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THE DARK SIDE OF GREEN

From deep sea mining to contrails, decarbonizing aviation presents environmental dilemmas that the industry must still grapple with. PAGE 24

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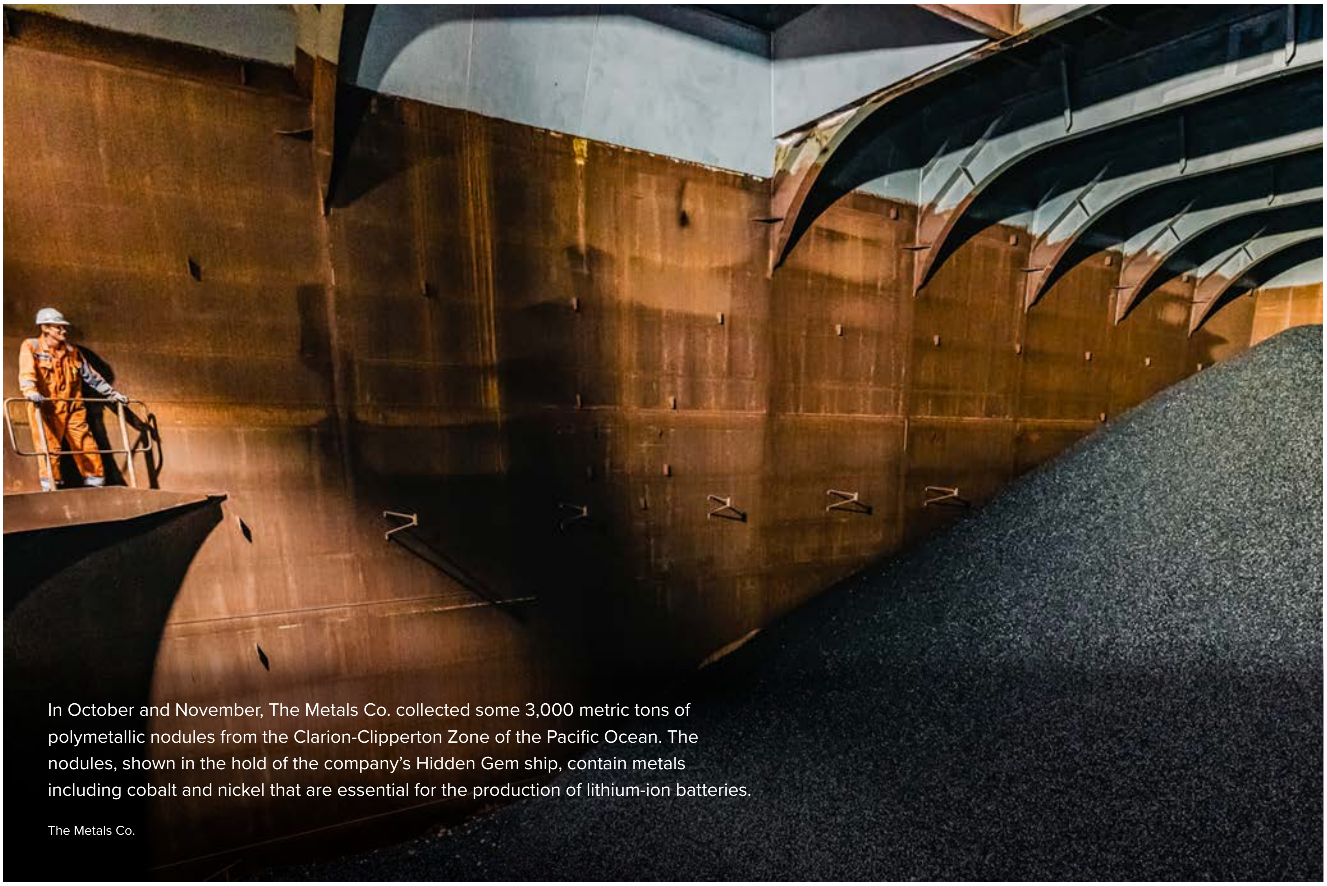

In October and November, The Metals Co. collected some 3,000 metric tons of polymetallic nodules from the Clarion-Clipperton Zone of the Pacific Ocean. The nodules, shown in the hold of the company's Hidden Gem ship, contain metals including cobalt and nickel that are essential for the production of lithium-ion batteries.

The Metals Co.

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Environmental trade-offs

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Lunar settlements? On-orbit manufacturing? Five pioneers describe what this phrase means to them.

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Studying Starship's launch pad

While SpaceX prepares for the next launch of a Starship rocket, FAA and independent experts are assessing the damage from the first test flight.

By Jonathan O'Callaghan

AEROSPACE
AMERICA

JUNE 2023,
VOL. 61, NO. 6

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Aerospace America (ISSN 0740-722X) is published monthly except in August by the American Institute of Aeronautics and Astronautics Inc., at 12700 Sunrise Valley Drive, Suite 200 Reston, VA 20191-5807 [703-264-7500]. Subscription rate is 50% of dues for AIAA members (and is not deductible therefrom). Nonmember subscription price: U.S., $200; foreign, $220. Single copies $25 each. Postmaster: Send address changes and subscription orders to Aerospace America, American Institute of Aeronautics and Astronautics, at 12700 Sunrise Valley Drive, Reston, VA, 20191-5807, Attn: A.I.A.A. Customer Service. Periodical postage paid at Reston, Virginia, and at additional mailing offices.

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IN THIS ISSUE

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Debra Werner

A longtime contributor to Aerospace America, Debra is also a correspondent for Space News on the West Coast of the United States.

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What aviation's small environmental footprint should and shouldn't tell us

A well-done feature story organizes lots of information in a logical manner but doesn't tell you, the readers, what to think. Naturally, different readers will find different insights.

I want to draw your attention to one potential takeaway from our cover story, "The dark side of green." If you read the article, you know that it refers to a study showing that aviation comprises an incredibly small percentage of the demand for the metals in lithium-ion batteries. The tempting takeaway would be that the aviation industry therefore shouldn't feel responsible for whatever bad things might happen when people scour the ocean floor or dig up the earth for the metals needed for lithium batteries; it's really all up to the automotive industry, because that's where most of the demand for metals is, and there's nothing that aviation can do about it.

On the merits, I'm not convinced that this low demand relative to the auto industry will always be the case. There are entrepreneurs who aim to have us all zipping around like the Jetsons in small electric aircraft. The revolution, in this view, will start with a few wealthy people flying the first electric air taxis, perhaps in just a couple years. The market would democratize from there over the course of years and decades. Could that happen on the scale of the auto industry? Well, some entrepreneurs are partnering with automotive companies to mass produce their aircraft, so perhaps. And what about those trucks on the highways? Why not divvy the cargo up on electric aircraft and get it where it needs to go faster and cleanly? Everything airborne, or just about. That's the message.

Do you want to be the one to tell Orville that this vision won't fly? I don't. Let's see if it does.

There is a more fundamental reason that yielding responsibility to the auto industry does not feel right. If I went through life tossing my old fishing line overboard, some birds would get tangled in it and drown. I'd be a jerk for letting that happen, but objectively speaking, the environmental impact of my actions would be limited. So why don't I litter? Because I am part of a community of anglers that respects the environment. So I discard my fishing line in the trash can and hope it doesn't end up in the sea anyway. I keep doing this, even though I find evidence of transgressions.

Likewise, the aerospace industry is part of a transportation community that has embraced sustainability. Yielding responsibility to the other guy is not being an upstanding member of the community. All must do their part, and I suspect most in the community feel this way too.

I will be surprised if many come away from our cover story thinking the aerospace industry bears no responsibility for how its batteries are produced. ★

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


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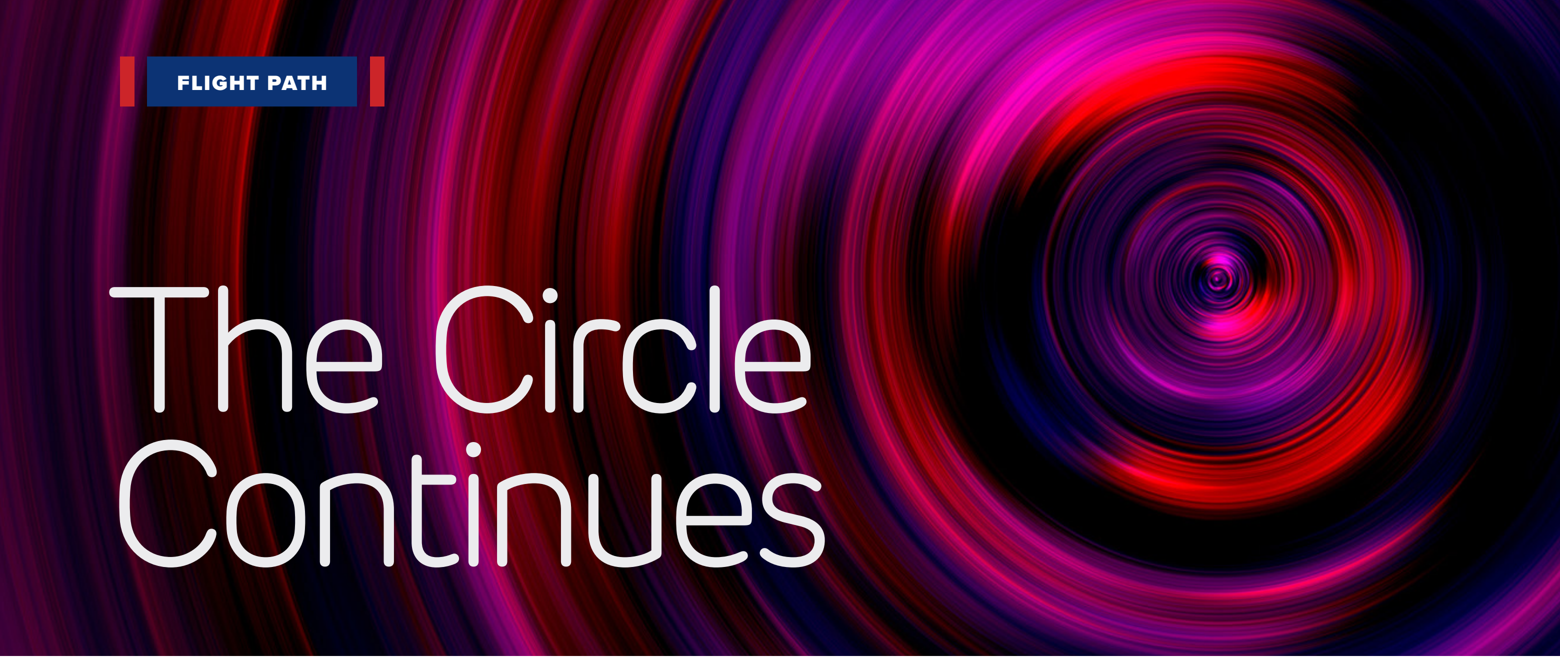

FLIGHT PATH

The Circle Continues

On a clear, starry night in May, we continued a decades-old tradition – inducting a new class of AIAA Fellows. With this ceremony, we celebrated three more accomplished professionals who were added to the storied list of AIAA Honorary Fellows, now totaling 241. We also celebrated 28 individuals joining the rank of AIAA Fellow, now totaling more than 2,000. This group of accomplished members represents an incredible body of work, advancing the state of the art in aerospace science and technology over the course of their careers. They have made a lasting difference in our world. That's what a career in aerospace does. Aerospace shapes the future for all of us.

In AIAA President Laura McGill's address to the new class of AIAA Fellows and Honorary Fellows, there was one comment in particular that resonated with me. Her words sum up the essence of AIAA membership as a circle:

> "I ask our new Fellows and Honorary Fellows to look back over the long reach of your career and remember someone who mentored you, who made you want to be part of our aerospace community, someone who pushed you to achieve, to learn, to question – and who helped you believe in yourself. Now, you must be that person to others. Be the mentor, be the encourager, and be the inspiration. Please accept this challenge as a professional responsibility."

When each of us advances, we take on this mantle of service to those who follow us. Today's leaders inspire and guide the next generation of our community, for they will become tomorrow's leaders. And so on. The circle continues.

As I listened to the remarks made by the new Fellows and Honorary Fellows, many of them included a nod to a key mentor, professor, or colleague. They looked back on their careers and could clearly remember and name individuals who were their champion, coach, encourager, guide, or inspirer. I deeply appreciate my own personal mentors – Bob Ryan, Otto Goetz, Joe Lombardo, J. Wayne Littles, John Dumbacher – and others who challenged, encouraged, and helped many continue to build for the future.

This year, we have been witnessing this circle of mentorship and encouragement in action. Accomplished professional members took hands-on roles that influenced and inspired our student members during the valuable Regional Student Conferences and the popular Design/Build/Fly (DBF) Competition. It has been a privilege and pleasure to attend some of the conferences and DBF to see this circle in action. From university faculty advisors, to judges, to organizing committees – AIAA members have stepped up at these events, volunteering their time and talents in support of the learning process for our student members. These "steps up" are more valuable than we may ever know in the moment.

While our student members are gaining practical experience presenting their research findings and receiving valuable feedback from professionals in the aerospace community, they are becoming part of the community. They are being included in meaningful ways, so they will in turn include others who follow them someday. You can meet the top winners of the Regional Student Conferences during the 2024 AIAA SciTech Forum, 8–12 January 2024, Orlando, Florida, and see for yourself what's in store for the future of our community.

In our community, we know there are new and difficult technology challenges to solve if we are to improve life here on Earth. We will be flying more sustainably, addressing climate change, and creating new opportunities by extending the human neighborhood to the moon, Mars, and beyond. Our greatest hope is to continue bringing along the next generation of innovators who will shape the future of aerospace for the benefit of ALL. The circle continues. ★

Dan Dumbacher
AIAA Executive Director

Meet the members of the Class of 2023 AIAA Fellows and Honorary Fellows at **aiaa.org/news.**

Enjoy the photos capturing the 2023 AIAA Fellows Induction ceremony in this issue of *Aerospace America* and in the online photo album: **flickr.com/photos/aiaaevents/albums**

AERO PUZZLER

Email us at aeropuzzler@aerospaceamerica.org

Birds of a feather

Q: This brown pelican is employing a strategy similar to one used by the Doolittle Raiders of World War II fame. What is the strategy and the science behind it?

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

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

FROM THE MAY ISSUE

INTERGALACTIC TRAVEL: We asked you to respond to a scientist's assertion that your clan seeking another galaxy should travel to one whose light took 13.6 billion years to reach your space telescope.

WINNER There are two points. The first is that since the light from the distant galaxy took 13.6 billion years to reach us, we are seeing the galaxy as it was 13.6 billion years ago, not as it is now. How do we know that the galaxy is still suitable? And since the galaxy will evolve for another 13.6 billion years while we are en route, will it still be suitable for us when we arrive? The second point, which works in our favor, is that because our spaceship is traveling at nearly the speed of light, we will not experience 13.6 billion years elapse if we do take the trip. Einstein's theory of special relativity says that time on a moving object passes more slowly than it does on an object at rest relative to us. The flip side of it is that a person on the moving object sees the rest of the universe "shrink" in the direction of its motion. Relative to our spacecraft when it is moving at nearly the speed of light, the distance to the galaxy will shrink to much less than 13.6 billion light years.

John Fay, AIAA Associate Fellow | Freeport, Florida

John is a subject matter expert in modeling and simulation of vehicle dynamics at Torch Technologies in Alabama, which provides engineering services to the U.S. Department of Defense, among other customers.

Reviewer Martin Elvis adds: *The universe is continuously expanding, so the galaxy is farther than 13.6 billion years away by the time its light reaches the clan's telescope. That distance will be shorter in the frame of reference of the passengers traveling at nearly the speed of light.*

This radar is poised for dramatic weight loss

BY PAUL BRINKMANN | paulb@aiaa.org

For maximum operational flexibility, tomorrow's air taxis, delivery and cargo drones will need to detect and avoid other aircraft. Honeywell Aerospace's path to answering that challenge begins with a radar panel about the size of a paperback novel.

I held one in my hand in April at Honeywell's Phoenix laboratory. It was surprising that something with so much potential to enable aircraft to fly at night, through clouds or beyond sight of their operators could be packed into such a small volume. At 1.4 kilograms, the unit seemed to have considerable heft for its size and that, it turns out, is an issue. "Our goal is to cut that weight in half," said Larry Surace, Honeywell's lead architect for advanced air mobility.

This unit was developed under the company's RDR-84k program, short for radar, 8 inches by 4 inches (20 by 10 centimeters), along with "K" for K band — the unit's operating frequency. The goal is to someday sell the coming lighter-weight versions for installation on drones of various sizes, air taxis and other small aircraft. Each will be a "standalone" detect and avoid system, in which algorithms inside the unit determine the locations of other objects. When an aircraft is equipped with multiple panels (up to seven), one will be designated as the lead processing unit to crunch the radar returns coming in from the other six.

To lighten the design, the company plans to incorporate the latest electronic circuitry behind the panel to make the unit thinner and lighter, Surace says. The dimensions of the panel's face won't be reduced because that would diminish the field of view. The RDR-84k can be electronically steered to scan 110 degrees azimuth, meaning horizontal, and 30 degrees vertical.

The version that I held has four circuit boards behind the face of the unit, while the next generation is being designed to have two. At Honeywell's location in Phoenix, engineers and technicians are working on new layouts to do this, a special concern being to dissipate heat, something that's being aided by new materials.

A 2021 flight test over the Phoenix parking lot proved the collision avoidance ability, when a drone equipped with the RDR-84k technology dodged another drone the company flew directly at it.

When could the half-weight radars be ready? Honeywell isn't offering a prediction, but intends to provide the technology to manufacturers who would seek FAA certification for their aircraft, complete with the RDR-84k technology.

"It would likely be delivery drones on a last mile trip," says Taylor Alberstadt, global sales leader for the AAM business unit. "They will need to have the capability to get around a recreational or commercial drone that might be in their path." ★

▲ The column of 16 gold squares on the right side of this radar panel transmits radio frequency waves that bounce off objects and are sensed by the receiving elements to the left of the large blank spot on the panel. Detect and avoid software inside the unit determines the location of objects. Honeywell plans to create a version for drones and air taxis.

Paul Brinkmann

Market master

Over the course of his career, Robin Riedel has gone from flying aircraft to studying those who aspire to build and operate them. A commercial airline pilot turned analyst, Riedel researches transportation trends as a partner in the McKinsey analysis firm, which has offices in 72 countries and clients from governments, industry and the investment community. Of late, Riedel has been largely focused on the emerging advanced air mobility market of electric aircraft for passenger and cargo transport, a sector whose products and services could reach a total value of $300 billion to $500 billion by 2040, according to McKinsey. How fast can the industry get there? Riedel offered me a prediction about the initial services and described the many obstacles that must be crossed for wide adoption of passenger services. I reached him at his home office near San Francisco. Here is our conversation, compressed and lightly edited. — *Paul Brinkmann*

ROBIN RIEDEL

POSITIONS: Since 2018, partner in the San Francisco office of McKinsey, co-leading the analyst firm's Center for Future Mobility established in 2015. He visits companies and works with McKinsey's consultants and researchers around the world to independently analyze the status and potential future of emerging transportation markets, including advanced air mobility. 2010-2017, management consultant at McKinsey focused on aerospace and airline aviation. 2006-2010, various positions at Air Canada, including overseeing passenger baggage policies as director of the Global Baggage Product Group.

NOTABLE: Wrote McKinsey's 2019 "Taxiing for Takeoff" article that laid out an early vision of the industry. Holds commercial pilot licenses from the European Union Aviation Safety Agency, FAA and Transport Canada and flew Airbus A320s and A321s as a contract pilot for the Blue Wings AG charter airline in Germany.

AGE: 43 on June 4

RESIDES: Orinda, California

EDUCATION: Bachelor of Science in aerospace engineering, 2004, and Master of Science in aeronautics and astronautics, 2006, both from MIT.

Q: Many electric air taxi developers envision receiving aircraft type certificates from FAA by 2024 or 2025. Tell us how such projections are panning out. Will we see commercial service soon?

A: I'm still bullish that we will see limited commercial service by the middle of the decade — so that could be '24, that could be '25 — meaning a certified aircraft that can be used for some kind of commercial mission. That doesn't mean we're going to scale up to mass production quickly. We'll need to see several iterations of aircraft, evolution of designs, before we reach mass production. We'll also need to see broader regulatory changes, the public embracing this as a new service, and development of public ground infrastructure. So, in the next few years, we will likely see one or two routes in a couple of cities. But that is still more of an initial test run than what you would call a mature, at-scale operation.

Q: What do you see as the biggest obstacles to starting commercial operations?

A: There are four major challenges. First is public acceptance. The public needs to be engaged and supportive of regulations allowing these aircraft to fly in their neighborhoods or downtown or wherever so that people understand why these aircraft are helpful, why they are not dangerous. Second is the development of regulations. Regulators have very much been helpful to the industry so far in creating pathways to get vehicles certified. But now we also need the details on how operations and pilots can be certified, and there is regulatory uncertainty around those questions still. Third is the technology itself. We are seeing electric aircraft flying now, but things like batteries and power management systems still need to advance to get to a wider, commercial scale. It is not necessarily science but engineering at this point. Fourth is really about funding and support for the industry. It's been quite fortunate in the way that it got funding and the support of the aerospace and automotive industries, but that needs to continue. Very few of the players out there today have enough funding to really get all the way to full commercial operations.

Q: Do you anticipate that some AAM players will drop out or close soon?

A: There are probably going to be a few players who cannot continue at some point, and that might take the form of them just shutting down. It might also take the form of merging with others or selling their technology. I wouldn't be surprised at all if we see a few players discontinuing this year and a few more next year.

Q: Is the goal of widespread air taxi service by 2030 still realistic?

A: By the end of this decade, we'll see a few markets in the world where we will see something that starts resembling full scale, meaning dozens of aircraft flights throughout the day. You could see a couple of the leading cities or rural areas that really kind of see the benefit of this. Maybe there's an airport route; maybe there's a route from the suburbs to a city center. But we're still going to be far away from the skies being constantly blackened by vehicles in the air.

Q: What's likely to happen first: regional service or urban service?

A: There's definitely a market for urban air mobility — eVTOLs [electric vertical takeoff and landing aircraft] flying shorter ranges, say up to 50 miles [80.5 kilometers]. Regional service, at hundreds of miles, will be the purview of extremely short takeoff and landing aircraft or aircraft powered by hydrogen fuel cells. And then there's cargo and drone delivery, which is related. I think all of these have their own potential in their own timeline, but I do think the timeline for regional air mobility is, in a way, maybe a little sooner. That's because regional mobility can leverage runways and regional airports that we already have today.

Q: How realistic are goals to fly passengers on mostly autonomous aircraft without a pilot on board?

A: It's important to define what we mean by autonomous. Is it autonomous, or is it a highly augmented aircraft that is much easier to fly? I do believe that on the

> "In the next few years, we will likely see one or two [air taxi] routes in a couple of cities. But that is still more of an initial test run than what you would call a mature, at-scale operation."

▲ Lilium of Germany last month began wind tunnel tests with a 40% scale model of its Lilium Jet at the German-Dutch Wind Tunnels facility in the Netherlands. The company is targeting 2025 for receiving type certification of its six-passenger air taxi design.

Lilium

cargo side, autonomy is going to start very early on. The U.S. military, for example, already flies multiple 100-pound-heavy [45 kilograms] drones high over our heads all the time. And you know, none of us really are bothered by that. But if you have unpiloted craft zipping around [neighborhoods], there's a bigger hurdle. For passengers, remotely piloted aircraft will take more time. I know some operators claim they can be ready for that in a few years, because it could be more cost-efficient. But it does raise questions around certification and regulation that you just don't have when you have a pilot, because piloted aircraft can use existing regulations. But I think we will see more autonomy by the end of the decade. One interesting thing to note, though, is that, historically, aviation has been very concerned about the people on board of the aircraft, right? And less so about the collateral damage on the ground because it hasn't been a big problem. Now, as we're starting to fly in urban environments more frequently, that might become a bigger focus and require some rethinking on the regulatory side as well, in terms of how we think about risk.

Q: On the topic of batteries, are we seeing the needed breakthroughs?

A: Even if all these electric aircraft plans are successful, it will still be only a fraction of the electric automobiles that are projected to be built. We're going to be in competition with the automotive manufacturers that want some of the same raw materials. And so that's going to get reflected in the price of manufacturing these vehicles.

Q: There's a lot of effort to miniaturize components and reduce weight for electric aircraft. How is that coming together?

A: We're fighting gravity all the time. But the AAM industry is helping us fund a lot of research and bring new materials and products to market, so it's really helped to accelerate innovation in aviation.

Q: Regarding workforce, will air taxi operators planning on piloted aircraft be able to recruit enough pilots?

A: It could be quite a lot of pilots when we're already short pilots for major aviation, but there are some promising developments. For one thing, if most of these air taxi flights are shorter trips, that means you can be a pilot and still go home to your family every night. That opens up the recruiting to a lot more people. If we do get to the point where we are

▲ Air taxi developer Wisk of California estimates it will take "the next several years" to receive FAA approval for its largely autonomous, four-passenger air taxi, the interior shown here. The company plans to hire "multivehicle supervisors" to monitor the aircraft from the ground and alter the flight path if needed, and install screens on the back of each seat that will display information to passengers.

Wisk

"We are seeing electric aircraft flying now, but things like batteries and power management systems still need to advance to get to a wider, commercial scale. It is not necessarily science but engineering at this point."

just monitoring highly automated aircraft, that could bring the cost of pilot training down. We can hope those trends also bring in more diversity, because right now these companies look very similar to the U.S. industry in general, with only about 15-17% of executives being female.

A 2022 workforce survey conducted by AIAA and the Aerospace Industries Association found that 30% of executives in the aerospace and defense industries were women. — PB

Q: I've frequently heard AAM executives and experts in congressional hearings warning that if FAA doesn't certify these aircraft soon, China or another country might emerge first in advanced air mobility. Is FAA under too much pressure?

A: I don't see the FAA disproportionately focusing on competition. The U.S. has a long tradition in aerospace, and so does Europe or the U.K., by the way. But the government is trying to find the right balance between furthering commerce while maintaining safety right now. The FAA's mandate is focused on safety, so I'm pretty sure they're not getting overly swayed by these considerations.

▲ Archer Aviation of California is targeting 2025 for the start of passenger service. The company has been conducting remotely piloted test flights with two of its Maker demonstrators, one shown at left, since late 2021, and plans call for beginning piloted test flights in 2024 with its Midnight production aircraft. A mockup of that air taxi is pictured here.

Archer Aviation

"Even if all these electric aircraft plans are successful, it will still be only a fraction of the electric automobiles that are projected to be built. We're going to be in competition with the automotive manufacturers that want some of the same raw materials."

Q: What do you make of the trend of AAM companies hiring former FAA staffers or government employees?

A: There's been a lot of hiring from FAA and from NASA to support these new companies, but I don't know what the history is or whether there's been an increase. At the end of the day, the agencies and the companies need good talent, and they're in a war for talent to find the best people out there. But it hasn't really hurt the agencies. I think they still have access to amazing talent, so it has not turned into a talent shortage or talent crisis yet. ★


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5 PIONEERS ON THE MEANING OF "BUILDING THE SPACE ECONOMY"

It’s a phrase uttered by old-timers, newcomers, entrepreneurs and government officials in the space industry, but what does it mean? Does it refer to people living and working in space, or to today’s construction of satellites and rockets on Earth? Is mining asteroids part of the plan? How about orbiting hotels? Debra Werner asked five space luminaries to elaborate on what “building the space economy” means to them.

BY DEBRA WERNER | dlpwerner@gmail.com

SIMON "PETE" WORDEN

Executive director of the Breakthrough Starshot Initiative, established by Stephen Hawking and Yuri Milner in 2016 to develop a fleet of microchip-sized, "ultra-fast light-driven" interstellar probes. A retired U.S. Air Force brigadier general known for bold ideas about the need to expand security measures to support economic expansion into space. A former director of NASA's Ames Research Center in California, Worden holds a Ph.D. in astronomy from the University of Arizona, where he was a research professor.

"THE SPACE ECONOMY BEGINS WHEN WE START HAVING SUBSTANTIAL OPERATIONS IN CISLUNAR SPACE, WHETHER FOR SECURITY OR ECONOMIC ACTIVITY."

I wouldn't say we have a space economy yet. When I go to meetings and they talk about all the things they're doing in low-Earth orbit, I think, "Those are just high-flying airplanes." Not that they're not important. In geosynchronous orbit, you're fiddling around in the harbor of the space economy. Maybe you can get fish in the harbor and put booms across the harbor entrance for defense. The space economy begins when you have settlements. You're providing things that came from space to other things in space. I think in a decade, the space economy will just be beginning. It will expand by the middle of the century to the inner solar system and maybe beyond.

The space economy begins when we start having substantial operations in cislunar space, whether for security or economic activity. Within a decade, we're going to start to see settlements on the moon. At that point, the space economy will be bringing something back to the Earth from cislunar space. The initial product is obviously information, but ultimately, there could be other things. First, it will be what resources are there and what competitors might be doing — if there are competitors in cislunar space — whether they're security competitors or economic competitors. An analogy is the Age of Exploration that began in the 1400s. The first thing is just information: What's there? What are our competitors doing? And then ultimately, are people going to go there? There may be products that are found on the moon that are useful. The initial products will be fuel that comes from water for propulsion and then fuel to support the human habitation on the moon.

Eventually, the resources might come from near-Earth asteroids or comets that are rich in water. After water, I suspect that the next product will be platinum group metals. Today, to get these things that are essential for the terrestrial economy, we have to dig ever deeper into the Earth's crust. Is it cheaper to dig down 5 kilometers or get the stuff in space? It may turn out the moon is important for that too. There was a demonstration many years ago by John Lewis [professor emeritus of planetary science at the University of Arizona's Lunar and Planetary Laboratory]. He had a little vial of lunar regolith that had been brought back from Apollo. He took a magnet over this little glass tube, and you could see these filings jump up. He said that the regolith is not very rich in metals, but it's been hit by micrometeorites, a few percent of which are metal, over billions of years. So, there's a fairly extractable quantity. Those metal fragments are natural alloys of iron, nickel and cobalt, but they will have a certain content of platinum group metals.

BRENT SHERWOOD

Senior vice president for advanced development programs at Blue Origin, overseeing initiatives including development of the Orbital Reef space station and efforts to establish permanent lunar operations. A pioneer in the field of space architecture, Sherwood led the Jet Propulsion Laboratory Innovation Foundry and developed human and robotic mission concepts for Boeing. An AIAA associate fellow, he holds a master's degree in architecture from Yale University and a master's in aerospace engineering from the University of Maryland.

The space economy centers around continued governmental investment in fundamental exploration and pure research, and hopefully also continued and perhaps increased government investment in basic technologies. Because as you know, the technologies to do amazing things in space are different from the ones that we need on Earth, and there's a high bar to invest in those things. Investment from both domestic agencies and foreign nation agencies should be steady and grow slowly.

On top of that, we want to see multiple wedges, new business segments that start small and have the potential to grow. Some of them will grow much faster than the continued growth of government investment. Then you get to the question, "What is commercial business in space?" A super good example, which we tend to overlook, is telecommunications and Earth remote sensing from geostationary orbit. It was pioneered by governments, but then look at how that mushroomed as a commercial business. A lot more billions of dollars are flowing from private capital into that business than from government sources.

There is a wedge that has started out very small, and I personally believe should be able to grow pretty aggressively: That is tourism. It's still super expensive. The systems aren't as reliable altogether as you'd like for flying private passengers, but reliability and amenities will increase, and costs will continue to come down. There is a large population of high-net-worth individuals in the world who can become the beginning of that tourism market. The way I see it is adventure travel leads to tourism. Adventure travel is climbing Mount Everest. Tourism is taking a cruise ship to the Arctic. Then, eventually maybe I want a condo in space or one-twelfth of a condo in space with 11 other people who also live there for a month of the year, with the best view in the solar system and an amazing address and all those things that we know about microgravity.

"HOWEVER MANY PEOPLE TRAVEL TO MARS, WE WILL HAVE 100 TIMES THAT MANY PEOPLE ON THE MOON. AND FOR EVERY PERSON WE HAVE ON THE MOON, WE WILL HAVE 10,000 TIMES THAT IN EARTH ORBIT. THE ECONOMICS SIMPLY DRIVE THAT."

The question of where people will go in space is very clear to me. However many people travel to Mars, we will have 100 times that many people on the moon. And for every person we have on the moon, we will have 10,000 times that number of people in Earth orbit. The economics simply drive that. I can't make a business case for tourism to Mars or any other business to Mars. It's too far away. It's too expensive. It's too uncertain. NASA hasn't even pioneered it yet for humans. For the moon, I can imagine a time decades from now when there begins to be tourism to the moon the same way we're already seeing tourism in LEO. By the time that happens, there will be lots of tourists in LEO routinely, every few weeks, every month, with some of them staying there for a long period of time.

CHIARA MANFLETTI

Professor of space propulsion and mobility at the Technical University of Munich, and director and chief operating officer of Neuraspace, a Portuguese company founded in 2020 to help satellite operators dodge debris and other satellites with artificial intelligence. Inaugural president of Portugal Space and a former head of policy and program coordination for the European Space Agency, where she devised ESA's campaign to pay for active debris removal. She holds a Ph.D. in aerospace engineering from Germany's Rhine-Westphalia Technical University of Aachen.

"HUMANS ARE NOT REALLY SPACEWORTHY. RADIATION, PRESSURE AND A LACK OF GRAVITY ARE PROBLEMS FOR US. WE TRY TO CONQUER SPACE, BUT OUR BODIES ARE NOT QUITE AS FLEXIBLE AS OUR SOULS AND OUR MINDS."

In the future, the space economy will be totally integrated with the terrestrial economy, with increased dependence of many industries — transport, health care, telecommunications, agriculture, banking — on space resources and services. When I was leading Portugal Space, I had conversations with telecommunication providers. They were so focused on ground infrastructure that they saw space as being in competition. It isn't. It provides services that they can't provide on the ground. When I think about the space economy, it's space no longer being the bubble that is discussed by a very tiny community. I see this bubble breaking, and I see space completely integrated with everything else.

Space infrastructure will become a lot more autonomous, a lot more resilient. Things will be manufactured in space. I'm not sure I believe in asteroid mining for the purpose of taking materials from asteroids and bringing them down to Earth. I'm sure that there will be someone doing it, but for me, it seems a lot more straightforward to take materials in orbits and then use them to make something else in orbit. There will be spacecraft refueling services. Space will become part of our economic sphere of influence more than it is today.

Going further into the future, people will use commercial space stations for producing materials, medicines and all sorts of other things. I think that the robotic side of space exploitation is going to be a lot stronger than the human side for sure. Humans are not really spaceworthy. Radiation, pressure and a lack of gravity are problems for us. We try to conquer space, but our bodies are not quite as flexible as our souls and our minds.

One of the big question marks is how political difficulties that we experience on Earth will have an impact on how the space economy is going to develop. Will it be a truly commercial economy, or is it going to be driven a lot by institutional sovereignty? How much is it going to be driven by ambitions of governments?

I tell my students that the space economy will definitely happen in their lifetimes. Teachers need to pass to their students a message that is optimistic of what the future will bring, so the students channel their energy toward something positive. I also tell them about policy difficulties, so they know what kind of hurdles they will have. But I want them to become the great leaders that we need to make all of this happen sooner rather than later.

JEFFREY MANBER

President of international space stations for Voyager Space, the Denver company that is developing the Starlab commercial space station. Pioneered commercial space tourism and research as CEO of MirCorp, a private venture that sold research space aboard Russia's Mir space station; managing director of Energia USA, the now defunct U.S. arm of the Russian spacecraft builder; and Nanoracks, which continues to build spaceflight hardware and arrange for experiments on the International Space Station. He holds a bachelor's degree in psychology from Northwestern University.

"IN THE NEXT DECADE, YOU SHOULD HAVE 10 COMMERCIAL DESTINATIONS WITH AMPLE DOMESTIC AND INTERNATIONAL VEHICLES GOING THERE. YOU WILL ALSO HAVE INTER-ORBIT SPACE TUGS. THE FUTURE IS BRIGHT FOR THE LOW-EARTH ORBIT ECONOMY."

The coming of age of the low-Earth orbit economy in the next 20 years is going to be a wonderful thing to witness. You have all the ingredients coming together: You have robust transportation to and from low-Earth orbit for cargo. Soon you will have multiple commercial carriers for humans. And equally exciting, you will have multiple destinations. In my view, there will be two to three U.S.-owned commercial space stations. India and China will have space stations. There will be a couple of surprises too: space stations from other sovereign nations and maybe a space station from a consortium of companies. In the next decade, you should have 10 commercial destinations with ample domestic and international vehicles going there. You will also have inter-orbit space tugs. The future is bright for the low-Earth orbit economy. The foundation is being put in place right now.

The first generation of commercial space stations will be driven by the NASA Commercial Lunar Destinations program. Starlab will be focused on research, biopharmaceuticals, manufacturing, agriculture. We want to offer the astronauts of the International Space Station partners that exist today — unfortunately, except for Russia — and new players access to fantastic state-of-the-art facilities. We have Hilton Hotels as a partner, designing a state-of-the-art habitat so you can live and work comfortably. In the second generation of commercial space stations, NASA will not be the guiding customer. You will see more advances like a robotic platform for very interesting and delicate work. It could be in biomaterials or thin film wafers. You will have a hotel in low-Earth orbit, and you may have a staging ground for exploration of Mars. I see some entrepreneurial efforts coming along with variable gravity. That's wonderful, but it's not the market for today. Not for the next five, six, seven years. We want to exploit the unique environment of space. We're not at a point where we want to duplicate Earth's environment. We want to get those breakthroughs when there's no gravity and finally realize that potential.

MORIBA JAH

A space environmentalist and chief scientist of Privateer Space, founded in 2021 with Apple co-founder Steve Wozniak to monitor satellites and debris in orbit. A fellow of AIAA and the MacArthur Foundation, Jah is an associate professor of aerospace engineering and engineering mechanics at the University of Texas at Austin. He holds a Ph.D. in aerospace engineering from the University of Colorado, Boulder.

To me, the space economy is just an extension of the economy period. We don't say, "What's the land economy?" or "What's the ocean economy?" It's just the economy. I think labeling it "the space economy" is part of the mistake, because it's not connected. It's like these things are mutually exclusive. Right now, we have critical services and capabilities that are uniquely provided by space: position, navigation and timing, and communications. These robots in the sky we call satellites are already fueling the economy. And looking at how we do space exploration, companies working on the moon, that's just an extension of the economy. I don't consider a space economy to be a disjointed thing. As humanity makes more and more use of space, the economy includes making use of this resource and this orbital ecosystem. It's no different than the economy based on things on land, in the ocean and in the air. Land, ocean, air and space have so many interdependencies. Eliminate any one of these things, and all of a sudden, the economy as a whole breaks down. If we just eliminated satellites, we'd be hosed. That would break the global economy, without question.

"AS HUMANITY MAKES MORE AND MORE USE OF SPACE, THE ECONOMY INCLUDES MAKING USE OF THIS RESOURCE AND THIS ORBITAL ECOSYSTEM. IT'S NO DIFFERENT THAN THE ECONOMY BASED ON THINGS ON LAND, IN THE OCEAN AND IN THE AIR."

As a space environmentalist, I like the idea of circular economies from a waste management perspective, and I like being able to link environmentalism across these different ecosystems to show that space is no different than land, air and ocean. People want to see sustainability and environmentalism happen for space. They need to connect with the rest of humanity that for decades has already been working on waste management and environmentalism in these other ecosystems. Space people tend to be very insular and come up with our own jargon, which is something that doesn't unify; it's divisive. I'm all about unification with the rest of the globe. Why make up terms when we don't have to?

My idea for the space economy is a circular one that focuses first and foremost on the prevention of pollution by prioritizing the reuse and recyclability of rockets and satellites. On the rocket side, clearly SpaceX is showing that rockets can be reasonably reusable and recyclable. We have not gotten there on the satellite side. I'm not proposing bringing satellites back to reuse them; I am proposing leaving them on orbit but designing them for reuse and recyclability before you launch them. That would also open up a marketplace for companies that could make use of existing satellites for repurposing them and recycling satellite parts in space. Responsible disposal in space can't keep on meaning abandonment. It can't mean companies disposing of satellites by moving them into an orbit that's sufficiently low to let Mother Nature take care of it. To me, that's abandonment of the objects. It's basically putting the trash on your front lawn and hoping there is a strong enough wind that blows it off. ★

THE DARK SIDE OF GREEN

Researchers are beginning to weigh the environmental trade-offs associated with decarbonizing air travel by switching to hydrogen combustion, hydrogen fuel cells and lithium batteries. Keith Button tells the story.

BY KEITH BUTTON | buttonkeith@gmail.com

A glider soars at 33,000 feet carrying a jet engine that burns hydrogen and spews a trail of frozen ice crystals, while an aircraft flying behind collects samples of the contrail. At the bottom of the Pacific Ocean, a device the size of a recreational vehicle churns across the muddyfloor, sucking up delicate potato-sized nodules.

These tests — the first one planned by Airbus for September, the other a demonstration late last year of seabed mining by The Metals Company based in Vancouver — might seem unrelated, but they are indirectly linked in that they are among the first attempts to assess the environmental impacts of two highly touted means of achieving net-zero carbon emissions for air travel.

Airbus is undertaking the "Blue Condor" glider project because it believes hydrogen-burning jet engines could power airliners with capacities of about 200 people, similar to the jetliners of today, and it is targeting 2035 to have such aircraft ready for sale. The exhaust from these aircraft won't contain soot or carbon dioxide, but it will contain nitrogen oxides, including the greenhouse gas nitrous oxide, and water vapor that can turn into icy contrails that may or may not trap heat in the atmosphere — the effect is still unknown.

As for the mining demonstration, the polymetallic nodules collected in October and November by The Metals Co. contained key ingredients for lithium-ion batteries, although not the lithium. There was nickel and cobalt, essential for battery cathodes, plus copper for the foil in their cells, and manganese, another ingredient in the cathodes but one that's relatively low cost so of less concern. The demand for these metals is driven largely by the electrification of cars and trucks, but drones flown by consumers and delivery companies are already powered by lithium batteries, and vast fleets of air taxis and other small electric aircraft will someday be powered by them too, if the ambitions of entrepreneurs in the advanced air mobility sector are achieved.

All told, Benchmark Mineral Intelligence of London, which has done work for The Metals Co., projects that by 2030, the demand for cobalt for electric vehicles of all kinds will increase by 200% and the demand for nickel by 300%. That equates to 5.6 million metric tons of nickel and 240,000 metric tons of cobalt. Projections like these, and the desire among nations including the United States to shed dependence on China, explain the motivation for undertaking the technical challenge of hauling nodules up from a depths of 4,000 to 6,000 meters in the Pacific Oean's Clipperton-Clarion Zone west of Mexico. For scientists, it also underscores the need to determine the effects such mining could have on the marine ecosystem.

Glenn McDonald, a consultant for aerospace

i industry investors and manufacturers at AeroDynamic Advisory in Ann Arbor, Michigan, says most of his clients know they should be concerned about where the metals in their batteries will come from. "But I don't think there's a lot of knowledge in the aviation industry specifically about how to measure that or what to be concerned about. I think aviation will come along for the ride with automotive and with other industries." In fact, he expects aviation to comprise only a low single-digit percentage of the global demand for lithium batteries. Benchmark Mineral Intelligence, which looked at the aviation industry's demand for battery ingredients through 2030, placed aviation's shares even lower: Aviation comprises 0.08% of the total demand for lithium, 0.12% of the demand for nickel and 0.06% of the demand for cobalt.

Turning again to hydrogen, "it's a little bit shocking, but we don't know in aviation what the relative contribution of the different drivers like contrails or contrail cirrus clouds [are]," McDonald says. "There's a chance that contrails and water vapor emissions are actually more important than CO_2, which would drive us away from hydrogen. We just don't know yet."

To try to answer the contrail questions, Airbus, with help from the German aerospace agency DLR, plans to attach a hydrogen-fueled jet engine on one glider and a conventional kerosene jet engine on another and compare the contrails. Gliders were chosen to avoid contaminating the contrail samples. Each glider will be towed to the test altitude, where the engine will be turned on. Sensors and gauges

▲ In September, Airbus plans to fly the Arcus glider pictured here, along with a second one modified to run on hydrogen propulsion. Plans call for a chase plane to follow both gliders during their separate flights so researchers can compare the contrails emitted by this glider's kerosene engine to those generated by the hydrogen engine.

Airbus/James Darcy

▲ The Metals Co. in October lowered this nodule collector to the Clarion-Clipperton Zone of the Pacific Ocean for a demonstration of its collection method. In 60 minutes, the collector sucked up 4,500 metric tons of multimetal nodules, the water jets on the front of the rig spraying up the sediment that covers the ocean floor.

The Metals Co.

from DLR on the turboprop chase plane will measure the size, distribution and density per unit of air of the ice crystals, levels of nitrogen oxides and any particulates in the exhaust of the engines, along with sampling the background aerosols in the atmosphere, plus temperature, air pressure and water vapor.

If the results of the glider tests are unfavorable, it's unclear what could be done. The water vapor exhaust can't be condensed or otherwise managed because it is part of the thrust that's pushing the plane forward, says James McMicking, vice president of strategy for ZeroAvia, a U.S. and U.K. company that is developing fuel cell propulsion for regional turboprops. Electricity-generating fuel cells are another option for carbon-free air travel, but probably for smaller aircraft. They do emit water as exhaust, but they aren't expected to generate contrails as easily as hydrogen combustion engines, if at all. Their exhaust is cooler at 100 to 180 degrees Celsius compared to 1,800 degrees for the combustion jet engine, and the water is concentrated into larger droplets.

Airbus is studying fuel cells too, and researchers at its ZEROe Aircraft unit think they perhaps can alleviate the risk of contrails by figuring out the conditions under which contrails form. They would then determine whether cooling, warming or altering the pressure of the air flow will prevent contrails from forming when the droplets are released into the flow, says Hauke-Peer Lüdders, head of fuel cell propulsion for ZEROe Aircraft.

Fuel-cell-powered flight at up to 27,000 feet will only rarely produce contrails under unique conditions, predicts Josef Kallo, chief executive of H2FLY. The Stuttgart, Germany-based company is

FACT

The metals that could be mined from the seabed aren't the only materials in lithium-ion batteries whose harvesting method presents environmental trade-offs. The lithium in their cathodes comes from lithium carbonate that must be extracted by entirely different methods. In the most common method, water from mineral-rich lakes is pumped into shallow pools to evaporate, leaving behind lithium salts that are then mixed with sodium carbonate. For this lithium carbonate, Benchmark Mineral Intelligence projects that the electric vehicle batteries in 2030 will need 2.3 million metric tons, up from 630,000 metric tons in 2023.

▲ These polymetallic nodules collected by The Metals Co. in October and November each contain cobalt, nickel, copper and manganese, essential ingredients for the lithium-ion batteries needed to power electric air taxis and smaller regional planes. Plans by manufacturers to build thousands of such aircraft, plus that of automobile manufacturers to develop electric cars, would require millions of tons of these metals by 2030.

The Metals Co.

developing fuel cell propulsion for a 40-seat turboprop, which would not fly above 27,000 feet. When a contrail does form, it will be much smaller with denser ice crystals than a kerosene-combustion contrail, so it lasts about 20% as long in the air, Kallo explains.

Meanwhile, on the ocean bottom are the nodules that formed over millions of years, accumulating metals around fossilized bone fragments or other solids. The Metals Co. predicts that when the carbon footprint of the collecting methods are factored in, mining the seabed will prove to be less environmentally damaging than collecting the metals on land, an exception being the warming footprint of cobalt. Mining on land "tends to be carbon intensive, polluting and associated with controversial social issues such as displacement of indigenous peoples," the company says in its "Life Cycle Assessment" report on its website. The company wants the go-ahead from the International Seabed Authority, a United Nations agency, to embark on its plan to harvest 240 million tons of the nodules over 20 years.

To test the harvesting method and assesss its environmental impacts, a crew lowered a remote-controlled, tracked vehicle to the ocean floor, where it sucked the nodules into pipes that carried them up to a ship, the Hidden Gem. The harvesting vehicle is "kind of a cross between a combine harvester and an underwater vacuum cleaner, but on the scale of a combine harvester," says Jon Copley, a deep sea ecologist and professor at the University of Southampton, who is unaffiliated with The Metals Co. Copley and other ocean researchers are studying how marine life in surrounding areas might be affected by the plume of silt left as the vehicle rolls along the seafloor. A second plume

results when the nodules are sifted from the mud aboard the surface ship, and the mud is released at mid-depth through a pipe.

Researchers are also studying whether the mining-free zones of the ocean floor that have already been set aside by the International Seabed Authority will be adequate to maintain the biodiversity of animal and microbe species that live in the sediment and in some cases on the nodules, which are the only hard surfaces at that depth, Copley says.

The environmental nonprofit Greenpeace is advocating for a deep sea mining moratorium, and BMW, Volkswagen and Volvo are among the automakers that have signed an online petition promising not to allow metals collected this way into their supply chains. So far, no aerospace companies have signed on.

"These deep sea ecosystems cannot be recovered in human time scales," says Arlo Hemphill, Greenpeace USA's lead for deep sea mining and ocean sanctuaries. "They take literally millions of years to evolve. So once it's done, any growth of deep sea organisms is just not at the scale that we'll ever see it again."

As for the mining issues on dry land, the practices for collecting cobalt and nickel are under particular scrutiny, says Laurent Pilon, a program director at the Advanced Research Projects Agency-Energy focused on electrical energy storage. Seventy percent of the world's cobalt is extracted from mines in the Democratic Republic of the Congo, where child labor and worker safety issues are rampant. As for nickel, critics charge that Indonesia, the world's largest producer, processes the metal with carbon-intensive, coal-produced electricity, while its mining practices pollute water, destroy forests and disrupt indigenous people. In March, Indonesia President Joko Widodo pledged to improve environmental monitoring of nickel mining, Reuters reported.

Research is underway on a potential new class of lithium batteries that would need fewer, if any metals [See "A battery technology with fewer tradeoffs" on next page]. Even advocates caution that market-ready versions of these lithium-air batteries, (called that because they cull oxygen from the air), are still years away.

But pressure from environmental groups could spur greater work on lithium-air batteries or other

▲ ZeroAvia in April flew its Dornier 228 test plane entirely on hydrogen power for the first time. The aircraft flew three loops around the Cotswold Airport in Gloucestershire, England, a hydrogen fuel cell powertrain driving the propellors. The company plans to sell conversion kits for replacing the turboprop engines of regional aircraft with its collection of fuel cells and electric motors.

ZeroAvia

In 2021, Illinois Tech researchers completed a little over 1,000 charging cycles with a coin-sized lithium-air battery, of the same design as the ones shown here. This experimental class of batteries cull oxygen molecules directly from the ambient air, eliminating the need for the metal strips in today's lithium-ion batteries that store electricity during charging.

Illinois Institute of Tech

A battery technology with fewer trade-offs

An experimental class of batteries that largely employ no metals other than lithium could make moot the question of where to get the nickel, cobalt and other metals for lithium batteries.

Though researchers are still in the early stages of developing them, lithium-air batteries are a candidate to power aircraft in a decade or so because each is capable of producing five times the power per kilogram of a Tesla battery. One promising lithium-air design developed by an Illinois Institute of Technology team has only lithium in its anode and a cathode containing molybdenum, which is mined in several countries including the U.S. and China, or created as a byproduct of copper mining. But the researchers believe they can make the cathode out of carbon and nitrogen-based materials, along with an electrolyte free of any metals, says Larry Curtiss, a researcher on the team and head of the molecular materials group at Argonne National Laboratory in Chicago.

If you wonder about hydrogen fuel cells, these do contain platinum, a rare metal that fosters the conversion of exhaust to less harmful gases in the catalytic converters of cars, mining platinum will not need to be done on nearly the scale of mining for the metals in batteries. That's because 99% of platinum in spent fuel cells and catalytic converters can be recycled. Also, cars will be replaced eventually by electric vehicles, so demand for platinum won't increase significantly as demand grows for fuel cells, says Hauke-Peer Lüdders, head of fuel cell propulsion for Airbus' ZEROe initiative to build a hydrogen airliner by 2035. — *Keith Button*

> "These deep sea ecosystems cannot be recovered in human time scales. They take literally millions of years to evolve. So once it's done, any growth of deep-sea organisms is just not at the scale that we'll ever see it again."
>
> **— Arlo Hemphill, Greenpeace USA**

technologies. "In the future, there [will be] a big push to reduce the reliance on cobalt and possibly nickel," predicts Pilon, the ARPA-E project director. As for elminating the need to mine lithium, that's probably not possible. "Looks like we're going to need lithium for a lot longer."

Lithium mining comes with its own challenges. In one method, lithium salts are extracted from pools of brine water, which can contaminate fresh water; in another, lithium is dug up, but doing so generates lots of carbon emissions. Also, China reportedly controls a growing share of the lithium mines around the world. The Institute for Energy Research, a conservative Washington, D.C., think tank, predicts that by 2025 China will control 32% of the lithium mines compared to 24% in 2022.

Regarding the environmental implications, uncomfortable trade-offs could be inevitable: "Is it better to emit CO_2 or contaminate water? I don't know. I mean, is malaria better than cholera?" Pilon asks.

What is the likely mix of aircraft that will dominate in the future? The Mission Possible Project, a consortium of companies advocating for decarbonization, expects sustainable aviation fuels made from renewable carbon sources to dominate the aviation market by 2050, measured by the percent of energy demand. Specifically, battery-powered aircraft are projected to comprise 2% of the demand, followed by hydrogen-fueled aircraft at somewhere between 13% and 32%, and SAF-fueled aircraft at about two-thirds. In this view, battery propulsion will be confined to smaller aircraft, while SAFs can be dropped into today's kerosene-fueled planes and existing supply chains with little to no hardware modification. Hydrogen-fueled aircraft will need new airframe designs, new propulsion, and new fuel delivery and storage setups.

An open question is whether the aviation industry could, if it wanted to, affect where the metals for batteries come from. If the 2% figure is correct, the supply chain will likely remain set up to feed the demands of the automotive sector.

Perhaps for this reason, most of McDonald's clients are focused on solving the technical and economic problems associated with future aviation concepts — like whether future batteries will be powerful enough, light enough and cheap enough. They're not worrying about the sourcing of battery materials.

Robin Riedel, an aerospace sector consultant at McKinsey and Co., sees things somewhat differently. Some aircraft builders and investors in the electrification space are tuned in to the environmental issues. "It's a pretty meaningful number, and yes, people are worried about it. But at the same time, people are saying, 'Well, the automotive industry, which had so much more demand — orders of magnitude higher demand — is going to lead the way on this stuff,'" Riedel says. [See our advanced air mobility Q&A with Riedel on p. 10]

Hydrogen combustion is a different matter, given that there are no automotive coattails to ride. Any warming impact from contrails would belong solely to the aviation industry. "If I were investing in hydrogen combustion at this point, I'd be a little bit cautious, or I would want to know where regulation is headed before anyone sinks tens of billions of dollars into a new airplane," says McDonald.

In his view, environmental considerations are beyond the expertise of aircraft builders, suppliers and investors, so therefore the industry needs standards or regulations that spell out how to weigh those concerns. Absent measures like a carbon tax or conflict mineral clauses restricting transactions involving metals or other minerals from war-torn countries, it's too difficult to weigh the relative environmental or human rights costs of obtaining metals from one source over another, or whether a change in the supply chain is warranted.

"If there's no regulation about how to consider those other environmental concerns today, they just won't be considered," he says. ★

BEFORE A Maxar satellite photographed the Starship rocket prior to its April 20 launch from Boca Chica, Texas. Maxar Technologies

A closer look at Starship's launch pad

FAA investigators are not the only ones looking into the fallout from SpaceX's decision to launch the Starship spaceship atop a Super Heavy booster without a flame trench or other protective mechanism.

Philip Metzger, a planetary scientist at the University of Central Florida, has been looking into the aftermath of the destruction of the concrete launch pad, caused when the rocket's 33 first-stage engines ignited to generate 64 meganewtons of thrust. That's nearly twice the power of the Space Launch System rocket that NASA launched in November.

Studying imagery and videos, he found that some pieces of debris were so large that they caused a six-story-high splash when they fell into the nearby Gulf of Mexico, while sand from the ground was recorded

AFTER Chunks of the concrete launch pad were blown away, exposing the ground beneath, as seen in this drone photo. RGV Aerial Photography

"five or six miles from the launch pad," he says.

The U.S. Fish and Wildlife Service said in a statement that "impacts from the launch include numerous large concrete chunks, stainless steel sheets, metal and other objects hurled thousands of feet away along with a plume cloud of pulverized concrete that deposited material up to 6.5 miles [10.5 kilometers] northwest of the pad site."

The staff found debris scattered over an area of 1.5 million square meters, and noted that a 14,000-square-meter fire started at Boca Chica State Park.

Much work will need to be done before the next test flight, which according to Elon Musk could possibly be in the next month or two, once a "water-cooled steel plate" has been installed to protect the pad. But the feasibility of that timing may depend on a lawsuit filed last month by a consortium of environmental groups against FAA for allowing the launch to proceed.

Metzger says the steel plate should help matters. "By having it water cooled, that solves the problem of melting the steel," he says.

Better still would be a flame trench, which SpaceX decided not to build at Boca Chica. "This could turn out to be a mistake," Musk wrote on Twitter back in October 2020.

Metzger and other space watchers were taken aback on launch day.

"The extent of the damage took me by surprise," says Laura Forczyk, a space analyst from Georgia-based Astralytical. "I did not realize SpaceX had taken shortcuts in the design of the pad." ★

— Jonathan O'Callaghan

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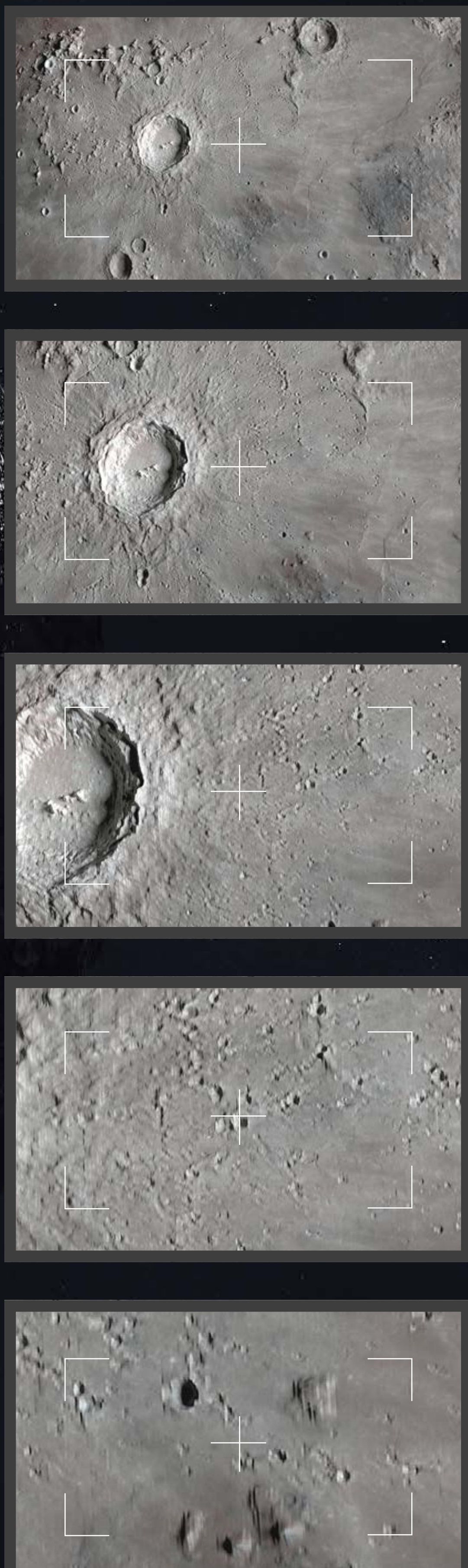
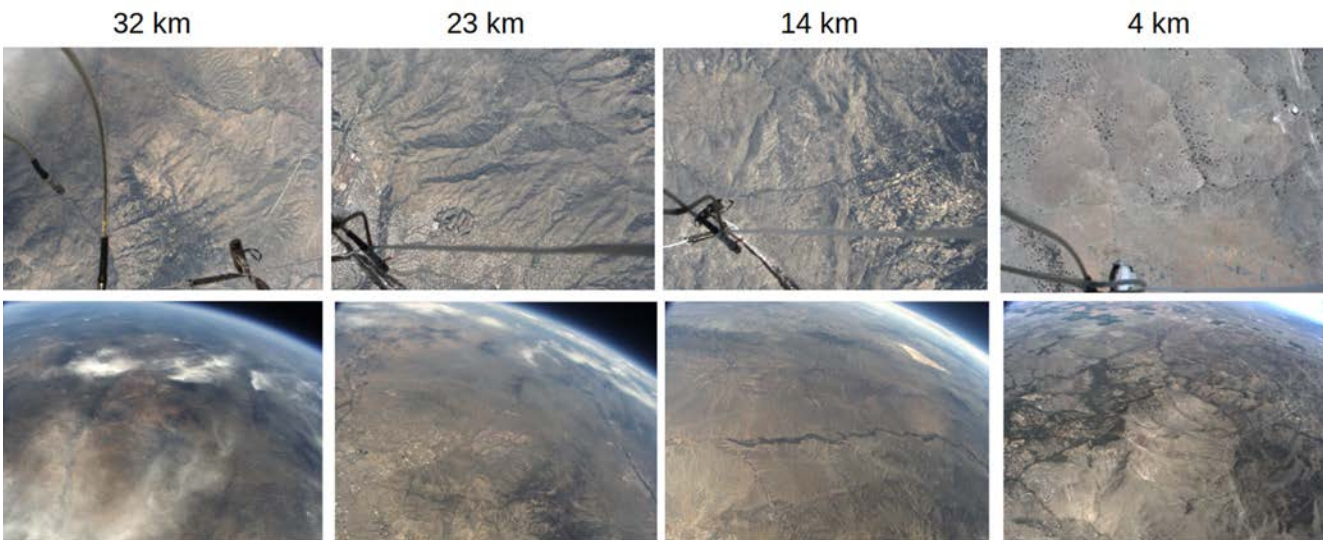
STICKING THE LANDING



Touching down on the moon safely, accurately and autonomously will require highly capable cameras and software. Dominic Maggio and Brett Streetman of Draper take us inside the flight testing of their team’s landing system.

BY DOMINIC MAGGIO AND BRETT STREETMAN



▲ The Draper Multi-Environment Navigator calculates its position relative to the terrain. These photos are from a 2019 flight aboard a World View high-altitude balloon. The top row was taken by DMEN's downward-facing camera, and the bottom row was taken by DMEN's sideways-facing camera.

Draper

A spacecraft on a descent toward the lunar surface has a singular goal of landing in a location that's free of boulders, craters and other hazards. For the coming wave of uncrewed landers destined for the lunar poles and far side, a safe landing is anything but guaranteed.

As space system engineers at Draper, we are keenly aware of how difficult it is to make it safely to the surface of the moon or a planet. So, we built and flight tested the Draper Multi-Environment Navigator, or DMEN, a computer, terrain analysis software and two video cameras that can be encased together in a shoebox-sized protective housing. Our end goal in this effort is to get DMEN ready for Draper's CP-12 mission, which is one of the landers NASA has funded under its Commercial Lunar Payload Services program.

As a terrain relative navigation system, DMEN fits within NASA's broad mandate from the early 2000s for members of the space community to develop an integrated suite of landing and hazard avoidance capabilities for planetary missions.

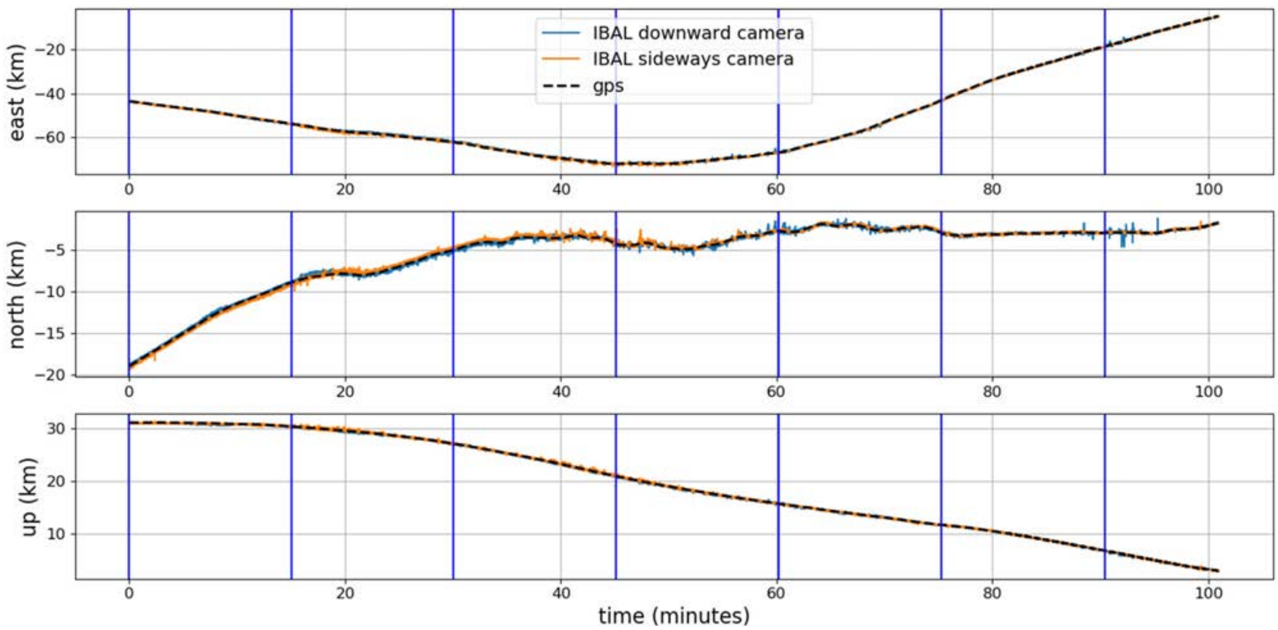
Flight tests can, of course, present their own challenges. We pushed a few boundaries and learned a few things when our DMEN system flew to an altitude of 8 kilometers on board the uncrewed Blue Origin New Shepard NS-23 mission last July and, three years earlier, on a World View Enterprises high-altitude balloon flight, which reached the Earth's stratosphere at 33 kilometers. Both flight campaigns were made possible with funding from NASA's Flight Opportunities office.

Neither New Shepard nor the balloon worked without challenges. New Shepard's capsule escape system was triggered, ending our data collection (or so we thought at the time), although all of the NS-23 payloads landed safely near the Texas launch site. The balloon flight took place on a particularly windy day in Arizona, resulting in lots of debris and a spinning balloon. But we improved DMEN as a result of both missions, moving it closer to serving as the visual-inertial navigation method for Draper's CP-12 mission.

The balloon flight

Draper, based in Cambridge, Massachusetts, earned

“CHALLENGES WERE EXACTLY WHAT WE WANTED TO ENCOUNTER IN ORDER TO PROVE DMEN’S CAPABILITIES.”



▲ During the 2019 balloon flight, the Image-Based Absolute Localization (IBAL) software aboard the Draper Multi-Environment Navigator calculated position and altitude by comparing images taken by onboard cameras to existing maps. When Draper engineers plotted positions against the balloon’s GPS, as seen in this chart, they determined that DMEN could accurately navigate over terrain at a high altitude.

Draper

legendary status in the 1960s for developing the Apollo guidance computer. In fact, we received the first major contract on Apollo, back when we were the MIT Instrumentation Lab and later the Charles Stark Draper Laboratory. Since then, Draper has contributed to the space shuttle program and International Space Station, and we are now contributing to the Artemis moon program due to our solid grounding in space systems. Such a heritage adds a dose of pressure in developing a terrain relative navigation system like DMEN.

Weighing just 3 kilograms, DMEN compares the images from its cameras to correlate the view to onboard maps and twice per second runs a multistep process to calculate the host spacecraft’s position and altitude during descent. DMEN crunches the data using software dubbed IBAL (pronounced like you think), short for Image-Based Absolute Localization. This system was our answer to NASA’s mandate.

In Arizona, we met up with a team from World View, who helped us put DMEN to the test. World View is a commercial stratospheric flight company selected by NASA to integrate and fly technology payloads to the boundary of space. In April 2019, World View launched DMEN with several unrelated payloads from Spaceport Tucson, the company’s primary launch location for high-altitude missions.

We watched as the balloon climbed to an altitude of 108,000 feet. DMEN gathered images at 20 hertz from its downward-facing camera and its sideways-tilted camera, which was angled at about 45 degrees. With the flight data, DMEN, in this test encased in its protective housing, compared the terrain features prominent in the camera images with a satellite image database of the area, pre-loaded to DMEN for this purpose. Potential matches were then passed to an optimization routine to both reject false matches and produce an optimal estimate of the vehicle’s pose. This is the process that took less than a second.

The Arizona flight had a few challenges for visual navigation. The balloon regularly experienced rapid rotations, in some cases over 20 degrees per second. Cords hanging below the balloon were visible to the downward-facing camera. Clouds blocked part of the terrain.

But challenges were exactly what we wanted to

The July flight of an uncrewed Blue Origin New Shepard rocket was the second time Draper flew its terrain relative navigation system. Each Draper Multi-Environment Navigator, or DMEN, includes a downward-facing and a sideways-facing camera. Those cameras were distributed in the windows of the New Shepard capsule for the 2022 test flight to capture different views. Blue Origin

encounter in order to prove DMEN's capabilities. During a real mission, DMEN and IBAL might need to overcome obscurants such as exhaust or ground debris kicked into the atmosphere during descent, which can interfere with a camera's ability to track and compromise a safe descent and landing.

The balloon flight showed us that DMEN can accurately navigate a payload at a high altitude, using only imagery and inertial measurements. We also learned that DMEN could accommodate differences in camera angles, vehicle constraints and mission requirements.

The rocket flight

The balloon flight had proven DMEN could perform well at high altitudes and during rapid rotations, but to validate our system at high speeds, we needed a rocket, and we selected Blue Origin's New Shepard.

We prepped our software and hardware at Draper here in Cambridge and then shipped it to Van Horn, Texas, for launch. The plan was to spend a couple of days mounting DMEN inside the capsule, including two cameras looking out the capsule windows.

IBAL's database was automatically constructed by extracting image patches from U.S. Geological Survey satellite maps. Combined with elevation maps, each patch could be labeled with a known GPS location and elevation. As in the balloon flight, we used a single database created before flight.

At Van Horn, we inspected and tested the software to ensure it was ready for the mission. The prep work took place in the weeks leading up to launch — running test code and hardening our in-flight software. Just like for the balloon flight, we installed two cameras on the capsule in order to run IBAL separately with each camera to see the impacts of different angles and the terrain on the navigation solution.

During flight, the DMEN computer is designed to operate autonomously and determine on its own when to turn on, initiate its sensors, log the data and seal the data. As with the balloon mission, we wouldn't know the results of NS-23 until we brought the unit, including its computer, back to Draper for processing.

As Blue prepared to launch New Shepard, the DMEN team gathered for a watch party at Draper. When the capsule escape system was triggered, those

Draper is planning additional flight testing of its terrain relative navigation software and cameras in preparation for the CP-12 mission, in which a Draper lander is targeted to carry three NASA payloads to the far side of the moon in 2025. The Draper Multi-Environment Navigator is shown here in its housing, but the cameras can also be distributed.

Draper

of us on site and at Draper gasped.

Suddenly, we faced uncertainty. We didn't know how much data we would have to work with. We didn't even know if our computer had logged anything. We would have to wait until the DMEN computer was returned for analysis.

Back at Draper, we unpacked DMEN's flight computer from the case and connected it to our monitors to see if the data had been logged. This was the watch party most of us were actually worried about. Whatever the rocket does during launch is out of our control, but what's on this computer tells us if we did our job correctly. Watching all the data appear exactly as it should became a moment of celebration.

With the data in hand, we next wanted to see if IBAL could use it to navigate. That brought the next victory. DMEN aced this flight test, with IBAL achieving average position error for the flight of less than 55 meters, despite reaching an altitude of 8 kilometers and speeds of up to 880 kilometers per hour.

Looking forward

The successful flight tests were a huge win for us, but we're already looking ahead. Plans are underway to add a secondary and completely independent software to monitor IBAL's performance during runtime, an enhancement that will leverage advances in machine learning and give the system additional redundancy. Future experiments with these datasets may give us new insights into the way perception methods can be advanced in systems like DMEN. Future versions could also be self-monitoring, operate without human supervision and better identify terrain using satellite imagery.

With these missions, we placed DMEN at a Technology Readiness Level of 5 on NASA's 9-point scale, because it has been flown in a relevant environment. We collected data and validated algorithms in a suborbital environment, which is now helping Draper advance DMEN's TRL toward Level 9, meaning flight in the intended operational environment of space in this case.

Software used in DMEN and IBAL is on course to be loaded and tested in Draper's guidance, navigation and control simulation lab for the CP-12 mission. DMEN is well on its way as a candidate for human missions, including Artemis astronaut landings. ★

Dominic Maggio is an MIT graduate student and Draper Scholar whose research focuses on autonomous vehicles and related fields, including terrain relative navigation.

Brett Streetman is the principal investigator for the Draper Multi-Environment Navigator. At Draper, he has worked on guidance, navigation and control systems for the International Space Station, lunar landers, lunar exploration and satellites. He holds a Ph.D. in aerospace engineering from Cornell University.

AIAA Bulletin

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To join AIAA; to submit address changes, member inquiries, or renewals; to request journal fulfillment; or to register for an AIAA event. Customer Service: 800.639.AIAA (U.S. only. International callers should use 703.264.7500).

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

Other Important Numbers: Aerospace America / Catherine Hofacker, ext. 7587 • AIAA Bulletin / Christine Williams, ext. 7575 • AIAA Foundation / Alex D'Imperio, ext. 7536 • Book Sales / 800.682.AIAA or 703.661.1595, Dept. 415 • Communications / Rebecca Gray, 804.397.5270 • Continuing Education / Jason Cole, ext. 7596 • Corporate Programs / Nancy Hilliard, ext. 7509 • Editorial, Books and Journals / Michele Dominiak, ext. 7531 • Exhibits and Sponsorship / Paul doCarmo , ext. 7576 • Honors and Awards / Patricia Carr, ext. 7523 • Integration and Outreach Committees / Angie Lander, ext. 7577 • Journal Subscriptions, Member / 800.639.AIAA • Journal Subscriptions, Institutional / Online Archive Subscriptions / Michele Dominiak, ext. 7531 • K–12 Programs / Jake Williams, ext. 7568 • Media Relations / Rebecca Gray, 804.397.5270 • Engage Online Community / Luci Blodgett, ext. 7537 • Public Policy / Ryan Cooperman, ext. 7541 • Section Activities / Lindsay Mitchell, ext. 7502 • Standards, International / Nick Tongson, ext. 7515 • Technical Committees / Angie Lander, ext. 7577 • University and Young Professional Programs / Michael Lagana, ext. 7503

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

Calendar

FEATURED EVENT

12–16 JUNE 2023
San Diego, CA

The only aviation event that covers the entire integrated spectrum of aviation business, research, development, and technology. This year's theme, Revolutionary Leaps Toward a New Age of Aviation, will focus on how the industry's evolved throughout the years and what the future of aviation will look like.

aiaa.org/aviation/registration

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2023			
6 Jun	OpenFOAM® Aeroacoustics Modeling Course	ONLINE (learning.aiaa.org)	
7 Jun	OpenFOAM® Dynamic Mesh Modeling Course	ONLINE (learning.aiaa.org)	
7–9 Jun*	10th International Conference on Recent Advances in Air and Space Technologies (RAST 2023)	Istanbul, Turkey	20 Mar 23
12–16 Jun	AIAA AVIATION Forum	San Diego, CA	10 Nov 22
19–23 Jun*	International Conference on Icing of Aircraft, Engines, and Structures 2023	Vienna, Austria (https://www.sae.org/attend/icing)	
20–23 Jun	Safety Management Systems in Aviation Course	ONLINE (learning.aiaa.org)	
27–30 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
14–16 Jul*	2023 International Conference of Unmanned Aerial Systems	Toronto, Canada (www.icuasa.org)	
19–28 Jul	Aircraft Maintenance Management Course	ONLINE (learning.aiaa.org)	
13–17 Aug*	2023 AAS/AIAA Astrodynamics Specialist Conference	Big Sky, MT (https://space-flight.org)	
11–14 Sep	Foundations of Digital Engineering Course	ONLINE (learning.aiaa.org)	
12–13 Sep	Fundatmentals of Space Domain Awareness Course	ONLINE (learning.aiaa.org)	
18 Sep–25 Oct	Spacecraft Design, Development, and Operations Course	ONLINE (learning.aiaa.org)	
19 Sep–12 Oct	Fundamentals of High Speed Air-Breathing and Space Propulsion Course	ONLINE (learning.aiaa.org)	
22 Sep	AIAA Rocky Mountain Annual Technical Symposium 2023	Fort Collins, CO (www.aiaa-rm.org/)	

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2023			
26 Sep–19 Oct	Practical Approach to Flight Dynamics and Control of Aircraft, Missiles, and Hypersonic Vehicles Course	ONLINE (learning.aiaa.org)	
2–6 Oct*	74th International Astronautical Congress	Baku, Azerbaijan (iac2023.org)	
2–18 Oct	Overview of Python for Engineering Programming Course	ONLINE (learning.aiaa.org)	
10–13 Oct	Applied Model-Based Systems Engineering (MBSE) Course	ONLINE (learning.aiaa.org)	
10–26 Oct	Metal Additive Manufacturing for Aerospace Applications Course	ONLINE (learning.aiaa.org)	
16–19 Oct	Space Domain Cybersecurity Course	ONLINE (learning.aiaa.org)	
23–25 Oct	ASCEND Powered by AIAA	Las Vegas, NV	22 March 23
24 Oct–2 Nov	Technical Writing Essentials for Engineers Course	ONLINE (learning.aiaa.org)	
30 Oct–15 Nov	Hypersonic Applications: Physical Models for Interdisciplinary Simulation Course	ONLINE (learning.aiaa.org)	
31 Oct–16 Nov	Space Architecture: Designing an Orbital Habitation System Course	ONLINE (learning.aiaa.org)	
7–16 Nov	Business Development for Aerospace Professionals Course	ONLINE (learning.aiaa.org)	
17–16 Nov	Wind Tunnel Testing for Aircraft Development Course	ONLINE (learning.aiaa.org)	
17–18 Nov	AIAA Young Professionals, Students, and Educators (YPSE) Conference	Laurel, MD (www.aiaaypse.com)	
4–7 Dec	Aircraft and Rotorcraft System Identification Engineering Methods for Piloted and UAV Applications with Hands-on Training Using CIFER® Course	ONLINE (learning.aiaa.org)	
2024			
8–12 Jan	AIAA SciTech Forum	Orlando, FL	25 May 23
2–9 Mar*	IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
16–18 Apr	AIAA DEFENSE Forum	Laurel, MD	17 Aug 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 (green rows)

RECOGNIZING TOP ACHIEVEMENTS

An AIAA Tradition

AIAA is committed to ensuring that aerospace professionals are recognized and celebrated for their achievements, innovations, and discoveries that make the world safer, more connected, more accessible, and more prosperous. From the major missions that reimagine how our nation utilizes air and space to the inventive new applications that enhance everyday living, aerospace professionals leverage their knowledge for the benefit of society. AIAA continues to celebrate that pioneering spirit showcasing the very best in the aerospace industry.

AIAA acknowledges the following individuals who were recognized between February 2023 and July 2023.

AIAA DEFENSE Forum

11–13 April 2023
Laurel, MD

Technical Excellence Award

2023 AIAA Missile Systems Award

Mark A. Weiner
MIT Lincoln Laboratory
"For significant national contributions to the development of surface-to-air and air-to-air missile systems and countermeasures through rigorous analysis and testing of radar and seeker technologies."

AIAA AVIATION Forum

12–16 June 2023
San Diego, CA

Premier Lecture

Larry A. Young
NASA Ames Research Center
Lecture: "NASA Aeronautics Contributions to the Ingenuity Mars Helicopter"

Technical Excellence Awards

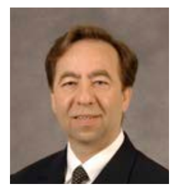
2023 AIAA Aeroacoustics Award

Yueping Guo
NASA Langley Research Center
"For significant contributions to understanding airframe noise and acoustic scattering and application in development of state-of-the-art, system-level prediction methods enabling innovative noise reduction."

2023 AIAA Aerodynamics Award

Roy J. Hartfield Jr.
Auburn University
"For the development of fast and practical predictive approaches to the problem of aerodynamic analysis of air vehicles at both conceptual and preliminary design stages."

2023 AIAA Aircraft Design Award



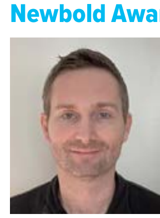
Adnan Raghdo
The Boeing Company
"For leadership of the Boeing MQ-28A design team, a stealth, multirole, UAS, force multiplier aircraft capable of teaming with crewed aircraft and performing autonomous missions."

2023 AIAA Chanute Flight Test Award

Credit: Dan Winters Photography

Mark P. Stucky
Blue Origin
"For being at the forefront of design, analysis, instruction, and flying in the military, NASA, and civilian flight test for over 40 years."

2023 AIAA F.E. Newbold Award



Lars Blackmore
SpaceX
"For vehicle-level design and the development of critical guidance and control technologies to achieve precision vertical landing of space rockets and advance their viability through full reusability."

2023 AIAA Fluid Dynamics Award

Kozo Fujii
Tokyo University of Science
"For many pioneering contributions to robust and efficient computational algorithms and their application to solve major industrial challenges using leading-edge supercomputers."

2023 AIAA Ground Testing Award

Luca Maddalena
University of Texas at Arlington
"For pioneering contributions in the development of arc-heated test facilities, advanced optical diagnostics, and data processing."

2023 AIAA Hap Arnold Award for Excellence in Aeronautical Program Management

Parimal Kopardekar
NASA Aeronautics Research Institute
"For excellence in developing a concept, initiating, and managing NASA UAS Traffic Management research as well as setting up a novel collaborative approach that resulted in a global impact for integrating new entrants into airspace systems."

2023 AIAA Hypersonics Systems and Technologies Award

Joseph A. Schetz
Virginia Polytechnic Institute and State University
"For sustained contributions to hypersonics through graduate education of a large cadre of Ph.D. students and seminal research on high-speed aerodynamics, heat transfer, and propulsion."

2023 AIAA Losey Atmospheric Sciences Award

Jeanne G. Mason
Boeing Commercial Airplanes (retired)
"For exceptional service to aviation safety for aircraft icing by organizing and directing partnerships that invest in solutions to understand convective weather ice crystal phenomena."

2023 AIAA Thermophysics Award

Michael Wright
NASA Ames Research Center
"For outstanding contributions to improving thermophysical models and simulation capabilities for high-enthalpy flows, and for leadership and dedication to NASA missions and the aerothermodynamic community."

THANK YOU to all the nominators and supporters of these award winners.

2023 AIAA Awards Gala Held in May

AIAA presented its premier awards at the AIAA Awards Gala, 18 May, at The John F. Kennedy Center for the Performing Arts in Washington, DC. The Class of 2023 AIAA Fellows and AIAA Honorary Fellows also were recognized.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1 Class of 2023 AIAA Honorary Fellows: (left to right) Mark Drela, Jim Maser, and William Sirignano.

2 Class of 2023 AIAA Fellows.

3 AIAA Executive Director Dan Dumbacher (left) and President Laura McGill (right) with Alison A. Nordt, recipient of the 2023 AIAA Engineer of the Year Award.

4 AIAA Executive Director Dan Dumbacher (left) and AIAA President Laura McGill (right) with Phillip J. Ansell, recipient of the 2023 AIAA Lawrence Sperry Award.

5 AIAA Executive Director Dan Dumbacher (left) and AIAA President Laura McGill (right) with Bill Nye, recipient of the 2023 AIAA Public Service Award.

6 AIAA Executive Director Dan Dumbacher (left) and AIAA President Laura McGill (right) with David R. Riley, recipient of the 2023 AIAA Distinguished Service Award.

7 AIAA Executive Director Dan Dumbacher (left) and AIAA President Laura McGill (right) with John S, Langford III, recipient of the 2023 AIAA Reed Aeronautics Award.

8 AIAA Executive Director Dan Dumbacher (left) and AIAA President Laura McGill (right) with Jennifer Love-Pruitt, Michael T. Menzel, and Lee D. Feinberg, recipients of the 2023 AIAA Goddard Astronautics Award. Recipient Charles Atkinson was unable to be in attendance.

9 AIAA Executive Director Dan Dumbacher (left) and AIAA President Laura McGill (right) with Jeremy John and Lindley Johnson, representatives from the NASA/Johns Hopkins University Applied Physics Laboratory DART Team, recipient of the AIAA Award for Aerospace Excellence.

10 2023 Roger W. Kahn Scholarship recipients: (l to r) Lydia Ames, Samannita Mukherjee, Anna Phan, and Valeria Santoyo.

11 AIAA Foundation Chair Basil Hassan (left) and Megan Mitchell, Blue Origin, and Lance, Bush, CEO, Challenger Center (right), with the 2023 Trailblazing STEM Educator Award winners—Caroline Little, Aymette Medina, and Taylor Whisenant.

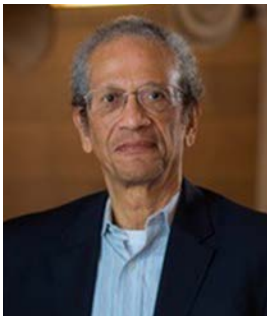
*Vincent A. Orlando, recipient of the 2023 AIAA International Cooperation Award, was unable to attend.

Introducing the New Board of Trustees Members

In May, the Board of Trustees (BoT) welcomed new members whose terms of office began at the end of the spring business meetings.

- **Dan Hastings** began his term as AIAA President-Elect (2023–2024). He will hold this position until May 2024, when he becomes President (2024–2026).
- **Steve Justice** (BoT Member–At Large) has been elected to the position of Treasurer-Elect. He will hold this position until May 2024, when he becomes Treasurer (2024–2027).
- **Three new Board of Trustees Members–At-Large** also began their three-year terms in May.
  - **Johnathon Caldwell**
  - **Keoki Jackson**
  - **Karen Willcox**

Get to Know Our New Board Members



President-Elect—Daniel E. Hastings, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology

Hastings has been on the faculty at MIT in Aeronautics and Astronautics since 1985. His research specializations include synergetic interactions between space systems and the space environment, space propulsion, space policy, and space systems architecting. Among his external appointments, he served as chief scientist in the late 1990s for the U.S. Air Force, where he led studies of Air Force investments in space. He was also the chair of the Air Force Scientific Advisory Board afterward and has served on the NASA Advisory Council and on numerous NASEM committees. He has been on The Aerospace Corporation Board of Trustees for over 18 years.

Treasurer-Elect—Steve Justice, The Ginn Group

Justice has over 40 years of experience across innovation, entrepreneurship, economic development, engineering, and information technology in both the public and private sectors. He is currently the Chief Innovation Officer at The Ginn Group. In the public sector working for the State of Georgia, Justice served as the Executive Director of the Georgia Centers of Innovation leading a wide-ranging program to support the state's strategic industries - Aerospace, Agribusiness, Energy Technology, Information Technology, Logistics, and Manufacturing. In the private sector, Justice provided technical and managerial leadership while serving at Lockheed Martin, Gulfstream Aerospace, Northrop, Delta Air Lines, Generation Orbit Launch Services, in addition to founding two Georgia-based aerospace companies. Justice is also the former Secretary of the Aerospace States Association, and long-time member of the Commemorative Air Force and the Experimental Aircraft Association.

Members–At-Large

Johnathon Caldwell, Lockheed Martin Space

Caldwell is the Vice President of Business Innovation Transformation & Enterprise Excellence for Lockheed Martin Space and serves on the Space Executive Leadership Team. Previously, he served as Vice President of the Navigation Systems mission area within Lockheed Martin's Military Space line of business. Caldwell's career includes a series of progressive leadership roles within Lockheed Martin serving in diverse roles from Global Positioning System (GPS) Program Leadership and Chief Engineer responsible for the overall GPS III Space Vehicle.

Keoki Jackson, The MITRE Corporation

Jackson is Senior Vice President and General Manager, MITRE National Security Sector, responsible for the strategic growth and execution of programs supporting Department of Defense, the Department of Justice, and the Intelligence Community. He also leads the National Security Engineering Center. Jackson joined MITRE after more than two decades at Lockheed Martin, where he influenced the design, development, deployment, and flight operation of major national security spacecraft and programs. Before joining Lockheed Martin, Jackson was a NASA research fellow at the Massachusetts Institute of Technology (MIT) in the field of human adaptation to the space environment. Jackson is a Fellow of the United Kingdom Royal Aeronautical Society and AIAA. He received his bachelor's, master's, and doctoral degrees in aeronautics and astronautics from MIT and completed the Stanford Executive Program at the Stanford Graduate School of Business.

Karen Willcox, University of Texas at Austin

Willcox is Director of the Oden Institute for Computational Engineering and Sciences, Associate Vice President for Research, and Professor of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin. She is also External Professor at the Santa Fe Institute. Before joining the Oden Institute in 2018, she spent 17 years as a professor at the Massachusetts Institute of Technology, where she served as the founding Co-Director of the MIT Center for Computational Engineering and the Associate Head of the MIT Department of Aeronautics and Astronautics. Prior to joining the MIT faculty, she worked at Boeing Phantom Works with the Blended-Wing-Body aircraft design group. She is a Fellow of the Society for Industrial and Applied Mathematics (SIAM), Fellow of AIAA, Fellow of the U.S. Association for Computational Mechanics (USACM), and member of the National Academy of Engineering (NAE).

Nominations for AIAA Election Are Being Accepted Through 14 July 2023

The Institute is currently seeking nominations for the following positions.

AIAA Board of Trustees – Members–At-Large Nominations

The AIAA Executive Nominating Committee (ENC) will compile a list of potential nominees for the Board of Trustees – Members–At-Large. The list will include nominees who will be selected to go to the next step of competency review and interview held by the nominating committee. The ENC will select specific candidates for the Institute's Board of Trustees – Members–At-Large in November 2023. The Board of Trustees – Members–At-Large will be elected by the Council of Directors in March 2024 and announced soon thereafter.

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

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

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

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

AIAA Council of Directors Nominations

The AIAA Council of Directors Nominating Committee (CNC) will compile a list of potential nominees for the open Director positions on the AIAA Council of Directors. This list will include nominees who will be selected to go to the next step of competency review held by the nominating committee. The nominating committee will select specific candidates for the open Director positions who will be voted on by the AIAA membership. The final slate of candidates will be publicized by December 2023 for the election that will be held January 2024.

Nominations are being accepted for Regional Directors, Integration and Outreach Group Directors, and Technical Group Directors for the term May 2024–May 2027. AIAA members may self-nominate or nominate members qualified for the open position.

Regions coordinate the activities of geographically-related sections to facilitate cooperative efforts between the various geographical areas. A Regional Director shall lead each region. Nominations are being accepted for:

- Region III – Central, Director
- Region VI – Western, Director

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

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

- Young Professionals Group, Director-Elect

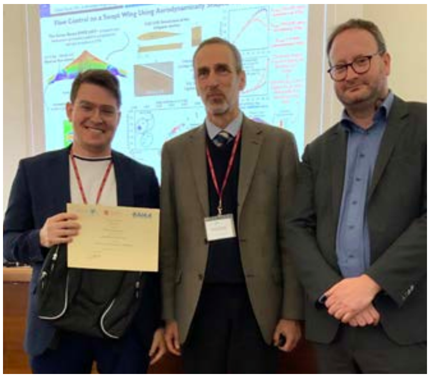
For more information on AIAA integration and outreach, visit aiaa.org/get-involved/committees-groups/Integration-and-Outreach-Division-Committees.

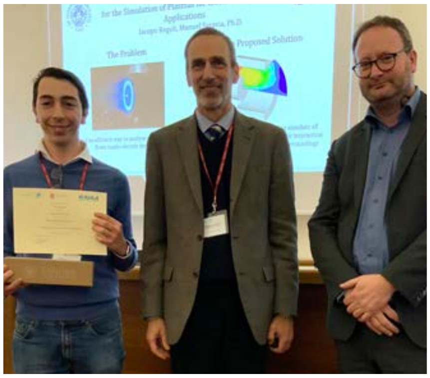
Technical Groups coordinate the activities of related technical committees to facilitate cooperative efforts between the various technical disciplines. Nominations are being accepted for:

- Aerospace Sciences Group, Director
- Aerospace Design and Structures Group, Director

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

Please go to AIAA Nominations and Elections (aiaa.org/about/Governance/nominations-and-elections) to learn more and submit nominations no later than 14 July 2023, 1800 hrs ET.





PEGASUS Student Conference Winners Announced

AIAA supported the 19th PEGASUS Student Conference, 14–15 April, at the Sapienza University of Rome in Rome, Italy. This annual conference gives graduate students the opportunity to present their technical work. The first-, second- and third-place winners receive cash prizes from AIAA and the first-place winner will compete at the International Student Conference at the 2024 AIAA SciTech Forum, 8-12 January.

- **1st Place –** "Flow Control on the Green Raven UAV Using Aerodynamically Shaped Vortex Generators," Carlos Neves, KTH Royal Institute of Technology Stockholm
- **2nd Place –** "Multi-Fluid Finite Volume Formulation for the Simulation of Plasmas for Electric Propulsion Applications, Iacopo Regoli, Università di Pisa
- **3rd Place –** "Analysis of Collision Avoidance Manoeuvres Using Aerodynamic Drag for the Flying Laptop Satellite," Fabrizio Turco, University of Stuttgart

Dayton/Cincinnati Section Gets a Tour of GE Aerospace's Learning Center

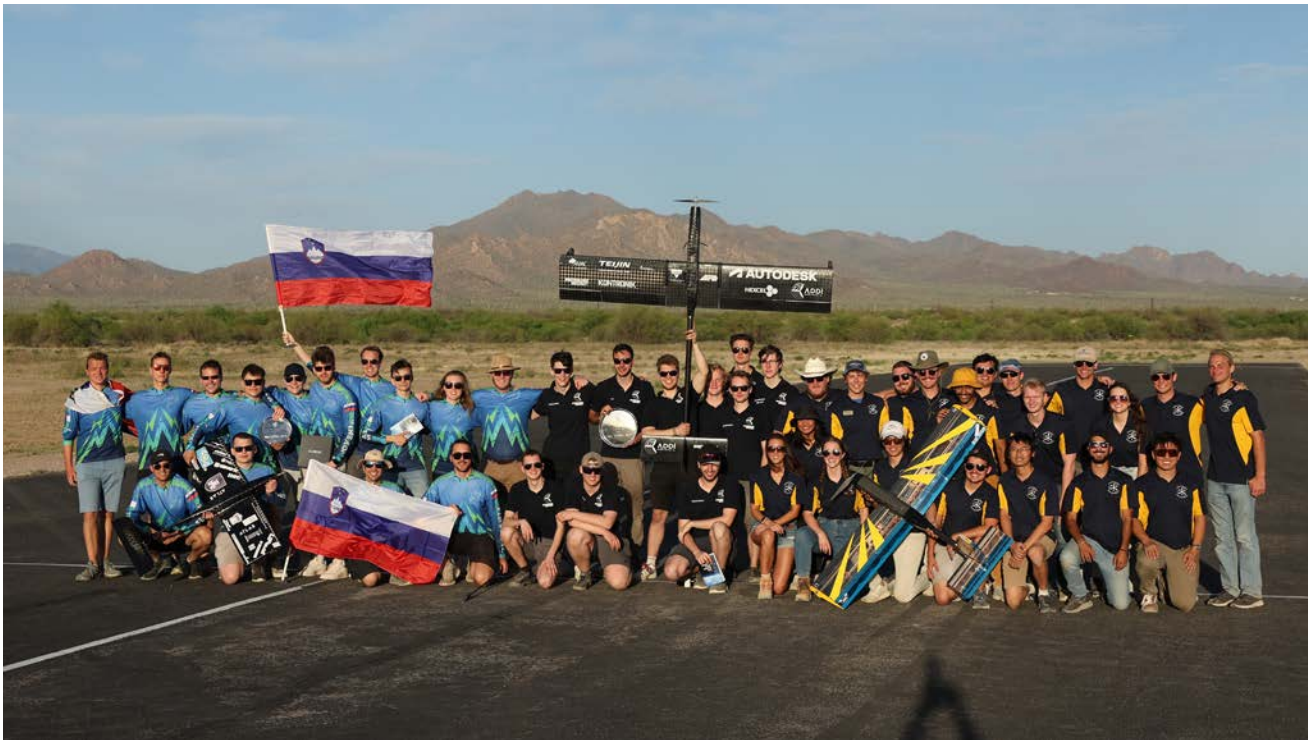
On 6 May, members of the AIAA Dayton/Cincinnati Section got a tour of GE Aerospace's Brian H. Rowe Learning Center in Evendale, OH. The tour included a museum of GE engines. Thanks to Gary C. Wollenweber, P.E., Consulting Engineer - Infrared Radiation and Thermal Design at GE Aerospace for the tour.

AIAA Public Review

AIAA S-157, *In-Space Storable Fluid Transfer,* has been issued for public review. This document provides the current industry best practices for development of prepared interfaces for in-space fluid transfer for storable propellants and other storable fluid commodities, including but not necessarily limited to: initial fueling, refueling and refilling. It is intended to provide guidance to developers and operators of both the servicer spacecraft and client spacecraft. Public review deadline is 16 July 2023. For a copy of the draft, submission of public review comments, or questions, please contact Nick Tongson (nickt@aiaa.org).

MAKING AN IMPACT

2023 AIAA Design/Build/Fly Competition

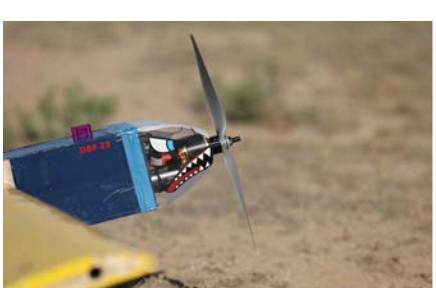


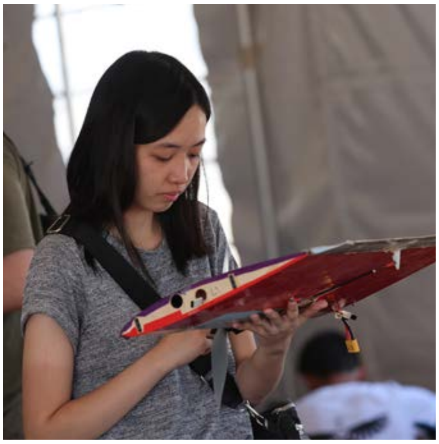
AIAA held its 27th annual Design/Build/Fly (DBF) Competition 13–16 April at Tucson International Modelplex Park Association in Tucson, AZ. Eighty-one teams comprising 868 university students from 14 countries participated in the flyoff. This year's flight objective was to design, build, and test an uncrewed aerial vehicle (UAV) to conduct surveillance and jamming missions for electronic warfare.

The 2023 DBF winners are:

- First Place ($3,000): RWTH Aachen University, Germany
- Second Place ($2,000): University of Ljubljana, Slovenia
- Third Place ($1,500): Embry-Riddle Aeronautical University, Daytona Beach, Florida
- Best Report Score ($100): University of Washington, Seattle

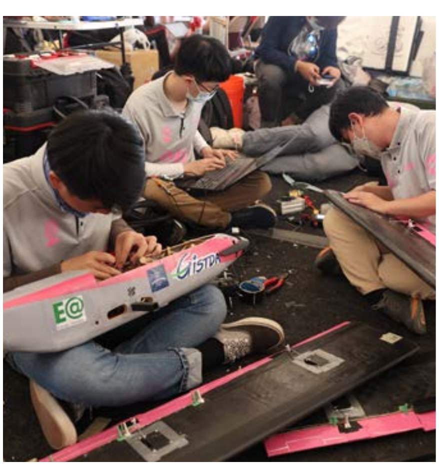
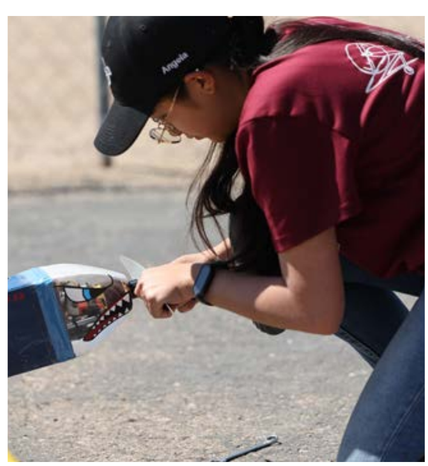
The success of DBF is thanks to the efforts of many volunteers from Raytheon Technologies, Textron Aviation, and the AIAA sponsoring technical committees: Applied Aerodynamics, Aircraft Design, Flight Test, and Design Engineering. 2024 AIAA DBF will be hosted by Textron in Wichita, KS, in April 2024; more information can be found at **aiaa.org/dbf**. For information on how your organization can engage with and sponsor this event, please contact alexandrad@aiaa.org.










Obituaries

Associate Fellow Rediess Died in July 2022

Herman A. Rediess died on 2 July 2022. He was 86.

Rediess received a Bachelor of Science with Honors in Mechanical Engineering from the University of California at Berkeley. He entered an engineering co-op program at the National Advisory Committee for Aeronautics (NACA) at Edwards Air Force Base.

Following graduation Rediess returned to Edwards AFB as a research engineer at the newly renamed NASA Flight Research Center (FRC). Most of his early career at NASA was focused on flight mechanics and control, working on the X-15 and F-100C Variable Stability Aircraft and other research aircraft. During this time, he pursued graduate studies at the University of Southern California, receiving a Master's of Science in Aerospace Engineering in 1964. Rediess then took leave from NASA to pursue a Ph.D. in Aeronautics and Astronautics from MIT, receiving his doctorate in 1969, with a thesis entitled "A New Model Performance Index for the Engineering Design of Aircraft Control Systems."

Following his return to NASA FRC in 1969, he rose through various leadership positions and ultimately served as Director of Research. In 1978, Rediess took a position at NASA Headquarters, overseeing all of NASA's aeronautics research in avionics, controls and human factors. In 1984, he left NASA to head up a new division of HR Textron; this division was acquired by Sparta where he went on to become a Vice President. Following 12 years in private industry, he took a position at the FAA Technical Center in New Jersey as Chief Scientist for Test & Evaluation, and later led the Aviation Research Directorate at FAA Headquarters. Rediess finished his career at the Department of Homeland Security where he managed a Counter-Man Portable Air Defense Systems program among others.

Rediess was a member of the AIAA Management Technical Committee in the early 2000s, and he became an AIAA Associate Fellow in 2006.

AIAA Associate Fellow Wright Died in January 2023

Martin C.N. Wright died on 17 January 2023.

Wright received his BSc in Mechanical Engineering from University of Newcastle upon Tyne (1982); MSc in Aerodynamics from Cranfield University (1984); and his diploma, Advanced Systems Engineering from Salford University.

Wright worked as a section leader in Performance Analysis at British Aerospace Dynamics (1984–1989) before becoming senior project supervisor, performing commercial transonic, supersonic, and hypersonic wind tunnel testing at Aircraft Research Association.

In 1994, Wright joined the European Transonic Windtunnel (ETW), first as an aerodynamicist and senior test engineer, before becoming group leader of test products and design. Since 2015, he had been manager, Aerodynamics and Testing. His comprehensive experience and knowledge on general wind tunnel testing and strong understanding of high Reynolds number testing in particular, made him a well-known authority in the global ground testing community. He developed fundamental cryogenic testing methods and strategies and played a key role in establishing and serving the organization's international user base. He significantly contributed to ETW's outstanding capabilities and renowned reputation. For many users, Wright was the principal point of expertise and the main face at ETW.

Wright was a Class of 2020 Associate Fellow and a member of the AIAA Ground Testing Technical Committee.

AIAA Fellow Skelton Died in February 2023

Robert (Bob) Eugene Skelton, UC San Diego Distinguished Professor Emeritus of Mechanical and Aerospace Engineering, died 15 February.

Skelton received an electrical engineering degree from Clemson, a master's from the University of Alabama, and a Ph.D. in Aeronautical and Astronautical Engineering from UCLA.

Working at NASA Marshall Space Flight Center, Skelton was integral to the design of control systems on Apollo, Skylab, the space shuttle, and the Hubble telescope. He was Professor of Aeronautics and Astronautics at Purdue for 22 years before joining UC San Diego in 1996.

At UC San Diego, Skelton architected the Dynamic Systems and Controls group in the Department of Mechanical and Aerospace Engineering. Under his targeted leadership, this group grew over two decades into one of the strongest academic modeling and controls programs in the country.

Skelton is broadly recognized as the principal pioneer in the field of tensegrity. His contributions were extensive, ranging from art, to architecture, to biology, physics and medicine, as well as to the building of bridges, large telescopes, space structures, and efficient-wave energy conversion systems in the ocean.

Skelton's research group at University of California San Diego studied structural systems and control, focusing specifically on the design, analysis, and control of tensegrity systems, a mathematically elegant yet innately practical research paradigm related to lightweight controllable structures. Skelton's book, *Tensegrity Systems*, coauthored with Maurício de Oliveira, provides a powerful mathematical formalism to understand the statics and dynamics of tensegrity systems.

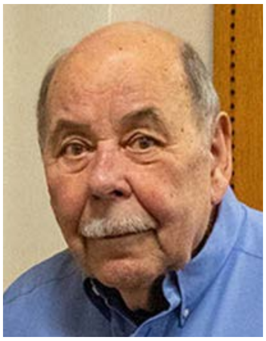
Skelton was an inspired researcher and a visionary architect of both novel mathematical ideas and effective new organizations, as well as of lightweight controllable mechanical structures. He was one of the first in his field to adopt a fundamentally interdisciplinary approach to academic research in control theory and its applications. He retired in from UC San Diego in 2009, and continued doing research as emeritus faculty until 2014. Skelton spent seven additional years as a Distinguished Research Professor in Aerospace Engineering at Texas A&M.

He wrote four textbooks and published over 200 journal articles, and received numerous awards across many different engineering disciplines in Civil, Electrical, Aeronautical & Astronautical, and Mechanical Engineering. He was inducted into the National Academy of Engineering in 2012, and he was the inaugural holder of the

Daniel L. Alspach Endowed Chair in Dynamic Systems & Control at UC San Diego.

Skelton was a life Fellow of the Institute of Electrical and Electronics Engineers (IEEE), a Fellow of AIAA and the American Astronautical Society (AAS), and a life member of the Alexander von Humboldt Foundation. His major awards include: the SKYLAB Achievement Award, the Japan Society for the Promotion of Science Award, the Humboldt Foundation Senior US Scientist Award, the Norman Medal from the American Society of Civil Engineers, the Humboldt Foundation Research Award, and the NASA Appreciation Award. He also received the 2017 AIAA Mechanics and Control of Flight Award.

AIAA Associate Fellow Wilson Died in April 2023



Don Wilson, associate chair of the Department of Mechanical and Aerospace Engineering at the University of Texas at Arlington (UTA), died on 11 April.

He earned a Bachelor of Science in aerospace engineering from Georgia Tech, a Master of Science in aerospace engineering from the University of Tennessee and a Ph.D. in aerospace engineering from UTA in 1973.

Before his career in academia, Wilson was involved in the development of electric arc heaters and MHD accelerators for hypersonic wind tunnel applications at the Air Force Arnold Engineering Development Center, and in the development of supersonic aircraft inlets at LTV Aerospace and Defense Company.

He joined the faculty at UTA in 1968 as an assistant professor in the Department of Mechanical and Aerospace Engineering. He became a professor in 1983 and served as department chair from 1997 to 2003.

He established the UTA Aerodynamics Research Center and was involved in the development of its numerous test facilities. He directed the NASA/UTA Center for Hypersonic Research from 1993 to 1997 and also initiated UTA's detonation wave engine research programs in 1994. Wilson spent two summers at NASA Lewis (now Glenn) Research Center as a NASA/ASEE Faculty Fellow. He was also actively involved in the NASA/DOE National MHD Power Generator Program.

Wilson had over 50 years of experience in the fields of gas dynamics, high-speed aerodynamics and propulsion.

Joining AIAA in 1965, he was a well-known volunteer, serving as a member of the AIAA Hypersonic Technologies and Aerospace Planes Technical Committee and as chair of the Education and Outreach Sub-Committee. He was awarded the AIAA Ground Testing Award in 2001.

Tenure Track Positions in Systems Engineering

NAVAL POSTGRADUATE SCHOOL

The Systems Engineering Department at the Naval Postgraduate School is searching for faculty to fill tenure-track positions at the Assistant/Associate Professor level. Start dates as early as July 2023 through December 2023 are negotiable.

The mission of the Naval Postgraduate School is to provide relevant and unique advanced education and research programs to increase the combat effectiveness of commissioned officers of the Naval Service to enhance the security of the United States. In support of the foregoing, and to sustain academic excellence, NPS and the DON foster and encourage a program of relevant and meritorious research which both supports the needs of Navy and Department of Defense while building the intellectual capital of Naval Postgraduate School faculty.

The Department of Systems Engineering is highly recognized for the quality of its educational programs and research as evidenced by being ranked in the top 25 of graduate programs in the nation by USNWR in the industrial, manufacturing, and systems engineering category. The Department of Systems Engineering has 40 faculty and staff supporting more than 400 graduate students including 20 PhD students in both residential and distributed learning programs. The Naval Postgraduate School is located in beautiful Monterey, CA. Further information on the Systems Engineering department is available at **https://nps.edu/web/seet.**

To apply, send a cover letter and curriculum vita to Chair of the Faculty Hiring Committee, Department of Systems Engineering, Naval Postgraduate School, 1 University Drive, Monterey, CA, 93943. The search committee is presently reviewing applications. Email: **SEhire@nps.edu.**

This announcement will remain open until positions are filled.

Candidates advancing beyond screening will be asked to provide three letters of reference, no more than three publications, and an official transcript of their highest degree claimed. (Applicants with foreign education will be required to select from a list of private organizations that are members of the National Association of Credential Evaluation Services, Inc. (NACES), which provide foreign education evaluations acceptable to NPS.) Initial consideration of applications will begin immediately and continue until the positions are filled.

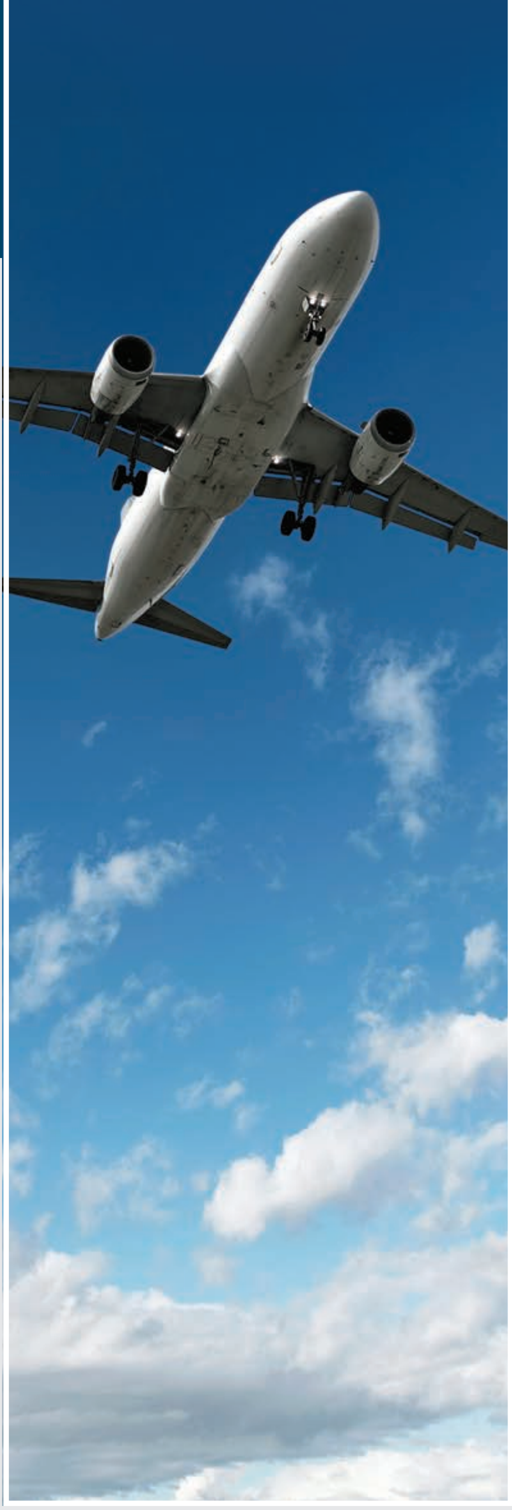
IF YOU ARE A VETERAN, you are strongly encouraged to: Identify your Veterans' Preference on your resume or elsewhere in your application package (type of preference, dates of service, date of VA letter, character of service, etc.) Additional Veterans' information: If you are not sure of your preference eligibility, visit the Department of Labor's website: **https://www.dol.gov/agencies/vets.** For more veterans' preference information, visit: **https://www.fedshirevets.gov/job-seekers/veterans/veterans-preference.**

The NPS is an equal opportunity / affirmative action employer. Eligibility for a security clearance and hence US Citizenship are required. For all positions, salary is competitive and depends upon qualifications. Relocation package including recruitment/relocation incentive may be authorized in accordance with applicable regulations.

The minimum qualification for tenure track positions is a PhD in engineering, with preference for systems engineering or a closely aligned field. We seek faculty with expertise in one or more of the following sub-disciplines/domains: systems engineering methodology, systems architecture and integration, model-based and digital systems engineering, combat systems (sensors, weapons, C4ISR, autonomous systems), system of systems engineering, system manufacturing development and production, engineering economics and cost estimation, system engineering applications. Candidates will preferably also demonstrate one or more of the following attributes: experience as a naval systems engineer and experience within the defense acquisition environment.

Expected Starting: Salary Range for Assistant Professor $83,313.00 – $195,000.00
Salary Range for Associate Professor is $107,277.00 – $195,000.00

The successful candidate will be expected to both teach and develop a research program. Applicants must have demonstrated the potential to both teach and train effectively and to develop a research program at the graduate level. For consideration at the Associate Professor level, a demonstrated ability to teach and train, a solid journal publication record, and a track record in obtaining competitive research funding are required.



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individuals and breaking down systemic barriers that have historically limited their progress. Part of this is finding different ways of measuring success and value that are inclusive of what these otherwise excluded groups are good at. Examples of physical measures include handicap parking and ramps, gender-neutral restrooms and the like. Recognizing and addressing injustices does not diminish the accomplishments of any group but rather promotes equity for all.

When we consider the importance of diversity within professional societies, we must acknowledge that true diversity goes beyond superficial characteristics such as race or gender. It encompasses a broad range of perspectives, including but not limited to cultural backgrounds, socioeconomic status, age, abilities, religious choices and sexual orientation. By actively cultivating an inclusive environment that values these differences, professional societies can tap into a wealth of knowledge and ideas, fostering creativity and innovation.

The argument for DEI is not myopically limited to the principles of equity and social justice; it is also pragmatic. The complex challenges and wicked problems facing humanity today require a multifaceted approach, and diverse teams have repeatedly proven their ability to provide holistic solutions. The inclusion of underrepresented voices tends to bring fresh insights, alternative viewpoints and unconventional approaches. By excluding these perspectives, organizations unintentionally limit their potential for breakthrough discoveries and progress.

Moreover, by neglecting DEI, professional societies risk alienating segments of society, thus missing out on the immense talent and contributions these individuals could offer. In an increasingly interconnected and interdependent world, diverse perspectives are vital for addressing global challenges, fostering collaboration and ensuring the sustainability of our collective future.

To embrace DEI within professional societies, a conscious effort must be made to address existing biases, create inclusive spaces and establish equitable practices. This requires an ongoing commitment to training, education and introspection on the part of all stakeholders involved. It also requires the establishment of policies and mechanisms that actively promote diversity and equal opportunity, both in recruitment and within leadership positions.

As we look to the future, the imperative to fully embrace DEI within professional societies becomes more urgent. By doing so, we not only foster an environment that promotes equity but also unlock the full potential of human ingenuity, enabling us to tackle the most complex challenges of our time. It's time for professional societies to acta non verba, championing diversity, equity and inclusion — and reaping the rewards of a truly innovative and inclusive future. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1923

June 14 The New Zealand Air Force is established. In 1934, it is reorganized and designated the Royal New Zealand Air Force. L. G. S. Payne, **Air Dates**, p. 42.

1 **June 27** The first complete midair pipeline refueling between two airplanes takes place in San Diego. From a De Havilland DH-4B fuel plane piloted by 1st Lt. Virgil Hine, 1st Lt. Frank Seifert drops a pipeline by rope control and pumps 284 liters (75 gallons) of gasoline into the DH-4B below, crewed by Capt. Lowell Smith and 1st Lt. John Richter. Seifert also transfers water and lubricating oil. The process was repeated eight times. **Aeronautical Digest**, July 1923, p. 117.

June 27 Flying boat service begins from New York City to Newport, Rhode Island. The Loening Air Yacht "Grey Lark," piloted by George Rummill and carrying Loening President Grover Loening and two reporters, leaves New York's East River and touches down at Codrington Cove, Newport. The new service takes several hours less than the overland journey. **Aviation**, July 9, 1923, p. 48.

2 **Also in June** This month marks the 100th anniversary of the publication of Hermann Oberth's "Die Rakete zu den Planetenräumen" ("The Rocket into Planetary Space"), a mathematical theory of rocketry that lays the foundations for future spaceflight efforts. The Transylvanian-born Oberth studies physics at the University of Heidelberg and in 1922 submits his doctoral thesis on the possibilities of spaceflight via liquid-propellant rockets, but it is rejected as "Utopian." He privately publishes it as the 92-page "Die Rakete zu den Planetenräumen." Among the contents are Oberth's calculations that rockets can work in the vacuum of space and that "men can be lifted in them" and safely returned.

1948

June 5 The second Northrop YB-49 Flying Wing turbojet bomber prototype crashes 10 miles northwest of Muroc Air Base, California, killing all five aboard. Structural failure during stall tests at 40,000 feet is cited as the cause of the crash, which prompts the Air Force to terminate development of the bomber and the flying-wing concept for several decades. In 1949, Muroc Air Base is renamed Edwards Air Force Base in honor of YB-49 co-pilot Capt. Glen Edwards. **Muroc AFB Semi-Annual Report**, January-June 1948, p. 6; William D. Feeny, **In Their Honor**, pp. 171-172.

June 15 The U.S. Air Force and NASA's predecessor, the National Advisory Committee for Aeronautics, confirm publicly that the two Bell X-1 research planes have repeatedly exceeded the speed of sound while flown by Air Force test pilot Capt. Charles Yeager and NACA research pilots Herbert Hoover and Howard Lilly. At the disclosure ceremony, Yeager receives the Mackay Trophy for 1947, as well as an oak leaf cluster to his Distinguished Flying Cross medal. Richard P. Hallion, **Supersonic Flight**, pp. 112-113.

June 26 The Berlin Airlift begins with U.S. Air Force flights from Wiesbaden, West Germany, to Tempelhof Airport in Berlin to bypass the Soviet blockade. By evening, 80 tons of medicine and food had been flown into the city. The U.S. and British air forces continue deliveries through September 1949, transporting some 2.3 million tons of supplies over 277,000 flights. The Soviets end the blockade in May. NASA, **Aeronautics and Astronautics 1915-1960**, p. 59.

Also in June National Advisory Committee for Aeronautics research scientist William Phillips publishes NACA Technical Note TN-1627, which contains a theoretical prediction of the problem of inertial coupling. The phenomenon later plagues aircraft with long fuselages and short wings and first manifests in flights of the Douglas X-3 research plane. Increasing the area of the vertical tail and the span of the wings solves it. NACA Research Memorandum H55A13 by the NACA High-Speed Flight Station, Feb. 4, 1955; NASA, **Aeronautics and Astronautics 1915-1960**, pp. 60-61.

3 **Also in June** Bell Laboratories announces the invention of the point-contact type transistor. NASA, Aeronautics and Astronautics 1915-60, p. 69.

1973

4 **June 1** Jeanne Holm becomes the first two-star female general officer in the U.S. military with her promotion to Air Force major general. She began her career as a truck driver in the Women's Auxiliary Army Corps in 1942 and is currently the director of the Secretary of the Air Force Personnel Council. The only woman to hold a command outside a service nurses' corps or women's branch, Holm becomes a driving force for expanding women's roles in the service. **Washington Star & News**, June 6, 1973, p. 2.

June 4 The Tass news agency announces that the Soviet Union's Lunokhod 2 lunar rover ceased operations in May. Throughout its four months on the lunar surface, the rover covered 37 kilometers of terrain and took measurements from the lunar surface that established that the moon is surrounded by a layer of dust particles in which the visible solar light and the reflected Earth light are dispersed. Lunokhod 2 also took 86 panoramas and 80,000 TV photos of the lunar surface. **New York Times**, June 5, 1973, p. 18.

June 5 NASA announces that its Pioneer 11 probe has traveled 48 million kilometers since its launch in April, one-fifth of its planned journey to Jupiter. During its voyage, the instruments sample the sun's wind, measure solar and galactic cosmic ray particles in interstellar space, and make star maps of the sunlight reflected from cosmic dust between Earth and Jupiter. Meanwhile, the twin probe Pioneer 10, launched in March 1972, has traveled 560 million kilometers and will make its closest approach to Jupiter in December. NASA, **Astronautics and Aeronautics, 1973**, p. 174.

June 8 The Soviet Union launches some eight Cosmos satellites on a single rocket booster from Plesetsk. Western specialists believe these Cosmos 564-571 satellites to be a military communications data-relay system. **New York Times**, June 10, 1973, p. 41.

June 10 NASA's Explorer 49 spacecraft is launched by a Thor-Delta rocket into a transfer trajectory for the moon. Also called Radio Astronomy Explorer B, the satellite will measure galactic and solar radio noise frequencies. **NASA Release** 73-105.

June 12 NASA announces that a specially equipped United Airlines Boeing 727-200 is testing two-segment landing approach procedures to reduce noise levels near airport landing patterns. The technology, developed jointly by FAA and NASA's Ames Research Center, is expected to achieve a 67% noise reduction. **NASA Release** 73-113.

June 18 The USS Wasp, a World War II aircraft carrier and NASA's prime recovery ship, makes its last voyage to a ship breakers' yard in Kearny, New Jersey. The 30-year old ship, which Union Mineral Alloys Corp. purchased for scrap metal, served as the recovery vessel for Gemini missions 4, 6, 7, 9 and 12 between 1965-1966. **New York Times**, Feb. 19, 1973, p. 39.

5 **June 22** Skylab 2 astronauts Charles "Pete" Conrad Jr., Paul Weitz and Joseph Kerwin splash down in their Apollo command module and are recovered by the USS Ticonderoga off the coast of San Diego. Plans had called for the astronauts to launch aboard a Saturn V in early May and rendevous with the Skylab space station for a 28-day stay, but one of the station's

solar panels ripped off during launch, delaying the launch of the crew by three weeks. Once docked with Skylab, the astronauts manually deployed a sunshade and the remaining solar panel. The New York Times wrote that "this first group of astronauts did much more than demonstrate man's biological capability to live and work in space for four weeks. They proved that men in space can do what machines cannot do: They can repair their vehicle." The Philadelphia Inquirer similarly commented that the astronauts could "deal with the unexpected, correct serious malfunctions and adjust routine to changed circumstances." **New York Times**, June 24, 1973; **Philadelphia Inquirer**, June 24, 1973.

June 25 NASA Deputy Administrator George Low accepts a silver plaque presented by the British Interplanetary Society at the opening of the 13th European Space Symposium in London in recognition of the Apollo program's "triumphant achievements" and to acknowledge "the dedicated service of many thousands of scientists and engineers which culminated in this great result." NASA, **Astronautics and Aeronautics, 1973**, p. 195.

June 26 NASA's Johnson Space Center in Texas announces its selection of a Pratt and Whitney TF33-P-7 turbofan engine for use on the space shuttle orbiters in atmospheric flight development tests. The engine is similar to those on the U.S. Air Force's C-141 Starlifter transport aircraft. The Air Force is to secure 25 of these engines for horizontal flight testing of the orbiters and for routine flights when the design becomes operational. **NASA Release** 73-121.

1998

June 1 In an attempt to compete with air carriers including Southwest Airlines, US Airways begins operating low-cost flights through its subsidiary, MetroJet, from its hub at Baltimore-Washington International Airport. R.E.G. Davies, **Airlines of the Jet Age**, p. 346.

6 **June 12** Ten days after launch, NASA's space shuttle Discovery lands in Florida, completing the ninth and final shuttle flight to the Russian Mir space station in STS-91. Discovery docked with Mir for four days. **Flight International**, June 24-30, 1998, p. 29.

June 19 The AsiaSat 3 communications satellite is salvaged by Hughes Global Services. Because of a malfunction in its Russian booster, AsiaSat 3 was placed in a highly elliptical orbit where it could not function. In April, Hughes began firing the satellite's thrusters for the first of two lunar flybys in which the moon's gravity helped the satellite correct its orbit around Earth. NASA, **Astronautics and Aeronautics: A Chronology, 1996-2000**, pp. 145-146.

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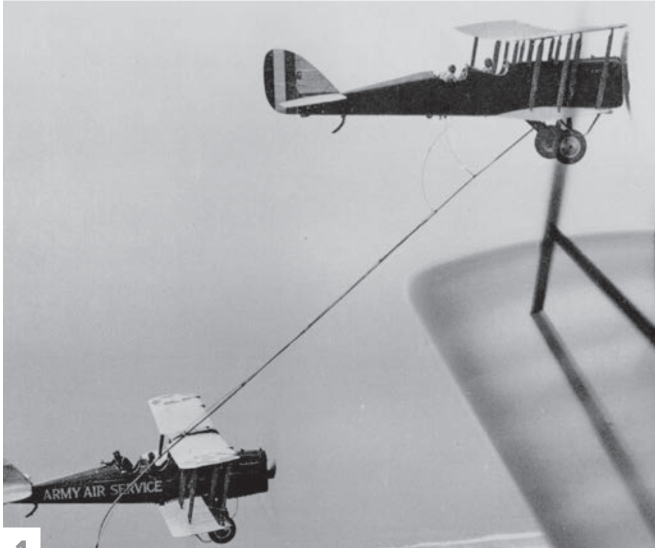

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Diversity, equity and inclusion is also about innovation and progress

BY MORIBA JAH | moriba@utexas.edu

As human society continues to evolve globally, the importance of diversity, equity and inclusion within professional societies is becoming increasingly evident. Organizations that fail to embrace DEI as a core tenet not only perpetuate inequality but also hinder their own ability to innovate and solve complex problems. Success, first and foremost, will require engaging doubters with understanding, while simultaneously not allowing DEI to be misconstrued or redefined.

It is essential to emphasize that DEI does not exclude white male heterosexual individuals, nor does it advocate for unqualified individuals from underrepresented groups to be thrust into roles beyond their capabilities. Instead, DEI encourages a collective effort to harness the power of humanity: diverse perspectives, experiences and talents for the betterment of all. A rising tide lifts all boats.

Professional societies are supposed to be built upon the principles of knowledge sharing, collaboration and advancement. However, in order to effectively fulfill these roles in a dynamic world, it is essential that these societies reflect the varied cross section of humanity. By embracing diversity, professional societies open doors to new ideas, nuanced approaches and innovative solutions that would remain inaccessible within homogeneous environments. DEI helps prevent groupthink, a concept developed by research psychologist Irving Janis in 1972 to describe how organizations with like-minded people can come to consensus-based decisions that can be detrimentally myopic of better solutions. An example of groupthink can be found in the space shuttle Challenger disaster, where, inter alia, forced consensus in the absence of diverse perspectives proved to be fatal.

DEI aims to achieve these diverse perspectives by creating equal opportunities, empowering

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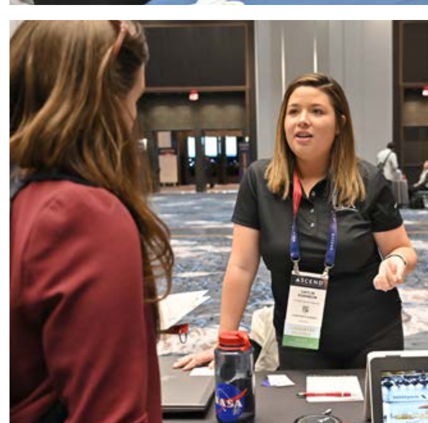
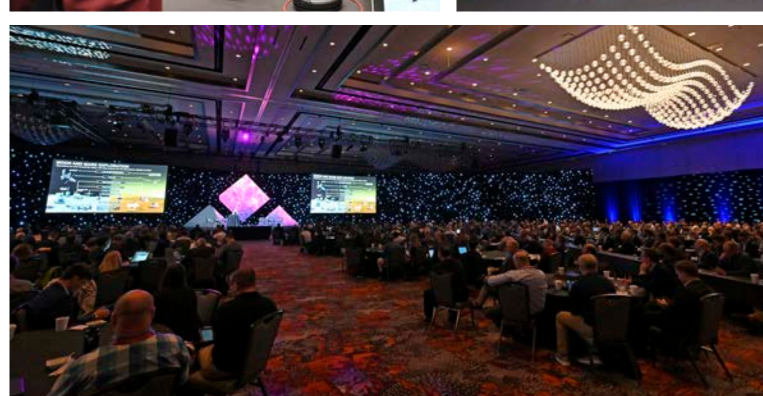
Moriba Jah is an astrodynamicist, space environmentalist and associate professor of aerospace engineering and engineering mechanics at the University of Texas at Austin. An AIAA fellow and MacArthur fellow, he's also chief scientist of startup Privateer.



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