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# AEROSPACE
## ★ ★ ★ AMERICA ★ ★ ★

# Fresh thinking about Mars

**Pushed by scientists, NASA weighs a bigger role for small spacecraft** PAGE 22

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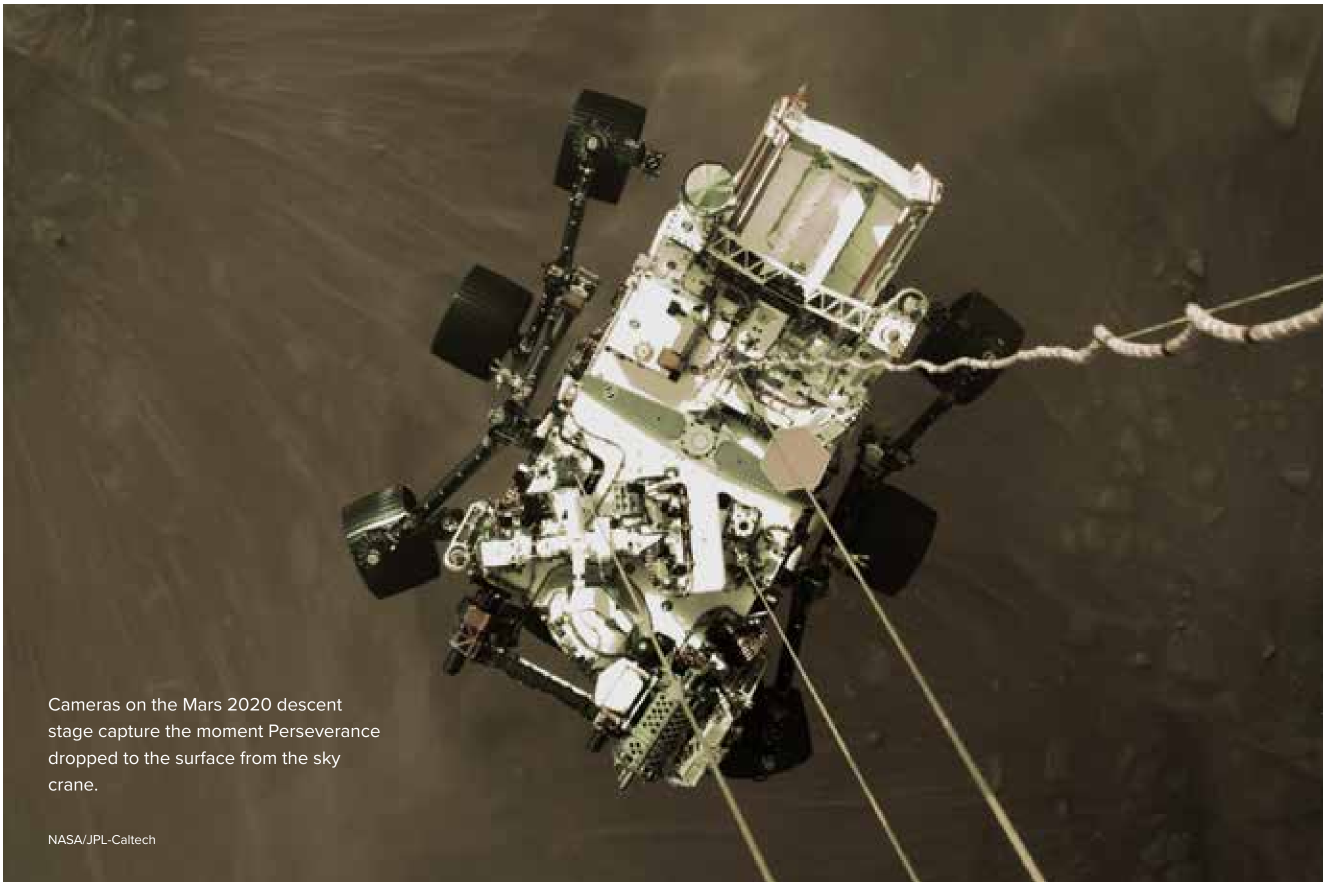

Cameras on the Mars 2020 descent stage capture the moment Perseverance dropped to the surface from the sky crane.

NASA/JPL-Caltech



**ON THE COVER:** This November 2020 selfie of NASA's Curiosity was created by stitching together dozens of photos taken by the Mars Hand Lens Imager camera on the turret at the end of the rover's robotic arm. Photo credit: NASA/JPL-Caltech

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## IN THIS ISSUE

### Keith Button

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

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### Leonard David

Leonard has reported on the space industry for five decades. He is the author of several books, including “Moon Rush: The New Space Race” and “Mission to Mars — My Vision for Space Exploration,” co-authored with Buzz Aldrin.

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### Aaron Karp

Aaron is a contributing editor to the Aviation Week Network and has covered the aviation business for 20 years. He was previously managing editor of Air Cargo World and editor-in-chief of Aviation Daily.

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### Moriba Jah

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

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### Paul Marks

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

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## DEPARTMENTS

# The value of failing now and then

As someone who reported on space exploration during NASA's "Faster, Better, Cheaper" era in the 1990s, it's startling to witness the concept being surfaced under a different name 25 years later, this time by Mars scientists and engineers, as Leonard David reports in our cover story.

In the '90s, some scientists were piqued when a caustic businessman-turned NASA administrator named Dan Goldin began pushing a strategy for smaller, higher-risk missions alongside his effort to expunge the redundancies he saw among the agency's field centers. There was heartburn, to say the least. A very specific rumor began to swirl at some point in the mid '90s that Goldin was preparing to resign. I ended up interviewing the administrator in his office, and when I asked about the rumor, he told me he wasn't going anywhere, and indeed he stayed some six more years.

This time, if the NASA leadership decides to adopt the newly proposed "Frequent, Affordable, Bold" strategy, I doubt the idea will stir that degree of emotion. It's a grassroots proposal that sprang from Mars workshops hosted last year by the Keck Institute for Space Studies in California. Advocates also are not gunning to make all NASA science missions meet their FAB criteria, nor even all Mars missions. They want a new class of small landers, rovers and fliers to be added on top of the Mars Sample Return mission that the European Space Agency and NASA plan to carry out in multiple steps through 2031.

Who could complain about that? Well, Mars is not the only interesting body in the solar system. Scientists who research other planets or moons might argue: Mars scientists chose to put their faith and dollars in a sample return mission, so now they must lay in that budgetary bed. Spirited, if not emotional, debate seems likely.

Of course, we might not learn the answer to the most fundamental question for years, which is whether FAB is a stroke of genius or something less. Absent a stunning breakthrough, like finding microbes or fossils, I suspect opinions will always vary. That's because sending less costly spacecraft to daring locations will inevitably result in some failures. That should be viewed as evidence of a well-thought out program. Here's how planetary scientist Elizabeth Frank explains this irony in an email: "The trick about failure is that if you're going to be risk-tolerant, you should fail because you were pushing the edge of technical capability." She is chief scientist at the First Mode engineering firm in Seattle and participated in the September workshop where the term FAB was coined. For an in-depth look at FBC, I recommend reading her blog article from 2019 , "Faster, Better, Cheaper: A maligned era of NASA's history."

The irony that failure can be evidence of wisdom is a hard one to grasp, and inevitably not everyone will. The circumstances matter: A mix up over unit of measures, like the one that sent the Mars Climate Orbiter plunging into the Martian atmosphere in 1999, is not the same as losing a spacecraft because you dared to explore a dark ravine without redundant components. In some eyes, all failures are equal, and that might be FAB's biggest hurdle. ★

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


# Unclear environmental impact of space launches

The article "Space transportation's pollution conundrum" (January 2022) demonstrates the importance of perception over facts. However, we should be informing our members of the facts to combat misperceptions. The shift from a few launches per year to potentially thousands per year is startling and has us wondering about the impact to our environment. However, solid rockets and those burning kerosene are unlikely to be part of this future. Methane and hydrogen are the fuels of choice. So will there be a pollution problem from these rockets? The author offers no evidence for such but does quote an environmental researcher's opinion on space tourism.

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**Let us hear from you**

Send letters of about 250 words to letters@aerospaceamerica.org.
Letters may be edited for length and clarity and may be published in any medium.

# Accelerate Your Learning at the Speed of Innovation

During my days on the Purdue University campus as a Professor of Practice, I encouraged students to stay curious, to always keep learning, and to continue asking questions – especially "why?" These are essential traits for success in aerospace. I repeat them to the students I encounter at AIAA events as well, yet I believe they apply to all of us, even when we're outside a formal educational setting. Over the course of our careers, we must stay curious to shape the future of aerospace. Our curiosity is what will drive the innovation, tackle the technical challenges, and solve the problems our industry needs.

To satisfy our curiosity we often need to learn new skills, dig deeper into a discipline, or broaden our awareness. Engineering is a great teacher in understanding a problem or situation, recognizing the constraints, and determining the validity of information to arrive at information-based conclusions and results. The engineering education we receive in our universities instills the fundamentals and points us toward the future, especially as we embrace systems thinking to accelerate our progress.

This year, we are working to broaden the portfolio of AIAA continuing education resources we make available to our community. It's part of our commitment to helping our members succeed at all phases in their career. What questions are you asking lately? What problems are you trying to solve in your current role? We know important topics for our future include hypersonics, electric aircraft, artificial intelligence, digital engineering, and more. Consider this – in 18 hours you could be several steps closer to a goal, or in eight weeks you could be well on your way to finding answers on these topics – after taking just one AIAA continuing education course. The industry needs you to be on the leading edge of these topics to move us forward at the speed of progress.

AIAA heard clearly that professional development is experiencing dynamic changes. From our "2021 AIAA State of the Industry Report," one out of four aerospace industry professionals believes that COVID-19 has transformed their thinking around traveling for essential education opportunities. We heard this especially from our members with 10+ years of experience. What's an aerospace engineer to do to stay sharp? AIAA is responding quickly to match the pace of this shifting demand with our accessible, robust professional development offerings.

Since the pandemic began, we've witnessed explosive growth in the popularity of online courses. In 2018 and 2019, AIAA offered 20 in-person courses each year, with only one online course alongside.

## Travel for Professional Development

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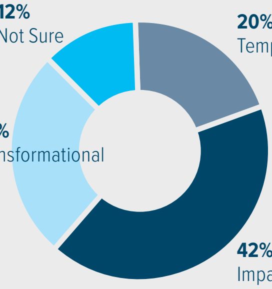



During 2020, we were able to deliver 11 courses in person before shifting solely to online delivery of 12 more courses. And in 2021, we increased the catalog to deliver 28 courses, all virtual. We anticipate that 2022 will see an even bigger increase in online learning, with more than 35 online courses planned.

We are offering 24 online courses in spring 2022 – more in one season than ever before. And there will be one in-person course held in conjunction with the 2022 AIAA DEFENSE Forum. I am confident there is something for everyone; take a look for yourself at **aiaa.org/events-learning/courses-workshops**.

We carefully select courses for their technical relevance today, taught by expert instructors who are part of the aerospace community. We want to ensure you have deep technical depth on today's topics, similar to the depth of what you find in AIAA journals and publications. The course experience is substantive and interactive – with lectures and notes, as well as Q&A and discussion. And we ensure you receive completion certificates and CEUs/PDHs to document the value you've gained. The benefits are realized in a few ways:

- **Stay sharp**. Learning the latest methods can enhance your current job performance and help demonstrate your proficiency in real-world applications.
- **Lead innovation**. Exploring the latest technologies and hearing new ideas can spark your creativity, positioning you as a leader.
- **Accelerate your career**. Whether you are navigating the climb of your career or building the future, your professional drive moves you closer to a promotion or a new role.

Shaping the future of aerospace is no simple task. It takes passion, discussion, innovation, collaboration – and you. AIAA is here to help you succeed. ★

**Dan Dumbacher**
*AIAA Executive Director*

**Find your topic in the Course Catalog** at aiaa.org/events-learning/courses-workshops. Register for a course today.

AERO PUZZLER

Do you have a puzzler to suggest? Email us at aeropuzzler@aiaa.org.

# Steering with wind versus sunlight

LightSail 2 photographed itself over the Arabian Sea in May 2021.

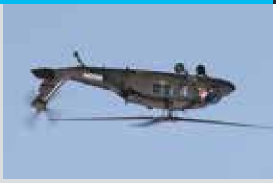
The Planetary Society

**Q.** A sailboat crew wants to reach a barrier reef around an island directly upwind, so the crew tacks the sailboat into the wind and follows a zigzag pattern to reach the reef. Now imagine that you are controlling a solar sail in space, and instead of wind the force available to you is sunlight. Is there any way you can move closer to the sun?

*We developed this question with Bruce Betts, manager of The Planetary Society's LightSail 2 program.*

**Your challenge is to answer the above in a maximum of 250 words that someone in any field could understand. Email your response by noon Eastern March 16 to aeropuzzler@aiaa.org for a chance to have it published in the next issue.**

## FROM THE FEBRUARY ISSUE



**INVERTED HELICOPTER FLIGHT:** We asked you to edit a screenplay passage about inverted helicopter flight.

**WINNER:** Unless the design is a full rigid rotor coaxial with negative pitch, it is unlikely the coaxial can remain in inverted flight more than a few seconds at best. R/C [radio-controlled] helicopters that are coaxial modify their rotor systems for this trick and do not have a mass such that the inverted flight condition causes coning of the blades. So an R/C model for the movie might work. Any current coaxial machine large enough to pick up a SEAL team would be subject to inverse coning, likely rotor strike to the tail structure, and only a minimal amount of negative rotor blade pitch. A Kamov helicopter might be able to pull it off for seconds before engine and transmission lubrication systems quit doing their jobs and the system would lock up. To date, the Sikorsky S-97 Raider has yet to demonstrate a full roll, let alone inverted flight. I worked with Red Bull pilot Chuck Aaron on engine issues for his BO-105 helicopter tricks — we worked out how many seconds he could stay inverted before the M250 oil system (highly modified for this machine) would dry up. But that one is not coaxial, so it might do the job for a few seconds.

**David Newill,** Associate Fellow
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Newill has been a consultant to aerospace companies since retiring from the U.S. subsidiary of Rolls-Royce Defence in 2016. He leads the Indiana branch of the Rolls-Royce Heritage Trust, which restores and displays the company's legacy engines and other artifacts.

For a head start … find the AeroPuzzler online on the first of each month at https://aerospaceamerica.aiaa.org/ and on Twitter @AeroAmMag.

# Test time for drone traffic management

BY AARON KARP | aaronkarp74@gmail.com

A future of hundreds of thousands of drones navigating low-altitude airspace appears to be inevitable, and that presents a serious safety question: How to prevent collisions among them?

FAA and NASA, the agency's technology partner, have been busy trying to define standards for managing these aircraft in the airspace not under the purview of FAA's air traffic control system, meaning areas under 400 feet in altitude, away from airports or other protected sites and beyond the drone operator's line of sight.

FAA and NASA are set to begin the next phase of their Unmanned Traffic Management field test program with a March 14 informational event in Washington, D.C., where FAA and NASA will provide in-person and online participants with a "walkthrough of project objectives."

The key, says FAA, will be establishing a method for information sharing and data exchanges among various drone operators. Drones will need to automatically communicate with one another to avoid collisions, and if there were an incident of some kind, FAA and law enforcement agencies must have the ability to learn who was operating the drone or drones.

Overall, FAA is after what it calls a "distributed information network" that will put more responsibility in the hands of drone operators compared to the two-way communications between air traffic controllers and pilots of conventional aircraft. Drone operators will be "responsible for managing their own operations safely within these constraints without receiving ATC services from FAA," the agency explained in its final report on phase two field testing conducted in 2020.

In the new phase, FAA and NASA will be "conducting flight test activities to validate industry standards and maturation of [traffic management] capabilities, including security of information exchanges," FAA said in prepared statement. Plans call for operating "multiple drone flights in realistic test scenarios to learn more about how to manage drone traffic in varying environments."

FAA will set standards and ground rules, and then it will be up to the drone operators and service providers to operate the new technologies to deconflict flight paths.

A central component, FAA says, will be Remote ID, basically an electronic license plate for drones that will identify their operators.

FAA has a separate program in place to give commercial and recreational drone pilots access to airspace controlled by FAA. Since 2018, FAA has used an automated system (replacing a manual system) to enable drone pilots to request permission to operate their aircraft below 400 feet in this controlled airspace. FAA in February announced it had issued its millionth airspace authorization for a drone pilot operating in controlled airspace.

The more challenging element of drone traffic management is in airspace not controlled by FAA, since numerous operators could be flying drones in very close proximity to one another. ★

▲ A Virginia Tech researcher flies a DJI Inspire 2 drone during a previous phase of FAA's Unmanned Traffic Management program. The October 2020 flight tests included a mock public safety mission in which onboard software had to deconflict multiple simultaneous drone flights to give priority to the most urgent.

Virginia Tech


# Hydrogen evangelist

In the tale of the airline industry's attempts to reduce its environmental impact, hydrogen is ether a godsend or an impossible challenge. Paul Eremenko is firmly in the first camp. His 70-person startup Universal Hydrogen has taken its first concrete steps toward creating a hydrogen fuel distribution network that would initially power small aircraft and eventually airliners. The startup's first products will be carbon fiber capsules that would be trucked to airports where technicians would swap out empty capsules for fresh ones. Plans call for selling the capsules to regional airlines starting in 2025 as part of a Universal Hydrogen kit for converting turboprop planes to hydrogen-electric aircraft. I reached Eremenko via Zoom at his California office to learn why he predicts the rest of the aviation industry will soon become hydrogen believers. — *Cat Hofacker*

## PAUL EREMENKO

**Positions:** Since 2020, CEO of Universal Hydrogen in California. Chief technology officer of United Technologies Corp., 2018-September 2019, leading the 30,000-person engineering and R&D division of the Connecticut-based conglomerate that is now part of Raytheon. Chief technology officer of Airbus Group, 2015-2018. Deputy director and briefly acting director of DARPA's Tactical Technology Office, 2009-2013.

**Notable:** Came to the U.S. in 1990 at age 11 from the Ukraine and became a U.S. citizen in 1999. At Airbus, helped establish Acubed, the company's DARPA-inspired Silicon Valley innovation center. Also established the Vahana and City Airbus electric vertical takeoff and landing demonstrator projects. At DARPA, started the experimental vertical takeoff and landing, VTOL, X-plane program. Licensed pilot; he doesn't own a plane but his favorite to fly is the two-seat DA20 Diamond Katana.

**Age:** 42

**Resides:** Los Angeles

**Education:** Bachelor of Science in aeronautics and astronautics, MIT, 2001; Master of Science in aeronautics, Caltech, 2002; Doctor of Law, Georgetown University, 2007

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**Q: How does one go from spearheading tech development at DARPA and Airbus to creating a hydrogen startup?**

A: One develops a very high level of frustration with the fact that the industry is basically ignoring the Paris Agreement. If you look at like the International Civil Aviation Organization forecast for aviation emissions, it goes in the opposite direction of the Paris Agreement. I was the guy in the Airbus C-suite and then in the United Technologies C-suite who was like, "What are we doing about this?" So I've looked at this problem of decarbonizing aviation for the better part of the last decade. I've worked on battery-powered aircraft, I've worked on hybrid-electric aircraft, I've worked on biofuels, and if you take the timeline of the Paris Agreement seriously — which I think we should because it's about as close to a consensus as we have as a species about where we need to go from an admissions perspective to avoid catastrophic climate change — there are only a few technologies that are plausible on the timescale that you need. If you want to decarbonize the sector, it's not enough to do small airplanes or air taxis; you've got to do the single aisle, the Airbus 320s and Boeing 737s. For that class to get to zero emissions, there's two options: You can go nuclear — probably not desirable from a safety perspective and from other kinds of environmental impact — or you can go hydrogen. And the answer to why that hasn't happened yet is not because hydrogen airplanes are difficult to build. The first manned hydrogen airplane flew in the '50s; Pratt and Whitney's entire West Palm Beach operation was created around a hydrogen engine program in the 1950s. The problem is affordable green hydrogen and getting hydrogen from the point of production to the airplane, the point of consumption. So we founded this company in 2020 when it started to become clear that the cost of green hydrogen was dropping at such a rate that by around 2025, it will be equivalent to the cost of jet fuel on an equivalent energy basis.

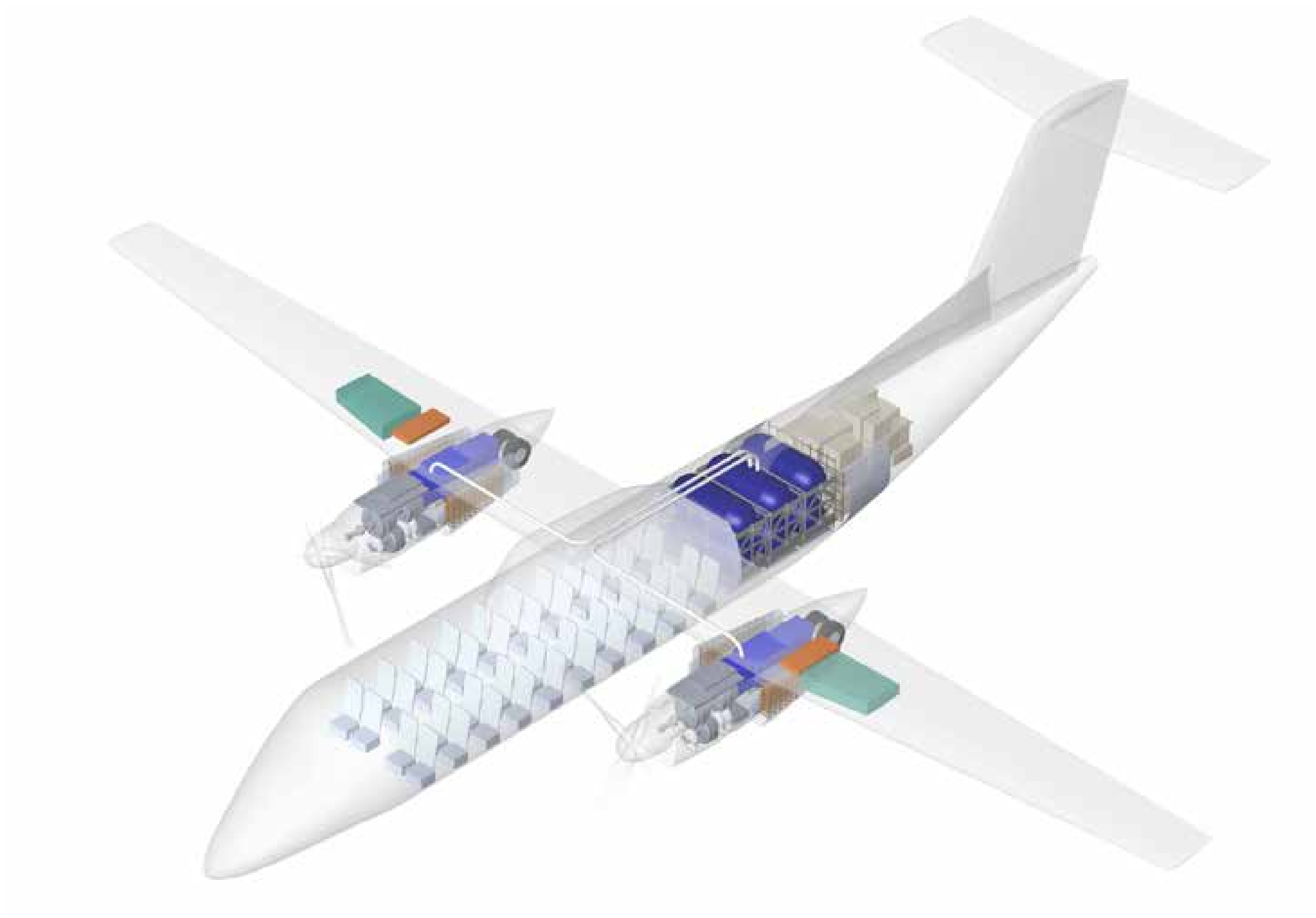
> "It will be an impossible decision for Boeing and Airbus to do anything other than launch a hydrogen single-aisle program in the late 2020s. The environment is going to change much more quickly than either of those companies anticipates today."

**Q: What's prompting this price decrease?**

A: The first is volume, which is a bit of a self-fulfilling prophecy: As you increase production, the cost of production goes down drastically. You can make hydrogen a number of different ways, but a lot of them take hydrocarbons and strip out the carbons and you have the hydrogen left, but then you got to do something with the carbon. But then you have carbon emissions, which is the exact opposite of what we're trying to do here. But you can make hydrogen by splitting water molecules into hydrogen and oxygen using electricity, and then the oxygen you can either release into the atmosphere, or you can use it for medicinal or other applications. That's green hydrogen, which means no carbon footprint so long as you use renewable electricity. There's two components to the cost: There's the cost of the electrolyzer and the cost of the electricity needed to run the electrolytes. The cost of electrolyzer has dropped because we're in that virtuous cycle of increased production. What reduces cost on the electricity side is the general increase in renewable electricity production. Take wind farms. They're blowing day and night, generating electricity, but the city or whatever you're powering is only consuming so much. And there's no way to store the excess electricity because you can't build batteries at that scale, so that off-peak electricity is available very, very cheaply and you can literally scavenge and produce hydrogen whenever there is less than peak demand on your power plant or wind farm.

**Q: Why is your approach the right one to provide the missing link between fuel producers and operators?**

A: If you take the conventional approach of how we move jet fuel today, we do it through pipelines to big airports, or we do it through fleets of tanker trucks and then we have a storage reservoir at the airport. In some rare cases, there's even on-site refining. You could do all three for hydrogen; the issue is that if you take the scope of even a modest regional airline network, much less the entire commercial air transportation network, a hydrogen infrastructure at every airport becomes a trillion-dollar investment. Then the question is "Who pays?" So if you



▲ To convert their turboprop aircraft into hybrid-electric planes with Universal Hydrogen's kit, airlines would replace the engines with electric motors, shown in gray, made by magniX of Washington, and Universal Hydrogen's fuel cells, in blue. A few seats in the back of the aircraft would be removed to make room for cylindrcal capsules, in blue, containing gaseous or liquid hydrogen.

Universal Hydrogen

take the Paris Agreement timeline and emissions trajectory as the constraint, the answer was to make hydrogen compatible with the existing network and with the existing cargo handling equipment that's at the airports. So we created capsules for gaseous and liquid hydrogen, we ship the capsules in a shipping container, and then at the airport we use the cargo handling equipment that you would use for palletized cargo to move it around and load it directly into the aircraft. There's no fueling operation, nothing has to change, every airport is hydrogen ready. I like to analogize it to the Nespresso coffee capsule model: You have Nespresso capsules, but somebody has to build the first coffee maker. We couldn't be a company that just solves infrastructure when there is no hydrogen airplane. So we're doing hydrogen delivery as a service, and we're going to build the first coffee maker, which is in our case that conversion kit for regional airplanes. Now, regional is not going to solve the Paris Agreement problem for aviation, but it's doable in the next couple years. It's doable within the scope of existing motor technology, existing fuel cell technology, and the airframes frankly are massively overdesigned; they're relatively easy to modify and they have a fair amount of volume.

**Q: Tell me about the different fuel tank designs the company came up with to transport and store both gaseous and liquid hydrogen.**

A: With gaseous hydrogen, you get less hydrogen in a given size capsule, but it's cheaper to produce because compression is less energy intensive than liquefaction. And it's cheaper to transport because they have an infinite shelf life. The liquid capsules have a shelf life of a couple days, so you have a pretty tight logistics network around them. You can hit about two-thirds of all regional routes with gaseous capsules, and you need liquid for the last third to be able to fulfill the range requirements. In anything smaller than regional, you want to go with gaseous. In anything bigger than regional, you want to go with liquid. Those forms require different cannister materials, but they are interchangeable in the aircraft. The same airplane can take liquid capsules on one route and a gaseous capsule on the next route. The gaseous capsules are made of a woven carbon fiber. It's a braid — not a composite in the sense that it does not have an epoxy matrix — and then there's a membrane inside the braid that traps the hydrogen molecules while the braid carries the pressure loads. We get rid of the epoxy to save weight. And then for the liquid capsules, they are today a dual-wall metallic solution with a vacuum insulation layer in between the two walls. We are looking at going to cryogenic composites in the future.

### Q: For the conversion kits, you're taking out a few seats to make room for the fuel pods, but how much additional weight is added by the fuel cells and motors?

A: The wings of regional aircraft are significantly overdesigned, so they're able to carry the weight of the fuel cell and electric motors — which weigh somewhat more than the conventional turboprop engines — without modifications. We also stay within the design max takeoff weight and balance envelope of the existing aircraft to simplify the certification process. Then in addition to the conversion kit for regional airplanes, we'll provide fuel as a service for other sectors — because again, the next big step in the decarbonization journey for the sector is going to have to be the single aisle. We have a good 10 years before the first hydrogen single aisle is likely to be in service. And our focus for them is fuel logistics and fuel services.

### Q: Is Airbus' 2035 target for its first hydrogen aircraft realistic?

A: It's totally realistic; the Soviets already did this once in the 1980s. There are plenty of engineering challenges — I'm not saying that it's easy — but nothing has to be fundamentally invented. Both Airbus and Boeing are going to do a new single-aisle design anyway because the 737 is old and the 737 MAX debacle shows that there's not going to be another derivative. And Airbus will have to do a clean-sheet airplane as well; the 320s are a little bit newer, but it's still a fairly old family of airplanes. So this new clean-sheet airplane will probably enter service in the mid-2030s, which means a program launch decision in the late 2020s — let's say 2027, 2028. Our goal is to be in service with regional aircraft by 2025 so that we have passenger butts in seats flying on real scheduled commercial flights that are truly zero-emissions. And I think once that happens, the fundamental dialogue around the single aisle is going to change. The tenor of that conversation is going to be such that passengers are going to demand it because they're going to say, "Well, I can fly in a hydrogen airplane here. How come you guys are building a brand new airplane that burns dinosaurs?" And maybe those airliners will be using a sustainable aviation fuel, but it's still an offset scheme; you're still burning a hydrocarbon at 35,000 feet. Passengers are going to say, "What are you doing?" Airlines are going to say, "Why are you doing less?" Governments are going to say, "Don't do that." It will be an impossible decision for Boeing and Airbus to do anything other than launch a hydrogen single-aisle program in the late 2020s. The environment is going to change much more quickly than either of those companies anticipates today.

### Q: Why did you decide to base Universal Hydrogen in the U.S., where the federal government and Boeing are much more open to tax credits and the like for SAFs, versus Europe, which is all in on hydrogen from a policy perspective?

A: Ultimately, this is a global problem. The aviation sector is a global sector, and it's going to have to be a global solution. We based ourselves in what we believe to be the two top aviation talent pools: One is Los Angeles; then we have our engineering center in Toulouse. Going back to World War II and in the '30s, all of the U.S. airplane production was in southern California, and Toulouse was the city in France that was farthest from reach of German bombers, which is why all airplane production got moved to Toulouse and is still there. They're the two talent hotspots, and so we want to be in both.

### Q: If this sea change in public opinions occurs as you predict in the late 2020s, how does the industry ensure there's enough green hydrogen to meet the demand?

A: You hit the nail on the head with public policy and government incentives. Today, green hydrogen costs more than jet fuel on an equivalent energy basis. It's on a steep decrease, but for sure having cap and trade schemes or carbon taxes or hydrogen subsidies and other forms of economic incentives will help ramp up production. For regional, we think that the green hydrogen production capacity is going to be there, but that sector is relatively small. For single aisle it'll be a challenge; a very significant ramp has to happen in the late '20s and early '30s. For sure, government loans and government investment are very, very helpful. The other part of it is the contextualization of SAFs, biofuels and synthetic fuels. SAFs are great if you have no other choice, meaning that you want a drop-in replacement that works today on existing airplanes and existing engines. But biofuels are just not scalable. The biomass areas that you need to produce the feedstock for the fuels are immense, and if you're starting to harvest those amounts of biomass, you will have other environmental catastrophes. That's why the most fashionable topic on SAFs today is synthetic fuels. It's still a hydrocarbon: To make it you take green hydrogen made by electrolysis and then you tack on carbon atoms, and you make your hydrocarbon. Then you take that hydrocarbon to 35,000 feet and you burn it, which is exactly the thing that you're trying to compensate for. But the reason


Eremenko leads Universal Hydrogen's efforts to deliver hydrogen to today's turboprops retrofitted for hydrogen and also to future passenger airliners such as this concept from Airbus. The 200-passenger airliner is one of the hydrogen-powered concepts Airbus is studying under its ZeroE project, with the goal of bringing one of the planes to market by 2035. The turbofan design would be powered by hydrogen fuel cells and by burning liquid hydrogen, which must be kept at temperatures around minus 230 degrees Celsius.

Airbus

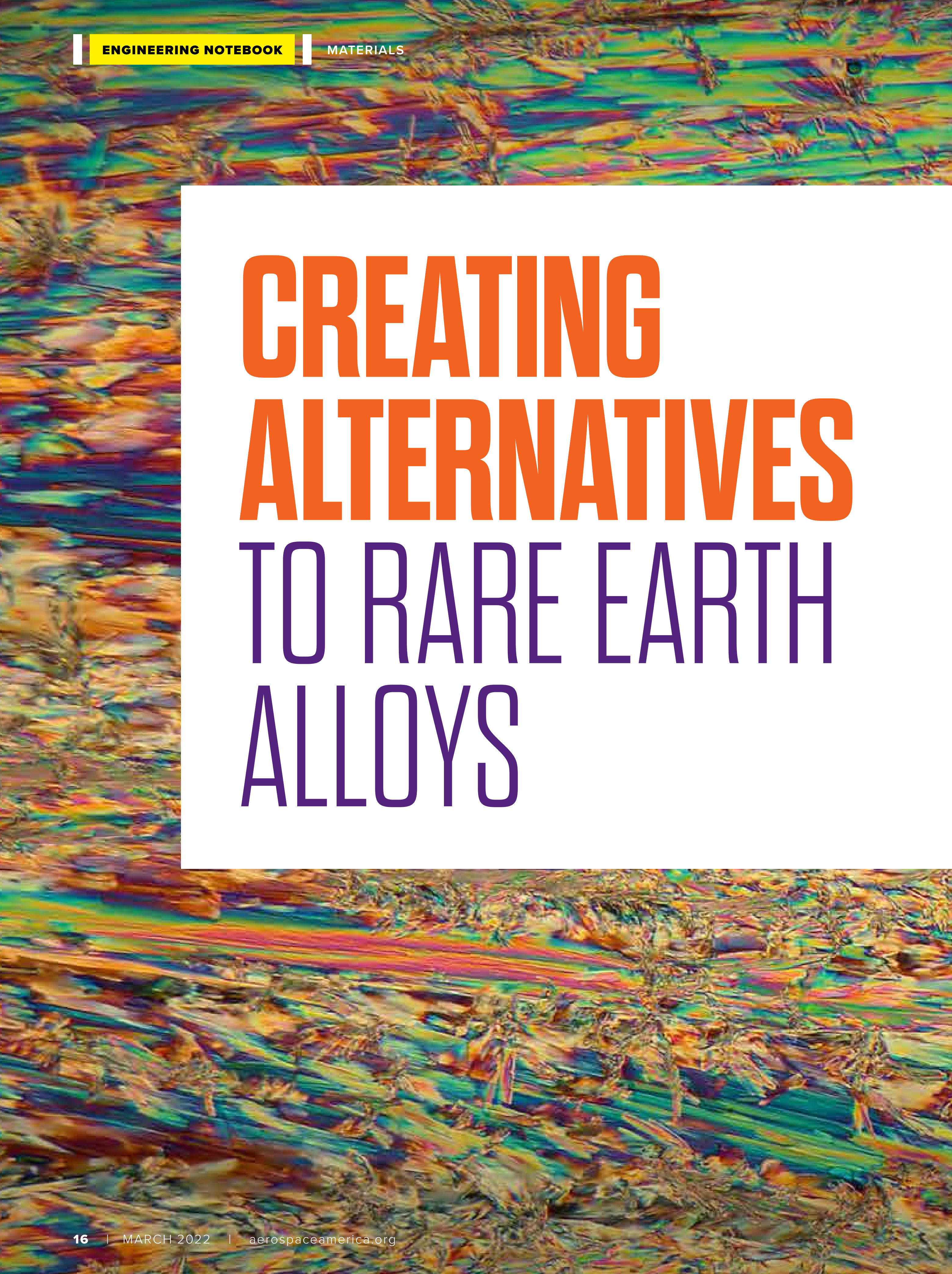

that's more appealing to some people than hydrogen is because a hydrogen-powered aircraft means you got to change the engine, you got to change the airplane, you got to have a distribution network. All these things sound really hard, and to me that's just laziness on the part of the aviation industry. I didn't become an aerospace engineer to be like "Oh, it's too hard. I'm not going to be able to solve that problem; it's a fuels problem."

### Q: Right, it seems like something like the blended-wing body that's among Airbus' hydrogen concepts should be an engineer's dream.

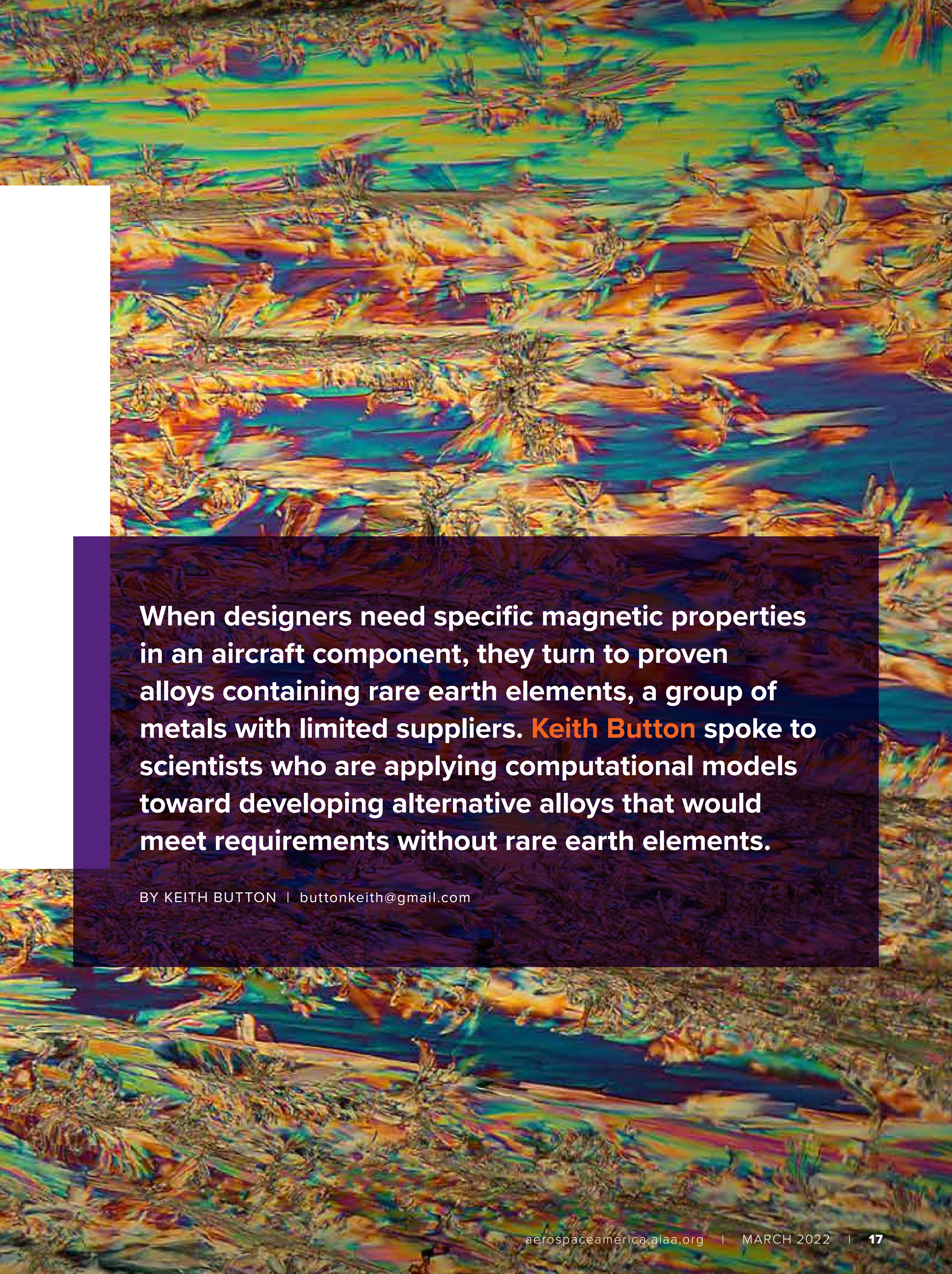
A: I don't think that the blended wing is going to happen for the single aisle, but it may need to happen for the next widebody, which I think would be in the 2040s as the replacement for the Boeing 787 and Airbus 350. All the data sets that Boeing and Airbus have are around the tube-and-wing configuration, so if you're going to do entry into service by 2035, I don't think anybody is realistically going to do a blended-wing body on that timescale. But nor do you have to. You can do a hydrogen single aisle with a very modest increase in length of the tube: about 9 meters of length extension on a standard narrow-body to store enough hydrogen for the Heathrow to JFK route transatlantic, which is the farthest you would ever fly now in a narrowbody. And if you're just trying to do LAX to JFK, it's about 5 meters lengthening of the fuselage to store enough hydrogen. These not huge design changes; this doesn't break anything. This is why I can confidently say that if the tenor of the discourse around the next-generation narrowbody changes, the technology's there; Boeing and Airbus and the Pratt and Whitneys and Rolls-Royces of the world are going to absolutely be able to do this airplane. The reluctance is more around an incrementalism mindset that is pervasive in this industry. We founded Universal Hydrogen to be freed from that tyranny of incrementalism and say, "Look, we're going to show the way, and we're going to catalyze it and we're going to make it so that doing anything else is just impossible." That's the goal.

### Q: Would that about face be enough to get the industry back on track to meet its portion of the Paris Climate Agreement and the net-zero by 2050 goal?

A: Remember, the buzzword "net-zero" means that you're offsetting. I think the industry can actually get close to true zero by 2050, but it will depend on the speed with which these airplanes sell. Roughly speaking, if hydrogen regional is available in the mid-2020s, then it'll take five to seven, maybe 10 years, for the entire regional market to convert. On the single aisle, there's a question of whether it's just one of Boeing and Airbus or both. The very interesting scenario would be if one of them does a hydrogen single aisle and the other doesn't. But my guess — and this has always been true in the duopoly between the two — is that it's tit for tat, and as soon as there's rumors that one is moving toward hydrogen, the other one will. So you start flying them around, say, 2035, it's going to take through the mid- to late 2040s for the entire single-aisle fleet to get replaced. The good news is that the single aisle accounts for about 60% of all aviation emissions, so between single aisle and regional you've mitigated two-thirds of your emissions, and then the widebody is the remaining. I refuse to believe the aviation industry can't achieve this because if we can't, people will stop flying. People will switch to trains or video or whatever. I think a lot of people go into aerospace because they think it's cool, but as I have grown up, I also recognize that one of the important facets of our industry is that we are one of the most powerful forces for globalization and cultural exchange and trade. It would be a real shame if aviation starts to decline because it's too carbon intensive of an industry. Because if aviation goes away, a lot of the positive forces of globalization and cultural exchange will go away. ★



# CREATING ALTERNATIVES TO RARE EARTH ALLOYS



**When designers need specific magnetic properties in an aircraft component, they turn to proven alloys containing rare earth elements, a group of metals with limited suppliers. Keith Button spoke to scientists who are applying computational models toward developing alternative alloys that would meet requirements without rare earth elements.**

BY KEITH BUTTON | buttonkeith@gmail.com

The various alloys in an F-35 contain 417 kilograms of rare earth elements, metals whose unique magnetic properties make them valuable for use in military and civilian aircraft for actuators, guidance systems, and electric generators and motors. Some in the United States are uncomfortable with so much reliance on these metals, given that China supplies at least 90% of them.

What if airplane builders could swap in custom-designed magnetic materials that didn't contain these rare earth metals? That's the vision that Pinar Acar, an assistant professor of mechanical engineering at Virginia Tech, and four graduate students hope to contribute to achieving under a $450,000 Young Investigator Research Program grant awarded to Acar, 34, in November 2020 by the Air Force Office of Scientific Research. If they succeed, a component designer could ask a materials scientist to create a new magnetic alloy tailored to meet a blueprint's specific needs, a process that would be the inverse of today's method of choosing from existing alloys. Acar and her team intend to create a computer model capable of defining a new alloy's required microstructure, based on magnetism specifications provided by the designer.

Success could also prove the viability of applying this inverse design approach to other areas, such as crafting new materials that would minimize aircraft fuel consumption and carbon dioxide emissions.

## First tasks

All magnetic materials can become demagnetized if exposed to high temperatures, other magnetic fields, or both.

So when research began last April, the team had two main tasks: First, build a computer model to predict the conditions that would cause a magnetic material to lose its magnetism, and then build the inverse design model to predict the microstructure of a material that will remain magnetized under a given set of conditions.

Ultimately, Acar wants to check the accuracy of the models by comparing their predictions to the results of experiments on existing magnetic materials.

As Acar and her team started building their first computer models, they didn't know the tempera-

▲ Some in the United States are troubled by the country's reliance on China for rare earth elements for aircraft components, such as those in the F-35, shown in production at Lockheed Martin's Fort Worth, Texas, manufacturing plant. Researchers hope to create new alloys that achieve the same magnetic properties without rare earth elements.

Lockheed Martin

ture-and-magnetic-field-combinations for demagnetization, but they did have a few known parameters. From prior experimental research, materials scientists know that each magnetic material has a Curie temperature, the temperature above which it can become demagnetized. For example, the rare earth element neodymium found in computer hard drives and aircraft electric generators, and which can be made into magnets that lift thousands of times their own weight, has a Curie temperature of about 320 degrees Celsius.

Scientists also know some of the external magnetic fields that can cause each magnetic material to become demagnetized — think of a strong magnet encountering your laptop computer and erasing the hard drive.

## Defining moment

The magnetic materials had to be represented computationally, and the question was how to do it. The difference in the level of magnetism between one metal and another depends on their microstructures. Metal consists of crystals, called grains in materials parlance, while magnetism depends on the average magnetism of the metal's grains. So the researchers decided to model the materials at the grain level and then build computational microstructures from the models of 10 to 20 grains.

In the models, magnetic materials were defined as a series of spinning atoms. That's because the spinning behavior of the atoms in a grain is what ultimately determines whether that grain is magnetized and, if it is, the magnitude and direction of its magnetic field.

Another issue was the large numbers of atoms. "It is a very huge computational problem," Acar says.

Each 1-micron grain in the microstructure of a metal typically consists of 100,000 to 1 million atoms. Each spins either in one direction or the opposite direction, and the interaction between each of these atoms and every other atom in the material determines the magnitude and direction of its magnetic field. But the most significant interactions are between each atom and the adjacent atoms, and then the significance dissipates for atoms that are farther and farther away. Computing those interactions would be too complex to calculate, so for their computer model the researchers eliminated all but the "nearest-neighbor" interactions; they counted only the interactions between atoms that were within a five- or six-atom span of each other.

In the first year, the team built a two-dimensional model to represent the microstructure of magnetic materials, as if that structure was just a single layer of atoms. Starting in April, when the second year of the three-year project commences, the researchers will model the microstructure in three dimensions, adding on to the software they wrote for the 2D model.

"We are starting from the outcome, and then we are trying to solve what should be the input to achieve this target outcome."

**— Pinar Acar, Virginia Tech**

### What's ahead?

By April 2023, the conclusion of the second year, they want to have finished building a model that can predict whether a given combination of temperature and an external magnetic field will leave a given microstructure magnetized or demagnetize it. The final year of the project will be dedicated to building a model to do the reverse: Predict the specific microstructure — the outcome — that will remain magnetized under a given range of temperatures and external magnetic field conditions.

"We are starting from the outcome, and then we are trying to solve what should be the input to achieve this target outcome," Acar says. Before solving the inverse design problem, "you should first have the forward problem."

Acar plans to build the inverse design model by applying an optimization approach, where the goal is to find the best mathematical solution out of all possible solutions. In the case of magnetic materials, the best solution refers to the material microstructure that would provide the strongest magnetism, given a certain range of temperatures and external magnetic fields. Alternatively, it could be the microstructure that would provide a specific level of magnetism at the given temperature and magnetic field conditions.

First, the team will pose an initial guess at the solution to the optimization algorithm — an expected combination of the atom spins that will lead backward to the desired magnetic material microstructure. Then, they will run the optimization algorithm to identify other combinations, which are either more likely or less likely to produce the desired magnetic material. The algorithm will keep comparing solutions, over and over, until it identifies the most likely combination of atom spins that will lead to the desired magnetic material.

### Brute computer force

One of the main challenges with inverse design is that it is a computationally expensive approach, requiring long periods of time from supercomputers. So until recent advances in computing power, inverse design was impractical. Inverse design problems "usually suffer from the curse of dimensionality," Acar says, meaning they have a relatively small number of equations to solve, but many, many variables.

With optimization algorithms, the issue is compounded because they have to run simulations thousands of times — 10,000 times, in some cases — before they identify the optimal solution. Acar plans to apply genetic optimization algorithms, which are very accurate but time-consuming, and gradient-based optimization algorithms, which are less accurate but faster. A single fast simulation on a genetic algorithm may take 10 minutes to run, and a problem that takes an hour to optimize with a gradient-based algorithm will take a day with a genetic algorithm.

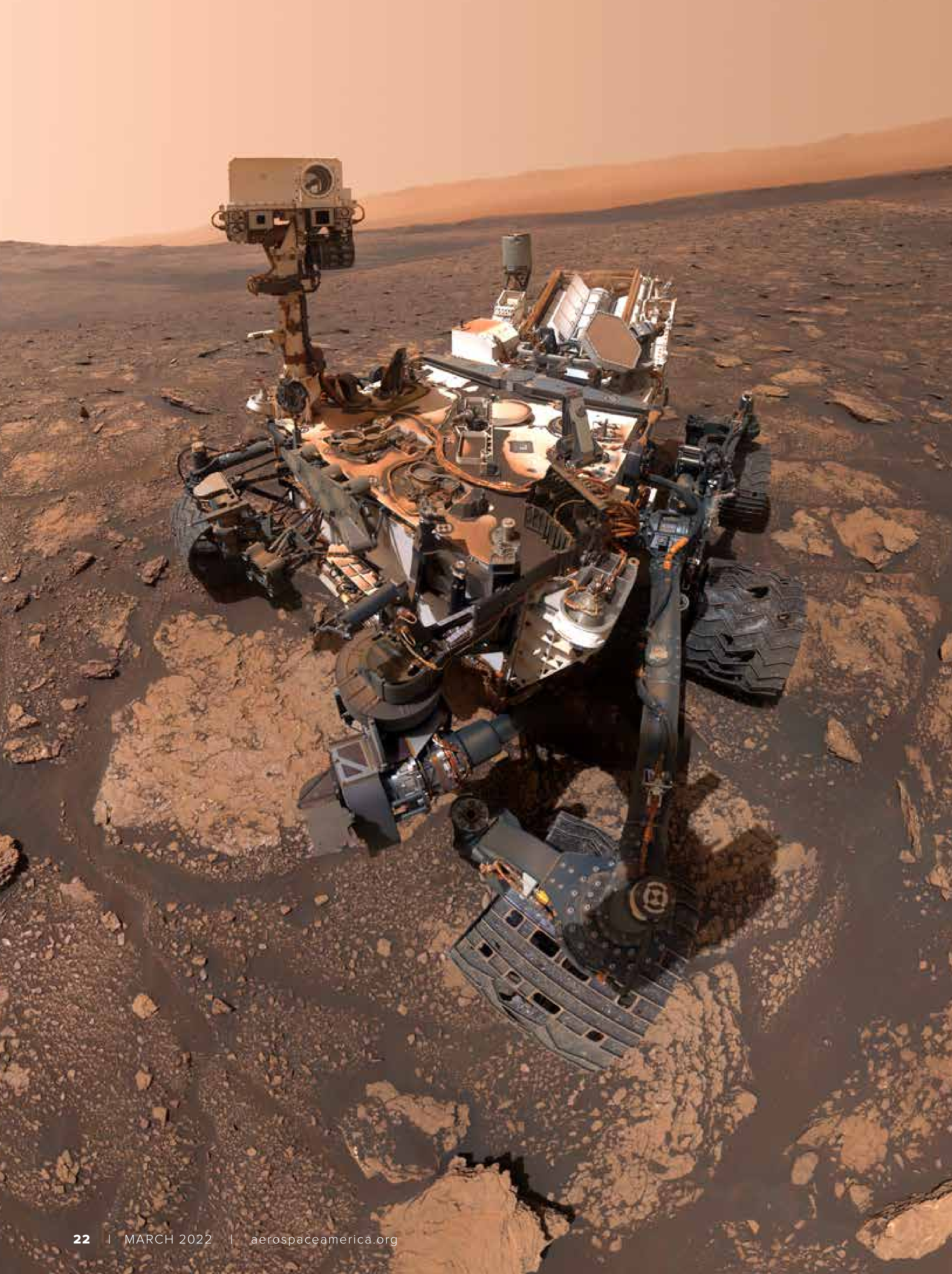
Genetic algorithms create successive so-called generations of solutions, with each new generation evolving to be better than the last, and they also introduce mutations into the solutions, just as evolution would into a population, by randomly changing some of the values.

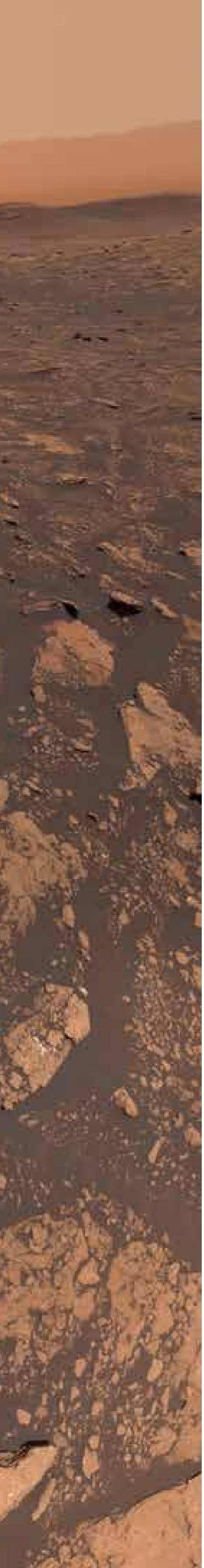
### Learning machine learning

Although the Air Force wasn't interested in funding machine learning approaches for the magnetic materials project, Acar sees a lot of potential for machine learning to advance inverse design for aerospace applications. Machine learning requires less computing time than the current algorithms, and can identify "a hidden feature that we may not have any idea about before applying machine learning."

If looking for a magnetic material microstructure, for example, a machine learning program might show that the solution will have certain atoms in the microstructure with positive spins and other certain atoms with negative spins.

Acar sees fertile ground there for more research. "I still think we need to learn a lot more on the machine learning side." ★





# NASA RETHINKS ITS MARS STRATEGY

**A chorus of scientists wants NASA to add small robotic spacecraft to its Mars Exploration Program in a shift from today's near-total focus on multibillion-dollar rover missions and preparations with Europe to return samples of Martian soil and rocks to Earth. Will these scientists get their way? Leonard David looks at the odds.**

BY LEONARD DAVID | newsspace@aol.com

Despite NASA's best efforts over the decades, Mars remains largely enigmatic. No proof has been discovered that life of some form once existed on the planet or that it still does, although there is tantalizing evidence for those possibilities. Meanwhile, NASA is outspoken in its desire to send astronauts to Mars, and Elon Musk has vowed to colonize the planet, even if scientists caution that they don't yet have sufficient knowledge about Mars to guide such endeavors.

It's in that context that NASA has begun collecting advice from scientists about how to renovate the agency's Mars program, an effort that includes welcoming a fresh look at the size and kind of spacecraft that should be sent how often and to which regions.

To date, NASA's Mars Exploration Program has focused on launching a succession of multimillion-dollar and multibillion-dollar landers and rovers about every six years on average, mostly to the equatorial region of Mars. The Mini Cooper-sized Curiosity rover landed in August 2012 and was followed in February 2021 by the nearly identical Perseverance rover, with its small Ingenuity helicopter making history not long after. Up next, a NASA-funded lander is supposed to touch down in 2028 carrying a European Space Agency-funded small fetch rover that will roll out and collect the samples of Martian soil and rocks that are currently in the process of being left behind in titanium tubes by Perseverance. An ascent rocket would blast those samples into space, where an orbiter would grab them and boost them toward Earth for a 2031 arrival.

Momentum has mounted for a new approach that would keep Mars Sample Return but add small, less expensive spacecraft. A turning point could come as soon as late March with the planned release of the U.S. Planetary Science and Astrobiology Decadal Survey by the U.S. National Academies of Sciences, Engineering and Medicine. This survey will be the latest in the once-a-decade reports that distill a variety of competing scientific views into a set of recommended priorities for NASA, in this case for planetary science starting in 2023.

Will NASA heed what looks like a tidal wave of calls for it to embrace the smallsat revolution currently seen mainly in low-Earth orbit? NASA isn't saying, given the pending decadal survey, but it is leaving no doubt that it plans to update its Mars strategy:

"Development of this strategy will be critical to determine the placement of new Mars initiatives among other Planetary Science Division priorities and for securing the requisite budget to support them," said Lori Glaze, director of NASA's Planetary Science Division, in a statement via a spokesperson.

The agency will consider the decadal survey recommendations, Glaze continued, "combined" with two other reports: One issued a few weeks ago by KISS, the influential Keck Insitute for Space Studies in California, in which NASA and industry authors called for launching small satellites at a regular cadence under an approach dubbed "Frequent, Affordable, Bold." A little over one year earlier, a NASA-chartered

working group laid the foundation for the ongoing discussions by issuing a similar call for small spacecraft.

## Millions, not billions

The working group's 2020 report, "Mars, the Nearest Habitable World — A Comprehensive Program for Future Mars Exploration," recommended that NASA carry out missions whose design, development, launch and operational costs fall within the range of $100 million to $300 million. By contrast, NASA spent $2.4 billion to build and launch Perseverance and expects $300 million in operating costs on top of that for a total of $2.7 billion. For Mars Sample Return, an independent review board in 2020 placed NASA's contribution between $3.8 billion and $4.4 billion. There's no comparable estimate of the European Space Agency's contribution, but during a pre-launch press conference for Perseverance in 2020, ESA's director of human and robotic exploration David Parker put the agency's portion at 1.5 billion euros ($1.75 billion).

Nevertheless, the working group was careful not to criticize the Mars Sample Return as it cautioned against overstating its likely scientific significance:

"As important as Mars Sample Return (MSR) is — and it will result in a major step forward for planetary science — examination of material from a single site will not tell us everything that we need to know about Mars," the working group wrote.

Bruce Jakosky, the University of Colorado, Boulder scientist who chaired the working group, summarizes the thinking like this: "We've seen an incredible expansion in capabilities of small spacecraft in the last few years. Concepts that were inconceivable just a few years ago can be done relatively easily today," he says.

▲ This illustration from the cover of the Keck Institute for Space Studies' February Mars report captures the think tank's recommendation for NASA to send a variety of small robotic spacecraft to regions inaccessible to today's landers and rovers.

Keck Institute for Space Studies (KISS)/Chuck Carter

▲ The first color photo from Perseverance, taken by one of the rover's Hazard Avoidance Cameras shortly after its February 2021 landing, shows the kind of benign terrain NASA chose for Perseverance and the nearly identical Curiosity rover. The agency could choose more daring landing spots for smaller, less expensive spacecraft.

NASA/JPL-Caltech

"We want to use small missions to address fundamental science objectives and not just send a spacecraft that can make a few interesting measurements," he adds.

Such spacecraft can also help set the stage for human explorers, in his view: "In that sense, small missions fit into the broader objective the same way as do larger missions — by measuring environmental characteristics that enable human missions and by identifying the science context and objectives that can be addressed by human missions."

This month, a different working group plans to hold a primarily in-person scientific workshop in Pasadena to discuss "Low-Cost Science Mission Concepts for Mars Exploration." Organizers want to bring forward ideas from the community about how a new class of lower-cost missions might advance the full range of Mars science study.

Meanwhile, the February report from KISS, located near the NASA-funded Jet Propulsion Lab in Pasadena, also went to lengths not to target Mars Sample Return. The discussion of its "Frequent, Affordable, Bold" proposal begins like this: "As we prepare to conduct the first sample return from Mars, now is the prime time to consider, 'what comes next?'"

The KISS report wants a succession of small spacecraft to be launched at a "predictable high cadence" under a coordinated "programmatic approach," according to the report, "Revolutionizing

“We want to use small missions to address fundamental science objectives and not just send a spacecraft that can make a few interesting measurements.”

— Bruce Jakosky, Mars Architecture Strategy Working Group

Access to the Mars Surface.” While the name is reminiscent of NASA’s Faster, Better, Cheaper missions of the 1990s, those missions were planned individually, according to the authors.

While Jakosky is heartened by all the ongoing discussion, studies and workshops on pursuing a more pricetag friendly science strategy for Mars, he adds a note of caution similar to the one issued by Glaze, the NASA planetary science manager.

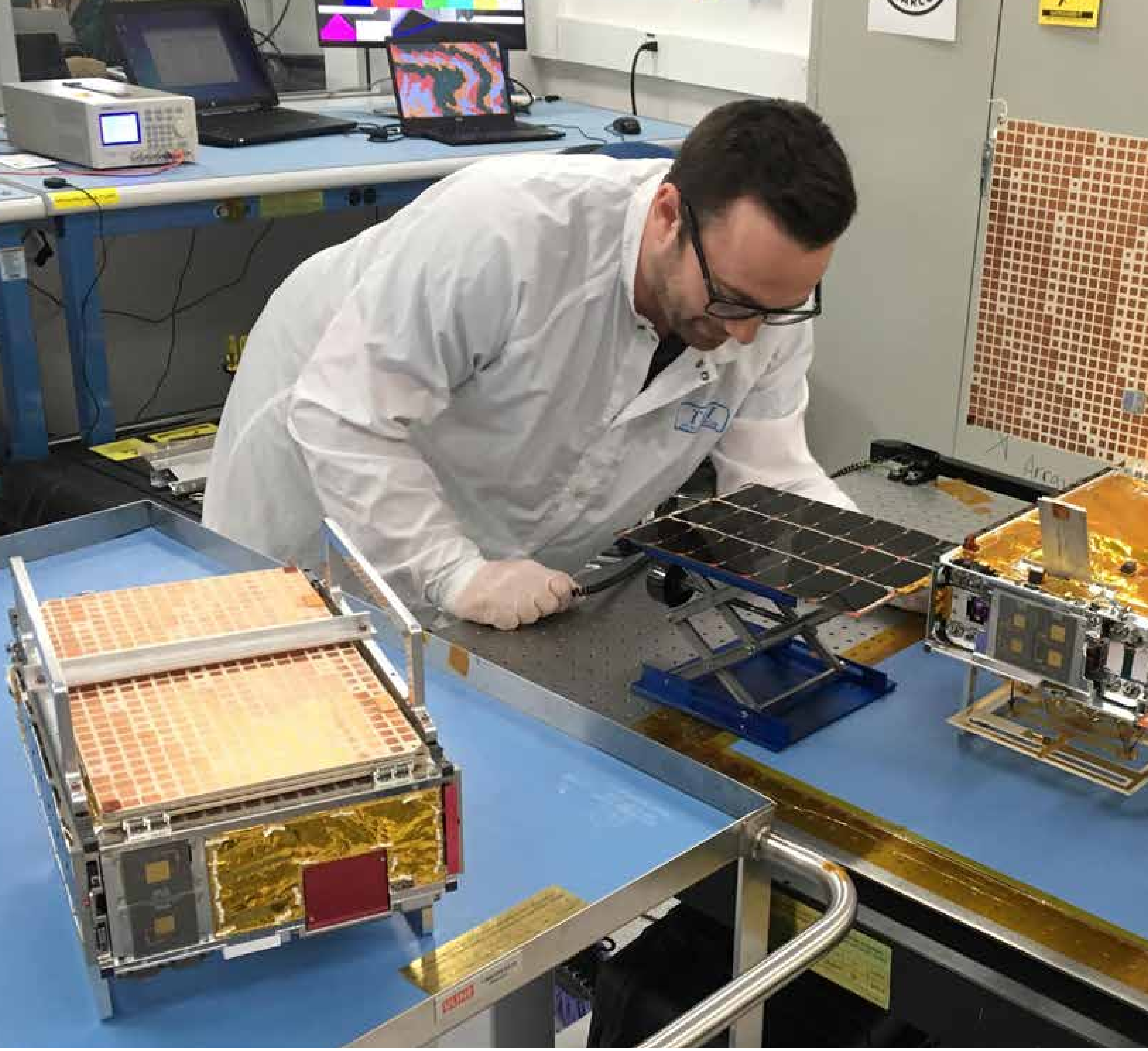
“To be blunt, whether any of this has any impact will depend on what the Planetary Science Decadal says about Mars exploration in the context of solar system exploration and whether the administration can be convinced to invest in reinvigorating a Mars program,” Jakosky says.

The first step, Jakosky notes, will be for NASA managers and Mars investigators to determine whether significant science objectives can in fact be addressed by small spacecraft. “Although I believe that the answer is yes, it is imperative that we hear ideas and concepts from the community and identify the most substantive ones as a basis for moving forward.”

## Elusive answers

The red planet is a taunting globe, shadowed by questions of whether this real estate was, or is even now, a host for life of some kind, such as microbes.

Mars does not put out a welcome mat for life as we know it. For one, it is bathed in ultraviolet rays



that sanitize the uppermost layers of Martian soil. But it may have been a nicer-to-life globe in the distant past. Mars orbiter imagery suggests that, long ago, liquid water might have flowed in channels and collected in lakes and ponds. Plausibly, the planet once supported an ocean.

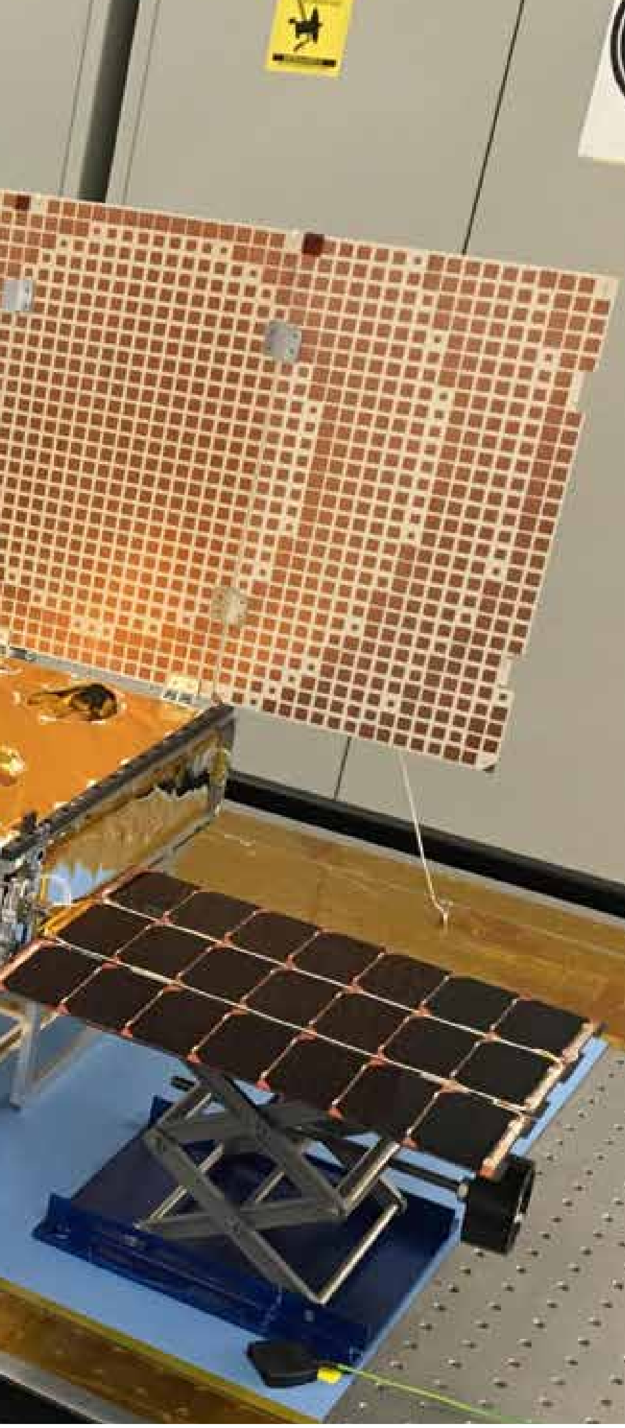
Early wet and warm Mars could have given rise to simple forms of life. There may be a fossil record of ancient microorganisms, if scientists look in the right places.

Scientists have all sorts of wild ideas about the possibility that microbial life has persisted to the present day. Perhaps underground alcoves sustained microbial habitats even as surface conditions became ever more inhospitable over the eons.

Bethany Ehlmann, a professor of planetary science at Caltech, says the search for Mars life is part of the reason NASA must get to the Martian surface with a variety of missions. In her view, Mars is like Earth in that multiple types of potential habitats existed at different times and places, including in lakes, rivers, hydrothermal ground water and soils. Such opportunities to define how life formed and possibly vanished are rare in the solar system.

"Mars, Earth, and Venus are the only places we can test our understanding of what makes a habitable Earth-like world, or not, over a long time," she says.

It is time to strategize new ways to gather more data from a variety of places on Mars, says Ehlmann.



NASA's Mars Cube One spacecraft are one example of how Mars could be explored via less expensive means. The pair of cubesats, pictured here in 2018 at NASA's Jet Propulsion Lab in California, relayed X-band signals from NASA's InSight lander, providing mission controllers real-time status updates about the InSight lander's November 2018 entry, descent and landing on Mars.

NASA/JPL-Caltech

**New kinds of exploration**

In the search for life, scientists have a variety of terrain and depths in mind beyond the equatorial regions and near surface explored by Curiosity and Perserverance.

Perhaps the deep subsurface harbors promising microbial habitat. "This is where smaller missions could come in, characterizing the subsurface and identifying promising drill sites," says Michael Meyer, lead scientist for NASA's Mars Exploration and Mars Sample Return programs at NASA headquarters in Washington, D.C. Large landers could then be sent to do the drilling.

Speaking of landers, Charles Edwards Jr., manager of JPL's Advanced Studies Office, envisions low-cost "rough" terrain landers touching down with electromagnetic sounders or trace gas "sniffers" to sense methane emissions that could be associated with biological processes.

In fact, such lander technology has been under development for several years at JPL. It's called SHIELD, short for Small High Impact Energy Landing Device. If the technology works, Mars could someday be dotted with dozens of SHIELD landers, each loaded with 5 kilograms of sensors.

Numerous landers would be affordable because none would need complex propulsive systems or parachutes to decelerate. Instead, each would deploy a drag brake to slow itself to roughly 50 meters per second, and then a crushable nose cone would absorb the impact energy.

One of Perseverance's navigation cameras took this photo of the rover's first sample collection attempt in August 2021, the first phase of the European Space Agency-NASA joint Mars Sample Return mission. Those samples aren't scheduled to return to Earth until 2031, so scientists hope NASA will fund development of smaller spacecraft in the meantime.

NASA/JPL-Caltech

"The flight system avionics are small satellite electronics but have been ruggedized to survive a 1,500 Earth-g impact," says JPL's Nathan Barba, systems engineer for SHIELD.

So far, SHIELD has undergone drop tests, instrumented to measure actual landing loads to demonstrate the feasibility of the concept.

Barba says SHIELD could tote weather sensors, cameras and mass spectrometers to the planet. "A low-cost lander like SHIELD could enable first-time measurements or pathfinder exploration like ground-truthing information that is critical for larger, more expensive missions," he says.

Perhaps the greatest fresh thinking about Mars stems from the flights of Perseverance's Ingenuity helicopter in Jezero Crater.

Shannah Withrow-Maser, the Mars Science Helicopter Vehicle Systems lead at NASA's Ames Research Center in Silicon Valley, is bullish about the prospect of a future hexacopter hauling payloads and flying greater distances than Ingenuity.

In fact, NASA is assessing the possibility of releasing a hexacopter part way through the entry, descent and landing phase of a future mission. Such an aircraft could scrutinize cliffs, polar caps and layered deposits, or zip over possible ancient springs.

Of special interest for scientists, and those who hope to send humans to Mars, are the planet's ancient lava tubes. Over the years, researchers reviewing orbiter photos have spotted pit craters that they believe are where the roof of a lava tube has partially collapsed and created a "skylight." In fact, the U.S. Geological Survey's Astrogeology Science Center has mapped the locations of at least 1,000 cave entrance candidates on Mars. Perhaps a rotorcraft could fly into a lava tube skylight and measure the feature's temperature and humidity.

"This could tell if the environment of the cave was more habitable than the surface," says Carol Stoker, a research scientist in the Space Science Division at NASA Ames. "This is not sampling for life, but it would be useful information and could be helpful reconnaissance for human missions that may want to use the lava tubes."

Overall, suggests JPL's Edwards, what's happening now are conversations over how best to incorporate low-cost mission ideas to create a mix of small and large missions, since that is what will be needed to address the complete spectrum of Mars science questions. Establishing an inventive exploration plan for Mars may well produce a ripple effect through NASA's planetary science enterprise.

"I believe that many of the technologies and approaches we might utilize in low-cost Mars exploration could have application to other solar system targets," Edwards says. ★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# O

**Fifty years after a British rocket last launched a satellite, the U.K. Space Agency is bringing the country back into the space launch business. Paul Marks explores the race to open three new spaceports this year.**

BY PAUL MARKS | paulmarksnews@protonmail.com

Small satellites are regularly launched into low-Earth orbit from spaceports including those in Kodiak Island in Alaska, the Mahia Peninsula in New Zealand, Wallops Island in Virginia and Mojave in California. This year, the list of potential smallsat launch sites is set to swell, not because of a newcomer to the launch business but because of a nation whose first launch occurred decades ago: the United Kingdom.

The U.K. is set to license at least three new privately owned smallsat launch sites in 2022, with others to follow, in locations from Cornwall on England's most southwesterly tip to the most northerly of Scotland's Shetland Islands. On top of that, a crop of U.K.-based rocket startups are scheduled to be among the first customers.

For customers wanting vertical rocket launch, plans call for beginning construction of launch pads this year in two locations. The SaxaVord Spaceport would be created at Lamba Ness on the island of Unst in the Shetlands and Space Hub Sutherland on the Moine Peninsula on the northern coast of the Scottish mainland. For those seeking air launch capabilities, some 8 kilometers from Britain's storied surfing capital, Newquay, developers are adding a hangar and ground support facilities for rocket carrier planes to part of the existing passenger airport — a former Royal Air Force base with a 2,700-meter-long runway — to create Spaceport Cornwall.

With all three spaceports hoping to conduct their first launch in 2022, the race is on to be the first to get a rocket in orbit. But there's no clear frontrunner, given that all three are still awaiting regulatory approval and covid-19 lockdowns have played havoc with everyone's timelines.

Those delays haven't hampered the plans of the U.K. Space Agency, UKSA, to put the three sites on the global smallsat launch map alongside the likes of Kodiak and Mojave. The agency has awarded tens of millions of pounds in grant money to help build some of the first spaceports and is also funding the development of future sites.

What's behind all these moves? Encouraged by the runaway success of Britain's satellite production and space services sector, which generated £16.4 billion ($22.1 billion) in revenue in 2019 (NASA's budget is $22.6 billion by comparison), UKSA wants to offer satellite builders the additional incentive of fast, responsive, smallsat launches.

In fact the U.K. government wants nothing less than to "capture" the European market, proclaiming in its latest National Space Strategy the goal of by 2030 becoming "the leading provider of commercial small satellite launch" among European countries, whether their launch sites are in Europe or elsewhere. Why, runs the Brits' sales pitch, should Europeans schlep all the

The locally owned Spaceport Cornwall is taking advantage of the existing runway at Newquay airport to begin air launches in mid-2022. The 2.7-kilometer runway is long enough for vehicles including Virgin Orbit's modified 747 carrier plane and Sierra Space's DreamChaser spaceplane.

Spaceport Cornwall

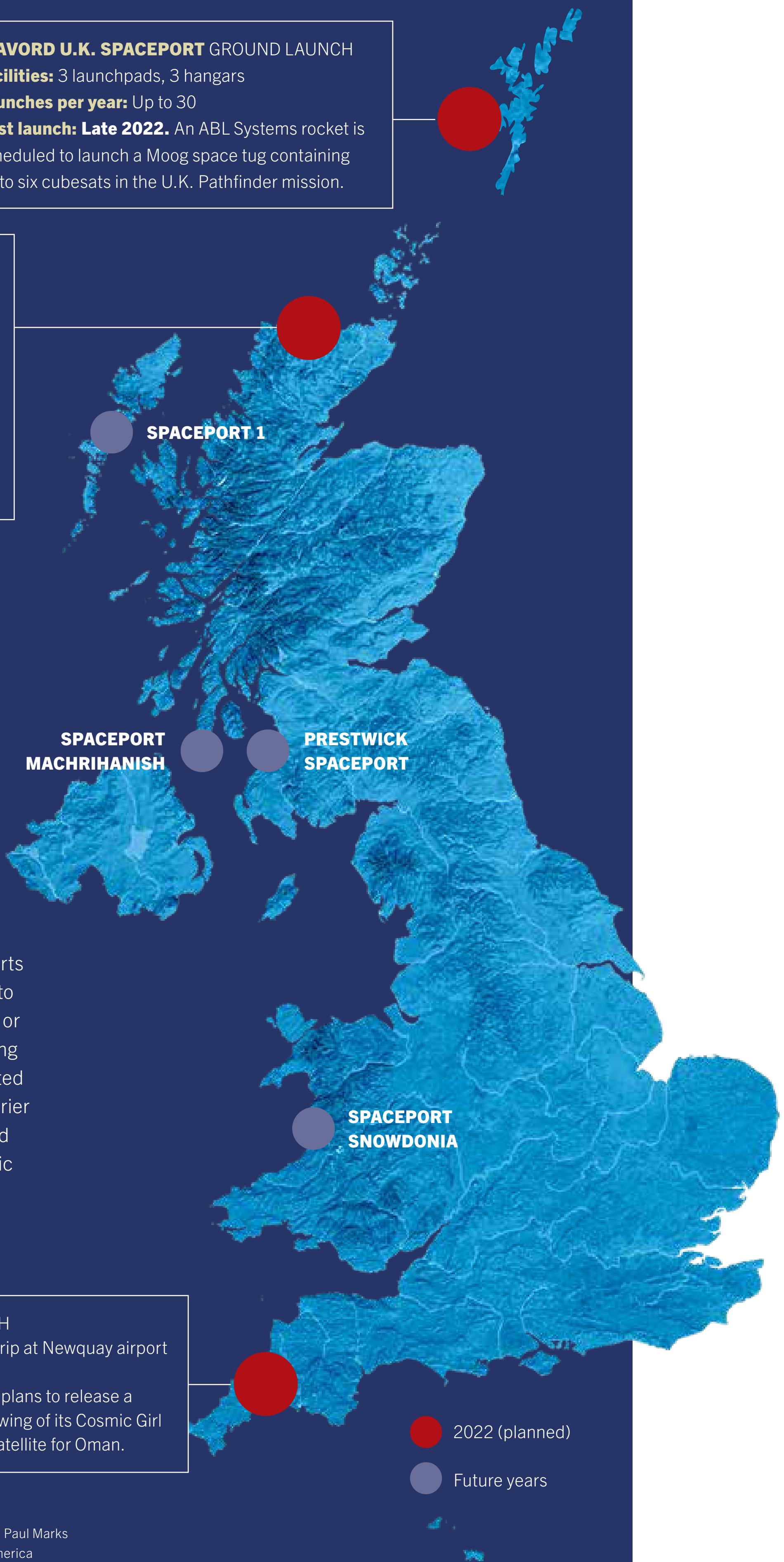
> "With a number of U.K. spaceports in development, arguably it's likely that not all them are going to reach full commercial sustainability."
>
> **— Greg Sadlier, know.space**

# Big plans for small rockets

The U.K. wants to establish itself as the go-to launch location for anyone in Europe or the U.K. who wants to launch a small satellite. The three northernmost planned spaceports will be sufficiently remote for rockets to liftoff from their pads and reach polar or sun-synchronous orbits without making extensive maneuvers to avoid populated areas. For the four southern sites, carrier aircraft will fly from new or repurposed runways and head out over the Atlantic Ocean or North Sea to release the launch vehicles.

**SAXAVORD U.K. SPACEPORT** GROUND LAUNCH
- **Facilities:** 3 launchpads, 3 hangars
- **Launches per year:** Up to 30
- **First launch:** **Late 2022.** An ABL Systems rocket is scheduled to launch a Moog space tug containing up to six cubesats in the U.K. Pathfinder mission.

**SPACE HUB SUTHERLAND**
GROUND LAUNCH
- **Facilities:** 1 launchpad, to start
- **Launches per year:** 12
- **First launch:** **Late 2022.** U.K. startup Orbex will launch one of its Prime rockets with payloads including an experimental one from U.K.-based Surrey Satellite Technology Ltd.




**SPACEPORT CORNWALL** AIR LAUNCH
- **Facilities:** 1 hangar; runway and airstrip at Newquay airport
- **Launches per year:** 12
- **First launch:** **Mid-2022.** Virgin Orbit plans to release a LauncherOne rocket underneath the wing of its Cosmic Girl carrier aircraft, carrying an imaging satellite for Oman.

Graphic by THOR Design, reporting by Cat Hofacker and Paul Marks
Sources: U.K. Space Agency, research by Aerospace America

way to the Guiana Space Center in Kourou to place their smallsats on, say, an Arianespace Vega rideshare when the U.K. offers at least three spaceports on their doorstep?

However, the U.K. will not be without European competition: The Swedish-owned Esrange Space Center, previously a venue for suborbital sounding-rocket launches, is this year planning to establish an orbital smallsat launch capability, launching 150-kg smallsats to orbit up to four times per year.

## Reviving space launch

What's helping make Britain's grand plans a reality is the legislative foundation of its National Space Strategy: the Space Industry Act of 2018, which, for the first time, put in place a licensing regime allowing entrepreneurs to take advantage of the smallsat revolution by operating government-licensed orbital and suborbital spaceports in the U.K.

And to get British satellites in orbit as soon as this year, UKSA has awarded grant funding to "kick-start commercial activity, igniting a fast-paced U.K. spaceflight sector," says Matthew Archer, UKSA's director of commercial spaceflight.

Specifically, the space agency has awarded a $31.8 million contract to the British arm of Lockheed Martin Space Systems for a mission dubbed the U.K. Pathfinder Launch. The contract covers establishing and running launchpad operations at the SaxaVord Spaceport and purchasing a launch vehicle, in this case an RS1 rocket from spaceflight newcomer ABL Space Systems of California. The 27-meter-tall RS1 would loft a space tug built by Moog of the U.K. to orbit, where it would deploy up to six 6U cubesats.

It wouldn't, however, be much of a U.K. launch venture without some British rockets, too. So UKSA in 2018 also awarded Scotland-based rocket startup Orbex a £5.5 million ($7.4 million) grant to help develop a 19-meter-high, two-stage smallsat launcher called Prime. Made from carbon fiber and with additively manufactured rocket motors, Prime rockets would launch payloads up to 150 kgs from Space Hub Sutherland starting in late 2022, if all goes as planned. Orbex has funding from the European Space Agency, too, as well the EU, highlighting interest in their services across Europe. UKSA also is partially funding the construction of the spaceport itself, with a £2.5 million ($3.4 million) grant to Highland and Islands Enterprise, the regional economic development agency that owns the Sutherland spaceport.

Also, a startup called Skyrora in Edinburgh received a €3 million ($3.4 million) European Space Agency grant toward developing its 22-meter-high, three-stage rocket called Skyrora XL for launching smallsat payloads up to 315 kg. Skyrora says its rockets will begin orbital launches from the SaxaVord Spaceport after some initial "derisking" suborbital flights with smaller rockets.

Timing wise, Lockheed Martin says a launch of the ABL rocket some time in 2022 remains possible, despite a mid-January explosion of an ABL second stage during a ground test at their Mojave facility. Both Skyrora and Orbex are aiming for the end of the year or early 2023.

For air-dropped launches, meanwhile, UKSA in 2019 provided a £7.35 million ($9.9 million) grant to the British branch of satellite launcher Virgin Orbit to build the necessary ground systems to fly its LauncherOne rocket and Cosmic Girl carrier plane from Spaceport Cornwall. It does not end there, however: Some $3.2 million is also going to study the possibility of equipping former military airstrips at Prestwick and Machrinhanish in Scotland, and Llanbedr in Wales, and possibly other sites for horizontal launches.

But will this multipronged approach work in the rocket launch arena? It's looking promising, says Greg Sadlier, cofounder of know.space, a London-based space industry consultancy.

"The U.K. has adopted a market-creation approach which fits with its overall attitude to the space sector, which is that it should be properly supported to get it started, but be commercially led," he says. "In launch and rocketry, they're creating new players and letting them compete, potentially capturing different parts of the market and fostering innovation."

That's not to say out-and-out success is guaranteed, Sadlier adds: "With a number of U.K. spaceports in development, arguably it's likely that not all them are going to reach full commercial sustainability."

## Repeating history?

Not reaching commercial sustainability, however, is something with which those with long memories in British rocketry will be all too familiar. To understand why, we need to rewind to Thursday, Oct. 28, 1971.

Just after 4 a.m. Greenwich Mean Time, the U.K. Royal Aircraft Establishment's three-stage Black Arrow rocket lifted off from the Woomera Test Range in the South Australian desert atop the almost invisible plume characteristic of its novel hydrogen peroxide and kerosene fuel mix. Staging went perfectly and, some 11 minutes later, the Black Arrow's solid-rocket-powered third stage placed the 66-kg science satellite Prospero into an elliptical low-Earth orbit, where it functioned for 25 years.

For Britain, that launch was of profound significance: This was the first U.K. space launch, and it was with a British satellite. It was a feat only five other countries had previously accomplished, and could have propelled the U.K. permanently into the ranks of launch-capable spacefaring nations — but it did not.

Three months before the Prospero launch, then Aerospace Minister Frederick Corfield announced to

Parliament that the British government, mired in an economic crisis, had decided to cancel the Black Arrow program because “the maintenance of a national programme for launchers of a comparatively limited capability absorbs a disproportionate share of the resources available.”

The Prospero launch proceeded only because the rocket and satellite were at Woomera already — and almost all the costs involved were by then already sunk. In the future, Corfield said, British satellites would instead fly on launchers like NASA’s Scout, a multistage, all-solid-rocket design that flew from the 1960s to the mid-90s.

As a result, the rocket test pads in the U.K. and the British launch pads at Woomera were demolished, the designs destroyed and the Black Arrow engineers laid off.

“Black Arrow’s cancellation rendered the rest of the National Space Technology Programme vulnerable and that too was canceled a few years later,” says Douglas Millard, spaceflight curator at the Science Museum in London. “The cancellation eroded Britain’s capability in space research and development.”

Fast-forward to today, however, and Sadlier is among those who think the time is right for a rebirth.

“The U.K. now has an opportunity, with rocketry coming back, to catch up quite rapidly because it can take advantage of all the technology advances developed in its own strong space sector, and also in new space more broadly, to restart its rocket program,” he says. Such advances might include the move to 3D-printed hardware, software-defined avionics and the use of off-the-shelf components to reduce costs.

But is it a British launch industry if these burgeoning spaceports rely in part on importing and launching American rockets? Non-U.K. customers are a vital component, says Nik Smith, the regional director of Lockheed Martin Space in charge of the U.K. Pathfinder launch program and a former Royal Air Force milsat specialist.

“The U.K. left the launch industry after Black Arrow. So we have atrophied and lost a lot of skills, plus the corporate and institutional knowledge of how to do launch over the last 50 years,” he says. “So partnering with the U.S., or other nations, is a really good way for the U.K. to speed up its experience, gain expertise quickly, and start creating more indigenous opportunities. It’s just a way of accelerating everything.”

In Sadlier’s view: “There’s a timing element to all this: the space economy is developing very rapidly and if the U.K. wants to restart its launch capability as soon as possible, then buying in that capability initially is sensible, whilst pursuing U.K.-developed launch technologies.”

A Virgin Orbit LauncherOne rocket fires its engine shortly after release from the Cosmic Girl carrier plane in January. The launch of a handful of satellites to low-Earth orbit for the U.S. Defense Department and others was the first of six missions Virgin has planned for 2022, two of which would be from Spaceport Cornwall in the U.K. The light retractions in this photo were created by the sun shining through the double-paned windows of the chase plane from which Virgin’s photographers were watching the flight.

Tod Seelie/Virgin Orbit

## Different strokes

With their northern latitudes, all three of the first planned U.K. spaceports could offer customers rides to polar or sun-synchronous orbits, so each is making a point to illustrate its unique advantages.

Spaceport Cornwall has been slated since 2018 as a destination for the captive-carry combo of Virgin Orbit's Boeing 747 Cosmic Girl carrier plane and LauncherOne rocket, but the English space hub has even bigger plans.

"Spaceport Cornwall will be a multi-user spaceport," says Melissa Thorpe, who heads the operation. "We have signed a memorandum of understanding with Sierra Space" of Colorado, the developer of the Dream Chaser spaceplanes.

The MoU, she says, means that Dream Chaser — perhaps on its way back from one of the six International Space Station resupply missions scheduled to begin this year — could choose to land at Spaceport Cornwall, gliding back to its runway.

But Virgin Orbit is very much the spaceport's high-profile anchor client, offering to launch up to 300-kg payloads into high inclinations from the two-stage LauncherOne. Virgin has a light ground footprint, with "essentially nothing by way of permanent infrastructure" needed at any spaceport it's asked to launch from, says William Pomerantz, vice president of special projects for Virgin Orbit.

"To conduct launches, we require only a runway, a launch license and a set of ground support equipment designed to prepare the rocket for flight and to mount it on the wing of the aircraft," he explains.

For the Cornwall spaceport, Oxford-based space company AVS is now building a Transportable Ground Operating System, used to prepare LauncherOne rockets for flight and help mount them on the spare engine pylon beneath the 747's wing.

The system needs to be ready soon. Virgin announced in January that its first Cornish mission will be a smallsat launch for the Sultanate of Oman, scheduled for later this year, and a second U.K. launch is also likely this year, says a Virgin Orbit spokesperson.

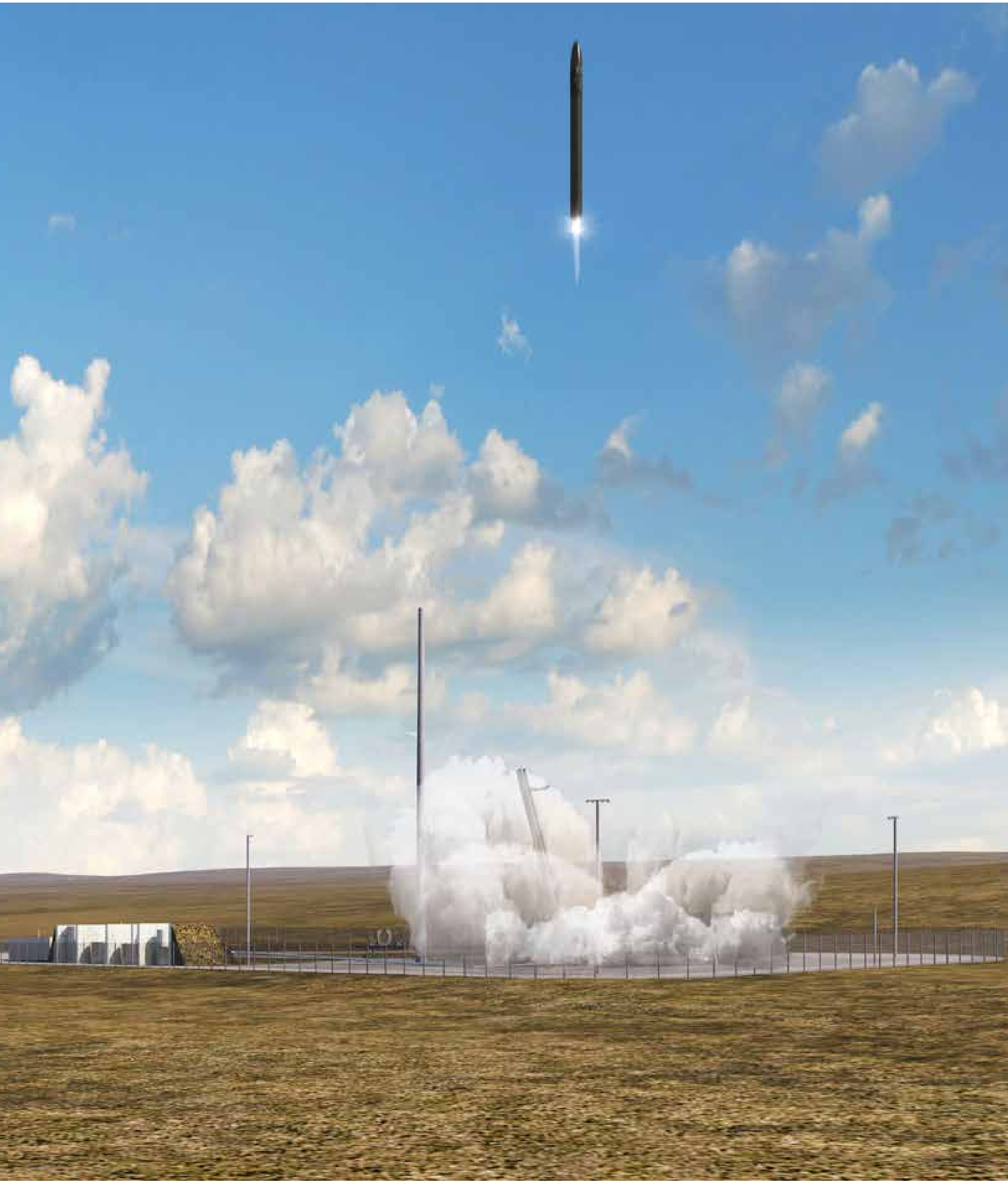
Virgin Orbit's arrangement with Cornwall is not exclusive, so if any of the other U.K. horizontal launch sites currently in the business planning stages need a flight to LEO, Pomerantz says Virgin Orbit will "consider customer requests to fly from any location."

For the two vertical launch locations, there are some clear differences in physical accessibility and payload-to-orbit capability for spacecraft operators to consider, thanks to their respective geographies.

Trajectories toward polar and sun-synchronous orbits from Space Hub Sutherland on the boggy Moine Peninsula of the Scottish mainland would intercept the populated areas of the Faroe Islands and Iceland. This means a launching rocket might need to undertake a dogleg maneuver to change its trajectory to

▶ The first launch from Space Hub's Sutherland sole launchpad, illustrated here with a generic rocket, could occur as soon as late 2022. The regional development agency that owns the spaceport is awaiting regulatory approval to begin construction.

Space Hub Sutherland



“To conduct launches, we require only a runway, a launch license and a set of ground support equipment designed to prepare the rocket for flight and to mount it on the wing of the aircraft.”

**— Will Pomerantz, Virgin Orbit**

avoid them, expending more fuel and so reducing overall mass-to-orbit. But the much more remote SaxaVord Spaceport — some 300 kilometers to the northeast, almost halfway to Norway in the middle of the frigid North Sea — has an absolutely clear shot at those same orbits.

As a result, Space Hub Sutherland is limiting itself to launching payloads of up to 500 kgs, says the spaceport’s project director Roy Kirk at Highlands and Islands Enterprise. But with its line-of-sight launch capability, SaxaVord Spaceport’s deputy CEO Scott Hammond says it can easily handle the 1,200-kg payload capability of ABL Space Systems’ RS1. But getting to SaxaVord on the Shetlands involves a sea crossing for the rocket, so some operators may see a logistical advantage to using Sutherland on the mainland.

But first, the new spaceports need to secure regulatory approval. Licences for U.K. launches will be issued by a new space regulation arm of Britain’s Civil Aviation Authority — and, if the rocket is American-made, an FAA licence will be needed, too. This export of U.S. spaceflight rocketry to the U.K. was made possible by the June 2020 signing of the U.K.-U.S. Technology Safeguards Agreement; this treaty ensures that exported U.S. rocket technology is securely protected in a counter-proliferation sense.

And in what is perhaps an encouraging sign of how close to reality a U.K. vertical launch is finally becoming, Orbex in February announced it had submitted its application for a launch license from the Sutherland spaceport, the first company to do so. Virgin Orbit also has its license application in for horizontal launch.

“Orbex already has six contracts for launch from Sutherland. So they are keen to start launching,” says Kirk of Highlands and Islands Enterprise. He expects that first Orbex orbital launch to happen

"towards the very end of this year, or more likely, the first quarter of 2023."

Getting that license application filed was a "major step" for the startup, says Orbex CEO Chris Larmour. As that licence grinds through the regulatory mill — CAA says it could take 9 to 18 months — the company is also preparing to run static fire tests of its Prime rocket motors on a test site under construction near Orbex headquarters. The tests won't happen at Space Hub Sutherland because ground has not been broken there yet to start pad build-out.

One reason for the delay, says Kirk, is that Highlands and Islands Enterprise has yet to appoint a launch site operator for the complex. What they are hoping to appoint is an experienced company well versed in running orbital ranges safely. While Kirk would not say who their likely operator may be — just that HIE is in talks with a number of them — the companies operating in that arena include the Alaska-owned Alaska Aerospace Corp., which has branched out from running its Kodiak launch site to also running the pad operations for U.S. launcher Rocket Lab on the Mahia Peninsula in New Zealand.

Once Sutherland and SaxaVord have met the environmental conditions laid down as part of their planning permission, launchpad construction can begin. It is unclear, however, how long that might take. For instance, one of Sutherland's conditions is that it has to protect a 76-hectare peat bog near its launch site — an important local $CO_2$ sink.

Much is being made over which of the three U.K. spaceports will be first to orbit a smallsat, but for Kirk, the bigger picture here is the chance to make up for the lost years of rocketry after Black Arrow was canceled.

"We now have a real opportunity for the U.K. to seize back what might have been," he says. ★

▲ The three planned launchpads for SaxaVord U.K. Spaceport would be built on undeveloped land at the tip of Lamba Ness on the island of Unst, near a former Royal Air Force radar station that is also being upgraded. A handful of large antennas located on Unst and five other locations around the world would provide telemetry for the Saxavord launches, the first of which is scheduled for late 2022.

Paul Riddel

# WAKE-UP CALL:
## You're more vulnerable than you realize

**Navigation technologies including GPS make planes vulnerable to cyberattacks and put them at risk of accidents. Josh Lospinoso of cybersecurity firm Shift5 assesses the challenges and possible solutions.**

BY JOSH LOSPINOSO

A common aviation security concern is that attackers will hack into an airplane's flight system and cause a mid-air collision or a crash. That hasn't happened yet, but the truth is that there are other aviation security weaknesses that should be of more concern. The navigation technologies pilots depend on to safely fly airplanes are vulnerable to attacks that could interfere with the flight altimeter and location information. Attackers could, for instance, send false location data into the air that overpowers the real signals from space. Such an attack would leave pilots with false information about their location and surroundings, and increase the chances of a mid-air collision or a crash.

The problem is that the navigation protocols, the standard set of rules that allow electronic devices to communicate with each other, predate the encryption and authentication security technologies that today safeguard all kinds of communications, from online financial transactions to text messages and emails. To address this, the U.S. government needs to prioritize development of new protocols for positioning, navigation and time that will serve as alternatives to older ones, and in the meantime turn to commercial technologies that use stronger broadcast signals. The commercial aviation industry, meanwhile, should adopt the higher-level security techniques that protect U.S. military aircraft and in foreign commercial planes.

A key to defense in both the short and long term is observability: You cannot defend what you cannot see. Observability is a core modern cybersecurity tenet for very good reason. Despite all the cybersecurity controls you might put into place, determined attackers can always find a way in. By decreasing time to detection through observability, cybersecurity professionals can respond to intrusions quickly, mitigate damage, and potentially prevent intrusions from happening in the future. Fortunately, increasing observability does not need to be expensive or onerous, and the technology exists to upgrade decades-old aircraft to support modern cybersecurity principles.

There are a variety of signals from today's aircraft creating vulnerabilities to spoofing and jamming that the Biden administration and U.S. Congress must address.

## 1) GPS

Aircraft rely on these satellite-based radio signals that form the basis for location and time services used in online maps and Wall Street trading transactions, among other areas, to precisely calculate their locations at any given point in time. Because the distance the signals have to travel is so vast, the signals are weak when they arrive and thus vulnerable to interference. Someone wishing to confuse a pilot could jam the GPS signal by broadcasting strong signals that drown out the GPS signals with noise, basically leaving the pilot in the dark as to the airplane's location. Or someone could cause a pilot to go off course by overpowering the GPS signals with falsified location data in a spoofing attack.

Spoofing is a growing problem for GPS. A 2019 report from the Center for Advanced Defense Studies in Washington, D.C., counted nearly 10,000 state-sponsored GPS spoofing incidents affecting at least 1,300 commercial air and sea vessels. The spoofing originated out of Russia, Crimea and Syria and was used in active Russian combat zones and specific areas where President Vladimir Putin happened to be traveling. Last year, Russia reportedly tried to jam GPS signals of a Royal Air Force transport plane carrying troops out of Cyprus. And there have been a number of spoofing cases involving ships, including one involving a British warship off the coast of Crimea last year and several possible cases involving a Swedish tanker and U.S. naval boats seized by Iran for allegedly straying into Iranian territory in the Gulf.

## 2) ADS-B

The Automatic Dependent Surveillance-Broadcast radio signals used by airplanes to broadcast their GPS position, altitude and speed via onboard transponders

▲ Signals coming to or leaving even the most sophisticated airliners make them vulnerable to jamming and spoofing, the author warns.

American Airlines

to air traffic control towers and other aircraft with ADS-B receivers are also vulnerable to spoofing and jamming. Security researchers were able to spoof ADS-B systems and even create fake ghost planes in 2012 that could have shown up on maps and displays in airports and on the displays of other airplanes.

### 3) TCAS

The Traffic Collision Avoidance System software that uses radio signals to broadcast an aircraft's location information to transponders on nearby aircraft would pose a more dangerous threat if compromised than GPS and ADS-B vulnerabilities because hackers could have access to the onboard avionics of a plane. If that were to happen, they could knock critical systems offline or otherwise interfere with the operations of the aircraft and cause direct physical impact.

### 4) ACARS

The Aircraft Communications Addressing and Reporting System is another common protocol used to transmit short messages between aircraft and ground stations via radio or satellite. The onboard electronic system provides route information to pilots for fuel efficiency and weather avoidance purposes and to air traffic control for providing departure clearances. Because it is also linked directly to the avionics, hackers would be able to remotely interfere with aircraft operations. If even one of the dozens of sensors or actuators reading such messages doesn't properly sanitize the input, a whole host of potential, well-known attacks using malware that exploit software vulnerabilities become possible.

In 2020, the U.S. Government Accountability Office recommended that FAA strengthen its oversight of airplane cybersecurity and listed flight data spoofing and outdated equipment as risks. Specifically, the report noted that ACARS transmissions are unauthenticated and could be spoofed and manipulated to send false messages, "such as incorrect positioning information or bogus flight plans."

### 5) ILS

Finally, there are also security issues with the Instrument Landing Systems that rely on a combination of onboard instruments and two different radio signals for vertical and lateral position data transmitted from antennas near runways to guide aircraft in via a glide slope. Security researchers have been able to spoof airport signals to trick navigation instruments and make it seem as if the plane was off course.

### Old protocols, weak security

The problem stems from the fact that most of these technologies were established decades ago before the advent of modern cybersecurity. They rely on obscurity rather than strong encryption and authentication. Fortunately, the picture is less bleak for U.S. military aircraft, which employ their own encryption-protected GPS system and anti-spoofing techniques. However, if the Defense Department needed to activate the commercial reserve fleet, they would be subject to the lesser security controls of the commercial aircraft.

Spoofing and jamming attacks aren't just within reach of nation-states. The equipment is very inexpensive and widely available. All that's needed to spoof these five insecure protocols is a portable radio transmitter running open source software.

Cryptographic techniques could prevent spoofing these protocols, but it's not a feasible option for these protocols. Authentication and encryption would re-

U.S. wireless carriers delayed rollout of 5G services in January because of concerns that 5G towers near airports could interfere with the C-band signals that aircraft altimeters rely on to gauge the distance from the ground during landings, among other purposes. The 5G portion of the spectrum is right next to the C-band frequencies used by altimeters.

quire a key management infrastructure and brand new avionics. Then we'd have to wait several decades for the insecure systems to age out.

## Possible solutions

There are a number of commercial technologies under consideration in the United States for use as a backup to GPS, including eLoran, antenna towers that would broadcast low-frequency radio signals that are about 1.3 million times stronger than the ultra-high frequency signals used by GPS. The technology is being used in many countries, including the U.K., Russia and China, but the U.S. is far behind on its adoption. It will take years to build and even longer for new devices that are compatible to be brought to market. Plus, eLoran only works in two dimensions (no altitude data) and only works regionally.

While the location data interference threats won't be solved anytime soon, there's software called Received Autonomous Integrity Monitoring that prevents a malfunctioning GPS satellite from transmitting bad data to airplanes by cross-checking it against other satellite data. While this system is designed to protect against accidental errors, it should make practical GPS spoofing more difficult to carry out in practice.

Congress has tried to address the navigation protocol security issues, but there have been hurdles. The National Timing Resilience and Security Act of 2018 required the Transportation Department to establish a plan for a "land-based, resilient and reliable alternative timing system" to GPS within two years, but the deadline passed in 2020. However, the concept is not dead. In a January 2021 report to Congress, DoT provided a roadmap to achieving a GPS alternative. A companion report issued at the same time said DoT had been working with the Defense Department and the Department of Homeland Security on a plan for a GPS backup and new positioning and navigation technologies for several years and detailed 11 technologies that government researchers had studied, including eLoran.

However, the fiscal 2022 U.S. budget includes a proposal to repeal the GPS backup act. It's time for Congress to make it a priority to get a more secure GPS adopted.

The issue of airplane safety is of increasing importance right now in the face of wireless technology advancements and heightened geopolitical concerns. Wireless carriers in January delayed their 5G rollouts near airports by a few weeks because of worries that it could interfere with airplane radio altimeters. Meanwhile, the crisis in Ukraine prompted U.S. government warnings about the potential for Russian-sponsored cyberattacks on U.S. critical infrastructure, including transportation.

Given the intensity of alarm around cyberattacks related to the crisis in Ukraine and the January ransomware attack on a Belarus railway system by pro-democracy Belarusian hackers, concerns about potential spoofing, jamming or other attacks on airplanes are not overblown. Attackers could use a spoofing attack to plant a false flag and make it seem like an adversary has entered a country's no-fly zone, or disrupt air travel around an airport and demand a ransom payment to open it back up. We shouldn't wait for a nation-state attack or catastrophic accident to happen before we act on addressing the security weaknesses that put aircraft navigation systems at risk. The vulnerabilities have been around for a long time, security researchers have proven they are real, attackers are exploiting them and more incidents will happen. ★

**Josh Lospinoso** is founder and CEO of Shift5 in Washington, D.C., which develops security technologies for planes, trains and weapons systems. As a U.S. Army captain, he was a founding member of U.S. Cyber Command. He holds a Ph.D. in statistics from the University of Oxford.


UPCOMING SYSTEMS ENGINEERING COURSES
SHARPEN YOUR SKILLS
AIAA has partnered with Teaching Science and Technology, Inc., to offer a series of space systems engineering courses this spring. The Understanding Space course is ideal for technical or non-technical professionals new to the space industry or those who need a refresher on fundamentals, while the other three courses are intended for systems engineers, payload principal investigators, subsystem engineers, or project managers involved in any phase of the space mission lifecycle.
Understanding Space: An Introduction to Astronautics and Space Systems Engineering
8–10 March | 18 Total Hours
Applied Model-Based Systems Engineering
26–29 April | 24 Total Hours
Applied Space Systems Engineering
2–5 May | 24 Total Hours
Designing Space Missions
6–9 June | 24 Total Hours
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# AIAA Bulletin

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# Calendar

| DATE | MEETING | LOCATION | ABSTRACT DEADLINE |
|---|---|---|---|
| **2022** | | | |
| 5–12 Mar* | 2022 IEEE Aerospace Conference | Big Sky, MT (aeroconf.org) | |
| 8, 9, 10 Mar | Understanding Space: An Introduction to Astronautics and Space Systems Engineering Course | ONLINE (learning.aiaa.org) | |
| 8–17 Mar | Trusted Artificial Intelligence Course | ONLINE (learning.aiaa.org) | |
| 14 Mar–6 Apr | Systems Thinking for Modern Aerospace Complexity Course | ONLINE (learning.aiaa.org) | |
| 22–31 Mar | Fundamentals of Thermal Vacuum Testing Science Course | ONLINE (learning.aiaa.org) | |
| 25–26 Mar | AIAA Region III Student Conference | West Lafayette, IN, & Online | 27 Jan 22 |
| 25–27 Mar | AIAA Region I Student Conference | Blacksburg, VA | 24 Jan 22 |
| 29 Mar–7 Apr | Technical Writing Essentials for Engineers Course | ONLINE (learning.aiaa.org) | |
| 1–2 Apr | AIAA Region IV Student Conference | San Antonio, TX, & Online | 31 Jan 22 |
| 1–3 Apr | AIAA Region VI Student Conference | Merced, CA | 5 Feb 22 |
| 4–5 Apr | AIAA Region II Student Conference | Atlanta, GA | 4 Feb 22 |
| 4–6 Apr* | 3rd IAA Conference on Space Situational Awareness (ICSSA) | Madrid (http://reg.conferences.dce.ufl.edu/ICSSA) | |
| 4–14 Apr | Fundamentals of Data and Information Fusion for Aerospace Systems Course | ONLINE (learning.aiaa.org) | |
| 8–9 Apr | AIAA Region V Student Conference | Colorado Springs, CO, & Online | 13 Feb 22 |
| 11 Apr–18 May | Design of Space Launch Vehicles Course | ONLINE (learning.aiaa.org) | |
| 12–21 Apr | Application of Thermal Vacuum Testing Course | ONLINE (learning.aiaa.org) | |
| 19–21 Apr | AIAA DEFENSE Forum | Laurel, MD | 19 Oct 21 |
| 21–24 Apr | AIAA Design/Build/Fly | Wichita, KS | |
| 22 Apr | Non-Intrusive Laser-Based Diagnostic Techniques for Hypersonic Flows Course | Laurel, MD (aiaa.org/defense) | |
| 26 Apr | AIAA Fellows Induction Ceremony and Dinner | Arlington, VA | |
| 26–29 Apr | Applied Model-Based Systems Engineering Course | ONLINE (learning.aiaa.org) | |
| 27 Apr | AIAA Awards Gala | Washington, DC | |
| 27–28 Apr | ASCENDxTexas: Accelerating the Business of Space Exploration Moving Beyond the Now | Houston, TX (ascend.events/ascendx) | |
| 2–5 May | Applied Space Systems Engineering Course | ONLINE (learning.aiaa.org) | |

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

| DATE | MEETING | LOCATION | ABSTRACT DEADLINE |
|---|---|---|---|
| **2022** | | | |
| 3–4 May | OpenFOAM CFD Foundations Course | ONLINE (learning.aiaa.org) | |
| 3–5 May* | 6th CEAS Conference on Guidance, Navigation and Control (EuroGNC) | Berlin, Germany (eurognc2022.dglr.de) | 31 Oct 21 |
| 4–27 May | Electrochemical Energy Systems for Electrified Aircraft Propulsion Course | ONLINE (learning.aiaa.org) | |
| 10 May–30 Jun | Human Spaceflight Operations: Lessons Learned from 60 Years in Space Course | ONLINE (learning.aiaa.org) | |
| 12–13 May* | AIAA SOSTC Improving Space Operations Workshop 2022 | Virtual Event (https://isow.space.swri.edu) | |
| 16–19 May* | 26th Aerodynamic Decelerator Systems Technology Conference and Seminar (ADSTCS) | Toulouse, France (https://earthlydynamics.com/adst-2022) | |
| 17–26 May | Digital Engineering Fundamentals Course | ONLINE (learning.aiaa.org) | |
| 24–25 May | OpenFOAM External Aerodynamics Course | ONLINE (learning.aiaa.org) | |
| 30 May–1 Jun* | 29th Saint Petersburg International Conference on Integrated Navigation Systems | Saint Petersburg, Russia (http://www.elektropribor.spb.ru) | |
| 6–9 Jun | Designing Space Missions Course | ONLINE (learning.aiaa.org) | |
| 7 Jun | OpenFOAM CFD Aeroacoustics Course | ONLINE (learning.aiaa.org) | |
| 8 Jun | OpenFOAM CFD Dynamic Mesh Modeling Course | ONLINE (learning.aiaa.org) | |
| 14–17 Jun* | 28th AIAA/CEAS Aeroacoustics Conference | Southampton, UK (aeroacoustics2022.org) | 12 Jan 22 |
| 21–24 Jun* | ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences | Prague, Czech Republic (icnpaa.com) | |
| 27 Jun–1 Jul | AIAA AVIATION Forum | Chicago, IL | 10 Nov 21 |
| 16–24 Jul* | 44th Scientific Assembly of the Committee on Space Research and Associate Events (COSPAR) | Athens, Greece (cospar-assembly.org) | 11 Feb 22 |
| 7–10 Aug* | AAS/AIAA Astrodynamics Specialist Conference | Charlotte, NC | 1 Apr 22 |
| 4–9 Sep* | 33rd Congress of the International Council of the Aeronautical Sciences (ICAS 2022) | Stockholm, Sweden (icas2022.com) | 10 Feb 22 |
| 18–22 Sep* | 73rd International Astronautical Congress | Paris, France (iac2022.org) | |
| 24–26 Oct | ASCEND Powered by AIAA | Las Vegas, NV | 31 Mar 22 |
| **2023** | | | |
| 23–27 Jan | AIAA SciTech Forum | National Harbor, MD | 1 Jun 22 |

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

● AIAA Continuing Education offerings

# 2022 AIAA Election Results

AIAA is pleased to announce the results of its 2022 election:

**Integration and Outreach Activities Division**

*Director–Aerospace Outreach Group*
Kevin Burns, Retired

*Director–Integration Group*
Thomas Irvine, TBI Aerospace Consulting, LLC

*Director-Elect–Young Professionals Group*
Dominic Pena, Ball Aerospace

**Regional Engagement Activities Division**

*Director–Region IV*
Ellen Gillespie, Retired

*Director–Region V*
James Guglielmo, Boeing Research & Technology

**Technical Activities Division**

*Director–Information Systems Group*
Michel Ingham, NASA Jet Propulsion Laboratory

*Director–Propulsion and Energy Group*
Rusty Powell, Axient, LLC

*The newly elected will begin their terms of office in May 2022.*

**Annual Business Meeting Notice** Notice is hereby given that the Annual Business Meeting of the American Institute of Aeronautics and Astronautics (AIAA) will be held on Monday, 25 April 2022, at 1:00 PM, at the Hilton Crystal City at Washington Reagan National Airport, Arlington, VA.

**AIAA Council of Directors Meeting** Notice is hereby given that an AIAA Council of Directors Meeting will be held on Tuesday, 26 April 2022, at 1:00 PM, at the Hilton Crystal City at Washington Reagan National Airport, Arlington, VA.

**AIAA Board of Trustees Meeting** Notice is hereby given that an AIAA Board of Trustees Meeting will be held on Wednesday, 27 April 2022, at 9:00 AM, at the Hilton Crystal City at Washington Reagan National Airport, Arlington, VA.

## New AIAA Student Branches

AIAA has chartered two new AIAA student branches—Cedarville University in Cedarville, Ohio, and the University of Calgary in Alberta, Canada. These schools join our 240+ AIAA student branches.

AIAA is currently accepting applications to establish additional student branches. If you know a college or university that is interested in chartering an AIAA Student Branch, applications are open until 11 April. For more information, visit **aiaa.org/get-involved/students-educators/Student-Branches**.

# Nominate Your Peers and Colleagues!

Do you know someone who has made notable contributions to aerospace arts, sciences, or technology? Bolster the reputation and respect of an outstanding peer throughout the industry.
**Nominate them now!**

**Candidates for SENIOR MEMBER**

- Accepting online nominations monthly

**Candidates for ASSOCIATE FELLOW**

- Acceptance period begins 1 February 2022
- Nomination forms are due 15 April 2022
- Reference forms are due 15 May 2022

**Candidates for FELLOW**

- Acceptance period begins 1 April 2022
- Nomination forms are due 15 June 2022
- Reference forms are due 15 July 2022

**Candidates for HONORARY FELLOW**

- Acceptance period begins 1 February 2022
- Nomination forms are due 15 June 2022
- Reference forms are due 15 July 2022

Criteria for nomination and additional details can be found at
**aiaa.org/Honors**

AIAA
SHAPING THE FUTURE OF AEROSPACE

MAKING AN IMPACT

# 2022 Kahn Scholarship Recipients Announced

In 2021, when AIAA announced the Roger W. Kahn Scholarship to honor Kahn and his passion for aviation and entertainment, we were thrilled to have so many high school seniors from all over the world apply. This year, we received scholarship applications from over 120 high school seniors, and after weeks of deliberation, AIAA is happy to announce that Favianna Colón, Nchenui Moundae Jamila, Elizabeth Kung, and Mariah Tammera will each receive a $10,000 Kahn Scholarship to support their educational journey in the fall. These students also will be awarded a travel stipend to attend the AIAA Awards Gala in April and an AIAA professional member mentor to help guide the student on their career path.

**Favianna Colón**

Notre Dame High School, Caguas, Puerto Rico

Born on the beautiful island of Puerto Rico to parents Christine Irizarry and José Colón, I am the eldest child, a trained ballet dancer, and the first member of my family to pursue university studies outside the isle's borders—I hope to attend MIT or Georgia Tech in the fall. My decision to do so came over four years ago, in 2018, when I traveled to Washington, DC, to compete in the National Science Bowl and fell in love with the vibrant campus life.

I am currently a senior at Notre Dame High School in my hometown of Caguas, Puerto Rico. I participate in a specialized STEAM program offered there that, over the years, has inspired my fondness of discovery and creation. At the school, I am an active member of numerous organizations, including the Chemistry Club, Honor Society, and Mathematics Club, of which I am president. Thanks to participation in these, I have managed to be a great prospect in competitions like the Puerto Rico Math Olympiad. Further, such institutions have assisted me in discerning my passion for Chemical and Biological Engineering.

Outside of school, in 2019, I participated in a research initiative hosted by NASA in the Arecibo Observatory called STAR Academy. I graduated as the program's salutatorian and, during my time there, investigated black hole types and emerging trends in their development throughout the universe. Such experience steered me to also seek a minor in Astronomy.

**Nchenui Moundae Jamila (Jamila)**

Paul M. Hodgson Vocational Technical High School, New Castle, DE

I am an aspiring aerospace engineer who grew up in the Central African country of Cameroon and moved to the United States when I was 10 years old. Engineering has always been something that I loved, and I was always fixing and assembling things as a child. I never knew exactly what type of engineering I wanted to specialize in, so I decided to apply for the manufacturing and pre-engineering vocational high school program, which explored every aspect of engineering spanning from machining to CAD design, coding, to circuity, rocket science and robotics. Though intrigued by different fields of engineering, I found rocket science, machining, and robotics units the most challenging and interesting. I wanted a specialization that combined all of my interests, and I always had a strong interest in global warming since I was 12 — I even did a science fair project on the effects of co2 emission. While researching the project I found that research and development for electric cars and solar power were almost definitive at the time, but that of electric airplanes was really far off. I then realized that aerospace engineering was perfect for me, as I could incorporate my interest in global warming, fulfill a personal vendetta against my misogynistic culture, and blend many of the types of engineering I had a passion for. I have a long-term goal of being a key part in the development of an electric airplane.

**Elizabeth Kung**

Sunset High School, Portland, OR

I was born and raised in Oregon and have always been an active person, curious to try new endeavors. In my early years, I attended a Chinese immersion school, and I am able to fluently read, write, and converse. I love the team atmosphere and the competitive nature of sports, and I've played football, was the captain of my rugby team, attended swimming competitions, and achieved a USA Ballroom Dance Nationals 2nd-place finish.

Space has always been my biggest passion. I was introduced to the magnificence of space through three movies: *October Sky* showed me how to dream, *Hidden Figures* showed me how to pursue, and *Apollo 13* showed me how to persevere. These films were an inspiration, leading me to participate in engineering classes, visit local companies like Boeing, and compete in the Conrad Challenge, becoming a "Conrad Innovator" for two projects: ClearCube (space debris removal) and Mile One (ecofriendly, sustainable shipping). I also had the pleasure of attending two NASA summer camps: one in Alabama, where my team won the "Commander's Cup," and another in Florida, where I witnessed a rocket launch.

I have a desire to further space exploration. Whether or not this involves working on rockets, researching new materials, assembling rovers, learning to fly, or cleaning up space debris, I want to be part of this special time in history. I intend to pursue a degree in Aerospace/Astronautical Engineering and work in the space industry.

**Mariah Tammera**

Highland School, Warrenton, VA

When I was in first grade, my favorite book was *There's No Place Like Space* by Tish Rabe. I remember thumbing through the colorful, eye-catching pages and absorbing every little detail about the planets, sun, moon, and lunar rovers. My childhood imagination expanded as thoughts captured these topics. It was from this point on that I realized my wholehearted passion for space exploration.

In the spring of 2018, my school gave me the opportunity to attend Space Camp in Huntsville, Alabama, for one week. There, I was able to delve deeper into learning more about the career opportunities in the Aerospace field, while also being challenged to use critical thinking and problem-solving skills in group activities. My experiences at Space Camp sparked an interest in a career in Aerospace Engineering. The specifics of my career aspirations began developing after being accepted into the Virginia Aerospace Science and Technology Scholars (VASTS) Online Course program during my junior year of high school and subsequently participating in the VASTS Summer Academy: an invitation-only program. While conducting research on robotic space missions for a module assignment, I discovered an inclination toward learning more about robotic space mission rovers and the scientific instruments used on those vehicles.

All these experiences — from childhood to present day — have encouraged me to set a future career goal aimed at contributing toward furthering humankind's preparation for long-term space exploration by aspiring to participate in the design and development of robotic apparatuses.

## MORE INFORMATION

**To find out how to get involved with AIAA and make an impact** please visit.aiaa.org/foundation or contact Alex D'Imperio, alexandrad@aiaa.org.

# SAT OC's Latest Endeavors

By Amir S. Gohardani, SAT OC Chair

The Society and Aerospace Technology Outreach Committee (SAT OC) continues to investigate the interests of its membership. With goals of advancing its mission of promoting the transfer and use of aerospace technology for the benefit of society, a recent committee meeting addressed a completed member survey. SAT OC members discussed various topics such as engagement and communications, allowing for clear objectives about the scope of current and future committee activities.

## SAT OC's History

At 2022 AIAA SciTech Forum, glimpses of SAT OC's history were presented in the paper, "The History of the AIAA Society and Aerospace Technology Outreach Committee," which was crafted following an initiative by the AIAA History Committee to encourage every committee, section, and AIAA Headquarters to document various historical elements for the AIAA Centennial. It was noted during a recent SAT OC meeting that with the emergence of more aerospace technologies affecting people in society, it remains crucial for this committee to continue its activities and to bring awareness about the impact of aerospace technology on society. Ranging from popular culture to life on other planets, there will certainly be no shortage of topics for exploration, and thus, exciting SAT OC times lie ahead.

## The Launch of the Diversity Corner

As a member of an outreach committee, I have always found it of paramount importance that voices belonging to members from all walks of life, all genders, ethnicities, and races should be represented within our committee. Having had the privilege of serving as the chair for SAT OC since 2017, there has been ample time for reflection. Over the years, I have come to realize that despite our best efforts, we occasionally fall short when it comes to the representation of the entire industry. This is partially due to the inherent silos between different committees and the limitations of committee activities. Therefore, this year, I have made a deliberate choice of reaching out to the AIAA Diversity and Inclusion Working Group. After floating the idea of the "Diversity Corner" that I have nourished in mind for quite some time now, I am delighted to announce that hereafter, a new collaboration between SAT OC and the AIAA Diversity and Inclusion Working Group will allow for a more inclusive AIAA. In a nutshell, this collaboration seeks to highlight individuals selected by the working group who have made notable contributions to the aerospace industry with significant societal impact. SAT OC is grateful to the AIAA Diversity and Inclusion Working Group for being receptive to collaborative efforts and equally excited about the launch of the first Diversity Corner, which coincides with the last day of Black History Month. In the United States, the contributions and sacrifices of African Americans who have helped shape the nation are honored during this important month. Claudine Phaire has graciously contributed to the Diversity Corner.

# Diversity Corner


**NAME:** Christine Darden

### NOTABLE CONTRIBUTIONS

Darden wrote a computer program for predicting the sonic boom that launched her 25-year career in sonic boom minimization. She has also served as a technical consultant on numerous government and private projects. Her efforts were critical in developing the Quiet SuperSonic Technology (QueSST), which has become the Low Boom Flight Demonstrator (LBFD) aircraft and is currently being manufactured by Lockheed Martin Skunk Works. Test data from the aircraft will help NASA provide regulators with the information needed to establish an acceptable commercial supersonic noise standard to lift the ban on commercial supersonic travel over land. Darden is the author of more than 50 publications in the field of high lift wing design in supersonic flow, flap design, sonic boom prediction, and sonic boom minimization. Featured in the book *Hidden Figures,* Darden has not only contributed to engineering excellence, but throughout her career, she consistently advocated for women to receive equal roles as men who had similar educational backgrounds.

### POTENTIAL SOCIETAL IMPACT OF CONTRIBUTIONS

Darden has inspired generations with her notable contributions. A breakthrough in low-boom fight could further open the doors to an entirely new global market for aircraft manufacturers, enabling passengers to travel anywhere in the world in less time than it takes today.

Please join AIAA, the National Society of Black Engineers, and the Royal Aeronautical Society for the Mary Jackson Lecture featuring Dr. Darden. Dr. Mary Jackson was the first black female aerospace engineer at NASA in 1958. The lecture will be held on Thursday, 10 March, at 1100 hrs EST and can be accessed at **https://bit.ly/3HdY936**.

# Obituaries

## AIAA Associate Fellow Haines Died in September 2021

**James (Jim) Haines** died on 15 September 2021 at the age of 77.

Haines grew up around London and graduated with a degree in electrical engineering. He started working for Hawker Siddeley in Stevenage as an electronics engineer, and then joined British Aerospace. In 1983, Haines moved to the European Space Agency in the Netherlands where he worked on programs like the Hubble Space Telescope, Mars Rover, Galileo, and many other ESA programs alongside NASA. He retired from the ESA as acting Division Head of the Electrical Power Systems.

Even after his retirement, Haines continued attending Space Power Conferences hosted by ESA in Europe and AIAA in the United States, where he was invited to organize and chair sessions in space power. Haines was a regular and longtime attendee of the Intersociety Energy Conversion Engineering Conference (IECEC), International Energy Conversion Engineering Conference (IECEC), and the Joint Propulsion Conference. He continued to travel to the AIAA conferences over the last 20 years to render his dedicated services as an author, paper reviewer, organizer, and session chair in aerospace power systems.

Haines was a longtime member of the AIAA Aerospace Power Systems Technical Committee, and for his significant and sustained contributions in space power, he was honored with the 2007 AIAA Aerospace Power Systems Award.

## Associate Fellow Fox Died in January

**Herbert Fox** died on 1 January 2022. He was 82 years old.

Dr. Fox graduated from the Massachusetts Institute of Technology and earned a master's degree and Ph.D. from Polytechnic Institute of Brooklyn in 1962 and 1964, respectively.

After receiving his Ph.D., Dr. Fox joined the faculty of the Aerospace Engineering Department of New York University. In 1970, he became a professor and dean of Science and Technology at the New York Institute of Technology. For several years after 1977, he served as vice president of consulting services at Pope, Evans and Robbins, Inc., a consulting engineering firm in NY. He was responsible for studies and designs dealing with alternative fuels and energy conservation. From 1982 through 1989, Fox rejoined New York Institute of Technology as senior vice president for scientific research. Under his leadership the school developed significant capabilities to serve the government and industrial communities. In 1989, he became senior vice president for academic affairs, playing a key role in elevating many technology programs at New York Tech into reputable ABET-accredited engineering disciplines. During his tenure as a faculty member, he worked to promote and expand research among faculty and students. In 1992, he returned to teaching, serving as a professor of mechanical engineering until he retired in 2012.

Dr. Fox's publications include over 70 articles and two books. He was a member of the American Society of Mechanical Engineers, New York Academy of Science, American Association for the Advancement of Science, and the Society of Sigma Xi. An AIAA Associate Fellow, Dr. Fox was an active AIAA volunteer, serving on the Board of Directors as Vice President of Education and on other AIAA committees.

## AIAA Associate Fellow Williams Died in January

**Francis L. (Frank) Williams** died on 1 January. He was 92 years old.

Williams earned a Bachelor of Science in Aeronautical Engineering from Alabama Polytechnic Institute in 1951, and was president of the student chapter of the Institute of the Aeronautics. He was commissioned a Second Lieutenant in the U.S. Air Force after ROTC, and he honorably served for seven years, achieving the rank of Captain. He was the flight engineer on the joint B52 mission that dropped the first hydrogen bomb over Bikini Atoll in the Pacific Ocean in 1956.

While serving in the Air Force, Williams earned a Masters Degree in Aeronautical Engineering from the Massachusetts Institute of Technology. Convinced that spaceflight could be a reality, he requested relief from active duty to work in Huntsville, AL, with the von Braun Team, continuing his career with NACA and then NASA.

From 1960 to 1969, Williams served as Deputy Director, Future Projects, and Assistant to Dr. Wernher von Braun, Center Director at Marshall Space Flight Center. He received the NASA Exceptional Service Medal for his contribution to the Saturn Launch Vehicle and Apollo Lunar Landing Program. He served with Frank Borman for one year at the Manned Space Craft Center in Houston where he established the Space Station Task Force, before moving to NASA Headquarters with Dr. von Braun in 1970.

While at NASA Headquarters, Williams served is Director of Program Analysis and Long Range Planning in special programs, and developed six satellites, including SEASAT. He retired from NASA in 1978, and accepted a position as Director, Program Development with Martin Marietta Corporation. He was instrumental in building the external fuel tank for the Space Shuttle Program. Williams was an AIAA Associate Fellow and the author of over 40 technical papers, a major author of the *Handbook of Astronautics*, and was a guest lecturer at several U.S. and international universities.

## AIAA Associate Fellow Blankenship Died in January

**Charles P. Blankenship** died on 21 January. He was 83 years old.

Blankenship was a graduate of Virginia Tech (Corps of Cadets, Class of 1960). He earned B.S. and M.S. degrees in Metallurgical Engineering, and he served as a commissioned officer in the U.S. Air Force.

In 1961, Blankenship was assigned to NASA Lewis Research Center, where he conducted materials technology development programs for aircraft and space transportation systems. After completing his Air Force tenure, he continued his materials development work with NASA at the Cleveland Center. In 1980, he transferred to NASA Langley Research Center as Chief of the Materials Division. And in 1983, he was appointed Langley's Director for Structures and led the center's aircraft and spacecraft research and technology programs in materials, structures, landing dynamics, and acoustics. He was selected to lead the center's newly expanded program for Technology Commercialization in 1993. He served as Deputy Director of NASA Marshall Space Flight Center beginning in 1994. In this capacity he was a leader in the development of the new super lightweight tank for the Space Shuttle. He returned to Langley in 1996 to serve as the Agency Manager for NASA's Subsonic Aircraft Technology Program.

During his NASA career, Blankenship received the Presidential Meritorious Award, the NASA Outstanding Leadership Medal, the SEA National Distinguished Executive Service Award, and the SAE Wright Brothers Medal. He published and presented numerous papers on materials technology developments for applications that included aircraft and automotive turbine engines, aircraft and spacecraft structures, and nuclear propulsion systems.

After retiring from NASA in 1997, he served as a technology consultant to industry and to several government agencies. He served as the Director of the Technology Commercialization Center from 2000 to 2003. In 2007, Blankenship was inducted into the Academy of Engineering Excellence, College of Engineering, Virginia Tech.

## AIAA Associate Fellow Landrum Died in January

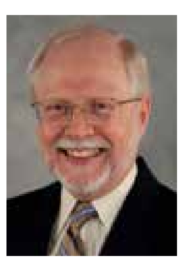
**D. Brian Landrum** died on 21 January. He was 59 years old.

Landrum received his B.S. and M.S. degrees from Texas A&M University in 1984 and 1986, respectively. After two years at Sandia National Laboratories, he completed his Ph.D. at North Carolina State University in 1992.

He then began his 30-year teaching career at the University of Alabama in Huntsville (UAH) where he was an Associate Professor and Associate Chair of Mechanical and Aerospace Engineering. He taught courses in aircraft and missile aerodynamics, and aerospace vehicle design. He also created and taught the introductory Principles of Aeronautics and Astronautics course. His research interests included aerospace system design, unmanned aerial systems, low-speed and biologically-inspired flight, hypersonics, engineering education, and aerospace history. He authored or co-authored more than 120 journal articles and technical papers, and Landrum also advised 5 Ph.D. and 39 M.S. degree graduates.

A 40-year member of AIAA, Landrum became an AIAA Associate Fellow in 2004. He was the longtime UAH Student Branch Faculty Advisor (1993–2021) and the Region II Faculty Advisor Liaison (2011–2021). He was also a member of the AIAA National Technical Activities Committee (2000–2009), the Plasmadynamics and Lasers Technical Committee (1993–2001), the Editorial Advisory Board for the AIAA Education Book Series (2001–2010), and he served as the Region II Deputy Director of Technical Activities (2000–2009).

Landrum was the AIAA National Faculty Advisor of the Year in 2004, and he received the Technical Activities Committee Distinguished Service Certificate from AIAA in 2010. He was also the recipient of the AIAA Greater Huntsville Section's Educator of the Year award in 2017–2018 and the Professional of the Year award in 1999–2000. In addition, Landrum was a member of the American Society of Engineering Education, the Association of Unmanned Vehicle Systems International, and the American Helicopter Society.



## AIAA Fellow Hodges Died in January

**Dewey H. Hodges,** one of the foremost aerospace researchers of his generation, died on 31 January. He was 73 years old.

Hodges majored in aerospace engineering at the University of Tennessee in Knoxville, where he earned a scholarship with the U.S. Army ROTC before graduating with high honors in 1969. He began graduate school at Stanford University on an all-expenses-paid NASA trainee fellowship, and he earned his master's degree in 1970 and his Ph.D. in 1973. Hodges became an officer in the U.S. Army, he made captain in 1975, and retired from active service in 1977.

In 1970, while a student at Stanford, Hodges took a summer job as a research scientist at the U.S. Army Aeronautical Research Laboratory at Ames Research. He parlayed that summer job into an illustrious 16-year career at NASA Ames. His many accomplishments at the Moffett Field research center include his seminal work on rotor stability and a 1974 NASA Technical Note, which he co-authored with Earl H. Dowell, detailing what became known as the Hodges-Dowell beam equations. This paper remains among the field's most cited publications of all time.

In 1986, Hodges joined the faculty of the Daniel Guggenheim School of Aerospace Engineering at Georgia Institute of Technology as a full professor. He became a world-renowned scholar who taught, published landmark papers and classic textbooks, conducted research, and advised graduate students for more than 35 years. In 2003, he authored another engineering breakthrough that bears his name. "Hodges' geometrically exact, fully intrinsic beam equations" superseded the Hodges-Dowell equations as the new standard in the field.

Though he was one of the world's foremost rotorcraft dynamics experts, Hodges always regarded his relationships with his graduate students as the most important aspect of his life's work. He became professor emeritus in May 2020 and continued to guide and collaborate with his remaining graduate students, edit academic journals, and contribute to the field. He mentored 36 Ph.D. and 42 master's degree students over his career.

Hodges' professional achievements include five books, five book chapters, two U.S. patents, approximately 230 technical papers in refereed journals, and another 175 published conference papers. One of his pioneering computer programs, VABS, which he developed with his graduate students, remains the standard tool for rotor blade design around the world. He served on the editorial boards of at least six academic journals and was elected fellow of four professional societies: the American Academy of Mechanics, the American Helicopter Society, AIAA, and the American Society of Mechanical Engineers. In recognition contributions to engineering, he received more than 20 prestigious national and international awards, including the 2013 AIAA Ashley Award for Aeroelasticity and the 2018 AIAA Structures, Structural Dynamics, & Materials Award.

CONTINUED FROM PAGE 64

that slows an object. Think of this sort of like sticking your hand out of a moving vehicle and feeling the air push your hand backward. If you change the orientation of your hand to the wind, you'll feel more or less force pushing your hand backward. Well, by only representing the space object population as cannonballs, those of us in the orbit prediction business are strapped with a limit on how accurately and precisely we can predict where many of these objects will be in the future. A sphere has omnidirectional surfaces. A box consisting of flat sides, not so much. Not having a more realistic description of space objects makes it, at best, really difficult for a space debris removal company to acquire the information it needs to decide whether an object can be removed by its chosen technique.

The astronomy community also needs better trait characterization, both for reasons of pure science and to ensure humanity can detect dangerous asteroids and comets with adequate time to defend against them. Reflections off of human stuff are a nuisance at best for astronomers and at worst a dangerous impediment. Astronomers would benefit from a service for predicting the light pollution that their telescopes will experience during a hypothesized observation period or campaign. Cannonball models are insufficient for such a service, because space objects have complex shapes and reflective characteristics. A surface produces a glint, meaning a sudden flash of light, when its material properties have some level of specularity, or mirror-like reflection, and the direction perpendicular to this surface comes close to aligning with the phase angle bisector, which is the angle between the illumination source — in our case the sun — and the observer. When the phase angle bisector comes within a degree or so of perpendicular, the light is reflected directly to the observer as glint. Glints have been mistakenly confused as genuine astronomical phenomena, such as gamma ray bursts.

Sensing resources should be brought to bear on space object characterization to include developing and deploying (a) hypertemporal sensors that would measure the reflected photons at tens to hundreds of times per second and tell us something about the orientation and shape of the space object, and (b) multispectral sensors that would measure the reflected photons in different wavelengths, which tells us something about the material properties of the space object. Also, the United Nations Convention on Registration of Objects Launched into Outer Space should be updated to require adherents to describe the physical traits of all spacecraft launched from their territories, whether government or privately owned. My dream is to develop a participatory sensing network in which all would be invited to contribute information to a globally sourced space object database. Creating such a collaborative network is one goal of Privateer Space Inc., a company I co-founded last year with Steve Wozniak and Alex Fielding.

To be fair, measuring and inferring the physical traits of the near-Earth anthropogenic space object population will take years and a significant amount of dedicated funding and support. Moreover, there must be a database capable of ingesting, curating, and exposing these traits to the global community. None of this is even planned by the world's leading space countries. Most scientific endeavors consider this task either beneath them or too applied to merit any consideration. And thus, this remains a core gap in our understanding of space debris. If we truly want to bring credible solutions to our space debris problem and space traffic management, we must develop a catalog that represents the space object population beyond the cannonball. ★

# LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

## 1922

1 **March 22** The U.S. Navy's first aircraft carrier, the USS Langley (CV-1), is commissioned at Norfolk, Virginia. A converted collier originally named USS Jupiter, the Langley has a flat top flight deck, two 3-ton moveable gantry cranes for lifting up aircraft and modified holds for storing aircraft and aviation gasoline. Norman Friedman, **U.S. Aircraft Carriers**, p. 36.

**March 23** NASA's predecessor the National Advisory Committee for Aeronautics releases Report No. 159, "Jet Propulsion for Airplanes," one of the earliest scientific studies of the subject. Author Edgar Buckingham of the U.S. National Bureau of Standards correctly finds that theoretically, jet propulsion devices consume four times the fuel of reciprocating propeller power plants at 250 mph, yet their efficiency greatly increases at higher speeds. Eugene M. Emme, ed., **Aeronautics and Astronautics 1915-60**, po. 14-15.

2 **March 30** The first attempt to fly across the South Atlantic begins when Portuguese naval aviators Commander Artur de Sacadura Cabral and co-pilot Rear Adm. Carlos Viegas Gago Coutinho take off from Lisbon in their single-engine Fairey IIID floatplane. After many delays and losing their aircraft, the aviators reach Rio de Janeiro in a replacement floatplane on June 17. They cover 8,383 kilometers in 62 hours and 26 minutes of flight time. David Baker, **Flight and Flying: A Chronology,** p. 142.

## 1947

**March 4** Air operations in the Antarctic known as part of Operation Highjump end. Started by the U.S. Navy on Dec. 4, 1946, the program included photomapping 3.8 million square kilometers of Antarctica's interior and 8,800 kilometers of the coastline by Martin PBM and Douglas R4D aircraft. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 56.

**March 7** A camera aboard a V-2 rocket launched from White Sands Proving Grounds, New Mexico, takes the first photograph at an altitude of 160 kilometers above Earth. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 56; W. Ley, Rockets, Missiles, and Space Travel, p. 458.

3 **March 17** A prototype of the North American XB-45 makes its first test flight at Muroc Army Airfield in California, piloted by George Krebs. The operational version of the XB-45, the United States' first operational jet bomber, will be powered by four General Electric J35 engines. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 56; L.G.S. Payne, **Air Dates**, p. 372.

## 1972

4 **March 2** A three-stage Atlas Centaur blasts off from Cape Canaveral, Florida, with NASA's Pioneer 10 Jupiter probe. The world's first mission to the outer planets, Pioneer 10 also becomes the first spacecraft to travel through the asteroid belt between Mars and Jupiter. The probe passes by Jupiter in 1973 and transmits about 500 images back to Earth, then starts its approximately 2-million-year transit toward the star Aldebaran. Pioneer 10 later crosses the orbits of Saturn in 1976, Uranus in 1979 and Neptune in 1983. The last, very weak signal from the probe is received in January 2003, when it is 12 billion kilometers from Earth. **NASA Releases** 72-25, 72-32, 72-50, 72-68, **and others**.

5 **March 7** This date marks the 10th anniversary of the launch of Oso 1, the first U.S. satellite devoted entirely to studying the sun. Short for Orbiting Solar Observatory, Oso 1 carries 11 experiments to collect data on solar radiation in ultraviolet, X-ray and gamma ray regions. It gathered more data on the behavior and composition of the sun during its first year of operations than any single ground-based observatory and all rocket, balloon and satellite missions. The satellite operated for nine years before ceasing observations in 1963. NASA, **Astronautics and Aeronautics, 1972**, p. 90.

**March 8** NASA announces St. Luke's Hospital in Denver is utilizing a germ-control and dust-purging technique developed by NASA and the aerospace industry to cleanse surgical areas. The method was created for sterilizing spacecraft and self-contained life-support systems. **NASA Release** 72-47.

**March 11** A Thor-Delta booster launches the European Space Research Organization's Thor-Delta IA astronomical observatory from Vandenberg Air Force Base, California. The 472-kg box-shaped spacecraft carries seven experiments from six European universities and research organizations to study high-energy emissions from stellar and galactic sources and the sun that are not visible from ground-based observatories. Thor-Delta IA is the first European-built spacecraft with a three-axis stabilization system. **NASA Release** 72-60.

**March 15** The Communications Satellite Corp. and Cunard Line Ltd. announce the start of a two-month test to demonstrate high-quality, reliable communications between the Cunard ship Queen Elizabeth 2 at sea and the ComSatCorp Laboratories in Clarksburg, Maryland. The test, conducted via the Intelsat IV F-2 communications satellite over the Atlantic and a 2.4-meter parabolic antenna on the ship, is the first satellite transmission of voice and data communications with a commercial passenger liner at sea. **ComSatCorp Release** 72-16.

**March 17** The second satellite launched by the U.S., Vanguard 1, begins its 15th year in orbit. At this time, Vanguard 1 and the rocket upper stage that launched it hold the record for the longest time in space by humanmade objects. Launched two months after Explorer-1 in 1958, the satellite operated up to 1964 but is expected to remain in orbit for about 240 years until its orbit decays. NASA, **Astronautics and Aeronautics, 1972**, p. 109.

**March 27** The USSR launches its 1,180-kg Venus probe Venera-8 from the Baikonur Cosmodrome. The spacecraft's instrumentation includes temperature, pressure and light sensors as well as an altimeter, gamma ray spectrometer, gas analyzer and radio transmitters. Venera-8 becomes the second robotic spacecraft to land on the surface of Venus on July 22, 1972, and transits data for 50 minutes and 11 seconds before failing due to the extreme pressures, heat and other harsh conditions of Venus. NASA, **Astronautics and Aeronautics, 1972**, pp. 119-120, 267, 275.

**March 30** The USSR launches the Meteor 11 meteorological satellite into orbit. Developed in the 1960s, the Meteor series is designed to monitor atmospheric and sea surface temperatures, humidity, radiation, sea ice conditions, snow cover and clouds. NASA, **Astronautics and Aeronautics, 1972**, p. 123.

**Also in March** NASA's Applications Technology Satellite 1 completes the first successful satellite transmission of fingerprint records, NASA announces, demonstrating possible state-to-federal government fingerprint transmission. NASA, **Astronautics and Aeronautics, 1972**, p. 126.

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**March 4** A Russian Start-1 rocket launches the Zeya military communications satellite, the first launch from the Svobodny Cosmodrome in the Amur Oblast region of far eastern Russia. A former Soviet-era strategic missile base, Svobodny is established as a launch complex to reduce reliance on the Baikonur Cosmodrome in a now-independent Kazakhstan. **Aviation Week**, March 10, 1997, p. 58.

6 **March 17** San Antonio aviator Linda Finch takes off in a restored Lockheed Electra 10E aircraft in a re-creation of Amelia Earhart's 1937 attempt to circumnavigate the globe. Finch makes 30 stops in 20 countries, including crossing the expanse near Howland Island where Earhart and navigator Fred Noonan disappeared. **Aviation Week**, March 10, 1997, p. 41; **Washington Post**, March 10, 1997, pp. A1, A2.

**Also in March** Researchers at Auburn University in Massachusetts conduct the inaugural test flight of the first remotely piloted electrically powered helicopter, known as the Solid-State Adaptive Rotor System. **Aviation Week**, March 31, 1997, p. 47.

**Also in March** The U.S. Defense Department's Outrider UAV design makes its first flight, negotiating a figure-8 course. The unoccupied aircraft are to operate from aircraft carriers or ashore for reconnaissance missions, including mine detection. **Aviation Week**, March 17, 1997.


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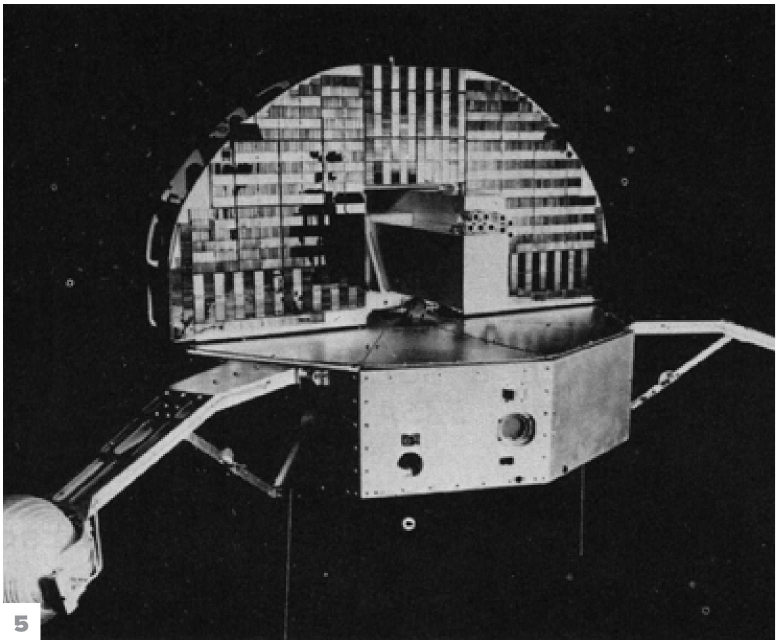
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# Space traffic pros need to know what the traffic looks like

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A growing number of companies are ready to roll up their sleeves and take on the arduous task of cleaning and removing junk in orbital space. It brings a certain warmth to my heart to think of the industry looking after our near-Earth orbital ecosystem. However, there is a foundational level of knowledge about all space objects, including junk, that at present is in absentia in the civilian world and must be obtained and shared among all spacefaring nations and companies.

The world's publicly available space object catalogs represent all objects as spheres, in essence, cannonballs. A spent rocket stage is modeled as a giant cannonball. The Landsat 9 imaging satellite is modeled as a large cannonball. A Starlink satellite is modeled as a small cannonball. A piece of satellite debris from Russia's anti-satellite test last year is modeled as a tiny cannonball. Treating objects as though they are all the same shape is unique to the space domain. We regulate and model Vespa scooters differently than semitrucks, kayaks differently than oil tankers, and Boeing 777s differently than Cessna 152s.

Today's approach is unsatisfactory, because nobody's debris removal business model is predicated on removing cannonballs, but rather objects of irregular shapes with various material properties and tumbling at different speeds and orientations. Since no one can predict the size and shapes of the debris left by a collision, for instance, the physical traits of those objects are mostly unknown. Even for known satellites that have been dead on orbit for many years, the material aging effects on the satellite are also unknown. It would be a bad day for a space debris cleaning company to grab a dead satellite and have it shatter into hundreds or thousands of pieces because it was weak, fragile, or brittle. This lack of knowledge about a space object's physical traits and structural integrity is at the heart of the on-orbit servicing and debris removal problem.

Another consequence of not knowing these physical traits is, inter alia, an inability to precisely predict orbital trajectories. Consider a nongravitational force acting on a satellite, such as the atmospheric drag

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