Q&A 12
Human-AI interactions

FROM THE EDITORS 9
Aerospace America turns 40

SPACE TELESCOPES 38
Ex-NASA chief Goldin on going bold

AEROSPACE AMERICA

40 YEARS

LIFE ON MARS?

NASA wants to bring samples home to find out. But is more on-site analysis a better option?

PAGE 28

First on the scene
Electric aircraft developers see a new market for their vehicles
PAGE 11

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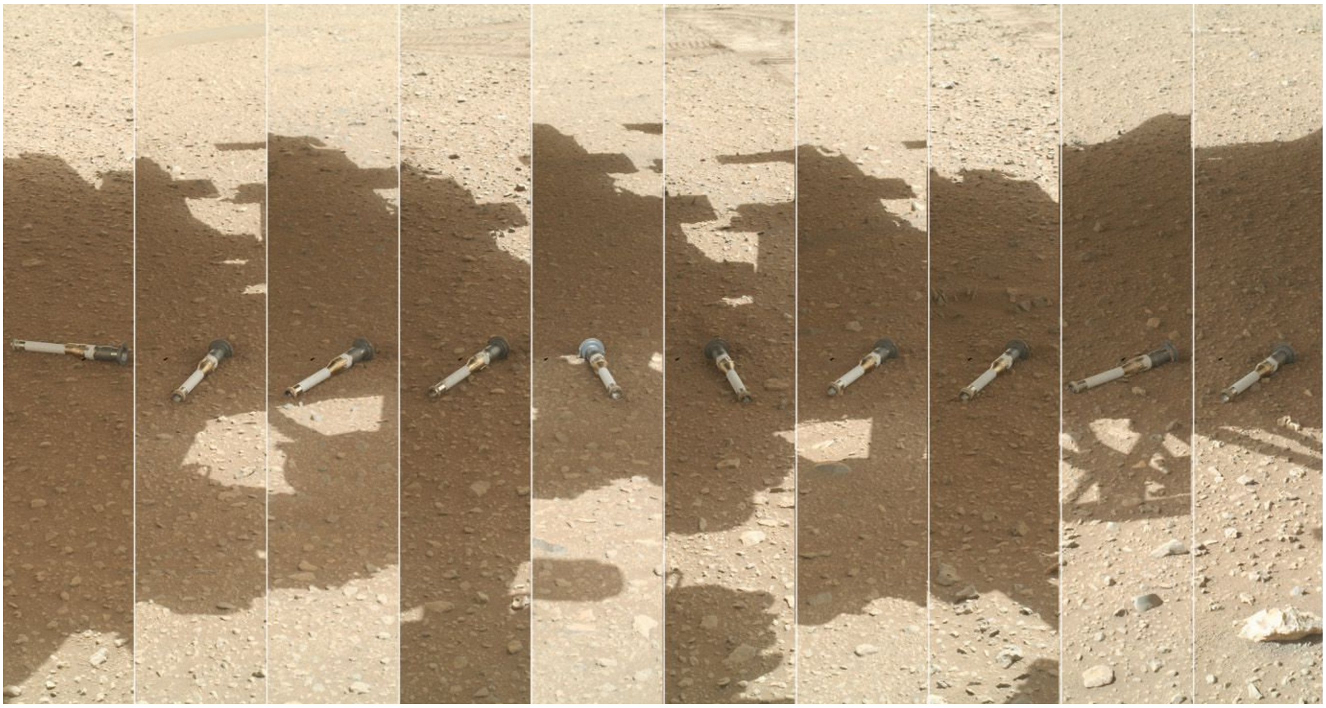

A year ago, the Perseverance rover on Mars dropped the last of 10 sample tubes at the Three Forks depot in Jezero Crater as a backup to the main stash of samples stored in its belly. Some of the pictured tubes contain dirt and rocks picked up along the rover's route, and some contain Martian air.

NASA/JPL-Caltech/MSSS

28

In situ versus sample return

An independent review board estimated that NASA's Mars Sample Return mission could cost $10 billion. We asked scientists whether bringing the samples back to Earth is worth the cost.

By Jon Kelvey

12

Decoding AI

Nisar Ahmed of the University of Colorado Boulder discusses how to measure trust in human-machine operations, as well as how to design AI to think like us and the questions that raises.

By Cat Hofacker

36

Test like you fly

The decision by Electra to place a pilot in the cockpit for the first flight of its hybrid-electric demonstrator was an unusual one in the world of advanced air mobility.

By Paul Brinkmann

ON THE COVER: The tubelike structures in this piece of Mars meteorite that fell to Earth resemble fossilized bacteria when viewed under an electron microscope. NASA/JSC/Stanford University

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SHAPING THE FUTURE OF AEROSPACE

IN THIS ISSUE

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

PAGE 18

Moriba Jah

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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 28

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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

Hope Hodge Seck

Hope is a freelance reporter and editor based in Washington, D.C., who has covered U.S. national defense since 2009. A former managing editor of Military.com, her work has appeared in The Washington Post, Popular Mechanics and Politico Magazine, among other publications.

PAGE 10

DEPARTMENTS

4 Editor's Notebook
5 For the Record
7 Flight Path
10 R&D
11 Aero in Action
18 Engineering Notebook
43 AIAA Bulletin
62 Looking Back

8 **AeroPuzzler** Could a super-sized bat fly?

9 **From the Editors** Marking 40 years of Aerospace America

38 **Opinion** The need for bigger, bolder telescopes

64 **Jahniverse** What's behind those space collision false alarms

AD INDEX

Aerojet Rocketdyne 35
Career Opportunities 60-61
Elysian Aircraft 5
Honda 6
Moog 27
RTX .... Back Cover
Space Foundation .... Inside Front Cover

Sparking your imagination to start 2024

▲ This star-forming region in the Carina Nebula was one of the first images NASA released from the James Webb Space Telescope. The telescope's Near Infrared Camera, or NIRCam, captured hundreds of stars previously hidden by cosmic dust.

NASA, ESA, CSA, STScI

The mark of a well-told story isn't just the information it provides; it's the thoughts it provokes. Several stories in this month's issue were especially strong in that regard.

My takeaway from our cover story on the planned Mars Sample Return mission was that, alas, artificial intelligence and machine learning won't solve all our problems. Physics, it seems, is physics, when it comes to fully analyzing samples of Martian soil and rocks for evidence of past or present life. Sometimes a large instrument or facility is the only thing that can answer a question, and those would be difficult if not impossible to set up on Mars. At least, that's where things stand now. I suspect there will be more to say on the topic of in situ research versus bringing samples home. The history of science is replete with feats that once seemed impossible. As the Ingenuity helicopter showed, there is no shortage of innovation among Mars scientists and technologists. Now, the question is whether and how that ingenuity can be marshaled to make Mars Sample Return affordable. Like you, we're anxious to see how NASA's review of alternative architectures turns out.

On the topic of astrophysics, who better to opine about the way ahead than former NASA Administrator Daniel S. Goldin? Nearly three decades ago, he pushed his agency and outside scientists to set a daring scientific agenda and design for the "Next Generation Space Telescope," now the James Webb Space Telescope. Goldin's commentary ("Bolder than Webb? 'You'll never know unless you go!'" page 38) made me wonder a few things: Is the success of Webb something that can be replicated in space-based astronomy? Or is Webb's groundbreaking science a result of mixing enough time, effort and dollars with a dose of good fortune that can never be guaranteed? After all, if Webb's hundreds of deployments had not gone perfectly, where would astronomers be now? It is not a happy thought. A decision about how far to reach, technology-wise, must always be nerve-wracking for the stewards of their nations' tax dollars.

Goldin's piece also made me wonder whether the multidecade timeline for development of the next Great Observatory is a reflection of the National Academies having learned a lesson from Webb. Perhaps it's better to underpromise on schedule and cost in hopes of surprising everyone by coming in on or below budget and ahead of schedule. It's unsettling to look at history and wonder if the anticipated timeline will nearly double in length, as was the case with Webb.

In aeronautics, we took a detailed look at the first flights of Electra's Goldfinch hybrid-electric demonstrator ("Pilot on board," page 36), and we dug into the idea of rushing medical personnel to the scene in single-person electric aircraft ("First on the scene," page 11). These stories made me wonder if this will be the year when any doubts are expunged about the market viability of these aircraft. The questions would then center around the degree to which they will revolutionize our lives and when.

On the topic of AI and machine learning, I'd commend you to our interview with Nisar Ahmed of the University of Colorado Boulder ("Analyzing AI," page 12). He discusses the promise and limits of the technology in refreshingly understandable terms devoid of hype. ★

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

▶ The Fluid Dynamics article on page 24 incorrectly listed the participants in a three-year study on flow field measurements of wing flaps. The U.S. Office of Naval Research led the study, with participation from the Air Force Research Laboratory, NASA, the Research Laboratory, Boeing and the University of Notre Dame.

▶ The Propellants and Combustion article on page 61 used an incorrect unit of measurement in the photo caption. It is millijoules, not megajoules.

LET US HEAR FROM YOU

Send letters of no more than 250 words to letters@aerospaceamerica.org. Your letter must refer to a specific article and include your name, address and phone number. (Your address and phone number won't be published.)


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Building on our Progress in 2024

As we enter 2024, we expect to see much excitement, growth, and innovation across the three AIAA Domains of Aeronautics, Aerospace Research and Development (R&D), and Space. The efforts in aeronautics building sustainable air travel, enabling autonomous air mobility, and furthering hypersonics are continuing the advances made since the early 20th century to take us farther, faster, safer, and cleaner. Our community is embracing leading-edge technologies in the next generation systems and missions, including digital engineering, artificial intelligence, autonomy, advanced manufacturing, and cybersecurity. Space is an essential part of everyday life on Earth as we keep building our off-world future by addressing space traffic coordination and creating the cislunar ecosystem. AIAA is enabling this type of future progress that will address generational-scale challenges by creating and fostering the all-important atmosphere inspiring innovation.

> All our efforts must be at the pace of innovation and the speed of the marketplace. **The ability to adapt quickly is crucial.** We understand the need for agility and responsiveness to emerging trends and technologies.

Expanding on our Accomplishments

We have witnessed our community's strength in the past year to prepare us for this next one. The list of remarkable accomplishments is long across the three Domains, as evidenced by the dozens of pages of year-in-review stories from AIAA Technical Committees and Integration Committees in the December issue of *Aerospace America*. Please read these excellent summaries that are a tribute to our community's incessant drive toward a purpose larger than ourselves, ultimately improving life on Earth and extending the human neighborhood to the moon and beyond.

These accomplishments are helping AIAA gain momentum advocating for the aerospace community across all of our stakeholders, including public policy, adjacent markets, and technologies. By providing technically informed input to key stakeholders, AIAA has been influential in Domain topic areas. We have been hosting focused events on Capitol Hill and around Washington, DC, to facilitate these technical exchanges. It was an honor to host NASA Administrator Bill Nelson and AIAA President-Elect Dan Hastings during our Aviation Reception in November. This type of policy advocacy will carry on in the coming year, with additional opportunities for AIAA professional and corporate members to be involved.

AIAA continues developing international connections and being visible on the global stage. Visits to Australia, Europe, and India during 2023 gave us the opportunity to deepen our relationships with aerospace professionals, as well as with AIAA members, local sections, and student branches. Sharing the AIAA vision, our Domain focus, and the ways to connect and participate in AIAA are delivering benefits. AIAA also has joined scores of companies and individuals as a signatory to "The Washington Compact on Norms of Behavior for Commercial Space Operations," an effort championed by The Hague Institute for Global Justice.

With the global challenges of rapidly evolving capabilities and competition, our community needs a workforce that is well-versed in science, technology, engineering, and mathematics (STEM). To realize this potential, AIAA continues to be a welcoming community, cultivating the needed diversity of thought by including everyone, especially those who have not typically been exposed to aerospace in the past. This is a vital element to a culture of inclusion.

All our efforts must be at the pace of innovation and the speed of the marketplace. The ability to adapt quickly is crucial. We understand the need for agility and responsiveness to emerging trends and technologies. AIAA facilitates an environment for our members to stay informed and connected to help meet the challenge of time to market.

Onward this Year

2024 should see new vehicles flying, innovative systems launched, and creative solutions implemented across the aerospace community. The Technical Committees, Integration Committees, local sections, student branches, and Domain task forces are essential to making these strides. AIAA remains steadfast in our commitment to a bright future helping our members and their organizations succeed. AIAA will be navigating the fast-paced global environment to help ensure a prosperous future for the aerospace community. We encourage you to leverage all the resources available to AIAA members to fuel your accomplishments throughout the coming year.

Together, we will tackle the challenges, seize the opportunities, and shape the future of aerospace. ★

Dan Dumbacher
CEO, AIAA

Email us at aeropuzzler@aerospaceamerica.org.

Could a giant bat fly?

Q: A bat happened to be hanging out in the rafters of a mad scientist's "scale-up machine" when the chamber was tested at level 100. Should the nearby town brace to be terrorized by a giant Nycticeius humeralis darting around in the evening sky? What do physics and aeronautics say about whether the creature could fly?

SEND A RESPONSE OF UP TO 250 WORDS that someone in any field could understand to aeropuzzler@aerospaceamerica.org by noon Eastern Jan. 16 for a chance to have it published in the next issue.

Scan to get a headstart on the February AeroPuzzler

FROM THE DECEMBER ISSUE

BLUE SKIES, BUT WHY?

We asked whether it's true that Earth's blue skies result from the same principle that exoplanet researchers rely on to study atmospheres. The question drew no responses, so astrophysicist John Mather of NASA provided an answer:

"Close but not quite true. Astronomers use the James Webb Space Telescope to study planets when they transit in front of their host stars for a few hours. Some of the starlight goes through the atmosphere of the planet, if it has one, on its way to the telescope, and we analyze that. Here on Earth, the sky is blue because of two things: First, our oxygen has destroyed almost all the molecules that give our outer planets their colors. That means that our atmosphere is very transparent at the wavelengths we can see. Second, in a phenomenon called Rayleigh scattering, molecules in our atmosphere deflect short wavelength light (blue) so that some bounces sideways and makes the sky blue. Short wavelengths scatter because high energy photons shake the electrons in the air molecules more vigorously, and those electrons deflect the light. But Rayleigh scattering can't tell us what specific molecules are in an exoplanet. With Webb, we spread out the exoplanet light into a spectrum, a rainbow of colors. Many molecules absorb light very strongly at particular colors, and when we see an exoplanet spectrum with those features, we can identify the molecules. So far Webb has seen Na, K, H_2O, CO, CO_2, and CH_4, but we didn't design it to find oxygen. For that we have to wait for a future observatory!"

40 YEARS

Aerospace America marks a milestone

The Cold War was raging and Ronald Reagan was U.S. president when Princeton University aerospace professor Jerry Grey put fingers to keyboard to inform AIAA members and others about a project he'd been leading behind the scenes: reconceiving AIAA's dense but informative membership magazine, Astronautics & Aeronautics, into Aerospace America, the magazine you have in your hands or on your screen.

"We plan to make our articles easier to read and even more analytical and more graphic than in the past," wrote Grey, our founding publisher, in our inaugural issue, published 40 years ago this month. He promised a "more useful" publication that would serve as a "leadership forum for the aerospace engineering profession."

Perhaps because of his engineering background, Grey knew that for the new magazine to flourish, he needed to lay down a strong foundation — or, in non-engineering terms, an independent soul.

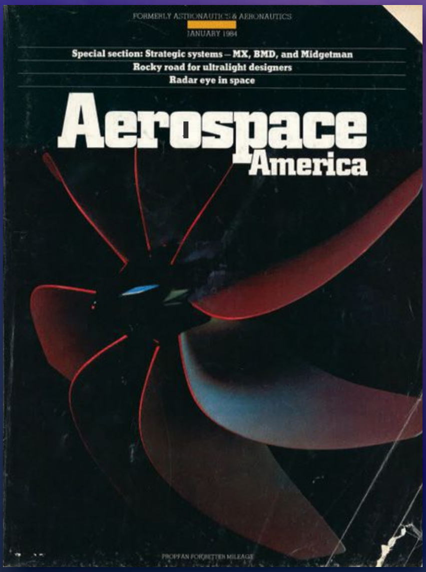
Our 40th anniversary provided us with a fresh opportunity to reflect on how we as a magazine and the topics we cover have evolved. So we pulled a dog-eared original of the January 1984 issue from a white envelope and turned it into a PDF.

Flipping — and clicking — through the issue, we noted how much of aerospace innovation in 1984 was driven by defense spending. Norm Augustine, then-AIAA president, provided an editorial noting the aerospace professional's role in "preserving the peace" through "qualitative superiority" of military technology.

Forty years on, the commercial world and private funds now drive much of the innovation. That's true for the space sector and increasingly in aeronautics with the development of electric air taxis. Aerospace America has covered that transition well, in no small part because Grey established that we should capture reality as it is and run op-eds expressing a rich variety of views about how it should be.

Our soul has been consistent over the decades. Elaine Camhi, editor-in-chief from 1991 to 2013, recalls that her goal was to make the magazine "interesting and informative without being tutorial." Reading it could not feel like "homework," she says. We have kept that philosophy over the last decade while adapting the design and look of the magazine to make use of today's digital production tools and platforms. Our page designs are notably more colorful and our graphics more ambitious and rich in context than any time in the magazine's history.

Substance-wise, while defense issues dominated the inaugural issue, a close look revealed the seeds of the topics that are dominant today. Strategies for returning astronauts to the moon were debated; questions were raised about the role of government versus commercial industry; ideas were broached for building more fuel-efficient jet engines. There was even one story about "autonomous" military "drones." Also on the military side, we noted a familiar refrain: "If the aerospace profession is in any danger of failing our nation today, it is certainly not because of a lack of technological prowess. Rather, it is more likely because of a

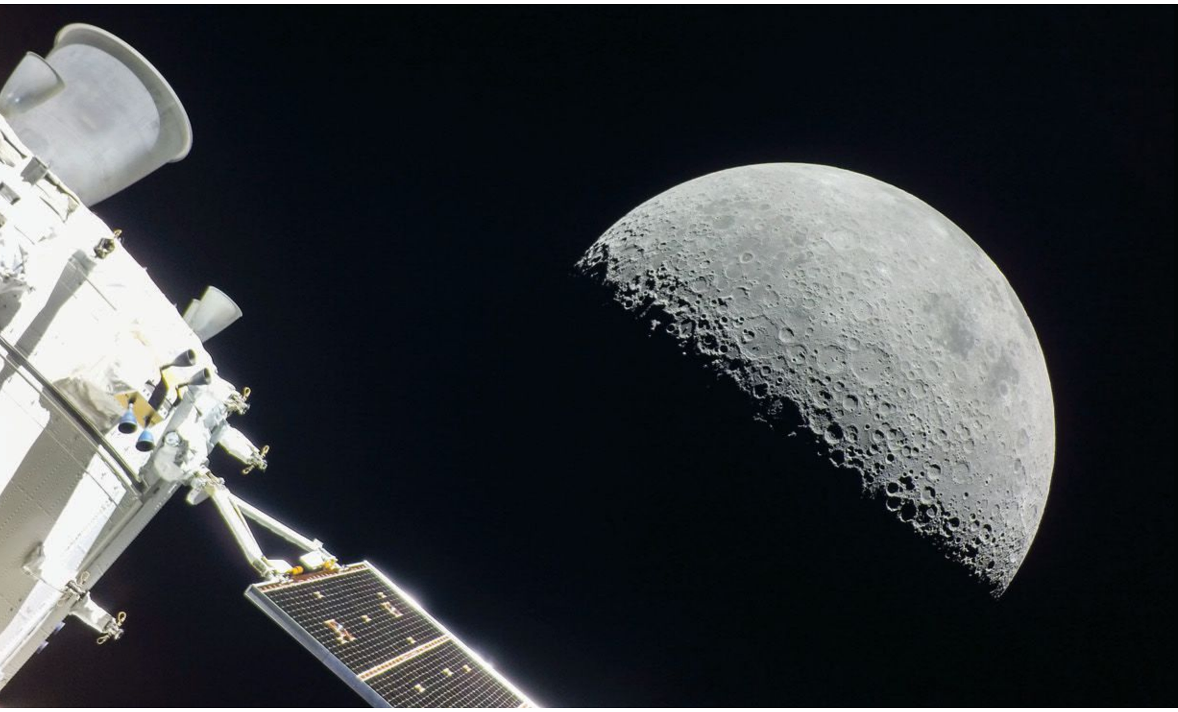


ponderous and often debilitating management process that oversees our military R&D activities," Augustine wrote.

Now, as then, we believe our role is to take you inside the debates among the scientists, engineers and government executives to show you how they are grappling with these and other topics. We won't shy away from the nitty-gritty technical details, but we will share them in a manner that's understandable and fun to read.

Above all, we won't fear change. As Grey noted in a New York Times profile of him in 1996, if humanity is going to survive and prosper, "we cannot stay still." This is true of Aerospace America too. ★

— Editor-in-Chief Ben Iannotta and Associate Editor Cat Hofacker



An unoccupied Orion spacecraft, visible in this photo taken by a camera on one of the service module's solar arrays, circles the moon in late 2022 during NASA's Artemis I mission. In the Artemis series, NASA plans to send a handful of crewed spacecraft and dozens of robotic ones to the lunar surface and cislunar orbit in the coming years.

NASA

Keeping watch in cislunar space

BY HOPE HODGE SECK | hopeanne@protonmail.com

Two years ago, a chunk of a leftover Chinese rocket crashed into the moon, leaving a fresh crater and highlighting an emergent challenge. Knowing that the yawning cislunar expanse from Earth orbit to the moon is about to get crowded, the U.S. Air Force Research Laboratory in New Mexico has a project underway to build a spacecraft to track satellites and debris in cislunar space to prevent collisions and help discern the intents of other nations. While the number of objects in that region is today limited, NASA predicts the next decade will see more human activity — and thus, more junk — in cislunar space than in the last 65 years combined.

Enter Oracle, formerly the Cislunar Highway Patrol System, a refrigerator-sized satellite in design by Advanced Space of Colorado under a $72 million contract with AFRL. A critical design review is planned for this year so that Oracle can be ready in time for its launch in 2027 to an orbit near the Earth-moon Lagrange Point 1, a position of gravitational and motion equilibrium "where an object will appear to be locked in place along the Earth-moon line," as Neil deGrasse Tyson has described it. By orbiting this position most of the way to the moon, Oracle will have a close-up view of objects that, from the vantage point of ground telescopes and Earth-orbiting satellites, are often obscured by solar glare.

Oracle's onboard photography and image processing equipment will need to overcome a hellish tracking problem. In cislunar space, the gravitational forces of both Earth and the moon — and to a lesser extent, the sun and Jupiter — affect the trajectories of small objects like satellites and rocket parts, making their movements difficult to predict. Oracle, which will be equipped with a combination of camera and telescope, must also have onboard detection and processing tools that can determine which distant and fast-moving specks are worth photographing.

By capturing enough images, scientists hope to determine the orbits, speed and distance for a wide range of objects. "There's going to be lots of hay in the haystack that we're looking for," AFRL's James Frith, principal investigator for Oracle, says.

The great distance back to Earth — 10 times farther than geostationary Earth orbit — creates a software development challenge. For transmission, each image must be compressed from tens or hundreds of gigabytes into a series of 10-kilobyte information packets in text format. While NASA missions have shown that detailed images can be sent to Earth from deep in the solar system, Oracle will be transmitting to commercial radio dishes rather than to NASA's array of Deep Space Network antennas. AFRL wants to receive images in minutes or hours, versus the more typical days or weeks, since timely knowledge could "prevent potential close approaches or conjunctions with functioning spacecraft," Frith says.

Advanced Space and subcontractors General Atomics and Leidos are working on the challenge of maintaining orbit near L1 while sensing and tracking moving bodies. For NASA's Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment, or CAPSTONE, program, which sent a 25-kilogram cubesat owned by Advanced Space into orbit around the moon in 2022, Advanced Space has been testing the accuracy of its tracking software and the calculations that estimate a spacecraft's state, or orbital shape and position, from images captured in cislunar space. ★

First on the scene

BY PAUL BRINKMANN | paulb@aiaa.org

In a medical emergency, there might be only eight minutes to deliver initial aid before a patient dies or incurs brain damage from lack of oxygen.

In rural locations, conventional helicopters are often the only way to reach victims within that precious window, but many areas lack access to them. Likewise, in urban settings, a conventional helicopter might not be available to whisk a medical worker over a traffic jam or have enough clearance to land and take off.

These issues have prompted many electric aircraft developers to view medical response as a potential market for their vehicles, which will have a smaller footprint than conventional helicopters. In such cases, a medical worker would be rushed to the scene with a defibrillator and other equipment to stabilize the patient until an ambulance arrives to take the person to the hospital, if necessary.

Among those companies is LIFT Aircraft of Texas, whose single-person Hexa multicopter is designed to travel 16.7 kilometers in 17 minutes, propelled by 18 rotors.

"This is 2023, and people are dying merely because we can't reach them fast enough. But we have the technology now," Kevin Rustagi, LIFT's chief commercial officer, told me in December.

Hexa is an ultralight, meaning that workers in the U.S. would not need a pilot license to operate one, just the training required under FAA's Public Aircraft Operations rule. LIFT indicates on its website that in addition to carrying medical workers, its aircraft could rush police, firefighters, rescue and disaster response workers to a scene.

Another company, Jump Aero of California, has designed a single-person electric aircraft specifically for medical response, with a goal of maximizing the distance that can be covered in eight minutes. That focus on rapid response "resulted in an aircraft highly differentiated from the rest of the emerging electric industry," says founder Carl Dietrich.

▲ Munich-based medical services provider ADAC Luftrettung has purchased two of Volocopter's VoloCity air taxis for quickly transporting emergency medical workers. Volocopter

The unique design of the planned single-seat JA1 Pulse, Dietrich says, is a "biplane standing tailsitter," meaning it stands upright on its tail when on the ground. Each of the JA1's eight rotors are designed to spin up in less than 60 seconds and propel the aircraft anywhere in a 50-kilometer radius in under eight minutes. So far, Jump has flown small, subscale demonstrators, but plans call for flying a larger one this year, with a 1.2-meter wingspan. The planned production model's wingspan would be 5.8 meters.

In contrast to the Hexa, each JA1 medical worker/pilot in the U.S. would have to be trained as a pilot under FAA's light sport category. For quick takeoffs, pilots will wear a harness that snaps into the cockpit seat, which will have the pilot in an upright, standing position for takeoff. After rising vertically, the JA1 will tilt on its side to transition to forward flight, meaning the pilot will be lying prone on the cockpit bench, staring at the ground through a large window. This process is reversed for landing, and Dietrich says the configuration "enables us to land on almost any unimproved surface."

Meanwhile, in Germany, air taxi developer Volocopter and ADAC Luftrettung, a Munich-based rescue company, plan to conduct research this year toward carrying doctors to emergency scenes aboard VoloCity multicopters that will be painted with the yellow ADAC branding. ADAC has agreed to purchase two of the two-seat VoloCity air taxis, with an option to buy another 150. The VoloCity, also with 18 rotors, has a cruise speed of 90 kilometers per hour and a top range of 65 kilometers. A pilot and a first responder could team up for medical missions.

Volocopter says on its website that urban areas are a focus for these planned research flights because dense traffic is among the factors that "contribute to delayed [emergency medical] response times." ★

University of Colorado Boulder

Analyzing AI

A conversation about artificial intelligence is like a finely woven sweater. Pull on a single thread — how machines could be taught to reason like humans, for example — and you quickly begin to unravel a series of interconnected threads: How do you make sure the AI is being trained with good information? How large of a role should humans play in monitoring the decisions AI makes? Aerospace engineering professor Nisar Ahmed has studied these and many more questions over the course of his career, which most recently has focused on the dynamics of human-AI collaboration. For the aerospace industry, the implications of more powerful AI range from machine-controlled fighter jets that could fly in formation with human-piloted craft to an AI-augmented spacecraft that assists astronauts traveling to deep space destinations, including Mars. I called Ahmed at his office at the University of Colorado Boulder to discuss these and other topics related to AI and machine learning. Here is our Zoom conversation, compressed and lightly edited. — *Cat Hofacker*

NISAR AHMED

POSITIONS: Since 2021, assistant professor of aerospace engineering sciences at the University of Colorado Boulder, which he joined in 2014 as an assistant professor. He oversees a group of graduate students conducting research at CU Boulder's Cooperative Human-Robot Intelligence Lab. Since 2018, CU Boulder director for the National Science Foundation's Center for Center for Autonomous Air Mobility and Sensing, a program for university researchers and their students to investigate, with industry partners, the challenges related to operating drones and remotely piloted aircraft, including the coming electric air taxis. 2012-2014, postdoctoral research associate at Cornell University's Autonomous Systems Laboratory studying how autonomous robots could learn to share information among one another.

NOTABLE: As principal investigator of a DARPA-funded university consortium, led development of algorithms that assess the "competency awareness" of machine learning software, meaning the ability of the software to know when it won't be able to complete a task and alert the humans in charge. Principal investigator of the Collaborative Analyst-Machine Perception project funded by the U.S. Space Force. CAMP aims to give satellite operators AI-driven surveillance visualization of the space environment to help them detect unusual or interesting events.

AGE: 39

RESIDES: Boulder, Colorado

EDUCATION: Bachelor of Science in engineering, Cooper Union for the Advancement of Science and Art in New York, 2006; Master of Science in mechanical engineering, Cornell University, 2010; Ph.D. in mechanical engineering, Cornell University; 2012.

Q: Aerospace has long relied on various forms of autonomous technology. What distinguishes those from artificial intelligence/machine learning?

A: AI is the broad field of using computation and algorithms for problem solving, and that really started kicking off in parallel with the blossoming of computer science as a field. It motivated a lot of people to ask how computers can think like people and what's the difference, and that's been very promising. ML only came onto the scene relatively recently, in the last few decades. It's arguably a subfield of AI that really looks at getting computers to automatically find functions that turn data X into data Y. It's almost like computational alchemy — "Turn this into this." And because it's been developed with these off-the-shelf tools and black box kinds of things like TensorFlow and PyTorch and other frameworks, anybody can use them without fully understanding exactly what's happening under the hood. In contrast, the autonomous systems that we've previously used in aerospace required a lot more specialized knowledge and required an understanding of the platforms and the systems and the domains you're operating in. The big difference is that whereas those systems are primarily built around the physics of the platform and what you had to do to keep things stable or to behave a certain way, with AI and machine learning, you can make higher-level decisions that before you had to have a person make for you: where to drive the car, where to drive the airplane, where to land on a planet, what to do in situation X. Now you can empower computers to do that for themselves and take people out of the equation to some degree. The other side of it is how they solve the problems. The other systems that we used to build for spacecraft — like Mariner 10, the Voyager probes — those are autonomous but extremely basic in what they could do. Now, we have all kinds of hardware and software and sensors and platforms, and you can hook them all up to computers and enable them to do more. That allows spacecraft and other vehicles to be deployed in more situations than we previously were able to do. But that comes with its own challenges and fundamental limitations of what AI and ML can do.

Q: An example I frequently encounter is automated transcriptions, which sometimes make the silliest errors. What explains the discrepancy of why AI is so good at some tasks but so bad at others?

A: It's just like any other engineered system, where if it's designed well — with a scope and a purpose in mind — then it should be really good at what it's designed to do. The problem comes when we're trying to solve more ill-posed or open-ended problems where suddenly context and meaning and other kinds of variables that are not necessarily easily captured become important. If we're talking about things like automatic transcription, what helps these systems improve over time is having more data and retraining them and getting access to more and more context so they learn from their mistakes. That doesn't always translate to every single kind of problem. Self-driving cars are a great example: Even though they've driven millions of miles, suddenly they can run into one situation that's nowhere in their training data set, and they don't know what to do because they don't recognize this object or that object or this situation. When we talk about autonomy, we mean the ability to make your own decisions, usually under uncertainty or without complete information, and being able to intelligently respond to the circumstances and situations around you. The problem is that these meanings are very fuzzy and flexible to us as people, and we know what we mean when we say that, but when you tell the computer, you have to tell it exactly what to do in those situations. At the end of the day, you need to pair the technology with the right kind of risk assessment and an understanding of what it needs to be able to do versus what it can actually do. So using something to write a document: If it makes mistakes, you can live with those mistakes. But if it's making a mistake on the road or in the air or in space, the consequences are very, very different.

> "I always go back to the idea that intelligence is not just being able to solve problems. It's also being able to ask the right questions, and then taking logical steps to find more information and detail about what the question really means."

Q: That reminds me of the MIT researcher Josh Tenenbaum, who's studying how humans are able to make such big inferences from such little information. It makes me wonder if AI can ever be taught to fully think and reason like a human.

A: It's a fascinating question. People are really good at filling in the details or coming up with some kind of a model of what's happening and forming beliefs around what they think they want to have happen. Another secret ingredient to human cognition is this desire element, which machines don't inherently have. They're programmed to do what we want them to do, so they don't necessarily have this desire to go out and find the answers to all these questions, because they're just built to answer certain questions. That goes back to why they're so good at some things but not others: They're very narrowly designed to solve very specific problems in very deep ways, but then they are not able to generalize that very easily the way humans can, because we are much more adept at finding those kinds of connections and associations without necessarily having to be very precise about it. It's an odd mix. I always go back to the idea that intelligence is not just being able to solve problems. It's also being able to ask the right questions and then taking logical steps to find more information and detail about what the question really means. And then you find the answer eventually, but you learn more by asking than you do by just having an answer that you always throw at the same problem all the time, which is essentially what machines are doing.

Q: For the aerospace industry, what are the areas where you think AI and ML will make the biggest difference?

A: The Holy Grail for robotics is to have something that's as capable as a human in terms of adaptability and intelligence but even better, and having more

California air taxi developer Wisk plans to ferry passengers in a fleet of largely autonomous air taxis that would be remotely monitored by company supervisors who could intervene if necessary. The company has flown a series of prototypes to prepare for such operations.

Wisk

computation, hardware power, horsepower. In the near term, we see things like air taxis and the next generation of unmanned aerial systems. How do regulators understand if these systems are safe to use and if they should be used and deployed in a way, as well as how do they work with the actual people operating inside these systems? In truth, there can never really be an entirely solo AI system because no one would care, right? Maybe we can automate things that are really monotonous, dull work that doesn't require anybody to be there. But very often, those kinds of problems already have pretty good guardrails and standards set up, so we don't need people to do them. But if you're talking about space exploration, landing on another planet or exploring the moon, doing search and rescue with drones to look for other people, you'll likely always need humans. There is a lot of information, and every problem is going to be a little bit different; oftentimes, people will immediately understand what's going on, but then they have to figure out a way to tell this machine what to do with it. And the machine system has to be able to go back to the person and say, "Where can you help me, and what am I missing?" So in the end, it needs to be human-centered, and the trick that we think we have at our disposal is that we have to design these algorithms to be exposed to some extent to the users in order to really work at that level. For example, very often the people who design things like autopilots aren't necessarily pilots; they don't necessarily know how to fly airplanes, but they understand control theory, and they understand physics, flight mechanics. In the same way for autonomy, the people who design robots to go out and look for people out in the wild are not computer scientists or roboticist. What do they know about what a real search mission involves? So to some degree, allowing the user to help reprogram or to keep up the programming or to maintain the

▲ Nisar Ahmed and graduate student researchers at the University of Colorado Boulder are devising a way for humans and artificial intelligence to work together during search and rescue missions to locate missing people. In one aspect of such a collaboration, the AI would continuously refine its commands to small drones, shown here, based on new information provided by human rescuers.

Cooperative Human-Robot Intelligence Lab

system is part of the challenge. How do you make it possible for these algorithms to still work the way they're supposed to work and still do things the right way, without sacrificing the ability of people to inform them in whatever situation that they're in?

Q: Human spaceflight seems like an interesting case, because not only will a high degree of AI and autonomy be required for things like missions to Mars, but the humans would be uniquely reliant on the AI.

A: Trust is an interesting concept. As designers and as engineers, there are things we can do to engender that trust in human-AI interactions or make sure that the right levels of trust are there. At the end of the day, it comes down to whether we understand what people expect of these systems in the first place. What is the person's job versus what is the machine's job? Sometimes they have to work together because there's no other way to do it; other times it will be a choice of whether they get to work together, and then that's where things get a little bit more fuzzy and difficult. Self-driving cars as an example — should you take the wheel or not? Imagine your car is driving itself down the middle of the highway, and the human driver suddenly gets control of the wheel and isn't ready for it. There's a term I heard recently called locus of control, and in cognitive science, just like when you're driving your car, you have a mental model of the motion you're going to get if you turn the wheel or hit the brake or do something. If you abstract away too much of that and you detach people from the problem, that can be a lot harder to grab onto. And then people start reverting to different patterns of behavior to try and maintain whatever locus of control they have, or they start misusing or abusing autonomy because it doesn't quite line up with their mental model of how they want things to go. So sometimes it comes down to whether or not it's convenient to use it. For things like sending people to Mars or exploring the moon with robots, we have to make it possible for the people working in those environments to adapt those systems the way they need, because we're not going to have ground support for long periods of time; you're not gonna be able to send it back to the shop. Sometimes that dictates simplicity in the design of the system. But it's hard to guarantee trust, because it's a personal choice at the end of the day. Training people to understand what the systems can and can't do and what they can and cannot do with the system will be the key aspect there. But allowing that fluidity, and allowing that flexibility so that people still feel like they have the control, is going to be one of the harder things.

Q: And depending on the application, the users might not have training. As a member of the flying public, I wouldn't get the opportunity to learn about the AI controlling my airliner, if we ever have self-flying aircraft.

A: I was a part of a panel at a robotics conference a few years ago where this exact same question came up: What if you don't know who's flying the plane? The cabin doors are locked, so it could be a robot for all you know. It's not an irrational fear. You trust the human pilot because you know that you both have a fear of death. If the aircraft is about to collide with something, you can trust that they're going to take steps to avoid that, so even though you're not in control, you at least understand what's going on or you can have some capability or feeling that puts your fears at rest. Whereas if you're dealing with a black box system that doesn't communicate with you and is thinking about the problem in a totally different way that humans can't necessarily comprehend, then that becomes a different prospect. And even with astronauts or people who are highly trained and skilled in certain areas, there can still be a range of reactions. We have a research project with the U.S. Space Force that's looking at automated target tracking and classification for satellite-based surveillance systems. AI is really good at chopping on really large amounts of data and analyzing all this information and trying to sort it and prioritize it for people to look at so that it helps them do their jobs a little faster and tags interesting events. But the challenge is that people have their workflow, and they're trained a certain way. So if the system is presenting information, even with the wrong color or the wrong shape and size fonts, those are things that to us as engineers seem completely trivial, but to somebody who's in the situation, they depend on those visual cues to order their tasks. Like, saying there's a 20% chance it'll be cloudy versus an 80% chance that it'll be sunny means different things

"At the end of the day, you need to pair the technology with the right kind of risk assessment and an understanding of what it needs to be able to do versus what it can actually do."

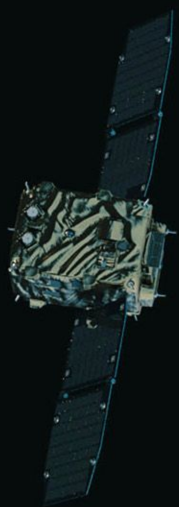
to us even though they're the same. Those are the kinds of things that are hard to teach your computer, and it's doesn't necessarily show up in the data all the time.

Q: Can you elaborate on the friction or areas of tension you've seen in human-AI interactions?

A: Good teams, even human teams, don't work without friction. They work through friction. You actually need that conflict to slow down and reflect and think about what the other agent or person or machine is trying to tell you, instead of just blindly accepting it or ignoring it. At CU Boulder, we did a study for a search-and-rescue scenario where we had people help reprogram the algorithms on the fly by providing new information as it came in. They could draw in features on a map that were not there before and assign semantics to that, and then the AI could actually come back and ask questions. While it was clear that the AI and the human had more or less the same picture of the world, the actions that resulted from that were not necessarily agreeable to all the humans who were interacting with the system. They would actually try to hack the perception, almost tell lies to the machine to get it to behave the way they wanted it to behave given the information that they thought they just provided, instead of just trusting that the machine knew exactly what it was doing and solving this really complicated optimization problem. That showed us that people expect a certain kind of interaction or a certain kind of behavior based on information that they give. In aerospace, computers are often designed to make decisions by the OODA Loop method — observe, orient, decide and act — but that's not how people make decisions. But that's how computers are built to make decisions. People don't just want to give information; they also want to suggest actions. And they don't want to just address actions; they want to give you information. Designing something that can accommodate both those approaches can be a little challenging.

Q: I can also imagine that in many cases, humans chafe at the idea that they are equal participants with the AI, instead of clearly being in charge.

A: I've heard stories that some fighter pilots don't like the idea of having the plane flown for them because they don't know that it's going to get done the way that they think it should be done, even if it's done in an objectively better way. But I think it depends on the person, and it depends on the context. For some people in high-risk, high-tempo situations, they don't want to depend on something that they don't completely understand in the heat of the action. And in some cases, you can't stop and ask questions. In other situations, you have that ability to deliberate and to question and to go back and forth. But knowing when that is tricky, and very often it's up to a person to decide. But if the person doesn't know what the system is capable of doing, then they won't know when the right time is to do that. So it's a bit of a chicken and an egg problem. That's why getting people into the design process sooner rather than at the end is important. It's unfortunate that for aircraft design, very often the pilot is the last person or the controls of the last thing you think about, whereas maybe you should design for handling and controllability before everything else. The same would be true for the algorithms: Maybe we have to have a more holistic picture of how these things work, how people and these machines work together first, and be OK with not knowing exactly how that might turn out later, but give them enough guardrails and affordances to adapt in the moment. ★



SPACE JANITOR

Astroscale is poised to embark on the next step in proving its business plan of grappling and removing orbital debris: sending a spacecraft to inspect an uncontrolled rocket stage in preparation for a future capture mission. Navigating up to and around such an object requires an intricate choreography of sensors, cameras and navigation algorithms. Keith Button tells the story.

BY KEITH BUTTON | buttonkeith@gmail.com

The spent rocket stage above is approached by the ADRAS-J spacecraft, facing page at top left, in this illustration of Astroscale's upcoming mission to demonstrate the navigation and inspection technology required for a future capture attempt.

Astroscale

▲ In a prior space demonstration, Astroscale showed that a "servicer" satellite could approach and dock with a mock "client" via a magnetic plate. The company unveiled the second generation of that plate, shown here, in July. Astroscale

Catching a piece of space junk without crashing into it is tricky. You need a spacecraft that can navigate to the debris from thousands of kilometers away, then autonomously view it and sidle up to it as you both orbit at about 7.5 kilometers per second, though the junk is likely tumbling and at an unknown rate. This spacecraft needs to perform "a very careful and precise dance to get really close," says Mike Lindsay, chief technology officer for Astroscale, a Tokyo-based, venture capital-backed company planning what would be the first commercial mission to closely approach a piece of space debris.

Astroscale engineers plan to demonstrate such a dance at a date to be decided early this year, with the launch of a camera and autonomous navigation equipped spacecraft from New Zealand by Rocket Lab, which specializes in launching small satellites, like the refrigerator-sized ADRAS-J, short for Active Debris Removal by Astroscale-Japan. If they are successful, the stage will be set for a planned follow-on mission to grab and remove a piece of junk from orbit — the same 11-meter-long spent H-IIA upper stage that ADRAS-J is aiming for. This rocket stage, from a 2009 launch for JAXA, the Japan Aerospace Exploration Agency, is one of the largest of about 60 still in orbit from past JAXA missions.

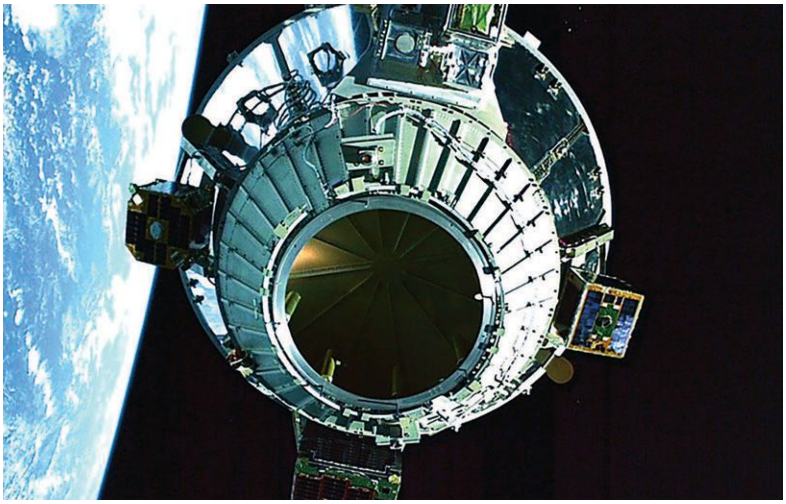
A reliable method for space debris removal — capturing an object and pushing it downward to fall back into the atmosphere and burn up — would reduce the risk of collision for the rapidly growing ranks of active satellites, which the European Space Agency now places at about 9,000 strong. Fewer collision risks would also save satellite operators time and the need to burn valuable fuel to steer their craft to avoid potential collisions. About 35,000 pieces of space debris — all larger than 10 centimeters — are tracked by networks of ground-based radar and telescopes, with an estimated 1 million pieces in the 1-cm to 10-cm range, and 130 million pieces at 1 millimeter to 1 cm.

ADRAS-J must avoid colliding with the JAXA stage and contributing more pieces of debris to the total. How bad could a mistake be? Jonathan McDowell of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, predicts that any debris created by a collision between a spacecraft and another object with a closely matched orbital path and velocity would be relatively minor when compared to something like the 2009 collision of an Iridium satellite and a deactivated Russian satellite. That incident created 2,000-plus pieces of trackable debris. That's largely because of the estimated speed of such a hypothetical collision. For instance, if a stuck thruster were to accelerate a spacecraft for several minutes before it crashed into an object with which it was trying to rendezvous — and trying to match orbits and velocities — the relative difference in velocity might reach 160 kilometers per hour, compared to the 42,000 kph relative difference in velocity for the Iridium and Cosmos satellites in the 2009 collision.

"As we do our approach, safety is the No. 1 priority," says Astroscale's Lindsay, who is based in Tokyo. To avoid colliding with the JAXA rocket stage, ADRAS-J must remain in a "passively safe orbit" that won't cross the orbit of the stage if Astroscale loses control of or communication with the satellite and can no longer control the trajectory. The engineers performed thousands of computer simulations of every trajectory or perturbation they could think of for every phase of the mission "to make sure that if the maneuver doesn't go exactly as planned or there's an anomaly, the maneuver puts us on to a trajectory that's not going to be an issue," Lindsay says.

While opinions vary about the viability of debris removal as a commercial service, there's broad consensus that even small pieces are potentially lethal to satellites. These fragments are what you think about "if you're an astronaut on the [International] Space Station and you're worrying about what might go through me like a bullet in the next 10 minutes," McDowell says. Removing the largest pieces from orbit would do the most good, since that would reduce the odds of collisions with other large objects that could break into hundreds of thousands of fragments. Such removal would also help avoid the feared Kessler Syndrome, a predicted cascading series of collisions now in its infancy that over the coming decades could create such a cloud of fragments that certain orbit

▶ The target of the ADRAS-J mission will be this spent H-IIA upper stage, part of the rocket that was launched in 2009 to send an Earth-observing satellite to orbit for JAXA, the Japan Aerospace Exploration Agency. This photo was taken by the satellite as it separated from the upper stage. JAXA



altitudes would be uninhabitable for satellites.

"If what you're worried about is some long-term chain reaction, then you want to go for a few big objects rather than a lot of small objects," McDowell says.

He continues: "As you study the history of space exploration and the population of orbital objects, you can't avoid becoming concerned about the increasing number of near misses and the potential for collisions and for bad consequences from space debris. Now it's time to actually start getting rid of the debris, and in particular, the bigger chunks of debris."

For the JAXA-funded ADRAS-J mission, Astroscale plans to build on the results of its 2021-2022 mission, ELSA-d, short for End-of-Life Services by Astroscale -demonstration. For ELSA-d, Astroscale demonstrated that a "servicer" spacecraft could repeatedly approach and dock with an uncontrolled mock "client" satellite via a magnetic docking plate installed on the client prior to launch. The spacecraft were launched in the same stack and separated once in orbit. In the final portion of the mission, the servicer separated from the client by 1,700 kilometers and navigated to within 159 meters of it, despite the failure of four of its eight thrusters. Since this demonstration, one broadband constellation operator has committed to installing Astroscale's docking plates on its satellites.

With ADRAS-J, Astroscale wants to show that the sensors and algorithms updated from ELSA-d can track an object from a longer distance. The plan is to maneuver the spacecraft around the spent JAXA stage so ADRAS-J can scan the stage from all angles from a few dozen meters away with visual and infrared cameras, lidar and laser range finders. Those scans are intended to show engineers what axis the stage is spinning around, how fast it is spinning and the condition of its surfaces — all important details for planning how robot arms might catch the debris on the subsequent mission.

"We would want to, in the inspection mission, make sure that the part that we want to grab on to is going to be unobstructed; not damaged; it's not going to fall off once we grab it," Lindsay says. Astroscale is designing a spacecraft for the follow-on debris capture mission, and JAXA has selected the company for a technology study for that mission, but the space agency has not yet awarded Astroscale a contract to conduct this demonstration.

> "If what you're worried about is some long-term chain reaction, then you want to go for a few big objects rather than a lot of small objects."
>
> **— Jonathan McDowell, Harvard-Smithsonian Center for Astrophysics**

For ADRAS-J, Astroscale's engineers have a good idea of the rocket stage's orbit, based on periodic updates of its position from the U.S. Space Surveillance Network via the space-track.org website. The network tracks active satellites and the thousands of pieces of debris larger than 10 cm with radar and telescopes. While the tumble rate of an orbiting object can be determined from the alternating brightness of the object as viewed from the ground, the task for most of the telescopes that are aimed at space debris is merely to track the orbits of these objects — so they know it's tumbling, but not how fast. But because of natural forces causing drift in the orbit, the predicted pathway of the JAXA stage isn't as accurate as it would be if it had GPS, as most satellites launched today have, so Lindsay says the estimated position could be off by several kilometers. The engineers coordinated with Rocket Lab to plan to launch ADRAS-J on a trajectory to position it in an orbit close to that of the spent stage, about 600 km above Earth.

After launching, plans call for firing the thrusters positioned on each corner of the rectangular spacecraft to shift its orbit closer and closer to that of the target. Astroscale will know the ADRAS-J orbit from its onboard GPS receiver and the rocket stage's estimated orbit based on the position updates from the Space Surveillance Network. From "several tens of kilometers" away, ADRAS-J with its cameras will see reflected light from the stage, and at about 2 kilometers away, the stage will look like a bright dot. At that point, ADRAS-J will switch its navigation technique, basing its navigation on its position relative to the stage instead of GPS position. Then, it will close the distance until it is a few dozen meters away from the stage and autonomously remain at that fixed distance.

To prepare for this planned navigation transition, the engineers trained ADRAS-J's onboard navigation algorithms to calculate the predicted path of the JAXA stage based on its motion relative to the star field behind it, Lindsay says. "You have to do these very precise calculations based on a speck of light."

The algorithm will then predict where it thinks the debris is going, telling itself: "We have this uncertainty; let's put ourselves into this trajectory to get a little bit closer," Lindsay says. "So maybe you cut the distance in half, and at that point, you can make a better assessment of where it is."

The algorithm loop will repeat itself: checking the sensor images of the stage, guessing the position and pathway of the stage, firing its thrusters to get closer

▲ Astroscale received a contract from JAXA, the Japan Aerospace Exploration Agency, in 2021 to demonstrate navigation and inspection of an uncooperative target in space with its ADRAS-J spacecraft, shown here in Astroscale's Tokyo clean room. The satellite's upcoming scheduled rendezvous with a spent JAXA upper stage is one of several activities the agency funds under its Commercial Removal of Debris Demonstration Project to demonstrate technologies for debris removal.

Astroscale

and checking again, he says. "It's this constant iterative process of making better and better guesses essentially of where the object is going and where it is, until you get close enough that you have resolved imagery and you're like, 'OK, I definitely know where it is; I know exactly how far it is; I can get really close if I want to, and I can do it safely.'"

Before the spacecraft was prepared for launch, planners also needed to find out how the control algorithms and sensors would respond to various lighting conditions in space. For that, they ran several ground tests at JAXA's Tsukuba Space Center in October 2022, April 2023 and July 2023. In one test, they set up at one end of a 10-m-long corridor a mock-up of a launch adapter ring from the stage, made of aluminum surrounded by gold-foil-colored multilayer insulation. At the other end was a platform on wheels, like a dolly, carrying the ADRAS-J sensors.

Electric motors on the dolly were directed by the ADRAS-J control algorithms to move the sensor platform in all four directions, with some rotation as well, to mimic orbital mechanics, changes in position relative to the stage mock-up and changes in velocity that the thrusters would initiate in space as the spacecraft maneuvered closer and closer to the stage. All the lights were shut off except for a sun simulator, and the engineers tested how the sensors responded to different angles of glare: the sun shining from behind the stage, directly in front of it or from the side.

"We wanted to test — to the limits — the instruments' responses and different lighting conditions and angles, specular reflections," Lindsay says. "Part of our mission is to assess whether the upper stage would be safe to grapple, and the adapter ring is an ideal place for this. If we do want to grapple the ring, we also need to accurately track and approach the ring while zeroing relative velocity. So we need good practice on determining the motion of this feature so we can safely dock with it."

Once ADRAS-J is orbiting next to the JAXA stage, controllers on the ground will command its sensors to record images and take measurements from fixed positions around the stage. The spacecraft will then make 360-degree flyarounds, slowly circling the stage to capture data from different angles and in various lighting conditions. The spacecraft's control algorithms are designed to execute the maneuvers and make small adjustments to maintain a safe distance, Lindsay says.

The sensor data from ADRAS-J will help Astroscale design the spacecraft for the future capture mission, assuming that it wins the JAXA contract, as well as other potential missions to capture, repair or refuel other satellites for other prospective clients, Lindsay says. For the JAXA capture mission, the ADRAS-J imaging is expected to reveal the specific rate at which the stage is spinning. So if the spin rate is 2 degrees per second, for example, engineers won't have to design robot arms for the follow-on mission that will function over a full 1- to 3-degrees-per-second range, Lindsay says.

"If at rendezvous you can narrow that range down, you can home in on the exact type of algorithm we

"As with any deep-tech, new-market ecosystem, there's going to be some hesitance among the commercial sector to buy into it immediately."

— Chris Blackerby, Astroscale

need or thruster technology that engages the specific solution, so you'd have a spread of capability," he says. "You just have to launch whatever's needed to do the job."

The ADRAS-J results will define how much sensor data is necessary to capture the stage or for other debris-capture or satellite-servicing missions, as well as what types of sensors are essential for identifying certain features of the orbiting object or to match the actual object to its computer model, Lindsay says. "You don't want to get up there and realize you can't see what you need to see because you don't have the right kind of data collected."

After years in space, an orbiting object's colors and other features may have been changed by atomic oxygen, radiation, ultraviolet light and micro impacts from orbiting dust. "When we make our simulations on the ground of what an object is going to look like and how we use our computer vision to see and understand the object, we are using models based on what we think the material looks like on the ground," Lindsay says. "I may need both visual and infrared to get a lock on features or a contrast of features on the client object to match the model."

If Astroscale can prove that it can capture space junk and take it out of orbit, is there a market for the service? Company executives think so.

Speaking to reporters during an October webinar, Chief Operating Officer Chris Blackerby said he expects that government contracts for research and proving technology for debris capture will help generate commercial demand that doesn't exist today. "It's a nascent market; we recognize that. As with any deep-tech, new-market ecosystem, there's going to be some hesitance among the commercial sector to buy into it immediately."

As for government projects, Astroscale — which has raised $383 million in venture capital to date — is developing a debris removal mission for the U.K. Space Agency and a refueling prototype for the U.S. Space Force's Space Systems Command, as well as an inspection mission for the Japan Ministry of Education, Culture, Sports, Science and Technology. On the commercial side, broadband constellation operator OneWeb has installed magnetic plates on its satellites that are compatible with the docking spacecraft that Astroscale demonstrated in its ELSA-d mission, which could allow for easier capturing and deorbiting in the future if those satellites don't fall out of orbit and burn up as they are designed to.

▲ Astroscale's plan to offer debris removal services has garnered interest among satellite operators. OneWeb, which operates a broadband constellation of some 600 satellites, in 2021 announced it would install magnetic docking plates on its spacecraft compatible with Astroscale's technology.

OneWeb

Still, not everyone is convinced there is a viable commercial market, because in the most popular orbiting altitude — between 400 and 600 km — there hasn't been any debris hazardous enough to spark satellite operators to pay for its removal. But governments might pay for removal or force owners to clean up their own wayward satellites to avoid fines, McDowell says. In October, the U.S. Federal Communications Commission fined DISH Network $150,000 for failing to properly relocate one of its geosynchronous television satellites to an assigned graveyard orbit, the agency's first space debris enforcement.

The incentive "may have to come from government, possibly through taxing the satellite operators," McDowell says. "The only reason a commercial operator is going to pay to remove debris is if the government fines you." ★

TAMING DEAD SATELLITES

Europe's Envisat is one of the large defunct spacecraft in low-Earth orbit that the Airbus Detumbler could prepare for deorbiting. Contact with the satellite, shown here in an illustration, was lost in 2012 shortly after the 10th anniversary of its launch. European Space Agency

Space is not the calm place it might seem. Once a satellite dies, various phenomena can cause it to tumble, making it hard to grab and remove from orbit. An experimental device in orbit now could solve the problem. Paul Marks spoke to its designers.

BY PAUL MARKS | paul.marks@protonmail.com

From harpoons and deployable nets to the grasping robot arms of space tugs, there's no shortage of ways in which spaceflight engineers believe a dead satellite can be captured for subsequent deorbiting.

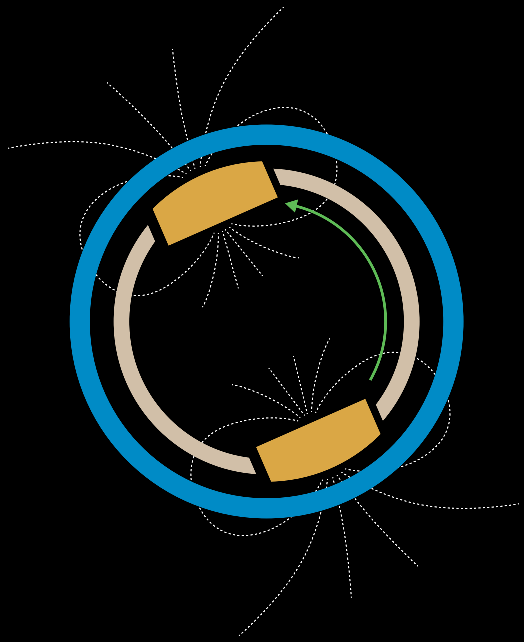
But such capture techniques can all be thwarted by one debilitating problem: A dead spacecraft lacks the propulsion and power it needs for attitude control and so can easily start tumbling. The spinning spacecraft is hard to grapple, and its angular momentum can break grippers or tear harpoon tethers and nets, in turn risking damage to the chaser vehicle and creating more space debris.

But with constellations of hundreds of thousands of internet-delivery satellites set to swell the population in low-Earth orbit over the next decade — Starlink, OneWeb and Amazon's Kuiper are just the start of what's becoming a gold rush — finding a way to de-tumble and deorbit the defunct ones has become a priority for the industry.

The numbers tell the story: In October, researchers at the University of British Columbia established that at least 1 million LEO satellites in some 300 constellations were registered with the International Telecommunication Union between 2017 and the end of 2022 for future launch — a potential 115-fold increase over today's orbital population. "The addition of hundreds of thousands of new satellites would greatly increase the complexity of operations and the risk of on-orbit collisions," the UBC team warned in the journal Science.

"This thing needs to be cheap and small if we're going to put it on every spacecraft in a massive constellation."

— Kristen Lagadec, Airbus Defence and Space



The Detumbler in action

HOUSING Made of aluminum, it doubles as the device's stator, or stationary part, and is affixed to the satellite.

ROTOR This aluminum wheel is free to turn.

MAGNETS Made of samarium-cobalt, these make the rotor turn to stay aligned with Earth's magnetic field.

A Detumbler could be robotically attached to a satellite at the end of its design life, or it could be affixed to a satellite before launch. The magnetic force it continually imparts is weak enough that during the satellite's life it would not interfere with station keeping maneuvers. But should the satellite die and start tumbling, the force would be strong enough to gradually slow that tumbling. As the rotor turns close to the housing, eddy currents are generated in the housing, and these currents generate a magnetic force in the opposite direction of the tumbling. The device does not need a source of electricity, since it relies on the electromagnetic properties of the materials.

But all may not be lost. A new gadget is in development that could stop defunct satellites from tumbling. Its inventors are confident enough to call it "a breakthrough for space sustainability."

The technology is the work of engineers Kristen Lagadec, Cyrille Tourneur, Laurent Boyer and Baptiste Brault of Airbus Defence and Space in Toulouse, France. Working with research partners at the French space agency CNES, the Airbus team has invented a lightweight electromagnetic device that could offer an inexpensive way to detumble defunct spacecraft.

Called — you guessed it — the "Detumbler," the gadget would be bolted to a satellite before launch but would only kick into action if the spacecraft were to start tumbling after it dies. The device itself is an unassuming aluminum can, 4 centimeters deep and 5 centimeters in diameter, that contains an aluminum rotor with two magnets, one on either side. The following may sound unlikely for such a diminutive device, but due to the particular principle of electromagnetism that the Detumbler's action is based on, its designers believe it will dampen the spin of any defunct satellite of up to 1.5 metric tons (1,500 kilograms), Lagadec says.

The choice of the Detumbler's operating principle was led by two major factors. First, says Lagadec, "This thing needs to be cheap and small if we're going to put it on every spacecraft in a massive constellation." Second, it had to work without being electrically powered or otherwise fueled, as most end-of-life satellites are "passivated" — that is, their batteries are discharged and all their propellant is vented to prevent explosive fragmentations and risky excursions from the orbital path. To meet these demanding conditions, Lagadec and colleagues decided to harness a principle of electromagnetism, described by Lenz's law, that is exploited in the contactless induction brakes used in some trains and trucks in place of friction-based brake pads.

In such brakes, a conducting disc is attached to a wheel axle and rotates between two electromagnets. When the driver brakes, those magnets are energized to apply a magnetic field across the conducting disc. But electric "eddy" currents generated in the conductor create a magnetic field in opposition to the applied one, producing a braking force that slows the vehicle without any contact between the disk and electromagnets.

Trucks and trains are not a perfect analog, though, for the way the Detumbler harnesses Lenz's law. "That's a very, very large-scale version of our technology. Ours only dissipates tiny picowatts of power. The Detumbler is a hybrid between [the braking mechanism] and a compass," Lagadec says.

Specifically, the Detumbler is fixed to the satellite so that in normal operation, the two magnets fixed to either side of its free-turning rotor wheel (see diagram) cause it to align with the local true north of the Earth's magnetic field, just like a compass. But, after the satellite is decommissioned, if solar radiation pressure, a propulsion failure or a debris strike has set it tumbling, the rotor will start to rotate to stay fixed on true north, and its magnets will induce eddies in the aluminum housing, the stationary part, or stator, of this electric machine. These eddies create an opposing magnetic force that dampens the motion. Over time, those tiny torques add up, combining to stop the tumble of a 1.5-ton satellite over something like 300 days.

"We hope to be able to detumble a relatively large spacecraft in significantly less than a year," says Lagadec. "Anything that can reduce or completely suppress tumbling would be a very, very welcome addition to a spacecraft in the eventuality that it might have to be actively removed if it cannot deorbit on its own at the end of its mission."

They might soon know if their idea has merit. The first test Detumbler is on orbit now after being launched on the SpaceX Transporter-9 ride-sharing mission in November. Bolted to an 8-unit cubesat called Exo-0 — owned by Exotrail and built by EnduroSat — the Detumbler was awaiting being spun up for tests as of mid-December.

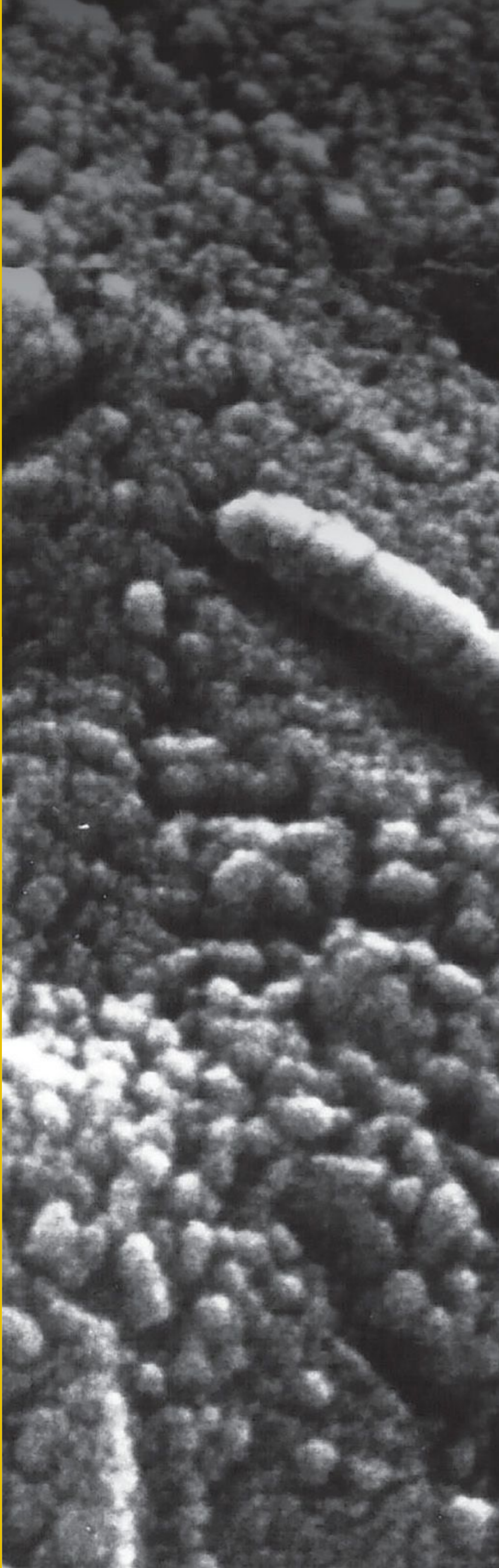
Airbus is not yet revealing the Detumbler's projected price, but Lagadec says that "the target is that it should be negligible with respect to the price of any other satellite avionics equipment." Although the potential market size makes constellations the device's primary target, he adds that Airbus will "probably be working on a version for larger spacecraft" that might also be attachable to existing space junk.

And that brings a fascinating possibility into play: the detumbling of some of the most dangerous debris, like the European Space Agency's 8.2-ton Earth observation satellite, Envisat, which died suddenly on orbit in 2012. Ever since, Envisat has been tumbling at 770 kilometers, threatening havoc in LEO if it were to collide with other objects or break up. Damping it would likely require a number of larger Detumblers, plus an accurate way to attach them to Envisat, says Lagadec.

But freeing LEO from being haunted by such threats would be worth it, he says. "It would be like applying a tranquilizer dart to an animal: We could then wait for the beast to settle down and then grab it." ★

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



NASA FACES ITS MARS CONUNDRUM

Theory holds that about 3.7 billion years ago, a meteor crashed into the equatorial region of Mars, cracking its surface and leaving a hole nearly as wide as Lake Michigan into which water seeped from below and melted snow flowed in from the sides, as NASA describes the scenario. The lake is now a dry crater, but the timing of this feature's watery phase has long intrigued scientists. Life arose on Earth about 3 billion years ago, an era when Gale Crater was still a lake, scientists believe. Perhaps life emerged there, too, and the sedimentary rocks in the crater hold records of it. So in 2014, NASA's Curiosity rover drilled into a piece of hardened sediment — mudstone — to look for chemical markers of ancient life.

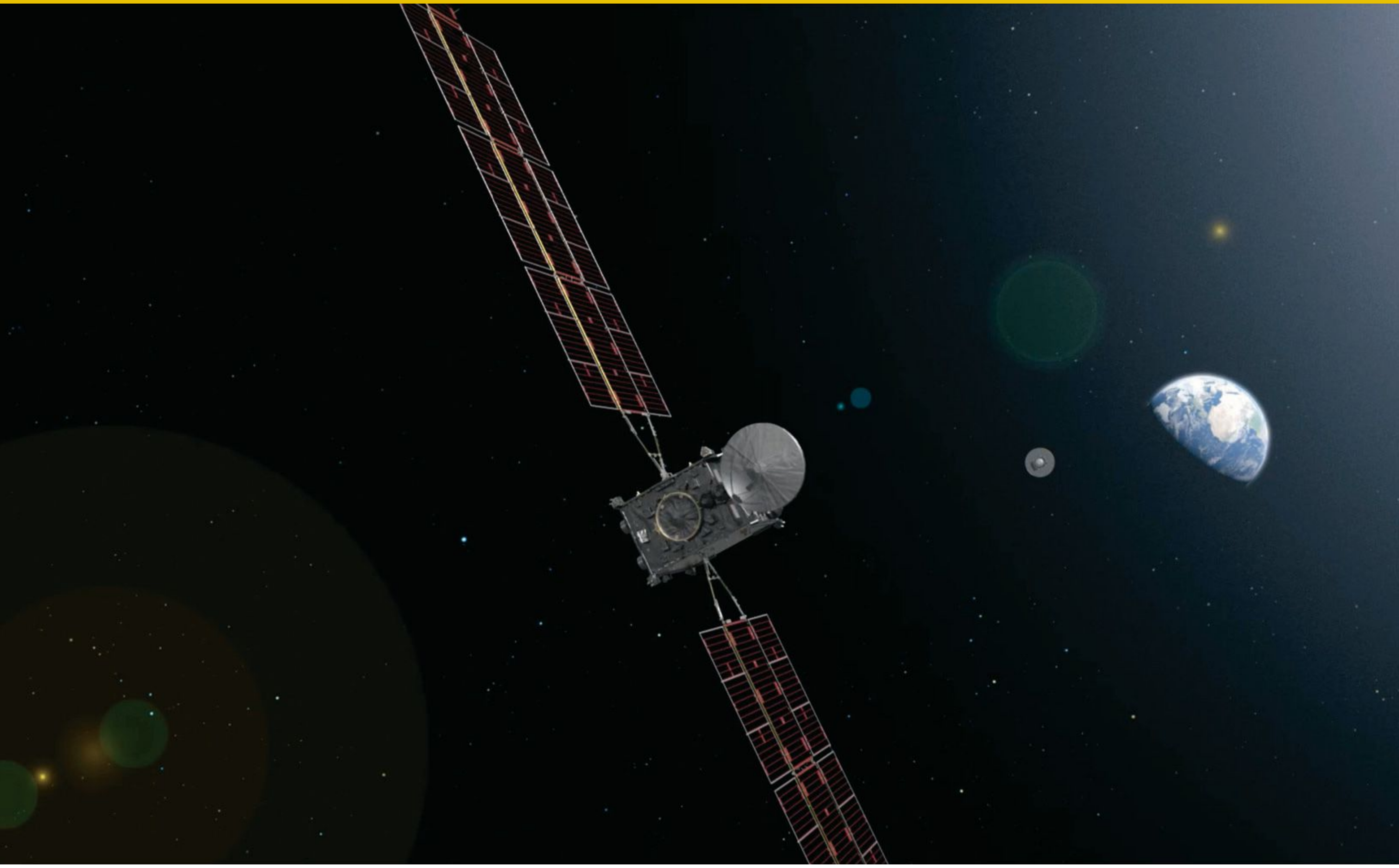
Inside its chassis, Curiosity heated the drilled material to 860 degrees Celsius in an oven to release fumes from it that were fed into the onboard mass spectrometer. The constituent particles were given an electric charge and sent through a magnetic field that deflected their trajectories by an amount corresponding to their masses. From those masses, the likely presence of particular molecules could be deduced.

The results hinted that the mudstone might contain kerogen, a complex organic compound that can be found in lifeless meteorites, but also, tantalizingly, "at least on Earth, is a leftover from the decay of plants," explains physicist Scott Hubbard. As head of NASA's Mars science program in the early 2000s, he restructured the effort partly toward bringing samples to Earth for analysis. On Earth, layers of kerogen were formed from deposits of algae, plant pollen and plankton in mud and underwater sediment that were squeezed by geological forces. Gale Crater was exactly the sort of place one might expect the Martian version of this process to occur, but there was a hitch: One technology was best suited for conclusively determining whether the material contained kerogen — and if it did, whether its origins were biological — but this technology was back on Earth in any of various massive particle accelerator facilities around the world.

My interviews with a dozen Mars scientists, lunar scientists and engineers show that the large size of the most capable technologies for addressing the question of life on Mars is not driven by a lack of intelligent computer code or microprocessors (as valuable as those could prove to be) but by the physics of

▲ With its onboard suite of science instruments, the Curiosity rover has conducted in situ analysis of the material in Mars' Gale Crater. However, the technology needed to conclusively determine whether the source of the material is biological would be too large to get to Mars.

NASA/JPL-Caltech/MSSS



▲ In the final step of the current Mars Sample Return architecture, a European-built Earth Return Orbiter (foreground) would release the sealed container holding the samples toward Earth. After plowing through the atmosphere, the container would land under parachutes in the Utah desert, similar to the September landing of NASA's OSIRIS-REx sample capsule, which held rocks and dirt from the near-Earth asteroid Bennu.

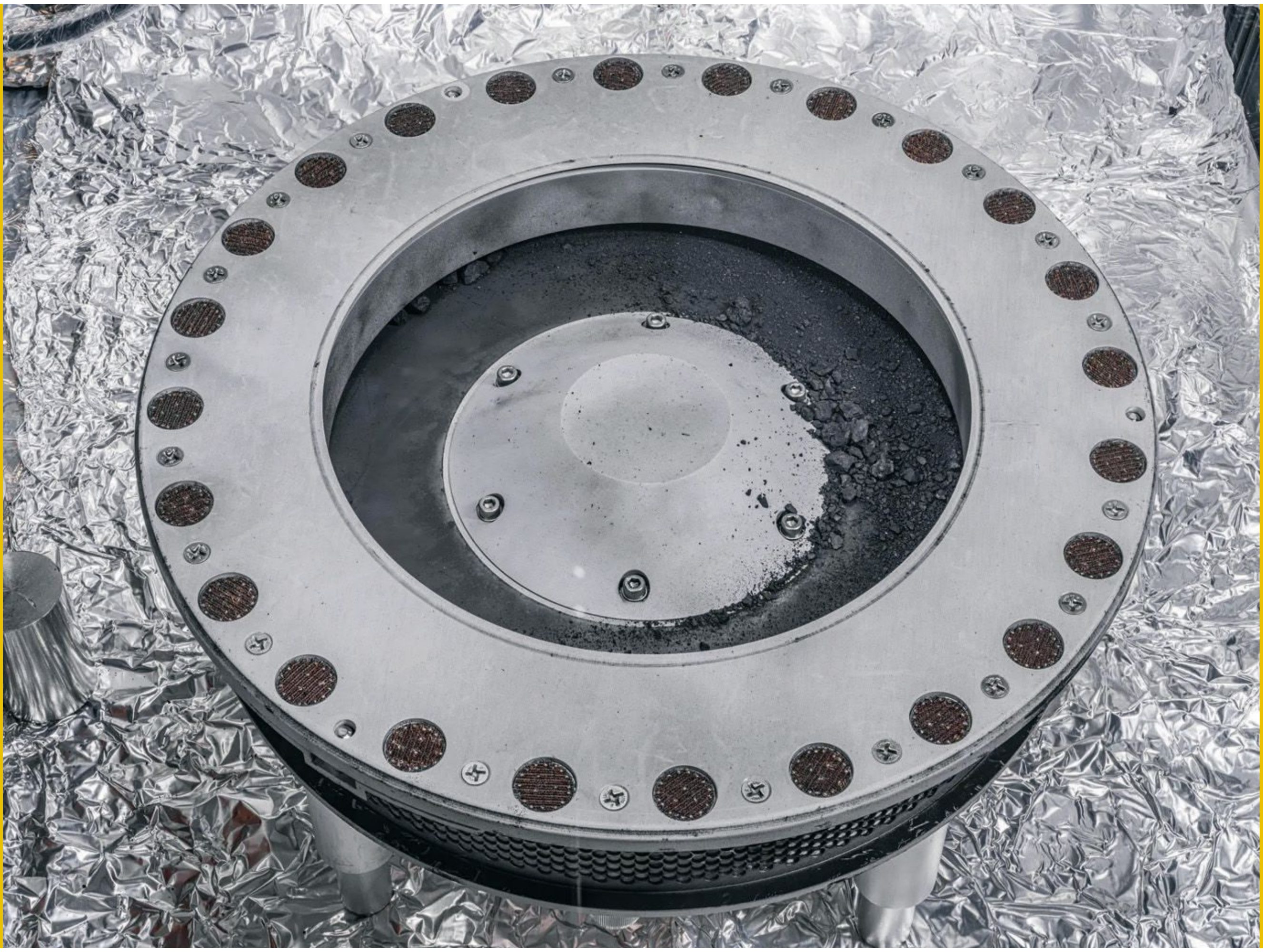
NASA/ESA/JPL-Caltech/Goddard Space Flight Center

fully analyzing samples. The size issue is true for an electron microscope that could in theory capture fossilized microbes, but whose dimensions are typically measured in meters. It is most apparent when employing synchrotron radiation, a form of X-ray light that must be generated in a particle acccelerator. If directed at a mysterious material, such as the core sample Curiosity drilled up, the X-rays would reveal unprecedented detail.

This size issue, more than any other, is why NASA so far has not wavered from its goal of bringing samples home, even as scientists continue to deliberate over specific science objectives and the agency searches for alternative mission architectures that could tame Mars Sample Return's escalating costs. The mission was projected in 2020 to cost $4 billion, but the estimate has since soared to $8-$10 billion, according to the September report from the Mars Sample Return Independent Review Board 2, the latest group to review the mission.

Under the current plan, samples would be brought home from Jezero Crater, a feature similar to Gale Crater in that it is also thought to have once been a massive lake but is now dry and might contain kerogen or other signs of Martian life. Curiosity's successor, the Perseverance rover, arrived there in 2021 and has been drilling samples and inserting the material in cigar-sized titanium tubes. Some of the tubes have been left on the surface for possible later collection, while others are riding on the rover. It's the next phase, in which those tubes would be collected and brought to Earth, where adjustments to the architecture are possible. The required Mars surface hardware has yet to be built, and the review board warned that existing plans cannot "be accomplished with the likely available funding." NASA responded by assembling an interagency team that's supposed to propose alternative mission designs by March. Congress has also taken note, with the Senate Appropriations Committee threatening in draft budget language to descope or cancel the mission if total anticipated costs are not brought down to $5.3 billion.

The existing mission design includes dozens of steps requiring coordination among as many as seven spacecraft of various kinds: Perseverance is to navigate to a U.S.-built lander, whose robotic arm would grab the tubes from the rover and place them in a protective sample container. NASA designed in a contingency plan, however, in case Perseverance is no longer operating when the lander arrives at Mars in 2030. In that event, two small helicopters



would be dispatched to retrieve the tubes. Once the tubes have been collected, a small U.S.-built rocket would blast off from the lander to boost the sample container into space, where it would be released and captured by a European-built Earth Return Orbiter. Once near Earth in 2033, the orbiter would release the container to enter the atmosphere for a landing under parachutes.

No one I spoke to suggested that a switch to analyzing the samples on the surface of Mars could match the quality of science that could be done by bringing samples to Earth and blasting them with X-rays or scanning them with an electron microscope. But one scientist said interesting science could be done in situ, even if not a direct replacement, and that costs and benefits of returning samples must be carefully weighed.

"For the price of one Mars Sample Return mission, you can do at least three solid in situ exploration missions," says Jorge Vago, project scientist for the European Space Agency's planned ExoMars mission, a separate endeavor in which a small rover would land on Mars in the late 2020s. "The cost of a Mars Sample Return class of mission must be justified by what you can learn with the material that you will bring back. So you need to be sure that what you return to Earth is worth it."

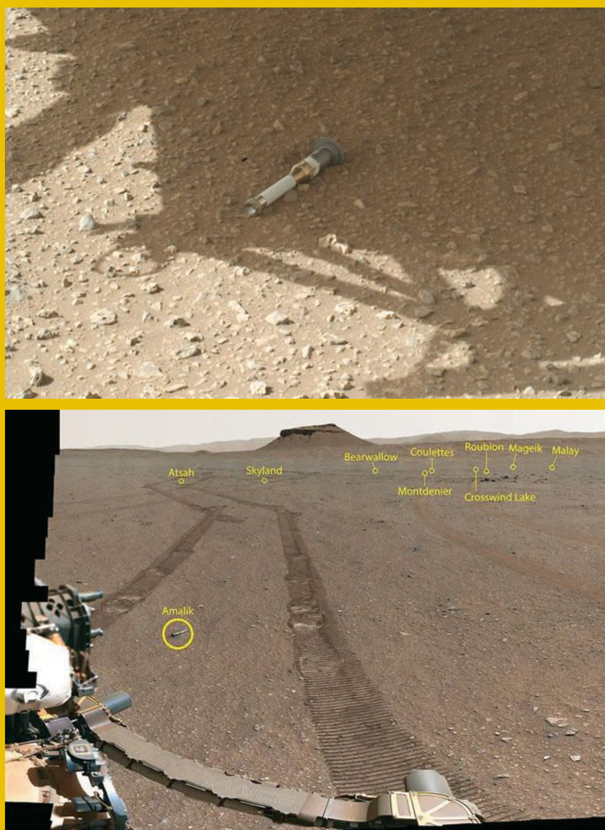
Ultimately, he says, "With a robotic mission we have — at present — no hope of being able to image putative microorganisms. We could see colonies, perhaps, but not the individuals." For instance, "we cannot make thin rock slices and image them with an electron microscope as we would on Earth."

Likewise, Susanne Schwenzer, associate director of astrobiology at The Open University in Milton Keynes in the U.K. and a member of the Mars Sample Return Campaign Science Group, believes that "if you take Curiosity one, five, 10 steps further, I think there would be a lot that we can do" in situ. But she, too, is not suggesting that such analysis could match the science that could be done if MSR succeeds in returning the samples.

For one thing, only so many instruments can fit on a rover. And no matter how advanced those instruments might be, Schwenzer says, you wind up with new, ambiguous discoveries that cannot be cleared up with the instruments on hand. "If you send a spacecraft, you've got a set of tools," she says. "And you can't exchange the toolbox."

▲ NASA in September began analyzing some of the rocks and dust retrieved by the agency's OSIRIS-REx spacecraft from the asteroid Bennu. Because NASA was certain Bennu does not harbor life, this analysis is being done in a lab at Johnson Space Center in Texas. In contrast, any Martian rocks, dirt and air returned to Earth would need to be analyzed in a laboratory with level 4 biosafety.

NASA/Erika Blumenfeld and Joseph Aebersold



“Viking taught us that there’s not a single measurement that’s going to answer your question of whether or not there’s life elsewhere. It has to be in context.”

— Michael Meyer, NASA’s Mars Exploration Program

▲ The Perseverance rover dropped this depot of 10 backup sample tubes in Jezero Crater, a contingency plan in the event the rover is not operating when the next phase of hardware for Mars Sample Return arrives. The rover is carrying the primary collection of 20 sample tubes in its belly.

NASA/JPL-Caltech/ASU/MSSS

Take NASA’s first landings on Mars, the Viking 1 and Viking 2 landers in 1976. Scientists at that time hoped to find out whether there were microorganisms on Mars, but they had no direct way to search for them. So they devised a “labeled release” experiment in which nutrients labeled with radioactive carbon-14 were added to Martian soil. If organisms were present, they would consume the nutrients and release carbon dioxide waste gas containing carbon-14. The results looked promising for the presence of organisms, but later were determined to be debatable.

“At the time they devised the instrument, we did not know that the Martian soil often contains perchlorate, which could mimic the ‘biologic’ reaction,” Schwenzer told me by email. “The power of the return samples is you go, ‘I found this unexpected thing! Now my colleague in Japan has a specialized instrument; why don’t I get the sample to him or her?’”

The discovery that soil often contains perchlorate had to wait for NASA’s Phoenix lander to arrive in 2008 — 32 years after the Viking landings. As important as that discovery was, solving other mysteries such as the one about kerogen cannot today be done by instruments of rover scale. “Synchrotron radiation is a great example of something the size of a football field that you’re not going to be able to put on a spacecraft,” says Michael Meyer, the lead scientist for NASA’s Mars Exploration Program. In fact, he jokes, “it’d be scary if you could put that on a spacecraft.”

And the size and weight are just one part of the problem: “Viking taught us that there’s not a single measurement that’s going to answer your question of whether or not there’s life elsewhere. It has to be in context.”

Over the years, NASA’s Mars program has slowly built up a contextual understanding of the geologic history of Mars. The Sojourner rover in the late 1990s and the twin Spirit and Opportunity rovers in the early 2000s helped establish that liquid water once flowed on the surface. Curiosity established that conditions on early Mars were ripe for evolution of life. “It had oxidized and reduced species. It had organic compounds,” Meyer says.

Meyer views MSR as the next logical step in NASA’s Mars science strategy. The rocks and dirt could be stored over the decades, he points out, just as samples from the Apollo program continue to yield new discoveries 50 years after the program ended.

"A decade from now, [scientists] can ask a question nobody thought of," he says. "They can use instrumentation that hasn't been invented yet."

While the architecture review progresses toward the March deadline, MSR scientists are at least partially in limbo in their planning. As central as the search for life (past or present) is to MSR, it is not the only priority whose details need to be settled. In 2018, the International MSR Objectives and Samples Team listed the search for life among other objectives, including interpreting the geological processes that created Mars, with a focus on water; determining what resources exist to support future human exploration of Mars; and identifying hazards to those explorers.

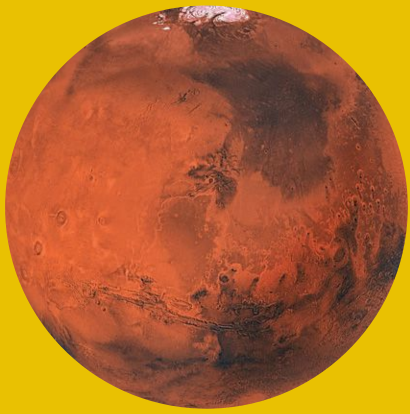
Just how to meet those objectives, which questions to ask with which instruments, testing which samples in what order, and storing them on the ground in what and where, is subject to ongoing debate among the scientists within the MSR Campaign Science Group.

"We are having very, very long discussions about these things," says Schwenzer, a member of the group. "For example, you take the headspace gas out of these sample tubes, what do you replace it with? Nitrogen? Argon? Helium? Something else entirely? Depending on whom you ask, the answer is different."

Optimizing something as simple as which neutral gas to use for storage is complicated because there are contrasting and even conflicting requirements for the different MSR science objectives. The samples must be stored under very dry conditions to avoid any terrestrial moisture seeping in and contaminating the material, according to Schwenzer. But that same dry atmosphere poses a challenge for preserving any hydrated matter, such as gypsum, a residue of saltwater evaporation, that might be on Mars. This drying could interfere with organic chemistry experiments "where we have time-critical measurements to make," she says.

There are similar tensions for determining at what temperature to store the Mars samples in order to facilitate both geological and astrobiological experiments. "If you really have something alive, minus 80 [Celsius] is the way to go to preserve it. That's what the biologists are telling me," Schwenzer says. But store something with water in it at minus 80, and it will develop cracks; "take it out and put it back into that cold, and you'll get freeze-thaw process damage," which could hinder mineralogical studies of the Mars material.

Also, the possibility of the samples containing still extant Martian life, however remote, introduces additional challenges not faced, for example, by the OSIRIS-REx team that last year brought back samples from the asteroid Bennu. The Mars samples



"The cost of a Mars Sample Return class of mission must be justified by what you can learn with the material that you will bring back. So you need to be sure that what you return to Earth is worth it."

— Jorge Vago, European Space Agency

can't be transported to a conventional clean room but must be held in a biocontainment level 4 facility, the same level of biosecurity used for the U.S. Centers for Disease Control and Prevention lab studying the smallpox and Ebola viruses. No such NASA facility exists at the moment, and that could be a problem.

"A lot of things that need to happen need to happen now. We need to build a receiving facility now," Schwenzer says. "These things take 10 years to build."

For now, the various teams of scientists are "on standby, almost, waiting for a better signal for what's the next thing they need to pay attention to, what's the next thing they need to work on," says David Beaty. He's a petrologist at the NASA-funded Jet Propulsion Laboratory in California and acting lead scientist for the sample receiving project, part of an office NASA opened early last year to manage the receiving and curation of the Mars samples.

There is some work still going on. For instance, the Measurement Definition Team, another set of international Mars scientists, is working on a report detailing which instruments should be included in the sample receiving facility, says Beaty. This report, also due in March, will provide the list of required instruments and the science and technical staff needed to operate them.

"We want the smallest number of instruments that we can and still do the job correctly," Beaty explains. "It's a pretty big driver on the sizing and therefore costs of the sample receiving facility. And we need to know that relatively soon."

As for when scientists might get their figurative hands on the samples, an air of realism has set in.

"I'm far enough along in my career that I don't have hope anymore that the samples will arrive in my professional lifetime. I worry more that they arrive in my physical lifetime," says Beaty, who started his career working with lunar samples from the Apollo program.

Despite the challenges ahead, Hubbard believes that MSR will go forward, one way or another.

"It is my belief that, like [the James Webb Space Telescope], NASA will find a way — with Congress — to fund MSR," he says. "The science return, possible fingerprints of life, is of the highest priority." ★

PILOT ON BOARD

In its initial flight test campaign, Electra established a distinctive course for itself in the emerging field of advanced air mobility through its lift-enhancing design and avoidance of remote piloting. Paul Brinkmann tells the story.

BY PAUL BRINKMANN | paulb@aiaa.org

When Electra's demonstrator aircraft, the hybrid-electric EL-2 Goldfinch, spun up its eight rotors and took off on its inaugural flight, there was a notable difference compared to first flights by most other companies working on aircraft electrification: Lead test pilot Cody Allee climbed aboard the two-seat aircraft.

Others in the field have tended to fly their aircraft remotely from the ground, often numerous times, before putting a pilot aboard. Having a person on the Nov. 11 flight from Manassas Regional Airport in Virginia ruled out a development approach in which lots of technical risk would have been accepted.

"It's a business decision — are you willing to crash [the plane] to learn whatever you're trying to find out on that first flight?" J.P. Stewart, Electra's vice president and general manager, tells me. "You can't take that trade when you have a person on the airplane."

Electra invested more time in modeling, simulation and ground testing to be confident about the odds of success and safety for that flight and the five additional ones in the initial test campaign, which concluded last month.

The flights gradually increased in duration and complexity. The first flight was powered only by

▲ Electra conducted six flights in Virginia with its piloted EL-2 Goldfinch demonstrator between mid-November and early December. Plans call for additional flight tests in 2024, including some to verify that the aircraft can take off from an "ultra-short" distance of 45 meters.

Electra

electricity running to electric motors from four lithium-ion batteries, and Electra did not reveal the duration. On the second flight, conducted Nov. 19, the hybrid-electric powertrain was engaged, demonstrating the range-enhancing capability for the planned production versions. This flight lasted 23 minutes, with Allee taking the aircraft to an altitude of 3,200 feet and covering 30 miles [48 kilometers] over the Washington, D.C., suburbs, according to Electra. The longest of the six flights lasted 50 minutes.

Allee emphasizes the safety of the design: "With eight motors and essentially five power sources — a generator and four batteries — there is incredible redundancy, meaning a failure of a single component has less urgency compared to a single or twin-engine airplane," he says by email.

As far as Electra knows, the Nov. 19 flight marked the first by a hybrid-electric, short takeoff and landing aircraft. Specifically, the company calls the planned production version an "ultra-short takeoff and landing" aircraft, and this year intends to demonstrate the ability to take off in as little as 45 meters. Such a short takeoff would be made possible by the eight rotors positioned across the wing. These rotors accelerate the air before it reaches the leading edge, augmenting the lift produced by the wing's shape and the plane's forward motion, in a "blown lift" technique.

Allee says blown lift, sometimes called blown wing, provided aerodynamic and handling benefits during the test flights.

When those eight motors are producing thrust and blowing over the wing, "it becomes a unique machine" and "more responsive," he says, adding that the company has "just begun to explore" the effects of the blown wing.

The Goldfinch was able to fly as slow as 35 knots, or 64 kilometers per hour, and "handled just the same as it did when flying faster, with no buffet or shaking that typically accompanies those speeds," Allee says.

Such stability at slow speed meant the aircraft could tackle a steeper angle of attack at the upper range of the altitude that the test flights reached, than conventional airplanes, he says. Slow speeds will be explored more in the upcoming test flights.

"We will begin to deeply explore the benefits of blown lift. We'll work to design approach and departure paths and techniques to maximize those benefits," he says.

The test flights on battery power only showed that the Goldfinch could take off and land without the louder turbogenerator, which could make such aviation a "better neighbor" to people living around airports, he says.

Allee might have kept the aircraft up longer on the second flight, but the near-freezing temperatures that day resulted in the lithium-ion batteries getting too cold for optimum operation, an effect that was expected based on the ambient temperature, says Stewart, the vice president. The demonstrator doesn't have the full thermal management system that future versions will have, particularly the ability to regulate the coolant.

"We've shown that our computer modeling and the whole design match pretty well. We thought that was true, but the rubber meets the road in a test like this," Stewart says.

> "We've shown that our computer modeling and the whole design match pretty well. We thought that was true, but the rubber meets the road in a test like this."
>
> J.P. Stewart, Electra vice president and general manager

Regarding power, electricity on the EL-2 sometimes flows only from the turbogenerator in its nose, sometimes only from the batteries, or sometimes from both, he says. When and how the right balance between these sources is achieved is something the company intends to study in future flight tests. The turbogenerator reflects Electra's business strategy, which is to expand from the small EL-2 Goldfinch to an eight-passenger production version that could be flown up to 800 kilometers without having to be recharged. By contrast, the purely electric aircraft in development have so far topped out at about 240 kilometers.

The longer range means Electra's aircraft could replace today's long car trips, which Stewart says amount to "one very promising market segment."

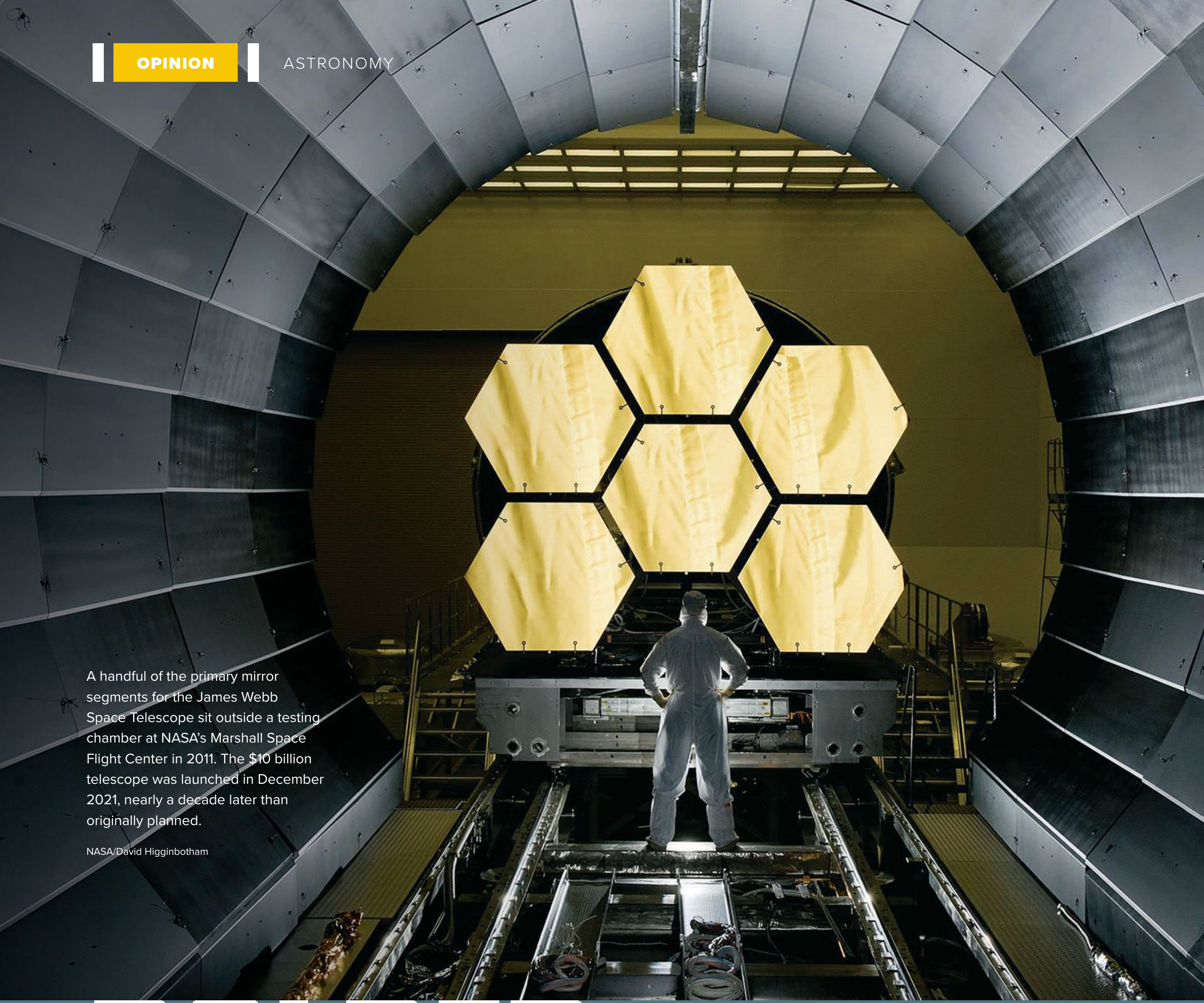
NASA's canceled X-57 all-electric plane would have tested a version of the blown-lift technique in flight, but the agency decided to end the project earlier this year without flying, partly due to problems with its electric motors.

Stewart says the aircraft share only very basic similarities. "We blow the wing all the time, using all the rotors," he says, whereas NASA had intended to turn off and stow some of the rotors after takeoff.

There also will be significant changes from the EL-2 to the as yet unnamed production version. The demonstrator has cables and pulleys connected directly to the flight control surfaces, whereas the production model will send electronic commands from the cockpit through software to the control surfaces, meaning it will be fly-by-wire.

Flying with mechanically controlled surfaces has shown that "you don't need fancy fly-by-wire systems in order to make the airplane safe and flyable," Stewart adds.

Future test flights will "drive into every detail of stability control and of aircraft performance," while the first two flights were designed to demonstrate "basic functionality of all of the systems, mostly that the hybrid system moves power through it as it should, and that temperatures stay within the ranges that they should" despite changes in altitude and range and outside temperatures, Stewart says. ★



A handful of the primary mirror segments for the James Webb Space Telescope sit outside a testing chamber at NASA's Marshall Space Flight Center in 2011. The $10 billion telescope was launched in December 2021, nearly a decade later than originally planned.

NASA/David Higginbotham

BOLDER THAN WEBB?

'YOU'LL NEVER KNOW UNLESS YOU GO!'

NASA and its partners should draw on the success of the James Webb Space Telescope, recent bold thinking in astrophysics observatory architectures, and utilization of the latest commercial space practices to reduce cost and schedule while increasing scientific return of the next U.S. Great Observatory. Former NASA Administrator Daniel S. Goldin makes the case.

BY DANIEL S. GOLDIN

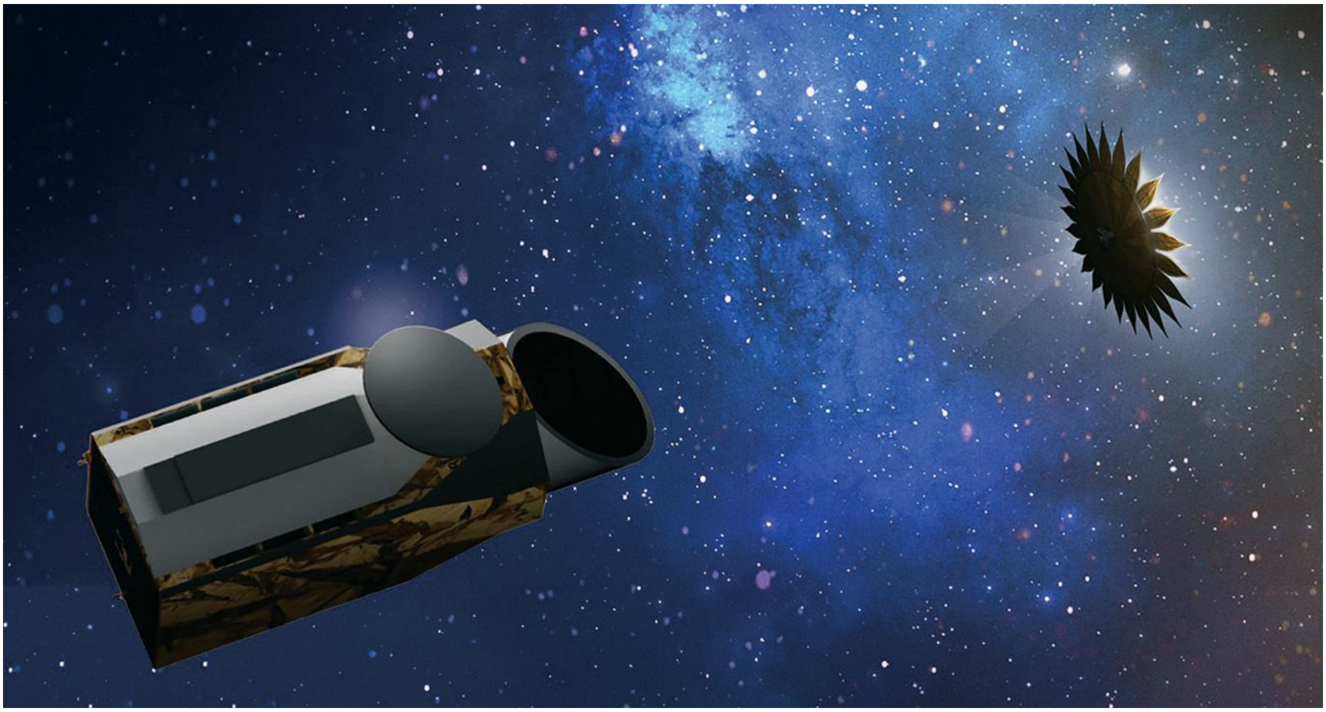
Very early in my tenure as NASA administrator, I faced a myriad of challenges, including severe budget constraints, technical hurdles and schedule performance issues, leading to a dip in confidence among our team and our supporters in Congress. This period was challenging, especially when Congress questioned NASA's capability to fulfill its commitments to human exploration and scientific research. During this time, I was inspired by a drawing and note from an 11-year-old student named Amanda. Her simple yet profound message, "You will never know unless you go," above a drawing of a rocket ship heading toward a planetary body resonated deeply with me and reinforced my commitment to deliver on NASA's mission commitments.

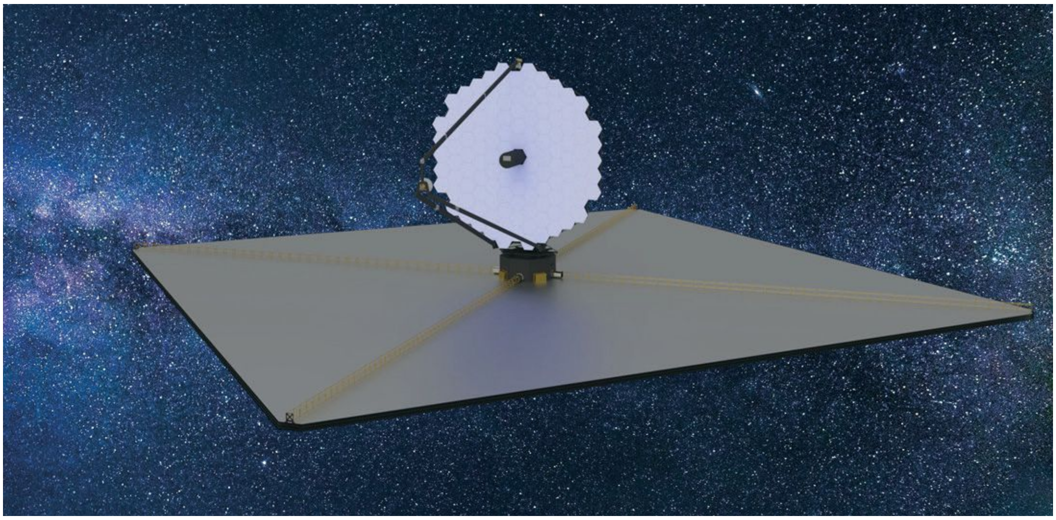
This message gained more significance when I read the latest National Academies Decadal Survey on Astronomy and Astrophysics when it was released. The report, "Pathways for Discovery in Astronomy and Astrophysics for the 2020s," is a guide for NASA's future Great Observatories and scientific endeavors. Interestingly, I reread the report about a year after its release — just about the same time as the James Webb Space Telescope's first images were released, marking a milestone in understanding the universe's origins and a strong call to action for me.

The National Academies report recommends developing a prescriptive 6-meter infrared/optical/ultraviolet space telescope with high-contrast imaging and spectroscopy, foreseeing it as a platform that will search for biosignatures from exoplanets in habitable zones. Unfortunately, the report proposes a prolonged development period of about a quarter of a century, potentially creating a significant gap in space astrophysical operations, given the uncertainty over whether Webb will still be operational so many years from now. Such a gap could mean American astrophysics will fall woefully behind.

The members of the survey panel established by the Space Studies Board should rethink their recommended approach to developing the next generation of Great Observatories in astrophysics and astronomy. By adopting innovative developmental and scientific approaches, it will be possible to reduce development time and cost, enhance scientific yield and enable scientists to participate in a variety of scientific exploration projects over the course of their careers. Drawing from the more efficient techniques of commercial space and considering a range of competitive scientific concepts, NASA and its contractors could create a better, faster, cheaper Habitable Worlds Observatory, as NASA calls the survey's next recommended Great Observatory, the 6-meter telescope.

I've had productive interactions with the National Academies, especially regarding space telescopes, including during my years as NASA administrator. Reflecting on the conception of Webb, I recall challenging conventional wisdom and embracing innovation. The initial design concepts for the Next Generation Space Telescope — NGST, later renamed the James Webb Space Telescope — were much too conservative. In early winter of 1995, about two years after engineers and astronauts enhanced Hubble's vision, I discussed NGST with scientists from the





▲ NASA is still conceptualizing the design of its Habitable Worlds Observatory, targeted for launch sometime in the 2040s, but the basic plan calls for this exoplanet hunter to be a combination of two proposals submitted for the latest decadal survey. The Large Ultraviolet Optical Infrared Surveyor (bottom) had a segmented mirror like Webb, while the Habitable Exoplanet Observatory paired a monolithic mirror with an external starshade.

NASA; Scott Gaudi/Ohio State University

National Academies. They proposed a conservative retrospective 4-meter solid glass mirror, but I envisioned a 6.5- to 8-meter deployable adaptive mirror, not limited by low-Earth orbit's constraints. Although we disagreed, this discussion was a pivotal moment, leading to the eventual development of NGST as a world-class observatory. What I said at the time was, "Be big, bold and cold. And deployable."

In January 1996, I presented my vision for NASA's astrophysics and astronomy program at the American Astrophysical Society meeting in San Antonio, including the infrared Spitzer Space Telescope, the Chandra X-ray Observatory, SOFIA (the Stratospheric Observatory for Infrared Astronomy) and NGST. The audience's standing ovation was my nutrition to strongly support this bold direction.

In today's rapidly evolving world, it's crucial to embrace innovation in space exploration and astrophysics. We must find ways to expedite progress while balancing ambition and pragmatism. The path forward for NASA and its partners is challenging yet exhilarating. Our commitment to pushing the boundaries of human potential will deepen our understanding of the universe and inspire humanity.

In addition to these reflections and strategies, other intriguing approaches in the search for habitable planets are being explored. Among the alternative ideas that should be considered is a space telescope concept described by astronomer Daniel Apai at the University of Arizona. His Nautilus Deep Space Observatory would use a novel thin diffractive lens, lighter and cheaper than traditional mirrors. Nobel laureate John Mather

The James Webb Space Telescope was launched to orbit (at left) a few weeks after the National Academies released its latest decadal survey for astronomy and astrophysics. One limiting factor for Webb was the 5-meter-diameter payload fairing of its Ariane 5 launch vehicle. Today, companies including Blue Origin, SpaceX and United Launch Alliance are designing rockets with larger fairings and higher payload weight capability, making a wider range of more affordable telescope designs possible, Goldin writes.

Chris Gunn/NASA; SpaceX

of NASA's Goddard Space Flight Center in Maryland leads development of another interesting concept, the Hybrid Observatory for Earth-like Exoplanets, or HOEE. Three large ground-based telescopes would utilize a space-based starshade to block the glare of host stars to capture images of faint extraterrestrial Earth-like planets. Both of these are exciting possibilities beyond the current conventional thinking.

Furthermore, it's crucial to consider why the National Academies haven't yet adopted lessons learned from the rapidly evolving commercial space industry. New space companies have demonstrated the effectiveness of rapidly designing and testing inexpensive prototypes in ground and space tests to find weaknesses early on. With new, lower-cost rockets featuring larger payload fairings, we have the opportunity to design systems without tight weight, dimensional and power constraints that previously limited experimentation. For instance, Pete Worden, a former director of NASA's Ames Research Center in California, is a member of a team developing a 6-meter telescope incorporating heavier but relatively low-cost mirror technology for only hundreds of millions of dollars.

Ironically, on April 26, 2023, as I once again reviewed the decadal survey, Andrew Jones of Space News reported on the Chinese Miyin project. His article noted that China "envisions sending four light-collecting telescopes and a beam combiner to Sun-Earth Lagrange point 2. Flying in formation, the spacecraft will use interferometric techniques to provide high angular resolution mid-infrared observations to directly image and characterize exoplanets around stars up to 65 light-years away." Current plans include on-orbit technology demonstrations in 2024 and interferometry experiments on the Tiangong space station in 2025. A prototype array is planned for launch around 2027, with a five-spacecraft system at L2 by 2030.

Miyin's proposed spatial resolution of 0.01 arcseconds, if achieved by the mid-2030s, would rival or surpass the capabilities of the $11 billion Habitable Worlds Observatory, the article noted. Miyin also would be operational a decade earlier.

In light of these developments, I strongly urge the members of the National Academies to reconsider their Decadal Survey on Astrophysics and Astronomy. Exploring these amazing possibilities and making courageous decisions could enable NASA to deploy systems within the next decade that could find habitable planets in our neighborhood, igniting the flame of American scientific leadership and innovation. ★

Daniel S. Goldin was NASA administrator from 1992 to 2001. A member of the National Academies since 1998, he is founder of Cold Canyon LLC, a tech advisory firm.

AIAA Bulletin

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Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2024			
8–12 Jan	AIAA SciTech Forum	Orlando, FL	25 May 23
10 Jan	AIAA Associate Fellows Induction Ceremony and Dinner	Orlando, FL	
16–25 Jan	Aircraft Maintenance Management Course	ONLINE (learning.aiaa.org)	
29 Jan–7 Feb	Mission-Based Vehicle Design Course	ONLINE (learning.aiaa.org)	
30 Jan–8 Feb	Cryogenic Fluid Management for Storage & Transfer of Liquid Propellants in Space Course	ONLINE (learning.aiaa.org)	
6 Feb–14 Mar	Vibration of Periodic Structures Course	ONLINE (learning.aiaa.org)	
13 Feb–7 Mar	Fundamentals of Aeroelasticity: From Basics to Application Course	ONLINE (learning.aiaa.org)	
14–15 Feb	ASCENDxTexas	Houston, TX	
21–22 Feb	Principles of Success in Spaceflight from Andrew Chaikin Course	ONLINE (learning.aiaa.org)	
26 Feb–3 Apr	Design of Space Launch Vehicles Course	ONLINE (learning.aiaa.org)	
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)	
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	26 Jan 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	2 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	29 Jan 24

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			
15–24 Apr	Technical Writing Essentials for Engineers Course	ONLINE (learning.aiaa.org)	
16–18 Apr	AIAA DEFENSE Forum	Laurel, MD	17 Aug 23
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)	
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	
14 May	AIAA Fellows Induction Ceremony and Dinner		
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)	
4–7 Jun	30th AIAA/CEAS Aeroacoustics Conference	Rome, Italy (aidaa.it/aeroacoustics/)	14 Dec 23
12–14 Jun*	CEAS EuroGNC 2024	Bristol, UK (https://eurognc.ceas.org)	
17–22 Jun*	Spaceport America Cup	Las Cruces, NM	
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
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)	

**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 Class of 2024 Associate Fellows

AIAA is pleased to announce its newly elected Class of 2024 Associate Fellows. The grade of Associate Fellow recognizes individuals "who have accomplished or been in charge of important engineering or scientific work, or who have done original work of outstanding merit, or who have otherwise made outstanding contributions to the arts, sciences, or technology of aeronautics or astronautics." To be selected as an Associate Fellow an individual must be an AIAA Senior Member in good standing, with at least 12 years of professional experience, and be recommended by three AIAA Associate Fellows.

The Institute will induct the class at the AIAA Associate Fellows Induction Ceremony and Dinner, Wednesday, 10 January, during the 2024 AIAA SciTech Forum, 8–12 January.

Class of 2024 AIAA Associate Fellows

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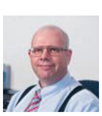
Hispasat

Jaemyung Ahn
Korea Advanced Institute of Science and Technology

Vineet Ahuja
Whisper Aero



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Northrop Grumman Space Systems

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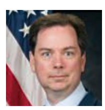

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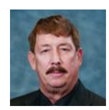

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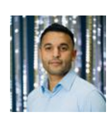

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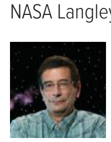

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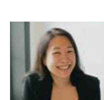

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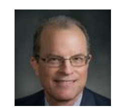

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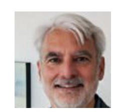

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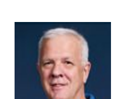

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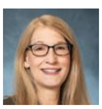
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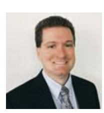
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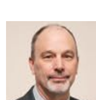
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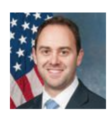
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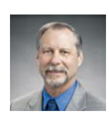
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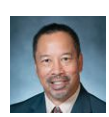
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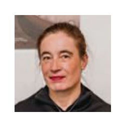
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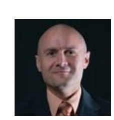
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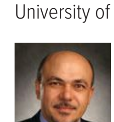
University of Central Florida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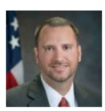

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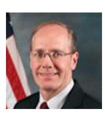

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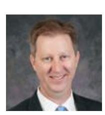

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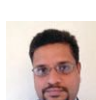

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Charles D. Norton
NASA Jet Propulsion Laboratory, California Institute of Technology

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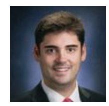

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Bernard Parent
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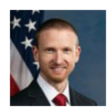

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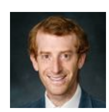

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Ryan Reynolds
Lockheed Martin Space

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Jacob Rome
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Michael Ross
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Alejandro Salado
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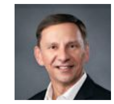

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Lockheed Martin Corporation

Michael Sangid
Purdue University

George Satornino
Sierra Lobo, Inc.

Vincent Schultz
NASA Langley Research Center

Rajnikant Sharma
University of Cincinnati

David J. Sharp
Jacobs Space Exploration Group

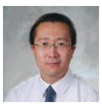
Kevin Shinpaugh
Virginia Polytechnic Institute & State University

Arvin Shmilovich
Boeing Research and Technology

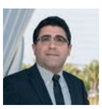
Jackelynne Silva-Martinez
NASA Johnson Space Center

Matthew Snyder
ARCTOS Technology Solutions

Weihua Su
University of Alabama



Wenting Sun
Georgia Institute of Technology



Ali Y. Tamijani
Embry-Riddle Aeronautical University

Erik Theunissen
Information Systems Delft

David Thipphavong
NASA Ames Research Center

Terri Lynn Brock Tramel
NASA Marshall Space Flight Center, Arnold Engineering Development Center, and Aerojet (retired)

Sedina Tsikata
Georgia Institute of Technology

Steve Ulrich
Carleton University

Kyriakos G. Vamvoudakis
Georgia Institute of Technology

Hemali Vyas
NASA Jet Propulsion Laboratory, California Institute of Technology

Haifeng Wang
Purdue University

Kevin Weed
Ball Aerospace

John Whittenbury
Northrop Grumman Aeronautics Systems

Douglas Wickert
U.S. Air Force

Shashank Yellapantula
National Renewable Energy Laboratory

Chih Chieh Yen
Jacobs Technology Inc.

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

AIAA

YOUR INSTITUTE, YOUR VOTE

POLLS OPEN 29 JANUARY–23 FEBRUARY 2024

Make your voice heard by participating in the upcoming AIAA Election. This year's election will continue to shape the future of the Institute as there are numerous open positions on the AIAA Council of Directors, the governing body that represents membership within AIAA. Don't forget, your vote is critical!

Visit aiaa.org/vote. If you have not already logged in, you will be prompted to do so. Follow the on-screen directions to view candidate materials and cast your ballot.

VOTE

Do not miss your chance to get involved and help select leaders that you think are best suited to lead AIAA into the future.

aiaa.org/vote

Diversity Corner

Joseph Connolly, AIAA Associate Fellow

NAME: Joseph Connolly

NOTABLE CONTRIBUTIONS: Connolly is Haudenosaunee (Iroquois) from the Six Nations of the Grand River. Out of the Six Nations comprising the Haudenosaunee, he is Onondaga and of the Wolf Clan. Connolly is the Deputy for Electrified Aircraft Propulsion Integration at NASA Glenn Research Center. He earned his B.S. in Aerospace Engineering and B.A. in Sociology from Ohio State University, his M.S. in Control Systems from Case Western Reserve University, and his Ph.D. in Aerospace Engineering from Ohio State University.

POTENTIAL SOCIETAL IMPACT OF CONTRIBUTIONS: Connolly serves as a technical lead in hybrid electric aircraft propulsion for the Hybrid Electric Thermally Efficient Core Project and the Technology Integration lead for the Electrified Powertrain Flight Demonstration Project. He also chairs the Advisory Group for Native Americans at NASA Glenn and helps with the broader Natives@ NASA support group. An AIAA Associate Fellow, he is serving as Chair of the Northern Ohio Section as well as a member of the Guidance, Navigation, and Control Technical Committee. Connolly previously led the Outreach subcommittee of the AIAA Diversity and Inclusion Working Group.

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

SAT OC's Strengthened Committee

By: Amir S. Gohardani, SAT OC Chair

The AIAA Society and Aerospace Technology Outreach Committee (SAT OC) has been busy with a variety of new activities and a growing membership. On 16 November, the SAT OC collaborated with AIAA to host the U.S. Aerospace Workforce: Obstacles and Opportunities webinar, which I moderated on behalf of Deloitte along with participation from panelists from NASA, Aerospace Industries Associations, and Stellar Solutions. This webinar was well attended, and it can be viewed on demand by going to **aiaa.org/webinars**. Also on behalf of the SAT OC, I will serve as the Deputy Technical Program Chair for the Space and Sustainability topic at the 2024 ASCEND in Las Vegas (30 July–1 August).

The sheer strength of this committee comes from its members, and I am delighted to announce that Irene Chan has been confirmed to be the SAT OC Secretary/Treasurer for the 2023–2025 term. Congratulations, Irene! Learn more about her in the SAT OC Spotlight below.

SAT OC Spotlight

Irene Chan

Irene Chan is an aerospace advocate, education enthusiast, and webmaster. She received her Bachelor of Science in Aerospace Engineering from the University of California, San Diego, and a Master of Aeronautical Science from Embry-Riddle Aeronautical University with specializations in Human Factors, Education, and Space Operations Management. She has supported the International Space Station Program Office as a web developer, Stowage Engineer, Requirements Engineer, and Flight Planning Engineer. She is transitioning to a flight planning role in NASA's Moon to Mars program.

As an AIAA Lifetime Senior Member, Chan has served in numerous student branch and section leadership capacities. In the last 13 years, she has led the Houston Section as Chair (2019–2020), Vice Chair – Operations (2017–2019), Webmaster (2012–2020), Councilor (2009–2010, 2013–2014), Secretary (2010–2012), Region IV Student Paper Conference Co-Chair (2010, 2012). You can often find Chan judging a STEAM competition, speaking about her career journey in a K-12 classroom or a virtual school engagement, tabling for NASA at a community STEAM fair, or mentoring students interested in pursuing a STEAM career.

Chan has been a member of the AIAA SAT OC since 2016. As the SAT OC Secretary/Treasurer, she hopes to leverage her gusto for AIAA, her professional and volunteer communication experiences, and her love of STEAM outreach to build on this OC's strength: fostering society's appreciation and curiosity for developments in the skies and beyond through different communication mediums and campaigns.

AIAA Announces 2024 Sustained Service Awards Winners

AIAA has announced the winners of the 2024 Sustained Service Awards. The award recognizes "sustained, significant service and contributions to AIAA." Recipients must be AIAA members who have shown continuing dedication to the interests of the Institute by making significant and sustained contributions. The 2024 winners are:

Ronald M. Barrett-Gonzalez,
University of Kansas

For continued support of AIAA in the Wichita Section, as a student branch faculty advisor, and on national technical committees.

Barrett-Gonzalez received B.S. and Ph.D. degrees from the University of Kansas in 1988 and 1993, respectively, and an M.S. from the University of Maryland in 1990 in aerospace engineering. He has authored more than 400 technical publications, holds 19 patents, and is a member of the Aircraft Design and Adaptive Structures TCs. He has served on faculties at Auburn, Alabama, TU Delft, and KU as the AIAA Student Branch Faculty Advisor.

John W. Dankanich,
NASA Marshall Space Flight Center

For continued and dedicated service to AIAA and the aerospace community.

Dankanich received undergraduate and graduate degrees from Purdue University in Aeronautical and Astronautical Engineering. He is the Chief Technologist of NASA Marshall Space Flight Center and the NASA agency Capability Lead for In-Space Transportation. He is a subject-matter expert in trajectory optimization, mission architecture design, and propulsion technology development and testing.

Stanley D. Ferguson,
The Boeing Company (retired)

For sustained service and support to the AIAA Pacific Northwest Section, national committees, technical meetings, student competitions, and STEM activities.

Ferguson retired from Boeing after a 40-year career in aerodynamic design, analysis, aircraft integration, and certification. His contributions resulted in numerous patents and awards. He received his MSE degree from the University of Washington in 1979, and BSAE from West Virginia University in 1973. Ferguson has served AIAA in local section positions, national committees, and is an AIAA Associate Fellow.

Kenneth Lui,
Ken's Consulting

For outstanding volunteer service to the AIAA Los Angeles-Las Vegas Section, demonstrating tireless dedication in organizing conferences, and establishing young professional, student branch, and diversity events.

Lui is Chair of the AIAA LA-LV Section and has been a Council Member since 2015. An AIAA Senior Member, he is also a member of the AIAA Space Settlement TC and the Microgravity and Space Processes TC. He obtained his Ph.D. in Applied Physics from Carnegie Mellon University and worked in institutes such as the University of Alabama, City of Hope, and UCLA. He has been a consultant for several years.

Anastasios S. Lyrintzis,
Embry-Riddle Aeronautical University

For over 35 years of sustained AIAA service, including leadership roles on committees, conference organization, and publications.

Lyrintzis has done research in aeroacoustics, authoring over 200 papers and advising 22 Ph.D. students. He has been a member and Chair of the AIAA Aeroacoustics TC, a member and Chair of the Aerospace Department Chair Association, and the Higher Education Committee. An AIAA Fellow, Lyrintzis has organized several AIAA conferences and served as an Associate Editor for *AIAA Journal*.

Kurt A. Polzin,
NASA Marshall Space Flight Center

For sustained, significant service and contributions at the local, regional, and national levels of AIAA.

Polzin received his B.S. from Ohio State University and completed his Ph.D. in Mechanical and Aerospace Engineering at Princeton University. He joined NASA Marshall Space Flight Center in 2004, and is presently the Chief Engineer for NASA's Space Nuclear Propulsion project. Polzin is an AIAA Associate Fellow and recently completed his second three-year term as Director–Region II.

Lawrence W. Stephens,
Lockheed Martin Missiles and Fire Control

For many years of impactful leadership and dedicated service to AIAA and its members at the student branch, section, regional, and national levels.

Stephens is Director of Engineering Affordability for Lockheed Martin Missiles and Fire Control. He was previously Director of Systems Engineering and then Chief Engineer for Advanced Programs and Special Programs. His contributions include system development programs in aircraft, space, and missile systems from concept studies through flight demonstrations. Stephens is an Aerospace Engineering graduate of the University of Texas at Arlington and an AIAA Fellow

Marilee J. Wheaton,
The Aerospace Corporation

For sustained contributions to the Economics and the Systems Engineering Technical Committees, for impactful service to the Fellows Selection and Honors and Awards Committees, and for technical leadership of the AIAA SPACE Forum and AIAA SciTech Forum.

Wheaton is a Systems Engineering Fellow at The Aerospace Corporation. She provides technical leadership and building capability to include enterprise systems engineering, digital engineering, systems architecting, and model-based systems engineering. Wheaton is a 2008 AIAA Fellow, and she is also a Fellow and current President of INCOSE, and a SWE Fellow and Life Member

MAKING AN IMPACT

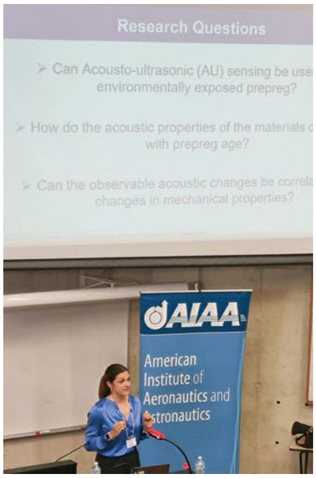
University of New South Wales Canberra Hosts 2023 AIAA Region VII Student Conference

AIAA is pleased to announce the winners of the 2023 Region VII Student Conference, held 27-28 November 2023, at the University of New South Wales Canberra and online.

Attendees presented 39 papers and represented 19 universities from 11 countries, including Australia, Bangladesh, Brazil, India, Saudi Arabia, South Korea, Thailand, Turkey, the United Arab Emirates, the United Kingdom, and the United States of America.

Students presented papers in three categories: undergraduate, masters, and high school. Their presentations were evaluated by experienced aerospace professionals. Additionally, the papers presented by university students will be published by AIAA and available on Aerospace Research Center (ARC) starting in January 2024.

For the undergraduate and masters categories, first-place winners received a cash prize of $500 and an invitation to participate in the International Student Conference at the 2024 AIAA SciTech Forum, 8-12 January. Second-place winners received a cash prize of $300 and third-place received $250. The high school students received $100 for first place, $75 for second place, and $50 for third place.



High School Category

1st Place: Cheney Wu and Nate Osikowicz, Cranbrook Schools, Bloomfield Hills, MI, "Exploration of Tensegrity Applications in Airfoil Designs"

2nd Place: Baldwin Chen, American International School of Dhaka, Bangladesh, "Regression Rates of Non-liquefying Fuels in a Hybrid Rocket Engine at Atmospheric Pressure"

3rd Place: Zhishan Lu, Bard College at Simon's Rock, Great Barrington, MA, "The Development and Application of Air-launch Technology"

Undergraduate

1st Place: Georgia Warren, University of New South Wales Canberra, Australia, "Development and Testing of a Stereo Photogrammetry System for Multi-Axis Optical Tracking of Free-Flight Models"

2nd Place: Alexandra Stewart and Graham Wild, University of New South Wales Canberra, Australia, "A Historical Analysis of Military Action against Civilian Aircraft"

3rd Place: Johnny Chen and KC Wong, University of Sydney, Australia, "Design of a Span Morphing Wing for a Blended Wing Body UAV"

Masters

1st Place: Jiwon Lee and Youdan Kim, Seoul National University, South Korea, "NMPC-based Control Deign for Transition Flight of Fixed-Wing VTOL UAV"

2nd Place: Lok Yan Poon, University of New South Wales Sydney, Australia, "Renewable Natural Fibre Reinforcement Development"

3rd Place: Bader Ayran and Abdullah Barakat, Istanbul Technical University, Turkey, "Propulsive Landing of a 6DoF Variable Mass Rocket System using Real-Time Nonlinear Model Predictive Control"

AIAA's student conferences are an opportunity for students to present and publish their work in front or their peers and members of the industry. Each of AIAA's seven regions host one conference each year. The Regional Student Conferences for Regions I-VI will take place in spring 2024.

AIAA would like to thank Lockheed Martin for supporting the program. Additionally, special thanks to the University of New South Wales Canberra, the Sydney Section, the judges, Professor Graham Wild, Professor Charlie Hok, Tjasa Boh Whiteman, and Region VII Director Cees Bil for coordinating the conference.

Attend the Teacher Workshop at AIAA SciTech Forum

During 2024 AIAA SciTech Forum in Orlando, FL, AIAA invites local educators to attend a professional development workshop where they can experience hands-on learning concepts to take back to their classrooms. Participants will hear from educators and engineers about the emerging aerospace challenges of the 21st century and learn about the incredible opportunities that exist for elementary, middle, and high-school educators to introduce your students to advanced STEM concepts, both through integrated projects and through newly developed standards-based curriculum.

There are additional opportunities for educators to network with colleagues and learn about AIAA's classroom grant funding and educator recognition programs.

When: Thursday, 11 January 2024, 0800–1400 hrs ET USA | **Where:** Hyatt Regency Orlando, Florida

To be eligible for this free registration, the attendee *must* be a K-12 educator (this includes classroom, out-of-school time clubs, active homeschool educators, and museum facilitators).

To register for free, sign up here: **https://forms.gle/UZDoqSZXGTbLJQ3Z8**. Reach out to K-12 Programs Manager Jake Williams at JakeW@aiaa.org with any questions.

AIAA Foundation Day of Giving Makes an Impact

The AIAA Foundation hosted its second annual Day of Giving on 28 November 2023. We are pleased to share that with the help of 68 donors we raised $62,000. The support of our members plays a critical role in the success of our student and educator programs. Thank you to the AIAA community. To donate to the AIAA Foundation, please visit **www.aiaa.org/foundation**.

Obituaries

AIAA Fellow Reed Died in August 2021

Wilmer (Bill) H. Reed III died on 26 August 2021. He was 95.

After high school Reed enlisted in the U.S. Navy, became a Naval Aviator, and earned his B.S. in Aeronautical Engineering at Auburn. In 1948, he was hired directly by NACA at Langley Research Center as an Aeronautical Research Engineer. He received his M.S. in Aeronautical Engineering from the University of Virginia in 1953.

Reed specialized in aeroelasticity and load analysis, creating engineering solutions that made supersonic flight and space exploration possible and more efficient, by streamlining and redesigning rocket and wing configurations and damping vibration (flutter). He became Chief Scientist at NASA, contributing 28 global patents and publishing 40 scientific articles. His work revolutionized the study of wind tunnel modern flight dynamics, and he received the NASA Exceptional Service Medal and eight NASA Special Achievement Awards.

After retiring from NASA in 1982, he worked as a scientist, consultant, and speaker for Dynamic Engineering Inc., where he invented the "Flutter Exciter," making commercial and military aircraft more efficient and safer. Reed was then a Representative Engineer for the FAA until his retirement in 1998.

An AIAA Fellow, Reed was recognized with three AIAA Engineer of the Year Awards from 1995 to 1997.

AIAA Associate Fellow Davis Died in September

William Robert (Bob) Davis Jr. died 1 September 2023. He was 76 years old.

Davis earned a B.S. in Engineering from Lehigh University followed by a Masters and Ph.D. in Aeronautic and Astronautic Engineering from MIT. After serving four years in the U.S. Air Force, retiring as a Captain, Davis joined MIT's Lincoln Laboratory where he enjoyed a 43-year career, retiring in 2020 as Assistant Head of the Engineering Division.

AIAA Member Lingenfelter Died in July

Lieutenant Colonel Andrew J. Lingenfelter, USAF, died on 19 July. He was 37 years old.

Lingenfelter studied at the University of Nebraska in Lincoln on an Air Force ROTC scholarship. After graduating with a degree in mechanical engineering, he started his first job at Eglin Air Force Base as a 2nd Lieutenant, kickstarting an over 14-year career in Air Force Acquisitions.

In 2011, Lingenfelter earned a master's degree in industrial and systems engineering from the University of Florida. In 2016, he earned a Ph.D. in aeronautical engineering from the Air Force Institute of Technology.

Lingenfelter won several Air Force awards for his research, papers, videos, and athletics. He was based at Wright-Patterson Air Force Base.

He was also the recipient or co-recipient of several best paper awards presented at the AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, AIAA Aerospace Sciences Meeting, and AIAA SciTech Forum (2015, 2016, 2018). Lingenfelter had been a member of the AIAA Survivability Technical Committee for six years and served as Secretary (2020–2022) and Vice Chair (2022–2023).

AIAA Associate Fellow Spann Died in September

Richard E. Spann died on 25 September 2023. He was 89 years old.

Spann attended Columbia University where he received both a B.A. in 1956 and a B.S. in Chemical Engineering in 1957. Having been in the ROTC program, he was commissioned a 2nd lieutenant in the U.S. Air Force upon graduation and stationed at Wright-Patterson AFB.

His time in the Air Force was spent helping develop solid rocket fuels for various systems including the Minute Man missile. In 1959 the propellant office was moved to what became known as The Rocket Site at Edwards AFB and he transferred to California.

In 1971, Spann decided to go to law school, enrolling at Loyola Law School in Los Angeles and graduating with a Juris Doctor degree in 1974. After passing the bar exam on the first try, he practiced law in Lancaster until 1989, when he was appointed as a Judge of the Municipal Court of Los Angeles County. In 2001, the state combined the Municipal and Superior Courts so Spann spent the remainder of his judicial career as a Superior Court Judge.

Astronaut and AIAA Fellow Borman Died in November

Frank Borman, commander of NASA's 1968 Apollo 8 spaceflight, whose astronauts became the first men to orbit the moon, died on 7 November. He was 95.

Borman was fascinated by aviation from a young age, obtaining his pilot's license at age 15. He graduated from West Point in 1950, and became an Air Force fighter pilot. After receiving a master's degree in aeronautical engineering from the California Institute of Technology in 1957, he became a test pilot and helped develop spaceflight testing programs for future astronauts at Edwards Air Force Base in California.

He was named to the Gemini group of astronauts, who followed the original Mercury Seven, in September 1962. In December 1965, he commanded the two-man Gemini 7 spacecraft with astronaut Jim Lovell on a 14-day flight. Gemini 7 took part in a pioneering rendezvous 185 miles above Earth when Gemini 6A caught up to it and flew alongside it in orbit. That kind of maneuver had to be perfected in order for a lunar module to descend to the moon from an orbiting command ship and later blast off from the lunar surface, then rendezvous and link up with the mother ship for the trip back to Earth.

After the January 1967 Apollo 1 fire that killed three astronauts, Borman served on the Apollo 204 Fire Investigation Board. He later became the Apollo Program Resident Manager, heading the team that re-engineered the Apollo capsule. He also served as Field Director of NASA's Space Station Task Force.

The Apollo 8 mission, including Borman (as commander), Lovell, and William A. Anders, was only the second manned flight in the Apollo program. It was also the first manned flight employing the hugely powerful Saturn 5 rocket for liftoff. Apollo 8 carried the three astronauts farther from Earth than anyone had ever traveled. It orbited the lunar surface 10 times, flying nearly 60 miles above its surface, to photograph a bleak and rock-strewn terrain, seeking potential landing spots for the moonwalks to come.

Borman retired from the Air Force and NASA in 1970. He held several positions at Eastern Airlines before being named chairman in 1976.

Borman later became chairman of Patlex Corporation, a holder of patents on laser technology, and flew antique planes.

Among his many awards, Borman was the recipient of the 1968 Robert J. Collier Trophy. In 1970, he and William Anders were co-recipients of the AIAA Haley Space Flight Award.

AIAA Associate Fellow Jurczyk Died in November

Steve Jurczyk, former NASA associate administrator, died 23 November. He was 61.

He graduated from the University of Virginia where he received Bachelor of Science and Master of Science degrees in Electrical Engineering in 1984 and 1986, respectively.

Jurczyk joined NASA in 1988 and rose through the ranks at NASA Langley Research Center, becoming center director in 2014. A year later he went to NASA Headquarters as associate administrator for space technology, and in 2018 became associate administrator. In that role, he led NASA's response to the COVID-19 pandemic in 2020.

He became acting administrator in January 2021 at the start of the Biden administration, serving in that role until the beginning of May, when Bill Nelson was confirmed by the Senate and sworn in as administrator. His brief tenure was highlighted by the successful landing of the Perseverance rover on Mars and the first crew rotation of commercial crew vehicles at the International Space Station as Crew-2 relieved Crew-1.

Jurczyk was the recipient of the NASA Distinguished Service Medal, two Outstanding Leadership Medals, the Presidential Rank Award for Meritorious Executive in 2006, and the Presidential Rank Award for Distinguished Executive in 2016. He was also a 2021 Service to America Medal "Sammies" finalist, one of the highest honors for federal civil servants, in the management excellence category for his leadership during the COVID-19 pandemic.

Jurczyk retired from NASA in May 2021. He became one of the co-founders of Quantum Space, a startup that announced plans in 2022 to develop robotic platforms in cislunar space. He led Quantum Space until June 2023, when he became executive vice president of IBX, a company established by Quantum Space co-founder Kam Ghaffarian whose portfolio includes commercial space station developer Axiom Space and lunar lander company Intuitive Machines.

AIAA Student Branches, 2023–2024

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

FA = Faculty Advisor
SBC = Student Branch Chair
* = Provisional Charter

Region I

American Public University System
FA: Kristen Miller
SBC: Anthony LaRosa

Boston University
FA: Sheryl Grace
SBC: Christopher Ayala-Bellido

Carleton University

Catholic University of America
FA: Diego Turo

City College of New York
FA: Prathap Ramamurthy
SBC: Islam McDowell

Clarkson University
FA: Kenneth Visser
SBC: Nathaniel Maitland

Columbia University
FA: Robert Stark
SBC: Nathan Coulibaly

Concordia University
FA: Hoi Dick Ng

Cornell University
FA: Dmitry Savransky
SBC: Christopher Chan

Drexel University
FA: Ajmal Yousuff
SBC: Maximilian Millenbach

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

George Washington University
FA: Peng Wei
SBC: Yazan Sawalhi

Hofstra University
FA: John Vaccaro

Howard University
FA: Nadir Yilmaz
SBC: Paa Sey

Lehigh University
FA: Terry Hart
SBC: Kevin Jun

Manhattan College
FA: John Leylegian

Massachusetts Institute of Technology
FA: David Darmofal

National Institute of Aerospace

New York Institute of Technology
FA: James Scire

Northeastern University
SBC: Cameron Bracco

Old Dominion University
FA: Colin Britcher
SBC: Phil Mantz

Pennsylvania State University
FA: Robert Melton
SBC: Jack Pence

Polytechnic Institute of Brooklyn
FA: Nicholas DiZinno

Princeton University
FA: Michael Mueller
SBC: Michael Hwang

Rensselaer Polytechnic Institute
FA: Farhan Gandhi
SBC: Kush Poddar

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

Rowan University
FA: John Schmalzel
SBC: Timothy Kuhn

Rutgers University
FA: Francisco Diez
SBC: Noah McAllister

Ryerson University
FA: Seyed Hashemi

Southern New Hampshire University
FA: Xinyun Guo

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

Stony Brook University
FA: Foluso Ladeinde
SBC: Alexis Herrera

University at Buffalo
FA: Aaron Estes
SBC: John Hudi

Syracuse University
FA: John Dannenhoffer
SBC: Sydney Jud

United States Military Academy-West Point
FA: Richard Melnyk
FA: Chalie Galliand
SBC: Gabriel Ester

United States Naval Academy
FA: Eric Brogmus
SBC: Chase Lee
SBC: Taher Telfah

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

University of Hartford*
FA: Paul Slaboch
SBC: Andrew Krebsbach

University of Maine
FA: Alexander Friess
SBC: Katherine Holmes

University of Maryland, Baltimore County
FA: Charles Eggleton
SBC: Shreyansh Kumar

University of Maryland-College Park
SBC: Kruti Bhingradiya

University of Massachusetts-Lowell
FA: Marianna Maiaru
FA: David Willis

University of Michigan
FA: Benjamin Jorns

University of Pittsburgh
FA: Matthew Barry
SBC: Carter Gassler

University of Toronto
FA: Kamran Behdinan

University of Vermont
FA: William Louisos
SBC: Seamus Howrigan

University of Virginia
FA: Christopher Goyne
SBC: Jennifer Farfel

Vaughn College of Aeronautics and Technology
FA: Amir Elzawawy
SBC: Utsav Shah

Villanova University
FA: Sergey Nersesov
SBC: Patrick Kumer

Virginia Commonwealth University*
FA: Bradley Nichols
SBC: Brenden Chaulklin

Virginia Polytechnic Institute and State University
FA: Greg Young
SBC: Akash Dubey

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

West Virginia University
FA: Christopher Griffin
SBC: Carla Posey

Worcester Polytechnic Institute
FA: Zachary Taillefer
SBC: Natanel Pinkhasov

Yale University

Region II

Alabama A&M University
FA: Zhengtao Deng

Athens State University
FA: J Wayne McCain
SBC: Brittney Smith

Auburn University
FA: Brian Thurow
SBC: Neer Patel

East Carolina University
FA: Tarek Abdel-Salam

Embry-Riddle Aeronautical University Worldwide
SBC: Roger Saurusaitis

Embry-Riddle Aero University-Daytona Beach
FA: Ebenezer Gnanamanickam
SBC: Nicholas Marshall

Florida A&M University
FA: Chiang Shih

Florida Atlantic University
FA: Oscar Curet
SBC: Jake Pearman

Florida Institute of Technology
FA: Paula do Vale Pereira
SBC: Matthew House

Florida International University
SBC: Gabriel Herrera

Florida State University
SBC: Tripp Lappalainen

Georgia Institute of Technology
FA: Dimitri Mavris
SBC: Ashish Cavale

Kennesaw State University
FA: Adeel Khalid
SBC: Cindy Vo

Louisiana State University
FA: Shyam Menon
SBC: Mary Dempsey

Mississippi State University
FA: Robert Wolz
SBC: Britain Steele

North Carolina A&T State University
FA: Michael Atkinson
SBC: Malik Henry

North Carolina State University
FA: Jack Edwards
SBC: Emily Hayman

Polytechnic University of Puerto Rico
SBC: Romulo Maldonado

Tennessee Technological University
FA: Rory Roberts
SBC: Ethan Pesterfield

Tuskegee University
FA: Mohammad Khan
SBC: Nathaniel Newsome

University of Alabama in Birmingham
FA: Roy Koomullil
SBC: Tabitha Berry

University of Alabama in Huntsville
FA: Kunning Xu
SBC: Alexander Denson

University of Alabama in Tuscaloosa
FA: Weihua Su
SBC: Zachary Herring

University of Central Florida
FA: Michael Kinzel
SBC: Mikaeel Danawala

University of Florida-Gainesville
FA: Richard Lind
SBC: Louela Carlos

University of Georgia
FA: Ramana Pidaparti
SBC: Hunter Haskins

University of Memphis
FA: Daniel Foti
SBC: Sophie Wood

University of Miami-Coral Gables
FA: Giacomo Po
SBC: Tristan Peterson

University of Mississippi
FA: Jeff Rish

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

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

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

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

University of Tennessee
FA: Damiano Baccarella
SBC: Emma Ferber

University of Tennessee Space Institute
FA: Phillip Kreth
SBC: Zane Shoppell

University of Tennessee-Chattanooga
FA: Kidambi Sreenivas
SBC: Morgan Young

University of West Florida
FA: Michael Reynolds
SBC: Ryan Ebbighausen

Vanderbilt University
FA: Amrutur Anilkumar
SBC: Zachary Friedman

Region III

Air Force Institute of Technology
FA: Marc Polanka
SBC: Emma Webb

Case Western Reserve University
FA: Paul Barnhart
SBC: David Kuhtenia

Cedarville University
FA: Thomas Ward
SBC: Virginia Clark

Cleveland State University
FA: Wei Zhang
SBC: Kevin Baldoza

Illinois Institute of Technology
SBC: Abrar Rafi

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

Kettering University
FA: Ahmed Mekky

Lawrence Technological University
FA: Andrew Gerhart
SBC: Rose Marie Gebara

Miami University
FA: Lawrence Butkus
SBC: Sawyer Martini

Michigan State University
FA: Patton Allison
SBC: Jake Rutkowski

Michigan Technological University*
FA: Kazuya Tajiri
SBC: Marcello Guadagno

Milwaukee School of Engineering
FA: William Farrow
SBC: Elizabeth Kuhn

Ohio Northern University
FA: Jed Marquart
SBC: Jennifer Zayac

Ohio State University
FA: Ali Jhemi
SBC: Maya Sivakumaran

Ohio University
FA: Jay Wilhelm
SBC: Michael Variny

Purdue University
FA: Li Qiao
SBC: Alyssa Lear

Rose Hulman Institute of Technology
FA: Matthew Riley
SBC: Tanner DeKruyter

Trine University
FA: Jon Koch
SBC: Noah Thompson

University of Akron
FA: Alexander Povitsky
SBC: Ana Clecia Alves

University of Cincinnati
FA: Bryan Kowalczyk
SBC: Matt Boller

University of Dayton
FA: Sidaard Gunasekaran
SBC: Scott Chriss

University of Illinois-Chicago
FA: Kenneth Brezinsky
SBC: Chalmers Phua

University of Illinois-Urbana-Champaign
FA: Laura Villafañe Roca
SBC: Matthew Brotnow

University of Kentucky-Lexington
FA: Alexandre Martin
SBC: Hawthorn Carson

University of Kentucky-Paducah
FA: John Maddox
SBC: Muhammad Bilal

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

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

University of Wisconsin-Madison
FA: Jennifer Choy
SBC: Julia Thormann

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

Western Michigan University
FA: Kapseong Ro
SBC: Derek Martindell

Wright State University
FA: Mitch Wolff
SBC: Caleb Wasserbeck

Youngstown University

Region IV

Lamar University
FA: Mason Li

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

New Mexico State University
FA: Andreas Gross
SBC: Preston Hager
SBC: Amber Diaz

Oklahoma State University
FA: Andrew Arena
SBC: Timothy Shoup

Rice University
FA: Andrew Meade
SBC: Nancy Lindsey

Tarleton State University*
FA: Hyedi Viehmann
SBC: Jayce Thedford

Texas A&M University
FA: Manoranjan Majji
SBC: Jackson Murphy

Universidad Autónoma de Baja California
SBC: Christian Sanchez
SBC: Juan Antonio Paz

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

University of Arkansas-Fayetteville
FA: Anthony Tello
FA: Po-Hao Huang

University of Houston
FA: Marzia Cescon
SBC: Isabel Ngiraidong

University of New Mexico
FA: Heng Zuo
SBC: Erin Lawlor

University of Oklahoma
FA: Ramkumar Parthasarathy
SBC: Luke Capehart

University of Texas at San Antonio
FA: Christopher Combs
SBC: Gianni Rossini

University of Texas-Arlington
FA: Zhen-Xue Han
SBC: Natalie Antis

University of Texas-Austin
FA: Renato Zanetti
SBC: Katherine Mueller

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

University of Texas-El Paso
FA: Joel Quintana
SBC: Andrea Galvan

Region V

Colorado School of Mines
FA: Angel Abbud-Madrid
SBC: Parmida Mahdavi
SBC: Abigail Baker

Colorado State University
FA: Ben Grier
SBC: Daniel Zhou

Fort Lewis College*
FA: William Nollet
Louise Holland

Iowa State University
FA: Shahram Pouya
SBC: Jonathan Hein

Kansas State University
FA: Scott Thompson
SBC: Mohanish Andurkar

Metropolitan State University of Denver
FA: Jose Lopez
SBC: Marcus Stengel

Missouri University of Science and Technology
SBC: Austin Sanders

Saint Louis University
FA: Michael Swartwout
SBC: Amanda Kohne

United States Air Force Academy

University of Calgary
FA: Craig Johansen
SBC: Raleigh Nolan

University of Colorado-Boulder
FA: John Mah
SBC: Conner Parker
SBC: Nikolas Ortega

University of Colorado-Colorado Springs
FA: Lynnane George
SBC: Rebekah Shepherd

University of Kansas
FA: Ronald Barrett-Gonzalez
SBC: Julio Casaleno

University of Minnesota
FA: Yohannes Ketema
SBC: Ryleigh McGiveron

University of Missouri-Columbia
FA: Craig Kluever
SBC: Graham Bond

University of Missouri-Kansas City
FA: Mujahid Abdulrahim
SBC: Kaitie Butler

Washington University in St Louis
FA: Swami Karunamoorthy

Wichita State University
FA: Linda Kliment
SBC: Megan Drake

Region VI

Arizona State University
FA: Timothy Takahashi
SBC: Lucas Guaglardi

Brigham Young University
FA: Steven Gorrell
SBC: Max Wirz

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

California Polytechnic State University-Pomona
FA: Subodh Bhandari
SBC: Sebastian Arteaga

California Polytechnic State University-San Luis Obispo
FA: Aaron Drake
SBC: Elena Felix

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

California State University-Fullerton

California State University-Long Beach
FA: Eun Jung Chae
SBC: Pedro Rendon

California State University-Northridge
FA: Peter Bishay
SBC: Donovan Hanna

California State University-Sacramento
FA: Ilhan Tuzcu

Embry-Riddle Aeronautical University Prescott

Northern Arizona University

Oregon State University
FA: Roberto Albertani
SBC: James Shea

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

San Diego State University
FA: Pavel Popov
SBC: Steven Nikolov

San Jose State University
FA: Periklis Papadopoulos
SBC: Svitlana Kuklenko

Santa Clara University
FA: Mohammad Ayoubi
SBC: Kevin Zhang

Stanford University
FA: Stephen Rock
SBC: Guillem Casadesus Vila

University of Alaska Fairbanks
SBC: Casey Lambries
FA: Michael Hatfield

University of Arizona-Tucson
FA: Jekan Thangavelautham
SBC: Matthew Banko

University of California-Berkeley
FA: Panos Papadopoulos
SBC: Yamilex Cruz Ramirez

University of California-Davis
FA: Zhaodan Kong
SBC: Shreya Chandra

University of California-Irvine
FA: Jacqueline Huynh
SBC: Vishnu Rajasekhar

University of California-Los Angeles
FA: Jeff Eldredge
SBC: Kate Oberlander

University of California-Merced
FA: YangQuan Chen
SBC: David Millet

University of California-San Diego
FA: Mark Anderson
SBC: Seth McLaughlin

University of Idaho

University of Nevada-Las Vegas
FA: Matthew Pusko
SBC: Christian Yuan

University of Nevada-Reno
FA: Aditya Nair
SBC: Jeremy La Porte

University of Southern California
FA: Geoffrey Spedding

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

University of Washington
FA: James Hermanson
SBC: Josephine Wilson

Washington State University
FA: Jin Liu

Region VII

Beihang University
SBC: Jing Pu

British University in Egypt

Cairo University

Chulalongkorn University
FA: Joshua Staubs
SBC: Supakorn Suttiruang

Emirates Aviation University

Ghulam Ishaq Khan Institute of Engineering Science and Technology

Hindustan University

Hong Kong University of Science & Technology
FA: Larry Li
SBC: Ho Hung Kan

Indian Institute of Technology Kanpur

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

Istanbul Technical University
FA: Bariş Başpinar

Khalifa University of Science Technology and Research
FA: Ashraf Al-khateeb
SBC: Fatema Almarzooqi

King Fahd University of Petroleum and Minerals*
FA: Ayman Abdallah
SBC: Housamaldean Alhoussawi

Korea Advanced Institute of Science and Technology
FA: Eunji Jun
SBC: Yiseub Yun

Middle East Technical University

MLR Institute of Technology

Monash University
FA: Daniel Edgington-Mitchell
SBC: Sweta Balakrishna

Moscow Aviation Institute

Nagoya University

Nanjing University of Aeronautics and Astronautics

Nitte Meenakshi Institute of Technology*
FA: Vinayaka Nagarajaiah
SBC: Tushar Shetty

Northwestern Polytechnical University

Queen's University Belfast

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

Sapienza Universita di Roma
FA: Daniele Bianchi
SBC: Alessandro Cervelli

Technion—Israel Institute of Technology

United Arab Emirates University

University of Adelaide
FA: Rey Chin
Natalie Hayman

Universidad de San Buenaventura
Eliana Hernandez

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

Universita degli Studi di Naples Federico II
FA: Francesco Marulo

Universität Stuttgart

University of Canterbury
FA: Dan Zhao
SBC: Kieran Williams

University of New South Wales
FA: Sonya Brown
SBC: Xiangyu Xu

University of Palermo

University of Queensland

University of Sydney
FA: Kee-Choon Wong
SBC: Ethan Englund

Von Karman Institute of Fluid Dynamics

JAHNIVERSE

CONTINUED FROM PAGE 64

obtaining evidence that would show that the null hypothesis is correct. The p-value is based on a test statistic, which for us is the probability of collision. A small p-value implies a small chance that the null, “all is good,” can be proven correct. Since our null says that the satellite is safe, our small p-value indicates that we’re unsure about that safety. Declaring a small chance of being able to prove something as correct is another way of saying there is uncertainty. In this case, that means there is a greater chance of incorrectly warning of a collision — a false positive. Put another way, which p-value to choose tends to depend on the rate of false positives we’re willing to tolerate. The caveat is that typically, when you have a process that generates fewer false positives or type I errors, you get an increase of false negatives or type II errors, and of course that’s not acceptable either, since a false negative in this case means you failed to notify spacecraft operators of a real collision.

Let’s first look at the consequences of false positives. Warnings that weren’t in fact needed are not benign. They can be economically and environmentally devastating. Satellites are directed to alter their trajectories or perform evasive maneuvers, incurring unnecessary costs and potentially disrupting critical services. Ironically, maneuvering needlessly creates new risks of collision: The operators could miscalculate their deconfliction maneuvers or unwittingly steer into the path of debris, given our currently incomplete knowledge about the tracks of these objects. This situation demands a reevaluation of our current space traffic management strategies.

We must select a p-value that helps us control the false positive or type I errors, but we also want zero type II errors or false negatives. That is to say, we want zero collisions to go unpredicted. But zeroing out type II errors tends to result in more type I errors and thus means we get lots of collision warnings that are not physically possible or meaningful. This then desensitizes the spacecraft operator community and makes the warnings unactionable and easy to ignore, an undesired outcome given that mixed among them are what could turn out to be legitimate warnings.

A solution would need to focus on processes, methods, and data that reduce type I errors without increasing type II errors. This might be achieved by refining the algorithms used to generate conjunction data messages, incorporating advanced machine learning techniques, and successful use of artificial intelligence. By fine-tuning these algorithms, we may be able to reduce the occurrence of false positives, ensuring that satellite operators receive warnings only when the probability of a collision is genuine. Simultaneously, efforts should be directed toward minimizing type II errors, as the consequences of missing a real collision would be catastrophic.

Collaboration among space agencies, satellite operators and experts in space debris mitigation is essential. A unified effort to improve the accuracy of conjunction data messages will enhance the overall reliability of space traffic management. Research and development initiatives should prioritize the exploration of innovative technologies that can discern between benign close approaches and genuine collision risks.

No country can solve this alone. International cooperation must be fostered to standardize procedures and share data. The global nature of space activities demands a unified approach to space traffic management, where information is seamlessly exchanged and effective practices are universally adopted.

As we stand at the forefront of a new era of space exploration, it is crucial to address the challenges that threaten to hinder our progress. By acknowledging the prevalence of false positives in conjunction data messages, we pave the way for a more effective and sustainable approach to space traffic management. Only striking the right balance between error types can we ensure the safety and longevity of our orbital environment. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1924

Jan. 2 A regular passenger and mail service begins between Buenos Aires and Montevideo, subsidized by the Argentine government. The Sociedad Rioplatense de Aviation flies Vickers Viking amphibian flying boats equipped with Napier Lion engines between the two harbors, **Aviation**, Feb. 11, 1924, p, 157.

1 **Jan. 16-17** The USS Shenandoah, the ZR-1 airship, is landed at a hangar in Lakehurst, New Jersey, nine hours after breaking away from its steel mooring mast during a heavy rain and a 110 kph wind storm. The airship sustains some structural damage, but the U.S. Navy Bureau of Aeronautics calls the recovery "one of the most remarkable instances of successful operation of the Dirigible" and says it "conclusively establishes the fact that the airship can be successfully handled in heavy rain storms and wind of great velocity." **Aeronautical Digest**, March 1924, p. 165; **Aeronautical Digest**, Feb. 1924, p, 83.

Jan. 20 Soviet astronautical pioneer Friedrich Arturovich Tsander presents a lecture on "Flights to Other Planets" to the theoretical section of the Moscow Society of Amateurs of Astronomy. He proposes a combination airplane and rocket for interplanetary flight to Mars and Venus and gives estimates of the rocket's performance and the temperature, pressure, velocities and internal friction of the engine. Tsander also proposes forming a "Society for the Study of Interplanetary Travel," which he establishes later this year with Konstantin Tsiolkovsky. F. A. Tsander, **Problems of Flight By Jet Propulsion** (NASA Technical Translation, TTF-147), pp. 18-19.

Jan. 29 Raúl Pateras Pescara flies his helicopter for 10 minutes, 33 seconds while attempting to win the 10,000-franc French Aero Club prize for the first 1-kilometer helicopter flight in a closed circuit. Although the performance sets a new record, Pescara's helicopter is disqualified when a sudden gust of wind causes the tailskid to touch the ground momentarily. **Flight**, Feb. 7, 1924, p, 77; **Aviation**, March 3, 1924, p, 236.

Also during January The Aeromarine metal flying boat, Morro Castle II, begins a 4,800-kilometer (3,000-mile) flight from Keyport, New Jersey, to Puerto Rico and other Caribbean islands. The flight is the first by a commercial amphibian aircraft between the New York area and Puerto Rico and the longest yet for the Morro Castle II, piloted by C.J. Zimmerman, brother of the plane's designer, Paul Zimmerman. **Aviation**, Jan. 28, 1924, p. 99; **Aviation**, March 17, 1924, p, 289.

1949

2 **Jan. 5** U.S. Air Force Capt. Charles "Chuck" Yeager completes the first and only rocket-propelled ground takeoff by an American supersonic research aircraft. Flying the first Bell X-1 from Muroc Dry Lake in California, he attains an altitude of 23,000 feet within 100 seconds of engine ignition, then glides back to a landing. Yeager was one of the recipients of the 1947 Robert J. Collier Trophy for his pioneering supersonic flight in the Bell X-1 that year. Richard P. Hallion, **Supersonic Flight**, pp. 114-115; **Aviation Week**, Jan. 17, 1949.

Jan. 18 The prototype of Westland Aircraft's W.35 Wyvern naval strike aircraft makes its first flight powered by a Rolls-Royce Clyde R.C. 3 turboprop engine. The test flights are to help Westland determine whether the Clyde or the Armstrong Siddeley Python turboprop will power the production version of the W.35, derived from the piston-powered W.34 Wyvern TF.1. The flight is cut short when a fuel leak causes the cockpit to fill with smoke. Rolls later cancels development of the Clyde engines and Westland chooses the Python turboprop engine. The Wyvern becomes the world's first turboprop-powered combat aircraft to enter military service. William Green and Roy Cross, **The Jet Aircraft of the World**, p. 92.

Jan. 26 The USS Norton Sound, the U.S. Navy's first experimental missile landing ship, starts launching trials by firing a Republic Loon pulsejet missile offshore from the Naval Test Center at Point Mugu, California. **United States Naval Aviation 1910-1970**, p. 168.

Also during January Jet pioneer Sir Frank Whittle predicts that a British jet transport will appear within three years. He says turbojets will decrease overall aircraft maintenance expense by 60-70%, and that, with proper encouragement, British manufacturers might capture the jet transport market. **Aviation Week**, Jan. 24, 1949, p. 32.

Also during January Philco engineers install a television set aboard a Capital Airlines Douglas DC-4, which flies nonstop between Washington and Chicago. **Aero Digest**, January 1949, p. 68.

1974

Jan. 1 Josef Boehm, one of the members of Wernher von Braun's team that developed the V-2 rocket, dies at 65 in Huntsville, Alabama. Boehm, like others on the original von Braun team, came to the U.S. after World War II under Project Paperclip, in which the U.S. government recruited German and Austrian engineers and scientists. He was instrumental in designing and engineering early U.S. spacecraft, beginning with Explorer 1, the country's first satellite that was launched in 1958. Boehm later was chief of the Electromechanical Engineering Division at NASA's Marshall Space Flight Center in Alabama and played a major role in developing the Skylab Workshop's Apollo Telescope Mount. **The Marshall Star**, Jan. 9, 1974, p. 4; **The Huntsville Times**, Jan. 1, 1974.

Jan. 8 A 5-million-kilometer hydrogen cloud surrounding Comet Kohoutek is photographed by an ultraviolet camera aboard a NASA sounding rocket. Launched from White Sands Missile Range in New Mexico, the Aerobee 200 reaches an altitude of 193 kilometers. Scientists theorize that the cloud was created when Kohoutek approached the sun, causing the water ice that comprises the majority of its structure to vaporize and break apart into hydrogen and oxygen atoms. **Naval Research Reviews**, January 1974, p. 29.

Jan. 8 RCA Corp. inaugurates the first U.S. domestic communications satellite service connecting the east and west coasts at 2:30 p.m. Eastern Daylight Time. Within minutes, conversations are relayed by Canada's Anik 2 satellite via a circuit leased from Telesat Canada. **Wall Street Journal**, Jan. 9, 1974, p. 34.

3 **Jan. 14** The crew of NASA's Skylab 4 mission reaches its 60th day in space, surpassing the record set by the Skylab 3 crew. Astronauts Gerald Carr, Edward Gibson and William Pogue log a total of 84 days in space before departing the station in February and splashing down in the Pacific Ocean. **NASA Johnson Space Center Oral History Project**.

4 **Jan. 18** NASA announces that the first evidence of water molecules in a comet were identified in the tail of Comet Kohoutek by Canadian scientists Gerhard Herzberg and Hin Lew, both of Canada's National Research Council. The data was collected by telescopes at Asiago Astrophysical Observatory in Italy and the Lick Observatory in California. **NASA Release** 74-13.

Jan. 24 NASA announces that scientists at Ames Research Center found more evidence that life on primitive Earth could have been triggered by chemical evolution of nonliving matter. Seventeen varieties of fatty acids, similar to those used by plants and animals to produce complex biological molecules, were discovered in two meteorites. **NASA Release** 74-16.

Jan. 25 Julian Nott and Felix Pole break the world altitude record for hot air balloons larger than 4,000 cubic meters, ascending to 13,971 meters in the 10,620-cu-m Daffodil II. The crew lifted off from Bhopoal, India, protected by a pressurized cabin and wearing special suits from the U.K. Royal Air Force. **NAA Record Book**.

Jan. 25-26 The Soviet Union conducts the first long-range tests of its SS-19 intercontinental ballistic missile with multiple independently targetable reentry vehicles. According to the U.S. Defense Department, two of the missiles are fired 7,240 kilometers from the Soviet missile research center at Tyuratam, a city in Kazakhstan, to a target area in the Pacific Ocean 1,370 km northwest of Midway Island. **New York Times**, Jan. 29, 1974, p. 1.

Jan. 27 NASA announces the discovery of hills 1,000 meters high on Mercury, as well as valleys 700 m deep and craterlike surface features 50 kilometers. Radar astronomers at the NASA-funded Jet Propulsion Laboratory identified the features during high-resolution scans. **NASA Release** 74-12.

Jan. 28-Feb. 1 The American Institute of Aeronautics and Astronautics holds its 10th Annual Meeting and Technical Display in Washington, D.C. During an honors banquet, the Robert H. Goddard Award is given to Paul Castenholz of Rockwell International Corp. and others for their significant contributions to the development of the practical liquid oxygen and hydrogen rocket engine. Other awardees include Harold Rosen of Hughes Aircraft Co., who receives the Spacecraft Design Award for contributions to the development of satellite communications systems, including the spin-stabilized synchronous-orbit spacecraft concept and commercial systems. Also during the banquet, Daniel Fink of General Electric Co. is installed as the 12th president of AIAA. American Institute of Aeronautics and Astronautics **History Newsletter**, May 24, 1974.

1999

5 **Jan. 3** NASA's Mars Polar Lander is launched by a Boeing Delta II from Cape Canaveral, Florida. The lander is designed to search for water on Mars, in conjunction with the Mars Climate Orbiter, and retrieve a soil sample to return to Earth. The lander is lost during its descent toward the Mars surface in December, which NASA later attributes to an engine failure. The Mars Climate Orbiter was lost a few months earlier as it approached Mars because navigation commands were sent in English units instead of the customary metric. NASA, **Astronautics and Aeronautics: A Chronology, 1996-2000**, p. 179.

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'The sky is falling': Let's reduce the false positives in conjunction data messages

BY MORIBA JAH | moriba@utexas.edu

Believe it or not, some satellite operators elect not to move their spacecraft when faced with an alarm about a potential collision. Why take what seems like a great risk at a time when our determination to prevent catastrophic collisions should be nonnegotiable? One reason is that nothing bad has happened so far from ignoring an alarm. Statistics tell us that luck will run out, but so far these nonmovers have yet to collide with anything.

The root of the problem is that conjunction data messages are ridden with false positives.

While I'm about to offer a suggestion for how to reduce the number of false alarms, I should underscore that even now conjunction data messages are a necessary space safety product. These alerts, generated when the probability of collision reaches or exceeds one in 1000, serve as a potential aegis against space debris-generating events. The caveat is the prevalence of false positives, or "type I errors," within these warnings.

Before we get to my suggestion, let's look at classical hypothesis testing, since conjunction analysis requires starting with hypotheses. You have a null hypothesis and an alternative hypothesis. The null is your default belief, and you only have two choices to make: You either reject the null or you fail to reject it. There are three criteria for failing to reject the null: 1) You have no evidence; 2) you have insufficient evidence; 3) you have overwhelming evidence that the null is probably true. For orbital collisions, the null hypothesis is, "All is good, and my satellite is safe."

Based on evidence and models, one needs to select the conditions by which the null would be rejected. Sometimes people use what is known in probability and statistics as p-values — a statistic that quantifies what you're concerned about testing — to indicate the likelihood of

CONTINUED ON PAGE 61

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


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