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MEGA

...to represent the tonnage from the coming megaconstellations. Learn about the risks. PAGE 34

A giant leap for **SPACE TOURISM?**
PAGE 18

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A cargo spacecraft burns up as it enters the atmosphere over the South Pacific Ocean in a photo taken by an astronaut on the International Space Station in 2014.
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JULY/AUGUST 2021,
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AIAA
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IN THIS ISSUE

Cat Hofacker

As our staff reporter, Cat covers news for our website and regularly contributes to the magazine.

PAGES 10, 18, 22

Moriba Jah

Before becoming an associate professor at the University of Texas at Austin, Moriba helped navigate the Mars Odyssey spacecraft and the Mars Reconnaissance Orbiter from NASA's Jet Propulsion Lab and worked on space situational awareness issues with the U.S. Air Force Research Laboratory.

PAGE 64

Paul Marks

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

PAGE 34

Alyssa Tomlinson

Alyssa has been a science writer for nearly a decade, covering unmanned aircraft systems research and aerospace engineering, as well as civil and transportation engineering.

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DEPARTMENTS

Daredevils vs. entrepreneurs

The buzz over the upcoming Jeff Bezos flight might remind boomers like me of a certain "stunt performer," as Wikipedia calls him, whose attempt to cross the Snake River Canyon in a rocket-propelled motorcycle failed dramatically, but not tragically, in 1974.

The atmospherics in the present buildup might feel roughly reminiscent, but Bezos is no Evel Knievel and Blue Origin's long road to launching New Shepard with people suggests hardier preparations than those on Knievel's Skycycle X-2, whose drogue parachute deployed early, leaving the daredevil and his vehicle tumbling to the canyon floor.

Exactly how risky will the Bezos flight be? That's hard to judge, because, without tax dollars and American prestige at stake, Blue Origin has not been forced to be transparent about its engineering and testing. However, the timeline Aerospace America assembled, "Key moments in the race," Page 18, gives a sense of the work that has gone into creating New Shepard and building confidence in the capsule and rocket. As Bezos has said repeatedly, the company's belief is that "slow is smooth, and smooth is fast," in a version of the adage attributed to the U.S. Navy SEALs. Bezos might be part showman, but he's mostly a businessman.

The July 20 flight will mark the 16th time a New Shepard rocket and capsule have left the ground. That's not many flights, given the human stakes, but one could argue that the testing over the years reflects more caution than NASA has shown at times. The first time NASA's Space Transportation System left the ground in its entirety was with astronauts John Young and Bob Crippen aboard in 1981. The space shuttle's successor, the expendable Space Launch System rockets, will carry a crew on the vehicle's second launch, after a test launch scheduled for November that was preceded by static engine firings and live tests of the capsule abort rocket motors.

Maybe most significantly, the business and societal stakes of the New Shepard launch are far richer than those of Knievel's flight. This mission is not just about ego, though one would expect the world's richest man to have plenty. The path to extending our Earthly societies into space probably will be cleared by billionaires, millionaires and space tourists. Success could mean acceleration of that.

On another level, a smooth mission also would be vindication for the Bezos strategy, which is distinct from those of his competitors in various ways. The New Shepard design of a capsule on top of a rocket is nothing like Richard Branson and Virgin Galactic's rocket-propelled, runway landing spacecraft. Blue Origin's business model is nothing like Elon Musk's strategy of building confidence in SpaceX by first launching cargo, then professional astronauts and, soon, paying customers.

So, here's hoping that on July 20, Bezos and his fellow passengers share something else in common with Knievel: that they all walk away. But this time, after making history. ★

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

Assessing work performance

The May issue had an opinion piece, "The price of passion," that concerns me, because it could give a young engineer or engineering student a wrong impression about our industry and how their job performance will be assessed. The article opens with a statement that passion is a factor and makes other similar statements and conclusions that weren't true based upon my 34 years of working in the industry. In my experience, work performance was based upon whether assigned tasks were completed to quality and timing standards and how well we worked with others. I doubt a personnel department would allow you to be judged on anything else. Having said that, your attitude is recognized by teammates, team leaders and supervisors. If you are working for a company or on a project that is not inspiring you to do your best, then you are doing a disservice to your professional reputation and to the users of the system you are working on. The author mentions unwillingness to work overtime could be held against you. Not all engineering jobs have normal work hours. If working overtime is an issue for you, then that needs to be discussed upfront at the job interview. If the overtime requirement is project specific, then it needs to be discussed with your supervisor before accepting the assignment.

Kevin L. Smith, AIAA senior member
California, Maryland

The time for full reusability

People often confuse full reusability with "aircraft-like" operations ["Why it's time to reach for full reusability," May]. Getting to space is still hard. We should not expect that launch vehicles will operate like aircraft for a long time. In my April 1997 article with Len Cormier in Aerospace America, we pointed out that partly reusable vehicles make a lot more sense, and the physics have not changed. We can reasonably easily reuse a booster stage. We can also return spacecraft from orbit, which is needed for return payloads, especially people, and reuse of these spacecraft is a reasonable consideration. It is the upper stages, especially large tanks, that make little sense to try to reuse. There is a significant payload penalty for adding reuse to these upper stages, and the value for reuse is less than for larger boost stages and spacecraft. Until we have used partly reusable vehicles for a while and increased the traffic to orbit, spending on fully reusable vehicles will not be justified.

James A. Martin, AIAA associate fellow, emeritus
Huntington Beach, California | jamesamartin5@outlook.com

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Professor, Department of Aerospace Engineering, University of Michigan

WILL ROPER

Former Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics

PROGRAM HIGHLIGHTS

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Monday, 2 August 2021

Technologies to Reshape Aerospace
Tuesday, 3 August 2021

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Wednesday, 4 August 2021

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Friday, 6 August 2021

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Accelerating the Pace of Progress

Solving challenging problems is the legacy we have received from the nearly 90 years of AIAA members who have come before us. They have developed the technologies and solutions enabling global commercial air travel, human exploration of low Earth orbit and the moon, missions across our solar system and beyond, and secure defenses necessary for our way of life. In short, AIAA members have been essential in the rapid technological progress since Kitty Hawk.

As the aerospace industry continuously and rapidly evolves from a primarily government-driven enterprise to government- and commercially-driven activities, AIAA and its members continue to tackle the technical challenges, providing critical solutions that help solve the problems of tomorrow and assuring society's future. The new ingredient needed is working at ever higher levels of systems integration and application. We must build upon our technical discipline foundation with systems thinking to accelerate our progress.

AIAA has the passionate members, the encouraging external stakeholders, and the tools to enhance dramatically the Institute's impact across the aerospace industry and profession. AIAA can and will continue to fulfill our mission of helping our members and their organizations succeed.

By focusing on the key priorities and issues across aeronautics, research and development, and space, AIAA visibly addresses the problems of today, tackling hurdles and building future aerospace systems for society. AIAA has added to its strong technical foundation the ability to address adjacent technologies, adjacent markets, economic and business aspects, policy considerations, and has developed the connective tissue to bring all of these talents and skills to bear.

Today is an increasingly innovative time in the aerospace community – led by the dedicated and passionate involvement of AIAA members. The wide commercialization of several technologies is here, or imminent:

- Electric aircraft are being developed with reduced carbon emissions.
- Autonomous air taxis are being built for more efficient transportation.
- Supersonic and hypersonic commercial aircraft are in development and already being sold.
- Hypersonic technology is being used to protect our society's way of life.
- Vehicles are flying on Mars.
- Sustainable operations on the moon are being planned.
- More in-depth exploration of our solar system and beyond is scheduled.

In the history of flight, never has there been this much new, creative, and innovative activity across aerospace. Based on a soon-to-be-released AIAA study on the state of the aerospace industry, more than 70% of respondents are excited about opportunities in space exploration, artificial intelligence/machine learning, and advanced manufacturing. This varied perspective on innovation requires us to address key needs and priorities to make progress at the pace required to accelerate the innovation. AIAA sees three areas of focus: aeronautics, R&D, and space.

- *For aeronautics*, there clearly is a need to address carbon emissions, autonomous flight and operations, a return to prepandemic commercial air travel levels, and the development of supersonic/hypersonic commercial air travel.
- *For R&D*, we must invest in advanced manufacturing, artificial intelligence, machine learning, cybersecurity, and many more areas to stay on the cutting edge. New technologies are needed for the future, new systems solutions are essential to continue improving our way of life.
- *For space*, key issues are developing the low Earth space economy, addressing space traffic awareness and coordination, developing the technologies and operations for human return to the moon for the long term, and continuing exploration of the solar system and beyond.

The essential cross-cutting AIAA efforts – particularly in terms of workforce development and diversity, equity, and inclusion – are critical to success across aeronautics, R&D, and space. We need to include diverse perspectives and bring new people into the profession to benefit from and reflect the richness of society. The U.S. aerospace industry faces an aging workforce, gender gap, lack of diversity, and significant hiring and retention challenges. Our industry needs more STEM-literate students readily adaptable to rapidly changing challenges and technologies.

AIAA is committed to solving the problems, developing new ideas, and applying technology in creative ways to shape the future of aerospace and build a better future for everyone. ★

Dan Dumbacher
AIAA Executive Director

Join us at 2021 AIAA AVIATION Forum and 2021 AIAA Propulsion and Energy Forum where you can keep the discussion going to make the progress needed, collaborate across industry sectors, and gain insight into other communities. Register at **aiaa.org/virtualforums** for one forum and receive access to both. See you there.

AERO PUZZLER

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

Claiming an aviation first

Q. You're a college student taking a test in a history of aviation course. An essay question asks who the first U.S. naval aviator was and the circumstances of his first flight. You write Eugene Ely for his 1910 and 1911 takeoffs and landings on a ship. Your professor writes that your answer is debatable and marks it as incomplete. How will you revise your answer?

Draft a response of no more than 250 words and email it by noon Eastern July 24 to aeropuzzler@aiaa.org for a chance to have it published in the September issue.

FROM THE JUNE ISSUE

A MATTER OF PERSPECTIVE: We asked you what a former space flight controller and friends saw to make the controller point to the sky and say, "Whoa, look at that jellyfish!"

WINNER: They are seeing a rocket being launched to orbit. The red-to-blue snake-like trail shows the fumes from the spent first stage booster. This trail is being blown by upper atmosphere winds and has its color like a rainbow in the sky due to the low sun angle shining through the atmosphere. The bright white light is the nozzle of the second stage as it is firing to make orbit, and we are looking at the nozzle as it is flying away and heading to go over the horizon. The round shell-like faint shape is the exhaust from the second stage as it is expanding in the near vacuum of space. The controller calls it a jellyfish in the sky because of the way it looks as the trail of it is blown by the upper atmosphere winds, and he knows that would get the attention of the three marine scientists.

Mike Helton, an AIAA senior member, is a retired risk manager on government programs. He lives in Rockville, Maryland. mr.helton@verizon.net

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

Photos by NASA

NASA's "red-letter day"

Like a high-priced athlete determined to rise from the developmental league, NASA's first Space Launch System rocket is starting to look formidable in the Vehicle Assembly Building at Kennedy Space Center in Florida, the same building where the space shuttles and Apollo rockets were once readied for launch.

In June, after lowering the SLS core stage between its two solid rocket boosters and bolting them together, technicians from NASA and its contractor Jacobs turned to the finer points of preparing the expendable rocket for the design's uncrewed debut no earlier than Nov. 22 for the Artemis lunar program.

The conical Launch Vehicle Stage Adapter was stacked on top of the core stage to be followed by the liquid-hydrogen-fueled Interim Cryogenic Propulsion Stage, whose single engine must propel Orion and its solar panel-equipped service module on a flyby of the moon to within 100 kilometers of the surface and then, with the aid of lunar gravity, out to a distance of 70,000 kilometers beyond the moon. Next will come the Orion Stage Adapter, an aluminum ring fitted with a composite diaphragm to prevent hydrogen gas from the upper stage from building up beneath the European-supplied service module and Orion crew module. Those will be stacked last and topped with the Launch Abort System motors, bringing the height to 98 meters. The 26-day Artemis 1 mission will end with the Orion crew capsule splashing down in the Pacific Ocean, as though it were bringing astronauts home from the moon.

A successful test, says NASA Administrator Bill Nelson, would be a "red-letter day" for the agency and the $28 billion, four-years-late SLS program. See Q&A, Page 10. ★

— Ben Iannotta

YOU SHOULD KNOW

- Artemis 1 was formerly called Exploration Mission-1
- Launch date: Nov. 22 is the "earliest possible date" and is for "planning purposes," says NASA.

WHO MAKES WHAT

CORE STAGE: Boeing (contains four RS-25 engines, flown previously on space shuttle missions, built by Aerojet Rocketdyne).

SOLID ROCKET BOOSTERS: Northrop Grumman

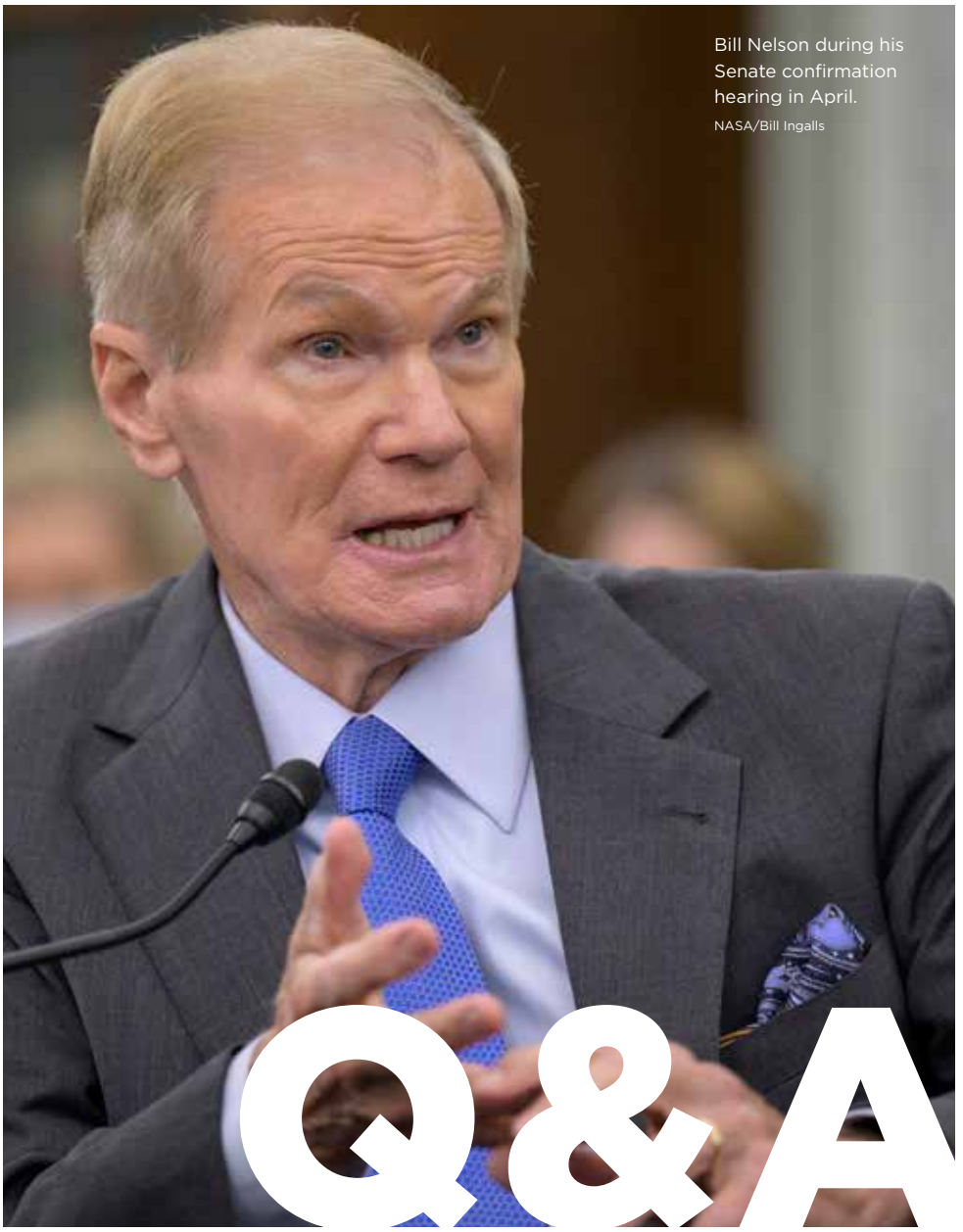
LAUNCH VEHICLE STAGE ADAPTER: Teledyne Brown Engineering

INTERIM CRYOGENIC PROPULSION STAGE: Boeing and United Launch Alliance (powered by a single Aerojet Rocketdyne RL-10B2 engine, like those on Delta IV second stages).

ORION STAGE ADAPTER: NASA's Marshall Space Flight Center

SERVICE MODULE: European Space Agency and Airbus

ORION CAPSULE: Lockheed Martin



Bill Nelson during his Senate confirmation hearing in April.
NASA/Bill Ingalls

Meet the new boss

After years of shaping NASA's priorities as a member of Congress, Bill Nelson must now steer the agency through what might be its greatest budget challenge yet. Plans call for proceeding with the multibillion-dollar Trump administration goal of returning astronauts to the moon in 2024 while also making climate research a "substantial" focus by starting development of the first of five planned Earth System Observatory satellites, all amid continuing robotic space missions and aeronautics research. To accomplish all this, the White House in May requested $24.8 billion for NASA in fiscal 2022, a 6.6% increase over what Congress appropriated for the current year. Now Nelson has the opportunity to explain to his former lawmaker colleagues how NASA will balance these competing priorities. I spoke with him in June via phone from his office at NASA Headquarters in Washington, D.C. Here's our condensed and edited conversation. — *Cat Hofacker*

BILL NELSON

POSITIONS: NASA administrator since May; U.S. senator from Florida, 2001-2019, and top Democrat on the Senate Commerce Committee that authorizes NASA programs, 2015-2019; in the U.S. House of Representatives, represented districts adjacent to NASA's Kennedy Space Center, 1979-1991; chaired the space subcommittee of the House Science Committee for six years.

NOTABLE: After completing astronaut training for those outside of the space program, became the second sitting member of Congress to go to space, flying aboard space shuttle Columbia in 1986 as a payload specialist conducting medical experiments. Ten days after Columbia landed, shuttle Challenger exploded, killing all aboard and prompting NASA to end its practice of sending those from other professions to orbit. As a senator, co-authored with then-Sen. Kay Bailey Hutchison, R-Texas, the NASA Authorization Act of 2010 that, among other provisions, directed the agency to design and build "a Space Launch System" rocket for deep space missions, to be ready by Dec. 31, 2016.

AGE: 78.

RESIDENCES: Orlando, Florida; Arlington, Virginia.

EDUCATION: Bachelor of Arts in political science, Yale University, 1965; Juris Doctor, University of Virginia School of Law, 1968.

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Q: During Administrator Jim Bridenstine's confirmation hearing, you were hesitant that a politician was the best choice to lead NASA. When President Biden called in January, what did he say to change your mind and get you to accept the nomination?

A: Fortunately, I've been a part of the NASA family for quite a while. I came to Congress in 1978, was assigned to the House Science Committee. Six years later, I'm the chairman of the space science and applications subcommittee [now called the House Subcommittee on Space and Aeronautics]. It was in that role as chairman that I was selected to train and fly with the crew of the 24th flight of the space shuttle. Then in the Senate, likewise having been either the chairman or the ranking member — depending on what party had the majority of the Senate — of the space subcommittee for almost all of my 18 years in the Senate, and then the last four years being the ranking member of the full Senate Commerce Committee. So when you have that kind of experience, it's been a privilege for me to be a part of the NASA family.

Q: The fiscal 2022 budget request would increase funding for almost all NASA programs across the board. How does that align with the priorities of the Biden administration?

A: The president has a number of major focuses. Climate change is clearly one of them, and that is reflected in the budget that they put out. There will be substantial work that will be done by NASA on climate change, but the president also has lots of other priorities. He wants to emphasize American jobs from research and development, which NASA is uniquely capable and positioned to do. The president wants to get a workforce that is the kind of workforce that we need for the 21st century, such as in STEM: science, technology, engineering, mathematics. You will see that as a major effort for NASA as well. Remember, the previous administration, they would zero out the STEM part of NASA [the Office of STEM Engagement] and the Congress would always restore it. The president also wants the federal workforce to be reflective of the American people in its diversity and inclusion, and we have that going as well. And then NASA has this unique role of helping the United States government project soft power because of the respect and the identification of NASA by people all over the Earth. A lot of that comes from the gee-whiz stuff that we do, not only in Earth science and planetary science — notice the enthusiasm all over the Earth about little Perseverance and the little helicopter — so not only in the direct sciences, but also in the exploration program, and it's not lost on many people that NASA is going back to the moon and on to Mars. And then finally, even another part of climate change is the first A in NASA, which is aeronautics. What you see there is NASA's developing an electric airplane, the result of which will be another way of diminishing pollution in the air that ultimately is causing a greenhouse effect in the Earth.

Q: The aeronautics directorate has historically gotten only about 3.5% of NASA's budget. Should aeronautics funding be increased, given the urgent need to help the aviation industry meet its portion of achieving carbon neutrality by 2050?

A: I'm not sure that I can answer the question about the money, at this point, but an example of NASA's contribution is the X-57, an all-electric experimental aircraft. There's one version now; they will then go into a different version that is more advanced. The one that they have now is scheduled for launch later this year, and we are working on the standards for electric aircraft, which could have a profound effect on air transportation, but it's in the research stage. I'd also call your attention to a study that had been done over the last three years at the Charlotte airport in North Carolina. It is complementary to what is well underway, the setting up of the next generation of air traffic control that involves NASA and FAA. What that does is get the aircraft routed, operating off of satellites instead of the traditional radar and voice system that we have, so that you can have a lot more efficient routes, as well as descending into airports and save a lot of time and fuel. And what NASA did at the Charlotte airport over the last three years, they said, "Let's see what we can do in the operation of aircraft from pushing off at the gate to the runway, and then getting to altitude." And what they found, they could save a million gallons of fuel and, gosh, you had millions of pounds of carbon dioxide that were saved; you had thousands of hours of engine runtime, that affected maintenance. So you had fuel savings, emission savings and maintenance savings, all done by this pilot study.

> "SLS is the largest, most powerful rocket ever. Needless to say, that will be a red-letter day."

Q: Given the number of obstacles facing the country, including recovering from the covid pandemic and reducing greenhouse gas emissions, can you make the case for keeping the 2024 goal of landing on the moon?

A: The goal is 2024. Space is hard. And when you develop the technologies to keep humans safe in that environment, often you run into, as history would tell us, delays. So I think we have to be soberly realistic, but the goal is 2024.

▲ The James Webb Space Telescope was scheduled for launch on an Ariane 5 rocket on Oct. 31, but the date has been pushed out to mid or late November. "In the big scheme of things, that's not very much" of a delay, says NASA Administrator Bill Nelson. In this photo, Webb's 6.5-meter primary mirror is deployed at Northrop Grumman in California in 2020.

NASA

Q: One possible delay is if the U.S. Government Accountability Office upholds the protests on the lunar lander award. Would that put a 2024 landing out of reach?

A: We already have a delay because of everything being on hold for a hundred days. So that's my answer, and I will answer your question once I know what the result of the decision is.

Q: Two big flagship missions are scheduled to launch this year: the Space Launch System and the James Webb Space Telescope. Given the delays both programs have had over the years, how confident are you that they will launch in 2021?

A: I'm confident. SLS is the largest, most powerful rocket ever. Needless to say, that will be a red-letter day. On Webb, I'm feeling good. I've seen some press reports. They make a big deal about another delay. The delay has nothing to do with NASA. It's only a couple of weeks, and it's because of the throughput at the French space center that they can only prepare the Ariane rocket one at a time, because you only have one building and they've got two other Ariane 5 launches before the James Webb. So their work throughput in that building is what they're anticipating. That's going to delay the Webb launch two weeks, but in the big scheme of things, that's not very much.

Q: NASA and European Space Agency officials have also attributed the delay to ongoing reviews of the Ariane 5 because of an unspecified issue with the payload fairing. How are you feeling about the rocket?

A: I've talked to Dr. Z [Thomas Zurbuchen, head of NASA's Science Mission Directorate] and I rely on his judgment.

Q: And speaking of 2024, Congress has only authorized the International Space Station through that year. What's the status of the extension?

A: When I was in the Senate, Sen. Ted Cruz, R-Texas, and I passed the NASA bill in the Senate, extending ISS to 2030. I am very optimistic that the Congress will pass and extend it this year to 2030; that is in the NASA authorization bill that passed the Senate in June, and I believe that the House will agree with that.

Q: In parallel, NASA is requesting $101 million to help develop privately owned space stations, but

▲ The electric X-57 Maxwell is an example of NASA's work developing carbon-neutral aeronautical technology, Nelson says. Here the aircraft undergoes testing at NASA's Armstrong Flight Research Center in California in May, ahead of its first flight, scheduled for later this year.
NASA

Congress last year underfunded that request. How are you making the case to lawmakers so you'll get the funds this year?
A: With regard to a low-Earth-orbit commercial follow-on, I've already talked extensively to the people on the Hill about NASA's position that we want the commercial industry to be ready to go with their own space station when the ISS would be shut down after 2030.

Q: Also looking to the future, do you foresee the day that NASA won't need its own rocket and can instead purchase rides on commercial launch vehicles for all its missions?
A: Eleven years ago, when Kay Bailey Hutchison and I wrote the bill that set NASA on the course it's on now, the anticipation was "get the commercial industry into low-Earth orbit and get NASA out of low-Earth orbit and go explore." What we have seen is the capability of extraordinary things being done just in the commercial world, which leads to your question and the answer to your question. There's always going to be a need for a government space program with government vehicles, with NASA vehicles, the commercial world on contract with NASA to produce the vehicles. Why this is important for the future: as we venture farther out with humans into the cosmos, NASA has to be involved in that because of the safety of astronauts and the cutting-edge and very expensive technologies that it's going to take to take a human crew all the way to Mars. Depending on the transit time, it could be as long as a total of three years. Therefore, I envision a combination of commercial and NASA, but when it comes to the human exploration, I think NASA will continue to be very heavily involved.

Q: Fast forward 50 years: How do you think NASA's role will continue to change as the private space industry keeps growing?
A: I'll give you an example. I think it's going to take NASA — as we have already demonstrated — to go to an asteroid and bring material from the asteroid. That's going to give us all kinds of science and understanding of the origin of the cosmos. But I see private industry eventually, with NASA's help, getting to an asteroid and doing mining on an asteroid that would have rare metals, rare materials. So I think it will be a joint partnership in some cases. We've already seen technology dramatically change since Kay and I wrote the bill, so stay tuned. ★

How's the weather on Mars?

On Earth, explorers centuries ago were probably confident about the range of bad weather they'd encounter along their journeys. Future Mars explorers cannot yet say the equivalent. That's why NASA and others have adopted a strategy of sending weather sensors ahead of the humans. Anni Torri, a senior scientist at Vaisala, the Helsinki-based measurement company, explains what it takes to make a weather sensor space-proof.

BY ANNI TORRI

▶ Humidity sensors onboard the Perseverance rover, like this one in the lab, have returned data indicating that the relative humidity is practically zero in Mars' Jezero Crater during the day, and it rises at night when the local temperature falls.

Vaisala

We will likely see explorers walk on Mars someday, but before that can happen, mission planners must accurately anticipate the weather conditions those explorers are going to face. Procedures and equipment can then be created that will empower them to endure those conditions. Right now, we know a lot about Mars. It once had flowing water, more benign temperatures and a much thicker atmosphere. Today, there are polar ice caps consisting of water ice with a layer of dry ice (carbon dioxide) on top. The planet's atmosphere is composed of 96% carbon dioxide and the surface pressure is only about 1% of Earth's. The summer temperatures at the equator can rise to 20 degrees Celsius, but the nighttime temperatures can drop to minus 70, and even lower. Mars also has seasonal variations, and in the winter the temperatures can go as low as minus 130. There are also frequent dust storms and, in some years, global dust storms that cover the entire planet.

We have a picture of Martian weather through data from the Curiosity rover, but not one that's refined enough to which human lives can be entrusted. Therefore, NASA and other organizations are developing a network of weather stations that will give experts a comprehensive picture of the dynamic atmospheric conditions on the red planet long before humans set foot there.

One node in this emerging network is the Mars Environmental Dynamics Analyzer, or MEDA, a 5.5-kilogram suite of weather instruments inside NASA's Perseverance rover.

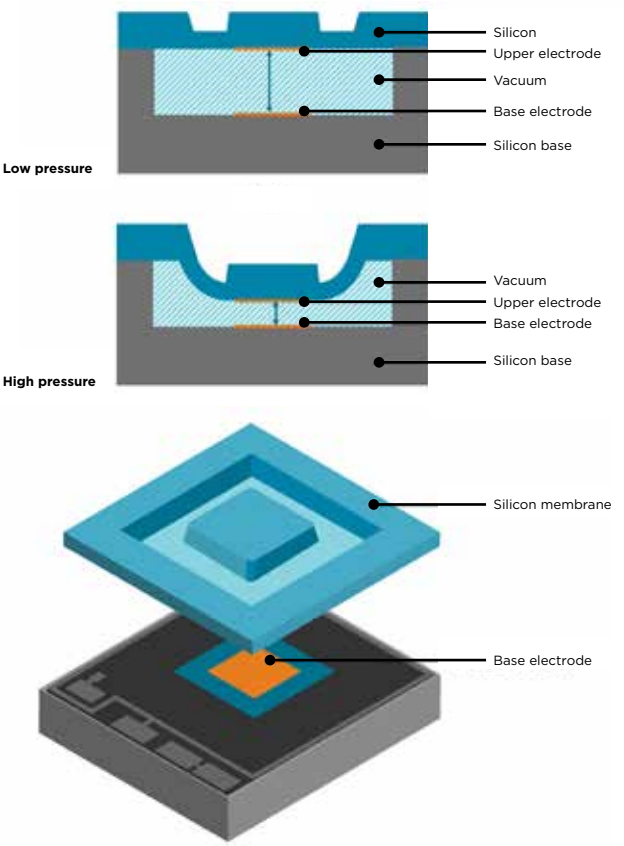
Among them are a barometric pressure instrument and a humidity instrument, designed by the Finnish Meteorological Institute, FMI. Both instruments carry Vaisala sensors.

FMI and Vaisala have worked together for

Performing under pressure

When NASA's Perseverance rover touched down on Mars in February, it carried a 5.5-kilogram suite of sensors to measure wind speed, temperature, humidity and barometric pressure. The pressure sensor, BAROCAP, includes a silicon membrane that flexes according to atmospheric pressure, which increases or decreases the height of a vacuum gap in the sensor. Pressure changes also prompt fluctuations in the strength of the electric charge generated by electrodes on either side of the vacuum, which are then converted into pressure readings.

SOURCE: Vaisala



30 years on space exploration projects, including a similar endeavor for the Curiosity rover and other missions, so the collaboration was a natural choice. Before heading to space, these humidity and barometric designs were rigorously tested during manufacturing, in the lab and in the field in the most extreme environments on Earth, from the Sahara Desert to the Antarctic.

Consider the design of Vaisala's HUMICAP humidity sensors. Each rectangular device about the size of a pencil eraser measures relative humidity via a thin-film polymer that absorbs water molecules. When Vaisala introduced the design in the 1970s, it was the first of its kind for measurements on Earth let alone the surface of another planet.

HUMICAP's applications on Earth are many. The sensors are released into hurricanes inside dropsondes. They measure humidity inside vaccine labs and production facilities, and they help keep some of the world's most famous works of art in peak condition. HUMICAP's design was proven on Earth in so many challenging conditions that no tweaks were required for the Mars version, which continues to dependably report data on the planet's humidity.

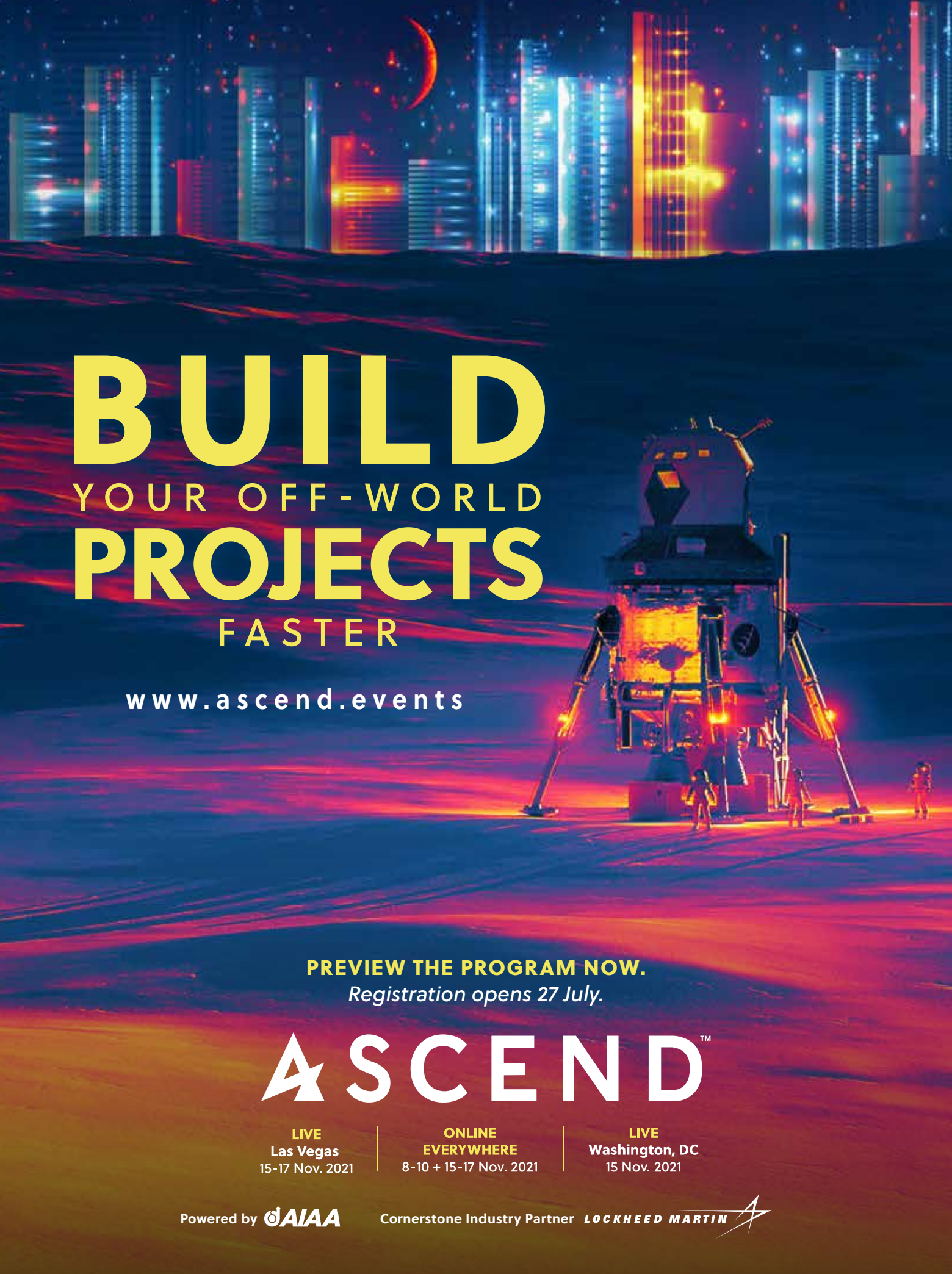
The story was different for the Martian version of Vaisala's BAROCAP pressure sensors, which like the Earth versions, were first released in 1985. BAROCAP sensors are square micromechanical devices no bigger than a fingertip that measure dimensional changes in a silicon membrane to deduce air pressure. Because the pressure is so much lower on Mars than on Earth, Vaisala had to make the silicon membrane thinner in order to record accurate measurements. The BAROCAP sensor's properties — good elasticity, low hysteresis, excellent repeatability, low temperature dependence and superior long-term stability — result from the single-crystal silicon material that forms this membrane.

Although these sensors were designed, tested and certified specifically for the Perseverance rover, iterations of both of these sensors have been certified "space-proof" many times for various missions including the Curiosity mission, and BAROCAP sensor were used in the Cassini mission to Titan in 1997 and the Phoenix Mars lander in 2007. Since they have no moving parts, they require no maintenance or repairs once in place and can endure the conditions.

As important as the exploration of Mars is, it's also worth noting that there is another application for reliable weather data about the planet. Measuring conditions on a rocky planet that isn't impacted by humans provides scientists with a control of sorts in their quest to define the effects of human activity on Earth's weather and climate.

Earlier this year, Perseverance began sending back measurements, confirming that the small sensors made the seven-month journey and survived a precarious landing. A key piece of the first meteorological network on another planet, Vaisala's sensors are helping to empower scientists with more knowledge of Mars' atmospheric conditions and insights into its planetary history, bringing humanity a step closer to walking on the red planet. ★

Anni Torri is a microsensor expert at Vaisala. She has participated in cooperative space projects between Vaisala and the Finnish Meteorological Institute, FMI, for 10 years.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KEY MOMENTS IN

The July 20 flight by Jeff Bezos and his fellow passengers will take about 11 minutes, but like astronaut Alan Shepard's 15-minute flight 60 years ago, the impact could be felt for decades. Success by Blue Origin would end a race with Virgin Galactic to send the first paying customer to the fringes of space and could spark regular tourist flights. The flight will be the 16th for the company's New Shepard rocket and capsule design. After capsule separation, the passengers will float free for three minutes as they continue to climb to 100 kilometers, and they will view Earth silhouetted against the black of space through six large windows before descending back to Texas for a landing under parachutes. Here are the top milestones in the battle of the billionaires, Bezos and Richard Branson of Virgin Galactic.

— Cat Hofacker

3

SECRET START

September 2000 — Jeff Bezos quietly founds Blue Origin. The company's existence isn't known publicly until 2003, when reports emerge of Bezos purchasing thousands of acres in West Texas to be converted into a launch site.

FIRST FLIGHT

1 **March 5, 2005** — Blue conducts a test flight of its jet engine-powered vertical takeoff and landing experimental vehicle, named Charon. The tank-like article reaches 96.3 meters in altitude and then fires its thrusters for a controlled landing.

OUT OF THE SHADOWS

2 **Jan. 2, 2007** — Blue makes the first public reference to "New Shepard," in a blog post on the company website signed by Bezos. He describes a November 2006 low-altitude test with a different experimental vehicle, a rocket-powered test article named Goddard that is "a first development vehicle in the New Shepard program."

MINOR SETBACK

Sept. 2, 2011 — A blog post on the company website signed by Bezos describes two "short hop" flights Blue conducted with the Propulsion Module 2 test vehicle. The rocket was destroyed during the second flight when "a flight instability drove an angle of attack that triggered our range safety system to terminate thrust on the vehicle."

NEW SHEPARD DEBUT

3 **April 29, 2015** — Blue completes the first flight of the New Shepard design, consisting of a rocket and unoccupied dummy capsule that reach about 93.5 kilometers in altitude. The capsule separates from the rocket for a parachute-assisted landing, but the booster crashes upon descent.

LANDING DOWN PAT

4 **Nov. 23, 2015** — Blue launches the second uncrewed flight of the New Shepard design. Both the capsule and the rocket, dubbed New Shepard 2, are recovered.

REUSABILITY MILESTONE

Jan 22, 2016 — Blue conducts the second uncrewed flight of the New Shepard 2 topped with an unoccupied capsule, the first time the company has reflown a rocket.

PLAN FOR PASSENGERS

Oct. 13, 2016 — Blue will fly employees as "test astronauts" in 2017, President Rob Meyerson says at the International Symposium for Personal and Commercial Spaceflight in New Mexico. This does not happen. He says commercial flights would then begin in 2018, and this does not happen either.

SCHEDULE SLIP

Oct. 10, 2018 — With the 2018 deadline slipping away, Blue plans to begin passenger flights in the first half of 2019, CEO Bob Smith tells attendees at the Aerospace Futures Alliance Summit in Washington.

BREAKING RECORDS

Dec. 11, 2019 — Blue launches the New Shepard 3 rocket for the sixth time, surpassing the record of five flights set by New Shepard 2 before that vehicle was retired.

A NEW ROCKET

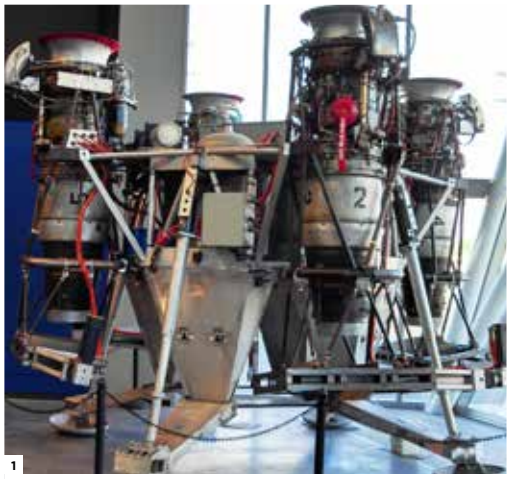
6 **Jan. 13, 2021** — The New Shepard 4 rocket, with an unoccupied crew capsule, makes its first flight. This is the version that will perform passenger flights.

READY FOR PASSENGERS

7 **May 5, 2021** — Blue holds a webcast announcing plans to auction off a seat aboard New Shepard's first crewed flight on July 20. The seat sells for $28 million in June to an undisclosed buyer.

THE RACE

BLUE ORIGIN v. VIRGIN GALACTIC



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ONGOING TESTS

Oct. 22, 2012 — Blue posts a video on its website showing the first test of the crew capsule escape system, a collection of thrusters that would propel the capsule and passengers inside away from a sizzling or exploding launch vehicle. In the video, a test capsule blasts off from the ground in a plume of smoke, landing under three parachutes.

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MULTIPLE FIRSTS

5 **Dec. 12, 2017** — Blue flies its first customer payloads. The 12 experiments from companies, universities and a K-8 school launch aboard Blue's Crew Capsule 2.0 and New Shepard 3 rocket, the first flight for both vehicles.

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BEZOS ON BOARD

8 **June 7, 2021** — Bezos posts on Instagram that he and his brother Mark will be among the four passengers on New Shepard's July 20 flight.

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KEY MOMENTS IN THE RACE

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BOLD BEGINNING
September 2004 — Richard Branson founds Virgin Galactic. He gives a press conference at the Royal Aeronautical Society in London, laying out plans to begin suborbital flights with customers in 2007 aboard piloted SpaceShipTwo planes, to be built by Scaled Composites and based on the SpaceShipOne design that won the 2004 X-prize. AvWeek reports that Branson and Scaled founder Burt Rutan will be Virgin's first passengers.

DEADLY EXPLOSION
July 26, 2007 — A tank of nitrous oxide at the Mojave Air and Space Port in California explodes, killing three employees of Scaled Composites, which was building the SpaceShipTwo planes for Virgin. Scaled becomes a Northrop Grumman subsidiary in late August, concluding a deal that was announced in July before the explosion.

SHIFTING TIMELINES
1 **July 28, 2008** — Virgin rolls out its WhiteKnightTwo carrier aircraft at the Mojave Air and Space Port in California with a ceremony that includes Branson popping a bottle of champagne and naming the aircraft VSS Eve (short for Virgin Space Ship), after his mother. He says passenger flights could begin between 2009 and 2011.

SPACEPLANE ROLL OUT
2 **Dec. 7, 2009** — Virgin unveils the first SpaceShipTwo, VSS Enterprise, at the Mojave Air and Space Port in California.

NEW MEXICO HUB OPENS
3 **Oct. 17, 2011** — Branson dedicates Virgin's hangar and runway at Spaceport America in New Mexico by rappelling down a balcony alongside aerial performers and swigging from a bottle of champagne. He tells event attendees and press that he hopes test flights will wrap up by the end of 2012 and that passenger flights from the facility, Virgin's planned hub, will begin shortly after.

FIRING THE ENGINES
4 **April 29, 2013** — Virgin completes the first powered flight of VSS Enterprise after a series of captive-carry and unpowered glide flights spanning three years. The spaceplane is released from the WhiteKnightTwo carrier aircraft and fires its hybrid rocket motor for 30 seconds. The two pilots then steer Enterprise for a glided landing at Mojave Air and Space Port.

TARGETING 2014
Jan. 10, 2014 — Virgin pilots complete the third powered flight of VSS Enterprise, and CEO George Whitesides says in a press release that "we are progressively closer to our target of starting commercial service in 2014."

A SECOND TRAGEDY
5 **Oct. 31, 2014** –Traveling at Mach 0.8 over Koehn Dry Lake, California, VSS Enterprise breaks apart seconds after it is released from the WhiteKnightTwo carrier aircraft. Co-pilot Michael Alsbury is killed, and pilot Peter Siebold parachutes to the ground but is severely injured. It will be two years before Virgin conducts its next piloted flight.

DEADLY ERROR
July 28, 2015 — Last year's crash was caused by pilot error and a design flaw, the National Transportation Safety board reports. Scaled should have considered that a pilot might prematurely pull the lever that held the vehicle's tail wings in place, leaving it vulnerable to drag that pulled it upward while Enterprise was traveling too fast and the atmosphere was too thick.

NEW SPACEPLANE
6 **Feb. 19, 2016** — Branson unveils the second SpaceShipTwo plane, Virgin Space Ship or VSS Unity, in a ceremony at the Mojave Air and Space Port in California. The spaceplane's first free flight occurs in December, when VSS Unity is released from the WhiteKnightTwo carrier aircraft and pilots steer it back to Mojave for a glided landing.

SCHEDULE UPDATE
April 26, 2017 — Virgin will begin customer flights in 2018, CEO George Whitesides tells the Senate Commerce Committee.

EDGE OF SPACE
Dec. 13, 2018 — VSS Unity burns its hybrid rocket motor for 60 seconds during its second powered flight, propelling the plane and its pilots over the 80-kilometer mark that the U.S. Air Force defines as the boundary of space.

FIRST PASSENGER
7 **Feb. 22, 2019** — Virgin's chief astronaut trainer Beth Moses joins the two pilots for a powered test flight aboard VSS Unity, becoming the company's first passenger. The flight also marks the second time VSS Unity reaches space.

GOING PUBLIC
July 9, 2019 — Virgin announces plans to become a publicly traded company via a merger with investment firm Social Capital Hedosophia, a deal closed in October. Executives say the plan is to begin passenger flights in mid-2020.

NEW TARGETS
Aug. 3, 2020 — Branson's flight aboard VSS Unity will occur between January and March 2021, according to a Virgin press release, delaying customer flights to mid-2021 at the earliest.

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Orbital tourism

While Blue Origin and Virgin Galactic are focused on going up and down on missions lasting minutes to at most hours, SpaceX's planned tourist flights would span days at much higher altitudes. In the company's Inspiration-4 mission planned for September, four private citizens will orbit Earth for three days in a Crew Dragon capsule. This would be the first SpaceX launch of tourists, and the company is marking the occasion with a Crew Dragon upgrade: the addition of a 2-meter-diameter glass dome in the capsule's nose, through which passengers would get a panoramic view of Earth and space from their orbit of 540 kilometers.

TESTING SETBACK

Dec. 12, 2020 — The first powered test flight of VSS Unity from Spaceport America in New Mexico is cut short when electromagnetic interference from Unity's flight computer cut off the data connection with the hybrid rocket motor, prompting the computer to end the ignition sequence.

GROWING THE FLEET

March 30, 2021 — Virgin rolls out the first Spaceship III plane, named VSS Imagine.

NEW MEXICO SPACEFLIGHT

May 22, 2021 — Virgin completes the first powered flight of VSS Unity from Spaceport America, reaching a speed of Mach 3 and altitude of about 89 kilometers, high enough for the two pilots to glimpse "the bright, blue-rimmed curvature of the earth against the blackness of space," according to a press release.

THE ROAD AHEAD

June 10, 2021 — In an email update, Virgin says it is "on track to complete VSS Unity's flight test program by late summer or early fall." The three remaining flights consist of tests with a handful of Virgin employees and then Branson, concluding with three spaceflight participants from the Italian Air Force. ★

Building vertiport cities

Metropolitan areas including Miami and Orlando have emerged as potential early adopters of urban air mobility flights aboard electric aircraft. But this new mode of travel won't take off unless UAM companies make the right business decisions about where to locate their vertiports and win permission from local authorities to build these landing pads. Cat Hofacker and Alyssa Tomlinson explore the distinct approaches unfolding in Florida.

BY CAT HOFACKER | catherineh@aiaa.org and
ALYSSA TOMILINSON | awolice89@gmail.com

The Lake Nona Vertiport in Florida would be the hub of a network of regional and urban air mobility routes. Electric vertical takeoff and landing aircraft (previous pages) made by Lilium Jets of Germany would carry a pilot and as many as six passengers up to 300 kilometers on one charge.

Lake Nona/Lilium

In Lake Nona, Florida, a planned community south of Orlando International Airport, autonomous Beep buses (with human attendants aboard) carry passengers here and there, poles with Verizon 5G cellular equipment are being installed to test autonomous mobility, and the windows of office buildings automatically adjust their transmissivity based on cloud cover and time of day.

These innovations are among the reasons the community has dubbed itself a "living lab." The newest reason remains, at the moment, an undeveloped expanse of pinelands and grasses that starts across the street from the University of Central Florida College of Medicine. Somewhere among these parcels Tavistock Development Co., the U.S. real-estate arm of the United Kingdom-based Tavistock Group investment company, plans to erect a vertiport, a single-story building with two landing and takeoff pads out back, technically called FATOs, short for final approach and takeoff areas. As early as 2024, electrically powered aircraft would whisk tourists or residents in minutes between these pads and other Florida cities, such as Tampa, 140 kilometers away, or West Palm Beach, 250 kilometers away.

If all goes as planned, this vertiport would be the hub of a regional and urban air mobility network, and one that will vie against other networks to serve as a springboard to an entirely new mode of transportation in the United States. Residents would have vastly more options about where to live, and for some, the calculus about how far is too far to go for dinner would be forever changed.

Success, analysts and researchers caution, must be defined as capturing a large number of passengers, not just the ultra-wealthy. That hinges on pricing and also how well these companies locate and design their vertiport networks.

Building infrastructure for new mode of transportation

Lilium wants to build a network of 11 vertiports to connect major cities in Florida. If the company's plan succeeds, some 20 million residents would be within a 30-minute drive of a vertiport.

"It's important to recognize the opportunity for UAM to connect areas that could benefit from revitalization — especially where other modes of transportation would allow for seamless intermodal connections," says Laurie Garrow, co-director of Georgia Tech's Center for Urban and Regional Air Mobility.

Location, location, location

First and foremost among the challenges is that, in contrast to Lake Nona's newness and zest for innovation, most other vertiports planned in Florida and around the globe will have to be built around existing and, in many cases, aging infrastructure.

Here's how Duncan Walker, CEO of the U.K.-based infrastructure company Skyports, sums up the challenges: His picture-perfect vertiport site would be a flat, open field that's entirely protected from wind and harsh weather events. It would also sit at the heart of a densely populated urban center, where rail and bus transit systems converge and it's easy to deconflict with other air traffic.

In other words, it doesn't exist.

"There's this constant trade-off between available space and desirability of location," Walker says.

So in the absence of this holy grail, companies must consult with city planners and conduct their own research about traffic patterns to decide where to build their vertiports, the goal being "solving for each region's individual pain points," he says.

And those discussions have already led to distinct business models.

▲ This two-seat prototype is being developed by Archer Aviation, which has also announced plans to establish urban air mobility networks in Los Angeles and Miami.
Archer Aviation

Take Archer Aviation of Silicon Valley, which in March announced plans to establish urban air mobility, or UAM, networks within the Miami and Los Angeles metro areas consisting of a yet unspecified number of vertiports and electric takeoff and landing aircraft, eVTOLs. In Miami, Archer wants to begin flights for select routes in 2024 with four-passenger eVTOLs that are still being designed, though Archer in June unveiled a two-seat prototype named Maker that the company plans to begin flight tests with later this year.

The four-passenger eVTOLs would fly routes under 97 kilometers, ideal for commuters catching a ride into their downtown Miami office from their suburban homes or tourists looking for a quick way to visit multiple nearby attractions in a single day.

The Miami network must be built so that "it can be integrated into how people already move around today," says Brett Adcock, co-founder and co-CEO of Archer with Adam Goldstein. Although the details are still being finalized, Archer plans to offer on-demand eVTOL rides, like Ubers for the sky: Passengers would simply open the Archer app on their smartphone, order an eVTOL and head to the nearest vertiport to board. The eVTOLs in the Miami network would be owned and operated by Archer and flown by company pilots. The company will also sell its eVTOLs to other operators; United Airlines in February announced a $1 billion purchase of 200 Archer eVTOLs for ferrying passengers among its hubs, with the option to buy 100 more eVTOLs in the future.

To figure out where to build the vertiports, Archer engineers are compiling publicly available traffic and location data and plugging it into the company's

Prime Radiant software to simulate likely UAM routes. Plans call for finalizing the vertiport locations in 2022, when construction would commence.

Details including the size and features of Archer's vertiports are still being decided, but Archer plans to construct all the vertiports for the initial network on top of existing structures, such as the tops of unused parking garages, in high-traffic areas so passengers could easily board and disembark.

"Our aircraft can seamlessly fit in with existing infrastructure — like helicopter landing pads, electric charging stations and local airports — [allowing us to build] our own eVTOL infrastructure based on where people frequently travel," Adcock says.

And Archer isn't alone. Joby Aviation of California in May announced a deal with parking garage operator REEF Technology for the exclusive rights to construct the landing pads, charging stations and other needed infrastructure for its vertiports on top of REEF garages, which number some 5,000 across North America and Europe.

Parking garages tend to be situated in high-demand locations, and little new infrastructure would need to be built on the roofs, Joby says. The company is targeting a handful of U.S. cities for eVTOL flights starting in 2024, including Miami.

The Magic City is also a top target for Skyports, though the company won't say whether it plans to compete to build vertiports for Joby or others planning Florida networks. The relative age of cities including Miami makes the parking garage strategy a good one, says Walker, but could pose a problem for eVTOL companies looking to build networks in historic cities like London or Paris. Few historic buildings have

rooftop parking structures that could be converted into landing pads for eVTOLs, Walker says, and tall buildings often create mini wind tunnels that could equate to a severely bumpy ride for passengers.

And, for those skyscrapers, there's another factor to consider.

"It was a bit of a lightbulb moment when I went to the top of Marina Bay Sands Hotel in Singapore," says Walker. "It took about 20 minutes to get to the top — that's 20 minutes added to your journey, which kind of negates some of the benefits of traveling by eVTOL."

The hotel roof is not among the Singapore sites on which Skyports is considering building vertiports but is across the bay from the full-scale vertiport prototype the company built with Volocopter of Germany in 2019.

Another eVTOL pioneer, Lilium of Germany, the company behind the Lake Nona vertiport plan, hopes to avoid the challenges of retrofitting existing buildings for its in-development Lilium Jets, a prototype of which first flew in 2019. These electric aircraft, propelled by 36 ducted turbofans embedded in the wings and tail, would ferry passengers between brand-new vertiport buildings, to be constructed over the next few years. Lilium in April announced the deal with Tavistock, which will oversee design and construction of the Lake Nona vertiport, the first in a series of hubs that Lilium plans in the U.S.

A 2024 entry-to-service date for that hub is where Lilium's similarities with Archer end. The company is focusing on building a regional air mobility network for short hops between cities. Because of Florida's lack of public transit options for trips of this length, "the regional routes are the ones in which you have the greatest time and efficiency gains," says Alex Asseily, chief strategy officer at Lilium.

Plans call for a network of at least 11 vertiports, including the Lake Nona hub, where up to six passengers would climb aboard Lilium Jets for trips up to 300 kilometers. That's enough range to connect almost every major city in Florida by eVTOL, including Miami, and to place some 20 million

▲ A vertiport prototype in Singapore was developed by U.K.-based Skyports and Germany-based Volocopter, which has said it will begin an air taxi service in the city.
Volocopter

Florida residents within a 30-minute drive of a vertiport, according to Lilium. (But excited travelers should note that although Disney World falls within range of Lilium's planned network, Asseily says there are no plans to ferry visitors to the park.)

The Lake Nona vertiport offers a rare opportunity to expand a community around the eVTOL infrastructure rather than squeezing it into a historical community, making it more likely that the vertiports would be readily accessible to passengers.

"We fundamentally think eVTOLs will change how people move," says Ben Weaver, Tavistock's managing director. "We consider Orlando to be an aerotropolis. For us, it's all about building cities around modes of transportation, similar to how cities have, historically, been built around ports."

Lilium's Asseily says that by 2024, a handful of vertiports will be ready for flights along "a couple of routes," and then gradually the service will be expanded.

Saving time

If eVTOLs are to be a serious alternative to cars, buses and trains, vertiport networks must be designed for frequent trips, almost akin to that of rail systems. For instance, Lilium plans to operate its Florida hubs as a "very tightly scheduled shuttle network," Asseily says, with seven- to 12-minute wait times for passengers.

And Archer is betting that the allure of ordering a ride aboard one of its eVTOLs on demand will have Floridians foregoing car trips in many cases, significantly easing road congestion.

Adcock, the Archer co-CEO, likes to use the example of the commute from Miami International Airport to South Beach: Instead of making the 19-kilometer trip by car — which can take over an hour during rush hour — simply order an Archer eVTOL and make the trip in 10 minutes.

But one researcher is skeptical that this promised decrease in traffic congestion will occur, at least initially. City commuters likely wouldn't notice a reduction in road traffic congestion unless vertiports are at least as ubiquitous as bus or rail stations, says Rolf Moeckel, an assistant professor of civil, geo and environmental engineering at the Technical University of Munich. Moeckel co-authored an August 2020 report in the Council of European Aerospace Societies Aeronautical Journal that found that in cities such as Munich, UAM networks might marginally worsen congestion before making it better.

"When we accounted for what we call access and egress trips — trips from home to the vertiport,

▲ A pilot flew the Volocopter 2X over Marina Bay in Singapore in 2019.
Volocopter

and from the vertiport to the final destination — we saw a slight increase in congestion," he says. "UAM had the counter impact to what we expected, even though Munich has a decent transit system."

The advent of UAM aircraft presents a once-in-a-lifetime test case for Moeckel and other modelers who must predict traveler behavior for a mode of transportation that doesn't yet exist. Without observed data, Moeckel conducts interviews with travelers and surveys them about their preferences. Perhaps most importantly, he creates incremental mode choice models, in which data is tapped from an existing travel mode, such as rail, and adjusts it based on factors such as estimated ridership per hour and turnaround time for flights.

"We ran analyses where we increased the price of UAM slowly to see how much it decreased demand, and we also adjusted travel time," Moeckel says. "By doing a lot of sensitivity analyses, you get a good sense about which dials you need to turn if you want to increase demand for UAM, and what are the driving forces behind UAM."

When Moeckel and his collaborators conducted these analyses on the Munich metropolitan area, they found that, no matter how they turned the dials, there was a negligible impact on traffic congestion. Moeckel attributes this in large part to the fact that most passengers would still rely on cars or taxis to get to or from the vertiport.

In order for UAM to have a positive effect on urban traffic congestion or the regional economy, a city or region must have the appropriate infrastruc-

▲ One of the many designs submitted by architectural firms after Uber Elevate solicited ideas for urban air mobility "skyports." Uber sold its UAM offshoot to Joby Aviation last year.

Uber/Corgan

ture in place to support it.

"That's not a trivial thing to do," says Marcus Johnson, a NASA engineer who's developing automation algorithms to support vertiport scale-up and safety for the agency's Advanced Air Mobility project. NASA coined the term advanced air mobility to incorporate use cases outside urban environments, such as for longer-range connections between cities or regions, or cargo delivery.

NASA plans to address many of the biggest obstacles to incorporating AAM via ongoing meetings of AAM Ecosystem Working Groups. Since March 2020, NASA has hosted periodic virtual meetings on topics including vertiport operations to draw input from aircraft manufacturers, community members, vertiport developers, regulators and service providers.

"This allows us to address problems related to community integration and really get a good understanding from cities and states and everyone that's attached to these types of operations," Johnson says. "What constrains their operations? What constrains what they can do within a city? It's about marrying these concepts together to have a clear picture of where vertiports can be located. It allows us to see how you measure the impact of operations and how you can report that impact to the wider community."

AAM for all?

Ultimately, the likelihood of success for Archer, Lilium and their competitors might not be apparent until passenger flights commence from the Lake Nona vertiport and other locations. Both companies believe their targeted price tags are low enough to entice a wide variety of passengers: Archer plans to charge between $3 and $4 per passenger mile, and Lilium is aiming for $2.20 per passenger mile — comparable to the price of ordering an Uber or Lyft.

"We can drive the cost down of the seat, make it more accessible, more affordable," Lilium's Asseily says. "And so we have more people coming in and out of these towns, and actually we're making this more available to non-billionaires basically."

Once again, the Lake Nona community offers a unique chance to gauge success. Perhaps we'll know that urban and regional air mobility is catching on when the vertiport there becomes just another innovation the city has embraced. ★

Editor-in-Chief Ben Iannotta contributed to this report.

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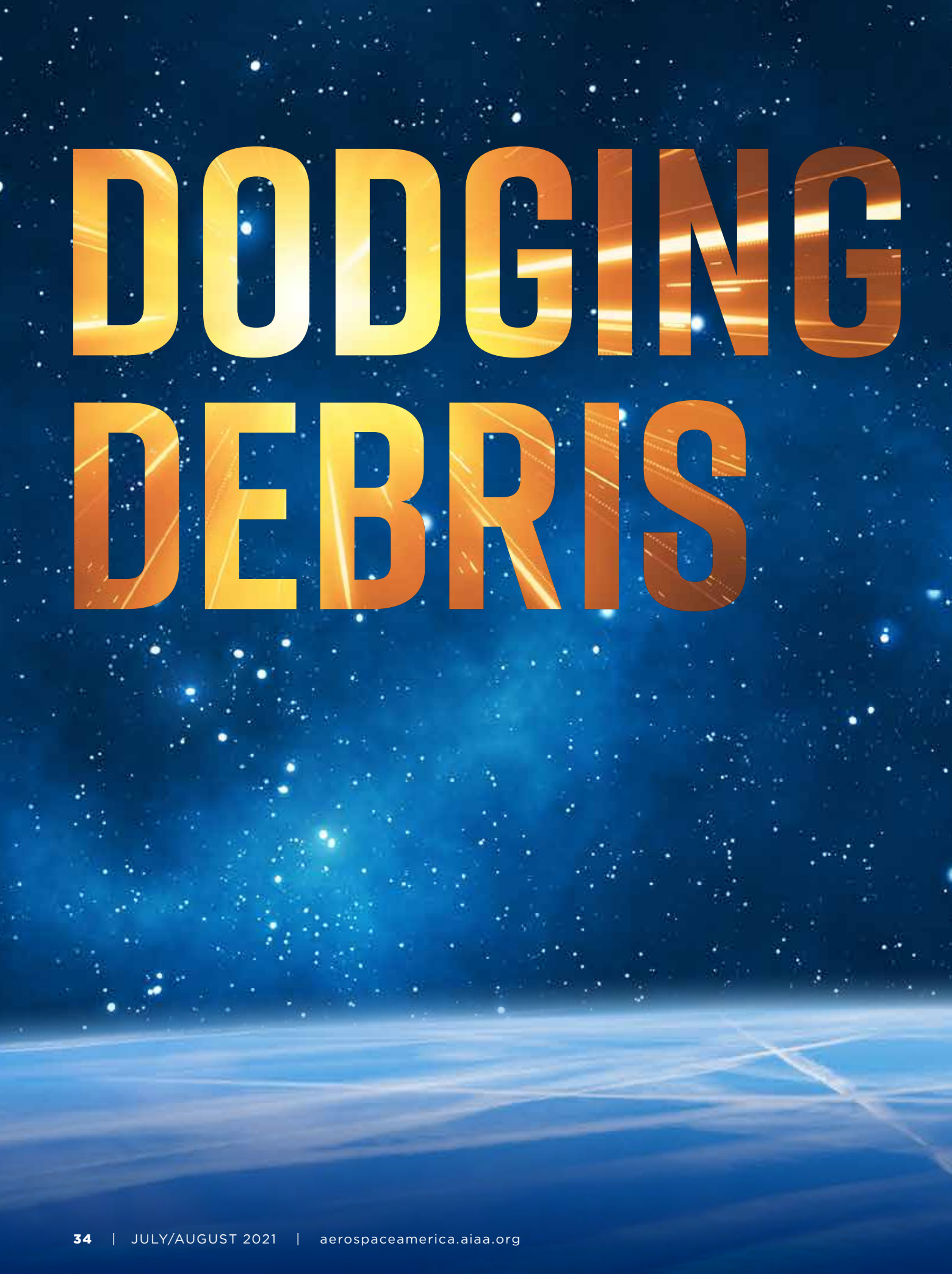

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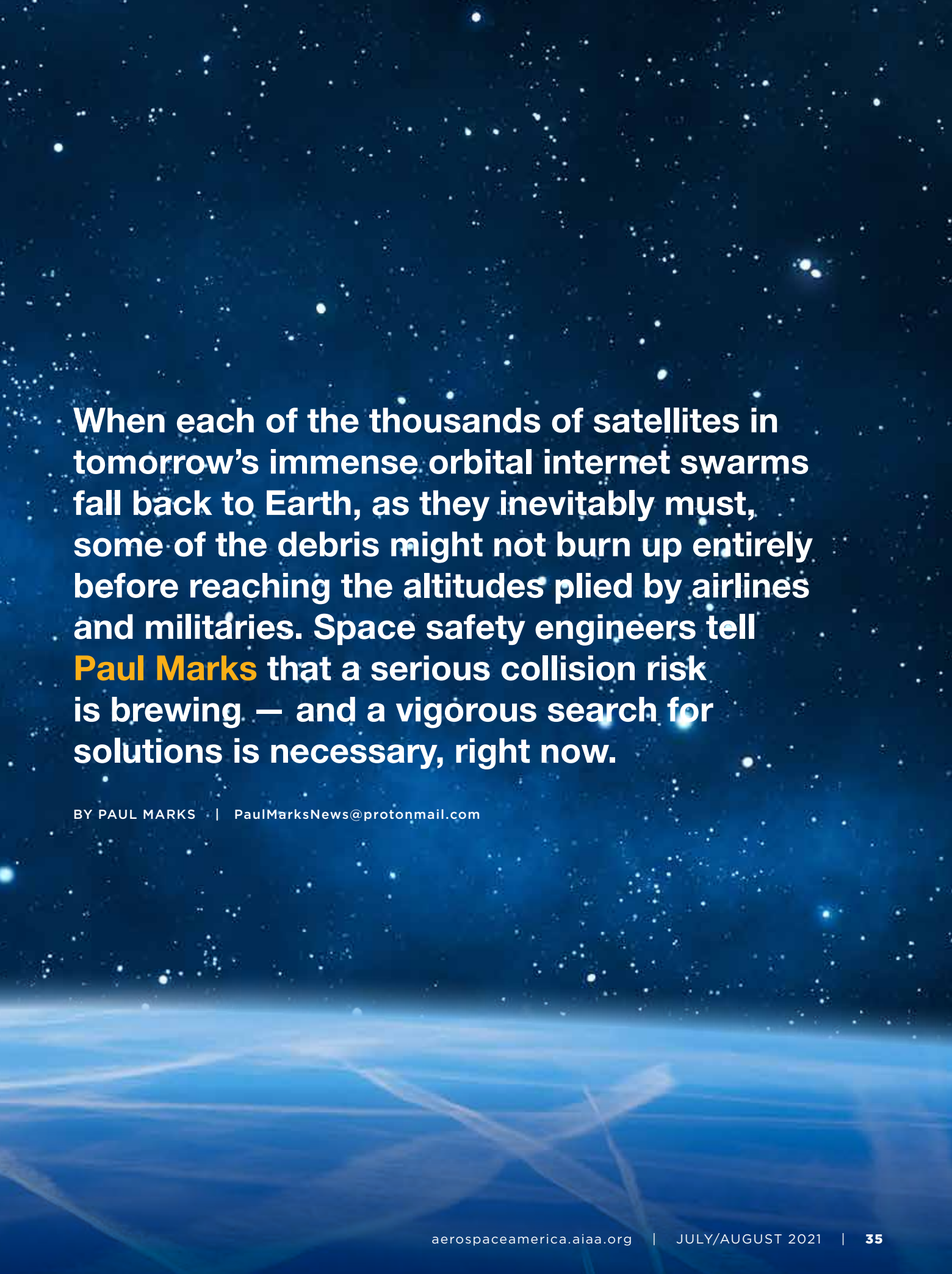


When each of the thousands of satellites in tomorrow's immense orbital internet swarms fall back to Earth, as they inevitably must, some of the debris might not burn up entirely before reaching the altitudes plied by airlines and militaries. Space safety engineers tell Paul Marks that a serious collision risk is brewing — and a vigorous search for solutions is necessary, right now.

BY PAUL MARKS | PaulMarksNews@protonmail.com

On Christmas Day 1996, a mysterious object, probably no bigger than a marble, smacked into the cockpit windshield of a Boeing 757 as it cruised at 31,500 feet en route from Beijing to Wuhan. The impact cracked the outer pane of the three-ply windshield, Reuters reported, threatening a cockpit depressurization and forcing the crew of the China Southern Airlines-operated jet to return to Beijing's Capital International Airport for an emergency landing.

"That report could well have been describing a fragment from a piece of a reentered space object," says William Ailor, a technical fellow at the Aerospace Corp.'s Center for Orbital and Reentry Debris Studies in California. "It shows that although a small fragment might not necessarily take down an aircraft or be fatal, it can still lead to a crew taking emergency action."

That windshield impact was rare, perhaps even unprecedented, in the annals of air travel, but spaceflight observers, Ailor among them, fear aviation's luck against satellite debris may be in danger of running out. The reason? The vastly increased numbers of spacecraft that will in the future need to be de-orbited given the growth of megaconstellations — immense swarms of satellites now being deployed in low-Earth orbit mainly to provide low-latency connections to the internet.

Operators should de-orbit each satellite at the end of its life safely over the ocean and away from air routes, but the sheer number of spacecraft leaves room for uncontrolled reentries, perhaps due to failures or impacts with fragments from orbital collisions.

Megaconstellation satellite builders, with the encouragement of the U.S. Federal Communications Commission, are designing their spacecraft for demise in the belief that choosing the right materials can make them burn up completely on reentry, even if they do not reenter where planned. Amazon's Kuiper division, which plans to orbit 3,200 satellites, would not discuss plans for demisability, except to say that it complies fully with FCC rules on de-orbiting, although right now, the FCC encourages but does not require demisability. SpaceX, which plans the largest constellation at 42,000, two years ago told the FCC that the latest Starlink satellites are fully demisable.

Some experts remain skeptical that a whole satellite is in fact capable of being wholly incinerated. So it is time, these space safety specialists argue, for the aerospace industry to begin looking into developing tools that would warn pilots of impending uncontrolled reentries so they can take evasive action.

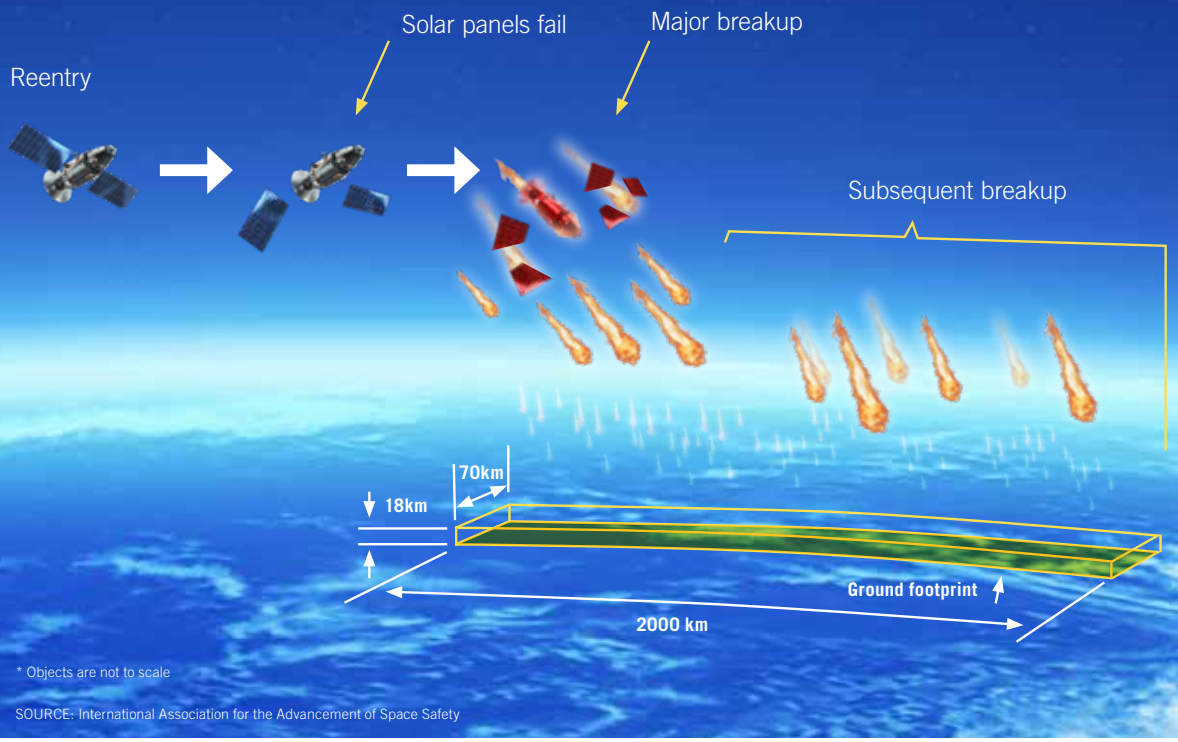
Massively boosting the number of spacecraft in orbit by many tens of thousands means that the

An artist's rendering of a European Space Agency Automated Transfer Vehicle reentering the atmosphere over the Pacific Ocean.

European Space Agency

Gauging the potential for impact

The location of reentering space debris is hard to predict, although experts say it's likely to have a long, narrow footprint. When a spacecraft reenters the atmosphere, plasma melts the casing and extremities like the solar arrays before the interior components begin to break up.



* Objects are not to scale

SOURCE: International Association for the Advancement of Space Safety

number de-orbited at the end of their circa-five-year lives will go up too. Currently there are 4,300 working satellites on orbit, out of the 7,200 launched since the dawn of the Space Age. In addition to SpaceX's Starlinks and the Kuiper satellites, the state-owned China Satellite Network Group plans 13,000; OneWeb, based in London, plans to orbit 650. Firms including Samsung, Telesat and Viasat also are planning such networks.

Until now, most concerns about these megaconstellations have centered on the risk of orbital collisions sparking a Kessler syndrome event — a cascade of collisions and fragmentations that could pollute near-Earth space for decades. Astronomers have also complained that the swarms can be visible to their large, sensitive ground-based astronomical telescopes.

Bringing the risk to Earth

Now, if the promised swelling of the orbital population comes to pass, the mass of satellites being de-orbited could grow about 30 times, from around 100 tons to as much as 3,200 tons per year, the Aerospace Corp. calculated in 2020. This would increase the risk to aviation, provided not everyone's satellites turn out to be fully demisable.

This stark warning was sounded by Michael Kezirian, an astronautical engineer at the University of Southern California, in the March 2021 edition of the peer-reviewed Journal of Space Safety Engineering — the technical periodical for the International Association for the Advancement of Space Safety.

In an extended editorial, "It Is Time To Implement Mitigation Strategies To Protect the Airspace From Space Debris," Kezirian, the journal's founding editor-in-chief, notes that the American Astronomical Society has predicted that in the next five years alone megaconstellations will multiply the number of objects accumulated in orbit by fivefold — and that those in turn will de-orbit at the end of their life, increasing the rate of reentries.

"Given the continued growth of new operational spacecraft, combined with the introduction of megaconstellations, the likelihood of a Black Swan event in the airspace is becoming more likely," Kezirian writes. A Black Swan event is one that is extremely rare, with causes beyond the design and risk

considerations engineers ordinarily cater for, and with severe consequences, such as the loss of an airliner.

This is more likely because the increase in de-orbiting frequency would heighten the chances of the kind of reentries nobody wants to see: unpredictable, uncontrolled ones, perhaps due to some kind of station-keeping failure on orbit, or a collision with a large piece of space debris, such as one of the most dangerous pieces of junk on orbit. An example is the European Space Agency's now-derelict 8-ton satellite, Envisat, which lost power in 2012 and has been tumbling out of control in LEO ever since.

Under United Nations guidelines, however, most modern satellites, including those in the megaconstellations, will undergo a controlled de-orbit by their operators into the atmosphere over a remote area like the South Pacific Ocean Uninhabited Area. As a reentering object plows into the atmosphere at 27,000 kph, intense friction with air molecules heats the air to an incandescence, creating an ionized plasma at 1477 degrees Celsius — which first melts slim extremities like the solar panels and the casing, and then the components the casing has been shielding, resulting in a sequence of catastrophic breakups.

"They look like a meteor coming into the atmosphere, a very bright fireball, which then breaks apart and creates a shower of particles. After a while all that stuff slows down, and at around 100,000 feet it all falls straight down and it's just a bunch of cooling fragments at that point, not something that is terribly visible," Ailor says. Owing to its speed, this cloud of fragments falls in a footprint some 2,000 kilometers long and 70 km wide, falling pretty much vertically, depending on the strength of crosswinds, into the 60,000-foot-deep (18 km) airspace volume plied by airplanes, such as where that Chinese 757 was flying.

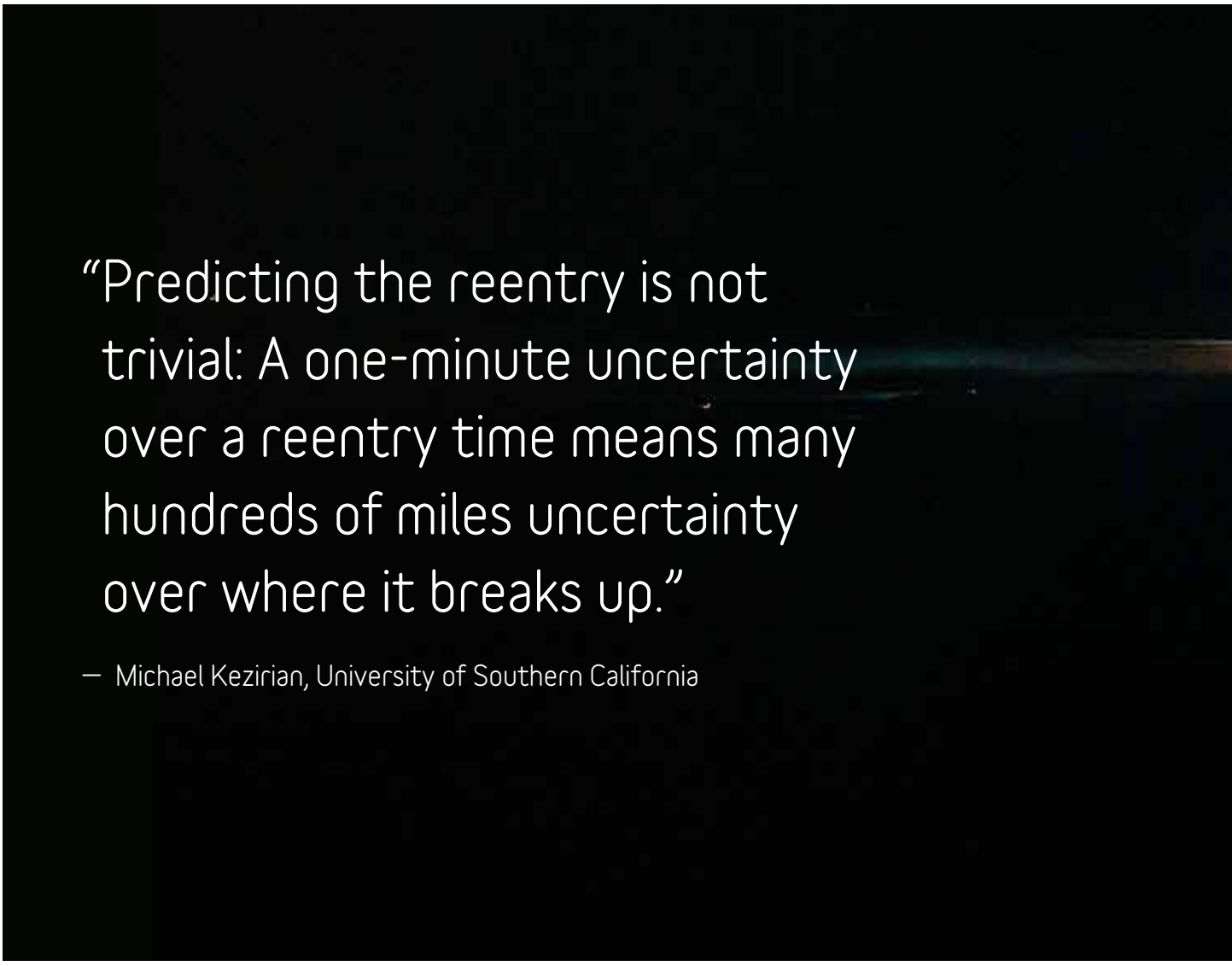
How much of the satellite survives? In 2008, Ailor, working with Paul Wilde of the FAA's Office of Commercial Space Transportation, estimated that of the 70 space objects with masses of 800 kilograms or more that fell to Earth that year, between 10% and 40% of the mass of each probably survived the fall into the airspace — with as many as 300 fragments that could be lethal to an aircraft. That was based on radar data and tests with a device called a Reentry Breakup Recorder, one of which was fixed to a European Automated Transfer Vehicle and another to a Japan Aerospace Exploration Agency H-II Transfer Vehicle before they de-orbited after leaving the International Space Station.

Risks increasing

Megaconstellations, however, consist of less massive satellites: The Starlinks come in at 250 kg, for instance, and OneWeb's at 150 kg. So just what is the risk that surviving chunks of those lighter spacecraft will hit an airplane once megaconstellations are swirling around the planet in multiple orbital shells and inclinations? Working it out is tough, as operators keep upping their numbers, but in February 2020, Ailor revealed some risk calculations, projecting the risk for 2030 when, at the time he performed his calculations, 16,000 satellites of 150 kg or larger were expected to be in LEO.

In a paper delivered at the February 2020 Science and Technical Meeting of the U.N. Committee on the Peaceful Uses of Outer Space, Ailor calculated that by 2030 the probability of casualties on the ground will rise to 0.1 per year. In other words, one human injury or death on Earth's surface can be expected every 10 years. And the probability of a fragment hitting an airplane in the airspace is 0.001/year, equal to one debris strike every 1,000 years, compared to a risk of once every 50,000 years for the current number of satellites. With an average of about 300 people on a single airliner, the maximum yearly casualty expectation rises to 0.3 per year. "If a large piece of space debris hits an airplane in flight, it is almost certain to

> "If a large piece of space debris hits an airplane in flight, it is almost certain to be fatal to everyone on board."
>
> — William Ailor, Center for Orbital and Reentry Debris Studies



be fatal to everyone on board," he says.

"The thing with aircraft strikes is that something has to hit the aircraft before you have a human casualty. And if debris hits the aircraft, you then have to ask: How many people are on the aircraft that would be affected by that? So that's where we get the larger number from," Ailor says.

But here's the thing: After Ailor wrote the 2020 paper, new applications arrived at the FCC, including one bringing the Starlink plan to 42,000 satellites, and to about 55,000 satellites over 150 kg overall. So, the risk will likely be even higher in 2030 than Ailor's estimate. Factor in growth in aviation as it bounces back after the covid-19 pandemic, and the risk could be higher still.

"The progress of new space, with increased numbers of users of the orbital space, has significantly increased the likelihood of the loss of aircraft from reentering space debris," Kezirian writes.

So I called Kezirian to see how he thinks aviation should respond to this heightened threat. He wants a clutch of emerging technologies to be harnessed to provide aircrew with inflight alerts that warn of impending uncontrolled reentries that threaten their airliners. "To alert aircraft you need to know when the debris is coming in, at what angle and at what time. Currently Space-Track [a service of the U.S. Space Surveillance Network] tracks the debris, but it does not tell you how likely a reentering piece is to hit a particular aircraft.

"And predicting the reentry is not trivial: A one-minute uncertainty over a reentry time means many hundreds of miles uncertainty over where it breaks up," Kezirian says.

So he believes developing such tools will involve enhancing space traffic management software to track the debris and predict its reentry point, plus using spacecraft breakup analysis tools to predict the debris footprint in the airspace, and creating a way to transmit and display warning predictions in

▲ An Automated Transfer Vehicle was photographed from the International Space Station as it burned up over the Pacific Ocean to dispose of waste from ISS. The ATV was equipped with instruments that documented its own breakup to help scientists predict date, time and debris footprints.

European Space Agency

a timely fashion to the crew.

This is not entirely a new idea, he says. The need to protect aviation from uncontrolled, debris-shedding reentries has its roots in a controlled reentry that went horribly wrong — one of crewed spaceflight's greatest tragedies: the space shuttle Columbia disaster.

On its reentry after a science mission on Feb. 1, 2003, hot, incandescent plasma invaded Columbia's left wing, whose reinforced carbon-carbon leading edge had, unknown to the crew and NASA, been holed by a briefcase-sized chunk of insulating foam shed by the shuttle's external tank during launch. As the orbiter's internal structure melted, it broke apart at an altitude of 37 miles on its way back to Florida, killing its crew of seven and shedding debris into West Texas, Arkansas and Louisiana.

What is less well known, however, is that no fewer than nine airliners flew through what Kezirian calls the "curtain" of debris the crippled spacecraft was shedding. Miraculously, none of those airplanes was hit. "For 40 minutes the debris objects came down and there was no mechanism in place to let [mission control] warn airlines of the risk," Kezirian says. That close call for those nine airliners shocked the FAA, prompting it to establish procedures designed to let it redirect air traffic around spacecraft debris in any future de-orbiting tragedy.

Issuing real-time alerts

What's really needed, the International Association for the Advancement of Space Safety said in a 2014 position paper, are real-time tools that can both track space object reentries and provide warnings to air traffic control and pilots when an uncontrolled reentry is likely. Called the Aviation Debris and Meteoroids Integrated Risk Evaluation white paper, such technology is high on the association's wish list, says Kezirian.

A constellation of SpaceX Starlink satellites looks like a string of lights as they move across the night sky.

Giancarlo Foto4U/flickr

◀ The European Space Agency Envisat satellite has been tumbling in low-Earth orbit since ESA lost contact with it in 2012, an indication of the size of some of the debris languishing in LEO.

ESA

While the technology to do this tracking was not available in 2014, it is starting to become available now, he says, through the emergence in the new space economy of commercial space traffic management companies. Such firms include NORSS in the United Kingdom, LeoLabs and ExoAnalytic in the U.S., Okapi Orbits in Germany and Share My Space in France. As these firms improve their capabilities with new ground-based cameras, telescopes and radars, and perhaps future space-based infrared, look-down sensing satellites, he believes they will be able to predict reentries "not tomorrow, but soon."

He envisions such data being fed to a regular cockpit route planning and weather alerting app like ForeFlight, which is owned by Boeing. He's so confident it will work that he's just filed a U.S. patent on a way of doing this efficiently.

The European Space Agency and the European Union's research arm have investigated a different approach to pilot reentry alerts, in which a device attached to every satellite before it is launched would sense the heat of reentry and broadcast the object's position and likely debris footprint to aircraft. But as this involves adding fuel-consuming mass to a satellite, it is an idea that might not be attractive to constellation operators, as carrying spare mass would reduce a satellite's service lifetime.

Any pilot alerting system will also need to be programmed with information on how different types of space objects break up, too, so that it knows which parts — like pumps, tanks, solar panels and thrusters — get torn off and survive the heat and which parts evaporate, and which parts produce a cloud of particles, perhaps, that drop into aviation airspace below 60,000 feet. But this may turn out to be difficult in the era of megaconstellations — because operators adopting demisable spacecraft insist the whole spacecraft burns up.

In this emerging technique, dense metallic components and tough materials like silicon carbide are replaced in the design and manufacturing steps with light, skinny alternatives that are supposed to vaporize as the structure succumbs to the extreme heat of reentry. SpaceX, which declined to discuss its demisable approach with me, told the FCC in 2019 that no part of its latest Starlink satellites "will survive atmospheric reentry, reducing casualty risk to zero."

But this technique is new, and some experts express frustration over the great faith being put into a method they view as unproven. "People need to wake up a little bit about design-for-demise. It's a

▲ A Delta II third stage reentered the atmosphere in 2001. Its titanium motor casing landed in Saudi Arabia.
NASA

hypothesis; it is not a proven technology," says Tommaso Sgobba, executive director of the IAASS, and former head of the Independent Safety Office at the European Space Agency's ESTEC research center in Nordwijk, Netherlands.

Is there any way to get that evidence? Maybe. "It's really hard to say whether or not you can actually get something to be 100% demisable on reentry. The only way you can really test it is to use a high Mach number plasma wind tunnel, which simulates reentry conditions," says Hugh Lewis, a specialist in reentry physics and space debris modelling at the University of Southhampton in the U.K. Even then, Sgobba cautions that the conditions in plasma chambers might not always reflect the realities of reentry.

Kezirian, a specialist in spacecraft composite overwrapped pressure vessel design, knows just how hard it is to make spacecraft tanks that are strong enough for their job but also demisable on reentry. There are other parts of a spacecraft he believes design-for-demise proponents will have trouble burning up, including thrusters, batteries and reaction wheels, which are often made of heavy metals or composites. Asked to comment on any design-for-demise progress they have made, SpaceX and Amazon's Kuiper declined to comment.

Whether all of a spacecraft demises or not, another risk of the approach was described in a paper in the May issue of Nature Scientific Reports, "Satellite Megaconstellations Create Risks in Low Earth Orbit, the Atmosphere and on Earth." Physicist Aaron Boley at the University of British Columbia in Vancouver suggested that regularly vaporizing Starlink satellites might deposit more aluminum particles in the upper atmosphere than meteoroids do now. This could adversely affect radio communication with spacecraft, says Kezirian, and perhaps radio astronomy too. There are even questions brewing over whether this metallic layer could act like atmospheric kitchen foil — trapping heat and so contributing to global warming.

What's absolutely certain, however, is that more and more spacecraft are going into orbit — across all applications, not just the orbital internet — and so more and more will have to de-orbit, increasing the likelihood of uncontrolled reentries due to failures or collisions that might then impact passenger-packed airliners. So Kezirian remains insistent: "My sense is that protection measures like those I'm suggesting are not very expensive; it'd be a small cost to a trillion-dollar industry. There is a lot that can be done to mitigate a pretty horrendous risk," he says. ★

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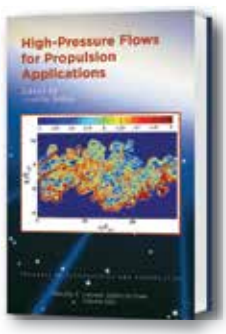

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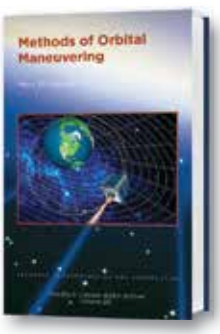

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2–6 AUGUST 2021
VIRTUAL

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DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2021			
5–30 Jul	Optimal Control Techniques for UAVs Course	ONLINE (learning.aiaa.org)	
20–29 Jul	Digital Engineering Fundamentals Course	ONLINE (learning.aiaa.org)	
26–29 Jul	1st AIAA Ice Prediction Workshop	ONLINE (learning.aiaa.org)	
2–6 Aug	AIAA AVIATION Forum	VIRTUAL	10 Nov 20
9–11 Aug	AIAA Propulsion and Energy Forum	VIRTUAL	11 Feb 21
11–13 Aug	AIAA/IEEE Electric Aircraft Technologies Symposium	VIRTUAL	
12 Aug	AIAA Aerospace Spotlight Awards Gala	VIRTUAL	
17 Aug	AIAA Fellows Induction Ceremony	VIRTUAL	
31 Aug	AIAA Career Fair	VIRTUAL	
1 Sep	2021 Section Awards Presentation	VIRTUAL	
6–10 Sep*	32nd Congress of the International Council of the Aeronautical Sciences	Shanghai, China (icas.org)	15 Jul 19
14–16 Sep	AIAA DEFENSE Forum (Postponed from April)	Laurel, MD	17 Sep 20
15–24 Sep	Hypersonic Applications: Physical Models for Interdisciplinary Simulation Course	ONLINE (learning.aiaa.org)	
16 Sep–7 Oct	Uncertainty Quantification: Machine Learning for Quantifying Uncertainties Course	ONLINE (learning.aiaa.org)	
21 Sep–5 Oct	Advanced Space Propulsion Course	ONLINE (learning.aiaa.org)	
22 Sep– 29 Oct	Turbomachinery for Emerging Space Applications: Liquid Rocket Propulsion Course	ONLINE (learning.aiaa.org)	

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28 Sep	ASCENDxSummit	VIRTUAL	
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7–28 Oct	Turbulence Modeling for Aerodynamic Flows Course	ONLINE (learning.aiaa.org)	
25–29 Oct*	72nd International Astronautical Congress	Dubai, UAE	
8–10 & 15–17 Nov	ASCEND Powered by AIAA	Las Vegas, NV, & ONLINE	30 Mar 21
15–17 Nov	AIAA International Space Planes and Hypersonic Systems & Technologies Conference	Las Vegas, NV, & ONLINE	30 Mar 21
29–30 Nov	Australian International Aerospace Congress & Region VII Student Conference	Melbourne, Australia, & ONLINE	15 Sep 21

2022

3–7 Jan	AIAA SciTech Forum	San Diego, CA, & ONLINE	1 Jun 21
7 Jan	3rd AIAA Geometry and Mesh Generation Workshop (GMGW-3)	San Diego, CA	
7 Jan	4th AIAA CFD High Lift Prediction Workshop (HLPW-4)	San Diego, CA	
8–9 Jan	1st AIAA High Fidelity CFD Workshop	San Diego, CA	
8–9 Jan	Aircraft and Rotorcraft System Identification Engineering Methods for Manned and UAV Applications with Hands-on Training using CIFER® Course	San Diego, CA	
5–12 Mar*	2022 IEEE Aerospace Conference	Big Sky, MT (aeroconf.org)	
1–3 Apr	AIAA Region VI Student Conference	Merced, CA	5 Feb 22
4–6 Apr*	3rd IAA Conference on Space Situational Awareness (ICSSA)	Madrid (http://reg.conferences.dce.ufl.edu/ICSSA)	15 Jun 21
19–22 Apr	AIAA DEFENSE Forum	Laurel, MD	
30 May–1 Jun	29th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia	
21–24 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
25–26 Jun	7th AIAA Drag Prediction Workshop ("DPW-VII: Expanding the Envelope")	Chicago, IL	
26 Jun	2nd AIAA Workshop for Multifidelity Modeling in Support of Design & Uncertainty Quantification	Chicago, IL	
27 Jun–1 Jul	AIAA AVIATION Forum	Chicago, IL	
24–26 Oct	ASCEND Powered by AIAA	Las Vegas, NV	

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Ioannis G. Mikellides
NASA Jet Propulsion Laboratory

Kristi A. Morgansen
University of Washington

Greg F. Naterer
Memorial University

Daniel I. Newman
Boeing Defense, Space & Security

Guillermo Paniagua
Purdue University

James E. Polk
NASA Jet Propulsion Laboratory

Shahrokh Shahpar
Rolls-Royce PLC

Walter A. Silva
NASA Langley Research Center

Karen A. Thole
Pennsylvania State University

William A. Welsh
Sikorsky, a Lockheed Martin Company

Oleg A. Yakimenko
Naval Postgraduate School

The Class of 2020 Fellows and Honorary Fellows will also be inducted at this ceremony.

YOU ARE CORDIALLY INVITED TO THE CLASS OF 2021 VIRTUAL INDUCTION CEREMONY

TUESDAY, 17 AUGUST 2021 | 1700–1900 HRS ET

https://live.remo.co/e/aiaa-fellows-induction-ceremony-/register

AIAA
SHAPING THE FUTURE OF AEROSPACE

Nominations for AIAA Board of Trustees

MEMBERS-AT-LARGE ARE NOW BEING ACCEPTED THROUGH 27 AUGUST

The AIAA Executive Nominating Committee (ENC) will compile a list of potential nominees for the Board of Trustees – Members-at-Large. The list will include nominees who will be selected to go to the next step of competency review and interview held by the nominating committee. The ENC will select specific candidates for the Institute's Board of Trustees – Members-at-Large in November 2021. The Board of Trustees – Members-at-Large will be elected by the Council of Directors in March 2022 and announced soon thereafter.

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

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

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

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

Please submit the nomination package directly to Christopher Horton, AIAA Governance Director, chrish@aiaa.org, no later than 27 August 2021.

Reminder: Nominations for AIAA Directors are Being Accepted Through 23 July

For nomination criteria, please go to: aiaa-awards.org/a/organizations/main/submissions/details/54295.

Please submit all nominations directly to Christopher Horton, AIAA Governance Secretary, chrish@aiaa.org, no later than 1800 hrs EDT, 23 July 2021.

MAKING AN IMPACT

AIAA Partners with Organizations to Inspire the Future STEM Workforce

Design|Build|Launch

AIAA is proud to partner with Blue Origin for the Design|Build|Launch (DBL) Competition as we both strive to inspire the future workforce in STEM fields. High school students are invited to develop research proposals in the fields of microgravity science or space technology that are judged on the basis of scientific/technical merit, outreach creativity, and feasibility. The 2021 winning proposal is "Acoustic Levitation Under Variable G," presented by **Puneeth Bheesetty, Anna Porter Puckett,** and **Jaden Shawyer** of Granby High School, Norfolk, Virginia. The proposal experiment is the second AIAA-sponsored payload that will fly on the New Shepard rocket.

Team leader Puneeth will contribute to the research of acoustic levitation, and lead the team as they design, build, and test the acoustic levitator. He has been interested in space since childhood. His ambition is to push the boundaries of space exploration by contributing to the innovation of space exploration vehicles. He is also enrolled in the Norfolk Science, Technology and Advanced Research, which allows him to pursue his passion for space exploration.

Anna, a rising junior, contributes to the team by offering her creativity, strategic planning, and communication skills to help create an innovative project with broad appeal. She would like to show girls that space discoveries and developments impact everyone, and to encourage them to participate in STEM projects and programs.

Jaden, also a rising junior, contributes to the team with his strong science and mathematics background and innovative problem-solving abilities. He believes that inclusive teams made up of people from diverse backgrounds and different perspectives can spark innovation and creativity.

We look forward to hearing Puneeth, Anna, and Jaden present their findings at 2022 ASCEND.

Conrad Challenge 2021 Virtual Innovation Summit

The Conrad Challenge is an annual, multi-phase innovation and entrepreneurship competition that encourages young adults to participate in designing the future. Each year, teams of 2-5 students, ages 13-18, from around the world create products and/or services to address some of the most pressing global and local challenges. They become entrepreneurial problem-solvers, addressing challenging social, scientific, and societal issues through utilizing their creativity and critical-thinking skills. This year the 2021 Virtual Innovation Summit took place 28–30 April, and featured students from 33 states and 49 countries.

The $2,500 AIAA Conrad Challenge Scholarship was awarded to **Kirsten Nelson** of the Eir Clean Company team from New Jersey. This team created the ValkEIRe autonomous airplane cleaning device. With the push of a button, this robot will sanitize aircraft using UVC light and disinfectant mist. The Eir Clean Company was formed through the It's a Girl's World STEM mentoring program, which Kirsten has participated in for three years. This opportunity has taught her how to develop business plans, practice STEM-related activities, and prepare for college with the help of dedicated volunteers.

AIAA "Look Up!" Award: Regeneron ISEF Winners

The AIAA "Look Up!" Award, presented at the 2021 Regeneron International Science and Engineering Fair (ISEF), held virtually on 16–21 May, celebrates exceptional high school-level research to encourage further study in aerospace. Winners of the AIAA "Look Up!" Award receive a cash award and AIAA student membership with access to all student programs and upcoming partnership competitions and challenges. We congratulate the 2021 winners and encourage students to Look Up! and see their future in aerospace.

First Place ($2000)

Isabella Weiner,
Holy Trinity Episcopal Academy,
Rockledge, FL

"In situ Resource Utilization of Martian Regolith for Construction, Year Four"

Growing up on the Space Coast, an interest in space exploration inspired her four-year research project on building using sulfur-concrete on Mars, which helped develop her passion for engineering and research.

Second Place ($1500)

Max Schaldach,
Freies Gymnasium Zurich,
Zurich, Switzerland

"Development of a Rotor with Improved Aerodynamics to Propel a Quadcopter - Design and Manufacture According to the Laws of the Propeller Theory by Betz and Schmitz"

I am especially looking forward to getting involved in the aero-space groups – such as the team developing RC aircraft for AIAA's Design/Build/Fly competition. After completing my undergraduate studies at Olin, I plan to pursue a master's degree in engineering. I cannot wait to see where this adventure will ultimately take me.

Third Place ($1000)

Melanie Deville,
Westminster Christian School,
Coral Gables, FL

"Visualization of Three-Dimensional Aerospike Nozzle Flow Using Schlieren Photography"

I am an avid lover of the sciences and the fine arts, being involved in activities such as science fair, dance, and choir. My love for science began with my father's passion for Aerospace Engineering, and he taught me to appreciate the world beyond our own. My love for the fine arts began with my mother, who always showed me the beauty and joy that music can bring to life.

AIAA Northern Ohio Section Holds Event on Biomimicry

On 22 May, the AIAA Northern Ohio Section held its first in-person event since the beginning of the pandemic, with 30 people attending. It was great to see our members and spend a beautiful day outside at the Cleveland Metroparks Zoo. After lunch at the picnic area, Dr. Vikram Shyam from NASA Glenn Research Center led a discussion on current research in the area of Biomimicry. The lecture was well received with AIAA members asking questions about the role of artificial intelligence in leveraging biomimicry engineering approaches, and the kids answering questions about penguins and polar bears. After the lecture, members were able to explore the zoo and put their new knowledge to the test.

Making a Difference at Mach 2

The AIAA Albuquerque Section held a virtual meeting on 18 March and invited **AIAA Associate Fellow Lt. Col. Tucker Hamilton**, USAF F-35 Developmental Test Director of Operations, to talk about his flying experiences and show pictures and videos of what it is like to be an Experimental Fighter Test Pilot. His stories included major life-threatening aircraft accidents, close saves, combat flying revelations, serendipitous opportunities testing first of its kind technology, flying over 30 aircraft from a zeppelin to a MiG-15 to an A-10, and managing the Joint Strike Fighter Developmental Test program for all three services. Hamilton started his Air Force career as an operational F-15C pilot. He then served as an Air Liaison Officer in Germany where he was the director of operations for a key command and control squadron. While serving in Germany he was hand-selected to be the initial cadre for the first MC-12 squadron in Afghanistan, heralding in the Air Force's first tactical Intelligence, Surveillance, and Reconnaissance aircraft. He served as the Chief Instructor for 200+ aircrew and accumulated over 400 combat hours. After these experiences he went to test pilot school and eventually went to Washington, DC, to work on the F-35 program. Hamilton transitioned to Edwards AFB, CA, where he currently flies the F-35 as the Developmental Test Director of Operations. He spoke about surviving a mid-air collision, and then advocated collision avoidance systems.

DEFENSE FORUM

14–16 September 2021 | Laurel, MD

SHARPENING THE COMPETITIVE EDGE THROUGH AEROSPACE INNOVATION

The AIAA DEFENSE Forum is a Secret/NOFORN event providing a venue for leaders from government, military, industry, and academia to advance and accelerate innovation. The 2021 forum covers the strategic, programmatic, and technical topics and policy issues pertaining to the aerospace and defense community. This year's theme will explore the strategic imperatives of competition – from great power competition to commercial innovation to competing in the marketplace of ideas.

FEATURED SPEAKERS

Wesley D. Kremer

President
Raytheon Missiles & Defense

VADM Jon Hill, USN

Director
Missile Defense Agency

NEW THIS YEAR

- Wargaming tabletop exercises
- Largest technical program yet—124 technical briefings presented in 30 sessions
- DoD Digital Engineering Strategy and Implementation plenary panel
- Space Asset Protection plenary panel

REGISTRATION OPENS 20 JULY

aiaa.org/defense

Obituaries

AIAA Honorary Fellow and Past President Currie Died in April

Malcolm Currie, engineering physicist and former chairman and CEO of Hughes Aircraft, died on 18 April. He was 94.

Currie enlisted in the U.S. Navy during World War II. After his discharge, he attended the University of California, Berkeley, where he earned his bachelor's degree in physics and doctoral degree in engineering physics. He began his career as a research scientist at Hughes in 1954, and rose to director of the company's research and development engineering division. Currie oversaw projects such as the first digital airborne radars, laser systems and early satellite communications electronics.

Currie was recruited by Arnold Beckman to lead research and development at Beckman Instruments. In 1973, Currie was appointed undersecretary of defense research and engineering, where he was responsible for planning, managing, and guiding the defense department's weapons research, development, and acquisition programs. In this position, he started and guided pioneering programs on the global positioning system and cruise missiles.

In 1977, he returned to Hughes and rose to become chairman and CEO before retiring in 1993. Currie is credited with leading its diversification from defense into such areas as commercial satellite communications and private business network products. After his retirement, he founded Currie Technologies, a developer and distributor of electric bikes and scooters.

Over the years, Currie and his wife generously donated to the University of Southern California, including the the 2008 endowment of the Malcolm R. Currie Chair in Technology and the Humanities. Currie was a member of the National Academy of Engineering, a Fellow of the Institute of Electrical and Electronic Engineers, and an AIAA Honorary Fellow. He was inducted into the Space Technology Hall of Fame in 1998 for his work on the global positioning system.

He held many patents and published numerous papers on topics from lasers to space propulsion. In 1994, he served as AIAA president.

Currie was a recipient of many awards including the U.S. Department of Defense's Distinguished Public Service Medal, the NASA Distinguished Service Medal, the National Intelligence Medal, the Air Force Thomas D. White National Defense Award, the IEEE Founders Medal, and the American Electronics Association National Achievement Award. In 1993, he was honored with the AIAA Goddard Astronautics Award for exemplary contributions to the advancement of astronautics through pioneering work in critical technologies and through distinguished public service and industrial leadership of advancements which transformed astronautics for the benefit of mankind.

AIAA Senior Member Bierley Died in January

Donald A. Bierley died on 18 January 2021. He was 88 years old.

Bierley was graduated from Miami University (Ohio) in 1954 with a degree in Mathematics and Physics. He worked as a civilian at Wright-Patterson AFB, OH, in the Aerial Reconnaissance Lab, for nearly five years. He then held an engineering position at the Air Technical Intelligence Center (ATIC), now the National Air and Space Intelligence Center (NASIC). He traveled extensively in the United States, Europe and Japan.

Bierley retired as the Foreign Space Systems Branch Chief in 1989 after 35 years as a civil servant. He then held a sub-program management position with Science Applications International Corporation (SAIC), retiring for a second time in 1999. He was also a U.S. Army Reserve veteran, serving from 1954-1964. Bierley was a 60-year member of AIAA.

AIAA Fellow Walsh Died in January

John B. Walsh, 93, died on 26 January.

He graduated from Manhattan College in 1948, Summa Cum Laude, with a Bachelor of Electrical Engineering and additional majors in Civil Engineering and Mathematics. Walsh served with a radar development group of the U.S. Army Signal Corps from 1946 to 1947 and was later commissioned Second Lieutenant in the Signal Corps

Reserve. He received his M.S. degree from Columbia University in 1950 and did postgraduate work at New York University.

From 1948 to 1951, Walsh was on the teaching staff at Columbia University. In 1951, he took a leave of absence to help establish the Rome, NY, Air Development Center, where he rose to be Technical Director of the Intelligence and Reconnaissance Division (1953). He taught again at Columbia as an Assistant Professor of Electrical Engineering and became Assistant Director of its Electronics Research Laboratories.

In 1965, Walsh became Deputy for Research to the Assistant Secretary of the Air Force for Research and Development, before becoming an Assistant to the President's Science Advisor and Senior Staff Member of the National Security Council. In 1972, he became Deputy Director of Defense Research and Engineering for Strategic and Space Systems. In 1977 he was offered the post of Assistant Secretary General of NATO for Defense Support – a diplomatic assignment – in which he was instrumental in obtaining the agreement of the 15 NATO nations to undertake the NATO AWACS (Airborne Warning and Control System) joint program.

Returning from NATO, Walsh joined the faculty of the Defense Systems Management College as professor and Dean of the Executive Institute. He also chaired several Defense Science board groups, and was a member of the Scientific Advisory Group for Effects of the Defense Nuclear Agency.

He retired from government service in 1982 and joined The Boeing Company as Vice President-Chief Scientist of the Boeing Military Airplane Company and later became Vice President for Strategic Analysis of the Defense and Space Group before retiring in 1993.

During his career, he authored multiple books and textbooks, and numerous published articles in scientific and professional magazines and journals. Walsh was the recipient of the Department of Defense Distinguished Civilian Service Award, the Department of Defense Meritorious Civilian Service Award, the Air Force Exceptional Civilian Service Award, the Air Force Association's Citation of Honor as Outstanding Air Force Civilian Employee of the Year, the Theodore von Karman Award of the Air Force Association, and The Commander's Award for Civilian Service.

He was very involved with AIAA and served as a member of the Missile Systems Technical Committee, Honors and Awards Committee, and Elmer Sperry Award Selection Committee. He was also on the AIAA on Board of Directors as vice president, Technical Activity Committee.

The Maui Space Surveillance Complex in Hawaii.
U.S. Air Force

CONTINUED FROM PAGE 64

across the ocean. This wayfinding tradecraft could have been completely lost, but it was preserved by a Hawaiian group that crafted an outrigger canoe in the ancient Polynesian tradition and called it the Hokule'a. In 1976, they sailed the Hokule'a on its initial voyage from Hawaii to Tahiti, proving the use of Polynesian traditional wayfinding knowledge and as we scientists are known to say, "quod erat demonstrandum," a Latin phrase meaning "it has been shown."

Why would a space environmentalist like me take so much interest in Polynesian wayfinding? Because the U.S. Space Force, which also looks to the sky, has a facility on the Hawaiian island of Maui called the Maui Space Surveillance Complex atop Mount Haleakalā. I worked there for several years doing space surveillance and tracking research to infer the behavior of objects in near-Earth space. It was a true joy for me and my family to live in the town of Makawao, in a region known to locals as Upcountry, on the slopes of Haleakalā. There were times on Maui when my native Hawaiian friends would share their frustration at feeling displaced and excluded from any decision-making regarding the use of the facilities on top of their sacred mountains. I never understood why the state and local government, and industry, never closed the educational gap on Maui, hindering native Hawaiians from being indispensable partners and contributors to space surveillance sciences and technologies. It is painfully ironic that these indigenous peoples are unmatched in wayfinding, being demonstrably great interpreters of data coming from our sky, and yet they're in absentia regarding the work and decisions on their islands for space surveillance. A child born in Makawao today should be able to direct the Maui Space Surveillance Complex tomorrow and never have to leave the island. This statement, at present, is unachievable. That's a problem, but there are current efforts to mitigate this, such as the Hawai'i's Engaged STEM Pathways program to link high school students from these underrepresented populations with the opportunity to earn STEM degrees in the University of Hawaii system.

To be sure, detecting, tracking and identifying the 30,000 objects orbiting the Earth as a consequence of human activities is a non-trivial task, even with the best sensing technology and skilled scientists and engineers. However, if we provided Polynesians with all the data we have gathered on these objects, along with the space weather data and other sources of information, they could apply their wayfinding principles and provide us with their own perspective and understanding of the proliferation of space debris and traffic that is in desperate need of holistic management and coordination. What I mean is that Polynesians have a process for interpreting data to better understand their environment and how to be successful at navigating on the seas. Perhaps they could apply the same empirical principles to space data and help humanity get a better understanding of the current space traffic problem and even how we could navigate around it, in a matter of speaking.

This contribution to space situational awareness and space traffic management based on Polynesian knowledge could be institutionalized at the Maui Research and Technology Park, a hub for technology and innovation on Maui. This could become manifest as a public-private partnership among government, industry and academia. We could work on getting native Hawaiians educated and employed in space situational awareness, bringing their cultural knowledge to bear on these wicked space problems. As a space environmentalist acknowledging the foundational role of traditional ecological knowledge, I'm all in. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1921

July 9-11 Bailey Willis of the Seismological Society of America arranges to fly over part of the San Andreas Fault in a U.S. Army airplane to test the viability of photographing and mapping geologic features. Eugene M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 13; **Science**, Vol. 54, No. 1395, pp. 266-268.

July 13-21 U.S. Army and Navy flying Martin bombers sink the captured German destroyer G-102, the Frankfort light cruiser and the battleship Ostfriesland in naval bombing tests off the Virginia Capes. Heavy bombers under the command of Army Air Services Brig. Gen. Billy Mitchell attack the Ostfriesland while an inspection team approaches the ship. No one is injured, but this breach of protocol turns many in the Navy, including Admiral William A. Moffett, the first Chief of Bureau of Aeronautics and an air power advocate, against Mitchell. Although the Ostfriesland was at anchor and had no anti-aircraft or damage control teams on board, it still takes the bombers two days to sink the battleship. Despite this, Mitchell declares the battleship and the Navy obsolete. David Baker, **Flight and Flying, A Chronology**, pp. 139-140.

1946

July 1 Frederick Koolhoven dies. The aircraft designer and builder was one of the first Dutch pilots, joined the French Deperdussin company and helped produce the aircraft in which Marcel Prévost set a speed record of 120 mph (193 kph) in 1913. Koolhoven later joined Armstrong-Whitworth in Britain and eventually formed his own company, N.V. Koolhoven, in 1926 where he designed and built aircraft sold throughout the world. Among them were the F.K. 31 and F.K. 41. In 1940, however, his plant in the Netherlands was destroyed by German bombers. **The Aeroplane**, July 12, 1946, pp. 34-35.

July 7 Film producer and aircraft designer Howard Hughes is severely injured when he crashes his experimental twin-boom XF-11 reconnaissance aircraft, which is powered by two Wasp Major radial engines that drive eight-blade contrarotating propellers. **The Aeroplane**, July 19, 1946, p. 60.

July 9 The U.S. Joint Chiefs of Staff's Subcommittee on Guided Missiles recommends that a site be chosen for a long-range missile proving ground. Cape Canaveral, Florida, is selected. E. Emme, **Aeronautics and Astronautics, 1915-60**, p. 54.

July 21 A McDonnell XFD-1 Phantom twin-jet single-seat Navy fighter becomes the first American all-turbojet to operate from an aircraft carrier, the Franklin D. Roosevelt, off of Virginia. E. Emme, **Aeronautics and Astronautics, 1915-60**, p. 54.

July 31 The national airlines of Denmark, Norway and Sweden form SAS, the Scandinavian Airlines System. The airline combines the assets of three national airlines: DDL, the Danish parent company, which was formed in 1918; ABA, the Swedish line that began in 1924; and Norway's DNL, which was formed in 1927. The SAS fleet is comprised of five converted Douglas C-54 Skymasters. R.E.G. Davies, **A History of the World's Airlines**, pp. 278-280.

1971

July 1 Astronaut Buzz Aldrin, the second person to walk on the moon, retires from NASA to become the commandant of the Aerospace Research Pilot School at Edwards Air Force Base in California. **Washington Post**, July 2, 1971, p. A3.

July 2 The cremains of Soyuz cosmonauts Georgy Dobrovolsky, Vladislav Volkov and Viktor Patsayev, who died when their spacecraft entered the atmosphere with an improperly sealed hatch, are buried in the Kremlin Wall in Moscow's Red Square. Their military funeral, climaxing a national day of mourning, was viewed by millions and attended by leading Soviet and foreign leaders. NASA astronaut Thomas Stafford represented President Nixon at the funeral. **Washington Star**, July 1, 1971, p. A-2; **New York News**, July 5, 1971, p. 7.

July 8 NASA launches the Naval Research Lab's Solrad 10 (or Explorer 44) solar radiation satellite from Wallops Island, Virginia, on a solid-propellant Scout booster. The satellite is to monitor the sun's X-rays and ultraviolet emissions. The 115-kilogram, 12-sided cylindrical satellite carries sensors to measure solar X-rays and ultraviolet radiation. **NASA Release 71-1**3.

1 **July 9** France's annual International Galabert Prize for outstanding successes in the exploration of outer space is presented to the Soviet Academy of Sciences for its uncrewed Luna 16 spacecraft that landed on the moon and brought samples of lunar material to Earth. NASA, **Astronautics and Aeronautics, 1971**, p. 191.

2 **July 15** NASA Administrator James Fletcher presents a lunar module similar to those flown in the Apollo 11, 12 and 14 lunar landings to former astronaut Michael Collins, director of the National Air and Space Museum of the Smithsonian Institution. The Apollo lunar module is to remain on permanent exhibit at the museum. **Smithsonian Release 111-71**.

July 16 The Soviet Union launches the Meteor 9 weather satellite from the Plesetsk Cosmodrome. The satellite carries meteorological equipment to obtain pictures of clouds and snow caps on day and night sides of Earth and collect data on thermal energy reflected and radiated by Earth and the atmosphere. NASA, **Astronautics and Aeronautics, 1976**, p. 195.

July 19 NASA announces that Apollo 15 astronauts will wear pressure suits instead of flight coveralls as originally planned during their lunar module jettison. The requirement for the crew to wear suits had been reevaluated after the deaths of three cosmonauts during the reentry of Soyuz 11 on June 30. **NASA Release 71-134.**

3 **July 26** A Saturn V is launched from the Kennedy Space Center carrying the Apollo 15 crew of David Scott, Alfred Worden and James Irwin on NASA's fourth lunar landing mission. During the trip, Scott and Irwin will land in the Falcon lunar module in the moon's Hadley-Apennine region, deploy the first crewed lunar roving vehicle, conduct experiments and collect lunar samples. **Washington Post**, July 27, 1971-Aug. 8, 1971.

July 28 The Soviet Union launches the Molniya I-18

communications satellite from the Plesetsk Cosmodrome to continue the operation of long-distance telephone and telegraphic radio communications and TV transmissions in the country's far north, including Siberia, the Far East and Central Asia. NASA, **Astronautics and Aeronautics, 1976**, p. 210.

4 **July 29** The U.S. Air Force's X-24A lifting body completes its flight-testing program and is to be reshaped and renamed the X-24B. The X-24A, as a joint NASA-Air Force program, made 28 flights since the test program began in 1969. Lifting bodies gather aerodynamic and other data toward the design of future spacecraft including the space shuttle. The X-24A's fastest flight was 1,687 kph. NASA, **Astronautics and Aeronautics, 1976**, pp. 210-211.

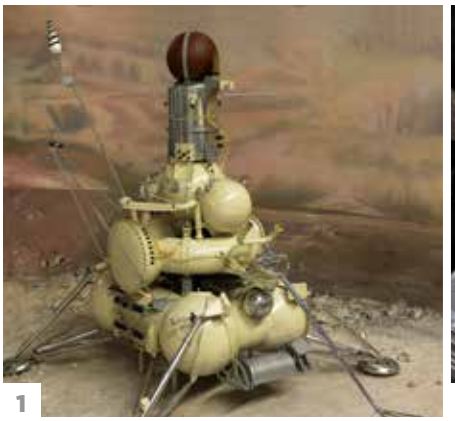
1996

July 2 NASA's Total Ozone Mapping Spectrometer on the Japanese Advanced Earth Observing Satellite is launched on an Orbital Sciences Pegasus XL from Vandenberg Air Force Base in California. NASA, **Astronautics and Aeronautics, A Chronology, 1996-2000**, p. 25.

5 **July 2** Lockheed Martin wins the contract from NASA to build the uncrewed X-33 reusable launch vehicle. It is a suborbital spaceplane technology demonstrator intended to lead to the VentureStar, a lower-cost replacement for the space shuttle. NASA, **Astronautics and Aeronautics, A Chronology, 1996-2000**, p. 26.

July 7 The space shuttle Columbia returns after a record-setting 17-day mission, landing at Cape Canaveral in Florida. Columbia is carrying a lighted torch for the 1996 Atlanta Summer Olympics, which is transferred to the Olympic relay team upon arrival. NASA, **Astronautics and Aeronautics, A Chronology, 1996-2000**, p. 27.

6 **July 22** It is reported that an Airbus A300B2 begins operations for CNES, the French Space Agency, as a zero-G parabolic flight training vehicle for French astronauts, similar to zero-G planes used in the U.S. The A300 normally carries 40 passengers, but the seats have been removed and a video camera and accelerometer have been installed. **Aviation Week**, July 22, 1996, p. 53.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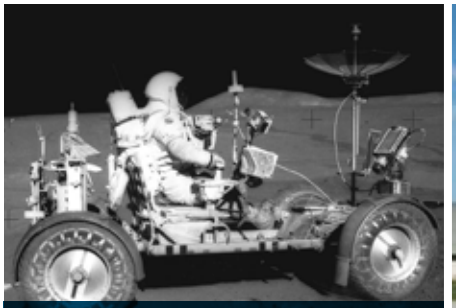
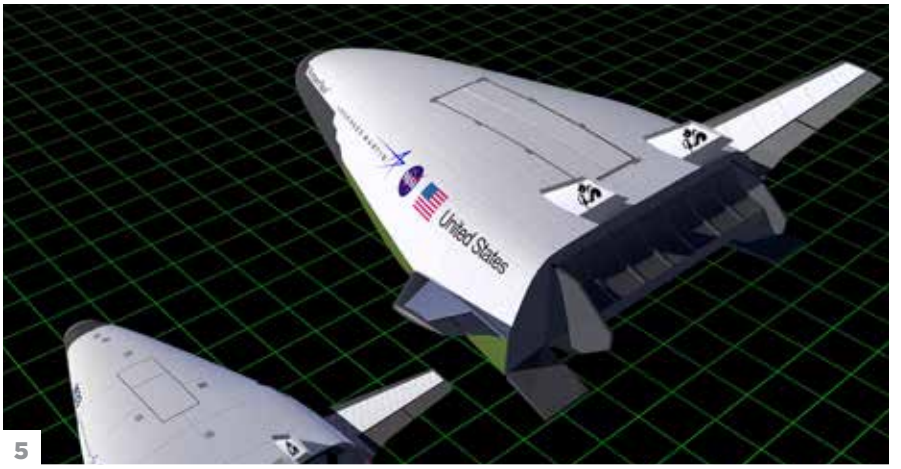

3 NASA astronaut David Scott in the lunar rover with rocks and soil collected near the Hadley-Apennine landing site. **NASA**

4



5

6

1921

1 **Aug. 1** The U.S. Navy Torpedo Squadron at Yorktown, Virginia, tests a World War I high-altitude sight mounted on a gyro-stabilized base, marking the completion of the first phase of development of Carl I. Norden's bombsight. When perfected, the Norden will become the primary computerized bombsight for U.S. Army Air Forces strategic bombing campaigns of World War II. Eugene M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 13.

Aug. 4 An airplane sprays some 5,000 catalpa trees in 15 minutes over Troy, Ohio, in an early test of what would come to be known as crop dusting. Eugene M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 14.

Aug. 10 The Navy Bureau of Aeronautics is established. It is responsible for all aviation development in the U.S. Navy and Marine Corps. Rear Adm. William Moffett is its first chief. David Baker, **Flight and Flying, A Chronology**, p. 140.

Aug. 11 Venice, Italy, is the host of the fifth Schneider Trophy competition for seaplanes. Some 16 Italian aircraft and one French aircraft begin the race, and four finish. A Macchi M.7 wins the cup with an average speed of 117.7 mph (189.4 kph). David Baker, **Flight and Flying, A Chronology**, p. 140.

1946

Aug. 1 British European Airways is formed from the European Division of the British Overseas Airways Corp., known as BOAC. The new airline operates mainly over routes in the British Isles and Continental Europe. The airline is composed of six used Douglas Dakotas, though these are soon replaced by Vickers Vikings. R.E.G. Davies, **A History of the World's Airlines**, pp. 303-304.

Aug. 8 The world's largest landplane, the Convair XB-36 bomber, makes its 38-minute first flight at Fort Worth, Texas. The aircraft, whose development began in 1941, is 50 meters long, has a 70-meter wingspan, a single 14-meter-high tail fin and a range of 16,000 kilometers. It is powered by six Wasp Major engines and has a maximum speed of 480 kph (300 mph). **Aviation News**, Aug. 19, 1946, p. 9.

Aug. 12 Congress passes Public Law 722, authorizing the National Air Museum as a bureau of the Smithsonian Institution. By 1948, the museum is housed partly in the Aircraft Building, a former World War I engine shop hangar, and partly in a corner of the Smithsonian Arts and Industries Building. In 1966 the name is changed to the National Air and Space Museum, and in July 1976 the new museum opens. It becomes the most popular museum in the world, receiving about 8 million visitors annually and reaching the 100 million mark in December 1986. **NASM Fact Sheet and articles, NASM Museum file, NASM Library**.

Aug. 17 U.S. Army Air Forces Sgt. Lawrence Lambert is the first person ejected from an aircraft using an emergency escape device in the United States. He is ejected from a Northrop P-61 Black Widow flying at 480 kph at 7,800 feet over Patterson Field, Ohio. E. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 54.

2 **Aug. 18** The Ilyushin Il-12, a 27-seat Russian airliner, is shown to the public in Moscow for the first time during Soviet Aviation Day celebrations. The twin-engine aircraft has a range of 2,400 kilometers and is intended as a replacement for the Lisunov Li-2, the license-built version of the classic Douglas DC-3. **The Aeroplane**, Aug. 23, 1946, p. 231.

Aug. 19 Sikorsky makes the world's first delivery of a commercial helicopter, an S-51, to Helicopter Air Transport in Camden, New Jersey. HAT immediately puts the helicopter to use in aerial photography, package delivery and passenger service. **Aircraft Year Book**, 1947, p. 264.

1971

Aug. 3 Georgy Babakin, one of the Soviet Union's leading designers of uncrewed spacecraft, dies at 56. Babakin was the chief designer at the Lavochkin Design Bureau. He was responsible for Luna 9, the first spacecraft to make a survivable landing on the moon, and Lunokhod-1, a lunar surface vehicle. **New York Times**, Aug. 5, 1971, p. 34.

3 **Aug. 4-13** The specially equipped Convair 990 jet aircraft Galileo, operated by NASA's Ames Research Center in California, carries 29 scientists and 4,500 kilograms of instruments on a series of flights from Hickham Air Force Base in Hawaii. The purpose of the flights is to investigate Mars' invisible infrared light radiations while flying above 99% of Earth's atmospheric water vapor during a period when Mars is closer to Earth than it has been in centuries. NASA, **Astronautics and Aeronautics, 1971**, p. 219.

Aug. 5 British aviator Sheila Scott arrives at London Airport in her Piper Aztec, completing her 55,000-kilometer solo flight in a light plane and claiming seven flight records. **Washington Post**, Aug. 6, 1971, p. A-6.

Aug. 5 The first commercial flight of the McDonnell Douglas DC-10 wide-bodied aircraft is made by American Airlines between Los Angeles and Chicago. The DC-10 remains in service as a passenger transport until 2014, although it continues as a freighter for FedEx and other applications. **Washington Star**, Aug. 18, 1971, p. D-10.

Aug. 6 The U.S. Air Force launches nine satellites from Vandenberg Air Force Base in California on one Atlas booster. These include the Ov I-20 Orbital Vehicle that carries a variety of scientific instruments to measure energetic particles in Earth's magnetic field; Ov-I-21; the Cannonball 2 and Musketball satellites to measure atmospheric densities; and several military satellites to gather aerodynamic data. NASA, **Astronautics and Aeronautics, 1971**, pp. 220-221.

Aug. 10 Australian pilots Trevor Brougham and Bob Dickeson land their twin-engine Beechcraft aircraft at Darwin, Australia, after their 125-hour and 27-minute flight around the world, a record for light aircraft. **Washington Post**, Aug. 11, 1971, p. A-6.

Aug. 16 France's Eole Cooperative Applications Satellite is launched on a NASA four-stage solid-propellant rocket from Wallops Island in Virginia. The primary objective of the 85-kilogram satellite is to study the circulation of the atmosphere from tracks of a series of 500 instrumented constant-density surface balloons flying at 36,000 feet and to obtain meteorological data from the balloons. The balloons are launched soon after the satellite launch from three sites in Argentina. NASA, **Astronautics and Aeronautics, 1971**, pp. 230-231.

4 **Aug. 18** The NASA supercritical wing, flown on a Vought TF-8A jet aircraft piloted by NASA test pilot Thomas McMurtry, completes its ninth flight. The flight at 35,000 feet is the first in a series to obtain data for performance evaluation of the critical wing. Previous flights were to familiarize the pilot. NASA, **Astronautics and Aeronautics, 1971**, p. 233.

Aug. 19 CNES, or France's National Center for Space Studies, announces that the Soviet Union will cooperate in the launching of two space probes from the Guiana Space Center in French Guiana. In one of these missions, a French Veronique rocket will carry a Soviet radio-frequency spectrometer. In the other mission, France will track a Soviet MR-12 sounding rocket launched from a Soviet ship near Kourou and carrying a French mass spectrometer. **New York Times**, Aug. 22, 1971, p. 35.

Aug. 20 The Soviet Union launches the Vertikal-2 cooperative geophysical research rocket to a 287-mile altitude to study solar ultraviolet, X-ray emissions and other phenomenon in the ionosphere and includes scientific instruments from Hungary, Czechoslovakia and East Germany. NASA, **Astronautics and Aeronautics, 1971**, p. 237.

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1996

Aug. 1 Boeing purchases Rockwell International Corp. for $3 billion. **Boeing press release**, Aug. 1, 1996.

5 **Aug. 8** Sir Frank Whittle, one of the two inventors of the jet engine, dies at age 89. The British-born Whittle developed a turbojet when he served in the Royal Air Force. After years of obstacles, Whittle saw his engine fly on the first British jet aircraft, the Gloster E28/39, on May 15, 1941. **Aviation Week**, Aug. 19, 1996, p. 94.

6 **Aug. 17** Japan launches its heaviest and most sophisticated satellite, the 3,500-kilogram Advanced Earth Observation Satellite, or Adeos-1, on an H-2 launch vehicle. The satellite is to study ozone depletion in the atmosphere and map the Earth's oceans, but it stops functioning in July 1997. **Aviation Week**, Aug. 28, 1996, p. 68 and July 7, 1997, p. 31.

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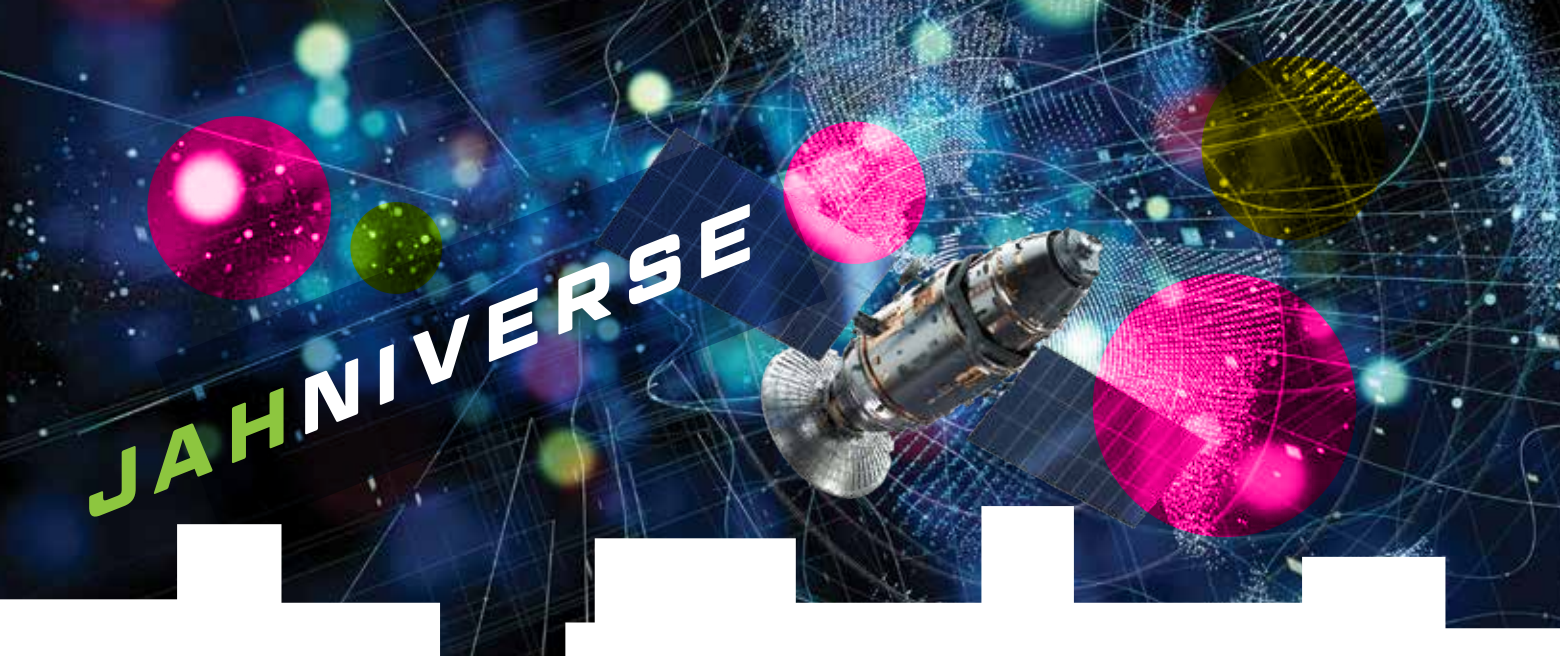

Where to find fresh talent for the space tracking field

BY MORIBA JAH

Wayfinding can be loosely understood as the tradecraft involved in orienting oneself in one's environment to go from one place to another. Many animals do it, and its brilliance can be seen in seasonal migration patterns, like those of whales that travel halfway across the planet's oceans to return to their place of birth in order to continue their family cycles. As for humans, it is quite difficult to find more impressive wayfinders than the ancient Polynesians and the modern-day indigenous people who are working to keep the tradition alive in this vast expanse of the Pacific Ocean that includes Hawaii, or Hawai'i, to include the okina letter of the native languages.

Regarding their wayfinding awesomeness, take Easter Island, for example. This is one of the most isolated and remote inhabited places on Earth, being 3,600 kilometers west of Chile and about 4,200 kilometers east of Tahiti. To put it into perspective, the distance from Los Angeles to New York City is about 3,900 kilometers. Imagine yourself on the open sea for that distance with no land in sight. The Polynesians have preserved the ability to navigate between all of the islands scattered across the Pacific Ocean. They are able to do this in an outrigger canoe and, inter alia, without any instruments aside from their knowledge of how to interpret stars and the sky.

The key to their wayfinding brilliance was a mastery of empiricism. From one generation to the next, Polynesian navigators passed on the traditional ecological knowledge of how to observe and interpret nature, meaning all that they saw in the sky and in the water that dominates their world. I've always thought that the Mariner, the central character in the movie "Waterworld," was inspired by the skills of the Polynesians. Specifically, these navigators were adept at observing and interpreting the types of clouds, their movements through the sky along with the stars and planets, the winds and types of winds, the swells in the ocean, types of animals observed and their behaviors. The Polynesians had to aggregate and synthesize all of these data to maximize their decision intelligence about when and where to move

CONTINUED ON PAGE 59

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