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Fueling up in space

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AIAA
SHAPING THE FUTURE OF AEROSPACE

If SpaceX's Starship spacecraft is to routinely deliver people and cargo to a future lunar settlement like the one in this illustration, the company must master refueling Starships shortly after launch via "tanker" versions stationed in Earth orbit. These depots would be filled with cryogenic methane and liquid oxygen. SpaceX

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

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DEPARTMENTS

Will we fly like the Jetsons? Journalism can tell us

We pride ourselves on giving you a uniquely technical look at such topics as climate change, the quest for alternative fuels, planetary protection and other issues of life and death importance. As weighty as these issues are, they are not the only ones that matter on our beat. We also cover technology that could someday become part of the amazing story of human progress, a history that's just beginning if one considers that for our first 299,900 years as a species, we could not turn on a light bulb, fly an aircraft, navigate the world with our phones or ride a rocket into space.

Could we soon be adding, "summon an electric aircraft" to that list?

Numerous companies are now testing competing designs for these small aircraft, and deliberations are underway about how to integrate them into our already crowded skies and our urban and suburban settings. The predicted dollar values are staggering for this emerging advanced air mobility market, a category that I should say also includes cargo aircraft and precursor drone designs. Will the AAM market really have an annual economic value of $115 billion someday? That answer will unfold in a multiyear drama of technical progress but also setbacks, demands for passenger safety and calls for regulatory streamlining, praise for free market enterprise amid questions about the equity of some of us bopping around like the Jetsons.

The drama is so intriguing and the outcome so potentially transformative for society that we have created a special online news focus devoted to the topic. We invite you to sign up to receive our True Mobility newsletter in your inbox so you can ride along with us as we chronicle this potential revolution. ★

Sign up for True Mobility

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

The limits of certification by analysis

The June cover story "Flying digitally" by Keith Button drew attention to the popular topic of certification by analysis. Regarding CBA, two points should be made: one from the computational simulation perspective and one from the regulatory perspective.

Professor Juan Alonso believes "simulations used for certification [should be] as good as the flight test." The critical issue is assessing the accuracy of simulation results. When computational simulation includes complex physical processes, especially coupled physics, results should be viewed more as expert opinion than physics-based simulation. Regardless of how much physics is incorporated in the simulation, there are always assumptions and approximations made not only in the physics models and their coupling but also in the common pollution of the physics by numerical solution error. The responsibility of industry management is to provide sufficiently accurate simulations for decision making, given constraints of budget and schedule. There should be a balance between these three, but the balance is always controlled by management.

The responsibility of the regulatory authority is to assess the accuracy of simulations provided by the manufacturer. However, as the story wisely points out, the European Union Aviation Safety Agency and FAA don't "have a knowledge base to do so, nor the resources to develop that knowledge." That's a critical strategic problem.

Computational simulation results are delicate artifacts, especially when diverse sources of uncertainty are incorporated and rare operational scenarios are considered. Physical testing is robust, convincing, and unequivocal. We must learn from our failures: the Gulfstream G650 accident, the Boeing 737 MAX disasters, the space shuttle disasters, etc.

William Oberkampf, AIAA Fellow
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Pop culture analog for Mars Sample Return

Re: "Calls grow for a safer Mars Sample Return" [June 2022], for all you readers out there concerned about contamination, NEVER watch the 2017 movie "Life" … or maybe you already have! *[An organism in a soil sample from Mars turns out to have a bad side.]*

Robert Allen, AIAA senior member
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Let us hear from you

Send letters of no more than 250 words to letters@aerospaceamerica.org. Letters may be edited for length and clarity and may be published in any medium.

Reframing the Great Resignation

At nearly every aerospace industry meeting we've attended this year, everybody is talking about losing great talent. Current resignation levels are at an all-time high in our community. The battle for talent is one of the most crucial challenges we're facing today. As leaders of the AIAA Corporate Membership Strategic Advisory Committee (CMSAC), we're asking ourselves what can we do about it, how can we reframe this situation: Continue complaining and suboptimizing our organizations' workforce? Or double down on attracting and keeping great employees?

Our answer: Be proactive and double down. That's what we agreed as a group. Now we want to enlist support across the AIAA membership to deliver it. It's a huge task, and we are part of an industry that takes on the biggest challenges in the universe. That attitude is part of our DNA, and actually part of the answer. We must do a better job selling the unique features of the aerospace industry to candidates:

- A culture of support
- A community of belonging
- Missions that matter to society

To do this well, AIAA must serve as the thought leader on this subject and also the catalyst for action. Together, AIAA members can lead our community through this tough time, tackling the challenge and building a resilient workforce.

The workforce challenge we face as a community is well documented. We have the data. AIAA published findings on workforce development challenges in the "2021 AIAA State of the Industry Report." AIAA also partnered with Aerospace Industries Association and Ernst & Young LLP to publish additional findings in the "2021 Aerospace and Defense Workforce Study: Realizing the Workforce of Tomorrow." The AIAA CMSAC has been examining the issue, working with McKinsey & Company, and analyzing additional data and findings (see box). McKinsey also will be releasing results soon from a 2022 workforce study they just finished. Take a look yourself to better understand the reasons talented employees are leaving: pandemic uncertainty, remote/onsite/hybrid work arrangements, not feeling valued or having a sense of belonging, and suffering from overwork due to all of the above. You'll also see why great candidates aren't joining the aerospace industry: lack of a strong STEM skills match, not seeing much diversity in leaders or teams, remote/onsite/hybrid work arrangements, and not perceiving an exciting career path.

The aerospace community is a great place to work! We're all in. Many of us would recommend a career in aerospace to a young person right now. In fact, respondents to the "2021 AIAA State of the Industry Report" gave the aerospace industry a net promoter score (NPS) of 29. As the world's leading metric on loyalty, an NPS score of 29 demonstrates solid confidence and commitment to the aerospace industry by today's aerospace workforce. And AIAA members scored the industry another point higher.

We've taken this challenge to the AIAA Board of Trustees for their support. The CMSAC advises the Board directly on issues impacting the overall aerospace industry, so we briefed them during their June meeting on our current priorities. They agreed.

Even with a sharp focus over this year, we know it must be a sustained, multi-year initiative to make the long-term changes that are needed. We proposed several tactics to get the work started — including the topic for discussion at AIAA forums, convening small groups to tackle education issues, and doubling down on sharing the impact our community makes to society. A key element to success will be mobilizing many AIAA members to create change even faster.

Consider yourself invited. Join us in our effort by taking a step immediately. Log in to the AIAA Engage platform and let us know two things: your current hiring challenges and the best ideas and programs that are currently strengthening your workforce retention. By sharing both our challenges and our best practices, we can gain some traction early.

As AIAA Executive Director Dan Dumbacher likes to remind us, today's students will make up the teams that will become the most technically proficient, professionally equipped, and culturally diverse workforce on the planet. These young leaders and team members will be the ones who can get us to Mars and beyond and believe the aerospace industry is the best place to work — both on and off the planet. ★

David Gallagher
Deputy Chair, AIAA Corporate Membership Strategic Advisory Committee, and Associate Director, Strategic Integration, NASA Jet Propulsion Laboratory

Michael Gazarik, Ph.D.
Chair, AIAA Corporate Membership Strategic Advisory Committee, and Vice President of Engineering, Ball Aerospace

Call to action: How A&D companies can build the workforce of the future

'Great Attrition' or 'Great Attraction'? The choice is yours

Debugging the software talent gap in aerospace and defense

Seizing the moment: Talent challenges and opportunities in aerospace and defense

Find these articles and more at: mckinsey.com/industries/aerospace-and-defense/our-insights.

Email us at aeropuzzler@aerospaceamerica.org

Have you seen the moon tonight?

Q: It's the future. All around the world, people are running outside to see if it's true, and it is. The face of the full moon is now rotating slowly in the sky. In your cranial implant, a planetary scientist explains, "The ______ lock between the moon and Earth was broken when a large _________ flew by." Fill in the blanks and explain.

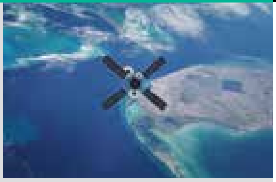
Send a response of up to 250 words that someone in any field could understand to aeropuzzler@aerospaceamerica.org by noon Eastern Sept. 14 for a chance to have it published in the next issue.

Get a head start on the October AeroPuzzler: Scan this QR code or follow us @AeroAmMag

FROM THE JULY/AUGUST ISSUE

EXPLAINING SPIN

We asked you to explain spin stabilization for satellites compared to knuckleballs in baseball.



WINNER A spin stabilized satellite acts like a gyroscope, and assuming it is balanced so it doesn't wobble, it will point in a fixed direction throughout its orbit. Think of a toy gyroscope balanced on the tip of your finger. As you tilt your finger, the gyroscope remains pointing vertically. Spinning the satellite is simpler and less expensive than having multiple gyros to control its attitude about each of its three axes. The spinning satellite's spin axis is determined by its axis of maximum moment of inertia. A baseball has a spherically uniform distribution of mass, so its moments of inertia are the same about each of its three axes — this means it has no preferred spin axis. The baseball's surface is not perfectly smooth, and it will experience aerodynamic effects induced by however the ball is spun when pitched. These two factors will determine the ball's attitude and trajectory.

Anthony Richards, AIAA senior member
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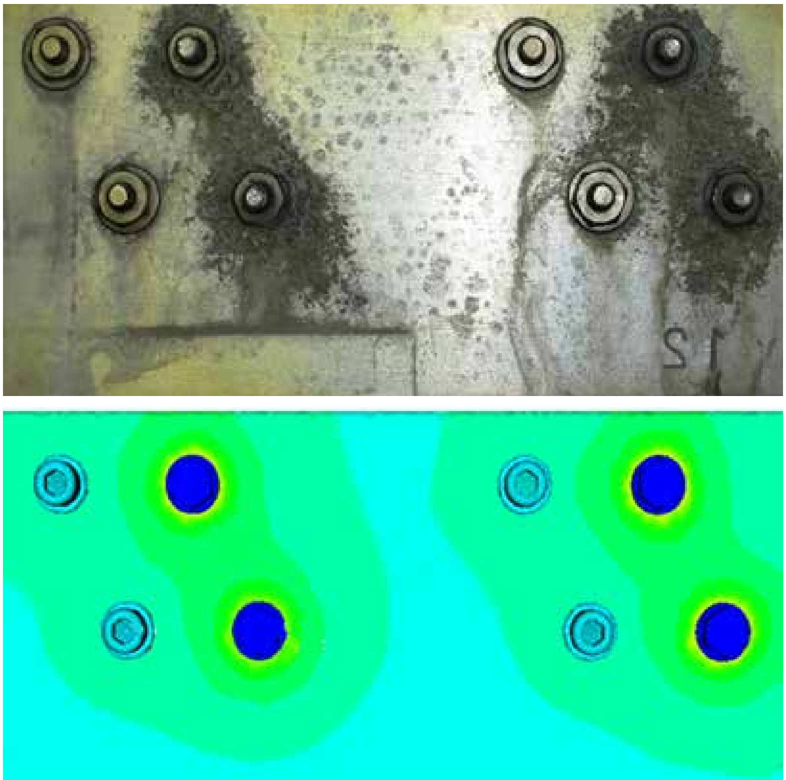
Anthony retired in 2005 from TRW, where he was a mass properties engineer specializing in spin-stabilized spacecraft.

Barton Smith, who reviewed your answers, couldn't resist adding a knuckleball explanation: "The interesting thing about a knuckleball is that you can throw them with no spin and they will gain spin in some random direction due to asymmetric shear on the surface of the ball, generated by seams. There are no aerodynamics in space."

Predicting corrosion with CFD

BY KEITH BUTTON | buttonkeith@gmail.com



▲ A Corrdesa CFD model predicted the rate of corrosion in an aluminum coupon sample (above) caused by fasteners made of stainless steel (shown by the dark blue dots) and titanium (shown in light blue). The bright green patches indicate areas of severe corrosion.

Corrdesa

Having shown that computational fluid dynamics software can solve corrosion equations to identify especially vulnerable areas on aircraft, the engineering company Corrdesa of Georgia now hopes to convince airplane builders to adopt the technique in the design stage.

Modern aircraft have locations where two different materials must adjoin, such as a titanium fastener meeting an aluminum surface. When one of the materials has greater electric potential than the other, the one with less electrical potential acts as an anode and the other as a cathode. If the area is covered by a thin film of electrolyte, such as water condensed on an aircraft, electrons will flow through it, and the anode material will corrode.

The locations and rate of this galvanic corrosion are difficult to predict, so Corrdesa applied the Siemens STAR-CCM+ CFD solver to the problem, along with the unique polarization curves it derived for various materials through lab experiments.

"CFD does not only relate to fluids in motion," explains Corrdesa engineer Julio Mendez, who is in charge of developing methodologies for corrosion applications. "We use the same framework, but with different equations, [those] for galvanic corrosion."

The polarization curves are supplied to STAR-CCM+ by Corrdesa's Corrosion Djinn database, he adds.

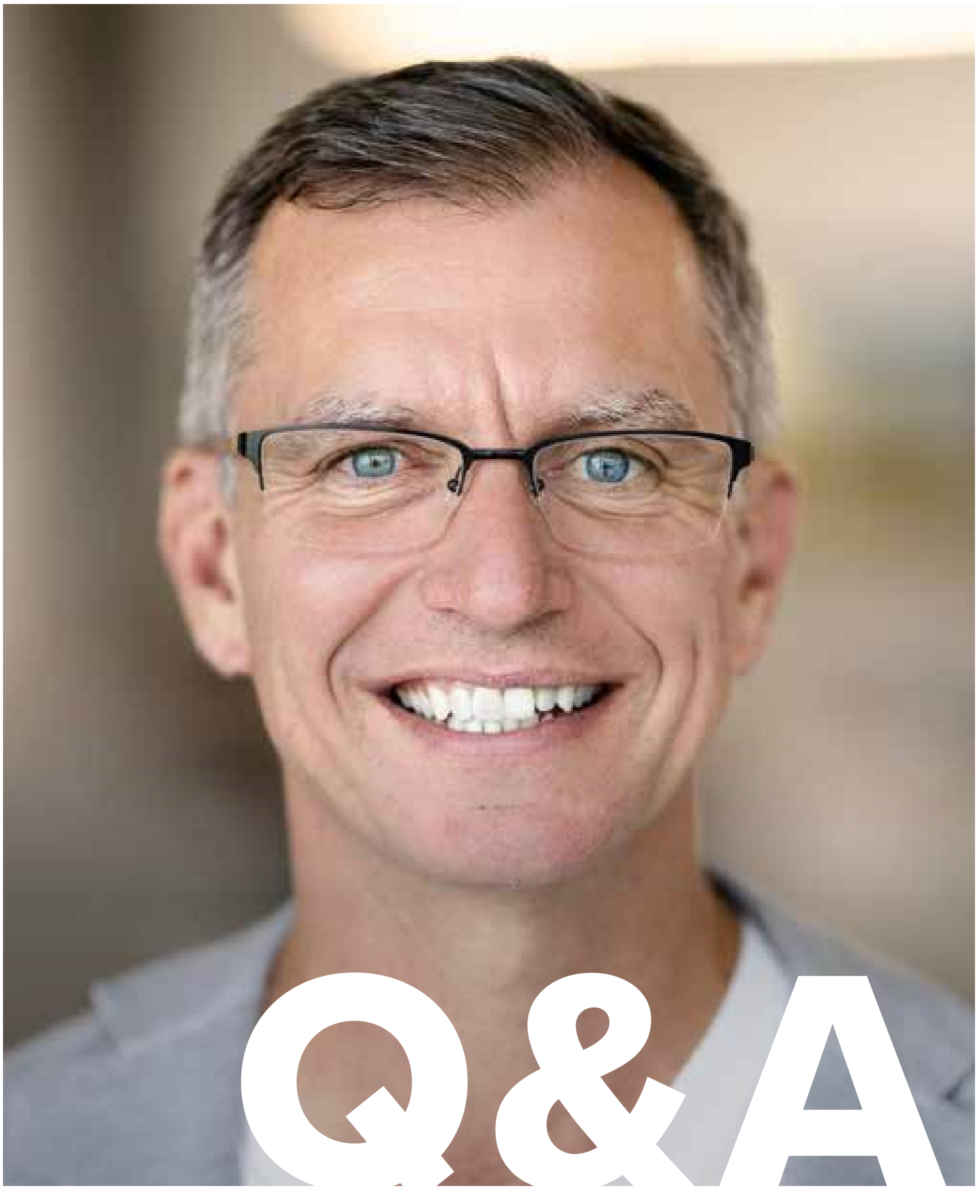
Mendez says the technique correctly predicted where specific spots of corrosion would occur around the fuel access doors in the wings of U.S. Air Force C-17 cargo planes. The rate of corrosion, measured in microns per year, can be translated into a standardized scale of 1 to 5 — 5 for the worst corrosion potential. This month, Corrdesa plans to demonstrate the technique for the Air Force at Wright-Patterson Air Force Base in Ohio.

Next, Corrdesa believes that if airplane designers incorporate the technique, they could adjust their geometries and choices of materials to head off expensive maintenance issues. Just as plane manufacturers have teams that design the plane's aerodynamic shape and its cooling and electrical systems, Mendez expects they'll soon employ an electrochemistry team to target corrosion. "That's what we think the future will look like."

With the "corrosion toolset," as Mendez calls it, such a team could load in specific geometries and materials, and the toolset will spit out a prediction. ★

FACT

Corrdesa's name is short for "corrosion-resistant design by environmental stress analysis."



Stratospheric tourism visionary

World View's stratospheric balloons are already in the history books, one of them having hoisted former Google executive Alan Eustace to an altitude of 41 kilometers for his record-breaking skydive in 2014. Now, CEO Ryan Hartman and his team are closing in on a loftier goal: regular passenger flights to the stratosphere via those same balloons starting in 2024. They have raised $120 million to fund test flights with eight-passenger capsules starting later this year. The company is racing against Florida-based Space Perspective, a stratospheric balloon venture focused entirely on tourist flights that was founded in 2018 by two former World View executives. To set itself apart, World View plans to make its six- to eight-hour balloon flights part of a multiday experience in which passengers would spend several days touring famous sites, including the Grand Canyon, before boarding their balloons for aerial views of these natural wonders. I called Hartman in his Arizona office to discuss the road to that first passenger flight. — *Paul Brinkmann*

RYAN HARTMAN

POSITIONS: Since 2019, president and CEO of World View. Since 2016, a member of FAA's NextGen Advisory Committee and Drone Advisory Committee that advise the agency on ongoing modernization of the U.S. air traffic system and how to integrate new aircraft, including drones. 2014-2018, president and CEO of Insitu, Boeing's Bingen, Washington, subsidiary that builds drones primarily for the U.S. military. 2002-2010, director and program manager at Raytheon, where he led the Unmanned Systems Directorate. 1999-2002, program manager at Raytheon Network Centric Systems, the company's communications security division. 1996-2002, naval aviator in the U.S. Navy. 1991-1994, airman in the U.S. Air Force.

NOTABLE: Has led World View to the sale of 1,200 advance tickets for its stratospheric balloon rides. Also under his leadership, the company has launched dozens of uncrewed balloons with research equipment aboard and kept one balloon aloft for 32 days. At Raytheon, oversaw development and production of the catapult-launched KillerBee drones instrumental in the U.S. Army's early development and testing of drone swarms.

AGE: 48

RESIDES: Tucson, Arizona

EDUCATION: Bachelor of Science in aerospace engineering and technical management, Embry-Riddle Aeronautical University, 2009.

World View says tickets are already sold out for 2024, the year the company plans to begin passenger flights in its Explorer capsule, shown here in an illustration. Test articles are scheduled to begin undergoing tests this year, along with the parafoils that would steer the capsule back to Earth after the high-altitude flights.

World View

IN HIS WORDS

The benefits of balloon flight

Our approach is to not sell something that is a thrill but to sell something that is truly a life-changing experience. We exist to inspire, create and explore new perspectives for a radically improved future. And the seven launch locations we are planning to build spaceports near, the seven wonders, were chosen for that purpose: the Grand Canyon, the Great Barrier Reef, the Giza pyramids, the Serengeti, the Amazon jungle, the aurora borealis in northern Norway and the Great Wall of China. So these are places where people can truly immerse themselves in the beauty of an area — the fragility and history of an area — before they spend time above it. So the time on the ground is important, and then time aloft viewing these places means so much more. So, yes, it's a slow ascent into the stratosphere versus a 6G rocket ride. Ultimately, that also means we can open this up to a broader set of passengers with physical abilities and age groups.

Choosing the launch sites

It started with listening to astronauts explain their experience with the overview effect. *He means the term coined by space philosopher and author Frank White in a 1987 book of the same name to describe the powerful shifts in perspective astronauts experience when they view Earth from space, especially because there are no national borders visible. — PB* One of the things that I heard repeatedly, as we were designing our space tourism solution, was that oftentimes for an astronaut the overview effect was triggered when they saw something they recognized, something they had seen or experienced up close. So that got us thinking about how we could deliver that kind of experience to the public. It became clear that we shouldn't limit ourselves to one place.

"We are seeing some people recognizing that this can be a yearly vacation because of the many sites we are launching from, so they can come to a different site next year."

The World View experience

Each flight has eight customer seats with two crew: a pilot and concierge. We offer this as a five-day experience, and each location will have a hotel, restaurant, virtual reality experience and local tours. The flight itself will launch before sunrise, which will give the passengers or customers the opportunity to view sunrise from the stratosphere. So you're seeing the sunrise against the backdrop of space, emerging from the dark behind the sun, which will be a very unique experience. Once they reach an apogee of about 100,000 feet

▲ World View designed its hexagonal capsule, shown here in an illustration, so that each of the eight passenger seats would face a window.

World View

[30 kilometers], then they'll be guided through the experience, meaning the pilot on board will be helping them understand what they're seeing. Each trip will be six to eight hours, and as long as 10, depending on weather conditions during flight or in the landing zone. We have hospitality experience on our leadership team with Dale Hipsh, our president, who formerly was a senior vice president with Hard Rock International. Passenger training will be more like an orientation, and it's really for them to understand the experience that they're going to have. At our first location, the Grand Canyon, we have identified a site for our Spaceport Grand Canyon in Page, Arizona. We have designs for a hotel and restaurant and are in the process of finalizing those designs and working through the permitting processes.

Passenger prerequisites

Right now, that's governed by FAA Part 460, Human Spaceflight Requirements. *Part 460's requirements include that passengers must be at least 18 years old, sign a waiver before flying and must be trained in emergency procedures. — PB* But I'm bothered by the idea that somebody who has a physical disability is locked out of space tourism. This is a solution that, all of a sudden, makes it possible. The nice thing about this industry, commercial spaceflight as a whole, is that we are all pulling in the same direction to ensure progress toward democratizing space tourism as a whole.

"Diverse" group of early travelers

We don't have plans finalized for our first crew, but we will work with the nonprofit Space for Humanity, whose mission is to expand access to space for all of humanity. We're approaching about 1,200 tickets sold. It's a very diverse group of people. There are space enthusiasts, and that's where we see younger folks buying reservations. And then we're seeing luxury travelers, those who like to find unique vacations or events. And then the other group of people are just the adventure travelers, maybe a 30- to 40-year-old couple that spends a lot of time traveling. So it's a broad spectrum of demographics that are purchasing tickets. We are seeing some people recognizing that this can be a yearly vacation because of the many sites we are launching from, so they can come to a different site next year.

Helium over hydrogen

A helium-filled balloon is simply the safest way to do this. We've done a lot of studies on the amount of helium we will need and the combustibility of other gases, and the reality is no matter how you try and spin it, hydrogen is still a combustible gas. The probability of an incident with hydrogen can't be said to be zero, but with helium there really is 0% chance of any combustibility or issues with the lift gas. It's true that helium is a finite gas, which is mined or extracted through radioactive decay of certain elements, but over a 10-year period we'll

▲ World View plans to open a handful of spaceports around the world near scenic attractions that include the Grand Canyon in the U.S. and the Great Barrier Reef in Australia. Passengers would spend a few days taking tours of the area, then board their Explorer Space capsule for a six-to eight-hour balloon ride at an altitude of about 30 kilometers.

World View

use less than 3% of the global supply of helium. We'll have a disciplined, deliberate approach and long-term contracts for the mining of helium. If there was a helium shortage, as there is sometimes, there's always a prioritization of needs such as medical uses, and we would subject to that.

Keeping a human in the loop

Most people familiar with skydiving these days understand the use of a parafoil, an inflatable parachute shaped like a wing that gives you some steering ability when landing. Our balloons will have a parafoil to enable use to choose a landing site. For example, Spaceport Grand Canyon will have six landing sites. Parafoil technology has been proven, so really the challenge is working through our program in designing and iterating things to a standard that is far beyond what is expected of us. We're adopting design standards for the parafoil that go above and beyond what is required of us. There will also be a backup parafoil in the event the first fails. The crew is there for customer convenience. So, the pilot is there to attend to the system itself and for passenger and crew safety, and the concierge is there to support the pilot but also to support the needs of the passengers: serving customers a light meal, serving drinks and cocktails, and just keeping them comfortable.

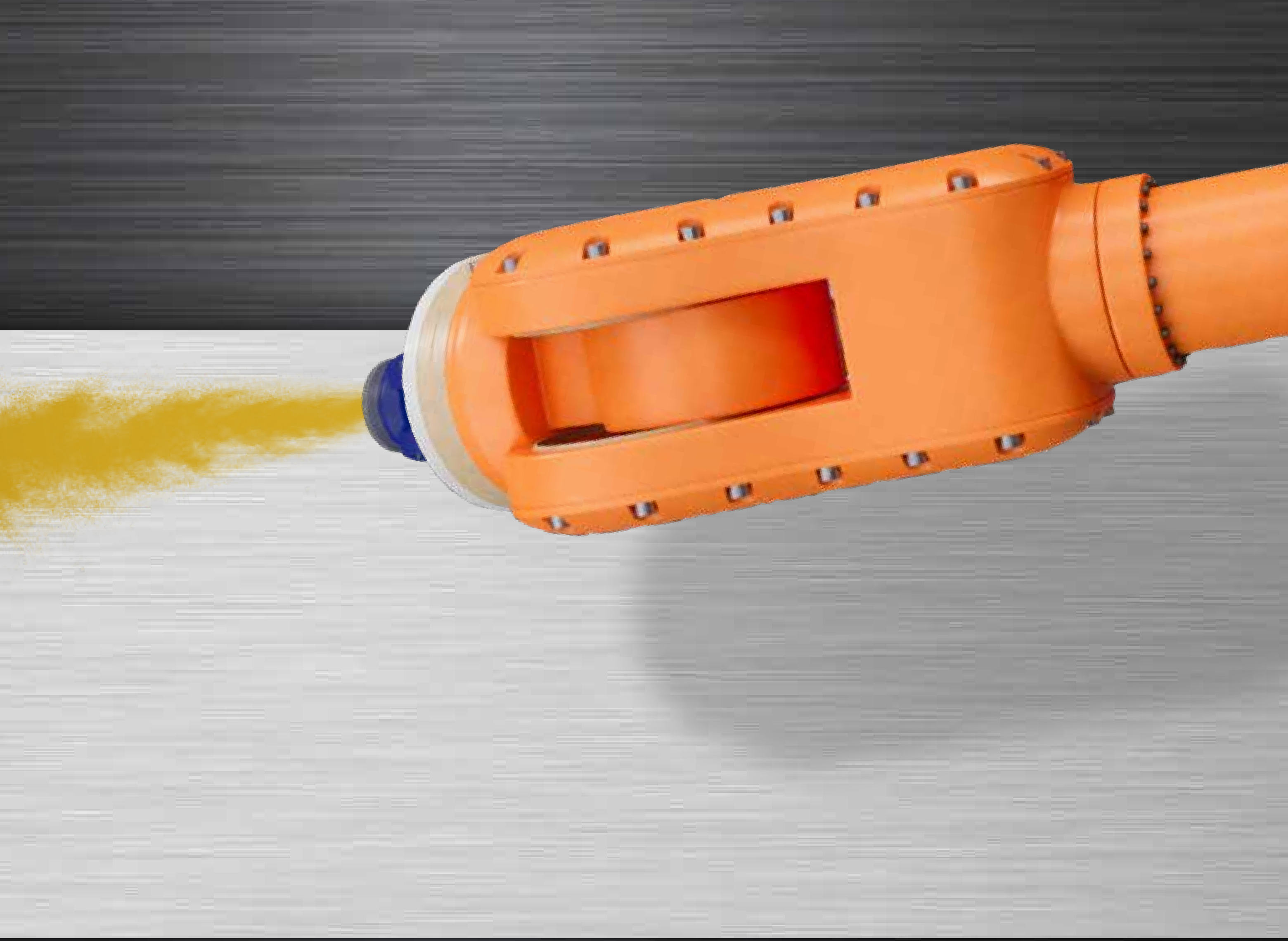
Coming soon: test flights

We are nearly through preliminary design and are entering critical design. And so we'll start cutting metal on prototypes of the initial flight asset early to middle of next year. We will test fly a full-size mass simulator with a full-size balloon, planned this year. The balloons are the exact same material and design that we use in our existing business for remote sensing balloons — our own blend of polyethylene — only much bigger. Remote sensing balloons are 4.5 million cubic feet [127,425 cubic meters], while the passenger flight balloon will be nearly four times larger at 17.5 million cubic feet [495,500 cubic meters]. The pressure vessel for the capsule will be carbon composite with external fairings, likely with a titanium structure to hold the capsule under the balloon. Testing starts with the full-mass simulator tests that we'll do later this year. Another series of tests will be done to further validate the parafoil technology. And then there's a series of tests to validate the capsule itself — pressurization tests, emergency procedures and so on. Then we'll enter into a flight test program where the capsule is instrumented, but without humans on board, to validate the environmental control and life support system, the pressurization, launch loads. And then we'll go into a fully integrated test, where we're testing the proposed production balloon sets, the proposed production parafoil sets, the proposed production capsule with humans on board. We'll go through all of that a number of times before we declare the system suitable for commercial operations. ★

APPLYING THERMAL PROTECTION "GOO" ROBOTICALLY

It's one thing to manufacture a few experimental hypersonic missiles. It's quite another to manufacture hundreds or more production versions. Automation has to come into play if it's to be done affordably. Keith Button tells the story of a company that figured out how to apply thermal protection material by robot.

BY KEITH BUTTON | buttonkeith@gmail.com



How do you get a robot to precisely spray a gloppy, oatmeal-like coating onto a part for a hypersonic missile before the mixture hardens into a concrete-like substance?

That was the problem facing engineers at Alabama-based robotics developer Aerobotix four years ago. Lockheed Martin, one of the company's long-standing customers, was relying on workers toting high-pressure spray guns to apply the material onto test versions of its hypersonic missiles. Lockheed Martin asked Aerobotix to automate the process, so it would be ready should a production order for hypersonic missiles come down from one of the military services. Then as now, the United States was anxious to research, develop and possibly field such weapons in its competition against China and Russia.

Lockheed Martin is but one example of the desire for automation. "The U.S. is right in the middle of that process of handing over things that have been done manually," says Iain Boyd, director of the Center for National Security Initiatives at the University of Colorado Boulder.

So far, contractors to the U.S. military services have focused on testing and developing the missiles.

"It's eight or 16 or 32; it's tens," Boyd says. "It's a big step to go from there to thinking about manufacturing hundreds or thousands of these things."

The work by Aerobotix illustrates the kinds of challenges that manufacturers are facing and the creative innovations that engineers must make to meet manufacturability goals.

The scope of the automation challenge was obvious from the start of the project in 2018. "I thought it was going to be quite difficult," concedes Mark Breloff of Minteq International, the Pennsylvania company that

▲ The robot arms modified by Aerobotix to spray thermal protectant on hypersonic missiles were derived from versions that apply paint and other coatings to aircraft, including the F-35, shown here at Lockheed Martin's Fort Worth, Texas, facility.

Aerobotix

makes the gloppy but essential coating. "It comes out in mixed consistencies and therefore doesn't land very smoothly."

Conventional wisdom said that only a human would have the finesse to evenly apply the coating and know when to pause the spraying because the nozzle was starting to clog. This material was unlike those that Aerobotix robots had applied to F-22s, F/A-18s and F-35s: It contained large particles suspended in the liquid, the material was known to clump in humid conditions and it had to be heated to lower its viscosity. Plus, it had to be mixed up from two components, a catalyst and a resin, for immediate spraying into a plume shaped like a semicircle hand fan. The application had to be correct for the coating to perform its crucial role of ablating, or wearing down, to carry heat from the outer surfaces of a missile slicing through the air at speeds of Mach 5 or greater.

At Aerobotix, step one for Keith Pfeifer, the engineer in charge of the project, was to travel with his team of 15 engineers and technicians to Wisconsin to watch a worker with Quality Paint & Coatings apply the Minteq coating for Lockheed Martin. Wearing a full hazmat suit, the worker held a pressurized spray gun attached to a 9-meter hose filled with the catalyst-resin mixture. As he sprayed, he carefully watched the material begin to cover the nose cone of a prototype missile. He would slow his pace now and then to give the mixture time to heat up, and pause when he saw buildup on the nozzle tip.

"The tricky part that we all saw was the decisions the operator was having to make based on how the material spread, or what he was seeing," Pfeifer says. "In real time, he's able to make a decision like: 'Oh, the plume doesn't look right; I need to do this to clean my gun.'"

When the spray gun is functioning properly, its spray plume should look like a triangle from the side; a lopsided plume means that the coating application will be uneven.

The plan

After returning from Wisconsin, Pfeifer's team members sat down to plan their approach. They were familiar with an off-the-shelf manufacturing robot made by Fanuc, a robotics company in Japan, that was popular as a spot welder. Aerobotix had installed at least 100 Fanuc robots for painting or sanding work for various customers. So they decided to adapt one of the armlike machines to mimic the Quality Paints setup.

At the end of the robot's arm, they bolted on a high-pressure spray gun like the one the worker in

"We needed to know more than 'Hey, the pump is running.' We needed to know exactly how fast it was running and how much material was exiting that pump."

— Keith Pfeifer, Aerobotix

Wisconsin wielded. But unlike in Wisconsin, they decided to keep the catalyst and resin separate for as long as possible. This would make the mixture less prone to curing too soon. So they strung two separate stainless steel braided hoses — strong enough to withstand high pressures — over the arm and joints of the robot. The resin and catalyst would flow in separate hoses and meet in a single hose a short distance from the gun.

Another crucial difference: They knew that the robot, unlike a human, wouldn't be capable of watching the spray pattern and adjusting in real time. They would need to find a different way. Inspiration came from the pressure sensors that in a more straightforward robot sprayer would alert the device's operating software of any irregularities in the flow of paint. On a typical robot spray system, they would install a pressure sensor at the pot — where the material to be sprayed is mixed — and a pressure sensor in the line after a pump pushes the material out of the pot toward the spray gun.

"We needed to know more than 'Hey, the pump is running.' We needed to know exactly how fast it was running and how much material was exiting that pump," Pfeifer says.

For example, if one of the pumps was pushing too much of its component into the coating mixture, then the ratio would be unbalanced and the coating would cure too quickly or not fast enough. So the team installed pressure sensors at the spray gun and in the two pots that each held a component of the coating. They also installed thermocouples to measure the temperature of both components after they were heated and at the spray gun. If the team could find the right temperature and pressure at which to spray the coating, then they could program the robot to maintain those levels and adjust accordingly.

After watching the human operator, they also realized that every delivery of the coating components from Minteq needed to have the same consistency before it was loaded into the pots, with little or no variations in viscosity. The robot wouldn't see changes in viscosity due to variations from delivery to delivery, and it wouldn't be able to adjust its approach like a human could. So they spoke with Minteq and were assured they would receive consistent batches.

Test runs

Once the team had set up the robot with high-pressure spraying equipment similar to what the human operator employed, they pumped the coating material through the gun without an air cap — the component that adds air to the spray and shapes the plume — just to determine the right nozzle size at which the

▲ Aerobotix could not share any photos of the thermal coating tests due to a nondisclosure agreement, but the company is no stranger to robotically applied coatings. Here, a Fanuc robot sprays topcoat on panels attached to an aircraft nose cone.

Aerobotix

material could flow through without having to exert extreme pressure, Pfeifer says. Then they added the air cap and started spraying samples on flat panels of aluminum.

They were searching for the right combination of conditions that would produce a perfectly shaped layer: an extremely flattened bell curve, when seen in a cutaway view from the side. It would be thicker in the middle and tapering off at the edges. That meant accounting for the temperature and pressure of the spray material, the air applied in the spray gun, distance from the surface and speed at which the gun passed over the surface.

If a sample didn't have the bell curve pattern, the team could adjust the pressure for one or both of the types of air delivered through the spray gun: fan air, which creates the semicircular fan pattern of the plume, and atomizing air, which atomizes the coating material as it comes out of the gun. If, for example, a coating sample was thin in the middle and thick at the edges, that could mean that the spray had too much fan air that blew the coating to the edges of the spray plume. If the coating was splotchy on the sample, that indicated bigger droplet sizes, possibly from the atomizing air not breaking up the coating material well enough. If the coating was too dry on the surface or drying before it hit the surface, then the spray probably had too much atomizing air.

To measure the coating thickness — and tell if they had achieved that bell curve — the team employed blue light and white light scanners, which project a pattern on the surface to be measured and then take a digital image of the pattern, calculating an elevation map of the surface accurate to within less than 25 micrometers. They would image the surface before and after spraying it and calculate the elevation differences to project the side view sprayed coating pattern.

Through the spray experiments, the team discovered that the high-pressure spray approach was inefficient — very little was making it to the surface, Pfeifer says. At 1,200 pounds per square inch, a large volume of coating material came out of the gun quickly, creating a plume about 1 meter wide from a distance of 1 meter from the surface. The result was that very little of the material would reach the surface, especially if that surface was narrow or cylinder shaped.

"It's just going into the atmosphere and you're just sweeping it up," he says.

Making adjustments

So they adjusted the setup to spray from a closer distance, under a lower pressure — 300 psi. To keep the coating material flowing through the gun at the lower pressure, they increased the temperature to 54 degrees Celsius from 32 degrees. They installed shear mixers, with blades designed to cut up the

large particles in the coating mixtures as they flow from their mixing pots to the spray gun.

To fight blockages, they added logic to the robot's software that would very quickly turn the spray gun trigger off and on whenever it detected a pressure spike. Because the spray gun is the smallest orifice in the system, it would most likely be the location of a blockage. Toggling the trigger would cause a needle in the nozzle to rapidly push into the orifice and then draw back, quickly unblocking the passage without affecting the spray results.

Once the team had adjusted the robot setup to produce bell curve-worthy sprays on flat, horizontal panels, they experimented with vertical panels and with spraying onto a horizontal surface from below to make sure the sprayed coating would adhere and not slide off.

With the setup and settings figured out for producing a reliably consistent bell curve spray pattern, they could direct the robot to spray at the correct step distance — the distance that the spray gun is moved over for subsequent passes. This technique makes the bell curve-shaped deposits from consecutive passes overlap to create a uniform coating depth across the entire surface.

So far, Lockheed Martin has two of the robots operating in Courtland, Alabama, and the setups will be replicated if the company ramps up for large-scale manufacturing, Pfeifer says. In the meantime, Aerobotix is adapting its solution for another customer: The company announced in June that it will share its robotic coating techniques with Automated Solutions Australia as allowed by a 2021 U.S.-Australia hypersonics research pact. Pfeifer says those robots will also be built from off-the-shelf components, with similar challenges to the Lockheed Martin project.

The team had a humbling moment after one of its first attempts at spraying a part for Lockheed Martin. Initially, the spray was a success, and the team members were high-fiving and congratulating one another. A few days later, Pfeifer says, he received an email from Lockheed Martin with photos showing the coating peeling away from the part surface.

"You think, 'Oh, man, how much of this do we have to start over, and what do we have to look at again?'" he says. "'What did we mess up, or what did we miss?' It takes your confidence away pretty quick."

All of the test results and settings for the tested setups were stored in a database, so the Aerobotix team and Lockheed Martin were able to figure out the problem in about a week: They had underestimated how precisely they needed to get the ratio of the two components of the coating mixture. The ratio was off, and the coating hadn't cured properly.

"That's one moment that kind of sticks with me," Pfeifer says. "Everyone was doing their own soul-searching." ★

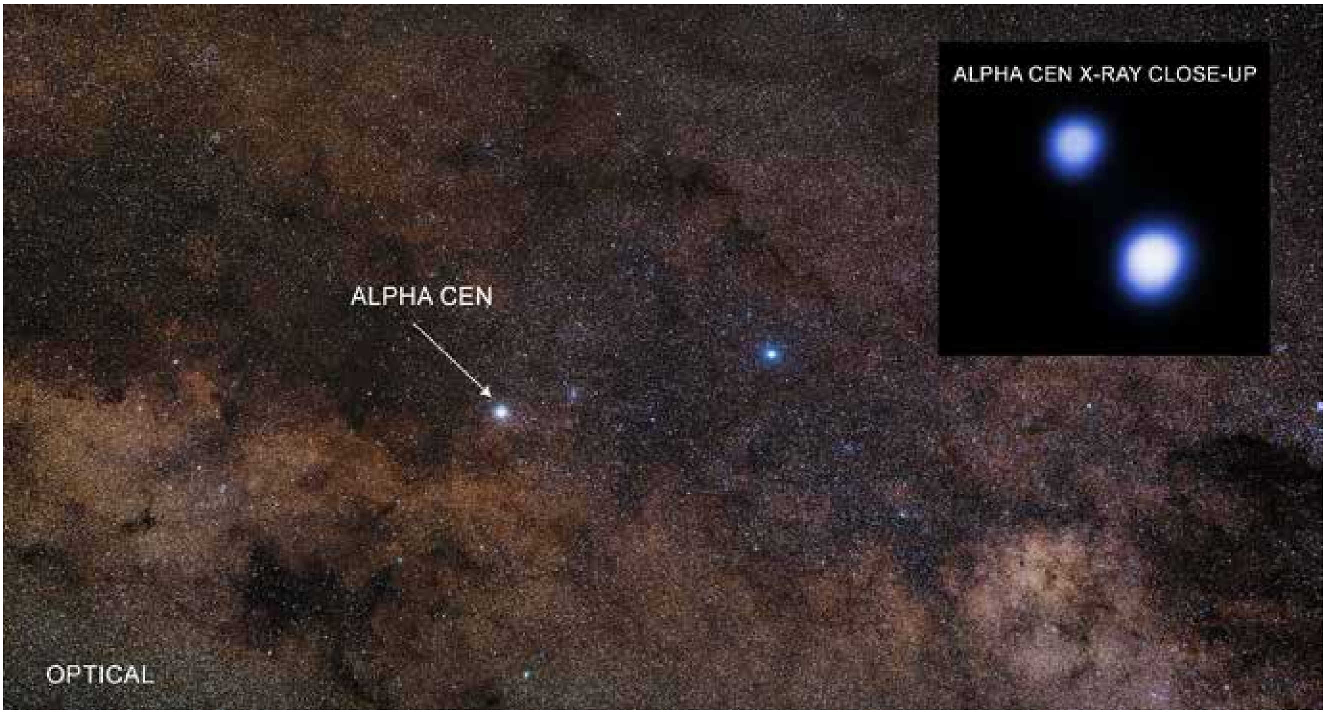
▲ Aerobotix's central challenge was that a robot sprayer would be unable to automatically adjust its sprayer nozzle and technique as it applied the thermal coating, unlike the Aerobotix worker shown here manually spaying paint primer onto an aircraft wing mold.

Aerobotix

NASA's next (next) telescope

NASA is starting to put together plans for a telescope that would launch in the 2040s to image Earth-like exoplanets and, perhaps, finally discover whether advanced life exists elsewhere. Jonathan O'Callaghan spoke to project scientists to learn how the work is unfolding.

BY JONATHAN O'CALLAGHAN | jonathan.d.ocallaghan@gmail.com



▲ The Alpha Centauri star system is just 4.35 light years away from Earth, making it an attractive place to begin the hunt for Earth-like planets. This 2017 image from NASA's Chandra X-ray Observatory shows the system's A and B pair that orbit relatively close to each other.

Zdenek Bardon, NASA/Chandra X-ray Center/University of Colorado

The James Webb Space Telescope wasn't conceived specifically to study exoplanets. Yet this magnificent machine, launched in December, has already begun delivering tantalizing spectral readings about a handful of such worlds.

Specifically, Webb has collected infrared light from TRAPPIST-1, a solar system in our galaxy consisting of seven Earth-sized worlds orbiting a red dwarf. If those planets have atmospheres, some of the light from the red dwarf must have passed through, and the spectral details of that light could tell scientists what their atmospheres consist of. As exciting as this feat would be, what scientists want most of all is to identify possible Earth-sized worlds in the habitable zones around suns like ours, analyze their atmospheres and image them. Webb is unlikely to be of help there. Its transit spectroscopy technique isn't optimal for analyzing the atmospheres of planets like ours, because we take so long to orbit around our suns. If a suspected Earth-like planet were found, imaging it would require blocking enough light from the host star so that the planet would suddenly become visible, and then enough photons would need to be eked out to create an image. Webb does have an internal coronagraph of masks and mirrors for blocking light, but they probably lack the fidelity to filter out a planet like ours from the light of its sun. In fact, engineers have yet to figure out how to make masks and mirrors of the precise shape and smoothness to guarantee the necessary contrast.

Which is not to say direct imaging will prove to be impossible. After its launch in 2026, the Nancy Grace Roman Space Telescope will point its 2.4-meter-diameter mirror to the stars in hopes of gathering direct images of gas giants. But even Roman won't block enough light to image Earth-like planets.

A newer, more refined machine would be required for that, and early discussions are underway among NASA managers and exoplanet scientists about the requirements for it. If this telescope is orbited in the 2040s as proposed, "we as a human species will be able to answer whether we're alone in the universe," says Ruslan Belikov, an exoplanet scientist at NASA's Ames Research Center in California. "It boggles my mind that, in our lifetimes, we could have the capability of finding life on planets orbiting other stars."

The telescope would be a combination of two proposals to study potentially habitable worlds, the Habitable Exoplanet Observatory, or HabEx, and the Large Ultraviolet Optical Infrared Surveyor, or LUVOIR. The concept was embraced in the Astro2020 Decadal Survey on Astronomy and Astrophysics, the latest in the reports issued every 10 years by the U.S. National Academies of Sciences, Engineering and Medicine. A steering committee of scientists recommended that NASA create a single telescope nicknamed LUVEx (pronounced "loov-ex"), a combination of LUVOIR and HabEx (Some also refer to the telescope as IROUV, pronounced "eye-roov," a reference to its observations in infrared, optical and ultraviolet light).

With a 6-meter-diameter mirror, LUVex should be capable of imaging about 25 Earth-like worlds, the decadal survey suggests.

"With 25, we should be able to say something statistically significant about the prevalence of potentially habitable planets, and maybe even inhabited planets," says Evgenya Shkolnik, an exoplanet scientist at Arizona State University.

Now one year on from Astro2020, the finer details of this proposed new telescope are being set forth by NASA. Plans call for its development to be incorporated into the agency's Great Observatories Maturation Program, a three-stage process that will see this machine gradually take shape over the coming years, with the first stage deciding exactly what science the telescope should do and how it should do it. That's the stage the telescope is at now, and in a fact a formal LUVEx team has yet to be established.

In April, 100 scientists met in an online workshop hosted by NASA to discuss some of the precursor science that might be necessary before development of this telescope begins. NASA plans to put out a call in early 2023 for ideas for those precursor investigations. Those could include finding the worlds for the telescope to observe prior to launch, perhaps by spotting the gravitational tug of these worlds on their host stars, a process known as radial velocity. Currently this technique lacks the accuracy required to find such worlds, so new ideas will need to be put forward about how it could be done.

"We don't have confirmed Earth-like planets around sunlike stars yet," says Eric Smith, the chief scientist in NASA's Astrophysics Division at Goddard Space Flight Center in Maryland. "Part of our work in the next couple of years is to assess if 25 is an achievable number."

While LUVEx could in theory do the hunting itself, preferable would be having predetermined targets.

"Time on the telescope is precious," says Smith. "We want to know which exoplanets we need to look at."

Also, identifying targets early would provide time to tailor the telescope's blueprint to meet the scientific needs.

"If we find there aren't that many [targets] that are close, we need a bigger mirror," says Smith.

The nature of the telescope's large primary mirror is also yet to be decided, whether it will be a single monolithic design like Roman or segmented into pieces like the now-proven Webb. A monolithic design would be less complex and could fit inside two much larger rockets currently in development: SpaceX's Starship and the planned larger Block 1B variant of NASA's Space Launch System.

Also being considered is how the telescope will block light from a host star to image rocky planets orbiting in the star's habitable zone, the distance at which temperatures are just right for liquid water and, thus, for life to exist. Precisely positioning a free-flying starshade at least tens of thousands of kilometers ahead of the telescope's aperture to block the starlight is one option, or installing a coronagraph instrument on the telescope itself.

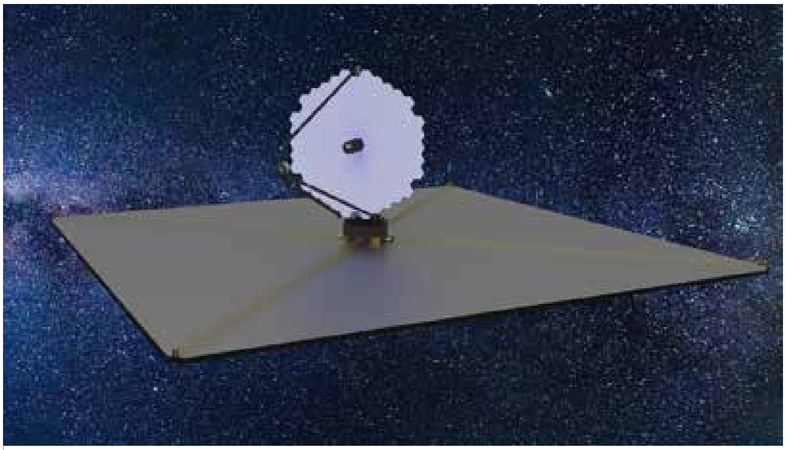
"We have not made any design decisions," says Scott Gaudi at Ohio State University, the lead on the HabEx proposal that was one of four concepts NASA submitted to the National Academies for consideration in Astro2020. "The decadal survey was intentionally vague about this architecture."

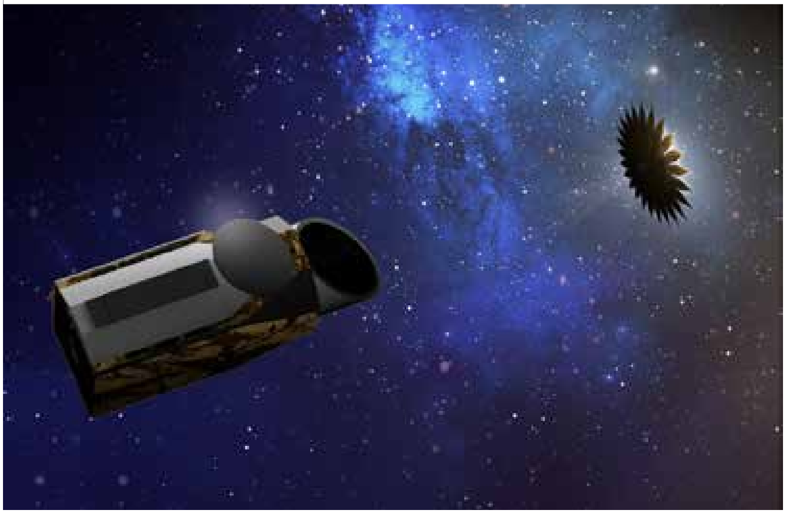
Belikov of NASA Ames says the light-blocking techniques could be particularly useful in studying any Earth-like planets in the place he'd like to study first: the binary star system of Alpha Centauri A and B. In cosmic terms, this pair — two of three stars in the Alpha Centauri system — is our closest neighbor at just 4.35 light years away, affording a potentially stunning view.

"If you can make an instrument that can handle the binarity, then Alpha Centauri would be by far the best target for this mission," says Belikov. "It's the nearest sunlike star by far. The next is two and a half times farther away. It's the cherry on the cake."

Also, "this telescope will be amazing for nonexoplanet science," says Gaudi. That could include magnificent views of galaxies, nebulas and more.

"Basically, you have the same wavelength range as Hubble but two and a half times the diameter," says





▲ NASA's exoplanet telescope will be a combination of two proposals submitted for the Astro2020 Decadal Survey. One of the concepts for the Large Ultraviolet Optical Infared Surveyor (top) proposed a segmented 15-meter-diameter mirror to maximize the number of photons it could soak up from faint exoplanets, while the Habitable Exoplanet Observatory concept paired a 4-meter-diameter monolithic mirror with an external starshade to block the blinding light from those exoplanets' host stars.

LUVOIR via NASA GSFC
HabEx via Scott Gaudi, Ohio State University

▲ NASA had to design the James Webb Space Telescope's 6.5-meter-diameter primary mirror to fold into three segments to fit into the 5.4-meter payload fairing of its Ariane 5 rocket, shown here at the French Guiana spaceport in South America about a week before the December launch. If the agency chooses a monolithic design for LUVEx's 6-meter-diameter primary mirror, a larger rocket such as SpaceX's Starship or future variant of NASA's Space Launch System would be required.

ESA/CNES/Arianespace

"Time on the telescope is precious. We want to know which exoplanets we need to look at."

— Eric Smith, NASA's Goddard Space Flight Center

Gaudi. "It would be similar images to JWST but in optical, ultraviolet and near-infrared bands."

Bruce Macintosh at Stanford University, an exoplanet scientist and part of the steering committee for Astro2020, says by not strictly defining the goals of the telescope outside of imaging Earth-like planets, it "leaves a lot of room to think about defining science capabilities and architecture."

The ultimate goal, though, remains imaging Earth-sized planets around sunlike stars."JWST, beautiful though it is, can't access those," says Macintosh.

Key will be avoiding the schedule delays and budget overruns that beset Webb, a project that was initially earmarked for a launch in 2007 at a cost of $1 billion, rather than the $10 billion cost at launch in 2021.

"We need to find a way to manage these megaprojects better," says Shkolnik.

A 2020 NASA study that wrapped up shortly before the decadal was released, the "Large Mission Study Report," suggested that such missions "require greater priority, resources, and attention during the pre-formulation period," an approach seemingly now being adopted with LUVEx.

Scientists might well find evidence of microbial or simple lifeforms in our solar system before LUVEx launches, such as in the oceans of icy moons or perhaps on the surface of Mars. But to find a planet like ours that's rich with potentially advanced lifeforms, "this is the only way to do it," says Macintosh.

For now, the focus is very much on Webb, and soon Roman, whose coronagraph will demonstrate the basic techniques needed to image Earth-like worlds.

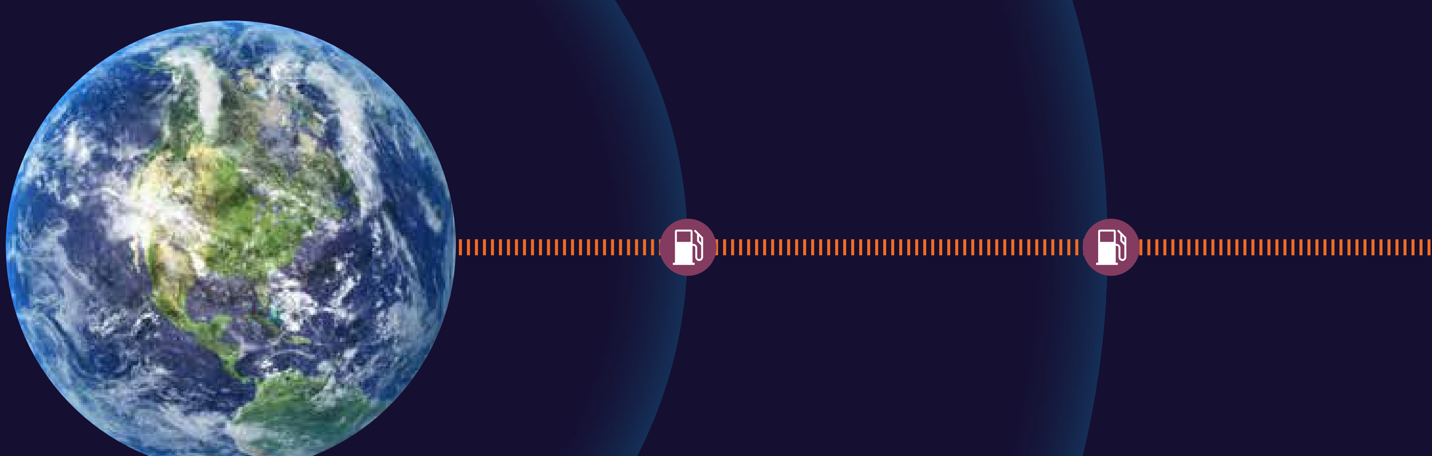
"I would not anticipate hardware development [of LUVEx] until after the Roman Space Telescope has launched in 2026," says Smith. But putting the work in now, with realistic goals and targets, might just be the key to seeing this fantastic machine getting off the ground in a reasonable time frame at an affordable cost.

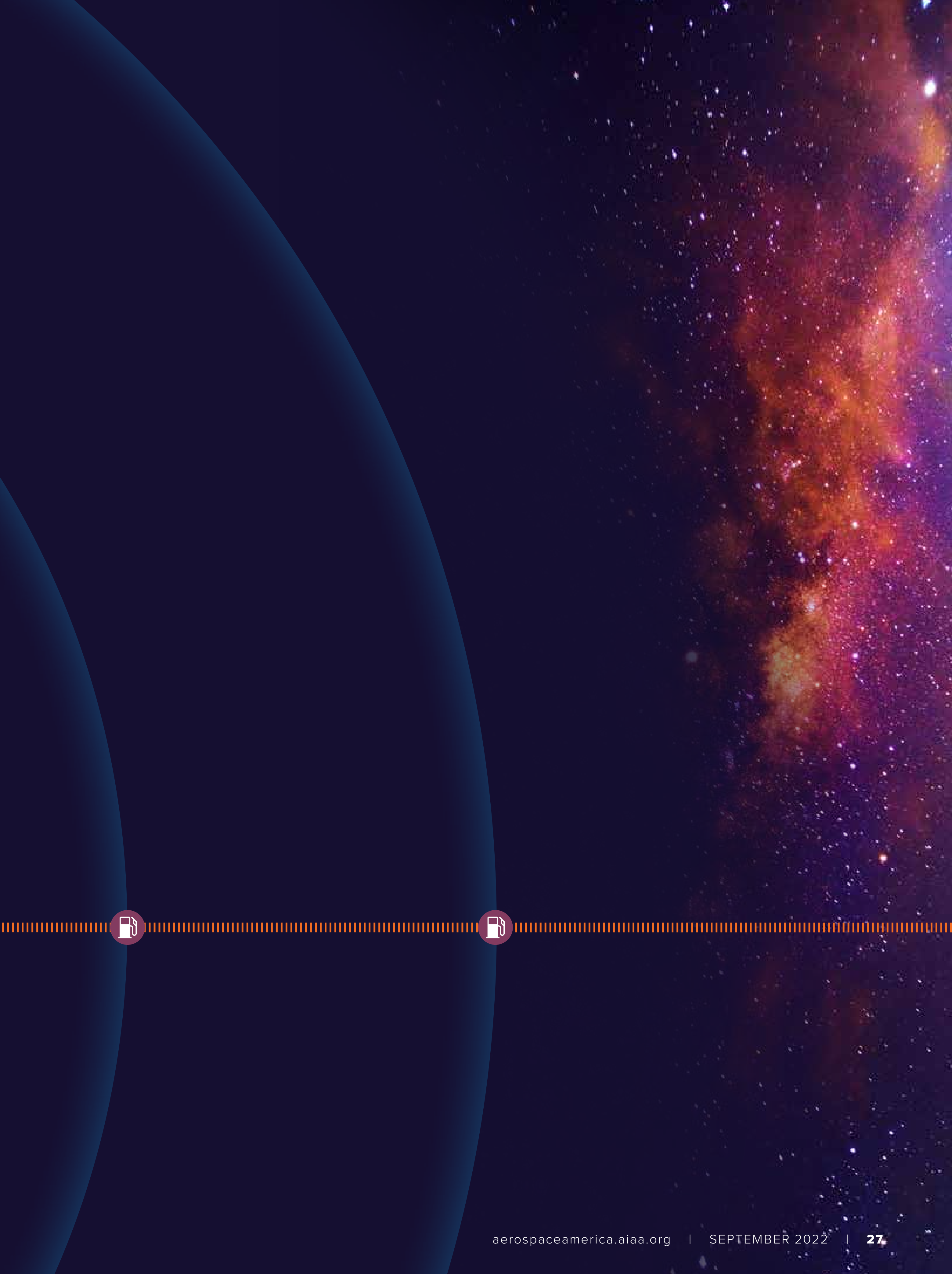
And of course, perhaps for the first time in history, answering if we are alone in the cosmos. ★

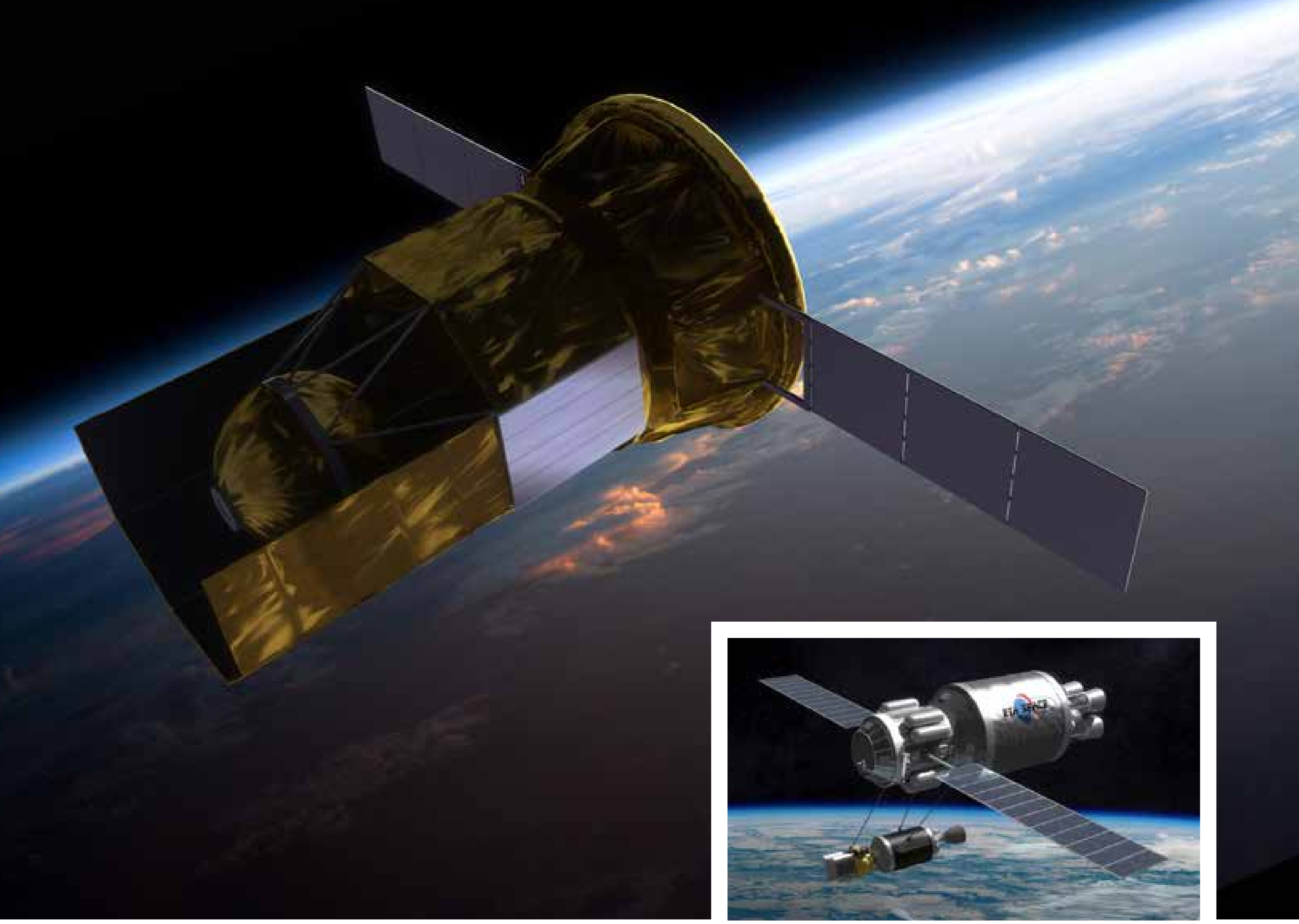
Fill 'er up

The push to expand Earth's economy into space has prompted NASA to pump millions of dollars into the old idea of establishing propellant depots in Earth orbit for satellites or passenger transports and cargo tugs headed for deep space. Jon Kelvey looks at the reasons for the renewed interest — and the hurdles ahead.

BY JON KELVEY | jonkelvey@gmail.com







▲ Eta Space plans to launch its LOXSAT demonstrator satellite in 2024 to test cryogenic fluid management in space. If all goes as planned, that demonstration will prepare Eta for a 2025 launch of its first depot (inset). Named Cryo-Dock, this cylindrical depot would rendezvous with various spacecraft to refill their propellant tanks.

Eta Space

William Notardonato is an expert in the cold: minus 252.87 degrees Celsius cold, to be exact. A 30-year veteran of NASA, Notardonato spent his career investigating in-space storage and handling of liquid hydrogen. Combined with liquid oxygen, these cryogenics are of course best known as common propellants for space launch vehicles, but if large volumes of them could be stored in tanks in space, rockets could swing by these depots in the vicinity of Earth, take on propellant and carry passengers and cargo into deep space, whether to the moon, Mars, an asteroid or a human outpost.

"We ended up doing a lot of things with liquid hydrogen [in the lab] that nobody's ever done before," Notardonato says. "Keeping it in a zero-loss storage condition, doing zero-loss chill downs, no vent transfers."

One thing he didn't do? A space experiment to verify that these techniques work as expected in free fall, also known as microgravity. So when Notardonato left NASA in 2019, he decided to pursue the goals that got away from him as a public servant, founding Eta Space with "a bunch of ex-NASA guys with a lot of good ideas."

He won't try to fuel anything up for deep space right away. Instead, Eta Space plans to launch its LOXSAT 1 technology demonstrator to low-Earth orbit in 2024. The 150-kilogram satellite mainly consisting of a spherical storage tank and a cubic radiator will demonstrate techniques essential to long-term storage of cryogenics. First up will be proving the satellite can store liquid oxygen with zero boil-off over its nine-month mission. Eta Space will also conduct pressurization and depressurization tests, practice zero propellant loss chill downs of fluid transfer components and attempt to transfer propellant between LOXSAT's internal tanks. NASA is on board, having awarded Eta Space $27 million in Tipping Point program funding for the LOXSAT demonstrator in 2020.

"A lot of this stuff we have done on the ground," Notardonato says. "It's really proving it now in a microgravity environment, which has never been done before."

Eta Space won't attempt to dock the LOXSAT demonstrator with another spacecraft, but assuming a successful mission, the company plans to launch Cryo-Dock, a larger version of LOXSAT 1 at 20,000 kg, as the first commercial propellant depot offering

liquid hydrogen and liquid oxygen to spacecraft ranging from rocket upper stages heading for deep space to orbital transfer vehicles conducting satellite servicing or debris removal. Eventually, Notordonato says, Cryo-Dock could even refuel shuttles and landers heading toward the moon.

Staging propellant in space or refueling on orbit isn't a new idea, but it's a concept enjoying a moment. In addition to Eta Space, NASA and SpaceX are depending on a lunar lander variant of SpaceX's Starship vehicle that is designed to require refueling with cryogenic methane and liquid oxygen in Earth orbit shortly after launch, a technique that SpaceX must prove as part of an uncrewed lunar landing demonstration with Starship before the first flight with astronauts. And in the satellite domain, the idea of propellant depots is gaining steam, with at least one operational facility offering noncryogenic propellants already. In the long term, proponents talk up the possibility of creating a sustainable cislunar economy as a foothold toward utilizing resources on the moon — or asteroids, or Mars — to create fuel where it's cheapest: outside Earth's steep gravity well.

It's enough to make one wonder just why depots are having a moment now, and not 10, 20 or 30 years ago. The answers are political and technical, with politics often dictating the pace of innovation.

Refueling research

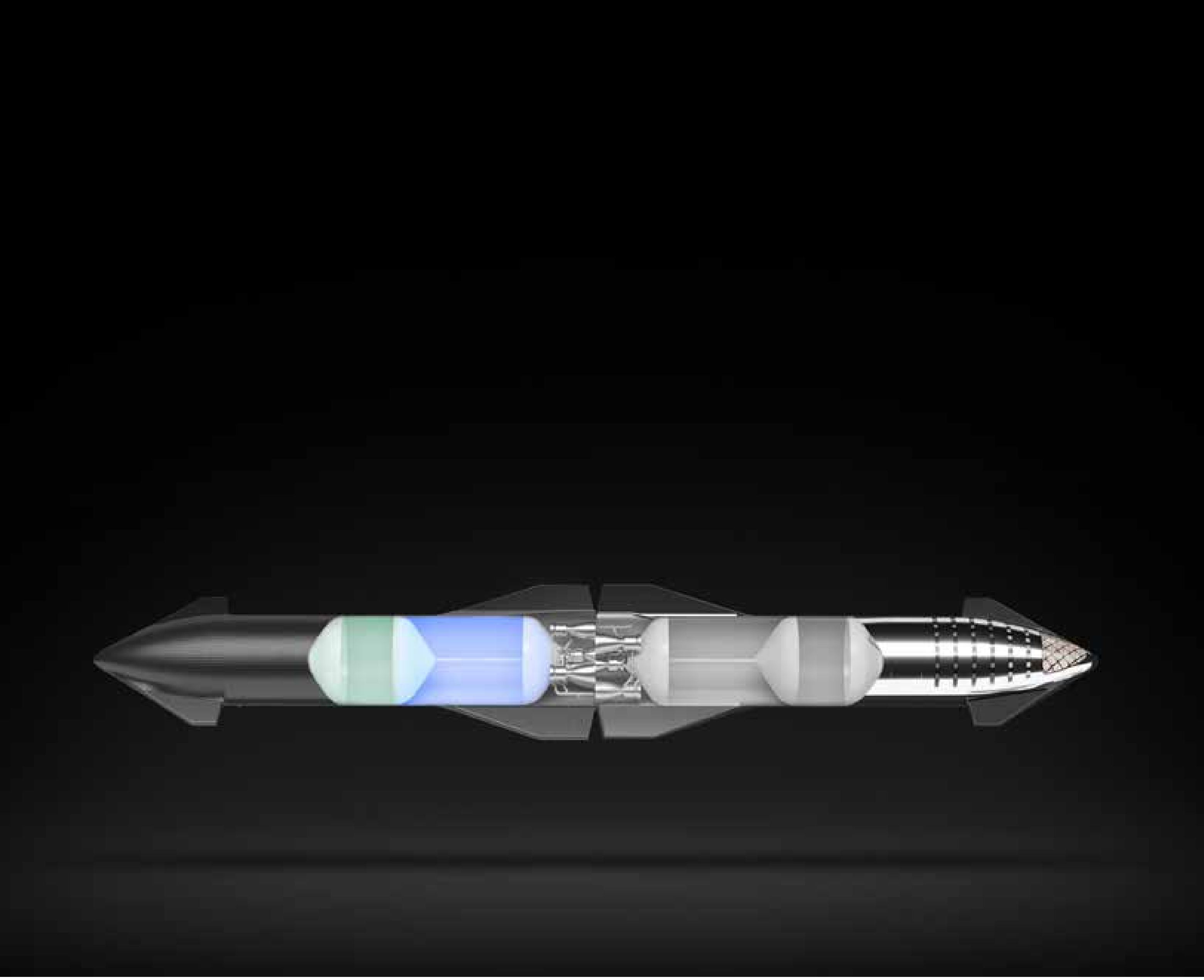
For rocket builders, depots could be the answer to one of their greatest conundrums: how to store as much fuel as possible without making a rocket too heavy to escape Earth's gravity well. Refueling a rocket's upper stage from an orbital depot means you don't have to carry everything with you in one go.

"Depots allow you to address bigger missions with smaller vehicles," says Jonathan Goff, the owner of aerospace consulting firm Starbright Engineering. And smaller, cheaper vehicles can make for a higher flight rate, "which is kind of key for getting the cost down." Depots can also enable entirely new operations and designs, such as reusable space stages that, for instance, could shuttle back and forth between Earth orbit and lunar orbit without ever returning to Earth.

Eta Space is the smallest of the four companies to receive 2020 Tipping Point funding from NASA, with Lockheed Martin receiving $89.7 million, United Launch Alliance $86.2 million and SpaceX $53.2 million. Lockheed Martin plans to demon-

▲ Orbit Fab is designing a multitank depot for refueling satellites in geostationary orbit. The Tanker-002 design, shown here in an illustration, is scheduled to launch in the mid-2020s.

Orbit Fab



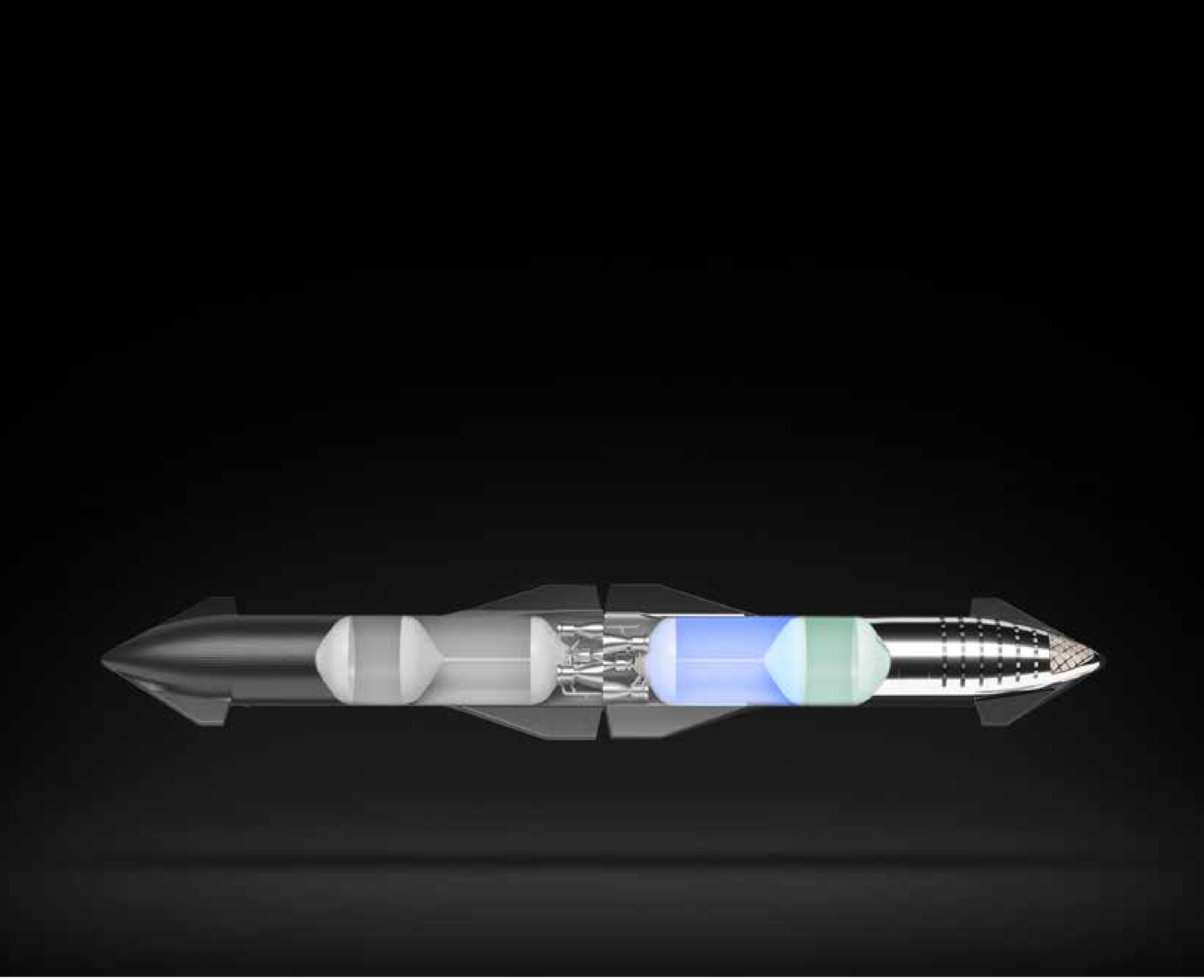
strate liquid hydrogen management in space. ULA is looking into keeping Vulcan Centaur upper stages in orbit after each launch and using them as deep space tugs, and so it plans to explore long-term storage and internal transfer of cryogenics within a Vulcan Centaur upper stage. And SpaceX would transfer 10 metric tons of liquid oxygen between tanks aboard a Starship spacecraft in Earth orbit, as though it were fueling up the Starship that will head toward lunar orbit and rendezvous with an Orion capsule to take two astronauts to the surface for NASA's Artemis III mission, currently scheduled for 2025.

And propellant depots are not just for rockets and deep space operations. The concept is further along in the satellite world: Last year, Colorado-based Orbit Fab launched its Tanker-001 Tenzing, the first operational propellant depot for defense satellites. Tenzing carries high-test peroxide, not more difficult to store than cryogenic propellant, although Orbit Fab co-founder Jeremy Schiel says the company might consider cryogenic depots in the future. Refueling satellites can not only extend their lives and make deorbiting them easier, it can also free operators to maneuver as their needs dictate, rather than their fuel budget, he says.

"Once you start refueling, it changes the paradigm," he says. "The hurdle that's being overcome in the next three to five years is just the 60 years of history of not having fuel on orbit."

Historical challenges

Each era of spaceflight has had its own circumstances that turned NASA's attention away from orbital fueling strategies. In the Apollo era, America's race to beat the Soviets to the moon led NASA to adopt a mission architecture in which a single rocket would boost the astronauts, their lander and command module toward lunar orbit, where the command module would dispatch the lander to the surface.



However, Wernher von Braun and others at NASA's Marshall Space Flight Center had favored the Earth Orbit Rendezvous concept, in which two spacecraft would have been launched by two rockets, one carrying the Apollo astronauts and the other carrying fuel as a tanker, for rendezvous and assembly in low-Earth orbit. Ultimately, von Braun and NASA decided that the Lunar Orbit Rendezvous approach was necessary to make Kennedy's famous deadline.

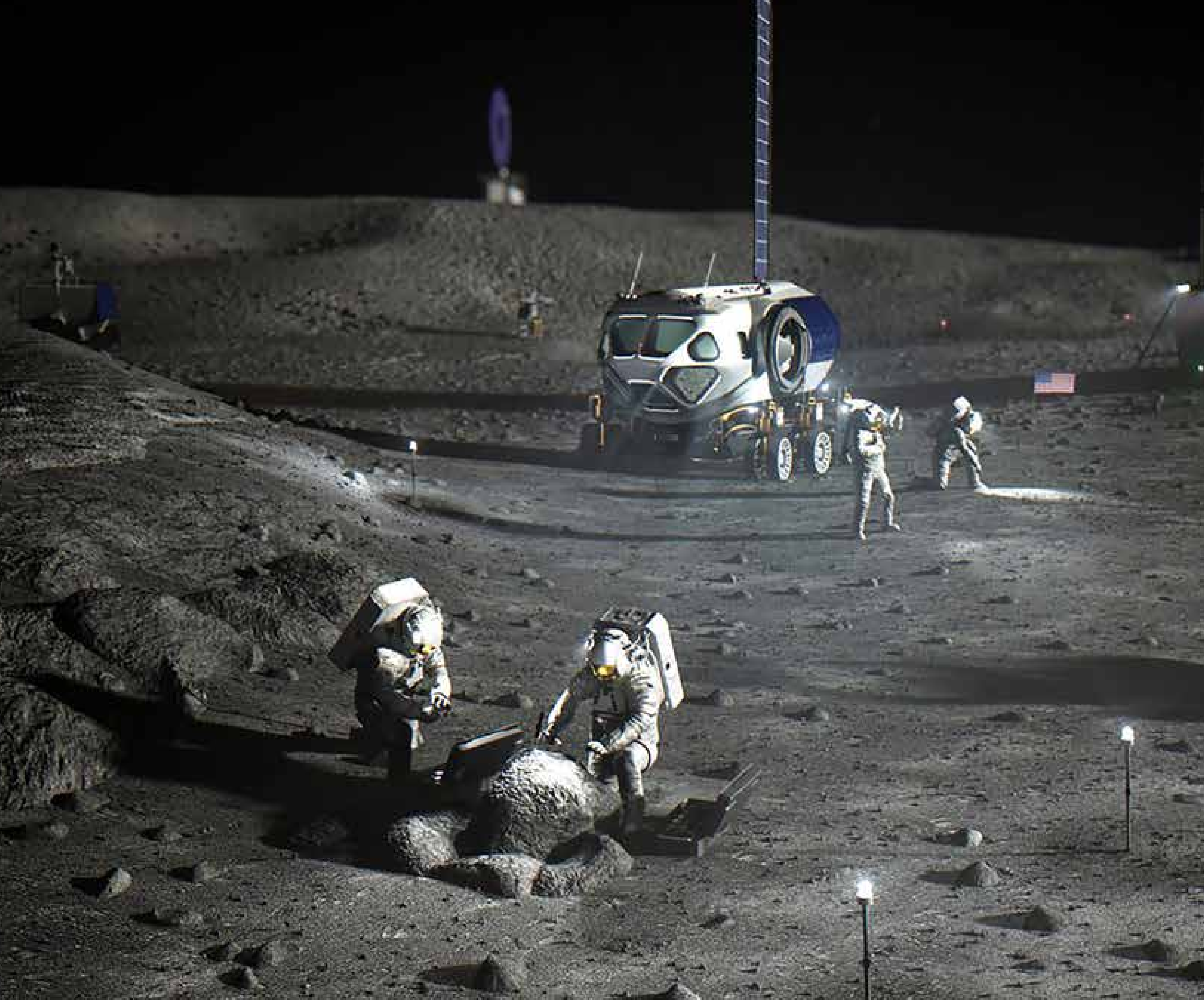
"If they had done the tanker mode, they wouldn't have needed as big of a vehicle; they could have gotten away with the Saturn 1," Goff says. That could have allowed for a higher flight rate and a more sustainable program, since "the technology would have been on the shelf where they could have done follow-on missions easier, even if they had shut down the capabilities."

As it happened, the Nixon administration decided to truncate Apollo after Apollo 17, and by the late 1970s, NASA transitioned into the space shuttle era. With NASA's focus on orbital spaceflight rather than deep space exploration, crafting fuel depots to unlock human exploration of deep space simply was not a priority, a trend that continued all the way through the early 2000s and the era of the International Space Station.

For a time during the Obama administration, it looked to Goff like depots might be back on the table. At the time, he was CEO of Altius Space Machines, a maker of robotic arms, propellant valves and other space technologies. In 2010, the new administration canceled the Bush-era Constellation program and its development of a giant moon rocket in favor of fostering development of privately owned rockets by the nascent commercial space launch industry for transporting astronauts to and from ISS. Those rockets might eventually also boost astronauts and equipment to the moon or Mars, Goff thought, an approach that would potentially lend itself to positioning one or more fuel depots in orbit for refueling.

▲ SpaceX released these illustrations in 2019 showing how a Starship spacecraft would rendezvous with a tanker version (at left) in low-Earth orbiting for refueling. Each tanker would hold up to 10 metric tons of liquid methane and liquid oxygen propellants.

SpaceX



▲ NASA wants to establish an Artemis Base Camp by the 2030s near the lunar south pole, which is covered in craters that scientists suspect could harbor water ice. In theory, that water could be harvested and converted into rocket fuel, among other uses, and stored on propellant depots either in lunar orbit or on the surface.

NASA

But he did not anticipate the political backlash.

"We really set up a dynamic where it was seen as depots versus big NASA rockets," Goff says. "And there are congressional people who care about the jobs that come from big NASA rockets and their districts."

Members of Congress led by Republican Sen. Richard Shelby of Alabama and Democratic Sen. Bill Nelson of Florida — now NASA administrator — still wanted a line of big, expendable NASA rockets, and they got it in the Space Launch System program. Once development of SLS began in 2011, Goff says, NASA and big contractors alike wanted nothing to do with propellant depot concepts.

"It was just verboten," he says. "If you said anything depot related, you were the enemy."

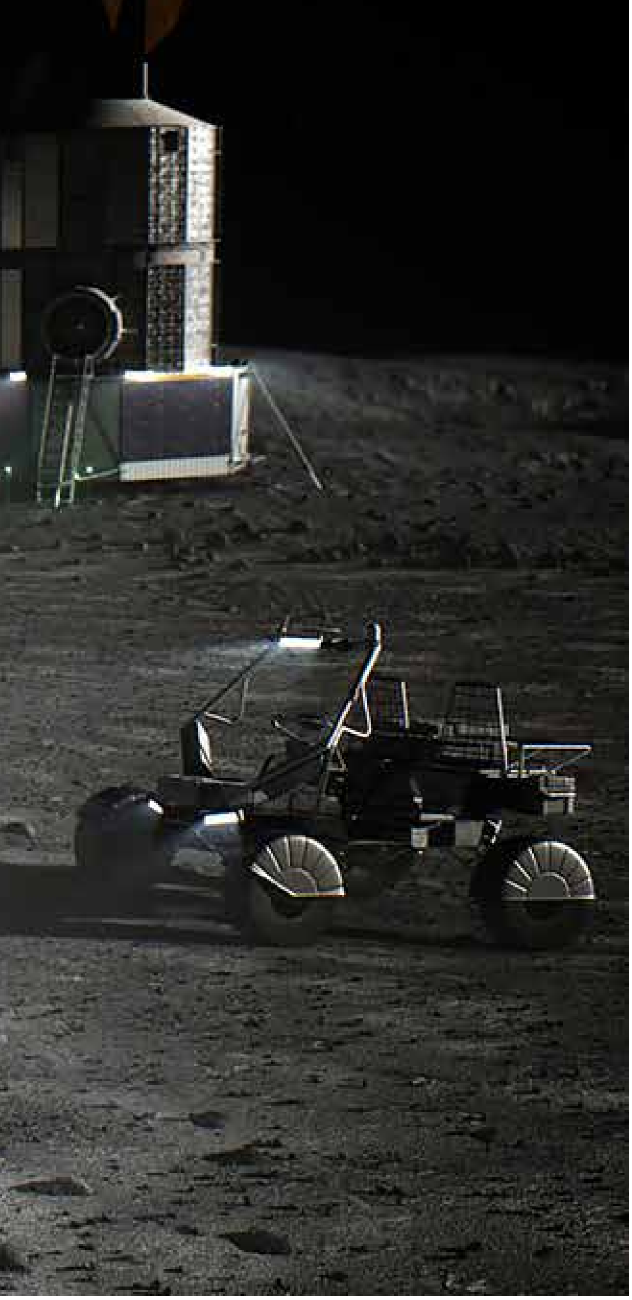
So one answer to the question of why orbital fueling is gaining traction now could be that much of the political pressure of the 2010s has now lifted. "SLS is about to fly, [SpaceX's] Starship is about to fly," Goff says. "Almost all the people in the Senate that are behind SLS have retired."

But that easing of pressure is not the only answer. The commercial space industry has heated up to the point where there's pent-up demand for services like satellite refueling. When Orbit Fab first looked at that market four years ago, "there were eight companies looking at doing satellite servicing," Schiel says. Now, globally, there are over 100 companies, including Northrop Grumman and its Mission Extension Vehicles and tug services like Momentous of California.

"We started at the perfect time when servicing was starting," Schiel adds.

Another reason the concepts are having a moment is also related to NASA and SLS.

"Why now is because of Artemis," says space consultant Laura Forczyk, author of "Becoming



"Fuel today is a capital expense. You put it all up, and once it's done, it's done."

— Jeremy Schiel, Orbit Fab

Off-Worldly: Learning from Astronauts to Prepare for Your Spaceflight Journey." When NASA selected a variant of SpaceX's Starship as the Human Landing System for the Artemis III mission, the agency committed to a mission architecture requiring as many as 16 Starship launches to fill a "tanker" version of Starship with liquid methane and liquid oxygen. That tanker Starship would then transfer fuel to the HLS Starship in Earth orbit.

A Starship prototype has yet to fly higher than 10 kilometers, and never attached to a Super Heavy booster needed to send it to orbit, but "NASA now is relying on this technology to be able to get humans to the surface of the moon," Forczyk adds.

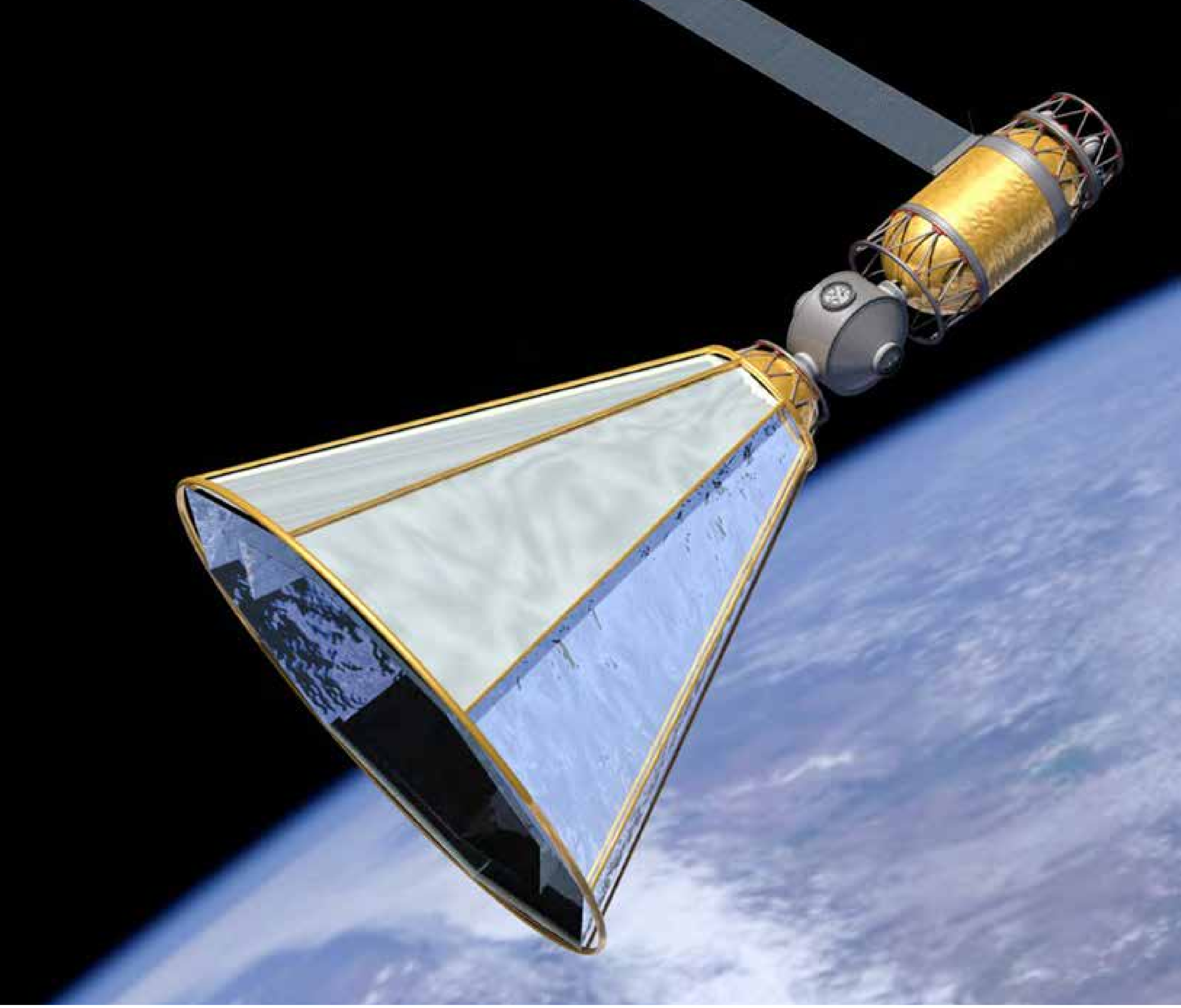
Making it work

And of course, there are also technological challenges remaining.

"If you've got a cryogenic propulsion system, there's a few key technologies that don't exist yet," says Jason Adam, who manages NASA's cryogenic fluids management portfolio project office. His team manages the Tipping Point programs, including preparations for Eta Space's demonstration mission, and also conducts research focused on the challenges of in-space cryogenic fueling.

The first challenge is active cooling. Insulation can only do so much when liquid hydrogen boils at just over minus 253.15 C, so if you had a camera inside a rocket on the launch pad, "it would be sitting there boiling." That problem doesn't go away in space just because convection is lost as a heat transfer mechanism, and any depot designed to store cryogenic fuel for long durations will need to minimize boil-off. Adam's team is developing a cryocooler technology to solve those issues.

"Think of it as a refrigerator motor that would go on a rocket," he says. The goal is to keep the liquid



▲ This United Launch Alliance concept of a propellant depot revealed about a decade ago consists of a "hot equipment deck" (top) containing avionics and a propulsion module, and a tank that would store several tons of either liquid hydrogen or liquid oxygen. The tank is shrouded by a conelike sunshield that would deploy to keep the propellant at cryogenic temperatures.

United Launch Alliance

hydrogen and liquid oxygen stable, "or what we call a zero-boil-off condition."

Cryocooler technologies have existed for a while, with much of the development driven by NASA science missions like the Hubble Space Telescope, according to Notardonato, but "the cryocooler technology was not as advanced in the 1990s" compared with today.

The second challenge, and one that all of the Tipping Point companies must contend with, is managing propellant in microgravity. You have a depot with a tank half full of liquid hydrogen and a spacecraft you want to transfer it to: Where is this hydrogen?

"On Earth, the hydrogen will be at the bottom of the tank because we're in 1G," Adam says. But in free fall, "where the heck is the hydrogen? It could be anywhere."

It's not yet clear if techniques long used to manage noncryogenic fluids in microgravity, such as inflatable bladders and internal storage tank vanes and baffles to make use of surface tension, will work for cryogenics, but Adam said the various Tipping Point programs aim to explore the possibilities.

Meanwhile, NASA engineers at Marshall Space Flight Center are working on yet another challenge: keeping the propellants contained.

"If you've ever had any experience in cryo systems, the one thing that you'll know is all cryo systems leak," Adam says.

A small amount of leakage isn't a big deal from a rocket that's delivering a payload in a matter of minutes and is then done. But for a mission to Mars or a liquid hydrogen propellant depot, getting cryogenics sealed in tightly is important.

And NASA's making progress: "We're doing some ground tests right now on some large cryogenic valves that would improve internal leakage

"A lot of this stuff we have done on the ground. It's really proving it now in a microgravity environment, which has never been done before."

— William Notardonato, Eta Space

between two and three orders of magnitude over the state of the art," Adam says.

He's fairly confident that NASA's research, along with the Tipping Point programs, will solve a lot of the problems with cryogenic fluid management, though certainly not all of them. "Cryo is pretty crazy stuff. I've been around long enough to know anything could happen."

The future with depots

It's true, anything could happen with cryogenics, and with space generally. But what if good things happen? What might success look like?

For Orbit Fab, it would mean launching its Tanker-002 later this year or early next year, a geostationary gas station carrying 90 kg of hydrazine, and getting satellite operators used to a whole new way of thinking about fueling.

"Fuel today is a capital expense," Schiel says. "You put it all up, and once it's done, it's done."

For Eta Space, success would mean a LOXSAT mission that proves the technology for the first Cryo-Dock and, eventually, propellant depots on the surface of the moon to support NASA's Artemis program — assuming SpaceX solves its cryogenic fluid transfer puzzle necessary to land astronauts.

At that point, Forczyk says, NASA and companies including Eta Space might start looking at manufacturing propellants from lunar resources and forgo launching them from Earth altogether.

The idea is to "leapfrog to the point where you're making that fuel in situ somewhere," she says. "The moon is our closest neighbor, and it does have all the materials that we need for fuel for propellants."

Government and industry might then consider building up a strategic propellant reserve on the moon, as ULA CEO Tony Bruno suggested to the National Space Council in 2020, which Forczyk calls "an excellent way to kick-start a cislunar economy."

That's getting maybe a decade ahead of the story right now, she notes, and the technical challenges and economic and political realities could change the pace of the plot. But "it seems like we're on the cusp of it beginning," Forczyk says.

"Some version of orbital refueling is happening, is going to happen. Whether all of the promises of orbital refueling come into play, I don't think anyone can say." ★

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Airborne connectivity doesn't have to come with cybersecurity baggage

The growing digital interconnectedness between aircraft networks is making operations more efficient for airlines and providing conveniences for the traveling public. But now, bad actors are threatening to turn this happy revolution against us. Josh Lospinoso puts on his hacker hat to point us to tactics for better cybersecurity in the air.

BY JOSH LOSPINOSO

Modern commercial aircraft are flying data centers connected to the internet or, in the case of some subsystems, private networks. On any given day, there are some 25,000 planes in the air globally, including 5,000 over the United States. Every one of them relies on hardware and software components made by thousands of suppliers. The avionics and controls in the cockpit and the in-flight entertainment screens are more connected internally and externally than ever.

The electronics and software that the crew relies on to control the aircraft, known as operational technology or OT, create valuable data for stakeholders across the modern aviation ecosystem, from real-time location information for air traffic controllers to performance metrics for mechanics. A Boeing 787 Dreamliner's Common Core System, the backbone of its computers, networks and electronics, hosts 80-100 applications. A 787 also reportedly generates half a terabyte of sensor data per flight. An Airbus A350 XWB has over 50,000 sensors and collects 2.5 terabytes of data daily. And a typical GE jet engine collects information at 5,000 data points per second.

There is no going back on this interconnectedness. In fact, the trend is likely to grow. Driven by the need to cut costs, find efficiencies and cope with an unprecedented employee shortage, operators now realize that analyzing big data at scale and in real time can help them gain competitive advantages.

Offloading, processing and operationalizing aircraft data quickly used to be challenging, but then onboard satellite-based internet broke down that barrier. Lufthansa was the first to offer this service in 2004. In 2013, JetBlue upped the game, providing broadband service with Viasat's Ka-band geostationary satellites. And soon, SpaceX's Starlink will provide Hawaiian Airlines with ultra-high-speed broadband from low-Earth orbit.

Internet connectivity on commercial aircraft comes with some complicated cyber baggage, though. Manufacturers of OT systems often don't give cyber resiliency the attention it deserves, leaving even the most modern aircraft without basic cybersecurity protections.

Unlike enterprise IT hardware and software used by large companies that are well-known to security teams, visibility into the cyber risks lurking inside an aircraft's components and networks is much more opaque. The more technology an aircraft has, the more complex it is to see and manage. And as more advanced, connected technologies make their way onto aircraft and as they become more closely interconnected with legacy systems, they will introduce new, unknown vulnerabilities.

This expanding, complex and largely unchecked attack surface is good news for bad actors seeking new opportunities to compromise our critical transportation infrastructure. They know that persistent connectivity with aircraft systems can make them as vulnerable as connected IT assets found in traditional businesses. They also know that failing to detect and fix a single exposure point could have a cascading

▲ Lufthansa was the first to offer passengers in-flight internet, during a 2004 flight from Munich to Chicago aboard an Airbus A340-300. Today, airlines must balance the increasing demand for speedy connections via broadband satellites in low-Earth and geosynchronous orbit with the need to secure their aircraft against cyberattacks, writes Josh Lospinoso of Shift5.

Airbus

effect on the entire aviation ecosystem.

In short, operators must balance the implementation of connectivity with the need to keep malicious adversaries at bay.

If I were a bad guy, here's what I'd do

Don't worry. I'm not sharing anything that bad actors haven't already considered. My purpose here is to give you a glimpse of how a successful aviation security team puts itself in the hacker's shoes. Hackers view the revolution in airborne connectivity as a tree of juicy low-hanging fruit. Implementing effective defenses against them begins with a security team recognizing that bad actors come in a variety of forms and, therefore, have a variety of motivations.

It begins with grasping the variety of threats. A security team must track nation-state operatives, cyber terrorists, hacktivists, script kiddies who buy code off the dark web and insiders who turn against their organizations. Motivations range from a desire for strategic advantage on the world stage, to a determination to change societal behavior through fear or by exposing information, to an attempt to earn financial gain or market advantage through the theft of intellectual property.

As you read on, imagine I'm a hacker who is after financial gain with ransomware. Hackers are increasingly attracted by how lucrative it can be to hold a company's network and data hostage. The average ransom payouts bad actors get from critical infrastructure operators and health care systems are well into seven figures. Still, victims would rather pay than risk financial and reputational damages — despite advice from the U.S. government.

The aviation industry is no stranger to ransomware attacks. Indian airline SpiceJet grounded flights in May due to such an attack. Another attack targeting Swiss aviation services company Swissport caused operational disruption in February. And last August, Bangkok Airways suffered a similar cyberattack resulting in the exfiltration of sensitive passenger information, including passport and credit card data.

An organization facing the risk of downtime losses may cut its losses and pay the ransom. This vicious cycle drives up the cost of ransom demands, encourages bad actors to seek new victims and emboldens them to devise novel attacks.

So with my motivation clearly defined, I can focus on execution. Bad actors have a history of rudimentary hacks on noncritical aircraft systems. Many of these systems remain vulnerable, and replicating a tried-and-true attack would take minimal effort. I'd attack one to make noise and get an operator's attention.

Among the low-hanging fruit would be an attack on an in-flight entertainment system. These systems fall into a category known in the aviation world as Design Assurance Level E, or DAL E, which are systems that are considered least critical to the safety of the passengers.

Systems in this category have been hacked before, and I'd do it again. Can I access flight-critical controls through the entertainment system? Hopefully not. So why would I pick that? At scale, a carefully executed attack there could impact the flying public's trust.

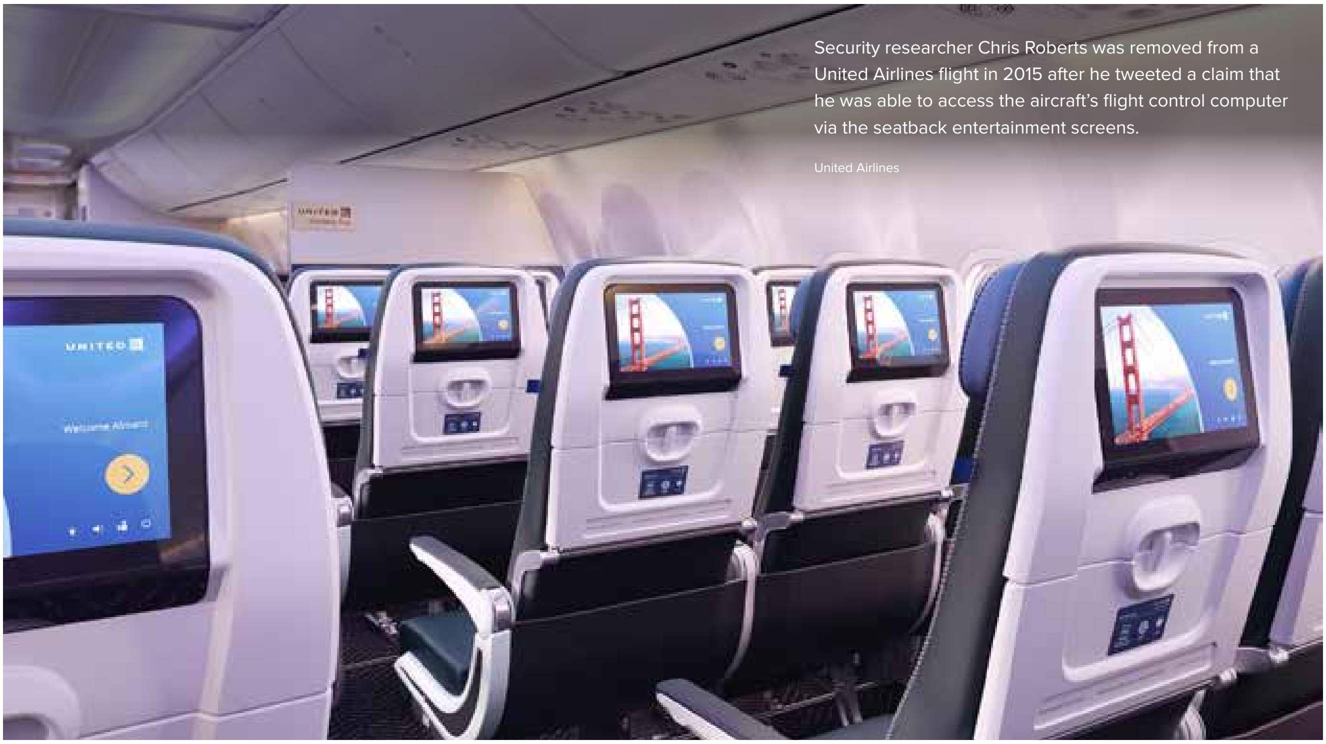
High over somewhere, I could take control of what passengers see on their seatback screens and present a demand that the airline pay a ransom before I will release my control. Such a demand is the last thing anybody wants to see while traveling at 450 knots and at an altitude of 36,000 feet. This type of attack could quickly incentivize an airline to pay a ransom rather than risk additional consequences.

But now, I'm emboldened to do more and seek higher payouts. Let's go a hypothetical step further.

Escalation

An attack on DAL E systems might cause passenger concern, but a suspected threat against one of the more critical systems in the DAL A-D range could ground a plane — or an entire fleet. If the airline doesn't decide to do so, the flight crew could refuse to fly. Evidence suggests adversaries are already escalating such attacks, and the White House continues to warn us about these threats. Even the U.S. Department of Homeland Security has remotely hacked one of its test aircraft to demonstrate how airlines are at risk.

Moving up the design assurance levels, I'd cause a disruption that motivates payment while understanding what an airline can afford. If the average



Security researcher Chris Roberts was removed from a United Airlines flight in 2015 after he tweeted a claim that he was able to access the aircraft's flight control computer via the seatback entertainment screens.

United Airlines

lease payment on an aircraft is $350,000, and if I can interfere with normal operations just enough to keep aircraft grounded, I could cost any of the four largest U.S. airlines (each with around 800 aircraft in their fleets) upward of $10 million a day.

How might I do it? When an aircraft pulls into a gate, communication between it and airline operations happens automatically. Wireless and cellular links exchange data like updates to electronic manuals, databases, minimum equipment lists in an aircraft's electronic flight bag, engine trend monitoring data and more. I could compromise those connections and move from one system to another until I find my next exploit.

If I get into these communications, I could alter data or transmit error codes back to the aircraft so it can't push back. Indeed, an over-the-air attack on a software update to primary avionics or a spoofed message to the flight control computer could trigger a master caution alarm, grounding an entire fleet until my ransom is paid.

But I'm not a bad guy, so now what?

Understanding an adversary's playbook helps you make decisions to better protect aviation assets. Defenders should focus on best practices to prepare for the inevitable threats of a fully connected future. I'm encouraged by operators thinking about cybersecurity ahead of regulators. Here's where to start:

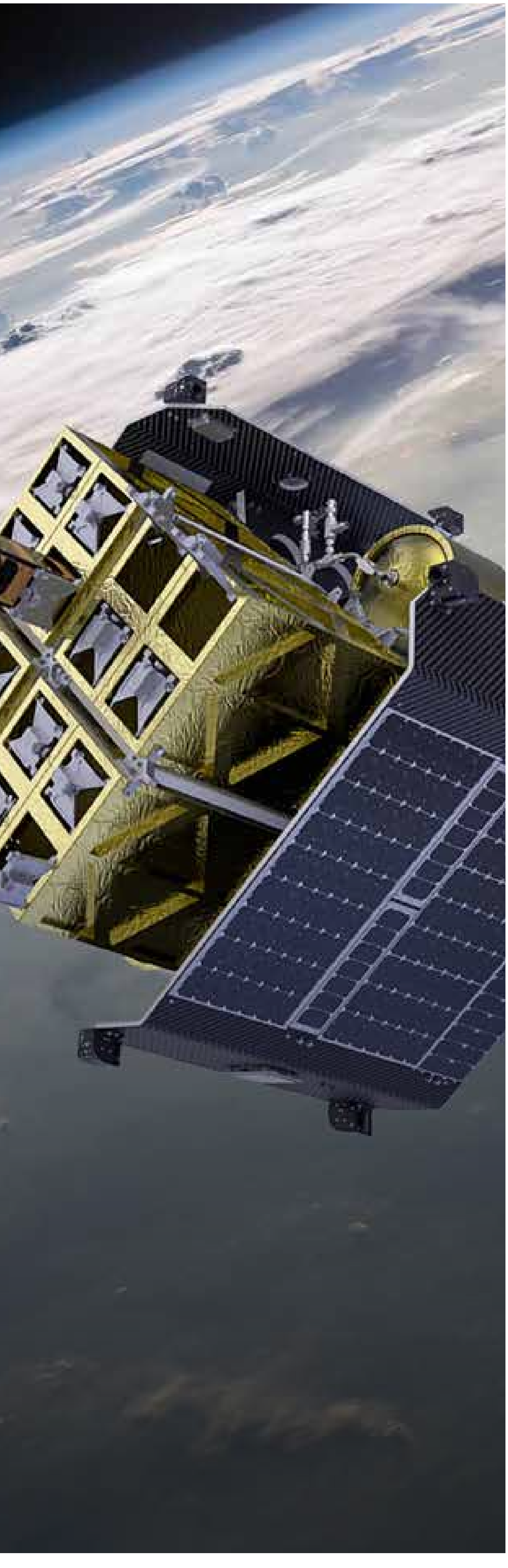
- **Observability:** Solutions that provide observability into IT infrastructure won't work on aviation assets, including critical flight control computers. To know what's happening inside each aircraft and across your fleet, you must invest in modern, purpose-built solutions that access and interpret the data created by all of an aircraft's onboard systems and networks.
- **Risk assessment:** Most aircraft components need critical software and operating system updates that often take years to get. Bad actors could exploit unpatched vulnerabilities in a component to move laterally across an aircraft. So protect your least critical systems as you do your most critical ones. Assess risks to onboard components and systems across all design assurance levels.
- **Threat detection:** The whole industry must internalize the government's continued warnings that critical transportation infrastructure is the ongoing focus of nation-state attacks. That means having solutions that can detect threats and active attacks before they escalate.

The siren's call for connectivity on commercial aircraft is too strong for the aviation industry to ignore. The irresistible benefits of data connections with fleet aircraft, including critical avionics systems, should be implemented in a way that protects flight safety.

The advice of the Federal Aviation Administration couldn't be any more explicit: "The increasing connections between airplanes and other systems, combined with the evolving cyber threat landscape, could lead to increasing risks for future flight safety." We must act without delay to embrace and apply modern cybersecurity principles to aviation environments and assets. ★

Josh Lospinoso
is founder and CEO of the Shift5 security company in Washington, D.C. 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.

OPENING NEW ORBITS FOR SATELLITE OPERATORS



Some of the most creative entrepreneurs and researchers can't afford to buy an entire rocket to deliver their wares precisely into their preferred orbits. Often, they must compromise or expend fuel maneuvering their spacecraft after launch. Matteo Bartolini of D-Orbit describes the challenges his company faced to develop a line of satellite transporters that could be the answer.

BY MATTEO BARTOLINI

Over the last decade, space has been colonized by nontraditional players working to make spaceflight and commercial space activities more cost-effective, accessible and reliable. The company where I work, D-Orbit, based in Como, Italy, is one of these companies.

The first mission at our founding in 2011 was to sweep debris from space. We still do that, but in the ensuing years we have recognized additional needs.

Most importantly, in 2016 we realized that some of those planning to launch experimental satellites or constellations of satellites had frustratingly little choice over the orbits for their spacecraft. For reasons of cost and performance, these customers were often relegated to sharing rides on rockets together with other satellites. In such a ride-share arrangement, the satellites are released almost simultaneously in the same orbit that was chosen by the launch provider based on the orbit's popularity and likelihood of bringing in the most customers. On a ride-share, one must either be satisfied with the slot where the launch vehicle released you or take on the burden of maneuvering to a preferred operational slot.

So, D-Orbit began drawing up plans to create a fleet of orbital transfer vehicles, or OTVs, capable of releasing multiple payloads into precise orbits. It turns out these OTVs, each an aluminum and composite cube-shaped dispenser roughly the size of an industrial washing machine, can also host cloud computing devices, cameras and other equipment. Today, we call these spacecraft ION Satellite Carriers, ION being short for "In Orbit Now." So far, we have launched six of them as commercial missions, most recently on May 25 aboard SpaceX's Transporter-5 ride-share mission.

Given our belief in protecting the space environment, we have a plan for deorbiting each carrier, and we help our customers be compliant with space debris regulations.

Our customers have the ability to choose the best orbit for their unique commercial or scientific needs. If conventional launchers can be thought of as the equivalent of ocean-going vessels transporting freight containers to a seaport, our ION Satellite Carriers are the delivery trucks that set off from that port to drop

▲ D-Orbit's fifth ION Satellite Carrier at the company's Italy headquarters before its April launch aboard a SpaceX Falcon 9. Two of the customer satellites can be seen peeking over the top of the black solar panels that encase the cube-shaped dispenser. The silver box at left covers ION's propulsion tanks, and the red bxoes cover multisensor modules.

D-Orbit

packages at each customer's door, a true "last-mile" delivery service in orbit.

We calculated that our ION Satellite Carriers reduce the time it takes to completely deploy a satellite constellation by 85% while reducing the launch costs of the entire constellation by up to 40%.

Early work

To achieve the required maneuverability, our engineers use a green, bipropellant propulsion system whose six nozzles maneuver the spacecraft to adjust orbital parameters including altitude, inclination relative to Earth's equator and swivel, also called the right ascension of the ascending node, or RAAN. They also devised a technique for adjusting the attitude of each carrier with reaction wheels. Now, from our mission command center in Italy, or in some cases even from someone's home office via cloud computing, we can program a carrier to maneuver to a new orbit and release one satellite in one direction and then adjust the attitude and release another satellite in an entirely different direction.

These technologies are the first of their kind, our knowledge of the industry shows. We have gone through several tests, both on the ground and on orbit, to improve our ability to perform orbital maneuvers and our mission control software. Every time we successfully test in orbit a performance improvement or a new capability of our carrier, it is a very emotional moment, filled with pride and satisfaction. Over the six missions we have launched so far, the team performed a multitude of complex orbital maneuvers with our carriers during different phases of the missions. We've demonstrated changing altitude and inclination, achieved true anomaly phasing and performed RAAN shifts. The first time we perform a new maneuver, we do much of the commanding manually, and on the following missions, the same maneuvers are performed in a more automatic and independent manner. Mastering new orbital maneuvers and capabilities during nearly every mission represents a fundamental milestone for us; to be as competitive as possible, we strive to increase the level of complexity, as needed, with each new mission.

In our first orbital mission, we were able to validate our precise deployment strategy, which is based on a combination of direction deployment and ejection force. This creates a wide separation between deploying spacecraft, so our customers can acquire the signal faster while ensuring a stable, collision-free formation. A triple fault-tolerant mechanism guarantees the release of all satellites before the end of the mission, even in case of malfunction.

Another important aspect of our missions is that we give customers the opportunity to test their technology in orbit. For customers performing space experiments, we recognized that a plug-and-play approach was needed. As a result, we created a mechanical, electrical and data interface that enables a faster integration of experiments and instruments onboard — while allowing mission controllers to operate them as subsystems of ION.

In order to do this, though, each ION Satellite Carrier needed to be able to provide power over different voltage values to one or more experiments simultaneously. The D-Orbit team had to think of an intermediate support structure that was easy to attach a carrier to on one side but could also allocate experiments of different volumes and sizes (from tiny electronic boards to optical elements) on the other side.

The data interface was also very difficult to figure out because a customer's test payload must work over different interfaces and protocols. Our engineering team had the challenge of designing and building an interface board capable of connecting all the possible interfaces the experiment could have with the ION Flight Computer.

In an example of our flexibility, a prospective customer informed us it could not afford to build and launch a free-flying satellite to test a new camera, so

After this SpaceX Falcon 9 rocket launched an ION Satellite Carrier and its six satellites to orbit last year, the carrier hosted on-orbit demonstrations of cloud computing methods and a laser communication terminal, among other technologies.

SpaceX

our engineers installed the camera into a tubular structure that was then integrated onto our carrier. Our flight operations team then operated the camera to test it for the customer.

Launching a multinational "Wild Ride"

A groundbreaking and unique mission for us because of its scope has been our third one, the ongoing Wild Ride, in which a Falcon 9 rocket in June 2021 launched an ION Satellite Carrier containing six satellites and 12 hosted payloads for clients from 14 different countries, including Bulgaria, Finland, Kuwait, the Netherlands, Spain and the United States. After releasing the satellites, we tested a miniature low-power, high-performance laser communication terminal specifically designed for small satellites. A subsequent phase of that mission has been the first test of our D-Orbit Cloud Platform, an on-orbit cloud computing and data storage service utilizing a radiation tolerant computing module by Unibap, an artificial intelligence company based in Sweden. This first test campaign executed 23 separate SpaceCloud-compatible applications from a variety of partners. A hypothetical customer could, for instance, feed images of Earth to the D-Orbit Cloud Platform, where AI software would rifle through them to detect an oil spill or a lost ship and send only the relevant images back to the ground, thus saving an enormous amount of downlink bandwidth and cost.

Every mission we launch, including Wild Ride, is also managed with Aurora, our cloud-based mission control software suite. Aurora aims to enable satellite operators to manage and control multiple payloads simultaneously from any location in the world, eliminating the high costs connected with software design, development, testing, deployment and maintenance.

The future of the new space economy

D-Orbit is also working on projects that do not involve space transportation. For example, we are in the process of attaching a synthetic aperture radar on the ION platform. Our goal is to show that ION is not only a good family of services for orbital transportation but can also serve as a valuable stand-alone platform. In the future, we hope to make ION available to more customers with the goal that they can install their own sensor in the satellite.

While we recognize the commercial space industry is still in its earliest years, we expect exponential growth and more innovation on the horizon. One of the key goals at D-Orbit is to make space available for customers with an approach that's even easier, moving it from a challenge to a service. By using some of the most cutting-edge technology and working together as a team, we can confront the challenges currently facing space sustainability and logistics and make it a truly exceptional field. ★

Matteo Bartolini is head of sales engineering for D-Orbit, based near Como, Italy. He has a bachelor's degree in aerospace engineering and master's degrees in aeronautical engineering and civil aviation management, all from from Sapienza University of Rome.

AIAA Bulletin

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Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2022			
1 Sep	2022 Section Awards Presentation	Online	
4–9 Sep*	33rd Congress of the International Council of the Aeronautical Sciences (ICAS 2022)	Stockholm, Sweden (icas2022.com)	10 Feb 22
7 Sep	ASCENDxNuclear: Nuclear's Future Role in Space	ONLINE (www.ascend.events/ascendx)	
7–30 Sep	Electrochemical Energy Systems for Electrified Aircraft Propulsion Course	ONLINE (learning.aiaa.org)	
13–22 Sep	Aircraft Reliability & Reliability Centered Maintenance Course	ONLINE (learning.aiaa.org)	
18–22 Sep*	73rd International Astronautical Congress	Paris, France (iac2022.org)	
18–22 Sep*	Digital Avionics Systems Conference (DASC)	Portsmouth, VA (2022.dasconline.org)	
20 Sep	AIAA Professional Virtual Career Fair	https://app.brazenconnect.com/a/aiaa/e/Y507w	
20 Sep–13 Oct	Flight Vehicle Guidance Navigation and Control Systems (GNC): Analysis and Design Course	ONLINE (learning.aiaa.org)	
27 Sep–3 Nov	Introduction to Aviation Data Science Course	ONLINE (learning.aiaa.org)	
28 Sep–21 Oct	Business Development for Aerospace Professionals Course	ONLINE (learning.aiaa.org)	
28 Sep–21 Oct	Fundamentals and Applications of Pressure Gain Combustion Course	ONLINE (learning.aiaa.org)	
4–20 Oct	Overview of Python for Engineering Program Course	ONLINE (learning.aiaa.org)	
4–27 Oct	Propeller Aerodynamics for Advanced Air Mobility: Fundamentals and Integration Effects Course	ONLINE (learning.aiaa.org)	
11–20 Oct	Higher Fidelity Designs for the Aerospace Industry w/ Fluid-Thermal Structural Interaction (FTSI) Course	ONLINE (learning.aiaa.org)	
12, 13, 14 Oct	Understanding Cybersecurity in the Space Domain Course	ONLINE (learning.aiaa.org)	
12 Oct–21 Nov	Spacecraft Design, Development, and Operations Course	ONLINE (learning.aiaa.org)	
18 Oct–10 Nov	Aviation Cybersecurity Course	ONLINE (learning.aiaa.org)	
24–26 Oct	ASCEND Powered by AIAA	Las Vegas, NV	7 Apr 22
1–10 Nov	Designing Better CubeSats Using System-Level Simulations Course	ONLINE (learning.aiaa.org)	
1–10 Nov	eVTOL Infrastructure Considerations for Advanced Air Mobility Course	ONLINE (learning.aiaa.org)	
7, 8, 9, 10 Nov	Space Mission Operations Course	ONLINE (learning.aiaa.org)	
18–19 Nov	Young Professionals Students and Educators (YPSE) Conference	Laurel, MD	

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			
28–29 Nov	AIAA Region VII Student Conference	Adelaide, Australia	31 Aug 22
5–8 Dec	Practical Design Methods for Aircraft and Rotorcraft Flight Control for Unpiloted, UAV, and AAM Applications with Hands-On Training Using CONDUIT ® Course	ONLINE (learning.aiaa.org)	
2023			
15–19 Jan*	33rd AAS/AIAA Space Flight Mechanics Meeting	Austin, TX (space-flight.org/docs/2023_winter/2023_winter.html)	
21–22 Jan	6th AIAA Propulsion Aerodynamics Workshop (PAW06)	National Harbor, MD	
21–22 Jan	3rd AIAA Aeroelastic Prediction Workshop (AePW-3)	National Harbor, MD	
23–27 Jan	AIAA SciTech Forum	National Harbor, MD	1 Jun 22
4–11 Mar*	IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
24–25 Mar	AIAA Region III Student Conference	Dayton, OH	
27–28 Mar	AIAA Region II Student Conference	Knoxville, TN	
31 Mar–1 Apr	AIAA Region IV Student Conference	Las Cruces, NM	
1–2 Apr	AIAA Region VI Student Conference	Davis, CA	
11–13 Apr	AIAA DEFENSE Forum	Laurel, MD	18 Aug 22
12–16 Jun	AIAA AVIATION Forum	San Diego, CA	10 Nov 22
27–30 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
2–6 Oct*	74th International Astronautical Congress	Baku, Azerbaijan (iac2023.org)	
23–25 Oct	ASCEND Powered by AIAA	Las Vegas, NV	

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

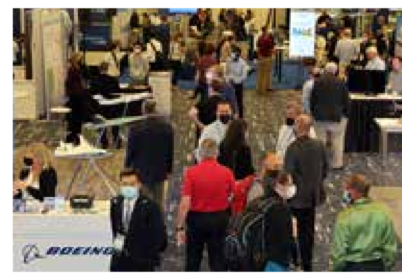
AIAA Continuing Education offerings

AVIATION FORUM

From 27 June–1 July, nearly 2,400 attendees gathered for the 2022 AIAA AVIATION Forum in Chicago, where experts from industry, government, and academia examined the theme, "Challenging Times, Unique Opportunities," and considered how to tackle the challenges around our supply chain, discussed engineering for safety, heard how the industry is transforming systems to reach net-zero by 2050, and addressed recruiting and retaining top talent for our organizations. The forum also featured nearly 1,000 presentations covering the latest aviation innovations and progress.




AIAA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MAKING AN IMPACT

2022 Scholarship and Graduate Award Winners

Each year, AIAA distributes over $100,000 in scholarships and graduate awards to undergraduate and graduate students studying aerospace engineering at accredited colleges and universities throughout the United States and overseas. In 2022, AIAA scholarship and graduate award winners came from all corners of the aerospace industry and are studying a variety of topics from digital avionics to hypersonics. Below, we profile this year's 25 scholarship and graduate award winners who are shaping the future of aerospace.

AIAA Graduate Award Winners

Neil Armstrong Graduate Award

Michelle Lin
Massachusetts Institute of Technology
Amount of Award: $5,000

Michelle is an AeroAstro Ph.D. student at MIT studying human behavioral health in Isolated, Confined, and Extreme environments. They are passionate about investigating the relationship between the human and the built environment in space, and creating functionally aesthetic architecture for a home away from home. After their Ph.D., Michelle hopes to continue studying how humans respond to stressful environments, how we can support them, and how those learnings can be translated to urban and refugee housing to improve housing equity. Michelle challenges and empowers their communities to be more inclusive and just, especially for the most marginalized populations. Michelle hopes to one day make it to Mars and live in a habitat they design.

Neil Armstrong's legacy has inspired countless across generations. I hope, even to a fraction of that legacy, to inspire those who don't see themselves represented in space exploration yet — and see that a young, nonbinary, queer immigrant is fighting for an inclusive, just, and accessible space future.

Orville and Wilbur Wright Graduate Awards

Shashank Maurya
University of Maryland - College Park
Amount of Award: $5,000

Shashank is a graduate student in the Department of Aerospace Engineering at the University of Maryland. He has been working on Aeromechanics Testing and Analysis of High-Speed Compound Rotorcraft under the direction of Drs. Inderjit Chopra and Anubhav Datta at Alfred Gessow Rotorcraft Center. His current goal is to conduct wind tunnel tests on a full compound configuration with an asymmetric wing and propeller added to the helicopter. This is a unique configuration, and it will be interesting to see the viability of such rotorcraft. The emergence of eVTOL technology has significantly boosted his interest in rotorcraft and his career goal is to work on the design and aeromechanics of eVTOLs and be a leader in this industry.

I sincerely thank AIAA for this graduate award. Recognition from such a prestigious organization is motivating and will push me further to continue my graduate research with full effort. Ph.D. research is a long journey, and things are not always smooth. Therefore, support from AIAA pushes me to go the extra mile.

Abinash Sahoo
North Carolina State University
Amount of Award: $5,000

Abinash is a Ph.D. research scholar in the Department of Mechanical and Aerospace Engineering at North Carolina State University. He works with Dr. Venkateswaran Narayanaswamy and Dr. Kevin M. Lyons in the field of combustion, high-speed flows, laser diagnostics, and atomic spectroscopy. The focus of his research is to develop diagnostic tools for 2-D temperature and species composition measurement in turbulent flames and use them to understand the combustion dynamics of ultra-clean flameless oxidation (FLOX) or the MILD (moderate or intense low oxygen dilution) combustion process. Abinash loves physics and engineering and dreams of being a good researcher and an effective science communicator. In the future, he aspires to become a faculty in a university and pursue his passion for research and teaching.

I am deeply honored to receive this award. This award inspires me to pursue my passion for research in the aerospace and energy sciences field and also boosts my confidence. This award is a reflection of all the hard work since my freshman year in aerospace engineering and is a big motivation for my future career.

Dr. Hassan A. Hassan Graduate Award in Aerospace Engineering

Brigid Donohue
North Carolina State University
Amount of Award: $5,000

Brigid is currently in school working toward a Master of Science degree in Aerospace Engineering with a focus on spacecraft systems and dynamics. She went into college undecided, but then saw Aerospace Engineering on the list of majors and hasn't looked back since. Brigid has been passionate about space exploration since she saw her first Space Shuttle launch as a kid and aspires to work in that field on innovative missions in space. She is also passionate about environmental science and astrophysics and the incorporation of those disciplines into space missions.

I am honored to have been granted this award. Receiving this award will provide funds for my education and give me the ability to focus on school and research. Achieving my degree will allow me to expand my knowledge and gain research experience to apply toward my future goals in space exploration.

Dr. Hassan A. Hassan Graduate Award in Aerospace Engineering

John Parrish
North Carolina State University
Amount of Award: $5,000

John is a prospective aerospace engineering graduate student at NC State University and is originally from Pikeville, NC. While at NC State University, he completed his undergraduate degree in the same field while conducting undergraduate research. He is also a 2nd Lieutenant in the United States Air Force who will attend Euro-NATO Joint Jet Pilot Training (ENJJPT) after completing his graduate degree. He hopes to apply his understanding of aerodynamics and cavity acoustics to flight testing.

I have a short amount of time before I must report for pilot training. During that time, I also do not earn any pay. The Dr. Hassan A. Hassan will allow me to focus more of my time and energy toward completing my graduate degree in the little time I have, while allowing me to conduct thorough research.

Luis de Florez Graduate Award

Aashutosh Mishra
Auburn University
Amount of Award: $3,500

Aashutosh is a doctoral student at Auburn University, currently working in the design, numerical modeling, and simulation of novel aircraft configurations, including urban air mobility (UAM) vehicles. He completed his undergraduate degree in Mechanical Engineering from Tribhuvan University in Nepal and joined Vehicle Systems, Dynamics, and Design Lab (VSDDL) at Auburn University to further pursue his interests in aircraft aerospace engineering as a graduate student. He aims to develop a unified vehicle design and simulation framework that incorporates assessment of aircraft stability and control in the design iteration, and in the next step, a real-time flight simulation of the developed concept can be carried out to better understand the dynamic behavior of the vehicle during flight.

It is an honor for me to get recognized for the work I have been conducting in the field of UAM vehicle model development, and I feel inspired to contribute to the best of my abilities towards connecting the gap between *a conceptual design and the actual flight through real-time flight simulation studies.*

Guidance, Navigation and Control Graduate Award

Damien Gueho
Pennsylvania State University
Amount of Award: $2,500

Damien is an aerospace engineer and a Ph.D. candidate in the CASS Lab in the Department of Aerospace Engineering at the Pennsylvania State University. He graduated from Centrale Lyon, France, in 2019 with an engineering degree and is currently working with Prof. Puneet Singla and Dr. Robert Melton at Penn State. His research focuses on a wide range of topics in data-driven analysis of dynamical systems, with particular interests for high-dimensional and complex dynamical systems, data-driven system identification, reduced-order modeling, stochastic analysis, uncertainty quantification and data-driven control. Damien wants to devote his professional life to the pursuit of novel research in the areas of data-driven analysis of complex dynamical systems, especially for space, air, or robotics applications.

I am immensely proud and would like to thank all the people — colleagues, family and friends — who have worked with me and supported me. I've found myself facing tough problems in the field of GNC and it has helped me develop a rigorous and analytical mind, studying some of the most challenging projects in engineering.

Liquid Propulsion TC Graduate Award

Tengjie Gao
Florida Institute of Technology
Amount of Scholarship: $2,500

Tengjie is an achievement-oriented doctoral researcher in the Aerospace Systems and Propulsion Laboratory (ASAP) at Florida Institute of Technology. As an interdisciplinary problem-solver and creative talent, he introduced the machine learning techniques to spacecraft propellant slosh analysis and implemented the techniques for modeling and optimization. Tengjie and his supervisors provided the lab industrial partners and technical community with a novel methodology of propellant slosh modeling for diaphragm tanks. He has also served the university as academic grader and college role tutor of aerospace engineering core courses. Tengjie's career goal is to become a leading researcher of his field of interest, leverage the wealth of knowledge and experience to support ambitious space programs, and to become one of the outstanding examples of an American Dream practitioner.

By awarding me this scholarship, I can continue the pathway to explore the knowledge of my field of interest related to liquid propulsion technology, and the expertise developed in the course of my research supported by this award may also become a valuable asset to the continued success of American space industry.

John Leland Atwood Graduate Award

Javier Viana
University of Cincinnati
Amount of Award: $1,250

Javier is a Ph.D. candidate in Explainable Artificial Intelligence at the Aerospace Engineering Department of the University of Cincinnati. His research focuses on creating novel transparent and high performing algorithms. He is currently doing research at MIT, where he designs deep neural network architectures to automate the characterization of polluted white dwarfs. Previously, Javier developed tailored AI solutions for different aerospace organizations such as Aurora, Boeing, Satlantis Microsatellites, NASA, ESA, Genexia, and CVG Airport. He has a Bachelor's in Mechanical Engineering from the University of the Basque Country, and Master's in Aerospace Engineering from the UC. His main research topics and interest include transparency in AI, deep fuzzy networks, genetic fuzzy systems, bio-inspired evolutionary optimization, and intelligent control.

Through this award I intend to raise awareness on the importance of Explainable Artificial Intelligence in Aerospace Engineering applications.

Martin Summerfield Propellants and Combustion Graduate Award

Hongyuan Zhang
University of Minnesota - Twin Cities
Amount of Award: $1,250

Hongyuan is a fourth-year Ph.D. student working under the supervision of Professor Suo Yang in the Department of Mechanical Engineering. He obtained his B.S.in theoretical and applied mechanics at Peking University, Beijing, China. He is passionate about multiphase compressible flows, turbulent combustion modeling, machine learning, and high-performance computing. His current research involves the simulation of multi-component transcritical flow. After graduation, he plans to look for a postdoctoral position and spend 1–2 years focusing on combustion and turbulence research. At the end of the postdoctoral period, he plans to look for a faculty position in a university to continue his research and start his teaching career.

This award is an acknowledgment of the efforts I have made in the past, and it will encourage me to continue and finish my work. I hope my work on developing high-fidelity CFD solvers based on vapor-liquid equilibrium (VLE) theory can provide a new tool to investigate transcritical flows and combustion.

Gordon C. Oates Air Breathing Propulsion Graduate Award

Rishi Roy
University of Maryland – College Park
Amount of Award: $1,000

Rishi is a doctoral candidate in Mechanical Engineering at the University of Maryland, College Park. His research primarily focuses on low-emission combustion using experimental diagnostics and artificial intelligence for propulsion and power generation. His experimental skills involve imaging (high and low-speed) of reacting flow fields, laser-based optical measurements, and gas analysis. Besides experiments he develops machine learning and computer vision models for parameter predictions in combustion for developing data-driven sensing techniques and autonomous experimental facilities. His interest lies in integrating data analytics to advance fundamental research in energy systems. He has authored and co-authored several peer-reviewed journals and conference articles in the field of combustion, heat transfer, and artificial intelligence areas. Besides combustion, he is interested in battery electric propulsion, and autonomous systems.

This is a huge honor for me to receive such a prestigious award from AIAA. My current research is trying to address some of the vital questions about developing efficient, near-zero-emission propulsion systems. This award will strongly encourage me to further contribute to the field of aerospace propulsion.

William T. Piper, Sr. General Aviation Systems Graduate Award

Michael S. Harwin
Florida Institute of Technology
Amount of Award: $1,000

Michael is an airline pilot employed by United Airlines and a part-time Boeing 737 simulator instructor employed by Swift Airways and International Aviation Services (IAS). He started his career at Embry-Riddle Aeronautical University where he obtained two Bachelor of Science degrees, the first in Aeronautical Science and the second in Airway Science. Michael obtained two Master's Degrees, one from Embry-Riddle Aeronautical University in Aeronautics and a second from Florida Institute of Technology in Aviation Human Factors. He was admitted to candidacy for a Doctorate in Philosophy in Aviation Sciences at Florida Institute of Technology. He plans to use his education to perform studies to enhance safety in the aviation industry.

Your achievements are only limited by what you are willing to do.

AIAA Undergraduate Scholarship Winners

AIAA Lockheed Martin Marillyn Hewson Scholarship (*New this year*)

Julianna Schneider
Massachusetts Institute of Technology
Amount of Scholarship: $10,000

Julianna is a U.S. Presidential Scholar, National Merit Scholar, Congressional App Challenge Winner, and FTC Dean's List Finalist. She led three FIRST robotics teams to win state, regional, and international awards and a team of NASA interns to publish research with the American Geophysical Union. Julianna created VoluntYOU, an award-winning, 501(c)(3)-backed digital platform that connects 500+ users to volunteering opportunities globally. She mentors NASA summer programs, Science Olympiad, and FIRST robotics programs. She conducts research on improving human-robot collaboration using a pipeline of machine learning models. Julianna is an incoming freshman at MIT who will major in AI & Decision Making. She aspires to earn a graduate degree and develop novel AI architectures that improve autonomous navigation systems throughout her career as an AI engineer.

I am thrilled to be selected as 2022 AIAA Lockheed Martin Marillyn Hewson Scholarship recipient. This *recognition not only provides financial support, but opens up new career pathways in the aerospace defense industry through which I can pursue AI engineering for application in unmanned aerial vehicles and robotics.*

AIAA Lockheed Martin Marillyn Hewson Scholarship (*New this year*)

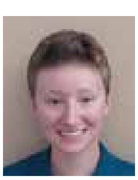
Penelope Nieves
University of Puerto Rico Mayaguez
Amount of Scholarship: $10,000

Penelope is a rising junior majoring in Mechanical Engineering at the University of Puerto Rico, Mayaguez Campus. Her plan is to continue studying after graduating with her bachelor's, to obtain a Ph.D. in Aerospace Engineering, with a minor in Astronautics. Having an immense interest in outer space from an early age, she plans to pursue a career in the aerospace industry, working with the development of rocketry technologies and space travel.

Receiving this award and being able to represent AIAA as well as Marillyn Hewson's legacy is a great honor for me. The AIAA Lockheed Martin Marillyn Hewson Scholarship will greatly enable me to pursue my dream of becoming an aerospace engineer and help develop the industry. I am profoundly grateful for all the support!

Daedalus 88 Scholarship

Rebecca Gilligan
University of Cincinnati
Amount of Scholarship: $10,000



Rebecca is pursuing a B.S. and M.S. simultaneously in Mechanical Engineering at the University of Cincinnati. She loves that engineering always presents opportunity to learn. FIRST Robotics helped Rebecca find her passion in engineering. She started a series of STEM summer camps in high school and now mentors a FIRST team. Rebecca is an Undergraduate Student Researcher at the UAV MASTER Lab, where she focuses on unmanned aerial vehicles and robotics research. She will be presenting her research project All-Terrain Aerial Robotic Interface (ATARI) at AIAA SciTech Forum. NASA's Mars program inspires her, and the challenge of space exploration fuels her excitement in robotics and engineering. Rebecca's dream is to work on autonomous vehicles research for the Mars program at NASA JPL.

I knew from a young age that I wanted to go to college and began working when I was 14 to afford it. Since then, I discovered robotics and UAVs as my passion and my way to leave an impact. This scholarship is providing me the opportunity to continue pursuing my education and get one step closer to achieving my dreams.

David and Catherine Thompson Space Technology Scholarship

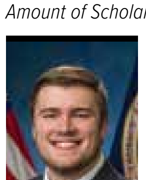
Kaila Coimbra
California Institute of Technology
Amount of Scholarship: $10,000

Kaila is a rising senior at the California Institute of Technology (Caltech) studying mechanical engineering and minoring in aerospace. After graduation, she will pursue a Ph.D. in Mechanical or Aerospace Engineering. With a doctoral degree, she plans on working in the space industry to advance space technology. Kaila is especially interested in developing technology that will advance NASA's goal of creating a sustained human presence on the moon. Because of her interest in the moon, she also aspires to become a NASA astronaut and personally conduct scientific experiments on future lunar bases. Ultimately, her main goal is to leverage her career and experience as a woman in engineering to inspire the next generation of female engineers and scientists.

I am very grateful for this scholarship and for its role in supporting my education and my goal of becoming a future aerospace professional. This scholarship validates my work as an aspiring aerospace enthusiast and gives me confidence in continuing to develop space technology for extended human presence on the moon.

Vicki and George Muellner Scholarship for Aerospace Engineering

Michael Esry
Purdue University
Amount of Scholarship: $5,000

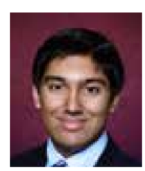


Michael is currently a senior at Purdue University studying Aeronautical and Astronautical Engineering with a specialization in Astrodynamics. He has served as the president of a fully student-run robotics team called Purdue Lunabotics. Outside of school, Michael has participated in the NASA Pathways Internship Co-op Program, spending alternating semesters working at the Johnson Space Center. Through this program, he has had the opportunity to support many different projects from the Commercial Crew program and International Space Station operations to trajectory design and orbit planning for the Artemis missions. After continuing his education to earn a masters degree in Aeronautics and Astronautics, Michael hopes to return to the Johnson Space Center to become a flight controller with the Flight Dynamics Officers and further space exploration.

I am currently funding the entirety of my education. Even with my co-op internship, it can be a challenge to afford tuition each semester. By being selected for the Vicki and George Muellner Scholarship, I am now able to pay for my final year of my degree and continue pursuing my dream to become an aerospace engineer.

Wernher von Braun Scholarship

Satvik Kumar
Georgia Institute of Technology
Amount of Scholarship: $5,000



Satvik has been fascinated with airplanes since childhood. This fascination stemmed from his yearly trips to India. His friends have always referred to him as the plane nerd. He's known that he wanted to study Aerospace Engineering since 5th grade! As he got older, he started to develop an interest in rocketry, space exploration, and vertical flight as well. He's been conducting research throughout his time at Georgia Tech as well as through his internships at NASA Ames Research Center and NASA Langley Research Center. His goal is to contribute to the aerospace field by continuing to be involved in groundbreaking research. To accomplish this, Satvik plans on attending graduate school following his undergraduate degree.

I am honored and grateful to be chosen again for the Wernher von Braun Scholarship. This recognition gives me lots of inspiration and motivation to spread my wings in unexplored aerospace research and to make a difference in the aerospace field.

Cary Spitzer Digital Avionics Scholarship

Jesus Delgado
Florida Institute of Technology
Amount of Scholarship: $3,000

Jesus is an undergraduate aerospace engineer student at Florida Tech. He joined AIAA in the fall 2021 semester and currently participates in student design teams like DBF and the Spaceport America Cup. He want to be part of a motivated group of professionals who create solutions to many of the problems we face today. His career goals consist of contributing to the future of space exploration and working on habitable space station technologies. Jesus wants to achieve a Senior Engineer position at an industry-leading aerospace company while being an active member of the aerospace community and encouraging STEM education for the next generation of scientists and engineers.

This scholarship is a blessing to my family and me because it relieves so much of the financial pressures of paying for college. It is also a great source of positive motivation to strive for success in the aerospace field and keep collecting the skills necessary to become a successful future professional.

Dr. Amy R. Pritchett Digital Avionics Scholarship

Adam Hale
Brigham Young University
Amount of Scholarship: $3,000

Aviation has always been Adam's passion. He spent years perusing piloting before deciding to build planes, not just fly them. Now he is a mechanical engineering student with an aeronautical emphasis at Brigham Young University. His interest in aerospace has led him to become president of his university's aeronautics club as well as to work in research designing aerial platforms which assist in developing navigation and control algorithms. Upon graduation, Adam hopes to work in structural design of fixed-wing aircraft in industry while pursuing a technical masters. As an upcoming engineer, he loves solving the world's most complex problems and he aspires someday to play a major role in developing technology that will impact the lives of others through aviation.

I am extremely grateful for the assistance being provided to me. Receiving this scholarship will allow me to focus on my passion for all things aerospace and prepare for life post-graduation. I look forward to being able to contribute to the field of aeronautics both now and in the future.

Dr. James Rankin Digital Avionics Scholarship

Patrick Bailey
University of South Carolina
Amount of Scholarship: $3,000

Patrick is currently majoring in Aerospace Engineering with a focus on aeromechanical systems at the University of South Carolina. Alongside his studies, he is pursuing research in composites and additive manufacturing processes such as 3D printing, carbon fiber layups, and a process called "Cold Spray." After graduating, he plans to pursue a masters in aerospace engineering followed by continuing his research and pursuing his PhD in the field of aerospace or material science. After his Ph.D., Patrick would love work in the space or hypersonics industry sectors to best apply his knowledge, and one day maybe start his own aerospace company/firm.

I am very thankful for being able to receive this scholarship because it will help to fund my education and relieves my financial burden. I can now pursue higher education to become more prepared for undertaking industry jobs and exploring my passions.

Ellis F. Hitt Digital Avionics Scholarship

Justin Self
California Polytechnic State University - San Luis Obispo
Amount of Scholarship: $3,000

In 2021, Justin graduated from Cuesta Community College with High Honors with transfer degrees in mathematics and physics while earning multiple scholarships and was awarded the 2021 Engineering and Physics Student of the Year awards. While pursuing his undergrad in Aerospace Engineering at Cal Poly, Justin is the lead researcher on an upper-atmospheric hypersonic project and has presented at several conferences. Justin plans to work with NASA on spacecraft design and mission concepts for planetary exploration and/or next-gen propulsion research. Justin, his wife Jenny, and their two sons Caleb and Joel, live in Morro Bay, CA. Justin and his family enjoy hiking and playing strategy games together. Justin also maintains a blog, a podcast, and has recently published his first book, *Face to Face* (2021).

I am tremendously thankful to the scholarship committee and the organizers of the Ellis F. Hitt Digital Avionics Scholarship for their consideration. These award funds provide not only a resource for my academic career, but a valuable and timely blessing to my family and me. We are overwhelmed by your generosity!

Denise Ponchak Digital Avionics Scholarship

Sanjay Kuruchanvalasu Jambulingam
SRM Institute of Science and Technology
Amount of Scholarship: $3,000

Sanjay is an aerospace engineer with a key interest in flight dynamics and aerospace propulsion. He is working on the flight dynamics of UAVs and his research area includes flow control methods for aerodynamic bodies and aerothermo-dynamics. His aim is to work on the new generation aircrafts and contribute his learnings toward the development of aerospace technology.

AIAA has provided me with a lot of opportunities. Earlier, I have participated in various student competitions provided by them. Now, Denise Ponchak Digital Avionics Scholarship provided great support to my undergraduate studies. Through this, I can further venture into my career goals without any economical barriers.

Space Transportation Scholarship

Rebecca Zurek
Embry-Riddle Aeronautical University - Daytona Beach, FL
Amount of Scholarship: $1,500

Rebecca is a sophomore at Embry-Riddle Aeronautical University–Daytona Beach, Florida, studying Aerospace Engineering. Rebecca has always been fascinated with space and innovation, and thrives on introducing young people to aerospace possibilities. Rebecca became the ERAU AIAA Outreach Chairperson, and is the Project Lead for Embry-Riddle's supersonic recovery systems research/development project, Project Zephyr. Rebecca will use her education and research to further the functionality and efficiency of space travel, particularly focusing on Mars and outer planets with a potential for life, security, and commerce. Currently, Rebecca works as an intern at Electra.aero designing and building electric aircraft to create more sustainable and efficient air transportation in the future. She aspires to further a world where the sky is not the limit, only the beginning.

I'm grateful for this award that enables me to continue my goal of becoming an Aerospace Engineer; developing new technologies that positively shape the future of aerospace. This scholarship enables me to continue my education, research, and passion, and prove that the sky is not the limit, only the beginning.

Leatrice Gregory Pendray Scholarship

Eszter Anna Varga
Virginia Tech
Amount of Scholarship: $1,250

Eszter is a rising senior in Aerospace Engineering at Virginia Tech, and will become the first-ever Hungarian Female Aerospace Engineer. She is a mentor and member of the New York Academy of Sciences and president of the Sigma Gamma Tau chapter. She participates in various organizations and clubs, and she also works at a makerspace. In her free time, she writes her own blog and runs a small business selling laser-cut builds. She aspires to be an aerospace engineer who promotes the importance of females in STEM and actively acts as a field advocate.

Another step in proving that you can be something you never saw. Hungary has no translation for aerospace engineering, and I will most likely be the First Hungarian Female Aerospace Engineer. Opportunities such as the scholarship allow me to continue on this path and dream.

Applications for the 2023 scholarships are being accepted from 1 October to 31 January (aiaa.org/scholarships). For more information, please visit aiaa.org/get-involved or contact Michael Lagana at scholarships@aiaa.org.

AIAA LA-LV on the Beach at the Aerospace Summer Games

In July the AIAA Los Angeles-Las Vegas (LA-LV) Section had an exhibition table at the Aerospace Summer Games, a fun, family-friendly event in Los Angeles organized for aerospace company professionals to compete in beach sport events. Courtney Best (with hat), LA-LV Young Professionals/Early Career Professionals Chair, greeted visitors to the table and introduced AIAA and the LA-LV Section to them. The visitors got to know about the Institute and membership while viewing the displayed models, receiving the cool promotional items, and chatting about aerospace news.

AIAA San Diego Section Held June Awards Gala

On 4 June, the AIAA San Diego Section held its annual awards gala for the first time in two years since the start of Covid restrictions. This annual event serves to install the new section officers, present the Reuben H. Fleet scholarship winners, and recognize local section and aerospace community award winners. The event was held at the Allen Airways Museum at Gillespie Field Airport in El Cajon. Guests had the opportunity to view the entire museum collection, including the historic aircraft, aerospace artifacts, and art during the cocktail reception. Dinner included an impromptu biplane flyby and was followed by scholarship and awards presentations. The section thanks AIAA headquarters, Allen Airways, and our local community for supporting such a wonderful event!

Braun Awarded 2022 Yvonne C. Brill Lectureship in Aerospace Engineering

AIAA and the National Academy of Engineering (NAE) have announced that Robert D. Braun, Space Exploration Sector Head at Johns Hopkins University Applied Physics Laboratory, has been selected as the recipient of the 2022 Yvonne C. Brill Lectureship in Aerospace Engineering. Braun will present his lecture, "Are We Alone? Grand Challenges in Solar System Exploration," on 4 October 2022, in conjunction with the NAE Annual Meeting in Washington, DC.

This lecture will discuss the search for signs of past or present life beyond Earth, a profound human endeavor that has occupied a place in our consciousness since humans first looked skyward. This quest requires an advance in space exploration capabilities, technologies, and knowledge that also informs our future on our home planet and the pace of human exploration beyond it. After decades of hard work, and through an interconnected set of missions, NASA stands poised to address this timeless question along multiple arcs. Braun will describe the scientific opportunities, locales, technologies, and missions from which we may advance our understanding of the potential for life elsewhere in the universe. The goals and present status of multiple astrobiology missions planned for the next decade will be highlighted.

Braun has more than 35 years of experience as a space systems engineer, technologist, and organizational leader. He has contributed to the formulation, development, and operation of multiple space flight missions and is a recognized authority in hypersonics technology and the development of entry, descent, and landing systems. Braun previously served as Director for Planetary Science at the Jet Propulsion Laboratory (2020–2022), Dean of the College of Engineering and Applied Science at the University of Colorado Boulder (2017–2020), a faculty member of the Georgia Institute of Technology (2003–2016) and a member of the technical staff of NASA Langley Research Center (1989–2003). He has served as a tenured professor at Georgia Institute of Technology, University of Colorado Boulder, and California Institute of Technology. Braun is a member of the NAE as well as a Fellow of AIAA and the American Astronomical Society. He is the author or co-author of over 300 technical publications.

AIAA, with the participation and support of NAE, created the the lectureship to honor the late, pioneering rocket scientist, AIAA Honorary Fellow and NAE Member, Yvonne C. Brill. Brill was best known for developing a revolutionary propulsion system that remains the industry standard for geostationary satellite station-keeping.

Registration for this lecture is free (aiaa.org/events-learning/events) and open to the public.

Membership Applications Open for 2023/2024 AIAA Technical Committees and Integration and Outreach Committees

The Technical Activities Division (TAD) and Integration and Outreach Division (IOD) work diligently with their committee chairs to maintain a reasonable balance in 1) appropriate representation to the field from industry, research, education, and government; 2) the specialties covered in the specific TC/IOC scopes; and 3) geographical distribution relative to the area's technical activity. TAD and IOD encourage applications of young professionals (those individuals 35 years and younger). Committees have a 50-person maximum unless approval is granted to exceed that limit. Applicants selected for membership who are not AIAA members in good standing must become members or renew their membership within 45 days of start of the membership term (1 May–30 April). If you currently serve on a TC/IOC, you will automatically be considered for the 2023/2024 membership term. Applications are submitted online. The form can be found on the AIAA website at aiaa.org, under My AIAA, Nominations and Voting, Technical Committee Online Application. Applications are due by 12 October 2022. Information about the committees can be found at:

- Integration and Outreach Committees: aiaa.org/integration-and-outreach-division-committees
- Technical Committees: aiaa.org/technical-committees

SAT OC – Continued Drive

By Amir S. Gohardani, SAT OC Chair

The AIAA Society and Aerospace Technology Outreach Committee (SAT OC) has been actively engaged in reviewing submitted abstracts for the 2023 AIAA SciTech Forum. We are delighted by the interest in our sessions and envision having a few tracks. Interested parties are encouraged to look for sessions beginning with the "SAT" prefix in the AIAA SciTech program.

During AIAA forums, the committee regularly calls for papers that examine the societal benefits of aerospace technologies/products, as well as the relationship between aerospace and society, culture, and the arts. Areas of interest include, but are not limited to:

- Group Dynamics & Societal Institutions in Isolated Communities (space settlements, Antarctica)
- Influences of Aerospace Technology on Popular Culture (art, literature, movies/TV, & music)
- Influences of Popular Culture on Aerospace Technology (i.e., science fiction as inspiration for R&D)
- Psychology, Social Psychology, Sociology, Anthropology, and Political Science Aspects of Aerospace
- Societal Consequences of United States and/or International Aerospace Policy
- Societal Impacts of Aerospace Technology and their Spin-Offs
- Societal Issues Involving the Use of Aerospace Technologies (UAS, satellite imagery, etc.)
- Sociology and Social Psychology of Aerospace Teams
- Other Topics in Society and Aerospace Technology

This committee welcomes collaboration with AIAA technical committees and other working groups and outreach committees specifically concerning the listed areas of interest.


Michelle Rouch

Michelle's piece, "Let Your Dreams Take Flight!," was featured at ArT 2022 Tehachapi, 22–24 July.

SAT OC Spotlight

We are spotlighting AIAA Associate Fellow Michelle Rouch this month. Michelle has been a SAT OC member since 2015. An engineer, illustrator, and renowned professional artist, she enjoys dedicating quality time and getting kids excited about the technical world through various STEM outreach activities. With over 20 years of experience in the aerospace industry, she has led many SAT OC arts-related efforts. In her artwork Michelle seeks to capture the emotions of people living and working in a thriving rich aerospace world on Earth and beyond. She published her first children's book, *Astronaut Al Travel to the Moon*, with author and Apollo 15 Astronaut Alfred Worden, winning a 2021 Mom's Choice Award and a 2021 Purple Dragonfly Children's Book Award. SAT OC celebrates the success of its membership and individuals such as Michelle for their dedication, skillsets, motivation, and contributions to a better future society.

Diversity Corner


Kristina J. Halona

NAME: Kristina J. Halona

NOTABLE CONTRIBUTIONS:

Kristina is an aerospace engineer and program manager, Antares Systems Engineering, at Northrop Grumman in Chandler, AZ. She received a B.S.E. degree in Aerospace Engineering from Arizona State University and an M.S.E. degree in Engineering Management from George Washington University. Kristina is originally from Sawmill, AZ, on the Navajo Reservation. She is of the Black Streak Wood People Clan born for the Folded Arms People Clan. The Bitter Water Clan is her maternal grandfather's clan and the Salt Clan is her paternal grandfather's clan.

POTENTIAL SOCIETAL IMPACT OF CONTRIBUTIONS:

Kristina has been an American Indian Science and Engineering Society (AISES) member since middle school competing in AISES science fairs, which led to AISES scholarships, internships, and leadership opportunities like serving as the AISES National Student Representative. As a professional and a Sequoyah Fellow she has been part of the AISES Professional Chapters in the Bay Area, Tucson, and Phoenix and is currently the Phoenix Professional Chapter Vice President. Kristina also currently serves on the AISES Board of Directors.

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

EMBRY-RIDDLE
Aeronautical University

Assistant or Associate Professor
AEROSPACE ENGINEERING DEPARTMENT

The Aerospace Engineering Department in the College of Engineering at Embry-Riddle Aeronautical University – Daytona Beach invites applications for several tenure-track and non-tenure positions at the Assistant or Associate Professor level. Candidates must hold a terminal degree in engineering, with preference given to those candidates who hold a Ph.D. in Aerospace Engineering. For non-tenure track positions, a Ph.D. degree could be replaced by an MS and substantial research experience. Preferred areas of expertise include: astronautics and space applications, hypersonics and air-breathing/rocket/space propulsion, experimental aerodynamics, composites and additive manufacturing. However, applicants in all areas of Aerospace Engineering will be considered.

The department seeks candidates who can expand its research expertise in aerospace engineering, as well as deliver student-centered teaching and provide mentoring to undergraduate and graduate students. Applicants should share the department's commitment to an inclusive, inviting and collaborative community. We strongly encourage individuals from populations who are traditionally underrepresented and underserved in STEM – women, Blacks, Latinx, Native Americans, persons with disabilities and persons of all gender identities and/or sexual orientation – to apply.

The Aerospace Engineering Department is the largest in the nation with an enrollment of over 2,200 full-time students. The department offers bachelor's, master's and Ph.D. degrees, including approximately 60 students in the Ph.D. program. The undergraduate program is currently ranked #5 (tied) by *U.S. News and World Report*, while the graduate program is ranked #32 (tied). To achieve national prominence, the Department has launched an ambitious agenda focused on expanding the graduate programs, facilities, recruiting talented faculty, and building research infrastructure and capabilities, In support of this agenda, the University has invested in a new 50,000 square foot engineering building, the John Mica Engineering and Aerospace Innovation Complex (MicaPlex), housing several research laboratories (**https://erau.edu/research-park/micaplex/labs**) a state-of-the-art subsonic wind tunnel, and a new Flight Research Center facility, all as part of a Research Park with incubator space and growing number of industry creating an ecosystem to support innovation and entrepreneurship. Embry-Riddle Aeronautical University has also recently received $25 Million from Philanthropists Cici and Hyatt Brown, and matching support from State of Florida to create a new Aerospace Technology Center to promote innovation, create high-quality jobs, and bolster Florida's advanced technology workforce.

Embry-Riddle Aeronautical University is the world's largest, fully-accredited university specializing in aviation and aerospace, with more than 70 bachelor's, master's and Ph.D. programs in Arts and Sciences, Aviation, Business and Engineering. The Daytona Beach Campus serves a diverse student body of approximately 8,000 students.

For more information about the position and to apply, please visit **https://careers.erau.edu**, click on the Career Search tab, and search for requisition no. R303915. Applicants must submit one single .PDF file that includes the following documents: Cover letter, Curriculum Vitae, Teaching philosophy, Research plan, The names and contact information for at least three references. Review of applications will begin in mid-September and will continue until all positions are filled. Appointments may begin in either January or August 2023. Questions about these positions may be directed to Dr. Tasos Lyrintzis, Department Chair, via email at **lyrintzi@erau.edu**. Embry-Riddle Aeronautical University is an AA/EEO employer.

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who trained with rigor and discipline above and beyond what many people thought was needed. When he was asked why he did this, he answered that because his purpose was to test experimental planes, he wanted to make sure that his body would never give out before the planes did. In other words, he wouldn't be able to know a plane's limits if somehow he broke or gave out first. The test pilot's actions were driven by his ideal that he needed to be at least as strong as the planes he flew.

If one truly wishes to be of service and give oneself to an ideal, then one must make sure that each experience is being met and responded to by the ideal, aided and not obstructed by oneself. The pilot in this example was determined to do so. On my path, I am determined to make sure that my body, mind and spirit have the capacity to do that which I am called to serve. If I don't train my body, mind and spirit, then I am not really dedicated to serve, and I compromise the ideal's ability to use me as its vehicle. Diet and exercise are not just about my body. They are about my mind, my ethos. I would not feel as confident talking on a stage or to the media if I did not work out and eat well. I would not be able to travel across the globe and get off the plane to go directly to an event requiring my full attention and engagement. It's that simple. That is how I stay centered and present. Your method might be different, but you definitely need a method.

I have lost count of the number of times I've been in the presence of those who claim to be of service but aren't really committed to it. These people often radiate anger, frustration, impatience, intolerance or apathy. Outside of aerospace, we see this distorted form of service most tragically in unjustified police shootings, when officers often have not adequately emotionally prepared themselves to set aside their egos in the service of all of us equally. In aerospace, we see this failure of service born out in less tragic form when, say, an engineer cuts corners during design and testing, extrapolating results from limited data and hoping for the best instead of being responsible and rigorous.

Alternatively, when I'm in the presence of those who have fully trained and prepared themselves to serve, their performance leaves no doubt that they're engaged in meeting their chosen purpose. Commitment to an ideal, rather than ego, drives their actions. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1922

1 **Sept. 4** U.S. Army Air Corps Lt. James H. Doolittle makes the first transcontinental flight within a single day, flying a modified de Havilland DH-4B from Pablo Beach, Florida, to San Diego. He made the 3,481-kilometer trip in 21 hours and 20 minutes, with one refueling stop near San Antonio. It was Doolittle's second attempt, as an accident had prevented the previous try. NASA, **Aeronautics and Astronautics 1915-60**, p. 15.

Sept. 14 The U.S. Army's C-2 airship takes off from Langley Field, Virginia, beginning a transcontinental flight that will establish an airship route, stimulate interest in commercial aeronautics, photograph landing fields en route and determine engine performance. The C-2 reaches Ross Field in California on Sept. 23 without incident. Gordon Swanborough and Peter M. Bowers, **United States Military Aircraft Since 1908**, pp. 630-631.

Sept. 29 Robert H. Goddard reports development of his multiple charge rocket to Charles G. Abbot, assistant secretary of the Smithsonian Institution in Washington, D.C. **Goddard Papers**, Vol. 1, p. 487.

1947

Sept. 2 A prototype of Hawker Aircraft's first jet, the Sea Hawk naval carrier-borne fighter, completes its first flight trial at Boscombe Down, England. The aircraft is powered by a Rolls-Royce Nene engine with 5,000 pounds of thrust. **The Aeroplane**, Sept. 12, 1947, p. 34.

2 **Sept. 6** For the first time, a captured World War II German V-2 rocket is experimentally launched from the deck of a U.S. aircraft carrier, the USS Midway, in the Atlantic Ocean. In addition to conducting upper atmospheric experiments, the test seeks to determine the feasibility of launching large-scale liquid-fueled rockets from a ship. However, the rocket prematurely explodes after a 10-kilometer flight. E. Emme, NASA, **Aeronautics and Astronautics 1915-60**, p. 58.

3 **Sept. 18** The U.S. Air Force is officially established as an independent service within the U.S. Armed Services. Supreme Court Chief Justice Fred Vinson swears in W. Stuart Symington as the service's first secretary. E. Emme, NASA, **Aeronautics and Astronautics 1972**, p. 320-321.

Sept. 22 A U.S. Air Force Douglas C-54 Skymaster makes the first robot-controlled transatlantic flight. The aircraft flew 3,800 kilometers from Stephenville, Newfoundland, to Brize Norton near London. E. Emme, NASA, **Aeronautics and Astronautics 1915-60**, p. 58.

Sept. 25 An Aerobee sounding rocket is launched from White Sands Proving Ground in New Mexico, the design's first test flight. The Aerobee becomes one of the most widely used sounding rockets in history. It goes through several modifications and is launched for 38 years, with the final launch occurring in 1985. The early Aerobees have solid fuel boosters and liquid sustainers with 2,600 pounds of thrust and can carry 68 kilograms of instruments up to an altitude of 80 kilometers to make astronomical and upper atmospheric measurements. E. Emme, NASA, **Aeronautics and Astronautics 1915-60**, p. 59; F. Winter, **Rockets into Space**, pp. 63-65.

1972

Sept. 2 The U.S. Navy's Triad O1-1X Transit navigation satellite launches from Vandenberg Air Force Base, California, aboard a four-stage Scout rocket. The objective of the mission is to simplify navigation procedures toward fully establishing the Navy Navigation Satellite System. NASA, **Astronautics and Aeronautics, 1972**, pp. 306-307.

Sept. 7 NASA releases three photos taken by the Mariner 9 probe that show the planet's north polar ice cap is shrinking. NASA, **Aeronautics and Astronautics, 1972**, pp. 309-310.

ALSO IN SEPTEMBER Aeronautics & Astronautics, Aerospace America's precursor, created the "Out of the Past" column, since renamed "Looking Back." Frank H. Winter of the Smithsonian National Air and Space Museum is the inaugural editor, and colleague Richard P. Hallion becomes his co-editor starting with the September 1973 issue. Hallion later departs the Smithsonian, and Robert van der Linden makes his debut as co-editor in the July/August 1981 issue.

Sept. 8-9 NASA celebrates the 25th anniversary of its Flight Research Center at Edwards Air Force Base in California. Events include an open house and a ceremony honoring the 14 original employees who had participated with the U.S. Air Force in the X-1 rocket-powered aircraft program that aimed to exceed the speed of sound in level flight. NASA Administrator James C. Fletcher presents plaques to seven of the original employees. NASA, **Astronautics and Aeronautics, 1972**, pp. 311-312. 319.

4 **Sept. 11** U.S. Air Force Lt. Gen. Samuel C. Phillips receives the Gen. Thomas D. White U.S. Air Force Space Trophy for his achievements as commander of the service's Space and Missile Systems Organization. **MSC Release** 72-197.

Sept. 13-15 NASA's Jet Propulsion Laboratory hosts the first national conference on remotely piloted systems. The applications discussed include aerial scouts that could survey Mars ahead of crewed missions and remotely piloted firefighting aircraft. NASA, **Aeronautics and Astronautics, 1972**, p. 316.

Sept. 16-17 The 25th anniversary of the U.S. Air Force is celebrated at Andrews Air Force Base in Maryland with aerial demonstrations, including midair refueling of a B-52 bomber, and other events. Static displays include an FB-111 swing-wing bomber, an SR-71 reconnaissance aircraft and a C-5 Galaxy, the service's largest aircraft. NASA, **Astronautics and Aeronautics, 1972**, pp. 319-320.

5 **Sept. 20** A Soviet Union Tupolev Tu-144 supersonic transport aircraft sets a flight time record, flying 3,000 kilometers from Moscow to Tashkent, Ukraine, in 1 hour and 57 minutes. NASA, **Astronautics and Aeronautics, 1972**, p. 325.

Sept. 20 Astronauts Robert L. Crippen, Karol J. Bobko and William E. Thornton emerge from a Skylab simulator at what was then called NASA's Manned Spacecraft Center in Houston. The astronauts have been isolated since July 26 to conduct Skylab medical experiments at simulated altitudes. **Chicago Tribune**, Sept. 21, 1972, p. 1.

Sept. 22 The Skylab Orbital Workshop arrives at NASA's Kennedy Space Center in Florida ahead of its May 1973 launch to low-Earth orbit. **New York News**, Sept. 23, 1972.

Sept. 22 The National Aeronautics Association announces FAA Administrator John H. Shaffer is the 1972 recipient of the Wright Brothers Memorial Trophy for his "outstanding leadership of the worldwide operations of the FAA, which has greatly enhanced all aspects of U.S. aviation to the benefit and safety of the general public and of all who fly." **Washington Post**, Sept. 23, 1972, A22.

Sept. 28 A rollout ceremony for the second Anglo-French Concorde supersonic airliner is held in Toulouse, France. Inaugural passenger flights are scheduled to occur in the next few weeks. **New York Times**, Sept. 29, p. 9.

6 **Sept. 29** Canada celebrates the 10th anniversary of the launch of its first satellite, Alouette 1, with special ceremonies highlighted by the opening of a new

Spacecraft Assembly and Test Facility at the Communications Research Center near Ottawa. Communications Minister Robert Stanbury notes that Alouette 1 is the "oldest satellite still sending back useful information from space." NASA, **Astronautics and Aeronautics, 1972**, p. 328.

1997

7 **Sept. 7** The Lockheed Martin F-22 Raptor, the U.S. Air Force's next-generation fighter, makes its first test flight. Plans call for the Air Force to acquire 339 of the stealthy Raptors to replace the McDonnell Douglas-built F-15. The Raptors, which are scheduled to enter service in 2004 or 2005, incorporate many advances, from their all-weather radar to their Pratt and Whitney turbofans engines with 40% fewer parts than predecessors. **Aviation Week**, Sept. 15, 1997, pp. 22-24.

8 **Sept. 11** The Mars Global Surveyor enters orbit around Mars. There is an incomplete deployment of one of the spacecraft's solar panels, which later shortens the mission. The orbiter ceased communication with Earth in 2006, at which point it had returned about 240,000 images. **Aviation Week**, Sept. 15, 1997, pp. 25-26 and Nov. 17, 1997, p. 36.

Sept. 25 Russia's Sukhoi S-37 turbofan-powered experimental forward-swept-wing fighter makes its first test flight at the Zhukovsky test site near Moscow. It is considered a fifth-generation fighter. **Aviation Week**, Nov. 10, 1997, p. 46.

Also in September A laser-powered launch vehicle model about 10 centimeters in diameter makes a 2-meter free flight at White Sands Missile Range, New Mexico. Developed by the propulsion directorate of the U.S. Air Force Research Laboratory, the technique is still in its infancy but could significantly reduce the cost of access to space. In the test, a ground-based pulsed laser is beamed to a reflector at the rear of the vehicle. **Aviation Week**, Sept. 29, 1997, p. 15.


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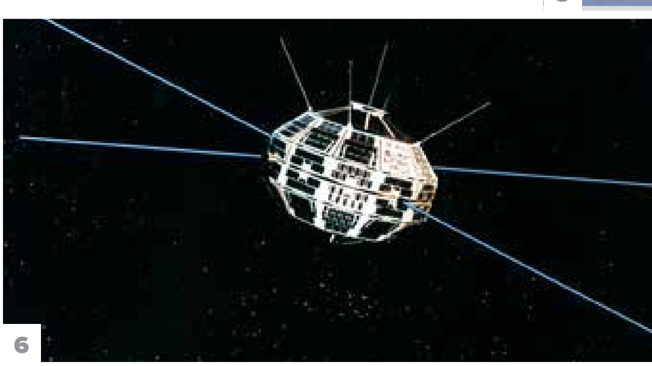
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Training to serve means more than building a skill set

BY MORIBA JAH | moriba@utexas.edu

Those who have fully committed themselves to being of service to humanity do more than just show up for duty. Whether they are scientists and engineers in the aerospace field, or first responders and religious leaders, each brings their mind, body and spirit to bear.

One's mindset is the starting point for this preparedness. In my career as a space environmentalist at the University of Texas at Austin and Privateer Space, the company I co-founded last year, I have come to view myself as a servant. The servant's ethos has become my essential guide. I know I must prepare myself above and beyond any requirements or expectations spelled out anywhere, and I must do what I can to keep my ego in check. I prepare by training — learning about a given space operator's societal culture, perhaps, or taking an online course — and also by making myself mentally, emotionally, physically and spiritually fit.

All this can, of course, be easier said than done.

On the matter of ego, the ideal that underlies a particular form of service must determine how one responds to a particular scenario as you perform that service. In essence, the ego must allow the ideal to choose the response to each instance, and it is then one's task to simply get out of the way and not allow the ego to obstruct. Yes, I'm attributing a sort of intelligence or sentience to an ideal. As an example, if you're a first responder, it is the drive from deep within you to help others that drives you to the edge of the possible and, some might say, into the realm of the miraculous. So giving oneself to serve is channeling this energy effectively, allowing it to interact with the world in the least hindered way possible.

Friends and co-workers often ask why in my diet I avoid sugars and focus on perishables and why I run daily. These questions always remind me of a story I heard years ago about a test pilot

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Moriba Jah is an astrodynamicist, space environmentalist and associate professor of aerospace engineering and engineering mechanics at the University of Texas at Austin. An AIAA fellow, he's also chief scientist of startup Privateer and hosts the monthly webcast "Moriba's Vox Populi" on SpaceWatch.global.