AEROSPACE
★ ★ ★ AMERICA ★ ★ ★

ERASING CONTRAILS

How far can sustainable aviation fuels go toward eliminating contrails? These scientists aim to find out. PAGE 22

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AIAA
SHAPING THE FUTURE OF AEROSPACE

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IN THIS ISSUE

Keith Button

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

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Cat Hofacker

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

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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.

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Sarah Wells

Sarah is a science and technology journalist based in Boston interested in how innovation and research intersect with our daily lives. She has written for a number of national publications and covers innovation news at Inverse.

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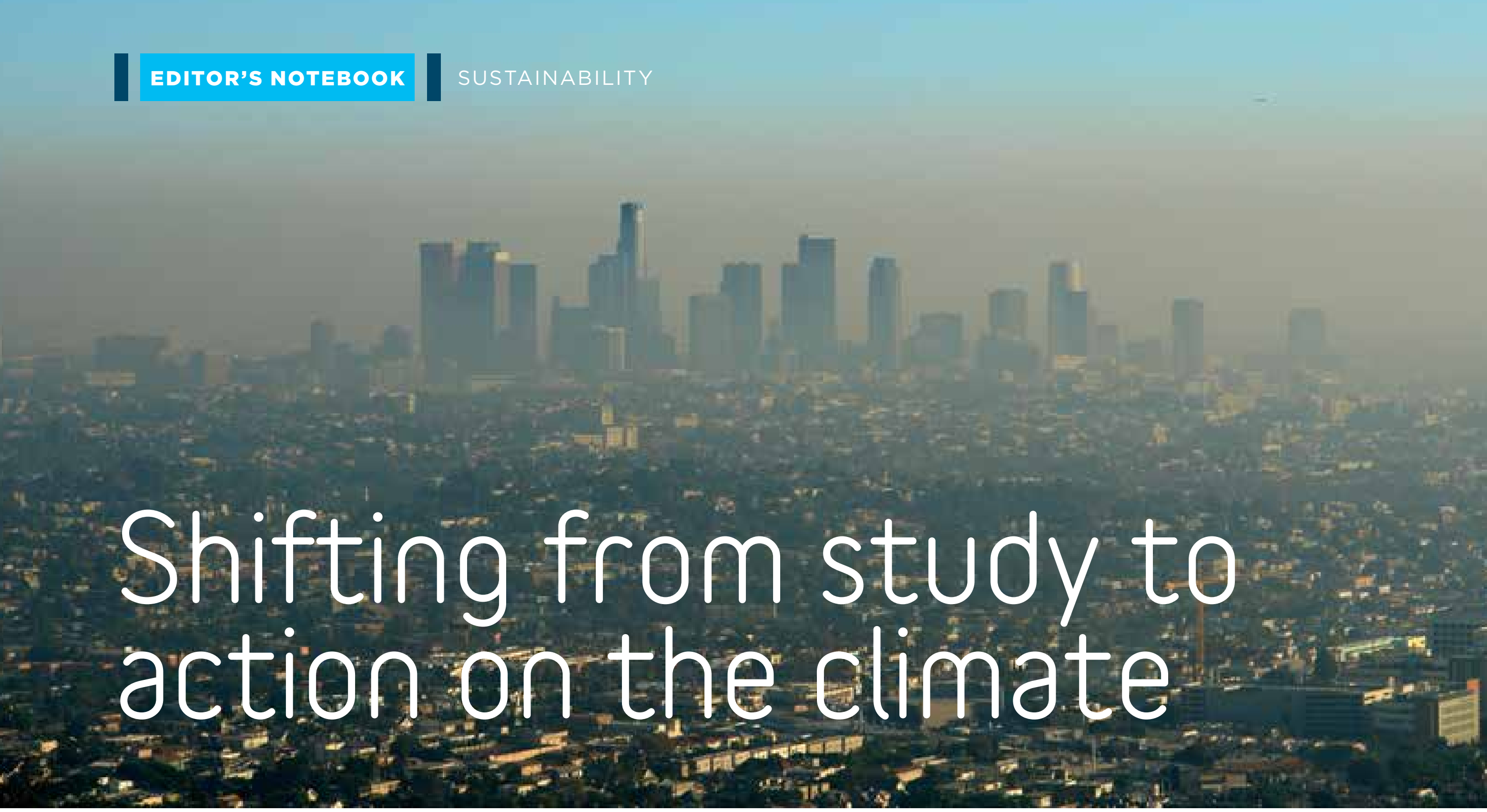
DEPARTMENTS



Shifting from study to action on the climate

For decades, the scientific community and many politicians viewed climate change as a mysterious, complex phenomenon worthy of continued study. Relatively little scientific effort was directed at real world action that could reduce warming of the planet or soften its effects. Our cover story about reducing jet contrails vividly illustrates the shift that's underway from observation to experimentation and action. First, scientists had to make sure they could document how aircraft emissions of soot morph into contrail clouds. With that complete, they're now in the process of figuring out which fuels safely maximize reduction of soot and contrail crystals.

We're now seeing a similar shift occurring in other research domains as well. The planet's coral reefs are vanishing at least in part due to warming seas. Rather than simply bear witness to the tragedy in research reports in hopes that policymakers will be activated, marine scientists are learning to cultivate and plant corals to restore reefs.

This kind of action is heartening, but just as in any endeavor, not all ideas will succeed. We need to be braced for some setback and failures. If we're lucky, the overall trend will be one of progress.

Our story about urban air mobility made me wonder about the possible climate effects of this emerging market. Perhaps the green aspect of these electric rotorcraft can be a selling point for potential passengers who remain leery of this concept for local travel, especially its autonomous flight aspects. Lots of questions need to be explored about this emerging market. For one, here in the United States we continue to love our automobiles, including SUVs, and we like to be captains of these ships. It's unclear to me whether Americans will bop from the suburbs or exurbs into cities as passengers in UAM aircraft in significant enough numbers to make a dent in the carbon footprint of our local travel. In any case, perhaps our ground vehicles will go electric before the UAM aircraft and the vertiport and traffic management plans can be rolled out.

However that market plays out, going electric in our local transportation is another example of positive action for the climate. ★

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

To The Class of 2021

It's graduation season again, when students receive their degrees and move into the next phase of life. To the Class of 2021, we celebrate your achievements. Congratulations! We applaud your hard work and perseverance to reach this significant milestone. In honor of this momentous occasion, I would like to share a brief graduation message. And for those experienced professional members of AIAA, I've got a related message for you as well.

A Year Like No Other

For students at all levels, learning during the past year has not been ideal. From moving to virtual classrooms, to losing familiar connections with your friends, to getting creative on completing group projects, the 2020–2021 academic year has been tough. There also have been fewer opportunities for fulfilling hands-on internship experiences. I have heard students' concerns that their resume upon graduation may not be viewed as stellar without the robust internships of the past.

You should acknowledge this year has been tough. I also believe you should use the resilience you've developed as fuel, propelling you toward your future.

Moving Ahead

While we have seen significant job losses this year, the aerospace and defense (A&D) sector is beginning its recovery. Each week, the U.S. government is awarding contracts to industry for major projects, commercial companies are continuing to sign customers, and universities are continuing to receive research grants. These organizations will need more qualified employees, so be encouraged – you are now qualified to enter the A&D workforce.

My Advice: Know When To Pivot

You are probably receiving a lot of advice right about now. Please allow me to add mine: *Be open to different options than what you planned.* The challenges brought by the pandemic make this mindset even more relevant. You may not find the role you want right away in today's recovering job market. If so, it may be time for you to pivot.

Perhaps pursuing a graduate degree is an option for you. Perhaps pursuing a role in an adjacent industry is an option for you, especially if you don't currently have a security clearance. You have options.

You have learned the fundamentals if you hold an engineering or science degree now. The fundamentals will help you contribute in many areas, in many roles. They also give you the foundation to build upon if you continue your education to the next level.

I learned about pivoting during my time at NC State University. I earned a bachelor's degree there in Aerospace Engineering in 1988, then a master's degree in 1990, and a doctorate in 1993. My focus during graduate school was the reemergent area of hypersonics, a field whose jobs were drying up by the time I finished in 1993. With the Cold War ending, employment in the A&D industry dropped off dramatically. I realized my dream job at NASA was not going to materialize. My future felt very uncertain. Yet, as a result of my studies, my undergraduate and graduate internships with NASA, and my experience writing technical papers for AIAA, I remained committed to learning the fundamentals and focusing on my future. I was fortunate to get a postdoctoral research position at Sandia National Laboratories and have been there ever since. Initially I worked in very different areas from my graduate training, but that foundation in the fundamentals contributed to my success. In the end, hypersonics made a comeback!

Your story will have its own path. Choosing a different option than the one you thought was your logical next step keeps you moving forward, which is the best direction to be going.

AIAA Is Here For You

We've all learned the value of connecting with others this year. You have a wealth of resources through your AIAA membership – mentors, classes, forums, books, and more. Moving to a Young Professional Membership will be a great step along your AIAA journey from classroom to career. I encourage you to connect with your local section to benefit from your AIAA support system.

One of the best decisions I ever made was joining an AIAA technical committee. At the urging of a mentor, David Throckmorton, I joined the Thermophysics Technical Committee. That step has led to my long affiliation with AIAA, volunteering in leadership roles, and now serving as its president. I did not realize then how important that decision was. I want to urge you to make a similar decision and stay involved with AIAA.

A Message For AIAA Professional Members

We have the opportunity to inspire the next generation to pursue a career in aerospace. We can do that through personal connections – like mentoring – and through personal contributions – like donating to the AIAA Foundation. Please join me in supporting the AIAA Foundation as it celebrates its 25th anniversary this year. Also join me in connecting directly with students in areas that align with your own passion.

Carry On

To the graduates – this pandemic academic year is a speed bump in your life. It may have slowed you down, but it didn't stop you. You will be stronger in the end having tackled the challenges you faced. Your resilience from this experience will serve you well as you make choices that move your career forward. Embrace the possibilities! ★

Basil Hassan
AIAA President

AERO PUZZLER

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

Crossing the Interplanetary Divide

True or false and why: Here in the Americas, most of us have heard of the Continental Divide, the invisible line demarcating where watersheds either flow west toward the Pacific Ocean or east toward the Atlantic Ocean. Interplanetary travel will be similar: On your way to Mars, at some point you are no longer in free fall toward Earth. You are in free fall toward Mars. It's that simple.

Draft a response of no more than 250 words and email it by noon Eastern May 13 to aeropuzzler@aiaa.org for a chance to have it published in the June issue.

FROM THE APRIL ISSUE

PLENTY OF HOT AIR: We asked you if a batted baseball would carry better on a cold day, as a fictional hitter claimed. Your answers were reviewed by Barton Smith of Utah State University and author of the blog, Baseball Aerodynamics.

WINNER: The baseball player's comparison of swimming and the flight of a baseball is inappropriate. It is true that saltwater is denser than fresh water. This causes a floating object (person) to displace less volume of water and have more volume immersed in the air above. The person swimming is operating on the interface between two fluids. The water is 800 times as dense and is much more viscous than the air so it is beneficial to have a smaller proportion of the volume in the water and the remaining, larger portion in the air. This is what makes swimming easier. The baseball is immersed only in air, not at the interface with another fluid, and the buoyancy is extremely small. There is no "cushion of cold air." For the baseball flying through the air, the denser, cold air creates more drag and reduces the flight distance. The player is only half right about the heat and humidity. Humid air is less dense than dry air and hot air is less dense than cold air, so the ball will fly farther on a hot, humid day. They both help, not just the humidity. The humidity is not really providing lift, just less drag.
Douglas Dobbin, an AIAA senior member, lives in El Paso, Texas, and works at White Sands Missile Range in New Mexico doing trajectory and risk analyses. He is studying fixed-wing airplane design in a graduate program at Georgia Tech. douglas.dobbin@gmail.com

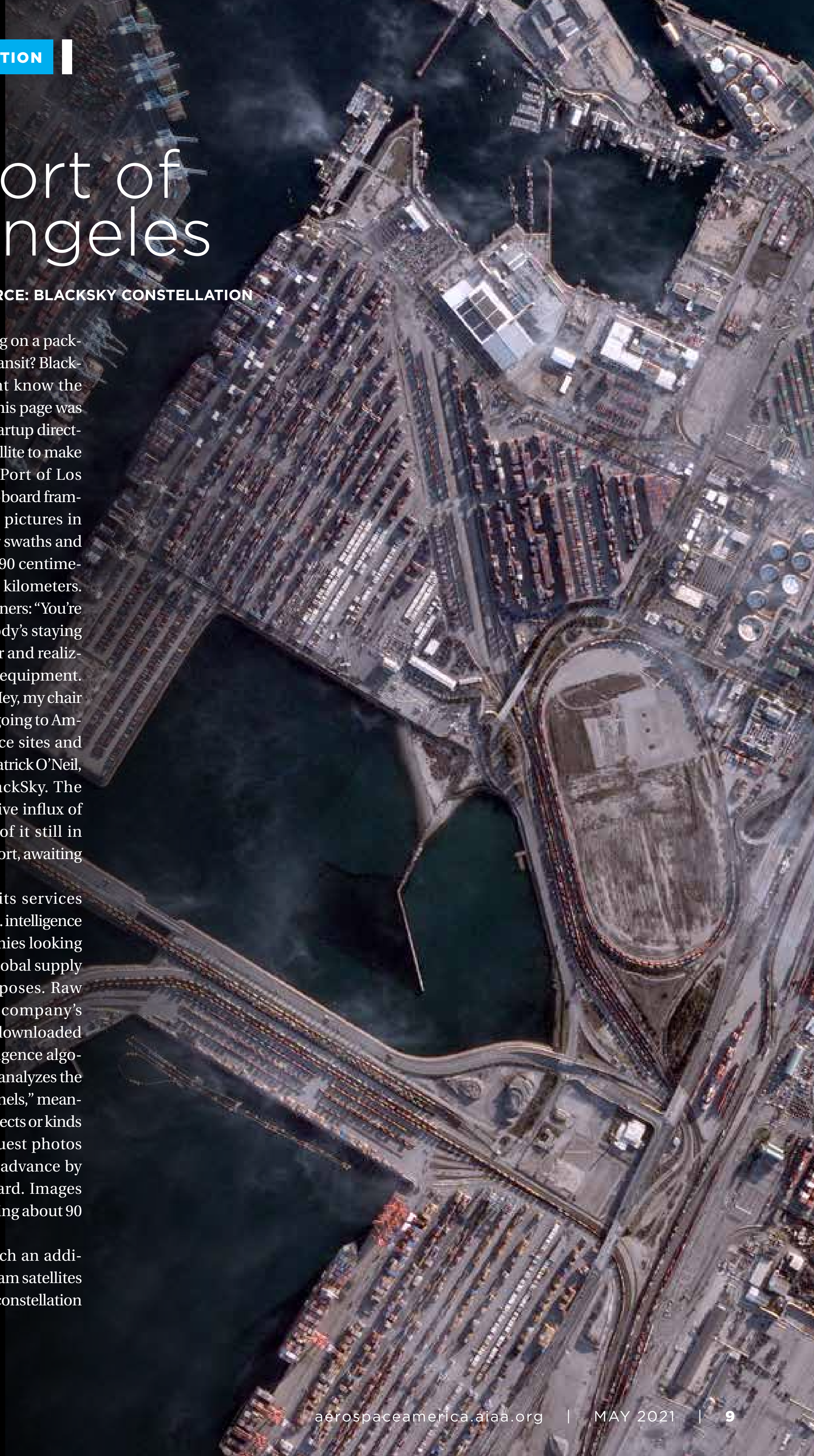
For a head start ... find the AeroPuzzler online on the first of each month at https://aerospaceamerica.aiaa.org/ and on Twitter @AeroAmMag.

AEROSPACE IN ACTION

SCENE FROM ABOVE

The Port of Los Angeles

MARCH 20, 2021 | SOURCE: BLACKSKY CONSTELLATION



Have you been waiting on a package that's stuck in transit? BlackSky Holdings might know the reason why. The image on this page was created when the Virginia startup directed its BlackSky Global-6 satellite to make multiple passes over the Port of Los Angeles. The spacecraft's on-board framing camera snapped color pictures in 6-kilometer-by-4-kilometer swaths and at a fine resolution of 80 to 90 centimeters from an altitude of 450 kilometers.

Note the shipping containers: "You're seeing the effect of everybody's staying from home for the past year and realizing, 'Hey, I need some gym equipment. Hey, I need a new monitor. Hey, my chair isn't that comfortable' and going to Amazon and other e-commerce sites and buying a lot of things," says Patrick O'Neil, chief data scientist at BlackSky. The images document a "massive influx of consumer goods," much of it still in shipping containers at the port, awaiting distribution, he says.

BlackSky is targeting its services toward the Pentagon and U.S. intelligence agencies, as well as companies looking for ways to monitor their global supply chains, among other purposes. Raw images from each of the company's initial seven satellites are downloaded and then an artificial intelligence algorithm, Spectra AI, sorts and analyzes the pictures for particular "channels," meaning geographic locations, objects or kinds of activity. Customers request photos related to the channels in advance by visiting an online dashboard. Images are made available for viewing about 90 minutes after downlink.

BlackSky plans to launch an additional seven of the 55-kilogram satellites by year's end, toward a total constellation of 30 satellites by 2023. ★

— *Cat Hofacker*

Aviation investigator

More online aerospace america. aiaa.org

Even after the pandemic winds down, full-time telework might be the norm for many aerospace professionals. Not so for the U.S. National Transportation Safety Board, says Dana Schulze. The 84 investigators she oversees in the Office of Aviation Safety will "always need that in-person ability to touch, gather, look" at the wreckage of all U.S. civil aircraft crashes to determine the probable cause. NTSB has found creative ways to get investigators this crucial hands-on access while minimizing their risk of covid-19 exposure. Schulze is confident the agency will employ that same creativity in ensuring its investigators are versed in the technology of emerging markets, including in-development urban air mobility vehicles, which would likely require different investigation techniques than those for today's aircraft. I called Schulze at her home office in Maryland to hear what it's like to be one of NTSB's crash detectives. Our conversation has been compressed and lightly edited. — *Cat Hofacker*

DANA SCHULZE

POSITIONS: Since July 2019, head of NTSB's Office of Aviation Safety, overseeing the 113 engineers, investigators and specialists that make recommendations to the U.S. Transportation Department and other agencies about air safety improvements based on findings of investigations into crashes involving U.S.-based airlines; head of the Major Investigations Division of the Office of Aviation Safety that leads crash investigations in which passengers or crew members have died or the aircraft was destroyed, 2008-2012; chief of NTSB's Aviation Engineering Division that determines the airworthiness of aircraft involved in major crashes, 2006-2008; manager of reliability, maintainability and safety at Hamilton Sundstrand in Illinois, 1997-2002.

NOTABLE: Since joining NTSB in 2002 as an aircraft system safety engineer, has chaired and participated in investigations including a probe into the 2000 crash of Alaska Airlines Flight 261 that was the inspiration for the 2012 film "Flight"; recipient of a 2017 Presidential Rank Award of Distinguished Executive, the highest honor the White House awards to career civil servants.

AGE: 54

RESIDES: Laurel, Maryland

EDUCATION: Bachelor of Science in space sciences and mechanical engineering, Florida Institute of Technology, 1989; Master of Science in mechanical engineering, Binghamton University in New York, 1998.

Q: Why have an independent agency, distinct from FAA, carry out investigations of plane crashes and make safety recommendations?

A: That's a foundational question for this agency, because the United States is in many ways unique in its approach to accident investigation. Not a lot of other countries have independent agencies like we are. Often, they are like NTSB was when it was first born: They're part of the department of transportation or the civil aviation authority. We report directly to Congress, and the importance there is that we don't have skin in the game, so we're objectively, credibly going to convince the public that we've done a comprehensive, thorough job and in doing that, really move safety change. In particular, if the public has a sense that — for example, if we were part of the FAA — that they weren't looking at themselves objectively, that would be a confidence issue for the public and the FAA. Credibility is all we really have to push safety change because NTSB does not have the authority to enforce its recommendations. We really need to convince our audience — which are the stakeholders in the aviation community: the manufacturers of aircraft and systems, the operators, the airlines, all the way down to the general aviation pilot and the regulator — that change needs to happen. Having that independent, no-skin-in-the-game third party really helps formulate that credibility.

"We do outreach because we want companies to know who we are and what we do. We always have the saying, 'We don't want to meet people in the middle of chaos.' We want to meet you before chaos."

Q: We often hear about government employees leaving for the commercial sector, but your experience was the opposite. What drew you to NTSB and government service?

A: I came from the manufacturing world, from the aircraft side of things. My education is engineering, but my craft was always safety and reliability. I always wanted to do something that felt novel, that felt like a deeper mission; I wanted more than either building something, designing something or ensuring its safety on that side. And I always was fascinated with the forensic side of accident investigation and the safety opportunities. What drove me to NTSB was that dedication to some greater cause. I'm not unusual in the sense that probably almost all folks that come to the NTSB come in that regard. The interesting thing about what we do is when we launch to the scene of an accident as a team, it's a very clear mission. That's our best work, as an agency and as an individual, when we're in the middle of responding to an accident and trying to get in there to make sure we get what we need to find out what caused the accident and how to prevent it in the future.

Q: Along with that higher vision you described, what were some other changes in transitioning from the private sector to government work?

A: When I came from industry, I was a manager, so I oversaw reliability and safety professionals. We had a lot of projects that I was responsible for providing technical expertise to in the private sector. When I came to the government, I came as an investigator. One of the leaps I took was, in a sense, going backward. I went from a leadership position to a rank-and-file employee. What I took away from it is that when you want to go outside your comfort zone, so to speak, and you want to expand your horizons, you might have to seemingly take a step backward to take a step forward. To be a more effective leader, where I am now, I don't know how I could have done it if I didn't learn from the grassroots, how we do our job, what challenges I would face day to day. It was scary a little bit because I wasn't as in control of my own fate because I wasn't a manager anymore, but it was a great experience. I still reflect on it being the right decision.

Q: With 400 total employees spread across the country, how do you maintain a unified sense of purpose?

A: I frankly would like to see us be a little bit bigger, but our investigation work units are small by design. It's very difficult to be agile and nimble and get what you need quickly during investigations if you have a cast of thousands, right? Our very distributed team of experts is a strength of ours because it allows us to respond quickly when accidents happen anywhere in the country. In some cases, it's easier to attract and retain the best talent if they can live somewhere that's more effective for their home life as well. That culture is a big part of our strength, but it's also something that has to be nurtured through that effective, useful communication, meaningful communication.

▲ **Cowling debris** from an engine failure on a United Airlines plane is collected at a hangar in Denver. The U.S. National Transportation Safety Board is investigating the incident that occurred shortly after the jet took off from Denver International Airport in February.
NTSB

Q: How did the pandemic impact you?
A: We had migrated to the Microsoft Teams platform in the fall of 2019, and we were doing all-hands meetings for all aviation employees on a periodic basis. Once March 2020 came around and we hit the pandemic, all of those technology solutions — Teams, SharePoint sites where employees can provide input, a portal site or employee site to convey information — became critical. That's how we've tried to maintain the culture.

Q: How has the agency adapted its investigative work in light of covid-19 travel restrictions, when so much of the NTSB's role involves traveling to the scene of these crashes?
A: As soon as the pandemic hit and travel was stopped, we really began thinking through, "How can we do the mission, but do it in a way that keeps people safe?" We fortunately have a number of medical doctors on staff who help support our investigative work, so we were able to consult with them, and we stood up a small working group to develop a focused covid management protocol. When we got notified of an accident, we had this checklist that we could go through and figure out if we could safely travel someone to the scene. For example, could they use their own car instead of having to go on a plane? What about staying at hotels? We led that effort in the Office of Aviation Safety because we are obligated to investigate every civil aviation accident. We did a pilot program of the use of this risk assessment form in the summer of 2020, and the agency rolled out a more general version for all divisions in September. We developed something called a covid positivity tracker. It's a dashboard you can pull up on your phone that if you have an accident happen in Allegheny County, Pennsylvania, for instance, you can go in your tracker and it'll tell you what the positivity rate is at that time for covid in that area. This allowed us to evaluate the covid situation where the investigators are coming from, where they're going and their exposure risk. We rolled this process out and although unfortunately we really were not able to launch on a lot of accidents, it did enable us to get back out there in some cases. On the other side of that, we relied on our party system — accident stakeholders who assist in our investigations, such as the airplane manufacturer. The FAA is always a party to our investigations by statute, and they have inspectors that are located across the country as well. Often when we couldn't travel, our investigators in charge were in direct contact with those local FAA inspectors, who would travel to the scene to the extent they could and help us photo document the scene, collect any other pieces of evidence that might be needed. The other process that we would employ

◀ **Damage to fan blades** in the No. 2 engine of a United Airlines Boeing 777-200 after an engine failure.
NTSB

is working through Teams or through phone calls, the investigator in charge would actually coordinate with the insurance adjuster. They would collect the wreckage and send it to a salvage yard or someplace where it can be locked down, that we could get to later once the covid numbers are acceptable, so that we can go do our inspection of the wreckage at that point with parties.

Q: While many of us have learned that our jobs can be done remotely, it sounds like NTSB has learned the opposite: In-person investigation can't be replaced. Why can't technologies like 3D scanning or drone imagery fill that gap?

A: At the end of the day, you still always need that in-person ability to touch, gather, look, but we have enabled some of those technologies. We have a fleet of drones, and we stood up a drone accident site documentation program in 2016. We have some very experienced, certified pilots who can go out and fly the drones above crash sites, but we still have to get the pilot to the scene to be able to actually launch the drone. These are small unmanned operating systems that don't have the range for beyond-line-of-sight operations. Another technology is when we had accidents in proximity to surveillance cameras, those could be used to photo document the wreckage or take video. One of the things that we commonly do outside of a pandemic is a tear-down examination, where we'll have representatives there from the aircraft manufacturer, someone from the operator and obviously the FAA gather while NTSB specialists examine the wreckage. Well, we didn't want to do that under covid because now we're bringing maybe four or five people in from all areas of the country, in some cases internationally. So we said, "OK, how about if we do this?" How about if we send our investigator to oversee or conduct the tear down at a salvage facility. That's a controlled environment, it's not publicly accessible and we know the ventilation is adequate. We would set up a camera somewhere so that the investigator could actually conduct the

▲ **Personnel with the U.S. National Transportation Safety Board** investigate a midair collision near Ketchikan, Alaska, in 2019. The wreckage in the water is from a DHC-Beaver aircraft.
NTSB

work and the parties could watch and maybe provide some guidance along the way. Because at the end of the day, the personal touch and firsthand evidence gathering is really critical to what we do.

Q: Crashes are rare, so what do the day-to-day, less visible parts of the job comprise?

A: When investigators are not running out the door to the accident site, they're doing follow-up work. Early in the investigation, it might be in the form of traveling to a manufacturer's facility to examine a piece of wreckage, or it could be bringing the wreckage to our labs in Washington, D.C., and being able to examine them in our lab with the parties. There's a fair amount of follow-up work that involves examinations. They may travel to do interviews, or they may do interviews through Teams or on the phone. To conduct interviews and document findings, they may also be reading up, researching on different topical areas that become pertinent in an investigation. The other thing that they're often doing that some people don't like is writing.

The first step in an investigation is to collect evidence and facts, but at some point you have to document them in a way that can be meaningful to the industries that need that data, to be able to understand whether it's pertinent to their operations but also to the public so that the public understands what happened, how did it happen and why? The other thing that investigators do in non-covid times is something we call advocacy, which is going out and meeting with the district groups, doing presentations to help get our safety recommendations adopted either voluntarily by industry organizations who can do something about it or through the FAA. That often can involve travel; it can involve being part of roundtables and workshops at our training center where we have the ability to set up roundtable events and things like that; it could be flying to an industry conference where we're going to present.

Q: How is NTSB preparing for the new range of technical experts it will need for emerging markets like advanced air mobility?

A: One of the things that we do a lot of is outreach, which is where we go out to the industries that are doing those things. We ask them to come in and talk with us, for a couple of reasons. First is just what you're talking about, to really become more technically adept at what skill sets are going to be needed. The second is to learn what evidence is going to be available in those systems. In the aviation world, we've honed that craft of knowing what data we can go capture and credibly know what happened during these crashes, but how do we do it in these new segments of the industry? For urban air mobility, one of the first things we started talking with some of our other government partners like NASA about was, "What does a black box on these vehicles look like? How do we capture the data that is managing the bigger system?" Because that's not a black box on one vehicle, it's some centralized data network, how do we capture that? We do outreach because we want companies to know who we are and what we do. Unfortunately, someday when that technology gets monetized and becomes an industry segment, they may have to work with us. We always have the saying, "We don't want to meet people in the middle of chaos." We want to meet you before chaos. We want to have that relationship. We want you to know very clearly what our role is versus what the FAA's role is, and how you can best enable the accident investigation process.

Q: How do NTSB employees become more versed in the technology of these emerging markets?

A: We might also bring in training opportunities for our staff, but those are a little more difficult to do in our world because what we do is so unique. I can't really go buy an off-the-shelf product from even AIAA on accident investigation of urban air mobility vehicles, for instance. Sometimes we will develop tailored training. We'll ask people to come in on specialized topic areas; that might be the control systems for these autonomous vehicles, for example. We might have somebody coming from a university or from a manufacturing industry to give us that training too. But I would say the outreach becomes one of the most important parts. The last thing that we have done are what we call externships. We ask these industry leaders, "Hey, can we embed some staff in your organization for two weeks, just to get them immersed in the technology?" That starts seeding that thinking about all these areas we need to worry about, our processes for investigating the data, evidence. That's been really effective. For the aviation and aerospace industries, hopefully it's valuable to them too, because again, they get to build that relationship with us. They'll know more about what to expect if their products were ever involved in an investigation.

Q: NTSB safety recommendations often prompt changes, from aircraft design to certification, but what's an example of investigations that prompted changes to your own protocol or methods?

A: In 2006, we investigated our first unmanned aircraft system accident. It was a U.S. Customs and Border Protection Predator drone accident that happened down by the southwest border of the United States in Nogales, Arizona. That's a pretty good size drone: about 10,000 pounds [4,536 kilograms] with a wingspan almost as long as a Boeing 737.

> **A Predator B drone has a wingspan of 20 meters compared to 38 meters for a Next-Generation 737 aircraft. — CH**

The interesting thing about this crash was that's a very sparsely populated area. There's nobody that lives out there, and yet this drone crashed and came down about a hundred yards from a private home. So when NTSB got notified in the event, the first question we had was, "Is this even within our authority to investigate? Is that an aircraft?" We made a decision at that time that this is an aircraft, and we are going to investigate this. It falls under our authority to investigate all civil aircraft, civil aviation accidents and certain public use aircraft that are operated by government agencies. What we learned, No. 1, is we need to amend our definition of an aircraft accident — at that time, it only included situations where a person gets onboard the aircraft, and they're not going to get on a drone, at least not yet. We ended up expanding our regulations to include unmanned aircraft accidents in 2010. The other thing that investigation taught us is boy, we need to have more published procedures on how we're going to investigate accidents. In piloted aircraft, you have a control system that the pilot sits at to manage the flight path, so how are we going to investigate these UAS accidents and capture these flight logs? It was very eye-opening, and it really formulated our thinking going forward on keeping ahead of emerging technologies.

Q: There's some mysteries or crashes that never get solved, for instance the Malaysia 370 flight that disappeared and was never found. In cases like that, how are you able to turn those into teachable moments?

A: That was an accident that we did not lead an investigation on, but we supported because it was a U.S.-manufactured airplane. There is an international protocol that the United States works under for that. At the end of the day, our contribution was to provide technical expertise to the Malaysian government to be able to identify recommendations so that in the future, if an airplane goes missing, there's more reliable data to know where its last location was before it crashed. That was the big problem with that accident — we just don't have viable data. Better satellite data tracking systems since then have been emerging, as well as deployable recorders where if an airplane is in a flight condition that clearly indicates some level of duress that the recorders automatically deploy and they float, if it's in a water environment. If it's overland, they're crash-hardened and protected so that we at least know where the aircraft is, where the wreckage most likely is. If we had a circumstance in the U.S. where that was a U.S. airplane, we would absolutely be looking for ways to ensure we could find that aircraft better in the future. It wasn't something we could do for that investigation. ★

Simulating threats

Military strategists need to be sure they are sending pilots to battle with electronic warfare equipment that can spoof and evade enemy radars in a host of scenarios. Assessing EW performance once required hours of costly and time-consuming flights, but today much of the work can be done on a laboratory bench or in a test chamber. Brad Frieden of Keysight Technologies describes how his company achieves this.

BY BRAD FRIEDEN

When military planners contemplate being in a battle, they must have confidence in their ability to control the electromagnetic spectrum as a means of protecting a war fighter on the ground, at sea, or in the air. Take, for example, a pilot in an aircraft that's been painted by the targeting radar of another aircraft. Multiple antennas on the painted aircraft's wings or belly feed a radar warning receiver, or RWR, on board, which must detect this electromagnetic energy and display a warning on a cockpit screen or helmet-mounted display. This warning must identify the other plane and refresh the information at rapid intervals. Most likely the aircraft is a foe, and the pilot's electronic attack system must be ready to automatically jam the threat radar, so the enemy can't fire a missile. Versions of this interplay can be seen in the ground and sea domains as well.

One option to test electronic warfare systems, such as the RWR or electronic attack radar jammer on an aircraft, is to take to the air with that equipment and perform actual flight tests, but those are expensive and may radiate signals that are sensitive and could be intercepted. That's why having a threat simulator, which can create the RF signals that would be present in a battlefield scenario, is critically important to put such systems through their paces before they're needed in a real conflict. And there are benefits if such a threat simulator can be scalable, calibrated, accurate and quickly available. It's also desirable if it can have an open architecture, meaning it could accommodate a variety of software packages and standard interfaces. Such a system of software and signal generators would produce an RF and digital rendering of an actual electronic threat, such as a targeting radar, to test RWRs and jammers against the threat without having to fly the aircraft or operate ground vehicles or ships.

We decided to make our threat simulator out of off-the-shelf building blocks, namely electronic warfare-oriented Keysight N5193A and N5194A UXG signal sources, which are benchtop instruments that can create radar/jammer RF pulses with fast-hopping frequencies for electronic warfare system testing. These can be assembled like Legos to create a variety of system configurations, scalable from simple to complex.

This idea of threat simulation wasn't a new concept, since jammers had been tested in lab environments simulating the electromagnetic spectrum in battlefield scenarios for many decades. But for customers, acquiring such a system with all these new attributes would be something cutting-edge. Keysight shipped its first threat simulator in 2018 and continues to improve upon it.

Converting an oscilloscope

As a primary element to augment a threat simulator's ability to create realistic EW signals, we converted a wideband oscilloscope, one normally used to measure the performance of high-speed digital communications devices, into an electronic warfare analyzer. Imagine, for example, that designers needed to verify that an aircraft's jammer would react properly to being painted by a radar. They can now run an RF cable between the aircraft's jammer and our oscillo-

scope, and then multiple RF cables from the threat simulator rack or racks to the RWR and to the jammer's input receiver. These cables deliver simulated radar signals as though the aircraft were being painted by an enemy radar. The oscilloscope readings would, for instance, show designers whether the jammer effectively achieves "pull off," in which electromagnetic pulses designed to look like radar reflections slowly pull the threat radar away from tracking the aircraft's location, deceiving it. With our oscilloscope and threat simulator, initial testing of a jammer and RWR can be done on a lab bench, with the threat simulator playing the role of an enemy radar. Designers can find performance issues early and fix them, long before any kind of validation in an anechoic chamber is attempted, if such a step were deemed necessary at all.

To create this technology, one challenge we faced was on the signal source side. Our simulated enemy radar signal might need to cover a range of frequencies from a few gigahertz to 40 GHz, sometimes hopping quickly between frequencies. In fact, multiple pulsed RF signals might need to be simulated simultaneously. This required sources that could switch from one frequency to another in mere hundreds of nanoseconds. At the same time, complex modulation schemes needed to be simulated with great accuracy to mimic a real threat. Keysight created a computing and hardware architecture to turn models of actual threats in an EW environment into digital representations of received threat signals and then into actual RF that could drive the RWR and jamming input receiver.

This goal for signal generation required us to design a customized application specific integrated circuit, or ASIC, to digitally place modulation on top of a carrier signal. An ASIC in each threat signal generator box creates pulsed signals at an intermediate frequency of 1.8 gigahertz, with precise control of the modulation that rides on the pulses at a bandwidth of up to 1.6 GHz, just as is found in today's most advanced radar and jammer signals. The most accurate way of placing this modulation on top of this intermediate frequency carrier signal would be to do it digitally, which is what the ASIC does. Through a process of digital upconversion, the baseband modulation signal gets placed on top of a 1.8 GHz carrier signal with great accuracy. Specifically, the integrated circuit achieves this modulation by applying the in-phase and quadrature phase, or I/Q, digital data technique, a method of modulation also used in ultra-high-speed digital communications.

In the real world, threat signals are analog, meaning these signals shift their amplitude smoothly over time. Therefore, we needed to smooth out the voltage steps in our intermediate frequency carrier signal, which we accomplished by incorporating a kind of analog circuitry known as a reconstruction, low-pass filter. This removed the step artifacts left over from digitization, leaving an analog signal.

▲ **In this game board view** from the Keysight Z9500 Simulation View application, the tracking radar on an enemy jet (Threat 1) paints a friendly aircraft equipped with a radar warning receiver, labeled SUT for system under test. Simulation View calculates the Threat 1 radar signals that the SUT would experience, and Keysight's N5194A signal generators create digital replicas of those radio frequencies. Two ground-based threat radars and their transmitted scanning antenna pattern beams are also shown.
Keysight Technologies

Painted by radar

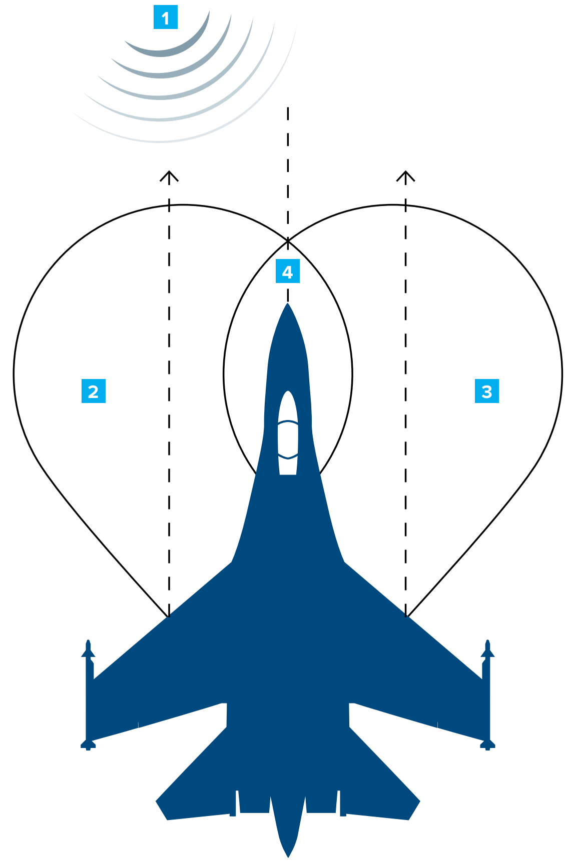
To jam or spoof an enemy's radar, an aircraft's radar warning receiver must deduce the location of the radar source by measuring the angle of the incoming radar. Here's how it works:

1 Enemy radar targets aircraft.

2 Radar wavefront enters receiving pattern of antenna on left side of aircraft.

3 Radar signal enters receiving pattern of antenna on right side of aircraft an instant later.

4 Radar warning receiver software deduces the angle of arrival from the measured phase difference and/or time difference between the signals captured by each antenna. The angle of arrival is relative to an axis straight ahead of the aircraft (the dashed line from the plane's nose called the boresight).



Source: Keysight Technologies

This 1.8 GHz analog signal leaves the ASIC and is upconverted to the final desired RF frequency, such as a simulated threat radar for the lab. In the real world, threat radars change amplitude of signals within a couple of hundred nanoseconds to try to outsmart a jammer, and it's common for an aircraft to face multiple threat signals. Therefore, we created a fast-switching nano field effect transistor, or FET.

Our architecture works off millions of pulse descriptor words, which are lists of parameters for each pulse specifying its start time, frequency, pulse width, amplitude and modulation on pulse. With this architecture we provide a real-time, pulse-descriptor-word-based tool that can be quickly delivered to customers and quickly reconfigured to address multiple threat configurations.

In a war-fighter's hands

How do our customers use this architecture? Consider first a case in which a radar paints an aircraft from a particular direction. If the angle of the incoming radar can be deduced, then the position of the radar relative to the aircraft can be calculated and placed on the RWR display, and now a war fighter could elect to send a signal in that direction to spoof the radar. More often the war fighter depends on their jammer to do this automatically. To determine the incoming signal's direction, the RWR on the aircraft receives the signal on multiple antennas and from that determines the difference in phase characteristics of the arriving waves. From that, software calculates the azimuth (left to right angle relative to boresight of the vehicle) and elevation (up or down relative to the boresight of the vehicle) of the other aircraft. These phase differences in the signals are called the angle-of-arrival characteristics since they relate to the threat emitter's direction. Our architecture creates multiple signals with accurate angle-of-arrival phase characteristics to test that a radar warning receiver is properly displaying a threat's direction. If you don't get those angles right, you're not measuring the RWR's ability to locate the threat emitter.

Our signal generators get these angles right through proper multiport calibration combined with Simulation View, software that calculates in real time the expected signal phase differences between the antenna ports, and also provides a graphical game board that shows the simulated aircraft and threats. The team developed a process to synchronize multiple sources together while still maintaining phase coherency across multiple ports. It is imperative to calibrate ports in amplitude, delta phase and delta time to create signals with the proper angle-of-arrival characteristics. The result is multiport signal generation capable of testing an RWR that should sense the phase difference between signals received, so it can properly calculate the azimuth and elevation of the threat radar to know its location.

With our oscilloscope and threat simulator, designers can find performance issues early and fix them, long before any kind of validation in an anechoic chamber is attempted, if such a step was deemed necessary at all.

Electronic warfare analyzer

Another challenge, but this time related to signal analysis instead of signal creation, was that we had to fundamentally modify our oscilloscope architecture so it could serve as an electronic warfare analyzer, capturing every received RF pulse into memory. Inside each UXR oscilloscope is a digital application specific integrated circuit that we developed, this one to enable us to combine two data-processing techniques. One technique was variable-length segmented capture, in which we capture the radar pulses when present and ignore the dead time between pulses. The other technique was real-time digital down-conversion, which allows us to strip off the modulation from the carrier and process and analyze only the modulation.

To understand the variable-length segmented capture and real-time digital down-conversion techniques, imagine that you attended a weeklong virtual conference but only wanted to hear and take notes on the sessions with a certain author. The variable-length segmented capture is analogous to your filtering the conference sessions by the author's name so only those sessions are printed in your schedule. Then if audio from the sessions of interest were broadcast on a local FM station at 98.1 megahertz, and you had a radio in your room tuned to that frequency, you could hear the sessions because the radio performs the analog equivalent of the digital down-conversion. The modulation arriving on the 98.1 MHz carrier RF is converted into sonic frequencies of 20 hertz to 20 kilohertz that you hear. The real-time digital down-conversion does a similar thing inside our oscilloscope but in that case, it pulls the signal modulation off a carrier through a purely digital process so you can analyze the radar and jammer pulses.

We also made the UXR's digital ASIC work together with a custom front-end module that could take an analog RF signal and convert that into a digitized waveform by taking voltage sample points at a sample rate of up to a 256 GHz per second. This maximum sample rate allows the oscilloscope to have up to a 110 GHz bandwidth and thus measure signals with carrier-plus-modulation-frequency content up to 110 GHz, easily covering the typical electronic warfare signal range that extends up to around 50 GHz.

The digital ASIC had to convert ultra-high sample rate data into to a much slower sample rate I/Q data format. For I/Q data format, the sample rate only has to be fast enough to support a bandwidth as wide as the modulation riding on the RF pulses. By doing this, the oscilloscope goes from being able to capture only a handful of milliseconds to potentially being able to have seconds of continuous capture, depending on how narrow the signal modulation bandwidth is.

The ASIC allows for the real-time digital down conversion I and Q data on each channel to drive an intermediate frequency trigger to sense when a pulsed RF radar/jammer signal, with a certain tuned frequency, is present, and only store the I and Q samples into oscilloscope memory for each channel when the signal is present. We call this variable-length segmented capture and it results in extremely efficient signal capture since samples are not wasted on simply capturing noise when no signal is present in between the RF pulses. We designed the ASIC so that with this capture mode there is zero trigger re-arm time between segment captures. Therefore, no matter how close together RF pulses may be, they can each be captured into variable-length memory segments.

An important customer application for the UXR oscilloscope would be to determine whether a range gate pull off jammer operates properly. A typical radar system transmits a signal toward a target and then measures a radar "echo" signal reflected back off the target and tracks each reflected pulse in time. The shorter the time for a radar pulse to return, the closer the target is to the radar. A range gate pull off jammer spoofs the radar by placing larger jammer pulses on top of the radar echo signals at first, and then slowly, over perhaps 10 seconds, moves the jammer pulses away from radar echo pulses up to perhaps 10 microseconds, causing the radar to track the jammer pulses instead of the radar reflection pulses, also causing the radar to believe a false target range. Then the jammer pulses disappear, leaving no signal present for the radar receiver, thus causing the radar to lose track of the target altogether and forces it to have to reacquire track.

Let's look more specifically at how the range gate pull off test can be accomplished. The UXR oscilloscope, in a normal acquisition mode for a 30 GHz carrier frequency radar, must digitize the input signal at 128 gigasamples per second, which burns through oscilloscope memory very quickly and can only capture 12 microseconds of time, not nearly the 10 seconds of an entire range gate pull off cycle. Through the ASIC, with variable-length segmented capture and real-time digital down-conversion, the 30 GHz input signals are still digitized at 128 GSPS, but the samples do not go into oscilloscope memory; instead, they are processed by the ASIC into 800 megasample per second I and Q data and stored into 800 megabytes of oscilloscope memory. They are then offloaded to the 89600 vector signal analysis software to conduct pulse analysis such as measuring the pull off times. And the ASIC only sends I and Q data samples to oscilloscope memory when the RF pulses are present as sensed by the intermediate frequency trigger. This results in the ability to capture every radar echo and jammer pulse over nearly 50 seconds to see multiple RGPO cycles and prove proper jammer operation where the radar has 1-microsecond-wide RF pulses that repeat every 1 millisecond.

Finally, we chose a software architecture that could both simulate moving platforms including aircraft, land vehicles or ships and simulate the signals that receivers on friendly platforms would receive on their antennas, such as enemy radar signals, while setting up analysis test and measurement equipment to easily ensure that the proper signals were created. Key signal characteristics such as center frequency, modulation bandwidth, pulse repetition interval and antenna scan rates are turned into oscilloscope setup parameters. This can save engineers and technicians many hours or days of time through automating the measurements.

With our UXR oscilloscope used as an EW analyzer, and multiple UXG signal sources acting as a threat simulator, important tests on EW systems can now be performed even more efficiently on the lab bench or in an anechoic chamber, thus saving time and money. The advances we've made in signal source ASICs and calibration allow the creation of real-life threat signals while advanced ASICs in oscilloscopes make the capture of wideband RF pulses over long periods a reality, thus meeting the testing challenge. ★

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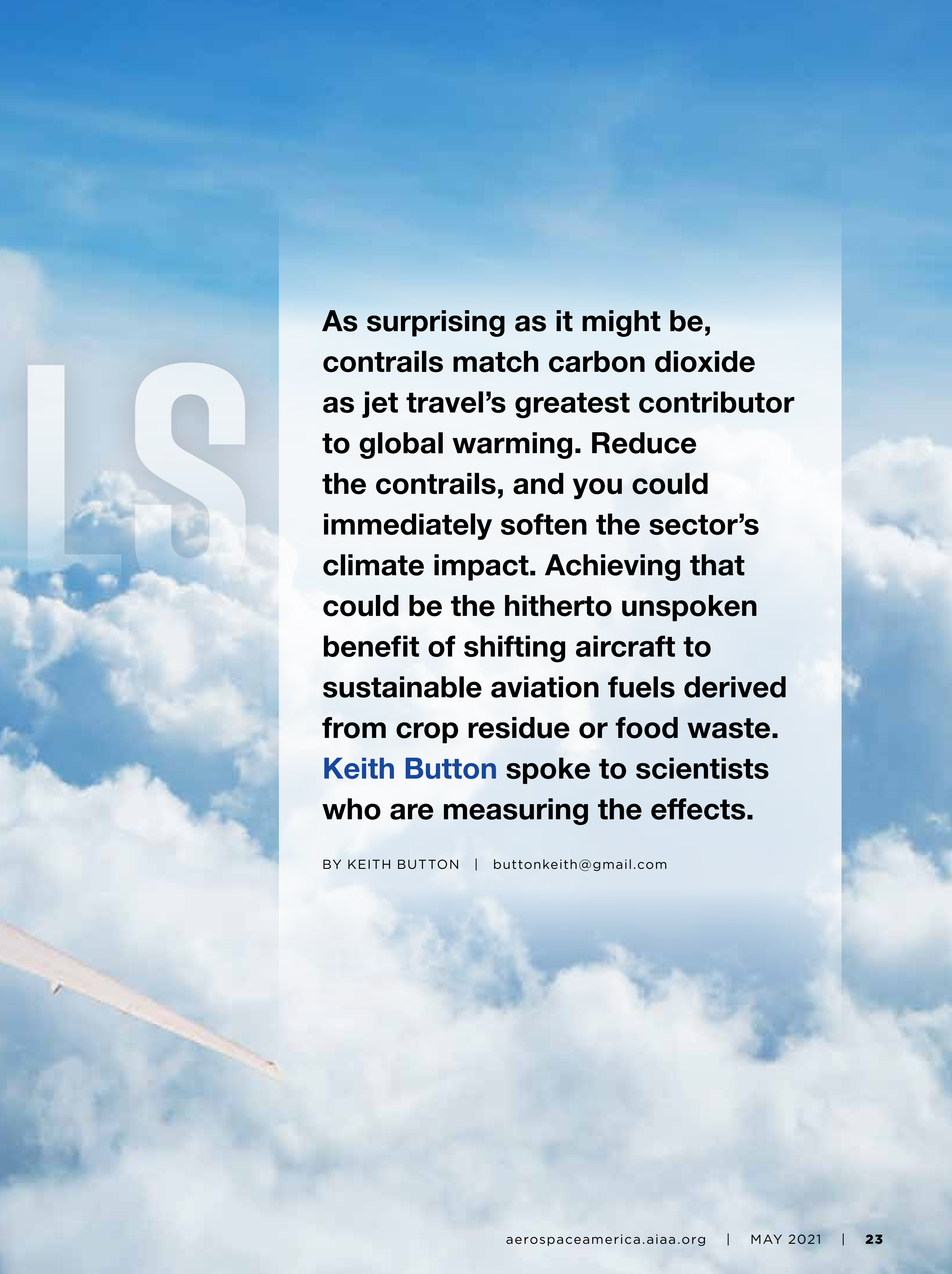
ERASING CONTRAI



As surprising as it might be, contrails match carbon dioxide as jet travel's greatest contributor to global warming. Reduce the contrails, and you could immediately soften the sector's climate impact. Achieving that could be the hitherto unspoken benefit of shifting aircraft to sustainable aviation fuels derived from crop residue or food waste. Keith Button spoke to scientists who are measuring the effects.

BY KEITH BUTTON | buttonkeith@gmail.com

I t isn't easy counting and measuring ice crystals in a cloud formed by a jet plane 10 kilometers up. But it's necessary work for climate scientists who hope to show how formation of condensation-trail cirrus clouds of ice crystals, also known as contrails, might be reduced by choosing the right kind of jet fuel. Contrails are aviation's largest contributor to global warming, and they cannot be accurately replicated in a lab.

Many of the climate scientists from Europe who flew instruments behind an A320 three years ago took to the air in April this year to begin the next phase of their crystal research, this time with an Airbus A350-900 chased by a Falcon 20E, plus ground tests in Toulouse, France. They're also about to publish findings from the earlier flights, and they say the news is big: Powering the aircraft with a 50-50 mix of regular jet fuel and a sustainable aviation fuel, or SAF, resulted in fewer ice crystals than when the plane burned 100% conventional fuel. Next, the scientists want to find out how far contrail production falls when a jet runs entirely on SAF, something not currently allowed except in an experiment like this one over France. The ongoing research suggests that the air transportation industry could, in theory, immediately reduce its global warming impact through a rapid shift to SAF, given that the warming effect of contrail clouds goes away when they dissipate. That said, the expense of such a shift remains a high hurdle.

Making the connection

Before they took off on a DC-8 for the 2018 flights, the scientists knew from similar flights in 2014 and 2015 that contrail ice crystals form around soot particles and that a 50-50 blend of regular jet fuel, which is kerosene, and a fuel from plant and animal fats produces fewer soot particles. The 2018 flights closed the loop by gathering the first experimental proof that fewer soot particles, in this case produced by a 50-50 fuel blend, indeed spelled fewer contrail ice crystals. The new flights, like those in 2018, will test a SAF called HEFA, short for hydroprocessed esters and fatty acids, but this time the fuel will be all HEFA instead of a 50-50 blend.

Other SAFs can be made from municipal waste, from forest waste or by processing water and carbon dioxide into hydrocarbons with solar electricity.

Why do SAFs result in less contrail coverage? Because they have fewer hydrocarbon aromatics,

▲ **A NASA DC-8** with a fast forward scattering spectometer probe followed a DLR A320 ATRA on nine flights over Germany in 2018 to measure ice particle concentrations.
Christiane Voigt

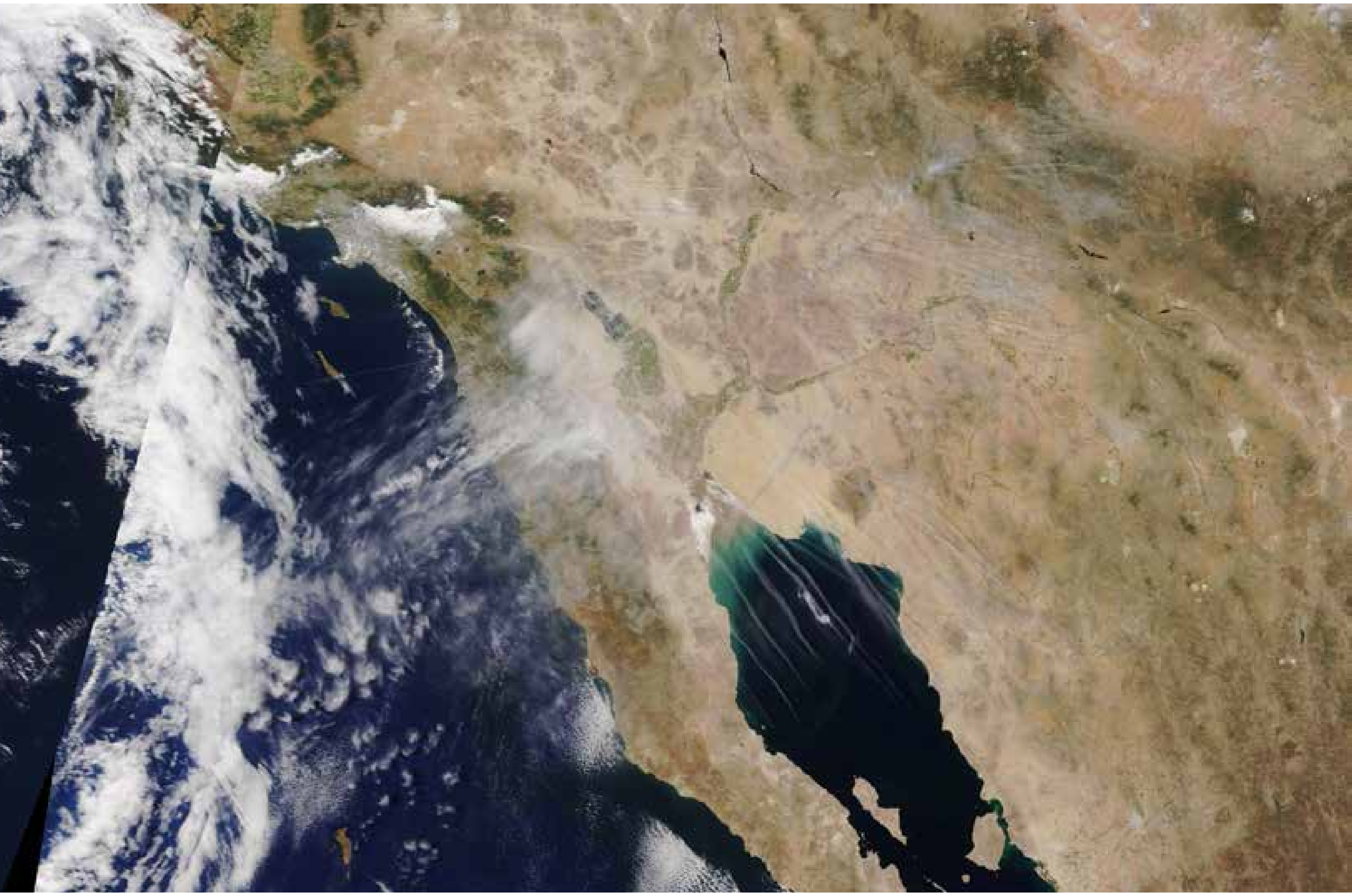
▲ **One of the probes** mounted on the trailing aircraft during flights.
Christiane Voigt

hydrocarbon molecules that are more likely to be chemically changed during combustion into the pure carbon soot particles that ice crystals form around. Aromatics make up as much as 25% of kerosene, but most SAFs have no aromatic content.

In the flights three years ago, the scientists from DLR, the German Aerospace Center; NASA; the Max Planck Institute and the University of Oslo flew nine flights in a DC-8 chase plane over Germany, collecting samples of the emissions in the contrail of an A320. They cruised at an altitude of 9.5 kilometers, where temperatures hovered around minus 60 degrees Celsius. The chase plane followed at 20 to 30 kilometers behind the A320, where the contrail was 1 to 2 minutes old and clearly visible: a merged cloud formed from the two contrails left by the two engines on the A320. The chase plane's pilots would descend into the tube-shaped contrail, which was about 200 meters deep and 70 meters across, and then the scientists on board the DC-8 would direct them more specifically where to fly for the best position for measuring ice crystal numbers and sizes, soot particle density, carbon dioxide concentrations, water concentrations, relative humidity and temperature.

They didn't collect the ice crystals — the crystals would've simply evaporated at the inlet. Instead, two-prong cloud probes attached to the roof and under the wings of the DC-8 sampled the contrails. Each probe shined a laser across the gap between the prongs and at the same time detected the light scattered by the individual ice crystals in the contrail, which revealed the number of ice crystals per cubic centimeter and their size. Similarly, the probe also detected shadows cast by the larger ice crystals that made up naturally occurring cirrus clouds — typically 100 micrometers in diameter compared to 1 to 10 micrometers for contrail ice crystals — to count and measure those. All told about 100 scientists worked on the project, including those who ran ground-based testing and analysis, where emissions samples were collected from a parked A320.

Out the windows of the DC-8, the scientists couldn't see a noticeable difference between the contrails produced during the 100% kerosene flights and the contrails produced by the 50-50 blend flights, says Christiane Voigt, a DLR climate scientist and lead author of the paper on the findings. The differences also weren't immediately known from the in-flight measurements. Counting ice crystals and soot particles wasn't enough; the scientists also had



“They have lifetimes of hours, so if we could avoid contrails or if those contrails can be mitigated by using those biofuels, then the effect on climate will be immediate.”

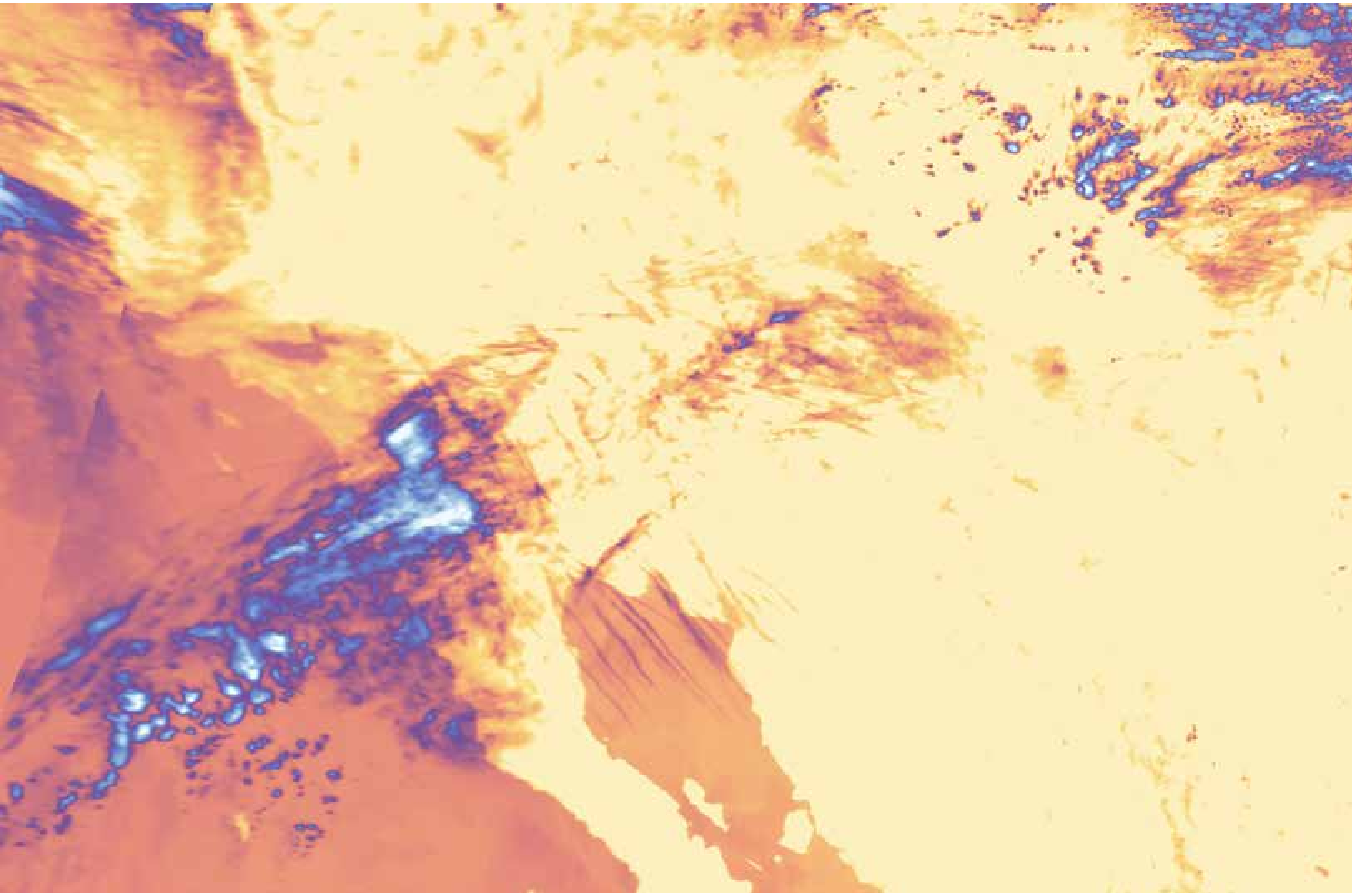
to calculate how conditions such as humidity, temperature, trailing distance, winds and the A320 throttling up or down were affecting the ice crystal formation at the time of measurement. They also tracked carbon dioxide to calculate fuel consumption at the time of ice crystal measurements and, ultimately, the amount of ice crystals formed per kilogram of fuel burned.

“To take into account all of these dilution effects, that’s a rather complex analysis,” Voigt says. “That’s also why it took quite awhile to get those.”

The scientists learned that the 50-50 blend of kerosene and HEFA produced a 50% to 70% reduction in soot and a corresponding reduction in contrail ice crystals.

Heightened interest

The findings from the 2018 flights take on added importance in light of a newly published assessment of aviation’s climate impact. The assessment, published in the January issue of Atmospheric Environment, “The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018,”



reported that aviation contributes 3.5% of human-induced global warming effects, with contrails comprising the largest portion of aviation's total. Contrail ice crystals reflect sunlight away from Earth — a cooling influence — but they also trap heat radiating from the Earth — a warming effect that outweighs the cooling. Contrails contribute about 67% more to aviation's global warming effects than carbon dioxide emissions, the second-largest contributor, and more than twice that of nitrogen oxides, which are third on the list. That means cutting contrail formation would have the largest and fastest impact on aviation's global warming.

"They have lifetimes of hours, so if we could avoid contrails or if those contrails can be mitigated by using those biofuels, then the effect on climate will be immediate," Voigt says. "If you really want to reduce the climate impact from aviation soon, in the next year or even in the next weeks to months, then we have to think of those short-term mitigation options, and that's what contrails are."

The 2018 flights also dismissed any notion that ice crystals might form around non-soot particles in the emissions, Voigt says. Before the 2018 tests, some scientists had theorized that tiny particles of volatile compounds, such as droplets of sulfuric acid, might serve as nuclei to form contrail ice crystals. But the tests showed that these particles were too small, at about 3 nanometers in diameter, or 0.000003 millimeters, for water to cling to, Voigt says. Soot, on the other hand, was an efficient nuclei for ice crystal formation: About 90% of the soot particles, which are 30 nanometers wide — about one-three-thousandths as thick as a human hair — formed ice crystals under the contrail conditions.

Fewer soot particles means fewer ice crystals. Less soot also leads to larger ice crystals, which may produce another benefit: The larger ice crystals drop out of the contrail and sublimate more quickly, so the contrail dissipates faster. The scientists discovered that the ice crystals produced during the 50-50 blend flights were slightly larger than the crystals left by unblended kerosene flights, because the moisture in the air had fewer ice crystals to cling to. How much faster the larger ice crystals might drop out of a contrail is difficult to quantify, in part because the

▲ **Contrails over** California and Mexico (left) were captured by the Moderate Resolution Imaging Spectroradiometer on NASA's Terra satellite. In the thermal infrared image (right), older contrails are visible in blue and white. Both images were taken at the same time.
NASA

▲ **A researcher tests** the cloud probes on a DLR Falcon 20E before a research flight.

DLR

scientists could only measure the crystals when the contrail was 1 to 2 minutes old, and not what occurred as the cloud grew older, Voigt says. A contrail's lifespan is typically one to six hours.

Sticking with aromatics

While aromatics are the source of soot, they're also considered an essential fuel ingredient by some plane manufacturers. They have pushed regulators to require alternative fuel blends to include a minimum 8% aromatics because they cause nitrile O-rings to swell, and seal better, which prevents fuel system leaks. But newer O-rings are made from fluorocarbons that don't need the seal-swelling effect of aromatics, which means the 8% limit could be lowered if testing proves the aromatics are no longer necessary, says Patrick Le Clercq, DLR's coordinator of alternative fuels research, who was a principal investigator on the 2018 flight tests.

Given that a 50-50 kerosene SAF blend reduces soot so significantly, what's to stop all of the airlines from flying with the 50-50 blends tomorrow? The answer comes down to cost and SAF availability.

Currently there are eight types of SAFs that are approved "drop-in" options, meaning a jet engine can burn 50-50 mixtures of them with kerosene without any modifications.

But the fuels on this list can be purchased only in small amounts, which means there is no market established, Le Clercq says. Purchase agreements for the fuels are private, so the specific prices are unknown, but observers estimate that the prices are two or three times that of kerosene, Le Clercq says. Airlines that do buy alternative fuels now blend them

at 30 parts SAF to 70 parts kerosene, at most.

Scientists also haven't determined how much contrail coverage and other global warming factors could be reduced by flying with 100% SAF. New airplanes are being designed to fly on 100% SAF, with Boeing, for example, announcing that its new planes will fly on all-SAFs by 2030. Existing airplanes that were designed for kerosene could conceivably fly safely on only SAF, but extensive testing would be required first, Le Clercq says. Like kerosene, the 100% SAF would have to stay liquid with no degradation at high altitudes and at minus 40 degrees Celsius and remain unaltered as it heats up substantially and acts as a coolant while traveling through the fuel system from the tank to the injectors in the engine. Every component that is in contact with the fuel has to be checked to make sure it won't cause something to

Beyond the contrail-reducing effects of sustainable aviation fuels are the reduced-carbon-footprint benefits.

break down and crash the plane, and numerous properties have to be analyzed, including density, viscosity, electric conductivity and energy content to make sure that the fuel won't ignite too early, for example, or evaporate.

Kerosene has some 200 types of molecules, and a SAF has a lot to prove to fuel producers, engine and airplane manufacturers, operators, standards organizations and regulators before it can pass muster as a replacement.

Kerosene remains the same "whether you're starting at the equator or Alaska; it's an amazing mixture," Le Clercq says. "It took years to fine-tune it so that the modern engines, the modern systems, can use it."

"It's a long research and check process before we can say: 'Yes, let's do that.' But there's definitely on the other side a huge potential and big advantages of using these types of alternative fuels," he says.

Beyond the contrail-reducing effects of SAFs are the reduced carbon footprint benefits. SAFs contain a higher energy content than kerosene, which means they burn more efficiently and produce less carbon dioxide emissions. But their main carbon footprint benefits are from the plant-, waste- and renewable energy-based production of SAFs. Overall, SAFs contribute a 60% to 80% reduction in carbon dioxide in the atmosphere compared to kerosene, according to the DLR, which equates to a 30% to 40% reduction for a 50-50 fuel blend.

Carbon dioxide lingers in the atmosphere for 100 years or longer, which is why those who are concerned about climate change are determined to reduce the emissions anywhere they can, including in the air transportation sector. The long lifespan of carbon dioxide adds urgency to the search for quickly reducing climate-warming emissions.

"The sooner we start, the better," says Le Clercq about pushing beyond the current 50-50 limits on SAF blends. He says there's no time to wait for exotic new aircraft and engine designs that would be fueled by hydrogen. "It will be too late."

▲ **The view of the A320** ATRA's exhaust plume **from the Falcon 20E chase plane**.
DLR

Beyond the contrail-reducing effects of sustainable aviation fuels are the reduced carbon footprint benefits. SAFs generally contain a higher energy content than kerosene, which means they burn more efficiently and produce less carbon dioxide emissions.

Contrails in perspective

While studies definitively show that contrails are the No. 1 warming factor from aviation, the newly published aviation climate impact assessment also shows that the gap between contrails and carbon dioxide at No. 2 on the list may not be as wide as previously believed, says Ulrike Burkhardt, another DLR climate scientist.

Clouds are always difficult for scientists to estimate in their climate models, and many suspect that contrails might take away moisture from the formation of natural clouds. That could retard the formation of natural clouds and their own warming effect, lessening the net warming effect of contrails plus natural clouds.

The best strategies for combating the overall climate impact of aviation would be to reduce both contrail formation and carbon dioxide emissions, Burkhardt says. That would not favor, for example, a strategy of flying around atmospheric areas where contrails are more likely to form if that means burning more fuel and creating more carbon dioxide emissions.

"We always need to remember that we don't know everything about the climate impacts of aviation and that what we do know is partly connected with very large uncertainties," Burkhardt says. "It could be a very risky strategy trying to avoid contrails at the cost of having larger greenhouse gas emissions."

For the April flights, Le Clercq, Voigt and others set out to reduce uncertainties about the scale of the reduction effect. The flights, which are a joint project with Airbus, engine maker Rolls-Royce and fuel producer Neste of Finland, will pause and pick up again in October.

Voigt, who leads DLR's planning for the April and October flights, says the scientists expect the 100% SAF will produce less soot, but they don't know how much less.

"That's just the question," she says. "There will still be unburned hydrocarbons, but how large is this reduction? That is one of the important topics to be investigated." ★

THE HUMAN QUESTION

Startups are testing the coming breed of urban air mobility aircraft in their back lots and hangars. The harder part could be convincing potential passengers that these aircraft, with their whirling rotors, electric power and control algorithms, can safely deliver them to the airport or home from work. Sarah Wells tells the story.

BY SARAH WELLS | sarahes.wells@gmail.com

▲ **ASX says it will begin** offering its MOBi-ONE vertical takeoff and landing vehicle to be flown with a pilot on board and plans it to fly fully autonomously by 2030.
ASX

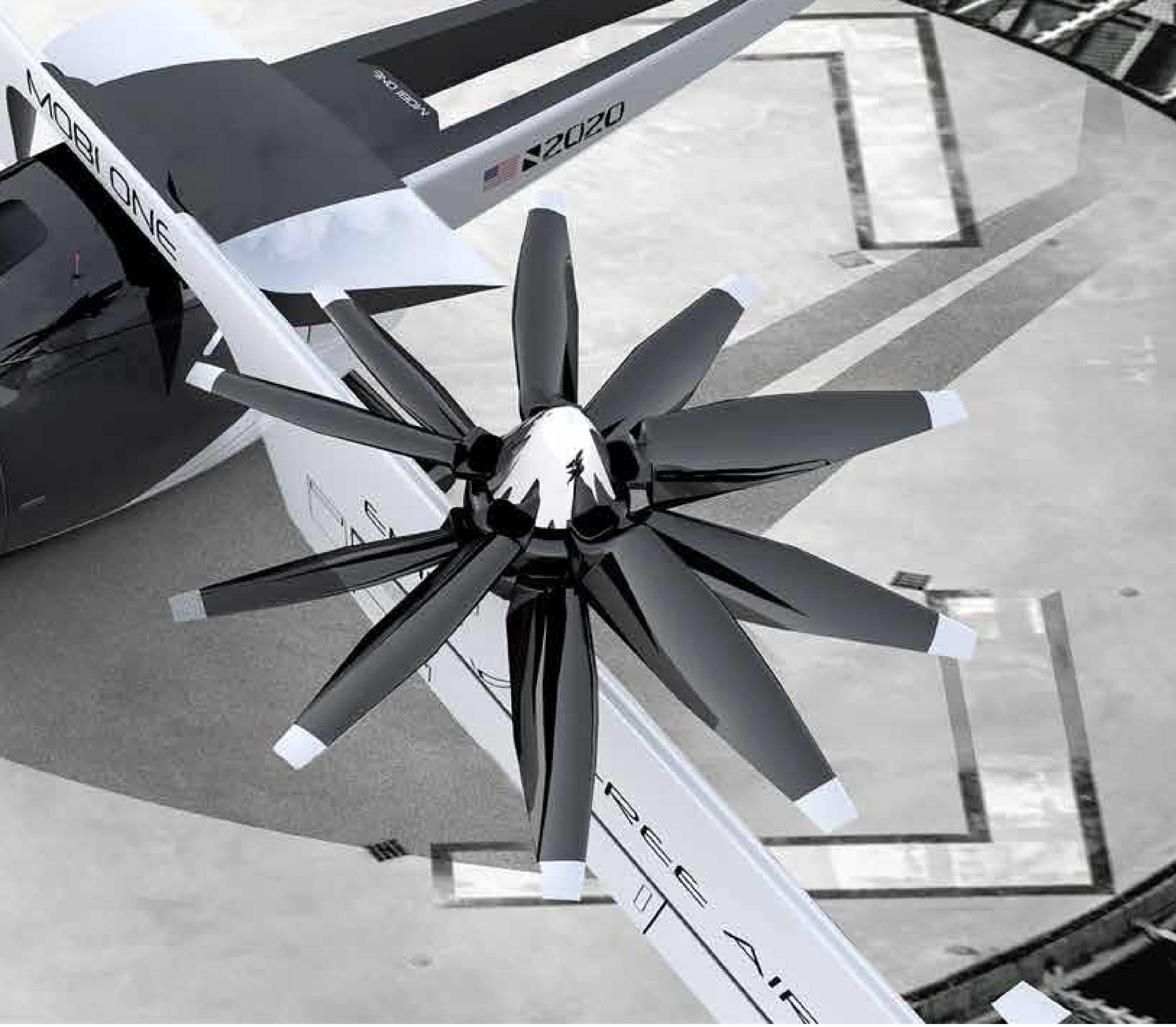
The dream of personalized aviation in the U.S. was born the night Charles Lindbergh touched the Spirit of St. Louis down in Paris in 1927, according to a report published last year by the National Academies Press.

Lindbergh's achievement became most famous for demonstrating trans-Atlantic flight, but the feat also awakened the citizenry to the power of small aircraft to take them places locally, according to the report, "Advancing Aerial Mobility: A National Blueprint."

Why drive or take a train when you could fly?

Interest in hopping between cities or towns on a whim in your Piper J-3 Cub or Cessna 120, for instance, remained high through World War II. In fact, the U.S. General Aviation Manufacturer's Association reported record high sales in 1946 of 33,254 aircraft. But this spike in sales did not last, and by the 1960s cramped commercial airliners were the predominant mode of flight for the masses, note the National Academies authors.

Close to 75 years later, the dream of small, agile and instantaneous airborne transportation is experiencing a revival. Startups and historic aerospace institutions alike want to create an entirely new mode of transportation: urban air mobility. In most concepts, electrically powered, vertical lift aircraft, eventually steered by intelligent algorithms rather than human pilots, would shuttle handfuls of passengers from quiet suburbs into bustling cities or back home in minutes. These UAM concepts would be the boldest category under a broader heading of advanced air mobility services that NASA is



seeking to nurture into existence for cargo and package delivery.

For the passenger versions, success will largely depend on whether developers can make potential passengers feel safe enough to board them, especially when it comes to trusting the autonomous pilot that would, in nearly all business plans, eventually take the place of a human at the controls.

Public perception

While engineers are hard at work testing aircraft designs and control software, researchers are doing what they can to gauge public opinion through market and human behavioral studies. Stephen Rice and Scott Winter, both professors at Embry-Riddle Aeronautical University in Florida, have conducted multiple studies on the underlying human behavioral factors that they believe will affect UAM adoption by the general public. In a 2020 paper, “A prediction model of consumer’s willingness to fly in autonomous air taxis” published in the Journal of Air Transport Management, they surveyed 510 people to determine how willing they would be to board an autonomous air taxi.

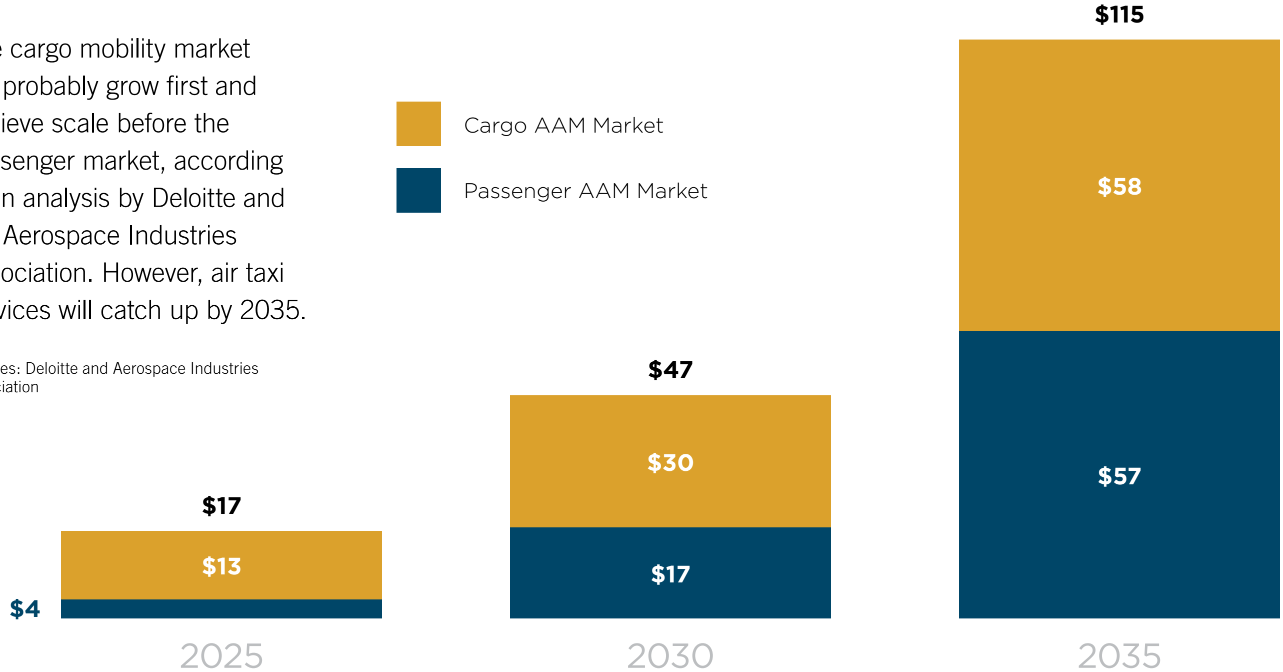
Rice and Winter found that approximately 46% of the survey participants would be willing to try an air taxi and that considerations like familiarity and fun factored heavily into that decision. Most participants, however, can best be summarized as having a “wait-and-see” attitude, the researchers say.

“A focus on the user experience, in addition to the engineering and technological design aspects, would be valuable efforts to encourage consumer buy-in and the success of urban air mobility,” they write in the study.

Advanced air mobility market growth (US$B)

The cargo mobility market will probably grow first and achieve scale before the passenger market, according to an analysis by Deloitte and the Aerospace Industries Association. However, air taxi services will catch up by 2035.

Sources: Deloitte and Aerospace Industries Association



A Booz Allen Hamilton market study done for NASA in 2018 dug a little deeper into what exactly might be holding back a majority of potential passengers.

Booz Allen surveyors reached approximately 1,700 potential UAM passengers from Los Angeles, Houston, New York, San Francisco and Washington, D.C., who were largely unfamiliar with the current work being done in the UAM space. According to the report, as few as 23% said they were familiar with current UAM designs.

To bring all participants up to speed on current UAM designs, Booz Allen showed them a debranded commercial from Uber Elevate, the rideshare company's UAM offshoot that it is selling to Joby Aviation of California, although the main Uber company will continue to invest.

With Uber's logo removed, the commercial put the viewer in the shoes of a UAM passenger hopping on a flying rideshare for a commute home. After watching the 90-second commercial, the researchers asked participants about their perspectives on UAM automation, safety and even potential ownership.

Just as Rice and Winter discovered in their study, the Booz Allen Hamilton study found that passengers largely disliked the idea of a fully automated craft. By contrast, 77% felt they could be persuaded to fly in a UAM if a pilot (or a flight attendant) were onboard with them — a steep increase in adoption.

This discomfort around automated aircraft can be interpreted in two ways, as a distrust of automation itself as well as a distrust of fellow passengers in the absence of a human pilot or flight attendant, the report found.

Participants "expressed concern that passengers on board would cause harm to other passengers," according to the report.

"Concerns about sexual assault were raised numerous times, particularly in an automated scenario without any flight crew on board," the report said. "Interestingly, many focus group participants said they were unwilling to consider using any form of automated mobility (e.g., shared automated vehicles) for this very reason."

UAMs pose a unique challenge compared to subway cars or buses because they are airborne, likely with fewer stops and opportunities to remove oneself from a dangerous situation. Also, because the vehicles will be small, passengers will be "unable to get up, if they feel uncomfortable or relocate to another seat or section of the aircraft."

While experts, including Rice and Winter, estimate that UAM companies are at least 10 years away from this kind of automation on passenger craft, participants stressed in the market study that passenger screening protocol (akin to a diluted Transportation Security Administration experience) would be crucial to guarantee safety on these flights.

Trust in automation

As for fears of crashing in an automated aircraft, the Booz Allen surveyors found that the overwhelming majority of survey participants listed that as a top reason why they'd be hesitant to hop aboard a UAM vehicle. While cyber hijacking was also among the participants' worries, the majority was more concerned about the aptitude of a fully autonomous pilot versus a human one, such as when flying through a storm.

Rice says that these kinds of views are driven by emotion, not necessarily logic.

This mistrust of autonomous control strikes some experts in the field as ironic, especially as studies on self-driving automobiles in recent years have demonstrated that relinquishing control over the wheel would be safer. A 2020 Insurance Institute for Highway Safety study concluded that as many as one-third of vehicle accidents in the U.S. could be prevented by automation.

One expert who feels this way is NASA's Advanced Air Mobility mission manager, Davis Hackenberg.

"There's a case to be made — and people have actually shown safety cases — for how ground-based detect-and-avoid and other detect-and-avoid autonomy can be safer than what we have today."

Take the 2002 midair collision of DHL Flight 611 and Bashkirian Airlines Flight 2937 over Germany as an example, says Hackenberg.

Both flights were on a collision course when their Traffic Collision Avoidance System software coordinated a "resolution advisory" that recommended Flight 2937 should climb and Flight 611 descend. Flight 2937 received conflicting instructions from the human air traffic controller and descended instead — directly into Flight 611. German investigators found that if both flights had followed their TCAS instructions they would have narrowly avoided each other.

"Automation needs to make the aircraft safer; that's the point of it," says Hackenberg.

Hackenberg points out that while consumers

▲ **Lilium released** illustrations in March of an all-electric vertical takeoff and landing jet that it says will carry one pilot and six passengers. In behavioral studies, potential passengers for urban air mobility vehicles have preferred to have a pilot or flight attendant on board.
Lilium

may be fearful of automation as it appears in new craft, they are already (even if unknowingly) used to it in commercial airliners, which rely on such technologies as autopilot and automated power distribution.

Looking at the degrees of autonomy UAM aircraft should have, Matt Scassero, director of the University of Maryland's UAS Test Site, says that there are five possible flavors ranging from the automation already included in many commercial aircraft today to a fully autonomous, thinking machine. This highest level of autonomy won't be fully achieved anytime soon, but Scassero says he believes it will find its way into UAM vehicles when the technology is ready.

Until then, Scassero says that the trend of automation for UAM vehicles will be similar to that of subway trains.

"Eventually, like some subway systems today, you will get to that leap where there's nobody in the car except for the passengers," he says. "Most people today don't even realize they don't even think about it, because they've demonstrated the safety."

Building trust

UAM companies will need to take a frog-in-boiling-water approach to automation if they hope to be successful — that is, increasing the level of automation bit by bit until they've reached a satisfactory safety level without passengers even noticing the change, Scassero says. For instance, Joby Aviation plans to start with human pilots in their aircraft.

In order for UAM companies to offer passengers autonomous flights as inexpensively as today's ride-shares, Hackenberg says that autonomy will have to get both better and cheaper.

"I think it all boils down to safety and economics," he says.

As for convincing passengers of that safety, Marilyn Smith, director of Georgia Tech's Vertical Lift Research Center of Excellence, says that companies like Amazon and UPS are warming customers up to

Approximately 46% of people asked in a study would be willing to try an air taxi and that considerations like familiarity and fun factored heavily into that decision. Most participants, however, can best be summarized as having a "wait-and-see" attitude.

— Embry-Riddle Aeronautical University researchers

▲ **Volocopter of Germany** says it is working on getting certification from the European Union Safety Agency to launch its VoloCity air taxis in the next few years. The Germany-based company has its sites set on large cities in the United States.
Volocopter

the idea of automated UAM vehicles by introducing them to automated delivery drones, a class of advanced air mobility craft. The idea is that these positive interactions will help customers build trust with UAM vehicles, which are in essence large drones equipped to carry people. In the U.S., drones are the only kind of fully autonomous craft with air space permissions to fly near inhabited areas, says Smith, all the while kept contained with geofence bumpers.

As for rolling out UAM services, countries in Asia such as Singapore and in the Middle East, mainly Israel, are closer than the United States to permitting autonomously flown passenger UAM services, which doesn't bother Smith.

"The U.S. is a little more conservative and is trying a lot of this with package delivery and other humanitarian assets," says Smith. "And to me, that's actually the way to go. A lot of people are saying that the U.S. is too conservative in that aspect, but I think that is partly because, for the U.S. and the E.U., human life is the No. 1 priority."

Some companies might be tempted to set up friendly computer screens in their aircraft as a stand-in for flight attendants who, on commercial jets, are trained to help passengers escape the plane in an emergency. Victoria Nneji, whose research at Duke University looks at the future of mobility and human interaction, says companies will need to go beyond that to convey safety as a priority. Instead, Nneji says, they must establish a culture of safety documentation, reminiscent of the air-bag safety campaign automobile companies ran in the 1970s with crash test dummies. Done correctly, this would prove to passengers that autonomous UAM vehicles cannot be hacked or hijacked and that they are "smart" enough to fly through a storm without crashing, she says.

Attention to details unrelated to safety also will be critical.

"Even if it's a small error that you notice about something with the interface, that can really reduce the trust that a person has in even taking that flight,"

“Automation needs to make the aircraft safer; that’s the point of it.”

— Davis Hackenberg, NASA’s Advanced Air Mobility mission manager

▲ **Wisk bills its air taxi** as self-flying and said in March that it plans to test-fly the all-electric vertical takeoff and landing vehicle in New Zealand later this year. Wisk is a joint venture between Boeing and Kitty Hawk Corp. based in California.
Wisk

she says. A potential customer might wonder, “if the developers failed at this really simple test, how can I really know how well they tested the other safety critical functions?” says Nneji.

The Booz Allen study also found that brand name recognition such as Uber or NASA’s involvement will go a long way toward building passenger trust and serve as good publicity. Luckily creating good publicity is something that Janet Bednarek, a professor of aviation history at the University of Dayton, says the aviation industry has plenty of practice with.

Before the popularization of commercial airlines in the 1960s with companies like Pan Am, it was common to see grisly aviation accidents (like the 1956 crash over the Grand Canyon that led to the creation of the FAA) splashed across local front pages. To counter this bad press, the companies began to run ad campaigns with an emphasis on safety and professionalism of both airlines and pilots alike, says Bednarek.

“Between the 1930s and the 1970s, airlines placed a lot of emphasis on just how safe airplane travel was,” says Bednarek. “For example, [in ads] they would show that men, women, children, young, old, all kinds of people could travel by air, so that more Americans could essentially see themselves on the airplane.”

This marketing supplemented other advertisements that positioned the airlines as professional and reliable and crafted an image of pilots as friendly and responsible tour guides of the sky. Bednarek suggests that UAM companies could follow a similar tactic and help passengers truly envision themselves on these craft and to put equal trust into their autonomous pilot as they would their human counterpart.

A future saturated by autonomous urban aircraft is still at least a couple of decades away, in most opinions, but Rice, Winter and Smith say that we may begin to see more earnest testing of these aircraft with human passengers in the next five to 10 years. Only then will we finally know just how accurate all our predictions really are. ★

OPINION

Why it's time to reach for full reusability

Now that SpaceX has vividly demonstrated the promise of reusability in space launch, it's time to revive the goal of aircraft-like reusability of launch vehicles. Eugene A. Ustinov and Philip I. Moynihan, both formerly of NASA, make the case and present a concept.

BY EUGENE A. USTINOV AND PHILIP I. MOYNIHAN

Even before Sputnik was launched, the fertile imaginations of the public and futurists alike widely believed that once space-borne with artificial satellites, humankind would quickly progress toward human spaceflight to the moon, Mars and Venus, all across the solar system, even to the stars. We assumed that the chemical rockets that opened the way to space would give way to nuclear and then to thermonuclear propulsion systems. The theoretical estimates of performance of nuclear and thermonuclear propulsion looked very promising. It was also widely believed that the corresponding technologies would be available soon, and the same generations that witnessed launch of the first Earth satellites would see rapid progress toward deep space flight not only by probes, but also by humans. It appeared natural that orbital space operations would assume only a minor fraction of all space operations, in a way similar to how the early seafaring navigation of coastal waters gave way to navigation of the high seas.

This didn't happen. Now, more than six decades after Sputnik, the space operations are almost exclusively limited to low-Earth orbit. Humans paid merely six brief visits to the moon and have sent a few tens of robotic missions to the moon and planets — most notably Mars and Venus. But the overwhelming majority of missions (only a tiny fraction of them having crews) were sent to the lower- and higher-Earth orbits.

What happened? Why did early expectations not materialize? Why in contrast to the rapid development of aviation throughout the 20th century has space flight stagnated essentially where it terminated a few decades ago when the first semi-reusable crewed spacecraft, the space shuttle orbiters, were launched? Conceptually, we've seen little development since the early 1980s.

Unrealistic expectations

The expectation that chemical rockets would soon give way to nuclear and thermonuclear rockets turned out to be unrealistic. It appears that chemical propulsion remains the only feasible option for the present time and the foreseeable future. The modern expendable rockets, the ancestors of customized missiles that provided a quick solution for space access in the late '50s and early '60s, remain the only practical means of delivery to space. Expendable is the key word. Prior to SpaceX's recovery of first stages in recent years, these vehicles, each costing many millions of dollars, were piecewise thrown away on their way to space. Until SpaceX revealed that the cost of a payload launched into low-Earth orbit may be possible for less than $2,700 per kilogram or for less than $7,500 per kilogram when launched into geosynchronous orbit, only those customers who can afford to pay $10,000 or more per pound of delivered goods can pay for conventional transportation.

The end of the Cold War spelled the end of an era of practically unlimited funding for space exploration. The large, well-established aerospace companies are still supplying expendable rockets and are developing new ones. And their cost per unit never substantially decreases. The principal reason why costs remain constant or continue to increase is that whatever innovations are engaged, the launch vehicles are still thrown away after a single use. Imagine a transcontinental airliner scrapped after each flight. Could you imagine that any forthcoming innovations could ever eventually reduce the cost of a flight on such a non-reusable airliner to anything near the current ticket price? That's not very likely.

So, launch-vehicle reusability is the only practical cost-effective option. Why then, well over half a century into the spacefaring era and with the exception of SpaceX's evolutionary first step, does reusability — specifically of the launch stage — remain primarily a technical dream? Like all revolutionary concepts, it requires considerable investment.

Competing for funding

There is one point necessary to mention. In our opinion, the destiny of reusable space launch vehicles was marred by the premature attempt to use the Earth's atmosphere in two ways simultaneously: as a support for aero assist with wings providing supplemental lift and as a supply of oxidizer (atmospheric oxygen) for jet propulsion. Hypersonic air-breathing propulsion turned out to be a technology area that was too difficult to be mastered simultaneously with reusable ascent/re-entry vehicle design. The ill-fated National Aero Space Plane, or NASP, project clearly demonstrated the limitations of the usability of that aspect. Our conclusion: At least for the time being, the choice of a reusable launch vehicle should be a rocket plane, not a hypersonic air-breathing jet plane.

As an initial consideration, the physics of an air-breathing reusable first stage imposes substantial payload restriction. In order to generate the required greater thrust necessitated by a heavier payload, an air-breather must have a larger intake duct in order to ingest more oxygen for the greater combustion demanded. And the ability to take in more oxygen increases directly with the first power of velocity. Meanwhile, the thrust required to overcome the increasing aerodynamic drag as the aircraft accelerates increases with the square of velocity. This combination of oxygen demand and overcoming drag sets a practical upper limit on payload size.

There is another point one must also consider. Single stage to orbit was another idea that turned out to be technically unrealistic to pursue with

◀ **A SpaceX Falcon 9** carrying the company's Crew Dragon spacecraft is launched from NASA's Kennedy Space Center in Florida.

▲ **The first stage of** a SpaceX Falcon 9 rocket is brought back to Florida on a drone ship after a launch from NASA's Kennedy Space Center in Florida in 2020.
Melissa Lawton

The capability of SpaceX to fully recover and reuse the first stage of a rocket demonstrates only one part of the potential value of reusability.

existing chemical propulsion. The propellant required for even the best-performing engines leaves less than 10% of the takeoff weight for both the payload and structure. This is very challenging technologically and economically unattractive. Two stages to orbit appears to be the only viable option.

Combined with the uncertainties of competing concepts and their unknown futures, the potential investors are understandably hesitant to direct their capital toward development of reusable vehicles.

The success of recovering and reusing launch stages demonstrated by SpaceX is definitely a significant accomplishment and a much-needed long-awaited first step in the right direction. But the engineering complexity cannot be overstated, albeit there are resulting overall cost savings wrought by this achievement. The continued application of this method will bring down the costs of future launch operations. Although this effort represents an evolutionary step toward reusability, what is really needed to significantly reduce launch costs is a revolutionary step. The capability of SpaceX to fully recover and reuse the first stage of a rocket demonstrates only one part of the potential value of reusability. The launches are still constrained to dedicated rocket launch facilities, and the recoveries of the launch stages are limited to highly specialized procedures and landing pads.

Also, the SpaceX concept involves a purely bal-

A one-third scale model of the National Aero-Space Plane was tested in the Transonic Dynamics Tunnell at NASA's Langley Research Center in Virginia. A full-scale model was never built.

listic first stage. Once the launch stack reaches the staging velocity and the second stage is released, the first stage must perform two maneuvers: 1) to decelerate from staging velocity to zero and 2) to hover back to the launch site — both requiring the budgeting of a predetermined quantity of propellant. For comparison, the first stage of the rocket plane launch vehicle would make a nonpowered U-turn followed by a glide back to the launch site.

The Pegasus concept of carrying a space-borne payload to low-Earth orbit with a first stage comprising a conventional aircraft is a cost-effective approach also. The first-stage aircraft is undeniably reusable, as it can operate from any conventional airport. However, the application of a conventional aircraft for the first stage, as with Pegasus, limits the size of the orbital delivery to a fairly small payload.

Operating from an airport

A rocket plane, which is in essence a fixed-wing rocket, would be a natural means of using the aero-assist of the Earth's atmosphere en route to orbit, while simultaneously enabling operations from any conventional airport. Aerodynamic lift developed by the wings can help compensate for the vehicle weight and thus reduce gravity losses, a major component of energy budget of the launch vehicle. Aerodynamic lift is instrumental during the entry and descent phase too. The space shuttle flights demonstrated that aspect every time a vehicle returned from orbit.

For operations from conventional airports, the initial wing loading of the stack of two launch stages needs to be complemented by a winged pre-stage to enable the takeoff from conventional-length runways at airspeeds of a conventional airliner. Two U.S. patents granted to Eugene, one in 2012, "Non-powered, aero-assisted pre-stage for ballistic rockets and aero-assisted flight vehicles," and in 2013, "Aero-assisted pre-stage for ballistic rockets and aero-assisted flight vehicles," suggest how this could be done. The first describes a nonpowered version, which, of course, would be easier to implement. The second describes an aero-assisted (winged) pre-stage that would be powered, which substantially eases the propellant budget of the launch vehicle.

We strongly recommend that a government organization such as NASA or the U.S. Defense Department, as well as interested private corporations, such as SpaceX or Northrop Grumman, which now owns the Pegasus rockets, conduct feasibility studies of the rocket plane as a launch vehicle. The referenced patents can be taken as a point of departure for this effort. Such feasibility studies could involve a detailed analysis of the rocket-plane concept, followed by a proof-of-concept suborbital flight demonstration. Suborbital flights could function as the intermediate goal toward final acceptance of the rocket plane as a truly low-cost launch-vehicle option. ★

Eugene A. Ustinov joined NASA's Goddard Space Flight Center in Maryland as a National Science Foundation postdoctoral researcher in 1994. In 1998, he transferred to the Science Division of the NASA-funded Jet Propulsion Laboratory in California where he contributed to numerous interplanetary missions until his retirement in 2014, though he continues to work there part time. He also has flight experience with both piston-engine and jet aircraft. He has a doctorate from the Space Research Institute in Russia and a doctorate from Tartu University in Estonia.

Philip I. Moynihan spent 45 years as an aerospace engineer, seven at Rocketdyne working on large rocket engines and 38 at JPL contributing to multiple systems ranging from propulsion to spacecraft instruments. He is also a private pilot. He has a doctorate in mechanical engineering from the University of Southern California.

OPINION

The price of passion

Getting ahead in the aerospace field has long depended on how one ranks in an information competition to see who can show the most passion for aircraft, satellites and rockets in and out of the office or lab. The obsession with passion is counterproductive and should stop. Engineer Sylvie DeLaHunt tells us why.

BY SYLVIE DELAHUNT

During a recent media interview, I was asked, "Why are you passionate about aerospace engineering?" Instead of conjuring up inspired visions of space exploration, search and rescue helicopters, or acrobatic fighter jets, my mind immediately initiated a downward spiral of panic. I felt guilty and embarrassed for not having an honest answer.

Is my work developing guidance algorithms and flight control systems for missile interceptors interesting, challenging and important? Definitely. Is it my "passion"? Not really. Despite this, I expand my technical knowledge, solve interesting aerospace challenges and bring a strong work ethic to my job each day. I am also dedicated to advocacy for diversity and inclusion in engineering and enjoy numerous hobbies, such as travel, sports, pets, reading and leadership.

Impassioned engineers constitute a crucial component of our aerospace teams; however, our industry's expectation and valorization of passion for aerospace can hinder retention efforts by alienating those with diverse backgrounds and interests.

Aerospace, more so than other industries, expects passion of its students and professionals. This is often characterized by devotion to one's career with a love for the field and an all-consuming desire to learn more that often extends beyond work hours. During interviews and while employed, professionals are consciously and unconsciously evaluated on their displayed passion: Does one know enough aerospace facts and history? Stay up to date on aerospace current events? Spend one's free time amassing new technical knowledge, skills or hobbies? Love watching and discussing the "right" shows and movies?

This pressure to both have and demonstrate a singular focus on aerospace can disproportionately disadvantage underrepresented communities in the industry. Professional interests are often sparked at a young age. Due to gender norms, boys are more likely than girls to have defining experiences that lead to a fascination with aerospace and related disciplines, such as playing with model planes or rockets, fixing cars or building computers. This can cause women, and others lacking early exposure to the field, to feel like misfits relative to their more "passionate" peers who shape perceptions of who will succeed. Even for students and professionals who are enthusiastic, impostor syndrome may lead them to anxiously question whether their drive is enough. Additionally, how passion is displayed and perceived is subjective and can be influenced by cultural norms.

Furthermore, passion is often at odds with balance. Some managers within the aerospace industry, which is not known for work-life balance, view a willingness to work late hours as demonstration of commitment and excitement for one's career. This metric can be detrimental to the career prospects of those who are the sole or primary caregivers of children, parents or relatives, even if their work is completed efficiently.

The pressure to demonstrate passion can also discourage people from pursuing other interests that are personally enriching and beneficial to our teams and industry.

The pressure to demonstrate passion can also discourage people from pursuing other interests that are personally enriching and beneficial to our teams and industry. Well-rounded engineers make critical contributions to their technical work — as well as leadership, team building, onboarding, sponsor and customer relations, outreach, public engagement and more. Although I am still early in my career, my enthusiasm for diversity and inclusion has enabled me to influence strategy and policies at all levels of my organization. Unfortunately, engineers pursuing supplemental interests may appear insufficiently committed to aerospace compared to their more singularly focused peers, due to the time each new activity takes away from technical work.

During the recent AIAA SciTech Forum, the Women@SciTech panel stressed the importance of empowering people to be their authentic selves in the workplace. Authenticity increases personal happiness, fulfillment, motivation, confidence and creativity while promoting employee engagement and meaningful, trusting relationships. The subjective nature of judging someone's passion risks disadvantaging a diverse subset of our industry and may also disproportionately discourage those with a variety of interests, instilling a fear that their authentic selves are inadequate.

Going forward, each of us in the industry should commit ourselves to promoting belonging. We should speak up and express caution when others seem to value passion over demonstrated performance and impact. Ask about and encourage pursuit of diverse interests. Reward all contributions in performance evaluations and interview criteria. Feature people with diverse backgrounds and experiences on panels. Highlight team members who bring different perspectives or have broader impacts. Recognizing the unique value of our members improves recruitment, retention and employee satisfaction while facilitating the diversity of thought that fuels innovation. Next time, instead ask: "What do you enjoy about your field?" or "What motivates you to go to work each day?" The answers you receive might surprise and inspire you. ★

Sylvie DeLaHunt
is a guidance, navigation and control engineer at the Johns Hopkins Applied Physics Laboratory in Maryland and a member of the AIAA Diversity Working Group, Women of Aeronautics and Astronautics Integration and Outreach Committee, and Missile Systems Technical Committee.

AIAA Bulletin

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Calendar

FEATURED EVENT

2–6 AUGUST 2021
VIRTUAL

The only aviation event that covers the entire integrated spectrum of aviation business, research, development, and technology. This year's program theme, Aerospace Leadership in a Transitioning World, will focus on challenges and opportunities affecting the direction of global aviation policy, emerging markets, technological proliferation, and more!

aiaa.org/aviation

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2021			
5–7 May*	POSTPONED to 2022: 6th CEAS Conference on Guidance Navigation and Control	Berlin, Germany (https://eurognc2021.dglr.de)	
5–28 May	Electrochemical Energy Systems for Electrified Aircraft Propulsion: Batteries and Fuel Cell Systems Course	ONLINE (learning.aiaa.org)	
7, 14, 21 May	Foundations of Model-Based Systems Engineering (MBSE) Course	ONLINE, 3 half days (learning.aiaa.org)	
18 May	AIAA Aerospace Perspectives Series Webinar: Sustainability	VIRTUAL (aiaa.org/webinars)	
31 May–2 Jun*	28th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (elektropribor.spb.ru/en)	
15 Jun	ASCENDxSummit	VIRTUAL	
21–23 Jun*	3rd Cognitive Communications for Aerospace Applications Workshop	VIRTUAL (http://ieee-ccaa.com)	
23–24 Jun	OpenFOAM CFD Foundations Course	ONLINE, 2 full days (learning.aiaa.org)	
24 Jun–13 Jul	Computational Aeroelasticity Course	ONLINE (learning.aiaa.org)	
5–30 Jul	Optimal Control Techniques for UAVs Course	ONLINE (learning.aiaa.org)	
20–29 Jul	Digital Engineering Fundamentals Course	ONLINE (learning.aiaa.org)	
27–28 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

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

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	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
13–15 Sep*	3rd IAA Conference on Space Situational Awareness (ICSSA)	Madrid, Spain (http://reg.conferences.dce.ufl.edu/ICSSA)	15 Jun 21
14–16 Sep	AIAA DEFENSE Forum (Postponed from April)	Laurel, MD	17 Sep 20
28 Sep	ASCENDxSummit	VIRTUAL	
25–29 Oct*	72nd International Astronautical Congress	Dubai, UAE	
15–17 Nov	ASCEND Powered by AIAA	Las Vegas, NV, & ONLINE	30 Mar 21
15–17 Nov	24th AIAA International Space Planes and Hypersonic Systems and Technologies Conference	Las Vegas, NV, & ONLINE	30 Mar 21
2022			
3–7 Jan	AIAA SciTech Forum	San Diego, CA	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	
1–3 Apr	AIAA Region VI Student Conference	Merced, CA	5 Feb 22
19–22 Apr	AIAA DEFENSE Forum	Laurel, MD	
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 and Uncertainty Quantification	Chicago, IL	
27 Jun–1 Jul	AIAA AVIATION Forum	Chicago, IL	
24–26 Oct	ASCEND Powered by AIAA	Las Vegas, NV	

AIAA Continuing Education offerings

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

2021 Sperry Award Winner Works On Next-Generation Advanced Propulsion Capabilities that May Take Us to Mars

From Sci-Fi to Electric Propulsion

As a big science fiction fan growing up, **AIAA Associate Fellow Benjamin Jorns**, the 2021 Lawrence Sperry Award winner, took the idea of space travel for granted. "The next planet is usually only a warp drive or wormhole away," he noted. But as he got older, Jorns realized how hard it is to actually move in space and became interested in finding better, faster ways to reach the stars.

After reading a popular science article on a concept for faster-than-light travel proposed by Prof. Miguel Alcubierre, he thought, "This is what I wanted to do." Jorns wrote to Prof. Alcubierre for his advice on how he could follow in his footsteps. The professor responded with a thoughtful note, explaining that "his warp drive was a theoretical construct that violated some of the stronger assumptions from general relativity." Jorns remembered, "He recommended that if I wanted to work on advanced propulsion, I look into electric propulsion."

Attending Yale for his undergraduate studies, Jorns picked physics as a major because it would help him figure out "how" and "why" things work. He also noted that "he placed a lot of value in a liberal arts education — I think it is very important for scientists and engineers to have depth that goes beyond their technical niche."

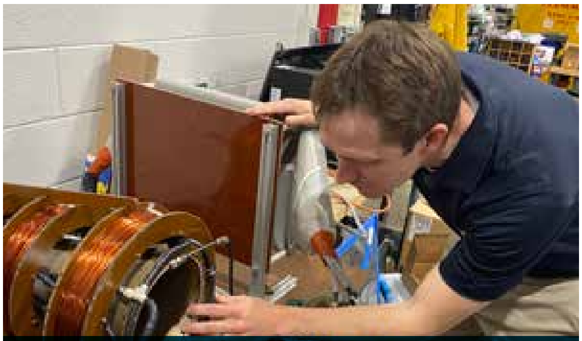
He founded an undergraduate group called the "Yale Drop Team" to participate in the NASA Reduced Gravity Student Flight Opportunity. The students constructed an experiment for a microgravity environment and took it on board the "Vomit Comet." While the experiment unfortunately broke on the first flight, the students still had a great time.

Jorns also did a couple of summer internships as an undergraduate — one at Purdue and one at NASA Goddard Space Flight Center. "This latter experience introduced me to the field of plasma physics," Jorns said, "which is the science underlying the propulsion systems I investigate. During my senior year, I had the opportunity to do my thesis under Prof. Juan de la Mora, whose work focuses on electrosprays. This technology, which can be used for electric propulsion, was my first exposure to the field."

For graduate school, Jorns knew that Princeton University was the historical epicenter for advanced electric propulsion research in the country. "The lab was founded in the 1960s by the late Prof. Robert Jahn who literally wrote the book on electric propulsion," he noted. "I had the opportunity to work under his former student, Prof. Edgar Choueiri, a pillar of the field in his own right. Prof. Choueiri's program emphasized an appreciation for first-principles theory and experimental work that I have tried to carry forward with me in my own work."

Translating Research into Application

After graduate school, Jorns joined the electric propulsion group at NASA Jet Propulsion Laboratory. "This was an amazing experience where I had my first opportunity to work with real flight hardware.



Inspecting a prototype Rotating Magnetic Field Field Reversed Configuration (RMF-FRC) thruster under development at Jorns' lab.

Jorns in front of the Large Vacuum Test Facility in his laboratory at the University of Michigan. It is one of the largest, most powerful chambers in the world for electric propulsion testing.

Nearly every day was an exciting opportunity to work on new and critical problems," he said. "With that said, academia is a great sandbox for exploring new ideas and technology. I thought I could use some the technical skills I had at learned at JPL to go after some of the big, fundamental challenges in our field. When a position opened up to become co-director of the electric propulsion lab at University of Michigan, I jumped at the opportunity."

Jorns started researching basic plasma questions related to wave-driven effects in Hall thrusters. He observed, "As time has passed, I have become increasingly interested in finding ways to translate my research directly to applications. I still emphasize basic science in my research group, but we do this work in service of improving current technologies, improving predictions of their performance, and finding new concepts that can advance our capabilities for space travel."

He also noted, "In this spirit, I have become really interested in data-driven methods recently. We have been exploring ways to use re-enforced learning to try to fill in gaps in our understanding of Hall thrusters and to more rapidly optimize the operation of new and exciting but unproven concepts like FRC thrusters. This, I think, could lead to major breakthroughs in the near term."

AIAA Lawrence Sperry Award

The AIAA Lawrence Sperry Award recognizes a notable contribution made by a young person, age 35 or under, to the advancement of aeronautics or astronautics. Jorns was honored "in recognition of his seminal experimental and theoretical work on wave-driven effects in Hall thrusters and his contributions to the development of advanced thruster technologies." But he noted that many people have helped shape his career. "First, I wouldn't be where I am today without my family – particularly my wife, Jenna, and son, Calvin. They keep me centered and are an unwavering source of support. Prof. Edgar Choueiri (AIAA Fellow) gave me a deep appreciation for first-principles analysis and plasma physics. The late Dr. Cynthia Phillips of the Princeton Plasma Physics Lab taught me everything I know about plasma waves. At NASA JPL, my group supervisor, Dr. Rich Hofer (AIAA Associate Fellow), and my senior colleagues, Dr. Dan Goebel (AIAA Fellow) and Dr. Ioannis Mikellides (AIAA Fellow), were hugely influential as teachers and mentors—particularly when it came to Hall thrusters. Alec Gallimore (AIAA Fellow, NAE member), the founder of the Plasmadynamics and Electric Propulsion Laboratory I now co-direct at Michigan, has been a guiding mentor throughout my career. He is an example to aspire to. I also would like to acknowledge both NASA and the Air Force Office of Scientific Research who have supported my work in my early career."

He also acknowledged his students, both at JPL and the University of Michigan. "This has been one of the most rewarding parts of my career so far, and I definitely would not be where I am professionally without their help."

Looking to the Future

Jorns is intrigued by small space as it has developed over the past decade, and he noted that "there are a lot of interesting physics-based and technical challenges with developing thrusters for this new paradigm. I think there is a lot to look forward to in that sphere in the next couple of years."

Jorns with a Hall thruster that is under active investigation at his research group.

However, he is most excited about the new age of in-space electric propulsion (EP). "Hundreds of spacecraft have EP on board for station keeping and orbit raising. NASA, ESA, and JAXA have all flown or proposed robotic missions with EP. The next technical hurdle is scaling up in power. State-of-the-art electric propulsion devices in orbit operate at ~5 kW and are used exclusively for robotic vehicles," he observed. "If we could increase that power level by a factor of 100 or 1000, crewed exploration would become a real possibility. We could be sending people to Mars and beyond with electric propulsion."

He noted that the National Academy of Sciences has a roadmap to illustrate how to use electric propulsion to support a Mars mission as early as 2039 if thrusters can be developed that can handle MWs of power, power supplies (nuclear) can generate this power with low mass penalty, and test facilities can demonstrate these concepts. "My goal is to help build the hardware and numerical and experimental tools that will help contribute to this vision of EP-enabled space exploration," said Jorns. "We recently started going down this path in earnest as a community. I will be the co-director of a newly funded NASA institute led by Prof. Mitchell Walker at Georgia Institute of Technology to develop high power electric propulsion test capabilities. This is the first step in building the infrastructure for realizing the next generation of advanced propulsion capabilities."

The Value of AIAA Membership

In his first year of graduate school, Jorns attended a Joint Propulsion Conference and became an AIAA member. As that conference grew into the AIAA Propulsion and Energy Forum, it "was a wonderful vehicle for interacting with the leading experts in the field," he remarked. "I have served on the Electric Propulsion Technical Committee since 2014, and I have had a number of roles including membership chair and website organizer. This has been a particularly rewarding service." And he has helped to inspire the next generation as a faculty advisor for the AIAA University of Michigan Student Branch, which "has been a pretty easy gig so far. The students are extremely capable and organized. It is great to be part of such an active organization with such enthusiastic students."

CONGRATULATIONS, CLASS OF 2021 AIAA FELLOWS AND HONORARY FELLOWS!

You are cordially invited to the Class of 2021 Virtual Induction Ceremony

Tuesday, 17 August 2021
1700 hrs ET

AIAA confers the distinction of Fellow and Honorary Fellow upon individuals in recognition of their notable contributions to the arts, sciences or technology of aeronautics and astronautics.

The 2021 Honorary Fellows are:

DANIEL E. HASTINGS
Massachusetts Institute of Technology

GWYNNE E. SHOTWELL
Space Exploration Technologies Corporation (SpaceX)

THE HONORABLE HEIDI SHYU
Heidi Shyu Inc.

The 2021 Fellows are:

JUAN J. ALONSO
Stanford University

RANDAL W. BEARD
Brigham Young University

CHIARA BISAGNI
Delft University of Technology

STANLEY K. BOROWSKI
NASA Glenn Research Center (retired)

CHIA-CHUN "GEORGE" CHAO
The Aerospace Corporation (retired)

OLIVIER L. DE WECK
Massachusetts Institute of Technology

JEANETTE L. DOMBER
Ball Aerospace

ERIC H. DUCHARME
GE Aviation (retired)

JACK R. EDWARDS
North Carolina State University

RICHARD SCOTT ERWIN
U.S. Air Force

ERIC M. FERON
Georgia Institute of Technology

IRENE M. GREGORY
NASA Langley Research Center

W. MICHAEL HAWES
Lockheed Martin Corporation

MICHAEL KEIDAR
George Washington University

ERICK LANSARD
Thales

ROGER D. LAUNIUS
Launius Historical Services

IVETT A. LEYVA
Office of the Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering

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.

For more information, please contact Patricia A. Carr at PatriciaC@aiaa.org

AIAA
SHAPING THE FUTURE OF AEROSPACE

MAKING AN IMPACT

Space for an Impactful Match


Caleb Anderson, 12


Rayon Harris

Rayon Harris graduated from the University of Central Florida in 2019 and now works at Lockheed Martin as an aeronautical engineer with a focus on structural design. He has recently joined AIAA's Mentor Match program and has been paired with Caleb Anderson.

Caleb, a twelve-year-old boy from Marietta, GA, loves outer space and has a dream of becoming an aerospace engineer; he was recently accepted to Georgia Tech beginning with the fall 2021 semester. He is one of AIAA's newest high school members and perhaps our youngest member entering college this fall. This unique situation is what makes this mentorship so impactful.

When establishing a mentor-mentee relationship it is important for it to feel natural. Rayon states "the most important part to the start to any relationship is for all parties to feel comfortable whenever they communicate. Anything that feels forced can potentially be a step in the wrong direction." During Rayon's first conversation with Caleb, he realized that Caleb was being raised by Caribbean parents and there was an instant connection as Rayon was also raised by Caribbean parents.

Despite all of Caleb's amazing accomplishments Rayon said, "what first sparked my interest in wanting to develop a relationship with him was seeing how passionate he is in aerospace at such an early age. It reminded me of myself when I discovered I wanted to 100% become an aerospace engineer at the age of 13."

Rayon and Caleb meet one to two times per month virtually, with the hope of meeting in person in the future. Rayon's goal is to take Caleb and his family to NASA Kennedy Space Center to view some of the exhibits. "He's never been and would be super excited to go," added Rayon.

AIAA launched the High School Membership program this past March and is encouraging all high school members to participate in the Mentor Match program as well to receive the same mentorship Rayon provides to Caleb.

If you are interested in signing up as a mentor or mentee, please visit **engage.aiaa.org/mentor-match**. Learn more about High School Membership at **aiaa.org/hs**.

2021 Regional Student Conferences Announce Winners

AIAA is pleased to announce the winners of six of the 2021 Regional Student Conferences. AIAA sponsors student conferences in each AIAA region for student members at both the undergraduate and graduate levels. In typical years, students present their research in person and are judged on technical content and clarity of communication by professional members from industry. This year, conferences were held virtually, but were still hosted by student branches.

The first-place winners in each category (listed below) are invited to attend and present their papers at the AIAA International Student Conference held in conjunction with the 2022 AIAA SciTech Forum in San Diego, CA, 3–7 January.

Region I

Undergraduate Category:

1st Place – "Novel Structural Connector System for In-space Assembly of Truss Structures," Ian Down, University of Maryland (College Park, MD)

2nd Place – "Convolutional Neural Network Modeling of Secondary Instabilities of Stationary Crossflow Vortices," Richard Qiu, Harvard University (Cambridge, MA)

3rd Place – "Constrained Control of a Simulated UAV Using a Learning-Based Explicit Reference Governor," Michael Higgins and Laurent Burlion, Rutgers University (New Brunswick, NJ)

Masters Category:

1st Place – "Wake Structure Analysis of a Pitching Blunt Body Using Particle Image Velocimetry and Computational Fluid Dynamics," Forrest Miller, Old Dominion University (Norfolk, VA)

2nd Place – "Employing CARS to determine flame temperature of ethylene/air counterflow diffusion flames," Sean Alberts and Chloe Dedic, University of Virginia (Charlottesville, VA)

3rd Place – "AI on the edge and in the air: Using deep learning to automate drones," Bhavesh Narala, Rutgers University (New Brunswick, NJ)

Team Category:

1st Place – "The Zero-G Drone," Jonathan Snyder, Jenna Wendt, Alejandro Salvador-Garcia, Raneem Elsayed, Pamela Grullon, and Huan Min, Rutgers University (New Brunswick, NJ)

2nd Place – "Subglacial ocean Probe Exploration, Access, and Research (SPEAR)," Jack Gallagher, Nathaniel Ruppert, Olivia Garcia, Alexandra Nordmann, State University of New York–Buffalo (Buffalo, NY)

3rd Place - "Multi-Mode Hybrid Unmanned Delivery System: Combining Fixed-Wing and Multi-Rotor Aircraft," Paul Wang, Muhammet Gungor, Camil Andruch, Nolan Angelia, Weihao Cheng, and Onur Bilgen, Rutgers University (New Brunswick, NJ)

Region II

Undergraduate Category:

1st Place – "Reducing the Computational Cost of Bicycle Wheel CFD using BEM," Drew Vigne and Michael Kinzel, University of Central Florida (Orlando, FL)

2nd Place – "Comparison of 3D confocal Raman and high energy X-ray diffraction for the measurement of molten sand infiltration in turbine blade coatings," Vanessa D'Esposito, University of Central Florida (Orlando, FL)

3rd Place – "Developing a Flapping Gear System for Butterfly-Inspired Motion," Frederick Schulze and Chang-Kwon Kang, University of Alabama in Huntsville, (Huntsville, AL)

Masters Category:

1st Place – "Low Gravity Natural Convection and Pool Boiling Predictions," Ashley Milligan, University of Memphis (Memphis, TN)

2nd Place – "Prediction of Noise from Turbulent Boundary Layers with Suction," Achyuth Rajendran and Steven Miller, University of Florida (Gainesville, FL)

3rd Place – "Flight Test Point Optimization Program for a Self-Protection Application," Oscar Klempay, Georgia Institute of Technology (Atlanta, GA)

Team Category:

1st Place – "Proposal for austere light attack aircraft - Project Aardvark," Joseph Hayes, Andrew Heath, Brady Alexander, Spencer Grady, Jorge Velasco, Noah Jorgensen, Veronica Rodriguez, and Joshua Richardson, University of Alabama in Huntsville (Huntsville, AL)

2nd Place – "Dynamics of a 9-DOF Heterogeneous Robotic Platform for Spacecraft Motion Emulation," Celeste Newman, Hunter Quebedeaux, and Ryan Ketzner, University of Central Florida (Orlando, FL)

3rd Place – "Kestrel Aeronautics: KA-Ranger," Madison Smith, Jason Burke, John McDonough, Lindsey Dow, Connor Hawkins, Nathaniel Matthews, Thomas Key, and Wyatt Dritz, University of Alabama in Huntsville (Huntsville, AL)

Freshman/ Sophomore Open Topic Category*:

1st Place – "Effect of Varying Reynolds Number on the Aerodynamic Design of Lifting Surfaces," Seshan Jayapregasham, Embry-Riddle Aeronautical University (Daytona Beach, FL)

2nd Place – "Slotted, Natural-Laminar-Flow Airfoil: A Revolutionary Technology for Fuel Efficiency," Sreya Kumpatla and Stephanie TerMaath, University of Tennessee, Knoxville (Knoxville, TN)

3rd Place – "Trust the Process: An Investigation into Astrophotography," Neil Adake, University of Florida (Gainesville, FL)

Regional Design Team Category*:

1st Place – "Affordable Earth Return On-Demand Reentry Vehicle Design," Sean Dungan, Kevin Fernandez Villanueva, and Mamoon Syed, Florida Institute of Technology (Melbourne, FL)

2nd Place – "University of Memphis Rocket Testing Team," Matt Sale, James Bay, Zhibo Liu, Emma Hill, and David Boers, University of Memphis (Memphis, TN)

Outstanding Student Branch Activity Category*:

1st Place – "UGA Community Outreach Project - Space Race: A Voyage to the Moon Board Game," submitted by Trevor Houghton on behalf of the AIAA University of Georgia Student Branch (Athens, GA)

2nd Place – "Meet the Geeks," submitted by Sarah Ketchersid on behalf of the AIAA Embry-Riddle Aeronautical University Student Branch (Daytona Beach, FL)

3rd Place – "NC State Student Branch of AIAA's Outstanding Student Branch Activity," submitted by Carissa Hardy on behalf of the AIAA North Carolina State University Student Branch (Raleigh, NC)

**Additional category sponsored by Region II only*

Region III

Undergraduate Category:

1st Place – "Optimizing Trajectories for Unpowered Hypersonic Waveriders during Atmospheric Reentry," Jonathan Richmond, Ohio State University (Columbus, OH)

2nd Place – "Application of Counterrotating Blade Rows for the Purpose of Increasing Power Density of Axial-Flow Rocket Engine Pumps," Forrest Lim, Purdue University (West Lafayette, IN)

Team Category:

1st Place – "Evaluation of Regenerative Cooling Channels for Nuclear Thermal Propulsion," Benjamin Stefanko, William Mullin, Emmanuel Adu, Keaton Melendez, Aaron Bell, and Grant

Davis, Ohio State University (Columbus, OH)

Region IV Undergraduate Category:

1st Place – "Aerodynamic Performance of a Low Aspect Ratio Active Rear Wing Package Designed for the OSU Formula SAE Team," Tanner Price and Ryan Paul, Oklahoma State University (Stillwater, OK)
2nd Place – "Copper-Infused, 3D-Printed Filament: Manufacturing and Preliminary Impact Testing," Nicolas Fabbri and Amber McClung, St Mary's University of San Antonio (San Antonio, TX)
3rd Place – "Probabilistic Structural Fatigue and Risk Analysis on the PIPER -PA-28 Fleet, A Case Study," Manuel Carvajal and Maria Isabel Vallejo Ciro, Universidad de Antioquia (Medellin, Colombia) and St Mary's University of San Antonio (San Antonio, TX)

Masters Category:

1st Place – "Preliminary Adaptation of Speech Source Localization Algorithm for Reduced Bandwidth of Interest in Tornadic Infrasound Signals," Brandon White and Ujjval Patel, Oklahoma State University (Stillwater, OK)
2nd Place – "Development of High-Speed Data Acquisition Triggering Systems for Hypersonic Wind Tunnel Applications," Valeria Delgado Elizondo and Elijah Lalonde, University of Texas, San Antonio (San Antonio, TX)
3rd Place – "Parametric Analysis of Surface Dielectric Barrier Discharge Plasma Actuators," Andrew Quinton, Jamey Jacob, Oklahoma State University (Stillwater, OK)

Team Category:

1st Place – "Microplastics and Extremophiles in the Stratosphere," James Simmons, Edgar Bering, Chloe Tovar, Desmond Etumnu, Phillip Pham, Hai Pham, Maxwell Omanga, and Harrison Azbell, University of Houston, Central Campus (Houston, TX)
2nd Place – "A Mass Simulator for Development of Rocket-Assisted Take-Off Systems of Unmanned Aircraft," Christopher Rathman, Seth Robbins, Sidney Francis, and Jacob Mobley, Oklahoma State University (Stillwater, OK)
3rd Place – "Constructing a Lightweight, Balloon-borne Instrument to Measure Atmospheric Conductivity at Two Latitudes," Alexandra Ulinski, Elizabeth Hernandez, Rachel Nathan, Andy Nguyencuu, and Adrian Rangel, University of Houston (Houston, TX)

Region V Undergraduate Category:

1st Place – "Effect of Varying Propeller Pitch Angle on Efficiency and Noise Production," Luca Zeitvogel and Charles Wisniewski, United States Air Force Academy (CO)
2nd Place – "Experimental Investigation of Shark Skin-Inspired Surface Treatments," Emily Berexa and William Decker, United States Air Force Academy (CO)
3rd Place – "Relationships Between Characteristic Detonation Length Scales" - Noah Pritchard and Mitchell Hageman, United States Air Force Academy (CO)

Team Category:

1st Place – "Vibrissae Inspired Mechanical Obstacle Avoidance Sensor for the Venus Exploration Rover AREE," Benjamin Alva, Raghav Bhagwat, Blake Hartwell, Emma Bernard, and Vinayak Rajesh, University of Minnesota (Minneapolis, MN)
2nd Place – "Functional LiDAR Analysis of Structural Health (FLASH)," Courtney Kelsey, Kunal Sinah, Jake Fuhrman Shray Chauhan, Ishaan Kochhar, Julian Lambert, Andrew Fu, Fiona McGann, Erik Stolz, and Ricky Carlson, University of Colorado Boulder (Boulder, CO)
3rd Place – "Passive Orbit Determination Based on Time Delay of Arrival," Keith Poletti, Ryan Prince, Noah Francis, Colin Ruark, Sam Firth, Tyler Pirner, and E Forest Owen, University of Colorado Boulder (Boulder, CO)

Region VI Undergraduate Category:

1st Place – "Measuring Electron Temperature and Density of a Sheared-Flow Z-Pinch Plasma Exhaust Plume," Michelle Graebner, University of Washington (Seattle, WA)
2nd Place – "An origami-based system for frequency bandgap tuning," Gloria Yin, University of Washington (Seattle, WA)
3rd Place – "Free Vibration of an Airplane Wing under Coupled Bending and Torsion: Approximation of the natural frequencies using uncoupled mode shapes for torsion and bending," Kellen Andrew and Arnold Deffo, California Polytechnic State University, San Luis Obispo (San Luis Obispo, CA)

Masters Category:

1st Place – "Investigation of Hydroxyl-terminated Polybutadiene Droplets Impacting Ammonium Perchlorate and Polytetrafluoroethylene Surfaces," Sahson Raissi and Joseph Kalman, California State University, Long Beach (Long Beach, CA)
2nd Place – "Comparison of Ammonium Perchlorate Pressed Pellets versus Single Crystal Wettability with Hydroxyl-terminated Polybutadiene," Aaren Cortes and Joseph Kalman California State University, Long Beach (Long Beach, CA)
2nd Place – "Wind Tunnel Force Balance Calibration at the San Diego State University Low Speed Wind Tunnel," Bradley Zelenka, Aldair Herrejon-Andrade, and Xiafeng Liu, San Diego State University (San Diego, CA)
3rd Place - "Best Practices for STAR-CCM+ 2D Hypersonic Flow," Nicholas Johnson and Eun Jung Chae, California State University, Long Beach (Long Beach, CA)

Team Category:

1st Place – "Design of a Modular and Orientable Electrodynamic Shield for Lunar Dust Mitigation," Luis Pabon Madrid, Malcom Tisdale, Isabella Dula, Polina Verkhovodova, Jules Penot, Leah Soldner, Kaila Coimbra, Tanmay Gupta, Rithvik Musuku, and Soon-Jo Chung, California Institute of Technology (Pasadena, CA)
2nd Place – "Design and analysis of MataMorph-3: An experimental fully morphing UAV with camber-morphing wings and tail stabilizers," Luis Ferrusquilla, Peter Bishay, James Kok, Brian Espinosa, Andrew Heness, Antonio Buendia, Sevada, Hezarjaribi, Paul Lacson, Jonathan D Ortiz, Ruiki Basilio, and Daniel Olvera, California State University, Northridge (Northridge, CA)
2nd Place – "A Novel Staged Warm Gas Thruster for CubeSats," Michael Mastrangelo, Spencer Powers, Connor Powers, Kamyar Zarkoub, and Spencer Wing, University of Southern California (Los Angeles, CA)
3rd Place – "UAV Flight Disruption via Acoustic Focusing," Miles Kay, Emma Roberson, Miranda Costigan, and Criss Edwards, University of Southern California (Los Angeles, CA)

Thank you to Lockheed Martin for being a sponsor of these conferences.

The AIAA Standards Steering Committee recently approved a new Committee on Standards (CoS) and a new project on Rendezvous and Proximity Operations (RPO) and On-Orbit Servicing (OOS) – Spacecraft Fiducial Markers. The new CoS will be called On-Orbit Servicing and Assembly (OSA) and will be responsible for developing the new standard on RPO and OOS – Spacecraft and Fiducial Markers. The scope of the standard is to establish RPO and OOS operating zones and approaches in the rendezvous phase. The standard also covers both robotic and Human Spaceflight (HSF) missions. International Space Station practices, SpaceLogistics MEV-1, and NASA's Restore-L are used as a basis for this standard. Stakeholders include a broad array of RPO/OOS industry participants from spacecraft equipment manufacturers, spacecraft operators, service providers, developers of RPO/OOS simulation, planning and safety tools, and insurers. It is intended to help establish responsible norms of behavior for RPO and OOS. For more information on how to participate in this project, please contact Nick Tongson (nickt@aiaa.org).

Obituaries

AIAA Senior Member Mara Died in June 2019

Jeanne Lee Mara, 65, died on 3 June 2019.

Ms. Mara was the President and CEO of Intelligent Light. Her leadership and guidance over the last 25 years built the company into a leader in the industry. In the late 1980s, she ran the computer animation operation for the company, producing pioneering CGI pieces for HBO, Cinemax, Nickleodeon, and many others.

AIAA Senior Member Aung Died in January

Dr. Kendrick Aung, 60, died on 13 January.

Aung, a mechanical engineering graduate from Rangoon Institute of Technology in Burma, earned his master's degree in energy technology from the Asian Institute of Technology in Thailand and his doctorate in aerospace from the University of Michigan. Aung was a postdoctoral fellow at Georgia Institute of Technology from 1996 to 1998. In January 1999, he joined the Department of Aerospace and Mechanical Engineering at the University of Southern California as a research assistant professor. In 2001, he joined Lamar University as an assistant professor in the Department of Mechanical Engineering. Aung had served as interim department chair since June 2020.

He was a gifted teacher, exceptional mentor always enthusiastic about his work with students and his research and an acclaimed academic who devoted himself to his discipline.

While at Lamar University, Aung mentored more than 50 senior Capstone design teams, and several of those teams won prizes and scholarships in regional and national design competitions. He served as faculty mentor to two McNair Scholars and he sponsored a paper published by a group of undergraduate students, "A Parametric Study of a 4-Stroke Motorcycle Exhaust System," 2004 International Mechanical Engineering Congress and RD&D Exposition in November 2004. Aung also received six senior design project grants from the American Society of Heating, Refrigeration and Air-Conditioning Engineers. Aung was the faculty advisor for student branches of several engineering societies

Aung was recognized with the Presidential Faculty Fellow for Innovation in Teaching Activity award in 2014 and 2015 and the Distinguished Faculty Fellow for Teaching award twice (2015–2018 and 2018–2021). He received the Presidential Fellowship in Research in 2014 and the Tim Kendall Memorial Prize from the Asian Institute of Technology in 1991. In 2019, he was the recipient of Lamar University's 2019 University Professor Award. His research on renewable energy and energy systems, hydrogen flames and combustion, and alternative fuels was widely published and presented at conferences.

AIAA Senior Member Weisenburger Died in March

Henry F. Weisenburger, age 96, died on 16 March.

Weisenburger was a member of CAP Coastal Patrol #3 during World War II before attending the University of Miami and the University of Florida. He graduated in 1951 from the University of Florida's Department of Mechanical and Aerospace Engineering.

His vocation of aeronautical engineering spanned 45 years. Weisenburger working for three companies including MIT Lincoln Laboratory and Raytheon, and he had remarkable contributions and accomplishments.

He was a member of AIAA for 70 years. When he was in Gainesville, FL, he would attend the monthly breakfasts at the Keystone Heights Airport.

AIAA Fellow Lunney Died in March

Glynn Lunney, 84, died on 19 March.

After two years at the University of Scranton in Pennsylvania, Mr. Lunney transferred to the University of Detroit (now the University of Detroit Mercy), where he studied engineering and took part in a cooperative training program with a forerunner of NASA. He joined the space agency after his graduation in 1958.

Lunney was selected in the Class of 1963 with John Hodge and Gene Kranz, and became NASA's fourth flight director. Flight directors are responsible for leading teams of flight controllers, research and engineering experts, and support personnel around the world, and making real-time decisions critical to keeping NASA astronauts and missions safe and successful in space. A key leader of NASA human spaceflight operations, Lunney was a member of the original Space Task Group at NASA Langley Research Center. After moving to Houston, the task group eventually became the Manned Spacecraft Center, now NASA Johnson Space Center. He was a flight director for the Apollo 11 moon landing mission, and was lead flight director for Apollo 7 (the first crewed Apollo flight) and Apollo 10 (the dress rehearsal for the first moon landing) at NASA's Mission Control Center in Houston.

He led the mission control team credited with helping to save three Apollo 13 astronauts aboard a spacecraft disabled on the way to the moon. On 13 April 1970, after an oxygen tank in the Apollo 13 service module exploded on the way to the moon, his team reacted quickly and effectively to prepare the astronauts and their spacecraft to complete a safe-return trajectory around the moon and return home safely. Under Lunney's direction, the team innovated and worked with the astronauts to deliberately shut down the command module systems so that the lunar module could be used as a lifeboat for the crew during the journey home to Earth. His team's work was widely credited with keeping the crew alive and safe while longer-term plans were developed for a successful reentry and splashdown. Lunney received the Presidential Medal of Freedom as part of the Apollo 13 Mission Operations Team.

Over the course of his career at NASA, Lunney worked on the Mercury, Gemini, Apollo, Skylab, and Space Shuttle programs. He was technical director in the planning and negotiations that led to the Apollo-Soyuz Test Project (ASTP) that culminated in the docking of an American Apollo and a Russian Soyuz spacecraft on 17 July 1975. This helped lead the way for today's cooperative international efforts on the International Space Station. Lunney retired from NASA in 1985 as manager of the Space Shuttle Program, but continued to lead human spaceflight activities in private industry with Rockwell International and United Space Alliance, before retiring in 1998.

Besides being an AIAA Fellow, Lunney was also recognized by AIAA with the Louis W. Hill Space Transportation Award (1965), the Lawrence Sperry Award (1970), and the Goddard Astronautics Award (2014).

AIAA Associate Fellow Rajagopalan Died in March

Professor R. Ganesh Rajagopalan died 19 March.

He received a B.S. in mathematics from Madras University in 1973, a B.S. in aeronautical engineering from the Madras Institute of Technology in 1976, and an M.S. in aerospace engineering from the Indian Institute of Science in 1978. Rajagopalan was a lecturer, teaching fellow, and research assistant at West Virginia University, and he received his Ph.D. in aerospace engineering from there in 1984.

Rajagopalan joined the Iowa State Department of Aerospace Engineering faculty in 1985 as an assistant professor and was promoted to associate professor in 1991 and professor in 2001. He was recently recognized by Iowa State's 25-Year Club for his 35 years of service to the university. A highly regarded researcher, he was responsible for unique contributions to rotorcraft, wind energy systems, and computational fluid dynamics (CFD). He and his students have made significant and wide-ranging contributions to the field of CFD. A dedicated teacher, Rajagopalan shared his knowledge in a wide range of subjects that included aerodynamics, gas dynamics, computational fluid dynamics, aircraft performance and flight dynamics, and wind energy, and he made major technical contributions the field of wind energy. Rajagopalan graduated 37 Ph.D. and M.S. students and taught numerous undergraduate and graduate-level courses during his time at Iowa State.

He had more than 70 research publications, 18 journal articles, and more than 50 conference papers from events around the world. He was principal investigator, co-principal investigator, or investigator on more than 30 grant-supported research projects.

Rajagopalan was an AIAA Associate Fellow and a lifetime member of the Vertical Flight Society (formerly American Helicopter Society) as a Gold Circle member (which recognizes pioneers and leaders in the helicopter industry) since 1985. He also received the Alfred Gessow Forum Best Paper Award at the organization's Forum 61 in 2005.

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In my intellectual curiosities I recently came upon the concept of correlation pleiades, a reference to a cluster of things mostly used in biology. This concept was formulated by Paul Terentjev, a leading Russian evolutionist, in 1931 and was expanded on by Raissa Berg, a Russian geneticist known for her research focused on measuring mutation rates in fruit flies, in 1960. In essence, a correlation pleiades identifies how in some organisms, the developmental and evolutionary processes of some set of physical traits or features seem to be correlated and this constitutes a cluster, or pleiades, within a common organism. This immediately made me wonder if there exists at least one correlation pleiades within this Gaia system, to include near-Earth orbital space. My hypothesis is that there are dependent and linked processes among Gaia's complex ecosystems that are presently unknown because they've not been evaluated holistically. By identifying any correlation pleiades of this Gaia system, we would be able to assess which traits and features collectively evolve via dependent and independent processes and perhaps even discover causal anthropogenic contributions to these processes. The outcome would tell us more about us as a humanity and provide greater insight into the consequences of our activities, as interacting constituents with this collection of finite environments. My foundational belief is that all things are interconnected in some way, irrespective of our ignorance regarding these connective mechanisms. Quantifying the Gaia system correlation pleiades would go a long way in helping us remove this ignorance.

One way to understand an ecosystem is to classify its constituents. We could classify the near-Earth orbital space constituents in terms of their roles in the birth, aging, death and elimination processes of this space object population. Specifically we would determine which objects in this ecosystem (a) produce other space objects, (b) are themselves actively controlled or alive, (c) are dead and no longer working, (d) cause the death of other objects, (e) decompose or degrade other objects, and (f) eliminate or remove other space objects from the population. Rockets and objects that explode are examples of birthing objects. Most space objects in this ecosystem simply get old and stop working but don't cease to exist. Some objects may cause the death of another object through a collision. The micrometeoroid and small untrackable debris population degrade and contribute to the decomposition of larger trackable objects. Collisions can be considered jointly as dying and birthing processes. With the advent of active debris removal, we have objects that eliminate the very existence of certain dead objects from the population. Dead objects can be detrimental to those that are alive, kind of like zombies, because they still move at very fast speeds, can't get out of the way of harming another object and may never be eliminated from the environment without human influence.

As you can see, this near-Earth orbital space ecosystem is quite complex, and truth be told, we have yet to fully characterize and understand it. This is why I propose studying this ecosystem in concert with those of the Earth, oceans and atmosphere as a holistic ecosystem of ecosystems, the Gaia system. The goal is to identify any correlation pleiades that may exist in the Gaia system and then seek to determine causal relationships. In so doing, we may discover otherwise hidden dependencies and can be empowered to find ways to mitigate any detrimental effects from our anthropogenic contributions. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1921

May 6 Despite international sanctions, the governments of Germany and Bolshevik Russia conclude a trade agreement to foster military aviation. As both nations are international pariahs, this agreement, which foreshadows the Treaty of Rapallo the following year, helps promote Russian aviation and allows Germany to circumvent the Treaty of Versailles that ended World War I and by training German military aviators in Russia. David Baker, **Flight and Flying: A Chronology**, p. 138.

May 13 Benito Mussolini, the leader of the Italian fascist movement, receives his pilot's license. John Gooch, **Mussolini and His Generals: The Armed Forces and Fascist Foreign Policy, 1922–1940**, p. 39.

May 15 American exhibition pilot Laura Bromwell completes 199 consecutive loops, setting a record for women aviators, over one hour and 20 minutes in New York. Daniel, Clifton, ed., **Chronicle of the 20th Century**, p. 280.

1946

May 8 The U.S. Navy's chief of naval operations directs the Bureau of Aeronautics to make a preliminary study of an Earth satellite vehicle that would "contribute to the advancement of knowledge in the field of guided missiles, communications, meteorology, and other technical fields with military applications." E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 54.

May 9 The first prototype Bristol Wayfarer aircraft, fitted with 32 seats, is test flown for the first time; it is to be the first Wayfarer to be put into service by Britain's Channel Islands Airways. The first flight coincides with the first anniversary of the liberation of the islands from German occupation. **The Aeroplane**, May 10, 1946, p. 559.

May 14 An SE. 161 Languedoc French airliner becomes the first such aircraft to land in England. The Languedoc, designed in 1937 but only produced after the war, is the first French transport aircraft to go into production since the liberation of France. Air France has ordered 40 Languedocs to be flown on the French Empire services and Continental routes, along with DC-3s. The Languedoc seats 33 people, has a cruising speed of 370 kph and has a maximum range of 3,200 kilometers. **The Aeroplane**, May 24, 1946, p. 616.

May 15 Flight Refuelling Ltd. starts a nine-month series of tests of in-flight refueling under operating conditions in connection with British South American Airways. The tests are to assess the practical application of the system to long-range commercial airline routes. Lancasters are the fueling aircraft. Rebecca Eureka radar equipment is installed in both receiver and tanker aircraft for establishing contact for the refueling operations in bad weather. **The Aeroplane**, May 10, 1946, p. 557.

1 **May 17** The Army Air Forces' first jet bomber, the Douglas XB-43, makes its initial test flight. Based on the propeller-driven XB-42, the XB-43 is powered by two GE J35 turbojet engines that give the aircraft a top speed of 800 kph, a range of 1,770 kilometers and a bombload of 3,600 kilograms. It does not go into production, but a second XB-43 is flown in tests. E.M. Emme., ed., **Aeronautics and Astronautics, 1915-60**, p. 54.

2 **May 22** The De Havilland Canada DHC-1 Chipmunk two-seat primary trainer makes its first flight at Toronto Airport. This is De Havilland Canada's first aircraft of entirely domestic design. **The Aeroplane**, May 31. 1946, p. 624.

1971

3 **May 4** Apollo 15 astronauts David Scott and Jim Irwin demonstrate the Lunar Roving Vehicle for the media at the NASA's Kennedy Space Center in Florida. Reporters are permitted to take turns driving the vehicle at a maximum of 16 kph. Scott and Irwin are to drive the LRV on the moon as far as 8 kilometers. **Washington Post**, May 5, 1971.

May 4 NASA announces its plans to study a "dial-a-plane" system in which a computer would accept telephone requests to determine the best aircraft itinerary to minimize trip lengths and passenger waiting, resulting in a more efficient air transportation system for smaller cities and less densely populated areas. If the studies prove the concept feasible, a proposal will be made to the U.S. Transportation Department and FAA, with NASA furnishing the computer and software. **NASA Release 71-79**.

May 5 The 10th anniversary of the first U.S. crewed spaceflight is celebrated at NASA's Kennedy Space Center in Florida. The suborbital mission launched Alan Shepard in the Project Mercury Freedom 7 spacecraft on a modified Redstone rocket. NASA, **Astronautics and Aeronautics, 1971**, p. 122.

4 **May 5** Eastern Airlines signs an agreement with Lockheed Aircraft Corp. to purchase 50 Lockheed L-1011 Tristar jet aircraft, the third wide-bodied jet airliner to enter production. **New York Times**, May 6, 1971, p. 63.

5 **May 8** The Mariner 8 Mars probe is launched by an Atlas-Centaur booster although the booster malfunctions after a normal countdown and liftoff. Anomalies begin to appear with the Centaur main engine start. This stage oscillates and subsequently tumbles out of control, and the Centaur and spacecraft separate and reenter the atmosphere approximately 1,500 kilometers down range and 400 km north of Puerto Rico. NASA, **Astronautics and Aeronautics, 1971**, p. 127.

May 12 A Lunar Module similar to those used on Apollo 11, 12 and 14 is placed on permanent display at the Smithsonian Institution's National Air and Space Museum. NASA, **Astronautics and Aeronautics, 1971**, p. 130.

May 19 The Soviet Union launches its Mars 2 space probe toward Mars from the Baikonur Cosmodrome and launches its twin spacecraft, Mars 3, nine days later. Subsequently, the Mars 2 lander crashes on the Martian surface; the Mars 3 lander becomes the first spacecraft to land on the planet on Dec. 2. Meanwhile, the Mars 2 and 3 orbiters circle Mars and transmit images back to Earth for another eight months. New York Times, May 20, 1971, p. 1; NASA, **Astronautics and Aeronautics, 1971**, pp. 134, 337.

May 20 Astronaut James Lovell is named the deputy director of science and applications at NASA's Marshall Spaceflight Center in Huntsville, Alabama. NASA, **Astronautics and Aeronautics, 1971**, p. 137.

May 27-June 6 A million people attend the 29th Paris International Air Show at Le Bourget Airport. Among the highlights are displays of the Soviet Tu-144 supersonic transport that makes its first appearance in the West; the Anglo-French supersonic airliners Concorde 001 and 002; the Soviet Mi-12, the world's largest helicopter; the Lockheed C-5A Galaxy, the world's largest aircraft; the Lockheed 1011 Tristar; and 200 private aircraft in a total exhibit of 600 aircraft. The U.S. Pavilion also has an exhibit of Apollo moon rocks. **New York Times**, May 26, 1971.

May 30 NASA launches the Mariner 9 spacecraft from the Kennedy Space Center on an Atlas-Centaur vehicle toward Mars. The 1,000-kilogram spacecraft carries an infrared spectrometer to measure surface and atmospheric radiation, an S-band occultation experiment to study the pressure and structure of the planet's atmosphere, TV cameras to transmit low- and high-resolution photographs of the surface, and an experiment to investigate the Martian gravity field. **NASA Release 71-75**.

May 31 Igor Sikorsky, the Russian-born aviation pioneer and founder of the Sikorsky Aircraft Division of the United Aircraft Corp., is named the 1971 recipient of the U.S. Air Force Academy's Thomas D. White National Defense Award, presented annually for significant contributions to "the national defense and security of the United States." **Aviation Week**, May 31, 1971, p. 23.

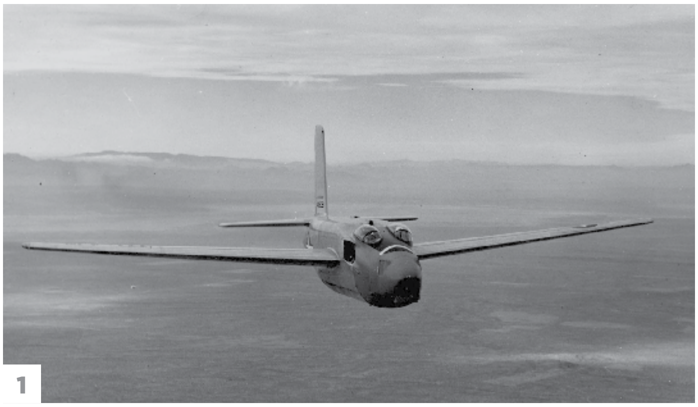
1996

6 **May 1** The Altus II low-speed uncrewed aerial vehicle completes its first flight. It was developed under NASA's Environmental Research Aircraft and Sensor Technology project known as ERAST. Altus II is designed to fly at altitudes between 60,000 and 100,000 feet using sensors to collect data on the atmosphere and test the ability of slow-flying high-altitude UAVs to function as inexpensive substitutes for communications satellites. Altus II is a civilian version of the military's MQ-1 Predator UAV. NASA.gov, **NASA Armstrong Fact Sheet: Altus II**, Feb. 28, 2014.

May 13 Lt. Col. Madan Khatri Chhetri of the Nepalese Army lands a Eurocopter AS350 B2 helicopter at Mount Everest's Base Camp 1 to airlift injured mountain climbers. He lands his helicopter at an extreme altitude of 19,600 feet (5,974 meters) while in a blizzard. Jon Krakauer, **Into Thin Air**, p.110.

May 15 Amos-1, Israel's first geosynchronous communications satellite is launched by the European Space Agency's Ariane rocket. Israel Aircraft Industries built the 990-kilogram satellite. The Ariane also launches the Indonesian Palapa C2 communications satellite. **Aviation Week**, May 20, 1996, p. 70.

May 19 Space shuttle Endeavour is launched from Cape Kennedy in Florida under the command of astronaut John Casper, who is on his fourth flight. He is accompanied by pilot Curtis Brown Jr. and four mission specialists. STS-77 is scheduled to last 10 days. Once in orbit, the crew deploys a retrievable satellite; the spaceplane also carries the SPACEHAB, which carries 1,300 kilograms of scientific instruments. NASA, **Astronautics and Aeronautics**: **A Chronology, 1996-2000**, pp. 19-20.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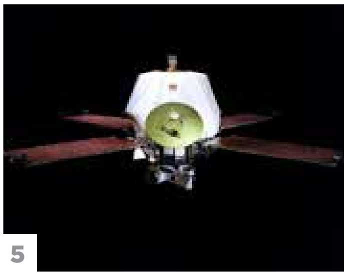
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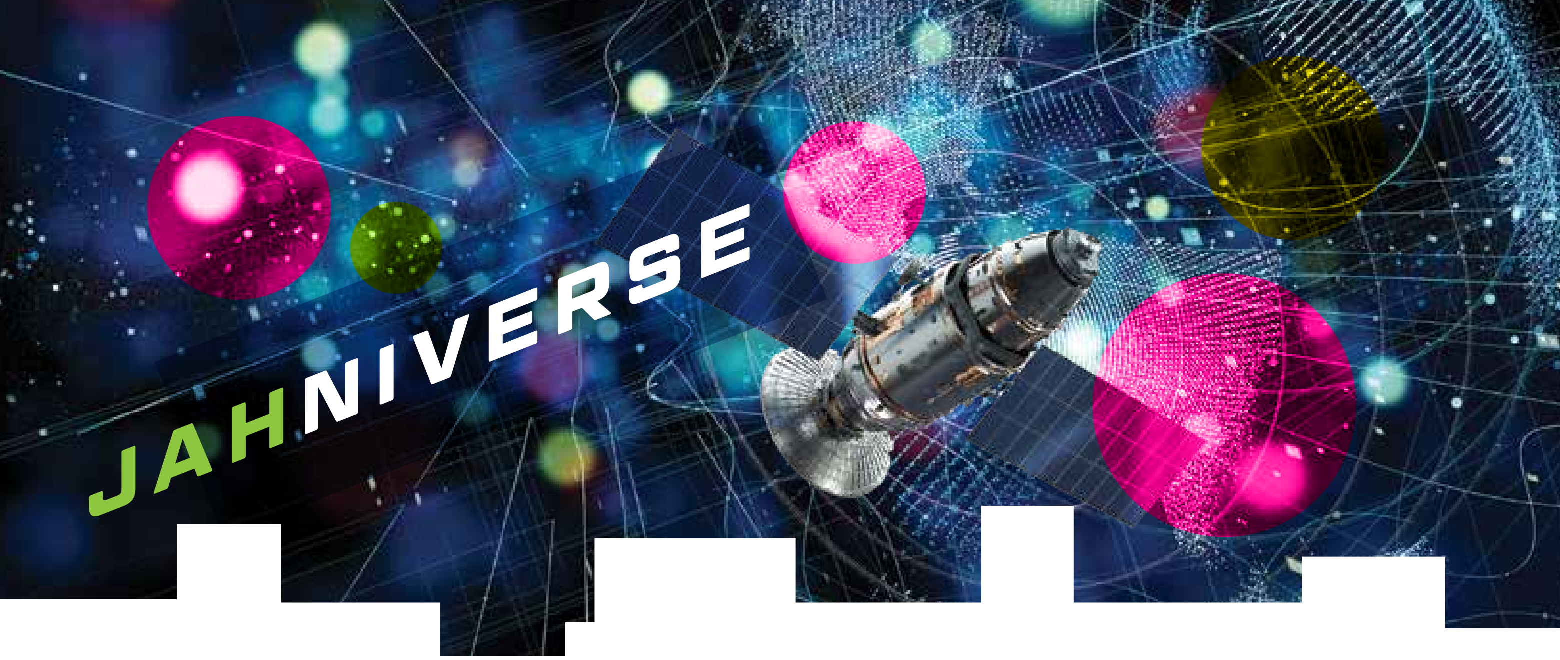

Discovering the interconnection between heaven and Earth

BY MORIBA JAH

Humanity knows of several ecosystems comprising the Earth, its oceans and atmosphere. We could cluster these as a holistic ecosystem of ecosystems, call it the Gaia system, after the Greek goddess who inspired the modern idea that Earth's living and inorganic content should be considered as one unit. By looking at Earth as the Gaia system, I've included the often overlooked near-Earth orbital space among these ecosystems. This orbital ecosystem is a population of mostly anthropogenic space objects, some abiotic objects like micrometeoroids and a few astronauts in low-Earth orbit, all interacting with and within a dynamic space environment. Moreover, there may be as-of-yet unknown processes driving the development and evolution of features and traits of near-Earth orbital space that are correlated with those of land, air and sea.

Near-Earth orbital space has gone largely unacknowledged as an ecosystem because it was invisible to humanity until people started sending satellites into orbit in the late 1950s. Like the wind, we notice near-Earth space only indirectly by observing how objects move within it. If you look at the sky, you don't actually see the air currents, but you can infer them indirectly by observing how birds, clouds and airplanes are affected by them. Similarly, with near-Earth orbital space, this milieu comprised of inter alia, solar flux, charged particles, magnetic field lines and micrometeoroids is indirectly visible to us by observing its effects on the motion of satellites, dead rocket bodies and orbital debris. This ecosystem is becoming increasingly visible with the exponential growth of anthropogenic space objects. It's time that humanity recognize near-Earth orbital space alongside the other finite environments of this Gaia system.

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