the black boxes nor any bodies were found. Three small pieces from MH370's wings and other debris linked to the plane were discovered in 2015 and 2016 when they washed up on shores along Africa's east coast, Madagascar and nearby islands.

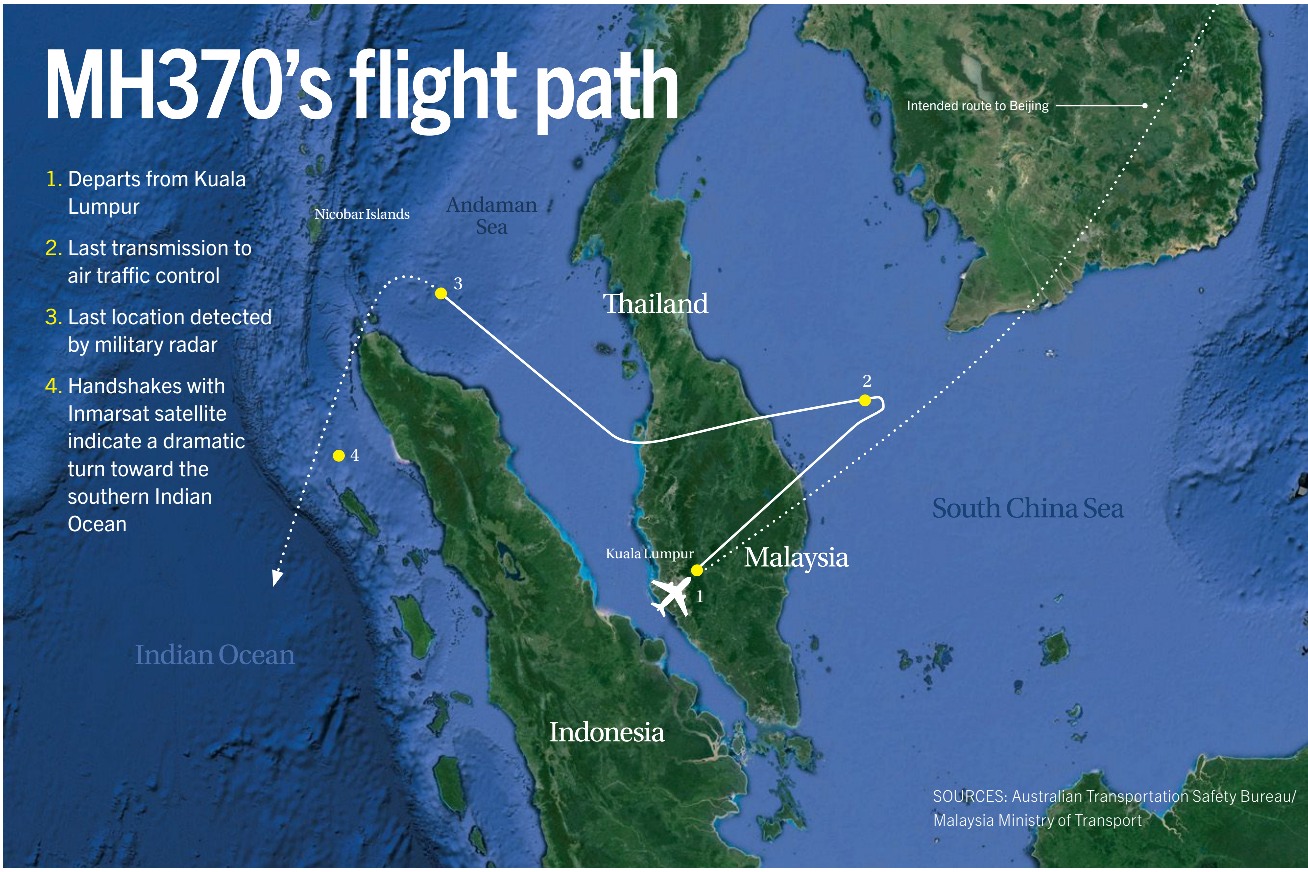
Today, if ADS-B wasn't operating and a plane went missing, the search area might be similar to the one in 2014. But there is one piece of technology on today's aircraft that would make zeroing in on underwater wreckage much less difficult, says Philippe Plantin de Hugues, head of European and international affairs at BEA, the French aviation accident investigation authority.

Since 2018, any large passenger plane flying over the ocean has carried an additional acoustic beacon. Located in the nose of Boeing aircraft and in the rear of Airbus planes, the new beacons would be triggered when submerged. Each is a watertight metal cylinder about the size of a soda can containing a single-cell battery and electronics to emit a ping every second for 90 days. On MH370 and other aircraft of that era, the only beacons were those on the black boxes, and they had only enough battery power to transmit for 30 days. The additional beacons are designed to transmit at a low frequency of 8.8 kilohertz, giving them a detection range of 5-10 kilometers, compared to the 3-km-range of the 37.5-kHz black box beacons that were aboard MH370, Plantin de Hugues says. But he notes a caveat for Boeing aircraft: The location of the beacons in the nose means they could be damaged or destroyed in the nose-first impacts that he says have historically accounted for 60% of Boeing crashes.

Plantin de Hugues led the multinational working group that made recommendations for new equipment

▲ Of the approximately 20 pieces of debris recovered in the search for MH370, this section of an outboard wing flap is one of the few that investigators have confirmed as a component of the Boeing 777 that disappeared in 2014. The Australian Transportation Safety Bureau led the yearslong search for the aircraft and the 239 aboard.

Australian Transportation Safety Bureau


MH370's flight path
1. Departs from Kuala Lumpur
2. Last transmission to air traffic control
3. Last location detected by military radar
4. Handshakes with Inmarsat satellite indicate a dramatic turn toward the southern Indian Ocean
Intended route to Beijing
Nicobar Islands
Andaman Sea
Thailand
Kuala Lumpur
Malaysia
South China Sea
Indian Ocean
Indonesia
SOURCES: Australian Transportation Safety Bureau/ Malaysia Ministry of Transport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▲ Airbus has pledged to install ejectable data recorders on its new designs. One such design scheduled to begin passenger service this year is the A321XLR, pictured here landing in Toulouse, France, in October. The test aircraft completed a six-hour demonstration flight with 200 Airbus employees aboard.

Airbus

following the Air France crash, including the additional beacons and the coming distress tracking capability.

But what if, despite all the new technology, the boxes still can't be found?

In the wake of Air France crash, the Plantin de Hugues working group saw a need to end the near total reliance on recovery of physical black boxes. The Air France boxes were eventually recovered in 2011, nearly two years after the crash, but when the working group met, the search was still on. The group recommended to the U.N.'s International Civil Aviation Organization that it create a standard that large passenger planes should carry technology to provide cockpit audio and flight data to investigators immediately after a crash.

A decade later, EASA enacted a rule based on ICAO's standard, requiring newly designed large passenger airliners to be equipped at least one of two

> "From my perspective as a safety professional, if you've lost one [aircraft], it's one too many."
>
> **— Anthony Brickhouse, Embry-Riddle Aeronautical University**

ways: With cockpit voice and flight data recorders that transmit data to the ground via satellite or with boxes that would be ejected from the plane's tail on impact. These deployable recorders would need to float, too, in the case of a water crash. Plantin de Hugues expects that it will take until 2025 or 2026 for aircraft to fly with one of the new technologies.

So far, adoption of the tech has been uneven. Airbus chose to install ejectable black boxes on its new designs. In the U.S., FAA hasn't adopted any rules based on the ICAO standard. Boeing, in response to written questions, did not disclose whether it has any plans to install or study ejectable or transmitting black boxes.

Because ejectable black boxes are designed to be recessed, or flush with the surface of the plane, airlines have deemed them too expensive to be a retrofit option because that would require altering the airframe.

So what about streaming? It would be fairly simple to install technology to allow transmission of black box data and audio, says Chris Thomson, a U.K.-based vice president at Curtiss-Wright Corp., the North Carolina-based maker of cockpit voice and flight data recorders. Five years after MH370, Curtiss-Wright and Honeywell agreed to jointly offer a "black box in the sky," a combination recorder that could stream flight data and the cockpit audio in real time via satellite. Adding hardware for the streaming feature would be easy, Thompson says: Just add a card to a slot in the black box, like adding a memory card to a laptop computer.

The demand would need to come from the airlines. "If an airline were to feel passionate about it, they

▲ Five years after MH370 disappeared, Honeywell and Curtiss-Wright Corp. announced their intention to develop an ejectable cockpit voice and flight data recorder that would store 25 hours of cockpit audio. The Honeywell Connected Recorder-25 last year was approved for installation aboard Boeing 737, 767 and 777 aircraft.

Curtiss-Wright Corp./Honeywell

would make an overture to the aircraft manufacturer, who would then decide whether they wanted to make that offerable or not," he says. The manufacturers responsible for most of the world's airliners — Airbus, Boeing, Bombardier and Embraer — often make new options available at cost for a particular customer, or they add new standard options if customer demand is widespread.

A decision would also need to be made about precisely which data and audio to transmit. An EASA-funded analysis released in June concluded that it would be too expensive to continuously transmit flight data recorder information and cockpit audio for the entirety of every flight, unless the plane's operator could also utilize the information for business purposes beyond crash investigations. Another option would be to transmit the audio and data in a triggered, sudden burst just before a crash. This would cost less but would come with the risk that not all the information would be received in the event of a sudden impact, for instance. Also, actions or developments early in a flight might cause a crash later, but it could be difficult to predetermine which factors should trigger a transmission, according to the study, conducted by Collins Aerospace, the North Carolina avionics maker.

In the case of MH370, audio could have supported or debunked a theory that today has thin evidence: that the plane's captain carried out a suicide-murder plot. The captain, Zaharie Ahmad Shah, flew a flight path similar to the final route of MH370 out over the Indian Ocean on his home flight simulator in Malaysia, just weeks before MH370, according to a 2016 New York magazine story that cited a confidential document from a Malaysian police investigation. Early flight data or audio could also explain why the plane "was not configured for a ditching," a conclusion of the Malaysia Ministry of Transport based on a piece of wing debris that was positioned for cruise. This implied that the captain and co-pilot had to be either unconscious or they deliberately allowed the plane to crash.

Setting aside sabotage, perhaps a gradual cabin depressurization had clouded the crew's judgment or they tried to descend to below 10,000 feet where pressurization is not needed but fell unconscious before they could complete the maneuver, leaving the plane to keep flying until it ran out of fuel.

Ultimately, the Collins study said, the streaming black box concept could be implemented in two to five years if a hybrid approach were employed. Information would be continually streamed during takeoffs and landings, when crashes are most likely to occur, but during cruise, streaming would only be triggered only in an emergency.

Given that by next year it will have taken 16 years to get distress tracking onto new aircraft and nine years to get additional beacons on new aircraft, a wait of two to five years could be considered an improvement.

The long timelines have been a source of frustration for advocates, including Anthony Brickhouse, a professor at Embry-Riddle Aeronautical University in Florida who teaches crash investigation courses.

"From my perspective as a safety professional, if you've lost one [aircraft], it's one too many. The technology is out there for us to have good data to use to do our investigations," he says. ★

Nation-states are blowing up satellites. Companies are launching megaconstellations of thousands of satellites. Dead rocket stages whiz around the planet for years. And yet, the International Space Station hasn't been destroyed, payloads reach deep space unharmed, and we're not trapped on Earth — at least not by debris. Either calamity is not upon us or we just don't recognize it. Jon Kelvey takes the measure of Kessler Syndrome, the theory that cascading collisions of debris could ruin humanity's future in space.

UNDERSTANDING THE MISUNDERSTOOD

KESSLER SYNDROME

BY JON KELVEY | jonkelvey@gmail.com

The European Space Agency and ClearSpace of Switzerland are targeting 2026 for a debris removal mission, in which a long-discarded payload adapter, at right in this illustration, will be grappled by a ClearSpace-made spacecraft equipped with an ESA-developed robotic arm.

ClearSpace

Irony isn't just limited to life in 1-g. Last year, a discarded payload adapter from a European Space Agency Vega rocket was orbiting Earth as it had for the past 10 years, when radars showed it had company — a small number of new objects traveling with it. ESA concluded that a "hypervelocity impact" with a piece of debris had broken fragments from the adapter.

Here's the irony: ESA was preparing to dispatch a spacecraft to the adapter to demonstrate a technique for removing such debris, the goal being to reduce the odds of collisions that would make the trash problem worse.

The collision "actually shows how much we are running against the clock here," says Portuguese engineer Tiago Soares. He's the lead engineer at ESA's Clean Space office, which helped conceive the planned cleanup demonstration, ClearSpace-1.

"We need to have reactive removal services available," he says. Otherwise, debris could continue colliding with the growing number of spacecraft in orbit, producing more hazardous debris, and "it's going to be much harder in the future to operate in space. There'll be a lot more risks of losing satellites or losing a mission."

Soares is referring to the Kessler Syndrome, a term inspired by the 1978 paper, "Collision frequency of artificial satellites: The creation of a debris belt," in the Journal of Geophysical Research. It was written by Donald Kessler, a researcher in NASA's Environmental Effects Office at Johnson Space Center in Houston, and a colleague at NASA Johnson, space scientist Burton Cour-Palais. They devised equations

> **"I THINK WE'RE NOT THERE YET, BUT WE'RE APPROACHING THE SITUATION VERY QUICKLY. THE DEBATE IS ABOUT WHEN IT WILL HAPPEN, WHETHER IT IS FIVE YEARS FROM NOW, 10 YEARS FROM NOW OR 20 YEARS FROM NOW."**
>
> **— Vishnu Reddy, University of Arizona**

to model the distribution of known objects in orbit, predicting how likely they were to collide and create orbital debris over time.

My review of the literature and interviews with seven experts ranging from aerospace engineers to planetary scientists to astrodynamacists show that the scientific community hasn't yet reached a consensus about whether the Kessler Syndrome has begun, or, if it has not begun, how bad it will be when it starts. There is consensus, however, that the basic concept is sound and that the space community needs to clean up its act.

For the moment, even the definition of "Kessler Syndrome" is open to debate. As Kessler, who retired decades ago, pointed out in a 2010 paper, it is "an orbital debris term that has become popular outside the professional orbital debris community without ever having a strict definition."

In 2013, the term went mainstream in dramatic fashion in the film "Gravity." A Russian missile destroys a satellite, spewing debris that collides with a space shuttle orbiter and the International Space Station, causing a cascade of collisions that take out all communications satellites in about 90 minutes.

That depiction was "Kessler Syndrome on steroids that defies physics,"says Abhishek Tripathi, director of mission operations at the UC Berkeley Space Sciences Lab.

That was one thing that all experts I spoke with agreed on: A Kessler Syndrome cascade is something that, whether it has begun or not, would play out over the course of decades if not centuries, rather than fitting into the runtime of a Hollywood drama.

For Tripathi's part, he doesn't think the syndrome has begun, and he doubts peaceful space operations will change that.

"A lot of things have to go wrong for us to end up in a Kessler Syndrome situation by slowly boiling the frog," he says, referring to predictions of a slowly unfolding cascade. But: "We have the launch capacity to intentionally cause a Kessler Syndrome if we wanted to."

Specifically, he worries about a nation-state kicking off a space war by knocking out satellites with missiles.

As for accidental collisions, meet physicist Mark Matney, whose first boss at NASA was none other than Kessler. Matney works in the Orbital Debris Program Office at NASA Johnson, and perhaps not surprisingly, he can rattle off the worst collisions to date. The most recent serious incident came in 2009 when an Iridium communications satellite and a Russian Cosmos satellite collided, generating some 2,000 pieces of debris at least 10 centimeters in diameter.

"I tell people that's a harbinger of things to come," Matney says.

In his view, Iridium-Cosmos was "the opening move" of the Kessler Syndrome: It is one of several unplanned collisions that have occurred, as Kessler predicted, and debris from Iridium-Cosmos could cause future collisions that grow debris, he warns. It's difficult, Matney says, to look at orbit right now and say for certain that a cascade is in motion, because of the long time frame over which Kessler Syndrome would play out.

"I don't think it's acute yet," he says, but "we're on

a timescale of something like a one in 10 chance each year of another major collision."

He does not take comfort that it's been 15 years and counting since the last big smashup — even if the gap might seem surprising, considering that today there are some 8,000 operational satellites in space compared to around 1,000 in 2009 and 300 in 1978. There's also much more debris, in part because of the nation-state actions that Tripathi worries about. India destroyed a satellite with a missile in 2019 to demonstrate an antisatellite weapon, and Russia conducted a similar demonstration in 2021. Together, the two tests generated a little over 1,500 pieces of debris. Following the Russian shootdown, the seven crew members aboard ISS had to temporarily take shelter in their Crew Dragon and Soyuz capsules, in case the station was struck. Regarding satellite proliferation, while there are many more satellites, the company responsible for most of them, SpaceX, places its Starlink satellites in a low orbit so they can naturally deorbit relatively soon — within five or six years, per SpaceX — if they fail.

A long gap in time between collisions is not unique. Thirteen years before the Iridium-Cosmos collision, the French CERISE satellite broke up after colliding with a piece of debris from an Ariane 1 rocket. In 1991, the Russian Cosmos 1934 satellite collided with debris and broke up in orbit.

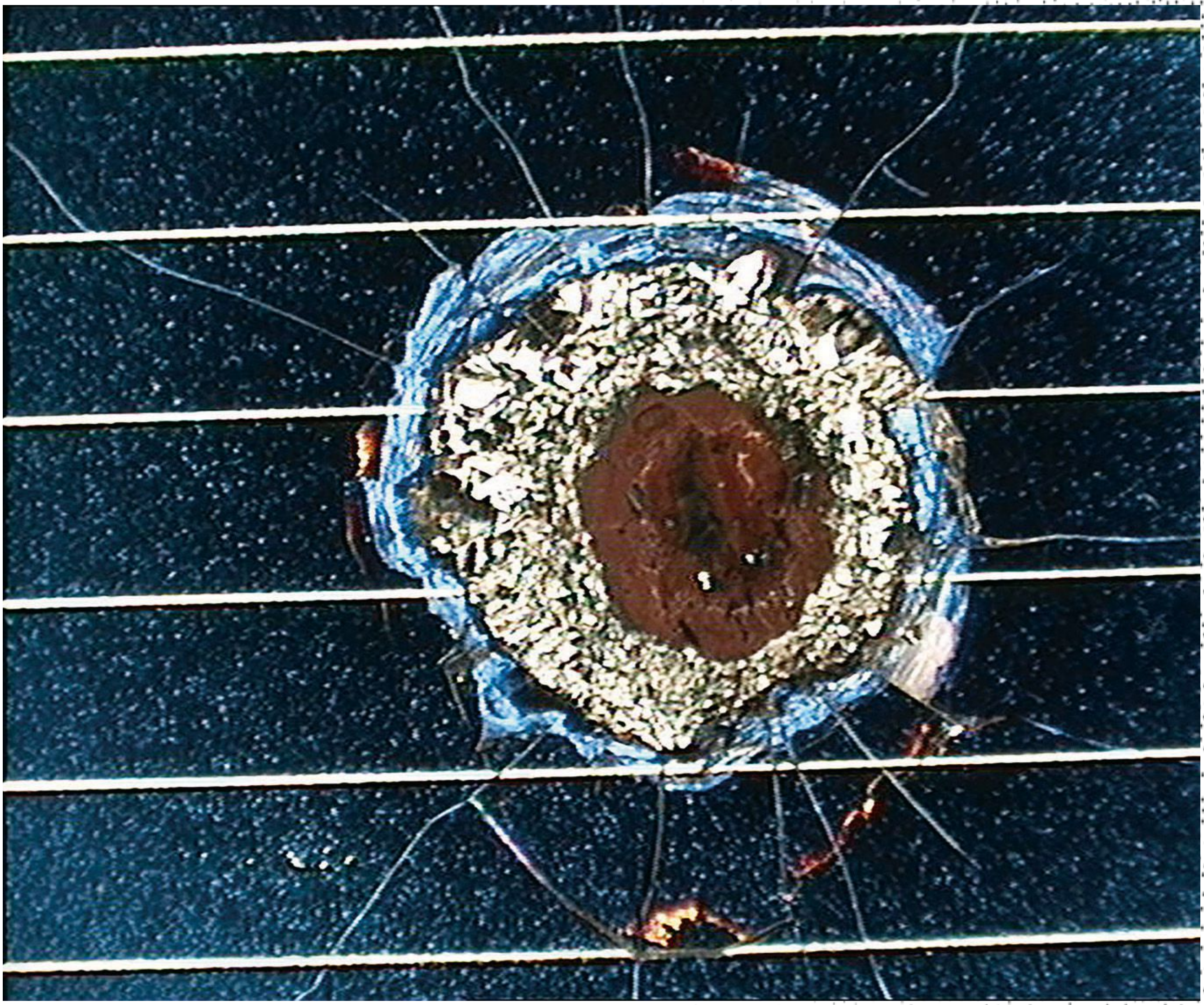
Somewhere in the middle in terms of views about Kessler Syndrome is Vishnu Reddy, an Earth and space scientist at the University of Arizona, where he also directs Space4, the university's space safety, security and sustainability center. He questions the timing, not the plausibility of the Kessler Syndrome.

"I think we're not there yet, but we're approaching the situation very quickly," he says. "The debate is about when it will happen, whether it is five years from now, 10 years from now or 20 years from now."

Rather than relying on Kessler's original mathematics and analysis, the experts are applying newer mathematics and models to simulate how debris and spacecraft interact in orbit — colliding or passing by

Today, many spacecraft experience some form of collision with micrometeoroids or minute pieces of debris. These solar cells from the Hubble Space Telescope, installed in 1993 and brought back to Earth by NASA astronauts in 2002, experienced multiple impacts during their nearly nine years on orbit.

European Space Agency



each other — and how the debris created by collisions or events like the spontaneous explosion of an old rocket motor may increase the odds of further collisions and debris growth. In Massachusetts, Richard Linares, an astrodynamicist and professor at MIT, and his colleagues load the masses, volumes and velocities of known spacecraft and debris into the MIT Orbital Capacity Assessment Tool. MOCAT then calculates the motions of orbital objects forward in time.

"We can calculate how many objects are generated from a breakup event" — when an object explodes or disintegrates due to a collision — "and each object will have a size and a mass," Linares says. "We can probably go up to 20 million objects in our simulation."

MOCAT also runs Monte Carlo algorithms that take the positions and velocities of thousands of objects in orbit, among other information, and create myriad random simulations to show a range of potential future debris scenarios based on various parameters entered by the scientists. These include the number of rockets projected to reach orbit in a given year and a

"IF THERE ARE COLLISION EVENTS, THOSE ALTITUDES CAN VERY QUICKLY TURN INTO A KESSLER-TYPE OF SCENARIO WHERE THEY GROW VERY RAPIDLY INTO MILLIONS UPON MILLIONS [OF PIECES] OF DEBRIS."

— Richard Linares, MIT

hypothetical number of major collisions between satellites occurring in the next 20 years.

"In those models, we see that we could have exponential growth [of debris] if the space traffic is too large," Linares says.

That exponential growth is what could make accessing space a more risky and expensive affair, where certain orbital lanes could become so clogged they are no longer worth trying to operate within.

ESA and NASA use similar analytical approaches, ESA with its Debris Environment Long-Term Analysis software and NASA with its LEO-to-GEO Environment Debris software. Soares says ESA's calculations suggest that orbital debris will continue to grow over the next two centuries even if all rocket launches stopped today.

"It would more than double the number of debris in orbit without us sending anything else up there," he says.

In contrast, NASA's modeling doesn't predict exponential debris growth, according to Matney, but rather linear growth over the next 200 years — even if launches continue. But things get more complicated when you factor in that LEO isn't a monolithic expanse, he says, and "in some altitude regions [debris growth] is exponential, some linear."

At around 400 kilometers and into the 500-km realm — home to ISS and the SpaceX Starlink satellites among others — atmospheric drag plays a major role. Dead satellites and debris usually slow and burn up in the atmosphere in just a few years. This natural cleansing process accelerates when the sun becomes more active and solar coronal mass ejections strike Earth and cause the atmosphere to swell.

"In those altitudes, we can probably do a lot and we will be forgiven," Linares says.

But this atmospheric drag drops off quickly as one goes higher. By the time you get around 600 km, the altitude of the Hubble Space Telescope, "now you're talking about decades for things to drag down," Matney says.

"When you get up to 800 or 900 km, we're now

▲ SpaceX in February said it plans to deorbit 100 of the early satellites in its Starlink broadband constellation, due to an unspecified "common issue" with these satellites "that could increase the probability of failure in the future." Almost 6,000 Starlinks have been launched since 2019, including some 1,300 of the v2 Mini variant pictured here.

SpaceX

talking about centuries for things to drag down," he adds. "When we get up to 1,000 km, you're talking about millennia."

A lot of satellites fly in those higher altitudes already, including some 70 Iridium communications satellites, at least 600 OneWeb broadband internet satellites and NASA's Earth-observation spacecraft, including Landsat 8 and 9.

"If there are collision events," Linares says, "those altitudes can very quickly turn into a Kessler type of scenario where they grow very rapidly into millions upon millions [of pieces] of debris."

However, humanity would not be "locked in" on Earth in such an event, he says, given that crewed spacecraft headed for deep space would cross the problematic altitudes so quickly. But there are still plausible scenarios that are far from ideal. Linares sees a potential future where "humans probably don't have any incentive to launch satellites, because we're losing 50% of them" to collisions with debris, he says.

Matney puts it like this: Kessler Syndrome "won't cause orbital altitudes to be unusable. It's more like a gradual degradation that's going to cost everybody more money."

The prospect of losing money leads naturally to the question of just what should be done about orbital debris, and there are two generally agreed-upon major actions to take.

"The first step is to make sure that new junk doesn't get added," says Reddy, the University of Arizona professor. "The second step is to remove large pieces of junk that have the potential to be the sources of cascading debris events in a Kessler Syndrome scenario."

Not creating new debris is largely a matter of adhering to the rule in the United States and Europe that satellites must not stay in orbit longer than five years after their mission is completed.

"It's the stuff you learn in kindergarten: You clean up your messes; don't hurt your neighbor," Matney says.

Removing existing space junk could have the biggest impact on the debris curve.

"It depends on how much remediation you do, but in principle, it actually flattens it out and starts letting it go down," he says.

That's why ESA isn't giving up on ClearSpace-1, or the idea behind the mission. Soares, the lead engineer, notes that ESA had its Copernicus satellites built with interfaces so they can be grabbed and redirected to deorbit should they fail. Eventually, he says, the goal is to build spacecraft that can grapple and remove large objects that pose a major debris hazard, such as ESA's multiton Envisage, which died in 2012.

"It's not easy because the satellite was not at all designed to be removed," Soares says.

No matter which view of the Kessler Syndrome one adheres to, the risk it describes might not be a fait accompli. "This is a problem that we have the capability and, hopefully, the willpower to solve," says Matney. ★

AIAA Bulletin

DIRECTORY

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

Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2024			
2–9 Mar*	IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
5 Mar	49th Dayton-Cincinnati Aerospace Sciences Symposium (DCASS)	Dayton, OH (aiaa-daycin.org/DCASS)	12 Jan
5–26 Mar	Financial and Business Acumen for Navigating the Aerospace Industry Course	ONLINE (learning.aiaa.org)	
11 Mar–17 Apr	Turbomachinery for Emerging Space Applications Course	ONLINE (learning.aiaa.org)	
12–28 Mar	Overview of Python for Engineering Programming Course	ONLINE (learning.aiaa.org)	
19–28 Mar	Aircraft Reliability & Reliability Centered Maintenanc Course	ONLINE (learning.aiaa.org)	
19 Mar–18 Apr	Design Evolution of Aircraft Structures Course	ONLINE (learning.aiaa.org)	
25–27 Mar	Understanding Space: An Introduction to Astronautics & Space Systems Engineering Course	ONLINE (learning.aiaa.org)	
23–24 Mar	AIAA Region VI Student Conference	Santa Clara, CA	2 Feb 24
4–5 Apr	AIAA Region II Student Conference	Cape Canaveral, FL	4 Feb 24
5–6 Apr	AIAA Region III Student Conference	Akron, OH	9 Feb 24
5–6 Apr	AIAA Region IV Student Conference	Stillwater, OK	9 Feb 24
5–6 Apr	AIAA Region V Student Conference	St. Louis, MO	9 Feb 24
10 Apr–1 May	Optimal Control for Unpiloted Aerial Vehicles (UAVs) Course	ONLINE (learning.aiaa.org)	
12–13 Apr	AIAA Region I Student Conference	Morgantown, WV	5 Feb 24
15–24 Apr	Technical Writing Essentials for Engineers Course	ONLINE (learning.aiaa.org)	
16–18 Apr	AIAA DEFENSE Forum	Laurel, MD	17 Aug 23
16 Apr–6 Jun	A Practical Approach to Gas Turbine Engine Performance & Design Using GasTurb14 Course	ONLINE (learning.aiaa.org)	
18–21 Apr	AIAA Design/Build/Fly	Wichita, KS (aiaa.org/dbf)	
20 Apr	Pacific Northwest Section Technical Symposium 2024	Lynnwood, WA	
23–24 Apr	OpenFOAM® CFD Foundations Course	ONLINE (learning.aiaa.org)	
26–27 Apr	PEGASUS Student Conference	Terrassa, Spain	
29–30 Apr	Essential Model-Based Systems Engineering Course	ONLINE (learning.aiaa.org)	
6 May–10 Jun	Test Foundations for Flight Test Course	ONLINE (learning.aiaa.org)	

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2024			
7 May–27 Jun	Human Spaceflight Operations Course	ONLINE (learning.aiaa.org)	
8–10 May*	4th IAA Conference on Space Situational Awareness (ICSSA)	Daytona Beach, FL (http://reg.conferences.dce.ufl.edu/ICSSA)	
8–10 May*	Dayton Digital Transformation Summit	Dayton, OH	
13–16 May	Composite Structures: Process Analysis, Progressive Damage, Failure Analysis, and Advanced Software Course	ONLINE (learning.aiaa.org)	
14 May	AIAA Fellows Induction Ceremony and Dinner	Washington, DC	
15 May	AIAA Awards Gala	Washington, DC	
18 May	19th Annual SoCal Aerospace Systems and Technology Conference	Irvine, CA	
21 May–13 Jun	Spacecraft Lithium-Ion Battery Power Systems Course	ONLINE (learning.aiaa.org)	
3–26 Jun	Design of Experiments Course	ONLINE (learning.aiaa.org)	
3–19 Jun	The Anatomy of Autonomy Course	ONLINE (learning.aiaa.org)	
4–7 Jun	30th AIAA/CEAS Aeroacoustics Conference	Rome, Italy (aidaa.it/aeroacoustics/)	14 Dec 23
10–13 Jun	Applied Space Systems Engineering Course	ONLINE (learning.aiaa.org)	
12–14 Jun*	CEAS EuroGNC 2024	Bristol, UK (https://eurognc.ceas.org)	
17–22 Jun*	Spaceport America Cup	Las Cruces, NM	
18–27 Jun	Guidlines for the Development of Civil Aircraft & Systems Course	ONLINE (learning.aiaa.org)	
13–21 Jul	COSPAR 2024: 45th Scientific Assembly	Busan, Korea	
28 Jul	Regional Leadership Conference (RLC)	Las Vegas, NV	
29 Jul–2 Aug	AIAA AVIATION Forum	Las Vegas, NV	12 Dec 23
30 Jul–1 Aug	ASCEND Powered by AIAA	Las Vegas, NV	12 Dec 23
2–3 Aug	5th AIAA CFD High Lift Prediction Workshop	Las Vegas, NV	
9–13 Sep*	34th Congress of the International Council of the Aeronautical Sciences	Florence, Italy (icas2024.com)	
14–18 Oct*	75th International Astronautical Congress	Milan, Italy (iac2024.org)	
19–20 Oct	SmallSat Education Conference	Cape Canaveral, FL	

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

● AIAA Continuing Education offerings

AIAA Announces its Class of 2024 Honorary Fellows and Fellows

AIAA congratulates its newly elected Class of 2024 Honorary Fellows and Fellows. The class will be inducted during a ceremony on Tuesday, 14 May, in Washington, DC, and celebrated during the AIAA Awards Gala on Wednesday, 15 May, at The John F. Kennedy Center for the Performing Arts, Washington, DC.

Honorary Fellow is AIAA's highest distinction, recognizing preeminent individuals who have made significant contributions to the aerospace industry and who embody the highest possible standards in aeronautics and astronautics. In 1933, Orville Wright became the first AIAA Honorary Fellow. Today, 242 people have been named AIAA Honorary Fellow.

2024 AIAA Honorary Fellows

Hitoshi Kuninaka
Institute of Space and Astronautical Science / Japan Aerospace Exploration Agency (JAXA)

John S. Langford III
Electra.aero

Azad M. Madni
University of Southern California

Christopher Scolese
National Reconnaissance Office

AIAA confers Fellow upon individuals in recognition of their notable and valuable contributions to the arts, sciences or technology of aeronautics and astronautics.
Nominees are AIAA Associate Fellows. Since the inception of this honor 2,064 persons have been elected as an AIAA Fellow.

2024 AIAA Fellows

Igor Adamovich
Ohio State University

Stephen Blanchette Jr.
The Aerospace Corporation

Ruxandra M. Botez
École de technologie supérieure (ÉTS)

Robert D. Cabana
NASA Headquarters (retired)

John R. Chawner
Pointwise (retired)

Charles J. Cross
U.S. Air Force Research Laboratory

Misty Davies
NASA Ames Research Center

Srinath Ekkad
North Carolina State University

Edward H. Gerding
The Boeing Company

John Mace Grunsfeld
Endless Frontier Associates LLC

Richard Hofer
NASA Jet Propulsion Laboratory, California Institute of Technology

Yiguang Ju
Princeton University

Joseph Majdalani
Auburn University

Richard Mange
Lockheed Martin Corporation

J.D. McFarlan III
Lockheed Martin Corporation

Mehran Mesbahi
University of Washington

Clayton Mowry
Voyager Space / International Astronautical Federation

Alison Nordt
Lockheed Martin Space

Daniella Raveh
Technion – IIT

Gregory W. Reich
U.S. Air Force Research Laboratory

Katherine Rink
MIT Lincoln Laboratory

Donna Cowell Senft
Air Force Global Strike Command

Jeffrey P. Slotnick
The Boeing Company

S. Alan Stern
Southwest Research Institute

John Tylko
Aurora Flight Sciences, A Boeing Company

Craig Wanke
The MITRE Corporation

Annalisa Weigel
Fairmont Consulting Group

Lesley A. Weitz
The MITRE Corporation

AIAA Announces 2024 Premier Award Winners

AIAA is pleased to announce the 2024 recipients of its most prestigious awards, recognizing the most influential and inspiring individuals in aerospace whose outstanding contributions merit the highest accolades.

Presentation of the 2024 AIAA premier awards and recognition of the Institute's Class of 2024 Honorary Fellows and Fellows will take place at the AIAA Awards Gala, 15 May, The John F. Kennedy Center for the Performing Arts*, Washington, DC.

The winners are:

AIAA Award for Aerospace Excellence
U.S. Air Force Combat Artificial Intelligence (AI) Technology Demonstration Team. "For demonstrating AI piloting the XQ-58A Valkyrie uncrewed jet aircraft, building on previous demonstrations with a crewed (F-16) VISTA X-62A, but taking it one step further to a full demonstration, and amplifying the importance of military government partnerships with industry and academia."

AIAA Public Service Award
Leland D. Melvin, Former NASA Astronaut, Leland Melvin LLC. "For tirelessly promoting STEAM and aerospace to young people of all demographics by word and personal example."

AIAA Reed Aeronautics Award
Mark S. Miller, Leidos, Dynetics Group. "In recognition of contributions to engineering advancement of grid fin aerodynamic control technology from seminal research through pervasive technology adoption into flight systems including reusable launch vehicles."

AIAA Distinguished Service Award
Paul D. Nielsen, Software Engineering Institute, Carnegie Mellon University. "For outstanding and distinguished leadership and service to AIAA and to the aerospace profession over the past four decades."

AIAA International Cooperation Award
Jean-Yves Le Gall, CNES (Centre National d'Etudes Spatiales), ESA Council (European Space Agency), Arianespace, IAF (International Astronautical Federation). "For extraordinary contributions and leadership, and for major collaborations with the international community in the development and operation of space missions for scientific and civil applications."

AIAA Engineer of the Year Award
Kurt Polzin, NASA Marshall Space Flight Center. "For inspired technical leadership as Chief Engineer of NASA's Space Nuclear Propulsion Project, positioning the nation to rapidly mature, demonstrate, and use nuclear propulsion systems."

AIAA Goddard Astronautics Award
W. Michael Hawes, Lockheed Martin Space (retired). "For a lifetime of contributions to the design, manufacturing, and operations of human space flight programs including the Space Shuttle, International Space Station, and Orion."

AIAA Lawrence Sperry Award
Michelle N. Banchy, NASA Langley Research Center. "For exceptional technical contributions in the field of aerodynamic design toward the development and application of natural laminar flow systems."

AIAA/ASME/SAE/VFS Daniel Guggenheim Medal
Michimasa Fujino, Honda Aircraft Company. "For technical innovation and leadership in conceiving, designing, and bringing HondaJet to a leading position in the business jet market."

For more information on the AIAA Honors and Awards Program, contact Patricia A. Carr at patriciac@aiaa.org.

**Note: This event is an external rental presented in coordination with the Kennedy Center Campus Rentals Office and is not produced by the Kennedy Center.*

Introducing the New Board of Trustees and Council of Directors Members

In January the Board of Trustees elected three new **Members–At-Large** who will begin their three-year terms in May.

- **Nancy Andersen**
- **Todd Mosher**
- **Cheryl O'Keefe**
- **Ben Linder** also was elected to fulfill an unexpired term.

Also in January, the **Council of Directors held the election for Speaker. Dan Jensen** was elected and will begin his three-year term in May.

Get to Know Our New Board and Council Members

Board of Trustees Members–At-Large

Nancy Andersen, Johns Hopkins University Applied Physics Laboratory

Andersen is currently an Assistant Program Manager supporting the Air Force Health and Human Performance program within the Global Health Mission Area at Johns Hopkins University Applied Physics Laboratory (APL). She earned a B.S. in Aerospace Engineering from the University of Cincinnati and an M.S. in Aerospace Engineering from the University of Maryland. At APL, Andersen has had the opportunity to support many sponsor domains with her expertise in systems engineering and project management, including efforts focused on military readiness and resilience, supply chain illumination and vulnerability analysis, video surveillance systems, systems architectures, nuclear detection, independent assessments, and independent research and development. Outside of APL, her career has included holding various technical and leadership positions at Lockheed Martin Space Systems Company supporting the Navy's Nuclear Weapons Security, Fleet Ballistic Missile D5 Life Extension, Reentry Systems Engineering, Defensive Missile Systems Multiple Kill Vehicle, and Wind Tunnel testing. Andersen is an AIAA Fellow and has been actively involved with AIAA for over 30 years.

Ben Linder, Boeing Commercial Airplanes

Linder is Vice President, 777 Chief Project Engineer (CPE) within Boeing Commercial Airplanes (BCA). He is responsible for overall product integrity and safety of 777 airplanes. He manages design requirements, authorizes design changes and airplane configurations, and assures design quality and regulatory compliance. Previously, Linder held leadership positions as 777/777X Director of Engineering, Director of Propulsion Systems Engineering, Director of Flight Sciences, 777 Fleet Support Chief Engineer, Chief Engineer of Aerodynamic Characteristics and Flight Performance, 777 Safety, Certification and Performance Senior Manager, and Everett (747/767/777) Airplane Safety Engineering manager. Linder joined Boeing as an Aerodynamics Engineer where he enjoyed assignments ranging from product development, sales support, flight test, certification, and fleet support. He received his Bachelor of Science in Aeronautical and Astronautical Engineering from Purdue University, his Master of Science in Aeronautics and Astronautics Engineering from the University of Washington, and his Master of Business Administration from Seattle University. He is involved with AIAA, American Society for Engineering Education (ASEE), and formerly with Snohomish County Science, Technology, Engineering and Math (STEM) Executive Board. Linder enjoys continuous learning in the areas of aviation, international business, and engineering. He resides with his family in the Puget Sound area of Washington and enjoys sports, fast cars, gastronomy, being outdoors, and travel.

Todd Mosher, Blue Origin

Mosher is a Director at Blue Origin, leading a team formulating tomorrow's space missions and systems. He has over 30 years of experience working in the aerospace industry and serving as a faculty member at three universities. He has directed the design of human spaceflight and robotic spacecraft projects providing technical authority and program management through the full product lifecycle. Mosher earned a Ph.D. and M.S. in aerospace engineering from the University of Colorado, an M.S. in systems engineering from the University of Alabama in Huntsville, and a B.S. in aerospace engineering from San Diego State University. An AIAA member since 1987, Mosher will serve his second consecutive term on the AIAA Board of Trustees. AIAA has given him opportunities for professional growth as a student, author, speaker, leader, advisor, and awardee with a diverse range of experiences working throughout the organization. In January, Mosher was chosen to be part of the 2024 class of Presidential Leadership Scholars; the program enables Scholars to learn about leadership through the lens of the presidential experiences of George W. Bush, William J. Clinton, George H.W. Bush, and Lyndon B. Johnson.

Cheryl O'Keefe, MIT Lincoln Laboratory

O'Keefe is a Technical Staff at MIT Lincoln Laboratory splitting her time between systems analysis and rapid prototyping for national defense since 2014. She earned her B.S. in Chemical Engineering from the University of Arizona in 2012, and her M.S. in Aerospace Engineering with an emphasis in Fluid Dynamics and Propulsion from the University of Colorado Boulder in 2014. O'Keefe is a former AIAA student liaison and young professional advisor to the Board of Trustees, as well as a member of the Young Professional Group.

Council of Directors Speaker

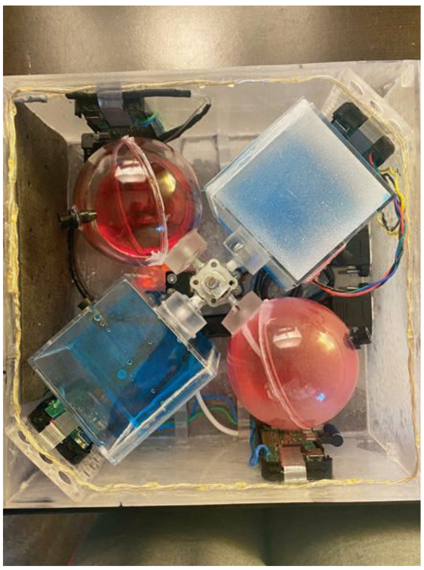
Dan Jensen, Rolls-Royce

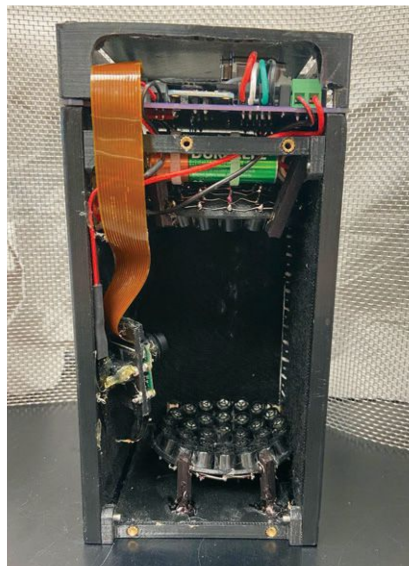
Jensen is currently a senior engineering manager at Rolls-Royce in Indianapolis and has held engineering leadership roles there since 1999. Prior to that, he held engineering roles at Rolls-Royce since 1995 after beginning his career at Boeing in 1989. During his career, he has worked in aerodynamics, fluid dynamics, heat transfer, propulsion installation analysis, engine control systems, project management, technology development, product definition and in-service support. He has been a member of AIAA for 38 years, beginning as a college student in 1985. Over the years, he has been active in a student branch, professional section, technical committees, and standing committees. Jensen has served as Chair of the Indiana Section, Chair of the Emerging Technologies Committee, Director of Region III, Chief of the Regional Engagement Activities Division, and a member of the Council of Directors. He has authored and presented a number of AIAA papers and is an AIAA journal co-author. He is an Associate Fellow and a life member. Jensen received a NASA "Turning Goals Into Reality" Award in 2005, AIAA Special Service Citations in 2006 and 2019, the Distinguished Alumni Award from the University of Illinois Aerospace Engineering Department in 2013, and the Jeffery W. Moss Outstanding Leadership Coach Award from the Illinois Leadership Center in 2016.

MAKING AN IMPACT

Design/Build/Launch Takes Flight

As part of the Design/Build/Launch (DBL) program, two AIAA-sponsored student experiments flew on the 19 December launch of Blue Origin's New Shepard rocket to see the effects microgravity would have on them.





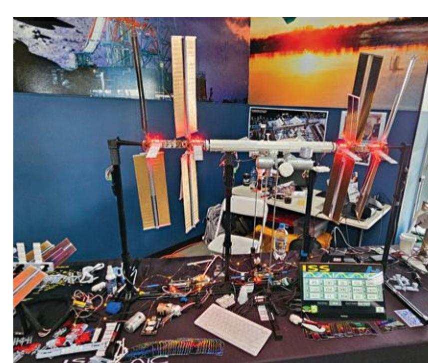
The 2020 winner, Eleanor Sigrest, is now a Junior attending Stanford University. Her payload "Stardust" tested a new technique to manage fluids and slosh in microgravity. Eleanor is reviewing the data and looking forward to presenting her findings at a future AIAA event.

The 2021 winning team, Puneeth Bheesetty, Anna Porter Puckett, and Jaden Shawyer (graduates of Granby High School, Norfolk, VA), tested their payload "Acoustic Levitation," in an attempt to demonstrate levitation of a metal ball in space.

The AIAA and Blue Origin partnership on DBL was created to incite innovation within the next generation of aerospace professionals and focused on experimental payloads designed to study short-duration microgravity effects. To learn more about the program, visit **aiaa.org/dbl** and sign up for updates.

AIAA Connects with Educators at SEEC

The 30th annual Space Exploration Educators Conference (SEEC) was held 8-10 February, at Space Center Houston. This one-of-a-kind conference brought together over 500 educators with a passion and interest in teaching space-related topics.



Each day of the event opened with a world-class keynote presentation. The speakers included Gamaliel Cherry and Mike Kincaid from NASA's Office of STEM Engagement, Mamta Patel Nagaraja from NASA's Office of the Chief Scientist, Michael Edmonds from Blue Origin and Club for the Future, and an inspiring panel of astronauts who are also educators, featuring Megan McArthur, Barbara Morgan, Dorothy Metcalf-Lindenburger, and Joe Acaba.

This year's SEEC also featured a delegation of educators from Central and South America, and sessions offered in both English and Spanish. In addition to presentations by and for educators, the conference also had a robust exhibit hall with organizations (including AIAA) offering resources, materials, and free benefit information to attendees.

For more details on SEEC, visit **spacecenter.org/education-programs/educator-resources/seec**.

Classroom Grants

The AIAA Foundation recently awarded a total of $40,000 in Classroom Grants to 80 educators. Each $500 grant directly supports STEM-related classroom projects or activities with an emphasis on aerospace. Recipients ranged from kindergarten to high school educators and represented 32 different states as well as three countries (USA, Columbia, Nigeria). AIAA Foundation Classroom Grants are made possible by a sponsorship from Boeing.

AIAA Grants Provisional Charter to Four New Student Branches

AIAA is excited to announce that four new universities were provisionally chartered as AIAA student branches during meetings held at AIAA SciTech Forum.

- George Mason University (Region I)
- University of Rhode Island (Region I)
- University of Hawai'i at Manoa (Region VI)
- Universidad de Antioquia in Columbia (Region VII)

The Student Branch Committee has adopted a "Provisional Charter and Decharter" format. Instead of full-on chartering universities as branches, each new student branch must go through a three-year review period to confirm the student branch is able to meet AIAA student branch requirements and is sustainable over time. After three years if the university continues to meet the branch requirements, the university will be formally chartered as a student branch.

Obituaries

AIAA Associate Fellow Pearson Died in June 2023

Steven D. Pearson, 64, died on 12 June 2023.

Pearson earned his bachelor's degree in electrical engineering from the University of Alabama in Huntsville in 1981, later finishing his master's degree in engineering management from Florida Institute of Technology in 1986.

Pearson's 37-year career with NASA began as an undergrad co-op in March 1979. He joined the agency full-time as an electrical engineer in 1981 and became the team lead for the Electromagnetic Compatibility and Lightning Safety Protection Team in 1991. Pearson was named branch chief for the Electromagnetics and Aerospace Environments Branch in 1993 and program manager of NASA's Space Environments and Effects program in 1995 – an effort that identified effects from the harsh environments of space, and development of ways to control or alleviate the problems.

In 1999, Pearson began serving as the manager of the Engineering Technology and Development Office and chief technologist in the Engineering Directorate. He was later named the deputy manager of the Avionics Department in the Engineering Directorate at NASA Marshall Space Flight Center (MSFC) in 2003. He also was appointed to the federal government's Senior Executive Service (SES). Pearson and his team members worked on research, design, development, testing, and verification of advanced flight and ground support avionics systems, which included all of the electrical and electronic hardware and software necessary for avionics architectures and their associated flight and ground support.

Beginning in 2004, Pearson served as Department Director of the Space Systems Department , which supported projects such as the Space Shuttle Program, the Fast and Affordable Science and Technology Satellite (FASTSAT-HSV01), and development of the Space Launch System (SLS) Launch Vehicle. Prior to his retirement from NASA in 2016, he served as the Deputy Director of the Safety & Mission Assurance Directorate at MSFC, assuring safety and mission assurance for the full range of center programs, projects, and institutional services. After his retirement he began Pearson Aerospace Solutions, where he supported the Marshall Integrated Programmatic Support Services (MIPSS) through the MTS/Emerald City Initiatives Team, which directly supported the Integrated Avionics & Software and Systems Engineering efforts in the SLS program.

Pearson was a member of the AIAA Atmospheric and Space Environments Technical Committee and the Management Integration and Outreach Committee.

AIAA Senior Member Pressel Died in October 2023

Philip "Phil" Pressel, noted for designing the cameras for the Hexagon spy satellites, passed away on 18 October 2023. He was 86 years old.

Pressel was born in Antwerp, Belgium, and his family sought refuge from the Holocaust during World War II. Pressel was separated from his parents in France and sheltered by a Catholic family. After the war, the Pressel family was reunited and immigrated to New York where Pressel attended Stuyvesant High School.

He earned his undergraduate degree from New York University and his MSME through the RCA Graduate Study Program at the University of Pennsylvania. His professional career in mechanical engineering was spent primarily at the Perkin-Elmer Corporation, where he contributed to top-secret programs, including the two decades spent designing the cameras for the score of Hexagon spy satellites and other space instruments. One of those classified programs involved designing a large missile-tracking telescope system known as "Lazy Cat" that was installed on a mountaintop in Iran and used to track Soviet missiles and rockets in flight. A low point was when the last Hexagon satellite, into which he had put many years of work, blew up on the launch pad.

Pressel joined the AIAA New England Section in January 1966, and transferred to the San Diego Section when he retired in 1999. In 2005, Pressel wrote a book of his experiences surviving the Holocaust, *They Are Still Alive* (Dorrance Publishing), and he received great fulfillment in addressing youth and school groups about the Holocaust. After the Hexagon program was declassified, he wrote another book called *Meeting the Challenge: The Hexagon KH-9 Reconnaissance Satellite* (AIAA, 2013). Pressel gave many presentations about the Hexagon Reconnaissance Satellite to AIAA groups and other organizations throughout the United States.

In 2015, he received the San Diego Section Award for Outstanding Enhancement of the Image of the Aerospace Profession. Even with setbacks, including a kidney transplant and mobility impairment, Pressel was an active section member and continued to attend section meetings and AIAA conferences.

AIAA Fellow Newberry Died in January 2024

Conrad F. Newberry died on 3 January 2024. He was 92 years old.

Newberry completed his undergraduate studies at the University of Southern California in 1957, receiving the BEME (Aeronautical Sequence) degree. His subsequent graduate studies at California State University, Los Angeles included both fluid dynamics and education, and he received his MSME degree in 1971 and his MAEd degree in 1974. He completed his doctoral studies at the University of California, Los Angeles in 1985. His research interests included experimental and theoretical assessment of waverider-configured platforms for both aeronautical and space flight missions, wingship design, exergy as a design variable, aircrew-centered system design, environmental security issues, and aircraft design.

For almost 20 years, Newberry worked for numerous aircraft companies, including Dixon Aircraft, North American Aviation, Atlantic Research, Celesco, Lockheed Aircraft Service, Northrop Aircraft, and Rockwell International. He also taught Aeronautical Engineering at California State Polytechnic University, Pomona, California for nearly 26 years (1964–1990). He then joined the faculty of the Department of Aeronautics and Astronautics at the Naval Postgraduate School (NPS) in 1990, where he taught naval aviators how to design military aircraft and guided missiles. His NPS students included military pilots who would eventually become aircraft program managers, as well as a number of students who eventually became NASA astronauts.

Newberry was the author of many AIAA technical papers, and he also co-authored the book, *The YC-14 STOL Prototype: Its Design, Development, and Flight Test* (AIAA, 1998), with John K. Wimpress. He was also a co-editor with Barnes McCormick and Eric Jumper of *Aerospace Engineering Education During the First Centry of Flight* (AIAA, 2004).

He received numerous awards and recognitions for his service throughout his professional career, including the 1986 AIAA J. Leland Atwood Award, a 1991 AIAA Special Service Citation, and the 2006 AIAA Distinguished Service Award, "for ceaseless efforts to enhance aerospace system design education, and for five decades of leadership in aerospace engineering technology, education, and career development." He was a Fellow of AIAA, the American Society for Engineering Education, the Institute for the Advancement of Engineering, and the British interplanetary Society.

Finally, Newberry was extremely active in AIAA and served on many AIAA committees and technical committees (TC), including the Career and Workforce Development Committee, the Atmospheric and Space Environments TC, the Aircraft Design TC, the Committee on Higher Education, the Student Activities Committee, the Technical Activities Committee, and the AIAA Board of Directors. He was a member of the editorial advisory board for the AIAA Education Series from 1998 to 2021.

AIAA Associate Fellow Gerard Died in January 2024

Mireille M. Gerard died on 6 January 2024. She was 84 years old.

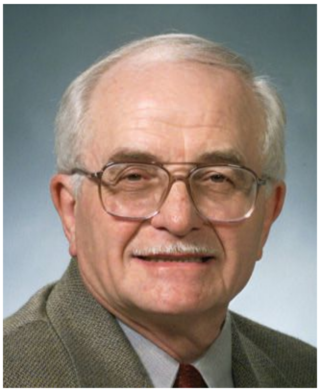
Gerard moved to the United States after graduate studies in business, economics, and law in Paris. She oversaw international and corporate relations for over 35 years.

Working with AIAA, she provided oversight to both AIAA Corporate Member interests and created the Corporate Member Committee. She oversaw the International Activities Committee (IAC), and she was the person responsible for strengthening AIAA's interaction with the rest of the world working through three primary multilateral partners: the International Astronautical Federal, the International Council on Aeronautical Sciences, and the Committee on Space Research.

Gerard pioneered the first World Space Congress (held in Washington, DC) in 1992, and its subsequent follow-up in 2002. The 1992 event was the first time that the international space science community was brought together with the international engineering community to discuss matters of importance that charted the future of the global engagement of space scientific and mission priorities.

At AIAA, Gerard also developed the Institute's engagement of and interaction with international governmental bodies such as the United Nations' Committee on the Peaceful Uses of Outer Space (UN COPUOS). She was the person who helped internationalize the operational elements of AIAA and broadened its appeal to non-U.S. professionals who engaged with the Institute.

In 2000, Gerard was recognized with the AIAA International Cooperation Award for "singularly distinctive contribution in developing and executing AIAA's international activities and advancing the spirit of cooperation throughout the world.



AIAA Associate Fellow Juhasz Died in January 2024

Albert J. Juhasz died on 11 January 2024. He was 87 years old.

Born in Hungary, Juhasz's family fled to Germany to escape communism at the end of World War II. The family emigrated to the United States in 1951. Juhasz earned a bachelor's degree in Mechanical Engineering from Case Western Reserve in 1960, and a master's degree from the University of Toledo in 1968. He began coursework on a Ph.D., but work and family obligations delayed his completion.

Juhasz started a distinguished career as an electrical engineer at NASA in 1963. His career as a Thermodynamicist and Space Power & Propulsion engineer spanned more than 60 years, and he was author or co-author of over 100 publications. Juhasz had a lifelong passion and natural aptitude for mathematics and engineering and developed specialized computer codes to study Brayton engines, lightweight radiators, and thrusters. In 2005, at the age of 68, he completed his doctoral dissertation and was awarded a Ph.D. in Mechanical Engineering from Cleveland State University.

Juhasz was recognized with a Space Act Award in 2004 and 2008. He served many years as a trustee for the Lewis Engineers and Scientists Association. A long-time member of the AIAA Northern Ohio Section, Juhasz was a very active volunteer. He served as a Technical Officer from 2011 until his death and was a STEM officer from 2010 to 2011. He also was a member of the AIAA Space Environmental Systems Program Committee (2011–2012). He presented a lecture for the section entitled, "Gas Turbine Energy Conversion Systems for Nuclear Power Plants based on Liquid Fluoride Thorium Reactor (LFTR) Technology." In 2001, he received an AIAA Special Service Citation.

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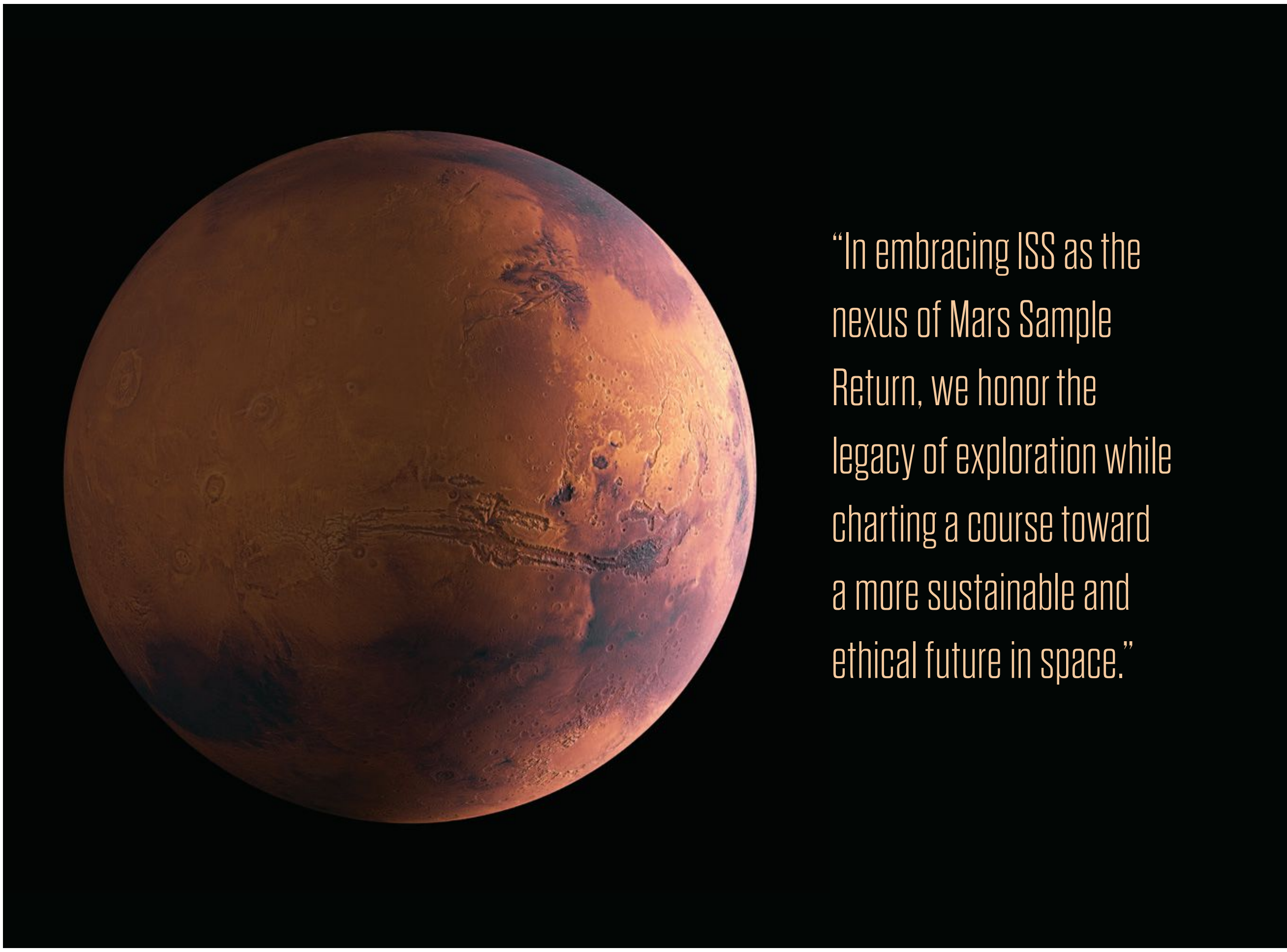


Another issue that I see no evidence has been properly considered is the very small, but still possible, event of a piece of space debris colliding with the Earth Return Orbiter that is to carry the MSR sample container, thereby compromising the integrity of the containment system. Perhaps such a collision would merely crack the canister, and a full break wouldn't occur until its parachute landing in the Utah desert.

A hypothetical collision is yet another unintended consequence of how we've been collectively polluting Earth's orbital space because of the way in which we perform our space exploration and utilization activities. A collision of space debris and the MSR spacecraft could significantly increase the probability of pathogen release. We must consider such black swan events; this is how risk should be quantified. The issue is that we don't have a way to realistically quantify the probability that MSR would collide with a piece of space debris, so we just assume it's negligible.

Bringing back samples to ISS would largely mitigate this risk. However, even if we assume that this is how MSR takes shape, history cautions us against succumbing to extreme optimism in the face of our technological awesomeness. We aren't strangers to the tragic consequences of hubris — from the Titanic disaster, to the space shuttle Challenger and Columbia tragedies, to the failed Mars Polar Lander and Mars Climate Orbiter missions, and to the catastrophic nuclear accidents at Three Mile Island, Chernobyl and Fukushima. These failures are stark reminders of the perils of complacency and the importance of humility in the pursuit of exploration.

By bringing Martian samples to ISS, we create a safer space of scientific inquiry, a sanctuary where researchers can conduct meticulous analysis without jeopardizing the integrity of Earth's biosphere. This approach would not only align with the highest standards of planetary protection but also foster international collaboration and transparency, as recommended by previous studies. As celestial stewards, it is our "kuleana" — Hawaiian for responsibility — to do so.

In embracing ISS as the nexus of Mars Sample Return, we honor the legacy of exploration while charting a course toward a more sustainable and ethical future in space. When we fail to remember our past, we're doomed to repeat it. Let us navigate the uncharted waters of space exploration with courage, humility and a steadfast commitment to the preservation of life, both on Earth and beyond. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1924

March 1 N1, the latest Italian semi-rigid airship, completes its first flight trial. Designed and built at the Italian State Airship Factory in Rome under the direction of Umberto Nobile, the 106-meter-long N1 can accommodate 20 passengers and carry 7 metric tons of cargo. Later renamed Norge, the N1 in 1926 becomes the first dirigible to fly to the North Pole. **The Aeroplane**, March 19, 1924, p. 248; **National Geographic**, August 1927; pp. 177-215.

March 4 The Aeromarine flying boat Morro Castle II makes the first flight of a commercial airplane between New York and Puerto Rico. The object of the flight is to demonstrate the construction quality of its new all-metal hull and to investigate commercial flying opportunities in the West Indies. The aircraft completes the 4,800-kilometer flight in 43 hours. **Aero Digest**, April 1924, p. 240.

March 4 Two Martin Bombers and two De Havilland DH-4s bomb a huge ice jam in the Platte River in North Bend, Nebraska, in hope of preventing flooding and the loss of property and lives downstream. The river is completely clear after the operation. **A Chronology of American Aerospace Events**, p. 25; **Aero Digest**, May 1924, p. 317.

1 **March 17** A team of U.S. Army Air Corps pilots depart Clover Field, California, for Seattle, the official starting point of their around-the-world flight in four Douglas World Cruisers. Once arriving in Seattle, the wheel undercarriages of the planes are exchanged for pontoons at the Boeing plant in preparation for the crew's departure in April. These pontoons are used all the way to Calcutta, India, and then swapped out for landing gear. Upon arrival in Hull, England, pontoons are again installed for the venture across the Atlantic by way of Iceland, Greenland, Labrador and Boston. **Aviation**, March 31, 1924, pp. 330-331; **The Aeroplane**, March 19, 1924, p. 240.

March 25 British Sq. Ldr. Archibald MacLaren, Flying Officer William Plenderleith and Sgt. W.H. Andrews leave Calshot Air Station, England, in their Vickers Vulture biplane, the G-EBHO, for an around-the-world flight expedition. Their attempt is aborted in August, when fog prompts them to land near the Bering Island. **The Aeroplane**, April 2, 1924, p. 284; **The Aeroplane**, March 26, 1924, p. 258.

March 25 Powered by two Rolls-Royce Eagle V-12 engines, the experimental Supermarine Swan flying boat completes its first flight. The day after this inaugural flight, the aircraft is delivered by air from Southampton to the British Royal Air Force at Felixstowe. The service orders six production aircraft, designated the Southamptons. **The Aeroplane**, April 9, 1924, p. 312; **Jane's All the World's Aircraft, 1925**, p. 89b.

1949

2 **March 2** U.S. Air Force Capt. James Gallagher and his crew of 13, aboard the Boeing B-50A, Lucky Lady II, complete the first nonstop around-the-world flight. The plane lands at Carswell Air Force Base, Texas, after having been aloft for 94 hours. Lucky Lady II was refueled in the air four times and flew a total of 37,742 kilometers at an average speed of 400 kph. **Aviation Week**, March 14, 1949, pp. 14-15; **The Aeroplane**, March 11, 1949, p. 249; **Aircraft Yearbook for 1949**, p. 330.

March 4 The Berlin Air Lift passes the million-ton mark of cargo flown into the city because of the Soviet blockade of all surface access. In the first eight months of operations, U.S. and British aircraft deliver a total of a little over a million tons, with U.S. aircraft ferrying 780,963 tons of the total, mostly coal and flour. **Aircraft Year Book for 1949**, p. 330; **Aviation Week**, March 14, 1949, p. 7.

March 4 Building on records set in February, the Martin JRM-2 Caroline Mars seaplane sets a new record for carrying passengers, flying from San Diego to Alameda Naval Air Station, California, with 263 passengers and a crew of six. **U.S. Naval Aviation, 1910-1970**, p. 168.

March 8 Capt. William Odom sets a nonstop world distance record for light planes, flying his Beechcraft Bonanza, Waikiki Beech, from Honolulu to Teterboro, New Jersey. He covers the 7,977.90 kilometers (4,957.24 miles) in 36 hours, 2 minutes. The aircraft was modified to carry wing-tip fuel tanks and an additional fuel tank in the cabin. The aircraft is currently on display at the Smithsonian National Air and Space Museum in Washington, D.C. **National Air and Space Museum**, "A Year of Anniversaries for Record-Setter Bill Odom and the Beechcraft 35 Bonanza." **Aviation Week**, March 14, 1949, p. 16; **Aircraft Yearbook for 1949**, p. 330.

March 9 Avro Aircraft chief test pilot J. H. Orrell completes the first flight of the Avro 696 Shackleton GR.1, a prototype of the Avro Shackleton maritime patrol aircraft. Derived from the Avro Lincoln and powered by four Rolls-Royce Griffon piston engines, the Shackleton becomes the Royal Air Force's principal anti-submarine-warfare patrol plane until its replacement in 1969 by the turbojet-propelled Hawker Siddeley Nimrod. **Interavia**, May 1949, p. 298; **The Aeroplane**, March 18, 1949, p. 290.

March 29 Joe De Bona sets a solo cross-country record for piston-engine aircraft during a flight from Burbank, California, to LaGuardia Airport in New York in a North American P-51 Mustang. De Bona completes the crossing in 4 hours, 59 minutes, 50 seconds. **Aircraft Yearbook for 1949**. p. 332.

1974

3 **March 1** The Sikorsky YCH-53E, prototype of the Super Stallion helicopter, makes its first flight, lifting off from the Stratford, Connecticut, plant of United Aircraft Corp.'s Sikorsky Aircraft Division. The three-engine helicopter has a 21-meter-diameter rotor blade assembly, a 23-meter-long fuselage and can carry 14,500 kilograms of external payload. **The Washington Post**, March 12, 1974, p. D7.

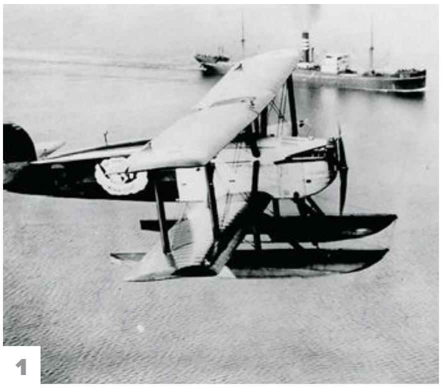
4 **March 4** NASA and the Soviet Academy of Sciences unveil the official emblem of the joint Apollo-Soyuz Test Project. **NASA Release** 74-49.

March 4 Soviet rocket pioneer Mikhail Tikhonravov dies in Moscow at 73. An aeronautical engineer by training, Tikhonravov's career in rocketry began in 1932 when he joined the Group for the Study of Reactive Motion, GIRD, and served as one of the four brigade leaders. His brigade built Russia's first liquid propellant rocket, the GIRD-09, which was launched in 1933. Among his achievements was his proposal of a multistage rocket that was the starting point for the R-7, the Soviet Union's first intercontinental ballistic missile, which was later converted into the launch vehicle for the first Sputnik satellite launched in 1957. **New York Times**, March 7, 1974, p. 40.

March 5 The Soviet Union launches its Meteor 16 satellite to collect information for weather forecasts. The meteorological satellite carries instruments to photograph clouds and snow cover on the day and night sides of the globe. **Spaceflight** (the British Interplanetary Society), Sept. 1974, p. 355.

March 5 NASA test pilot John Manke completes the first supersonic flight of the X-24B Lifting Body. Like other lifting bodies, the X-24B research vehicle was developed to test reentry technology for future aircraft that would cruise at hypersonic speeds. On this flight, the X-24-B is released from a B-52 carrier at 13,700 meters and reaches an altitude of 18,400 meters and speed of Mach 1.09. **NASA Release** 73-130.

March 8 The United Kingdom's Miranda experimental satellite is launched aboard a NASA Scout D booster. Also called X-4, Miranda was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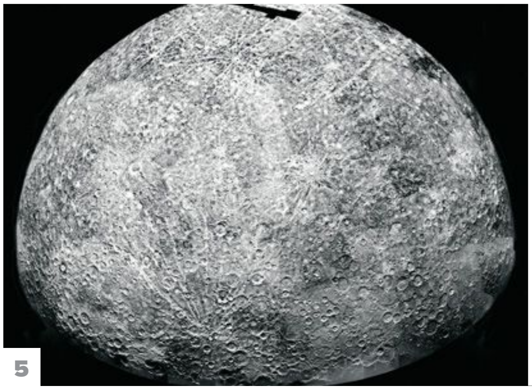
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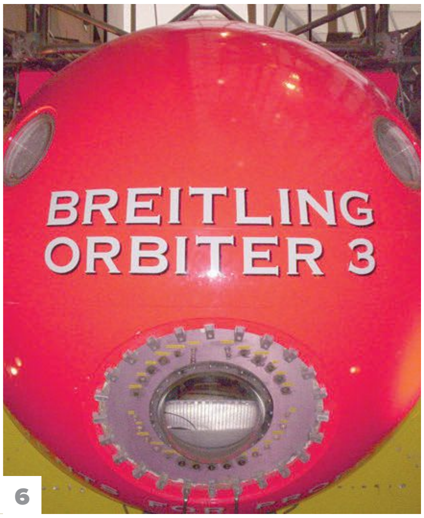

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designed to demonstrate attitude control with far greater accuracy than previous systems, as well as to test the on-orbit performance of newly developed infrared sensor components and measure the density of sun-reflecting particles near the spacecraft, among other objectives. All the objectives of the mission are met by March 19. **NASA Releases** 74-36 and 74-53.

March 8 The National Space Club holds its annual Goddard Memorial Dinner in Washington, D.C. Among the honorees are the NASA Ames/TRW System Group Pioneer 10 team, which receives the Nelson P. Jackson Aerospace Award for its "historic achievement in obtaining close-up photos and measurements" of Jupiter, according to the event program. Over the course of its 970 million-kilometer journey, Pioneer 10 became "the first spacecraft to fly beyond the orbit of Mars" and "the first to penetrate the asteroid belt." **NASA, Aeronautics and Astronautics 1974**, pp. 58-59.

March 9-12 The Soviet Union's Mars 6 and 7 probes, launched in August 1973, fly past Mars but fail to achieve their objectives. When Mars 7 approaches on March 9, its descent module separates from the spacecraft earlier than planned and misses Mars. In the case of Mars 6, its descent module separates as planned on March 12 and descends through the atmosphere. It transmits data for 224 seconds, but radio contact is lost just before landing. Subsequent media reports speculate that high winds on Mars might have destroyed the spacecraft. **Aviation Week**, March 25, 1974, p. 17.

March 15 French aviation pioneer Henri Piquet dies at Vichy, France, at 86. Piquet flew a free-floating balloon in 1905 and was licensed as France's 88th pilot in 1910, after teaching himself to fly. In 1911, he piloted the world's first official mail flight, between Allahabad and Nani in India. **Washington Post**, March 17, 1974, p. B7.

March 20 NASA's Pioneer 11 probe becomes the second spacecraft to pass through the asteroid belt. By this point, the spacecraft has completed 70% of its mission, traveling 700 million kilometers of its 1-billion-km journey toward Jupiter. **NASA, Aeronautics and Astronautics 1974**, p. 65.

5 **March 23-April 5** NASA's Mariner 10 completes a 12-day flyby of Mercury, becoming the first spacecraft to explore the planet. The probe returns some 1,700 TV photos and information on Mercury's atmosphere, surface, mass and shape. **Los Angeles Times**, March 20-April 1, 1974.

March 23 Leading U.S. atomic scientist Edward Condon dies at 72. In the 1950s, he developed a missile nosecone to withstand the high temperatures of reentry into Earth's atmosphere, later used by U.S. astronauts. He also conducted a U.S. Air Force study to investigate unidentified flying objects, UFOs. **NASA, Aeronautics and Astronautics 1974**, pp. 70-71.

1999

6 **March 1-21** The first nonstop around-the-world balloon flight is made by the Swiss-British team of Bertrand Piccard and Bryan Jones, piloting the Breitling Orbiter 3 gondola. They lift off from the Swiss village of Chateau d'Oex and land 19 days, 21 hours, 55 minutes later near the Dakhla Oasis in the Egyptian desert. During their 40,814-kilometer (25,361-mile) journey, Breitling Orbiter 3 ascends as high as 37,313 feet. Made of Kevlar and carbon fiber, the gondola is later donated to the Smithsonian's National Air and Space Museum. **National Air and Space Museum press release**.

March 18 The AIM-9X, the latest generation of Sidewinder infrared guided air-to-air missiles, is fired in a test from a U.S. Navy Boeing F/A-18C Hornet fighter over the China Lake Naval Air Weapons Station, California. The Sidewinder is one of the most successful and widely used missiles and traces its origins back to 1949. **Flight International,** March 31-April 6, 1999, p. 6.

March 27 The first test of the Sea Launch platform is conducted, placing a simulated payload into a geosynchronous orbit. This ocean-based launching platform, which utilizes Zenit first and second stages and a DM-SL third stage, is located some 2,200 kilometers southeast of Hawaii to take advantage of the Coriolis, or spinning, effect along the equator to gain greater momentum. **Aviation Week**, April 5, 1999, p. 65 and Sept. 27, 1999, p. 39; **Frank H. Winter,** Rockets into Space, p. 95.

Also during March The Colorado School of Mines' Center for Commercial Applications of Combustion signs a deal to fly a space furnace on the International Space Station, becoming the station's first commercial customer. The goal is to produce different types of glass and ceramics in zero-gravity conditions. **Flight International**, March 17-23, 1999, p. 30.

Why it's best to keep the Mars sample in space

BY MORIBA JAH | moriba@utexas.edu

NASA's highest priority in planetary science, the Mars Sample Return mission, has suffered budget cuts that could stifle its reality, but let's assume for a moment that MSR survives. In that case, we have a pressing issue to consider: the possibility of backward contamination — bringing back a Martian pathogen to Earth.

What to do about that possibility has spurred impassioned debate and rigorous scrutiny within the scientific community. Recognizing the gravity of this challenge — pun intended — I endorse a bold yet pragmatic solution: harnessing the capabilities of the International Space Station as the focal point for Mars sample containment and analysis before their return to Earth. (Another idea that has been previously floated is getting the samples to the moon instead, but the probability of contaminating the moon shut that idea down rather quickly.)

Of course, there is also debate about how long ISS will be in service. Thus far, NASA has committed to operating the station through 2030. In the current timeline for MSR, the samples would arrive on Earth in 2033. If both these schedules hold, the station idea would be moot unless there is another destination in low-Earth orbit for the samples to be kept. But let's assume that this is a nonissue for now.

The station idea, born out of a synthesis of scientific inquiry and ethical imperative, represents a paradigm shift in our approach to planetary protection. By leveraging the controlled environment of ISS, we can mitigate the inherent risks of backward contamination while advancing our understanding of Martian geology and astrobiology. Of course, that still leaves questions about whether astronauts and cosmonauts could still visit ISS once the samples are there and, if so, how those visitors would be protected against possible contamination and the like.

The answer to these and other concerns aren't straightforward and will require lots of thought, not for the things we can imagine might happen but more so for the black swan events or enigmas we can't really imagine occurring. And some contingency plan must be created, because while black swan events are of seemingly negligible probability of occurring, there are high consequences if they come to pass.

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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 and MacArthur fellow, he's also chief scientist of startup Privateer.