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Flight shaming's surprising impacts

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Deciding how quiet they need to be

# AEROSPACE
★ ★ ★ AMERICA

# PROTECTING THE OFF-PLANET ECONOMY

Entrepreneurs want the U.S. Space Force to expand its reach to deep space. The risk of debris raises questions about what the force can do to keep the peace. PAGE 18

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SHAPING THE FUTURE OF AEROSPACE


U.S. Space Force Gen. John "Jay" Raymond, chief of Space Force operations and head of the multiservice U.S. Space Command, talks to troops at an all-hands meeting before the Space Force was established.

U.S. Air Force


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# AEROSPACE AMERICA

APRIL 2020, VOL. 58, NO. 4

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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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### Adam Hadhazy

Adam reports on astrophysics and technology. His work has appeared in Discover and New Scientist magazines.
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### Jan Tegler

Jan covers a variety of subjects, including defense, for publications internationally. He's a frequent contributor to Defense Media Network/Faircount Media Group and is the author of the book "B-47 Stratojet: Boeing's Brilliant Bomber," as well as a general aviation pilot.
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### Debra Werner

A frequent contributor to Aerospace America, Debra is also a West Coast correspondent for Space News.
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## DEPARTMENTS

# Closing the aerospace disconnects

Aerospace specialists in the U.S. seem to be in tune with the views of the public on just one of the three topics we explore in this month's feature articles.

These disconnects are a problem, because they can spawn surprise, even anger, among the populace or risk pushing government policymakers toward poor decisions.

First, consider flight shaming in the air travel market. Surprisingly, the flying public and business leaders are starting to get in sync on this issue. Wise airline executives, engineers and manufacturers now recognize that, particularly in Europe, a significant portion of the public wants to fly on cleaner aircraft and offset their carbon emissions through tree-planting programs or other measures. By taking flight shaming seriously, these leaders are starting to think like the generals and admirals who long ago left the policy arguments over climate change to the politicians. Like it or not, retreating Arctic ice has created new navigable seas to protect, and some air travelers now feel guilty enough about their carbon footprints to switch to the train or wish they could.

Regarding the U.S. Space Force, President Donald Trump's State of the Union speech probably did little to bridge the chasm between what the average person thinks this new branch of the armed services is about and what its mission actually is. Trump's references to the Space Force could have led some to believe that the Space Force is about getting war fighters out into space. In reality, this new branch is beginning to absorb the space specialists in the "Chair Force," the playful term for the Air Force personnel who work at computer terminals. Their mission is as much about ensuring that troops have GPS coverage, communications and satellite imagery as it is about confronting bad actors in space. Strategists in the Space Force know the danger of creating debris and the need to find creative ways to deter or punish bad actors. Our article explores what the force should do in the years and decades ahead, as the space economy expands to deep space.

Urban air mobility is where I sense perhaps the greatest disconnect. Pioneers of this field would be wise to be more forceful in socializing the idea that one day, perhaps not so long from now, thousands of small, electric aircraft will ply the skies of our neighborhoods and cities. It's good to see NASA and FAA gathering data about the potential noise from these proposed aircraft. Residents will be more accepting if they know this change is coming ★

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


Regarding the article "Futuristic flow control" in the February issue, it is good to see that research in non-mechanical flight control is advancing significantly to a flight demonstrator stage. One of the concepts being considered involves using jets of air blowing over various flight surfaces. This is of special interest to me as I remember well the research and wind tunnel testing on a control concept of "spanwise blowing over aerodynamic surfaces" in the very early 1970s. This early work was performed in our Research Laboratories at the Lockheed Georgia Co. (near Atlanta, now Lockheed Martin). As mentioned in the article, non-mechanical aerodynamic active flow control research goes back a very long way. Finally, real progress is about to be made.

**John S. "Jack" Gibson,** AIAA fellow
Hideaway, Texas, w4svh@aol.com

## CORRECTION

***In the February article "Futuristic*** flow control," our reference to the ecoDemonstrator's active flow control flights should have noted that these flights were not the first such experiments. The XV-15 tilt-rotor tested active flow control in flight in 2003. Synthetic jets in its flaps and ailerons reduced download forces, a kind of drag caused by rotor downwash during takeoff and hover. The flights were sponsored by DARPA and occurred at Bell's Arlington, Texas, facility with Boeing, the Illinois Institute of Technology, Tel Aviv University and University of Arizona. Also, researcher Michael Amitay's comment about minimizing the number of jets referred to an effort that preceded the ecoDemonstrator project.

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

Peter Miller

# Batter up

**Q:** Suppose Major League Baseball executives are considering raising the average seam height on the baseballs thrown to Houston Astros hitters as a punishment for their stealing pitch signs in the 2017 and 2018 seasons. The executives believe higher seams will increase drag and make it harder for the Astros to hit home runs. Explain why they are right or wrong.

**Draft a response of no more than 250 words and email it by midnight April 9 to aeropuzzler@aiaa.org for a chance to have it published in the March issue.**

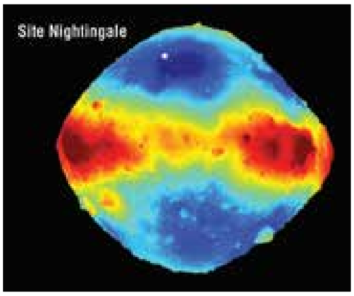
## FROM THE MARCH ISSUE

**FUEL EFFICIENCY:** Climate scientists are returning home after delivering a presentation about cirrus clouds. The pilot announces, "Ah, folks, we're taking the shortest possible route from Washington Dulles to Vienna this afternoon, so sit back and relax, knowing we've done all we can to reduce this flight's climate impact." The scientists let out a collective groan. Why?

**WINNER:** The climate scientists groaned, because they were well aware of the North Polar Jet Stream. Taking the shortest geographic route might seem like a good idea to shorten a flight and burn less fuel, but that assumes the atmosphere is stagnant. Solar-powered convection and the Coriolis force created by our spinning planet lead to powerful currents that flow at speeds of 180 km/hr on average, and have been measured at up to 400 km/hr. The North Polar Jetstream, one of the most powerful jets, flows east around 60° N latitude at 9-12 km altitude — where passenger jets typically fly — and is often used by airlines to provide a massive tailwind to eastbound flights. While a direct flight would travel less distance, were a plane to hitch a ride on the jet stream, it would cross the Atlantic in far less time and use less fuel.

Jeffrey J. mach
**Santa Clara, California**
**Mach works for Sierra Lobo Inc. As a site manager at the thermophysics facilities branch of NASA's Ames Research Center.**

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




▲ **OSIRIS-REx's laser** altimeter shoots laser pulses through the circular window, shown at right, while an internal mirror directs the beam to different locations as it scans Bennu's surface. At left is the box where the data is stored. The color-coded map was produced from OLA's laser scans. Red indicates peaks rising 60 meters higher than the lowest features, shown in blue.
NASA

# Mapping Bennu

BY CAT HOFACKER | catherineh@aiaa.org

If NASA's OSIRIS-REx mission were a play, the star would be the disk-shaped suction mechanism that in August will attempt to pull small rocks and dirt off the asteroid Bennu's surface for return to Earth in 2023. But every star needs a cast of supporting actors, and one of the key ones has turned out to be OLA, short for OSIRIS-REx laser altimeter.

"OLA became much more significant once we saw the surface of Bennu," says Michael Daly, the instrument scientist for OLA at York University in Ontario, referring to the craggy rocks and deep craters that surprised scientists when OSIRIS-REx began orbiting Bennu in December 2018. Scientists had expected a relatively smooth surface, with just a few areas to be logged as inaccessible after scanning by OLA.

With selection of the collection site now looking trickier, OLA began its work of mapping Bennu by bouncing lasers off its surface and measuring how long the reflections took to arrive at its receiver. These value tables, stored in the instrument's electronics box, were downlinked to the University of Arizona in Tucson, where imaging software turned them into color-coded 3D maps.

The process began with OLA's high-energy laser transmitter, or HELT, which fired 100 light pulses per second from a 7-kilometer orbit. Once the spacecraft descended to 1 kilometer above Bennu's surface last June, OLA's low-energy laser transmitter, LELT, took over, firing 10,000 pulses per second.

Over the next two months, LELT made approximately 3 billion measurements that scientists turned into a terrain map of Bennu with a resolution of about 5 centimeters. Based on those scans, NASA in December chose a 16-meter swath in Bennu's north polar region, nicknamed Nightingale, for the sample collection.

Luckily, scientists got what they needed from LELT before it stopped firing its laser in February for reasons that are still being investigated.

"It is sad," Daly says, "but we captured all the science data we really expected and more."

OLA has two different transmitters because lidar instruments "have to make a trade" between distance and detail, says Dante Lauretta, principal investigator for OSIRIS-REx. "When you're using the low energy transmitter, you can send a lot more pulses out rapidly, but they're not as energetic and therefore you can't be far away from the asteroids. So you trade a longer distance for a lower sampling rate."

Its mapping task completed, range data from OLA now focuses one of the on-board cameras, PolyCam, ensuring that its pictures are "nice and crisp and clear," Lauretta says. Those pictures and range data go to the flight computer's Natural Feature Tracking catalog that OSIRIS-REx will consult as it navigates its collection arm to the surface. ★


FLIRTEY

## MATTHEW SWEENY

**POSITION:** Flirtey CEO, 2013-present

**NOTABLE:** Built the first prototypes of his company's electric delivery drones in his college dorm room before founding the company in 2013; two years later, Flirtey delivered medical supplies in Virginia in the first FAA-approved drone delivery; since 2018, Flirtey has tested drone delivery of medical supplies within the city of Reno as part of FAA's Unmanned Aerial System Integration Pilot Program.

**AGE:** 31

**RESIDENCE:** Reno, Nevada

**EDUCATION:** Bachelor of Arts in international studies from the University of Sydney, 2011

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# Delivering the drone revolution

"Look! In the sky! It's a bird, it's a plane, it's a ... drone?" That's the future envisioned by Matthew Sweeny, co-founder and CEO of Flirtey. In less than 10 years, the Australian-born businessman has turned his drone startup into an industry pioneer helping to bring about a world in which swarms of small, autonomous aircraft deliver food, medical supplies and other goods to U.S. consumers. Sweeny in 2014 moved the business to Nevada, where Flirtey is among the companies delivering packages under an FAA pilot program. I called Sweeny at his office in Reno to discuss Flirtey's future.

*— Cat Hofacker*

## IN HIS WORDS

### Attracting investment

From our perspective, Flirtey is the pioneer of the drone delivery industry. I founded Flirtey in 2013; at the time, we were the first drone delivery service in the world. We're not just building a company, we're pioneering an industry, and I realized that in order to pioneer this industry, I'd need to move Flirtey to America from Australia, so that we could attract investment from the leading investors in the world, and so that we could hire the smartest engineers in the world. We went through YCombinator, which is the leading accelerator program for startups in Silicon Valley. We raised investment from a combination of family offices, venture capitalists and strategic investments. And we then set this incredibly ambitious goal to beat Amazon, and Google, to conduct the first-ever FAA-approved drone delivery in history. We teamed with NASA Langley, who flew in medicine on an optionally piloted aircraft, which we then loaded onto our delivery drones and delivered into the hands of doctors at the largest free health care clinic in America.

### As revolutionary as automobiles

We're building a future where drones will routinely deliver AEDs [automated external defibrillators] to people who've had cardiac arrests to save lives. When people want food on demand, they can push a button on their phone and have a Flirtey drone deliver it, with a goal of that arriving in less than 10 minutes. We sit today at the inflection point of the commercialization of a revolutionary new technology that is going to transform the way we get our goods and packages; faster, at a lower cost and more efficiently. I think this is just as revolutionary as the invention of the automobile, or just as revolutionary as the first flights that the Wright brothers conducted, because they both pioneered revolutions in logistics. That's exactly where we're at today.

### The value proposition

We live in a society where people want instant gratification. The internet enabled instant purchasing, but we're not yet at the point where the logistical infrastructure enables instant delivery and fulfillment. Drone delivery is that next revolution. If you take it back to first principles, the core value proposition of drone delivery is threefold. First is fast delivery. And this is in a world, for example, where many of the largest on-demand food delivery companies average about 60 minutes a delivery. This [drone delivery] is a significant improvement of any other form of technology that exists to enable people to have what they want, when they want it. Then the second core value proposition is that drone delivery is cost-effective. Flirtey already has FAA approval for one of our remote pilots to oversee the flight of up to 10 drones at the same time, and each of our drones can do more than four deliveries per hour. That means as our industry grows, one Flirtey pilot remotely overseeing our autonomous delivery drones can do 40 deliveries per labor hour. It's revolutionary not only from a speed perspective, but also from a cost perspective. And in addition to that, there's a really important element of efficiency. We don't think it makes sense to have a 4,000-pound vehicle deliver a 4-pound package when we have delivery drones that are fit for the purpose, and more efficient. And so if we, for example, think about efficiency from the perspective of lowering emissions, then delivery drones significantly lower emissions in package delivery over trucks, cars, or even autonomous electric vehicles that have significant emissions during the battery production process.

> **"As we looked at ways to deliver packages, we concluded very early on that the safest way is for that drone to be above trees, above power lines, at a distance from any potentially malicious actors, so that it could just precisely lower that package to your front doorstep, your backyard or to the hands of a waiting customer."**

### Dominating

The analogy that I would draw is that when the internet came along, it didn't replace the radio or the television, but it certainly became dominant in capturing market share. I think that's where we will be in the near future with drone delivery. There will still be packages that get delivered by traditional means, but drone delivery will become a dominant method of delivering and capture enormous market share because it is a faster service that is more cost effective and better for the environment. We've built our aircraft, the Flirtey Eagle. We've built our takeoff-and-landing platform that enables us to employ a modular and scalable infrastructure, so that ultimately any mall in America that wants drone delivery can have Flirtey drone delivery. And we've built the software that enables our drones to fly themselves autonomously. When we look at the numbers, I see a future where three-quarters of packages are delivered by drone routinely; that whilst these other methods of delivery still exist, I think that when we live in a world where you can push a button on your phone and have a drone deliver your package in less than 10 minutes, I think it will become a dominant form of delivery.

### Safety first

We've designed our technology, including the Flirtey Eagle, to hover and precisely lower its contents by lowering a tether at a height that is above trees and above power lines while the drone's suspended in the air. And then once the package is delivered, the drone retracts the tether and then returns back and does an autonomous precision landing on top of the portal so that it can then be reloaded and conduct another delivery. As we looked at ways to deliver packages, we concluded very early on that the safest way is for that drone to be above trees, above power lines, at a distance from any potentially malicious actors, so that it could just precisely lower that package to your front doorstep, your backyard or to the hands of a waiting customer. We've also done a lot of work in the safety of the aircraft itself. We hired the head of NASA Langley's drone program who was in charge of drone flights over people, and in controlled airspace, to lead our engineering program. Part of what he led was the design and development of, for example, a parachute system for safe flight over people. The U.S. Patent Office just granted us a patent that gives us the ability to detect an error and send a trigger to release the parachute, but also gives us the ability to have a cutoff circuit that can, for example, apply a brake to the lift mechanism of the drone. It can also be independently powered. We believe it's going to become an industry standard because anyone that wants to fly delivery drones over heavily densely populated areas is likely to need an independent safety mechanism that can apply a break in the lift mechanism.


### A human in the loop

Our technology already has a very high degree of autonomy to enable one pilot to oversee up to 10 autonomous delivery drones flying and delivering packages at the same time. But as we think about scaling it, we think it will be important for the foreseeable future to have a human in the loop. What we mean by that is our delivery drones have the autonomy to fly themselves, but we have a human in the loop similarly to how you would have an air traffic controller in an FAA tower, where planes are coming in and the pilots are landing them, but you have a human in the loop so that in the unlikely event anything would've gone wrong, they can intervene. Our autonomous navigation software enables our pilot to see a live display of all of the delivery drones that they are overseeing while they're conducting their missions. There is health monitoring in live time, so if anything deviates from the expected operation, then our human pilot can be notified and then make a decision as to whether or not they issue a command to the aircraft, for example, to bring it in to land.

### Beyond food delivery

We're partnered with REMSA [Regional Emergency Medical Services Authority], which is the ambulance service in Reno, and our long-term goal is to be automatically integrated into the 911 network. So if someone has a cardiac arrest, in addition to the local ambulance service sending an ambulance, we can dispatch a Flirtey delivery drone carrying an AED. Nationwide in America today, despite all the money that we spend on health care, 90% of people who have a cardiac arrest in their home do not survive because ambulances can just take too long to arrive. Ambulances can still get stuck in traffic. And so through our work with REMSA we've looked at the historical data on cardiac arrest, and we've concluded that just one of our drones in Reno with an AED and integrated into the 911 network will save one life every two weeks on average, and that we can increase the survival rate of cardiac arrest from a national average of 10% today up to about 47%. When we then take that nationally, we project that Flirtey drone delivery can save over 150,000 lives a year, just with AED delivery. That's before we even think about delivery of EpiPen, delivery of Narcan or any of these other very positive impacts that our technology is going to have on society.

### Made in the USA

If you look at just the drone market as a whole, we view a very big distinction between the hobbyist world and the commercial world. So in the hobbyist world, you have a Chinese company that makes 80% of all of the drones sold in America, and those drones were previously used by the Army, until they were banned, and now previously used by the Department of the Interior, until they were banned, out of concerns that the data on military operations and American infrastructure could potentially be transmitted overseas. I think it's really important for the national security of the United States that there is domestic manufacturing of small delivery drones, and Flirtey is on


Among its delivery services, Flirtey wants to rush external defibrillators to heart attack victims.

Flirtey

the forefront of that. If we then move from the hobbyist industry to the commercial industry, the major distinction is there are Chinese companies that are just mass producing low-reliability drones that are used for hobbyist purposes. We've built a manufacturing base for high-reliability manufacturing with quality assurance procedures to build commercial delivery drones that are closer to aerospace standards than the lack of standards in the hobbyist world. That will not only serve the purpose of drone delivery, but also provide a very important manufacturing base for small drones in America.

### Building public trust

It reminds me of when Henry Ford invented the automobile. There were a lot of people in society who were concerned that it might interrupt the horse and cart, and so there were red flag laws that got passed that said not to drive an automobile; you had to have a person walk in front of the automobile carrying a red flag to ensure separation between cars and horses. Naturally, that limited the utility of cars, but eventually it was demonstrated that technology is reliable and that the society not only accepts it but wants it and needs it. Cars led to a revolution in transportation and logistics, just like delivery drones are leading to a revolution in logistics and package delivery. So I think any time you have a revolutionary new technology, there are people who have a tendency to be afraid of the unknown, and as a result I think it's incumbent on the companies in the industry to really take steps that earn the trust of society. For example, at Flirtey we see ourselves as the independent alternative to some of the larger technology giants, in what we see as the David-versus-Goliath industry. We're nimble, and also importantly, we've got privacy-driven core values. Our focus is delivering packages, whereas some of our larger competitors, they're focused on just collecting as much data as possible to trade on it. I think by being that independent, safe, privacy-conscious and trusted brand in drone delivery, not only do we help win the support of the community, but we help bring a service to market that's going to have a tremendously positive impact on society.

### Remote ID "very important"

When 80% of the hobbyist drones in America are manufactured by a Chinese company, I think it's very important for a number of different reasons, including national security, that the operators of those aircraft can be identified. In the commercial drone delivery world that Flirtey pioneered and operates within, then of course our aircraft are going to be identified, and we're going to be a responsible operator of those aircraft. It is reasonable for hobbyists to also be identified as well. And when we think then about the scalability of our technology, we want to ensure that our commercial operation is unlikely to be impeded by rogue hobbyists so that we can all share the national aspects and operate together in it. I think what is important is that the identification of aircraft can be transmitted securely and reliably, and there are a variety of technical solutions that can enable those objectives.

### 2020 flight path

Currently at Flirtey, our focus is conducting routine drone delivery demonstrations at the Tahoe-Reno Industrial Center, or TRI Center, which is located in Nevada. And for context, this is the largest industrial center in the United States; it's home to more than a hundred companies, including Tesla's Gigafactory, Walmart, Google, Panasonic and Home Depot, and the facilities employ about 25,000 people on site. Right now, we're conducting routine drone delivery demonstrations that are in preparation for routine food delivery on site. Our goal is to prove the scalability of our technology for drone delivery of food and beverages on an industrial campus, which we view as a stepping stone to other campuses, other industrial campuses, medical research campuses, college campuses, and other-use cases, which are then in and of themselves a stepping stone to our vision of store-to-door delivery. And so we've got this kind of huge opportunity to improve the scalability of our technology here in the coming months, with the goal of then scaling that model nationally. ★

# Virtual strength testing

**Conjuring a new recipe of composite and testing it can be expensive and time consuming. By testing for strength virtually, some materials scientists are beginning to rule out certain blends without making samples, and engineers are learning to rapidly identify the best candidates for specific applications. Keith Button tells the story of this software.**

BY KEITH BUTTON | buttonkeith@gmail.com

▲ **The LEAP jet** engine has parts made from ceramic matrix composites. Engineers and researchers are testing the limits of new composites with modeling software.
Adam Senatori

Want to know how strong something is? Break it.

That's how materials scientists have traditionally operated: Pull it, flex it, compress it, repeatedly bend it back and forth, twist it, slam it with a hammer — until it breaks. Such tests are crucial for a new material, because aerospace engineers need data before deciding whether that material might be suitable for airplane wings, engine parts and other structures.

Some scientists and engineers are beginning to anticipate the strength of new carbon composites without making samples and testing them. The calculation challenges of this virtual testing are enormous, and engineers must still test a material before trusting it in aircraft structures or jet and rocket engines. But trial and error is reduced, and engineers can quickly identify the best candidates for a particular application.

Those are the challenges that computational mechanics engineer Flavio Souza took on when he founded MultiMechanics, a Nebraska software company purchased by Siemens last November and folded into the Germany-based technology giant. Souza now works with his staff in Orlando, Florida, under the Siemens Digital Industries Software unit.

This is the story of Souza's company and its virtual testing software, called MultiMech. Today, customers including DLR, the German Aerospace Center, rely on Souza's software to predict the mechanical strength of new materials, especially carbon fiber composites.

## Early work

Our story begins in 2006, when Souza moved to the U.S. from Brazil to work on his engineering mechanics doctoral degree at the University of Nebraska. Souza sensed the excitement over new materials, especially composites, but he also saw a problem.

"There were materials being created and nobody knew how to properly simulate them," he recalls. Creating physical samples and testing them in the lab was a poor option because of the expense and time. "I set out to try to develop something that would be efficient," he says.

So in 2010, after earning his doctorate, he and his business partner, Leandro Castro, formed MultiMechanics to develop software that would accurately model the strength of materials.

At the time, most mathematical models of new materials were adapted from models of existing materials, such as metal alloys, whose characteristics are vastly different from those of carbon fiber composites. Carbon fibers, some of which are 10 times thinner than a human hair, introduced a level of complexity that even large computers had difficulty modeling. With potentially billions of fibers in a carbon fiber composite airplane wing, each linking at different points and different angles, "it's impossible to match that kind of geometry; account for every single fiber," Souza says. Computer simulations of new materials that were based on models of existing materials could take several days to complete, and their accuracy was suspect. Some relied on simplified models or assumptions that sped up the simulations but sacrificed accuracy.

▲ **A jet engine** turbine blade made from ceramic matrix composites.
GE Aviation

## Examining microstructures

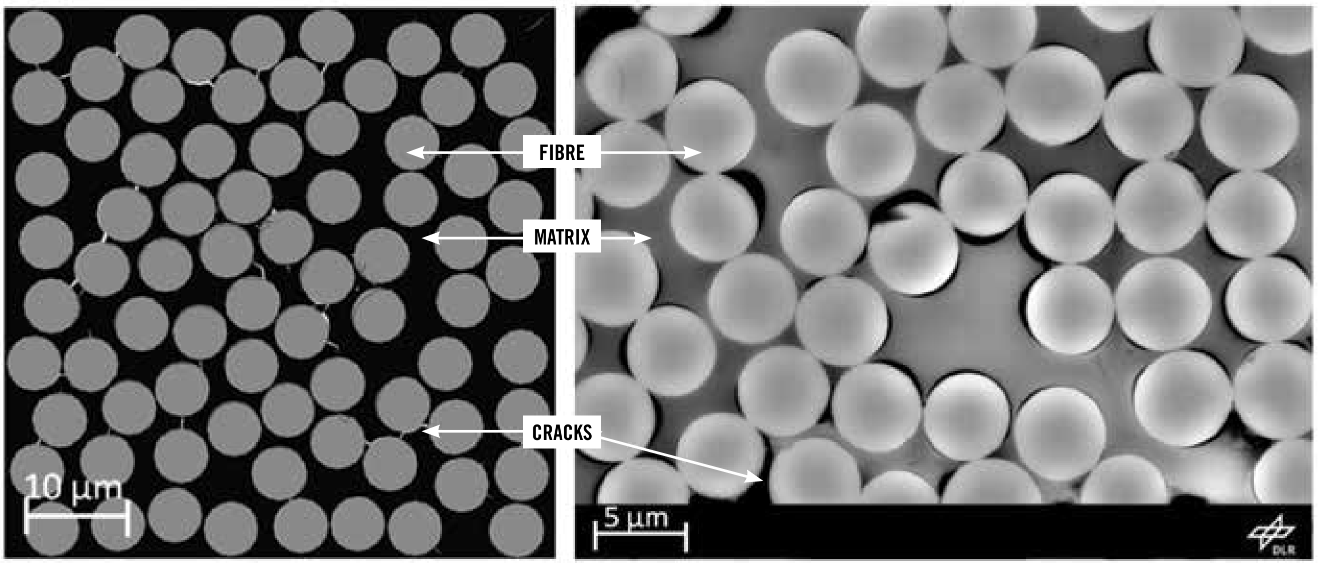
Souza believed that the key to modeling new materials lay in their microstructure, not in applying physical loads to a material to test its strength. "The way you load the material does not define the property; the property is already there," he explains. "It's just a matter of finding a way to try to extract that information from the material's microstructure without having to apply a load. I pushed through that belief for three years, two and a half years."

Souza's starting point at MultiMechanics was the mathematical formula he developed in graduate school to define how strong a material was

▲ **Ceramic matrix** composites (dark gray) make up shroud components of GE's LEAP engine. The white material is an environmental barrier coating.
GE Aviation

at a microscopic point that might measure just 2 microns by 2 microns. The first iteration of his software was based on this microstructure mathematical formula, and it modeled how the material would crack at the microscopic level. But Souza faced a scaling-up problem that would take years to resolve. To predict how strong a material was at the size of an engine part or airplane wing, his software needed to calculate the microstructure model for the millions of points contained in that larger object. To minimize computing time and memory required to make those calculations, he needed to minimize the number of microstructure models that the software had to analyze.

His solution: Reuse the calculation results from microstructure models that had similar virtual cracks. While none of the microstructures would have cracks with exactly the same direction and length, those with similar cracks could be grouped together. By applying this form of multiscale finite element modeling, the software saved time and computer memory by not having to run new calculations for every individual microstructure. Also, anyone running the software could dial in the level of accuracy versus the speed of the calculations. The more similar the microstructures had to be for the software to reuse the calculations, the more accurate the software's results would be. But increased accuracy would come at the cost of computing speed.




▼ **The left image is a** mathematical simulation created by MultiMech software and the right is a scanning electron microscope image of the same hardened polymer of carbon fibers and carbon resin. The carbon fibers are round and the resin is the black or gray in between. Cracks show as white in the left image and black in the right.
DLR

"The way you load the material does not define the property; the property is already there. It's just a matter of finding a way to try to extract that information from the material's microstructure without having to apply a load. I pushed through that belief for three years, two and a half years."

—Computational mechanics engineer Flavio Souza

In 2017, Souza wrapped the scaling-up concept into the software. His company's main customer, Solvay, a materials and specialty chemicals company based in Brussels, became an investor.

Then Souza and his 10 employees spent another two years refining the software by making the coding more efficient and improving how it managed computer memory during its calculations.

### Modeling composites for DLR

DLR became a customer in 2018, when it began virtually testing new carbon fiber ceramic composites with the MultiMech software, specifically composites made for high-temperature aerospace applications, such as rocket engine surfaces and jet engine turbine blades, where temperatures can exceed 2,000 degrees Celsius.

The software helps DLR narrow the field when it is considering various combinations of carbon fibers and resins to create a new composite, says Neraj Jain, head of simulation and engineering for the ceramics group at DLR in Stuttgart, Germany. Typically the resin is a liquid or paste, and the carbon fiber is a continuous thread or woven like cloth. The fiber is dipped in the resin and draped or wound around a form, or pressed in a mold with the resin, and then fired in a furnace to create the hardened ceramic composite, and then milled into its final shape. Each potential composite has at least 10 potential candidates of carbon fiber, each with its own diameter and elastic properties, and each fiber can be formed into multiple types of weaves or threads. Then there are 10 to 15 types of resins with known properties, or 100 to 150 types if all possible resins are included.

Instead of physically making a composite ceramic from every possible fiber-resin combination being considered, the software helps the DLR engineers pick the best few, Jain says. "Then I can really go into the research process where I can specifically manufacture the material and test it, and then I can validate the predictions which I made with my preliminary analysis: Does it match or not?" Before they started running Souza's software, the DLR engineers would eliminate new composite candidates based on the ceramic group's experience with the materials over about 30 years, but they may have been missing out on new and unfamiliar carbon fiber materials. The software helped them broaden their range.

The software produces a mathematical depiction of how cracks would form in the microstructure, and those virtual cracks tell the DLR engineers about the strength and flexibility of the composite material. If a crack is smaller and it zigzags wherever it meets with a fiber, then it signifies that the material will be ductile, not brittle, and won't break readily under strain. If a crack is longer and it cuts more of a straight line, it signifies that the material is more likely to break apart.

DLR engineers have given MultiMechanics feedback on the software and their thoughts about new capabilities they would like to see added to it, such as modeling microstructures at multiple temperatures and over time after repeated exposure to extreme temperatures, Jain says.

For the future development of the software, Souza and his team are examining how the microstructure modeling can be tweaked to tell materials scientists about other properties besides strength, such as heat resistance, acoustic characteristics, thermal characteristics and characteristics of fluids, such as viscosity. They've also applied the software to new types of structural foams and metal alloys.

"You can tie basically everything back to the microstructure information," Souza says. "Right now we're more focused on structural; mechanical characteristics. But the technology can absolutely be extrapolated to other physics, like thermal diffusion or other things." ★

# PROTECTING THE OFF-PLANET ECONOMY

**Debris tends to stick around in space, and this fact poses a unique challenge for military strategists who are used to keeping the peace elsewhere partly by threatening destruction. This reality complicates the U.S. military's efforts to define how the newly established U.S. Space Force should go about its work and how far that reach should extend as entrepreneurs seek to open up the moon, asteroids and free space to commerce. Debra Werner tells the story.**

BY DEBRA WERNER | werner.debra@gmail.com

France has a bold idea for deterring uncomfortable dances like the one in January between a school-bus-sized U.S. spy satellite in low-Earth orbit and a pair of smaller Russian satellites, one of which approached within 13 kilometers of the American satellite, prompting the U.S. satellite to fire its thrusters to scoot away.

After a similar experience with Russia in 2018, French Defense Minister Florence Parly announced that starting in 2023, France will guard its military satellites with nanosatellites equipped with lasers capable of temporarily blinding cameras. "If our satellites are threatened, we will consider dazzling those of our adversaries," Parly said in a speech last July.

The U.S. hasn't described how it will defend its satellites, but in December the country indicated a stronger focus on space defense when U.S. President Donald Trump signed a massive defense bill establishing the U.S. Space Force as the sixth service branch of the country's armed forces. The first test for Space Force did not take long. The Russian maneuver in January was "unusual and disturbing" and that brought "the potential to create a dangerous situation in space," said Space Force Gen. John "Jay" Raymond, chief of Space Force operations and head of the multiservice U.S. Space Command, in an email to me. Raymond didn't elaborate, but he may have been referring to the risk of a collision that would scatter dangerous debris through critical orbital altitudes for American satellites and those of other countries.

This was not the first such encounter. In 2017, a pair of Russian inspector satellites released a high-speed object that "exhibited characteristics of a weapon," Raymond said in the same email.

Such is the troubling context in which legions of entrepreneurs in the U.S. and abroad plan to extend today's Earth-centered space economy into deep space by establishing factories, fuel depots, mining operations, human settlements and more.

The U.S. created the Space Force partly with commerce in mind, although at least for now the area of responsibility of U.S. Space Command, which controls the new force, goes no farther than geosynchronous orbit. "From the beginning, our space economy was a big piece of what the president and the vice president wanted us to focus on," says Air Force Maj. Gen. William J. Liquori Jr., who heads the strategic requirements, architectures and analysis office for the Space Force. Liquori was also the space policy director on the White House National Security Council staff from 2016 to 2018.

As yet, there is no consensus among strategists and entrepreneurs over exactly what the U.S. Space Force or similar organizations in other countries should do to protect the developing space economy. Some question whether even the strongest military forces can, without diplomacy and laws, achieve the desired stability and security for commercial enterprises.

### Small step toward a grand vision

So far, not much has changed with creation of the U.S. Space Force. Email addresses are being updated with "ussf" in them, and some personnel in

## CONTENTIOUS SPACE

**The U.S. is the latest country to establish a space force, partly to protect the burgeoning space economy. However, actions in orbit suggest the major space powers have been working on technologies to attack each other's satellites.**

**JANUARY 2007**
China destroys one of its aging weather satellites. The U.S., U.K. and Japan criticize the missile launch and resulting debris.

**FEBRUARY 2008**
U.S. destroys one of its own spy satellites with a missile launched from a Navy cruiser. Stated goal is to prevent the nonfunctional satellite from crashing into the atmosphere causing a hydrazine explosion. Most experts see Operation Burnt Frost as the U.S. answer to China's anti-satellite test.

**MAY 2013**
China launches a rocket close to the geosynchronous satellite belt, where U.S. military satellites and numerous commercial communications spacecraft orbit. China calls the mission a science experiment.

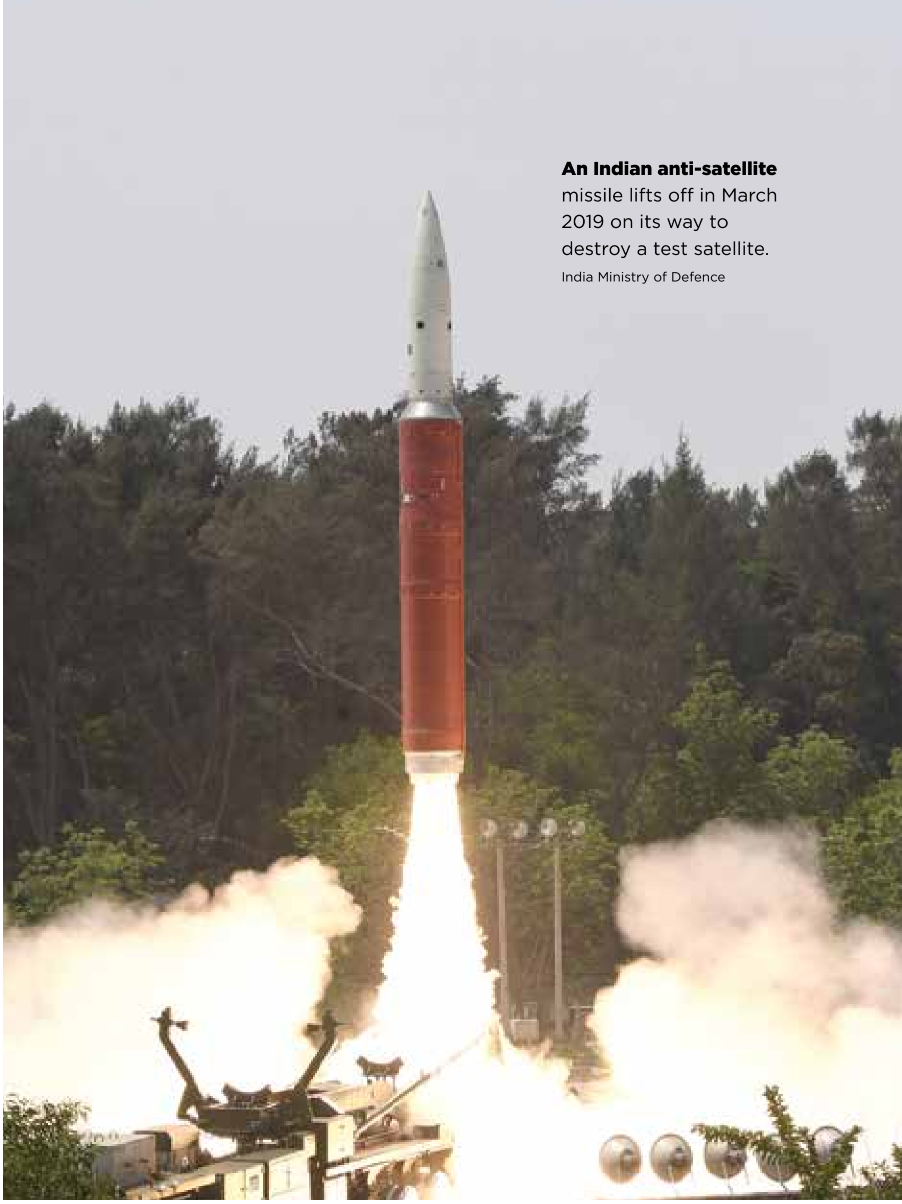
**FEBRUARY 2014**
U.S. Air Force Gen. William Shelton declassifies plans to launch surveillance satellites to near-geosynchronous orbit to maneuver near "objects of interest" for enhanced surveillance. Two Geosynchronous Space Situational Awareness Program satellites are launched in July.

California and Colorado will switch to Space Force uniforms in a bureaucratic transition that will unfold over the next 18 months. The transition will touch Joint Task Force Space Defense in California, where today mainly Air Force personnel but also those from other services monitor large screens as they figure out how to defend the country's missile warning, GPS, National Reconnaissance Office and communications satellites. The transition also will reach the nearby Combined Space Operations Center, where Air Force personnel and those from other services and coalition partners make sure military satellites are tactically tuned to the needs of troops in the field.

Some want a U.S. Space Force with a mission far beyond protecting and operating satellites circling Earth.

One of them is Simon "Pete" Worden, the retired U.S. Air Force brigadier general who headed NASA's Ames Research Center in California for nearly a decade. The long-term imperative for the new force should be "providing a predictable, stable environment for economic development beyond Earth orbit," says Worden, who has been sharing that vision since he co-authored the book "Whither Space Power: Forging a Strategy for the New Century" in 2003.

Worden thinks a lot about the moon, in particular. Entrepreneurs and government agencies have set their sights on lunar resources, beginning with water ice in the permanently shadowed craters of the moon's south pole. NASA aims to send astronauts to explore the region by 2024 as part of Artemis, the lunar program named for Apollo's twin sister in Greek



**An Indian anti-satellite** missile lifts off in March 2019 on its way to destroy a test satellite.
India Ministry of Defence

**APRIL 2015**
Russian military satellite Luch/Olimp-K parks within 10 kilometers of the Intelsat 7 and Intelsat 901 communications satellites for five months. Russia gives no comment.

**MARCH 2016**
DARPA unveils the Robotic Servicing of Geosynchronous Satellites program, saying space drones would repair satellites in geosynchronous orbit with two multi-jointed robotic arms and a toolkit. Congress is debating the program amid a contracting policy conflict lawsuit filed by Orbital ATK.

**JUNE 2016**
China launches the Aolong 1 "Roaming Dragon" debris removal drone into low Earth orbit. It reportedly ends its mission in August 2016 after grappling objects with its robotic arms and tossing them back to Earth.

**JUNE 2017**
Russia launched Kosmos-2519, a satellite to inspect other satellites. Kosmos-2519 released a small satellite in August, Kosmos-2521. Then, either Kosmos 2519 or Kosmos-2521 released a high-speed projectile into space. The United States reported the activity to the United Nations Conference on Disarmament in 2018.

mythology. Meanwhile, China, which has emerged as the top U.S. rival in deep space, has its eyes on the same region. If all goes as planned, China's Chang'e 6 lander will collect samples from the lunar south pole in 2023 or 2024 before establishing a robotic research station a few years later.

"We are within a decade of a human settlement on the moon," Worden says.

He thinks Space Force should protect these settlers.

Expanding the domain of the force to deep space seems only natural, says retired Air Force Lt. Col. Peter Garretson, a senior fellow for defense studies at the American Foreign Policy Council, a Washington, D.C., think tank. "Space commerce is going to expand to the moon and asteroids where there are millions of times the natural mineral and energy resources that we have on Earth," Garretson says. "Because of the potential for wealth and the ability of that wealth to change national power, it's typical that the flag follows trade."

Another advocate for a strong Space Force is Dennis Wingo, CEO and president of Skycorp, an aerospace engineering firm. He says Space Force should keep tabs on space weather, defend Earth from asteroids and back up future commercial mining rights on the moon or asteroids. To preclude what he calls a "space Pearl Harbor," Wingo thinks the Space Force should gradually replace its geosynchronous military satellites with equipment on Mars, the moon or in free space. Spreading them out would make it more difficult for an adversary to attack them all at once than if they were confined to geosynchronous orbit.


▲ **Gen. Jay Raymond**, chief of space operations for the U.S. Space Force and commander of U.S. Space Command, displays the Space Force's uniform nametape.

U.S. Air Force

Today's Space Force is a long way from wielding that kind of power over such a vast area of responsibility. The U.S. is just now catching up with others in forming a space organization to consider such issues. Russia in 2015 created the Russian Aerospace Forces by merging its military satellite and missile defense organizations with its Air Force. China established the People's Liberation Army Strategic Support Force in 2015 to oversee space warfare, cyber activities and electronic warfare. France created a Space Command in 2019 and reorganized its Air Force into a single Air and Space Force.

Emiliano Kargieman, CEO and founder of Satellogic, an Argentine company that operates Earth imagery satellites, predicts that as nations begin mining operations in space they are likely to create

## CONTENTIOUS SPACE TIMELINE *CONTINUED*

**OCTOBER 2017**
Russian military satellite Luch/Olimp approached French-Italian military communications satellite Athena-Fidus. French Defense Minister called it an act of espionage.

**MARCH 2019**
India destroyed its own military satellite, Microsat-R, in low Earth orbit with an anti-satellite missile fired from the ground.

**JANUARY 2020**
Russia's Cosmos 2542 satellite and a smaller satellite ejected from it in November moved within 13 kilometers of USA 245[1], a National Reconnaissance Office Satellite.

space forces of their own, though not necessarily with that name.

### Unsettled role

What might the U.S. Space Force do in deep space? During his February State of the Union speech to Congress, U.S. President Donald Trump, implied that members of the U.S. Space Force might one day go to space. The moment came when Trump asked the 13-year-old grandson of a Tuskegee airman in the audience to stand. Introducing the eighth-grader, Trump said the boy "has always dreamed of going to space" and "has his eyes on the Space Force."

In reality, the Pentagon has no plans to send members of the Space Force to space. Keeping boots on the ground does not trouble advocates of a strong Space Force. Worden sees the force's most important task, initially, as tracking and surveilling spacecraft in orbit and activity on the surface of celestial bodies.

The Space Force also will need the ability to quickly intervene in a conflict, but that intervention will be robotic in the near term, Worden predicts. In short, rather than Starship Troopers or Space Guards patrolling commercial sites, the men and women of the Space Force are likely to remain Earth-bound for years to come, Worden and others say.

The U.S. Navy was something of a template for the new force. In fact, Raymond' title -- chief of Space Force operations -- was inspired by the Navy's chief of naval operations role. Garretson, the think tank analyst, compares the work of the Space Force to how the U.S. Navy ensures free passage of commercial ships at sea. "The U.S. Navy protects U.S. interests on the high seas on a daily basis but not because it stands next to and babysits every ship," says Garretson. "In fact, the U.S. Navy couldn't possibly stop an anti-ship missile from striking a U.S. tanker or container ship," he adds. Deterrence keeps the peace: "Everyone knows the U.S. Navy has the ability to retaliate."

If deterrence becomes the mission, the question is what form that deterrence should take, given that space debris, unlike the remnants of a retaliatory strike at sea, does not sink to the bottom and cannot be easily hauled out of the way. One piece of debris can collide with another, putting into play the Kessler Syndrome, which says that once debris reaches a certain density, pieces will bang into each other and shatter in an unstoppable cascade of collisions. Certain orbits would be rendered useless for satellites or for spacecraft transiting through those orbits to deep space or back with people or cargo.

Would the Space Force ever go on the offensive with some kind of kinetic weapon? The answer is not exactly no. Liquori puts it like this: "We have no desire to weaponize space." After all, he adds,

## Law manual seeks to reduce odds of space war

Legal scholar Ram Jakhu sees a need for a clear, objective guide to military space laws that would help prevent space-faring nations from stumbling into a war in space.

An associate professor at McGill University's Institute of Air and Space Law in Montreal, Jakhu and colleagues are compiling a law manual to clarify issues addressed separately — and at times differently — by a range of law bodies and international treaty provisions.

The publication will be called the Manual on International Law Applicable to Military Uses of Outer Space, or the "McGill Manual" for short. The manual will be a practical resource for militaries around the world, and also a resource for identifying laws that are needed but don't yet exist.

From McGill's campus, Jakhu's team has orchestrated the consensus-gathering project. Space law experts from 17 countries, including China and Russia, are drafting the manual, their activities coordinated — but not dictated — by Jakhu's team at McGill. The manual will collect and clarify all laws and treaties directly or indirectly applicable to military uses of space during peacetime, the goal being to reduce the odds of hostilities breaking out over a misunderstanding.

China, India, Russia and the U.S. have each now demonstrated anti-satellite weapons by shooting down one of their own satellites, and so Jakhu wants countries to hit pause before something happens to trigger a conflict.

So many vital aspects of modern life rely on the security of satellites that with "all the militarization" happening, including the establishment of the U.S. Space Force, all parties need a grip on the ground rules upfront, he says.

The experts — 38 in all who will be listed as contributors — meet for periodic workshops on their various continents to debate and finalize about 60 so-called "rules" that will make up the manual. The experts are from universities, institutes, companies, foundations and military branches; they are experts in space law, international law and military law advised by technical experts on spacecraft and the space environment.

Even those who work for a government are expected to be independent and make objective contributions. Of the seven experts taking part from China and Russia, six are from higher-education institutions and one is from a Russian company.

"Nobody is directing us. Nobody expects us to do something for them," Jakhu says. All experts must reach a consensus on the text.

Rules that apply to military uses of space might not seem overtly military. For example, where does airspace stop and space begin? Other rules might be more clearly tied to military uses. Is it legal for countries to test anti-satellite weapons by destroying their own satellites, risking the spread of debris? In space, in particular, what constitutes an act of self-defense?

The contributors will meet in April at the University of Mississippi to debate the few rules still to be finalized. Jakhu hopes the manual will be published before the end of 2020.

"If we're stuck fighting a war in space, that's going to be a very, very serious business for humanity," Jakhu says.

*— Amanda Miller*

▲ **SpaceX's launch of 60** Starlink satellites from Florida in January was the first overseen by the airmen of the 45th Space Wing since they became part of the U.S. Space Force.

U.S. Air Force

"no one wants a shooting conflict in space that's going to create debris that has the possibility of polluting that environment and making it unusable for all of us."

## Deterrence

Some analysts hope that nations will see the wisdom of forging an international consensus against destroying equipment in space, whether that destruction were with weapons stationed in space or via anti-satellite missiles launched from the ground.

That consensus won't come easily. One at a time, the space-faring nations have taken it upon themselves to prove their ability to destroy satellites in orbit with missiles launched from ships or land. The most recent demonstration was by India. In March 2019, Prime Minister Narendra Modi announced that one of its anti-satellite missiles destroyed a target satellite launched a few weeks earlier. The shootdown put India in the league with China and the U.S. as having demonstrated an ASAT missile, although the U.S. has always maintained that its 2008 Operation Burnt Frost shootdown of a falling spy satellite was about protecting people on the ground from a hydrazine explosion.

For retired U.S. Air Force Gen. Robert Kehler, all this fascination with ASAT missiles reminds him of a pediatrician distracting a patient with a stuffed blue bear. "At some level, direct-ascent anti-satellite weapons are the blue bear," Kehler says. There are more effective weapons that could be applied in space. "Network disruption, cyber activities, jamming and other things can be just as effective without creating debris," Kehler says.

If U.S. military satellites are attacked, retaliation will not necessarily occur in space. Instead, the attack "will be met with a deliberate response at a time, place, manner and domain of our choosing," Liquori says. The counterattack could occur on the ground, at sea, in the air or in cyberspace.

## Missing ingredients: Law and diplomacy

Analysts who opposed creation of the U.S. Space Force, or were agnostic to it, say the Trump administration should increase its focus on diplomacy. In the other war-fighting domains (land, air and sea), a network of laws and diplomatic channels help to keep the peace, admittedly not perfectly. When fighting breaks out, laws and diplomatic channels lessen the damage of war.

Something similar to the United Nations' Convention on the Law of the Sea for the space domain would be far more helpful "than someone coming in with guns blazing," says Daniel Faber, CEO of Orbit Fab, a San Francisco startup that wants to establish refueling stations in orbit.

Mary Lynne Dittmar, executive director of the Coalition for Deep Space Exploration, says the Law of the Sea is a promising template because it includes a systematic approach to dispute resolution and a focus on peaceful settlement of disputes. "I want to see the continued evolution of this sort of rules of engagement," says Dittmar, who is a member of the U.S. National Space Council Users' Advisory Group, a panel of aerospace industry, researchers and scientists who offer advice and opinions on federal government space activities.

Without such a construct, some observers fear that kinetic attacks will always remain tempting to militaries. Consider a war between Russia and NATO or one between the United States and China, or between India and China, says Brian Weeden, program planning director for the Secure World Foundation, a Washington think tank that promotes sustainability in outer space. "There will be a lot of incentive to use destructive weapons against satellites," predicts Weeden, who argued against creation of the Space Force.

The discussion of weapons in space leads to the question: Wasn't space supposed to be free of them? It's true that the 1967 Outer Space Treaty prohibits nations from placing nuclear weapons or weapons of mass destruction in orbit. It also bars testing and deployment of weapons on the moon or other celestial bodies. But there is no ban on conventional space-based weapons. Nor have nations agreed on any rules for satellites approaching one another. "When is it OK, when isn't it OK and how do you communicate your intention?" says Laura Grego, a senior scientist in the Global Security Program at the Union of Concerned Scientists in Massachusetts who opposed creation of the Space Force. "If you get too close, is using a weapon ever considered self-defense?" Resolving those questions and turning them into an international agreement will require diplomacy and negotiation, but that is not happening, says Grego.

Diplomats of competing nations tend to reprimand each other for missile tests or satellite stalking, but that is not negotiation. Indeed, after the Russian satellites approached the U.S. spy satellite in January, the U.S. government "raised its concerns directly with Russia through diplomatic channels," says Raymond, the Space Force general.

Regarding ASAT missile tests, little if any progress has been made to stop them before someone's test goes awry. India reportedly constructed its test so that the intercept would happen at low altitude and the debris would fall to Earth quickly. But a mistake or miscalculation by a country could pollute certain orbits for years.

The Trump administration recognizes the ASAT problem. "Right now, the greatest threat to satellites is not from weapons in outer space, but rather from ground-based anti-satellite weapons that are designed to destroy, damage or disrupt the normal functioning of objects in outer space," Ambassador Robert Wood, U.S. permanent representative to the Conference on Disarmament, said in Geneva in August. Instead of seeking to hammer out a treaty, the United States wants to work with international organizations to encourage transparency and confidence-building measures and to define best practices, he added.

In the view of Grego and Frank Rose, a senior fellow for security and strategy at the Brookings Institution, a Washington think tank, and assistant secretary of state for arms control, verification and compliance during the Obama administration, the United States has not done enough to negotiate those confidence-building and transparency measures.

Regarding stationing conventional weapons in space, the record shows that the Conference on Disarmament has for two decades been unable to reach consensus on whether to ban them, Rose says, adding that he does not expect progress in the foreseeable future. China and Russia have drafted a treaty aimed at preventing nations from stationing weapons in space, which the United States has rejected, saying the language does not resolve the ASAT missile issue.

A big question hovers over these issues and the future of the Space Force: Will Donald Trump be re-elected in November? Neither of his likely competitors has expressed enthusiasm for the new force.

Of course, with or without a service branch, whoever is president after January 2021 will face the familiar challenge of creating a stable, secure environment in space. ★

▲ **A modified tactical** RIM-161 Standard Missile 3 (SM-3) launches from the U.S. Navy Aegis cruiser USS Lake Erie in 2008. The missile destroyed a non-functioning National Reconnaissance Office satellite about 247 kilometers over the Pacific Ocean.

Astronauts won't be the only ones driving
# humanity's push toward an off-world future.

ASCEND, powered by AIAA, is the planet's first event bringing together all those with an important role to play in making space exploration's next giant leap possible. Join astronauts, authors, ethicists, academics, entrepreneurs, and more to discuss just what it'll take to get humankind's permanent presence in space off the ground, 16–18 November 2020 in Las Vegas.

**James Bridenstine**
NASA's 13th Administrator

**Harrison Schmitt**
Apollo 17 Astronaut
and Former US Senator

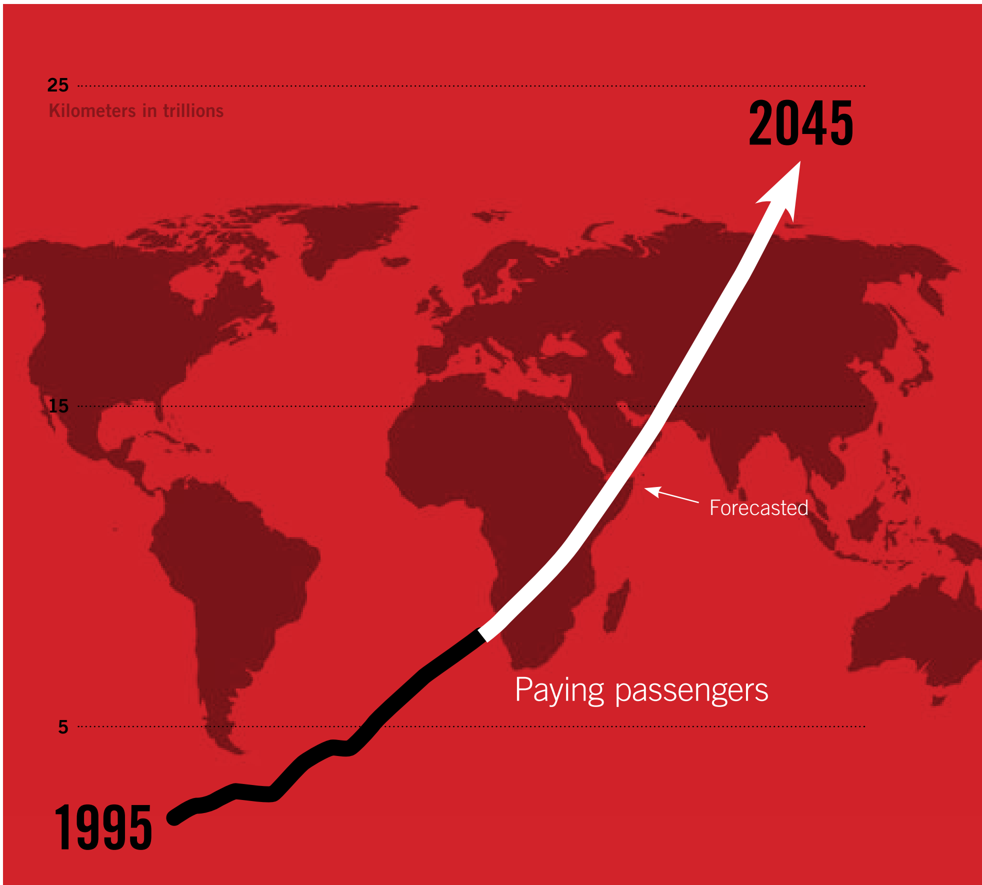
**Marillyn Hewson**
Chairman, President and Chief Executive
Officer, Lockheed Martin Corporation

**Alec Gallimore**
Robert J. Vlasic Dean of Engineering,
University of Michigan

**Andy Weir**
Author, *The Martian*
and *Artemis*

**Sandra Magnus**
Deputy Director, Engineering
Office of the Under Secretary of Defense
for Research and Engineering

# FLIGHT SHAMING'S SURPRISING POWER




## Global air traffic

Escalating air travel through midcentury could boost the sector's share of worldwide greenhouse gas emissions to 10%.

Source: ICAO

**When the trend of air travelers feeling guilty about their carbon footprints first arose, it seemed to some in the U.S. that it could be a passing fad. Now it looks like flight shaming is not going away and could even begin impacting aircraft designs. Adam Hadhazy checks in with environmentalists and the aviation industry.**

BY ADAM HADHAZY | adamhadhazy@gmail.com

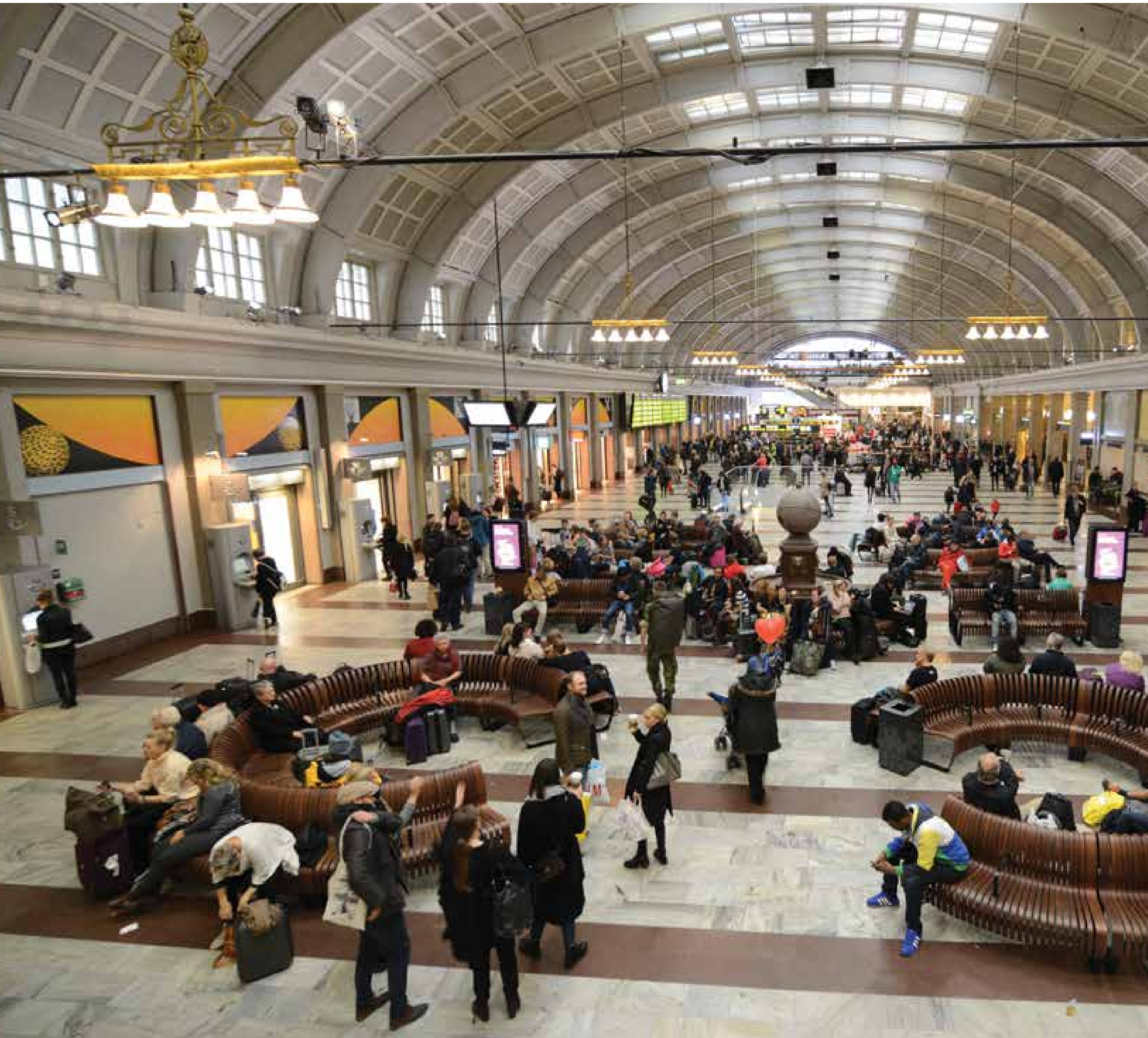
For a country of barely 10 million people, Sweden has a history of punching above its weight, bestowing upon the world such household names as IKEA, Volvo and ABBA. Now one of the latest Swedish exports to go global is "flygskam" or "flight shaming," a reference to the guilt that some airline passengers feel about the environmental impact of their flying, particularly over aviation's carbon dioxide emissions that contribute to planetary warming.

Catchily branded eco-consciousness is nothing new, of course, and aviation has long been caught in green crosshairs. What is striking, however, is that flight shaming is having a discernible impact — and not, as one might expect, on the perennially easy target of the wealthy flying in business jets, but on average air travelers. Commercial airline passenger numbers have downticked in Sweden, for instance. Several European countries are eyeing legislation to promote train travel while making flight taxes more punitive for ordinary flyers. In response, airline companies and aviation advocacy organizations have defended their record and made multiple gestures acknowledging they've heard passengers' concerns.

The rise of flight shaming could prove a pivotal moment in the trajectory of the aviation industry. The movement might succeed in coalescing long-standing

**European politicians** are considering measures to encourage travelers to switch to trains. Below is Stockholm Central Station in Sweden, where the flight shaming movement started.

Jorge Láscar



concerns of aviation's environmental impact, possibly leading to significant business changes that then inevitably lead to technological changes.

Flight shaming is "suddenly a thing," says Brian Foley, founder of the aerospace-focused consultancy Brian Foley Associates. "Companies and people are strategically positioning themselves for how to handle this, so [flight shaming is] definitely one of the more urgent issues for this decade."

### Easy target emissions

Aviation industry executives see undue finger-pointing given their sector's relatively small slice of the greenhouse gas emissions pie — right around 2.5%. Richard Aboulafia, an analyst with the Virginia-based Teal Group points out that data centers worldwide are estimated to contribute an even bigger share, closer to 3%. Yet data centers and the online services they undergird do not receive anywhere near the level of criticism and scrutiny as aviation, Aboulafia says. A big reason is perception; goofing off on Facebook from the comfort of one's own smartphone is not as obvious as hurtling along at 35,000 feet. "You don't see the consequences of your actions," says Aboulafia. "With air travel, you see it right away. You get on a metal tube and you're flying through the air, burning hydrocarbons."

Joe Wilding, chief technology officer at Boom Supersonic in Colorado, says the shaming is a "bit unfair" because it discounts the societal benefits of air travel. The company is designing supersonic airliners that will "remove the barriers to experiencing the planet," as he put it in a presentation at AIAA's SciTech Forum in January.

Yet where the climate-conscious — flight-shamers included — might have a point is with aviation's relative intensity of emissions and the sector's projected emissions growth. Pound-for-pound, over a short period of time, few human activities generate climate-altering gases with as much gusto as aviation. It's not that jet fuel is especially carbon-heavy; burning a gallon of it produces 9.57 kilograms of $CO_2$, comparable to gasoline at 8.89 kg per gallon. But the fact that thousands of gallons are burnt on a typical domestic flight, and tens of thousands on international flights, racks up emissions quickly. "It's a really easy way to burn multiple barrels of oil in a given day in one fell swoop," says Dan Rutherford,

**"This isn't sort of a fringe issue for the far left anymore. People are saying this is a central issue for corporate America, that we actually need to be doing something about it."**

**— Bradley Tilden**, CEO of Alaska Airlines director of aviation programs for the International Council on Clean Transportation, a Washington, D.C.-based nonprofit research group. Rutherford has diligently tracked his own carbon footprint and calculated that on the days he flies, his footprint multiplies 75-fold.

Growth-wise, the current worldwide fleet of approximately 22,000 commercial aircraft is projected to double by 2037 in order to ferry around twice as many passengers as today, currently at 4 billion annually. Such growth would put aviation's global emissions share closer to a whopping 10% come midcentury, according to the United Nations' International Civil Aviation Organization. That's not counting the possible return of commercial supersonic flight, tentatively slated for the mid-2020s by Boom, which plans scheduled passenger service, and Nevada-based Aerion, which plans to start with private jets. Estimates vary, but these planes could generate between two and a half to seven times the carbon emissions of subsonic aircraft, according to studies by the International Council on Clean Transportation and other research groups.

The aviation industry responds that it has made considerable gains in addressing emissions and is committed to further improvement. A modern transcontinental flight, for instance, emits on average about half of the carbon dioxide of a flight 30 years ago. The latest generations of aircraft continue to make gains. For instance, the Airbus A320neo family, which entered service in 2016, is 15% more fuel-efficient than just its predecessor generation, courtesy of new Pratt & Whitney engines, airframe tweaks and the addition of drag-reducing blended winglets (nicknamed sharklets because of their uncanny resemblance to a shark's dorsal fin).

"Credit is never given to the aviation industry for engine technology that is always improving, aerodynamics that are improving," says Foley. "It goes unnoticed."

### Where flygskam has taken off, or stayed grounded

Some environmentally minded individuals and groups contend, though, that aviation could and should be doing far more.

In that vein, Swedish singer Staffan Lindberg publicly announced his intent to fly less, coining the term flygskam back in 2017. Another famous Swede, the opera singer Malena Ernman, signed on to Lindberg's cause. The movement gained additional momentum because of Ernman's daughter, now-17-year-old Greta Thunberg, who has emerged as a global climate activist and was named Time magazine's Person of the Year 2019. (Flight shaming has also thus been dubbed the "Greta effect.")

So far, the impact appears greatest in Sweden. Scandinavian Airlines has blamed flight shaming for its traffic falling 2% compared to the prior annual flight period, while Sweden's state-owned airport operator has reported a significant drop — 9% — in the number of annual domestic flight passengers.

Like other European countries, Sweden has a well-developed rail system. It provides an attractive domestic alternative to flight in terms of cost, time and lower emissions. Not so, however, in the United States, a sprawling, rich country and the world's largest aviation market. Outside of the small, densely populated northeast, rail is rarely competitive with air travel — a key reason why analysts say flight shaming has not registered in U.S. aviation data — or at least, not yet. "You have to have an alternative to air travel wherever [flight shaming] does get traction," says Foley, "and really the only logical place after Sweden would be Europe."

Evidencing Europe's seriousness, some legislators in France have proposed a ban on most domestic flights. Germany, meanwhile, intends to institute minimum air travel costs, raise flight taxes and slash train taxes by more than 60%.

This sort of activity dovetails with a report from UBS, the Swiss bank, which does suggest that America and other big markets, such as China, could soon feel flight shaming's impact. The bank surveyed flyers in countries including France, Germany, the United Kingdom and the United States, first in May 2019 and then again in October 2019. The results showed that the percentage of respondents who claimed they had foregone at least one flight because of environmental concerns doubled from 21% to 42% in just that short span. Celine Fornaro, head of European Industrials Equity Research at UBS, commented in the report that flight shaming is "gaining momentum," further borne out when UBS surveyed flyers in the additional countries of Australia, China, Japan and Sweden.

### Some steps taken

The International Air Transport Association, or IATA, is accordingly not assuming that flight shaming will turn out to be an environmental fad that fades away. The trade group, which represents 300 airlines worldwide, has announced a campaign in 2020 to push back against flight shaming and highlight the industry's substantial efforts to reduce its carbon footprint.

A large share of those efforts harkens back to 2009, when airlines came together through IATA to pledge a set of environmental targets. These included a U.N.-adopted efficiency standard for new aircraft, an aviation carbon offsetting program known as CORSIA, short for Carbon Offsetting and Reduction Scheme for International Aviation, and initiatives to certify sustainable aviation fuels, or SAFs, such as biofuels with lower carbon footprints.

▲ **The aviation industry** says flight shaming fails to take into account improvements in fuel efficiency among its newer aircraft.

Jorge Láscar

The targets, though, "were really all symbolic, not substantive," says Rutherford. The efficiency standard was crafted such that new Airbus and Boeing aircraft already under development would meet it; CORSIA by its design does not address fundamentally reducing sector emissions; and SAFs — as of 2018 — have accounted for a measly two-one-thousandth of 1% of global jet fuel use, Rutherford says.

Now with the rise of flight shaming, Rutherford thinks the industry is in for a fresh reckoning. "Flygskam hit, and there's a realization that 'no, [those targets are] not going to be enough,'" says Rutherford. "I'm increasingly optimistic that we will see a fundamental shift toward decarbonization now."

### The future, sooner or later

Where and how might this shift occur? On the business front, Rutherford thinks airlines will increasingly pledge carbon neutrality, setting their own emissions targets and highlighting their carbon offsetting outlays. (JetBlue, for example, announced this intention in January.) In addition, more airlines will offer passengers the option of lessening their guilt by purchasing carbon offsets; Delta, Ryanair and British Airways are among the bigger carriers to have offered this option, and in some cases going back over a decade, though the number of carriers worldwide offering some degree of offsetting has ramped up. The offsets fund various carbon-reduction projects, such as planting trees and introducing fuel-efficient cooking stoves in developing countries.

Nevada-based Aerion, for instance, has pledged to plant 100 million trees to offset the emissions from its future fleet of AS2 supersonic business jets, scheduled to start service in 2026. Also, the GE Affinity engine that GE Aviation is building for AS2 is designed to work with sustainable aviation fuels. "The entire fleet will be carbon neutral," said Matthew Mejia, Aerion's chief financial officer, at the U.S. Chamber of Commerce's Aviation Summit in Washington, D.C.

The efforts boil down to more than retaining customers; it's also about satisfying investors. In an annual letter to executives, CEO of Blackrock investment firm Larry Fink wrote that "climate change has become a defining factor in companies' long-term prospects."

"He basically said, you guys don't deal with this, we're not going to be investing in your companies," Bradley Tilden, CEO of Alaska Airlines, told attendees at the Aviation Summit. "This isn't sort of a fringe issue for the far left anymore. People are saying this is a central issue for corporate America, that we actually need to be doing something about it."

An October report from Citi, the multinational investment bank, outlined how significant such offset practices could be in the new era of flight shaming. For leisure travel alone, Citi put a cost figure of $3.8 billion for carbon offsets over the next five years (though with the caveat that this estimate could be 10 times too low). Airlines would absorb most of this expense, even when some cost is passed on to passengers, because higher flight prices might discourage travel.

On the technological side, meanwhile, achieving lower emissions boils down to fuel, engines and airframes. Fuel-wise, sustainable aviation fuels are chemically similar to standard, kerosene jet fuel. SAFs come from renewable feedstocks as varied as cooking oil to leftover forestry wood to algae. Overall, they have significantly lower life cycle carbon footprints compared to fuels derived from buried hydrocarbons. At present, though, SAFs remain too expensive for wide availability and adoption.

Take Boom Supersonic. The company plans to power its XB-1 demonstrator plane with carbon-neutral synthetic fuel made by Prometheus Fuels of California, which sucks carbon dioxide from the air and converts it into jet fuel via a process called direct air capture. Availability of SAFs permitting, the company might fuel its operational Overture aircraft with the new fuels.

**Flying is "a really easy way to burn multiple barrels of oil in a given day in one fell swoop."**

— Dan Rutherford, International Council on Clean Transportation


▼ **The A320neo is 15%** more fuel-efficient than Airbus' generation of aircraft that preceded it, largely due new Pratt & Whitney engines and airframe modifications.

Airbus


▲ **Trains at Gothenburg** Central Station in Sweden, where air travel declined in 2019.

Wikepedia

For long-haul air travel, "there's really no good alternative to jet fuel today and nothing coming anytime soon," says Boom's Wilding.

IATA's current goal is to increase SAFs' use to 2% by 2025 — which doesn't sound like much, until one realizes it's about a 1,200% increase over today's production.

Engines-wise, there remain some efficiencies to squeeze out of conventional internal combustion engines. "The airframers, Boeing and Airbus, they are very good at turning the screws on Rolls-Royce, GE and Pratt & Whitney to always get better engines," says Rutherford. The aviation industry's goal is to eventually transition to emissions-reducing hybrid propulsion, where fuel is burned primarily or exclusively on energy-intensive takeoffs, while cruise is purely electric. And after that, the technological goal is fully electric flight provided by a new generation of airframes smaller and lighter than today's. "Engine manufacturing companies are looking toward the next chapter in aviation propulsion, and that chapter is electric," says Foley. Yet even hybrid propulsion in any mainstream commercial capacity looks to be at least a decade away, Foley adds.

Also a ways off is any major revamp of airframes. Going back decades, airframers have focused on "reengining" existing airframes, versus taking the riskier, capital-intensive plunge for clean sheet design. Rutherford's group published a study in 2016 that found that constant reengining is getting in the way of bold configuration changes that would deliver substantially better aerodynamics, while taking advantage of new, lightweight materials. "Where we're seeing things stall is actually on the airframe side," Rutherford says. "Our conclusion was that new aircraft fuel efficiency is only improving about half as fast as it could be because of the reengining issue."

The design of the 737 MAX could be a case in point. "The 737 MAX debacle has really changed some thinking," Rutherford says. With the MAX, Boeing tried a major reengining of its classic 737 design, delivering better fuel efficiency in the process. But compared to prior 737 generations, the MAX's new engines with their large, efficient front fans had to be mounted farther forward under the aircraft's wing, complicating the aerodynamics. The engines produced lift that tended to tilt the airplane's nose up, potentially triggering a stall, so Boeing added the Maneuvering Characteristics Augmentation System, or MCAS, software to the cockpit to tip the nose down should sensors report a too-high angle of attack. That system was partly blamed for two fatal crashes, one in 2018 and one in 2019. The second crash prompted a worldwide grounding of the 737 MAX fleet at a cost of at least $18 billion to Boeing. "What could [Boeing] have done if they


invested that $18 billion directly into a new airframe?" says Rutherford. "Probably something pretty radical."

Just one example is the trussed wing design Boeing has long worked on. Trusses from the plane's underside help support a top-mounted wing that is both longer than today's wings, as well as shorter between the wing's leading and trailing edges, and with less sweep. Another cutting-edge airframe rethink is the "double bubble," pursued by NASA and the Massachusetts Institute of Technology. It fuses two aircraft body tubes to create a wide-body craft with three, ultra-high-bypass-ratio turbofan jet engines mounted in the rear. An even more revolutionary concept that gets away from tube-and-wing design is the blended wing body. Instantly recognizable as the distinctive shape of the Northrop Grumman B-2 "stealth bomber," the whole aircraft generates lift while minimizing drag. All three designs deliver better fuel economy, and paired with still-better engines and fuels, would drastically lower emissions by several tens of percent.

Wilding of Boom thinks a solution will eventually come. "As a society, as a world, let's keep doubling down on innovation in those fronts because I think it will get there. Or who knows, maybe there'll be some other energy source, fusion perhaps, in the next couple of decades that comes out that could solve this problem. But none of that is imminent, so in the meantime we've got to do what we can do with what we can do."

## Change in the air?

It remains to be seen if flight shaming galvanizes the public, and in turn aircraft makers and airlines, or proves a mere footnote in the leadup to the eventual major business and technological changes that eventually will rock aviation, the same as any other industry. A dip in passenger numbers in Sweden is one thing. An actual cratering of an otherwise booming market for more flights is another.

Teal Group's Aboulafia is skeptical that flight shaming will ultimately dent the growing demand for flight. "The history of humanity is more travel, not less," he says.

But if there ever were a time for aviation to have a reckoning on climate stewardship, now might be it.

"I've been working on these issues since 2008," says Rutherford, "and I would say the amount of press attention, activism and airline interest in climate change — it's like a hockey stick over the past two years."

"[Flight shame] is rolling up into a social movement," he adds. "We'll see where it goes." ★

*Staff reporter Cat Hofacker contributed to this report.*

▲ **The percentage of** respondents to a UBS survey who said they had foregone at least one flight because of environmental concerns doubled from 21% to 42% between May and September 2019.

Raul Lieberwirth

# NOISE

**Dozens of companies are designing and in some cases test-flying urban air mobility aircraft, also known as air taxis. No one can say for sure how U.S. residents will react to such aircraft whooshing overhead or easing onto the vertiports that might one day sprout up on the fringes of their neighborhoods. Jan Tegler tells us about a NASA-led campaign to find answers.**

BY JAN TEGLER | wingsorb@aol.com

# ALERT!

Basil Yap is one of the few people in the U.S. who has heard the sound made by a prototype urban air mobility vehicle, or air taxi. The unmanned air system program manager for the North Carolina Department of Transportation was on hand in early January for a demonstration flight of the EHang 216, a Chinese-built remotely piloted aircraft with two passenger seats, although on this day it was flown with no one aboard. Powered by 16 electric motors and rotors, the craft made a five-minute flight over a grassy, tree-lined area in front of North Carolina Gov. Roy Cooper, state legislators and staff from the Department of Transportation.

Yap says the multirotor vehicle was "not as loud as I expected" with "a hum at a much lower frequency" than small consumer drones, while noting that a consistent wind might have diminished the noise from the aircraft 150 meters away. During a prelim-

inary flight earlier in the day, Yap stood 60 meters from the EHang 216 as it passed. He said the sound was "bearable, maybe half as loud" as a helicopter.

Noise is one of the top two challenges facing the emerging urban air mobility or UAM industry. Proponents including Uber Elevate, the rideshare behemoth's initiative to give customers airborne options, envision a future of thousands of air taxis shuttling commuters around urban and suburban locations.

Before the UAM business can take off, regulators will have to define and create a host of standards describing how these craft should operate, including limits on noise.

▼ **Joby Aviation plans** to fly its prototype air taxi in NASA's Advanced Air Mobility National Campaign, formerly the UAM Grand Challenge.

Joby Aviation

NASA, FAA and university researchers are developing software tools to model and predict UAM noise, the goal being to aid manufacturers in designing quieter vehicles. Developers will begin assessing the accuracy of those tools during NASA's Advanced Air Mobility National Campaign, a series of four test events between now and 2027. NASA will kick off the campaign in November, readying testing procedures for initial flight trials in early 2021 with Joby Aviation of Santa Cruz, California. The company will fly its prototype air taxi at the U.S. Army's Fort Hunter Liggett near King City, California, in scenarios designed to help FAA "better understand how UAM vehicles fly," says Starr Ginn who leads the campaign. The four test events will build toward tests in an urban environment, Ginn adds.

Benchmarking the noise made by individual and multiple vehicles will be one of the many focus areas of the campaign's test events. Ultimately, the data gathered will help FAA set noise certification standards for each UAM craft. But how long it might take to certify each type of UAM vehicle for noise is unknown at this point, according to FAA. That could impact Uber Elevate's plans, given that Joby Aviation, Uber's first aviation partner, has a "committed timetable" to begin flying customers in 2023, according to a joint Joby-Uber December press release announcing the agreement.

Further, for noise standards to be meaningful, regulators may have to go beyond setting an objective certification decibel level for noise, says Susan Gorton of NASA's Langley Research Center, who leads the agency's Revolutionary Vertical Lift Technology project.

"Where is the threshold for annoying noise?" Gorton says. "There's a difference between the noise level that is a certification standard and what is acceptable to the public for UAMs operating near and around them in a very high-tempo operation. We're trying to characterize human response, what the metrics for annoyance might be and how they could be taken into account in vehicle design."

According to FAA, an annoyance metric is not in its plans for UAM noise certification. Standards for noise certification are based on the effective perceived noise level, or EPNL, the agency says. This is the same metric the FAA applies to traditional airplanes and helicopters. Described by the International Civil Aviation Organization as "a single number evaluator of the subjective effects of aircraft noise on human beings," EPNL is a measure of the aircraft noise people hear from the ground.

Of course, in the future, tens, hundreds or even thousands of UAM vehicles could be flying in a locale. That scenario could give someone on the ground a

▲ **Aspiring passengers** could only sit in the two-seat EHang 216 when it was on the ground..

North Carolina Department of Transportation

▶ **Bell's Nexus 4EX** prototype air taxi

Bell

sense that noise is coming from all directions, even if the decibel levels of individual aircraft might meet a standard. FAA told me that its noise certification "does not account for the number of operations of those vehicles."

That puts further emphasis on the question of public acceptance of UAM noise or "community noise," as FAA refers to it. However, FAA explains that for certification a UAM vehicle "does not need to be tested in multiple places." The agency says that its research program for UAM and community noise is still evolving, and "FAA has not determined the extent of the testing/measurement needed."

### What do they sound like?

FAA uses EPNL, measured in decibels, to set noise certification standards. This is done by calculating the sound an aircraft makes over the course of 10-second "pass-by" events. Pass-by events are recorded in three flight phases — takeoff, flyover and approach — by ground-based noise measuring stations below the vehicle's flight path in open terrain. Integrating the instantaneous noise levels captured by microphones along the flight path over the period of the pass-by produces an EPNL.

Gorton says NASA can't state what specific EPNL number a UAM vehicle should aim for yet and FAA tells me it currently "does not have a decibel level target in mind for UAM noise reduction." But Carey Cannon, chief engineer of technology and innovation at Bell, says that he's hearing that "UAMs need to be 15 decibels quieter" than helicopters.

According to Cannon, Bell's Nexus 4EX prototype air taxi, an optionally piloted five-passenger vehicle with four electrically powered ducted fans has so far yielded "a 7-decibel noise reduction" compared with traditional helicopters at a simulated altitude of 400 feet in wind tunnel testing.

Eric Greenwood, an assistant professor of aerospace engineering at Penn State who specializes in helicopter acoustics research says, "You have to get a 10-decibel reduction for an aircraft to sound half as loud, at a perceived decibel level."

Martin Peryea, chief technology officer for Jaunt Air Mobility, says the New Jersey company's electric gyrodyne, the term for an aircraft that combines rotor lift with the forward propulsion of a propeller or propellers, will achieve a reduction of 20 decibels in noise compared to helicopters in a similar gross weight class. Jaunt's gyrodyne design has a single large main rotor for vertical takeoff and landing and four wing-mounted propellers for forward flight.

"I'll take these predictions to the bank because of the configuration of our aircraft," he says. The Jaunt prototype aircraft, due to fly in 2023, will

**“There’s a difference between the noise level that is a certification standard and what is acceptable to the public for UAMs operating near and around them in a very high-tempo operation.”**

— Susan Gorton, NASA’s Revolutionary Vertical Lift Technology project

▲ **A pilot flies** Volocopter's 2X test model in Singapore. The company proposes building vertiports, where passengers would board and exit its urban air mobility craft.

Volocopter

produce an approach noise level of "roughly 70 decibels" EPNL.

Joby Aviation's all-electric air taxi powered by six tilt rotors, which has made some piloted test flights, produces less than 70 decibels of noise at 500 feet altitude, the company says.

## A generic vehicle

UAM vehicles, whether concepts or flying prototypes, are incredibly diverse, including wingless multirotor, ducted fan and combination rotor/propeller designs as well as tilt-rotors, tilting jets and flying cars. Propulsion includes hybrid-electric, all-electric and hydrogen-powered options.

Gorton says that assessing the noise the wide variety of designs may make is challenging but she explains that NASA plans to get around that problem in part by testing the noise made by a range of components not tied to one vehicle configuration.

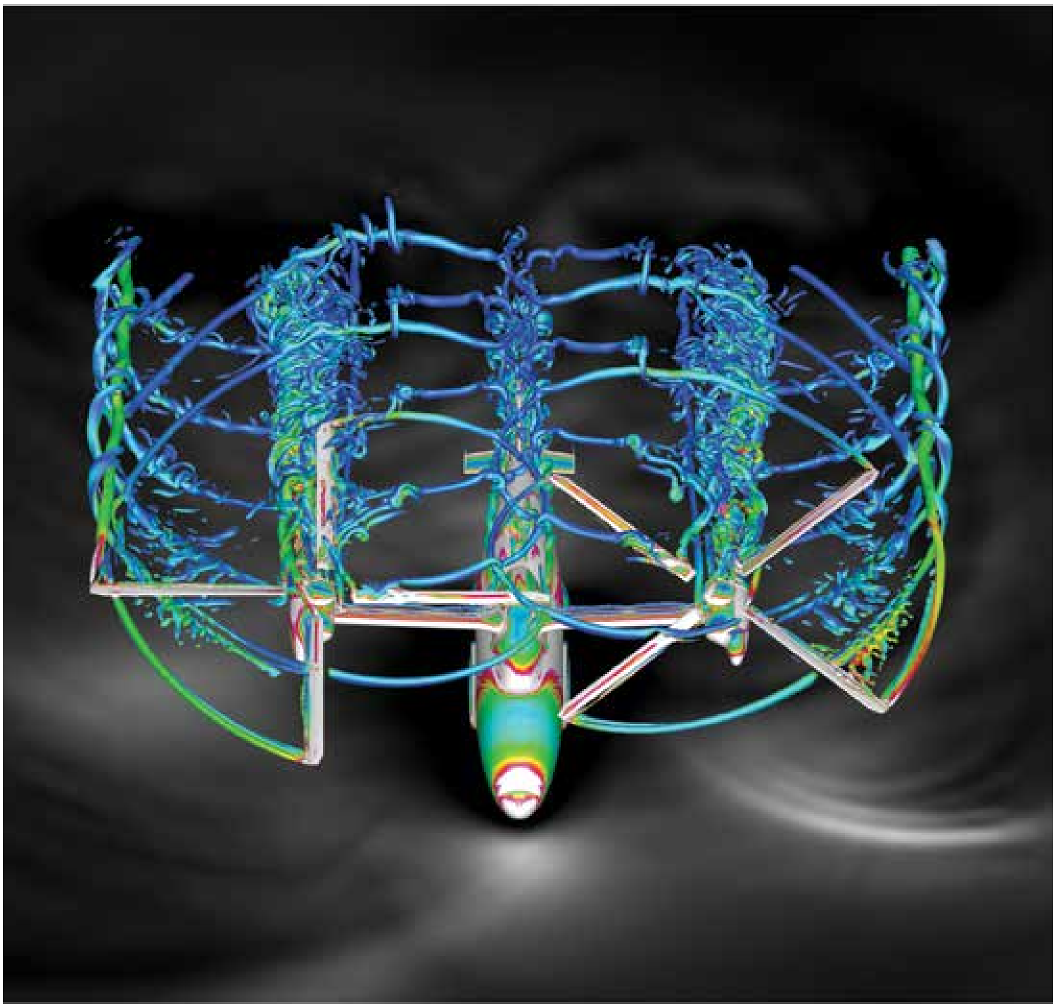
"We can do a lot of our validation data and testing with components that are generic — a generic wing, with several props, for example. My project just completed a test in a wind tunnel at NASA Ames [in Silicon Valley] last fall on what we call the multirotor test bed. It's a generic, fixed prop-rotor configuration."

Charles Tinney, a research scientist at the University of Texas at Austin's Applied Research Laboratories who studies the noise signatures of drones, says that testing generic components should provide useful noise data for regulators and UAM designers but cautions that the variety of approaches to design makes it hard to account for the noise every configuration may make. Also, UAM manufacturers are protective about the competitive details of their technology, which doesn't help.

"It's hard to even come up with a generic platform because almost none of the private sector are willing to share their information with us," Tinney notes.

Gorton says NASA is used to working with proprietary concepts. For example, NASA has made preliminary measurements of the noise from SureFly, the electrically powered, eight-rotor UAM prototype built by Moog Inc. of Elma, New York.

"Intellectual property isn't an issue," she says. "With resources we have and with partners, I think we'll be able to work with the FAA to get the basis for certification that they need."



## Broadband noise

Gorton says NASA also understands the need to predict the noise that many UAM vehicles in flight simultaneously will make. Multiple vehicles approaching or departing vertiports — sites where commuters would board or exit an air taxi — are a special concern. "We're looking at a tool to predict the noise from multiple operations over a certain trajectory in a certain area but we're not there yet."

Broadband noise, the term for a sound that a listener can't pin to a specific source, will be a focus of NASA's research, Gorton says. Produced by a single vehicle or by multiple vehicles, Gorton likens broadband noise to the noise you hear when you lean your head against the cabin of an airliner in flight. "It's the kind of noise that raises the noise floor but it's not distinguished by tone. Generally, you could describe it as a background noise level. You can't pick it out but it's noisy. That's the kind of noise we'll have to look at for these vehicles."

Measuring broadband noise will be part of NASA's Advanced Air Mobility National Campaign, Gorton says. But for now, no one can say what kind of broadband noise tens or hundreds of UAM vehicles operating in proximity may generate.

Bell's Cannon points out that noise predictions also should take into account the noise made by vehicles of various configurations. "At a vertiport you may have four Nexus 4EX vehicles, two of Joby's aircraft and three of something else," Cannon says. "What kind of noise will they make together? I don't think regulation can happen until vehicles are being built and you can make a variety of measurements."

## Industry prognostications vs. noise certification

While FAA cannot say when a UAM vehicle will be certified for noise, the agency did tell me that no UAM manufacturer has as yet submitted a certification basis for noise, the precursor to going through the agency's noise certification trials.

Cannon opines that the "basis for noise certification, not certification itself, is three to four years away."

That would put Uber's timeline for commercial air taxi operations in question.

Noise certification standards and the test methods described above are covered under Part 36 of

▲
**The whitish areas** below and behind the rotorcraft in this simulation depict the acoustic pressure waves caused in part by the vortices from the aircraft's intermeshing rotors. Researchers at NASA's Ames Research Center in Silicon Valley produced the simulation of this conceptual air taxi with high-fidelity computational fluid dynamics software.

NASA/Patricia Ventura Diaz

FAA regulations. Part 36 standards apply to jet-propelled aircraft, large and small propeller-driven aircraft, helicopters and tilt rotors.

The agency says it thinks Part 36 will be suitable for UAM vehicles as well. "Ideally, any new UAM could be certificated under one of these existing categories." If the variance in UAM design proves too broad to be covered under existing regulations, FAA says it can write new standards. "USC 44715 (a section of federal code controlling aircraft noise and sonic boom) provides the opportunity for FAA to develop the necessary standards for any aircraft type, including UAM."

▲ **The autonomous** EHang 216 flies a demonstration for state officials in North Carolina. The two-seat aircraft did not carry passengers for the flight.

North Carolina Department of Transportation

**"At a vertiport you may have four Nexus 4EX vehicles, two of Joby's aircraft and three of something else," Cannon says. "What kind of noise will they make together? I don't think regulation can happen until vehicles are being built and you can make a variety of measurements."**

**— Carey Cannon**, Bell

Theoretically then, noise certification could get underway now. But if new standards have to be written, FAA cannot say how long that might take.

Gorton says she doesn't expect NASA's aircraft noise prediction software — the tools that will generate data for FAA — to be validated until 2023.

"We need to know how noise is generated at the vehicle and how it propagates to the ground through the atmosphere," she explains. "What kind of environment are you in? Do you have reflections from buildings or absorption or scattering? What kind of weather conditions prevail? Those things all go into the prediction. I don't think all of our terrain stuff is prime time yet."

Recognizing that very few UAM vehicles are flying now, NASA must do what it can ahead of time to gather noise data and let manufacturers know how to make their vehicles as quiet as they can, says Gorton.

Tinney, the Austin researcher, cautions: "The last thing you want is for one of these new UAMs to come out and it has a horrible acoustic footprint and it automatically puts a bad taste in people's mouths."

Silence is impossible, and that's "an unfortunate artifact of the physics of the problem," he says. "There's an annoyance perception issue that the UAM community is going to have to tackle as a whole." ★

# AIAA Bulletin

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# Calendar

**FEATURED EVENT**


**15–19 JUNE 2020**

## Reno, Nevada

The 2020 AVIATION Forum will explore how the promise of aerial mobility could connect people and countries like never before, spurring economic growth and productivity. Take advantage of early member rates and register today.

**aiaa.org/aviation/registration**

| DATE | MEETING | LOCATION | ABSTRACT DEADLINE |
|---|---|---|---|
| **2020** | | | |
| 2–3 Apr | Region V Student Conference | Wichita, KS | 15 Feb 2020 |
| 6 Apr | AIAA Policy Breakfast | Washington, DC (aiaa.org/events-learning/events) | |
| 6–7 Apr | CANCELLED: Region II Student Conference | Tuscaloosa, AL | 21 Feb 2020 |
| 16–19 Apr | CANCELLED: AIAA Design/Build/Fly Competition | Wichita, KS (aiaa.org/dbf) | |
| 21–22 Apr* | CANCELLED: AIAA SOSTC Improving Space Operations Workshop 2020 | Suitland, MD (https://isow.space.swri.edu) | |
| 24–25 Apr | CANCELLED: Region I Student Conference | State College, PA | 1 Mar 2020 |
| 5–7 May | AIAA DEFENSE Forum | Laurel, MD | 8 Oct 19 |
| 8 May | Trusted Autonomous Systems Course | Laurel, MD | |
| 16 May* | The American Rocketry Challenge | The Plains, Virginia | |
| 19 May | 2020 AIAA Fellows Dinner | Crystal City, VA | |
| 20 May | 2020 AIAA Aerospace Spotlight Awards Gala | Washington, DC | |
| 25–27 May* | 27th Saint Petersburg International Conference on Integrated Navigation Systems | Saint Petersburg, Russia (elektropribor.spb.ru/en) | |
| 13–14 Jun | 1st AIAA CFD Transition Modeling Prediction Workshop | Reno, NV | |
| 13–14 Jun | Design for Advanced Manufacturing: Aviation Lightweighting Course | Reno, NV | |
| 13–14 Jun | Design of Electrified Propulsion Aircraft | Reno, NV | |
| 13–14 Jun | Design of Unmanned Aircraft Systems Course | Reno, NV | |

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.).

| | | | |
|---|---|---|---|
| 13–14 Jun | Hypersonic Flight Vehicle Design and Performance Analysis Course | Reno, NV | |
| 13–14 Jun | Missile Aerodynamics Course | Reno, NV | |
| 13–14 Jun | Practical Design Methods for Aircraft and Rotorcraft Flight Control for Manned and UAV Applications with Hands-on Training using CONDUIT® Course | Reno, NV | |
| 14 Jun | 2nd AIAA Workshop for Multifidelity Modeling in Support of Design & Uncertainty Quantification | Reno, NV | |
| 14 Jun | Certification Workflows with Model-Based Design Course | Reno, NV | |
| 14 Jun | Experimental Measurement Uncertainty for Engineers and Scientists Course | Reno, NV | |
| 15–19 Jun | AIAA AVIATION Forum | Reno, NV | 7 Nov 19 |
| 16–20 Jun* | Spaceport America Cup | Las Cruces, NM | |
| 23–26 Jun* | ICNPAA 2020: Mathematical Problems in Engineering, Aerospace and Sciences | Prague, Czech Republic (icnpaa.com) | |
| 9–13 Aug* | 2020 AAS/AIAA Astrodynamics Specialist Conference | South Lake Tahoe, CA | 10 Apr 2020 |
| 15–22 Aug* | 43rd Scientific Assembly of the Committee on Space Research and Associated Events (COSPAR 2020) | Sydney, Australia (cospar2020.org) | 14 Feb 20 |
| 22–23 Aug | 5th AIAA Propulsion Aerodynamics Workshop (PAW05) | New Orleans, LA | |
| 22–23 Aug | Design and Operations of Composite Overwrapped Pressure Vesselss (COPV) Course | New Orleans, LA | |
| 22–23 Aug | Liquid Rocket Engines: Emerging Technologies in Liquid Propulsion Course | New Orleans, LA | |
| 22–23 Aug | Missile Propulsion Course | New Orleans, LA | |
| 24–26 Aug | AIAA Propulsion and Energy Forum | New Orleans, LA | 11 Feb 20 |
| 14–18 Sep* | 32nd Congress of the International Council of the Aeronautical Sciences | Shanghai, China (icas.org) | 15 Jul 19 |
| 26–27 Sep* | CEAS-ASC Workshop 2019 on “Advanced Materials for Aeroacoustics” | Rome, Italy | |
| 12–16 Oct* | 71st International Astronautical Congress | Dubai, UAE (mbrsc.ae/iac2020) | |
| 29 Oct–1 Nov* | 37th International Communications Satellite Systems Conference (ICSSC 2019) | Okinawa, Japan (kaconf.org) | 15 May 19 |
| 16–18 Nov | ASCEND Powered by AIAA | Las Vegas, NV (ascend.events) | 17 Mar 20 |
| **2021** | | | |
| 11–15 Jan | AIAA SciTech Forum | Nashville, TN | 8 Jun 20 |
| 20–22 Apr | AIAA DEFENSE Forum | Laurel, MD | |
| 31 May–2 Jun* | 28th Saint Petersburg International Conference on Integrated Navigation Systems | Saint Petersburg, Russia (elektropribor.spb.ru/en) | |
| 5–11 Jun | AIAA AVIATION Forum | Washington, DC | |

● AIAA Continuing Education offerings

*Meetings cosponsored by AIAA. Cosponsorship forms can be found at aiaa.org/Co-SponsorshipOpportunities.*

# CONGRATULATIONS, AIAA CLASS OF 2020 FELLOWS AND HONORARY FELLOWS

*"The 2020 Class of AIAA Honorary Fellows and Fellows have earned the respect and gratitude of the aerospace community for their dedication, creativity and contribution to better understanding our world in terms of its limits and how we can push past those boundaries. They are the best minds in the industry. I congratulate them on this career accomplishment."*

**John Langford, AIAA President**

## 2020 AIAA HONORARY FELLOWS

**Robert D. Briskman**
Telecommunications Engineering Consultants

**Wes Bush**
Northrop Grumman Corporation (retired)

**Jason L. Speyer**
University of California, Los Angeles

## 2020 AIAA FELLOWS

**Holger Babinsky**
University of Cambridge

**John S. Baras**
University of Maryland

**Rodney D. W. Bowersox**
Texas A&M University

**Russell R. Boyce**
University of New South Wales

**Salvatore "Tory" Bruno**
United Launch Alliance

**Mark Campbell**
Cornell University

**Campbell D. Carter**
U.S. Air Force Research Laboratory

**Walter Engelund**
NASA Headquarters

**Hermann F. Fasel**
University of Arizona

**Hector Fenech**
Eutelsat SA

**Farhan Gandhi**
Rensselaer Polytechnic Institute

**Michael Gazarik**
Ball Aerospace

**Stanley Gustafson**
Lockheed Martin Space

**Steven J. Isakowitz**
The Aerospace Corporation

**Christopher T. Jones**
Northrop Grumman Corporation (retired)

**David Klaus**
University of Colorado Boulder

**Christophe Laux Ecole**
CentraleSupélec, CNRS
University Paris Saclay

**Joaquim R.R.A. Martins**
University of Michigan

**Beverley J. McKeon**
California Institute of Technology

**Daniel Mooney**
Boeing Global Services

**Scott A. Morton**
U.S. Department of Defense

**Nelson Pedreiro**
Lockheed Martin Space

**Christopher Pestak**
Universities Space Research Association

**Amy Pritchett**
Pennsylvania State University

**Dhanireddy R. Reddy**
NASA Glenn Research Center

**Donald O. Rockwell**
Lehigh University

**Suzanne Weaver Smith**
University of Kentucky

**Edgar G. Waggoner**
NASA Headquarters

**Michael M. Watkins**
NASA Jet Propulsion Laboratory

## AIAA FELLOWS AND HONORARY FELLOWS

You are cordially invited to join us at the Class of 2020 Induction Ceremony at the annual AIAA Fellows Dinner.

**Tuesday, 19 May 2020**
Hilton Crystal City, Arlington, Virginia

Reception: 1830 hrs
Dinner: 1930 hrs

For more Information and Registration, please visit
**aiaa.org/2020-Fellows-Dinner**
***By invitation only – only AIAA Fellows and Honorary Fellows***

AIAA
*SHAPING THE FUTURE OF AEROSPACE*

# 2020 AIAA Election Results

**AIAA is pleased to announce the results of its 2020 election:**

**Director–Aircraft Technology, Integration, and Operations Group**
Richard L. Mange
*Lockheed Martin Aeronautics*

**Director–Business and Management Group**
Leslie Lake
*Reynolds, Smith & Hills, Inc.*

**Director–Region I**
Steven X. S. Bauer
*NASA Langley Research Center*

**Director–Region II**
Kurt Polzin
*NASA Marshall Space Flight Center*

**Director–Region VII**
Cees Bil
*RMIT University*

**Director–Space and Missiles Group**
Lawrence "Robbie" Robertson
*Air Force Research Laboratory*

**Director-Elect–Young Professionals Group**
Ashlee Youngpeters
*Pratt & Whitney*

The newly elected will begin their terms of office in May 2020.

## Annual Business Meeting Notice

Notice is hereby given that the Annual Business Meeting of the American Institute of Aeronautics and Astronautics (AIAA) will be held at the Hilton Crystal City at Washington Reagan National Airport, Arlington, VA on Monday, 18 May 2020, at 1:00 PM.

## AIAA Council of Directors Meeting

Notice is hereby given that an AIAA Council of Directors Meeting will be held at the Hilton Crystal City at Washington Reagan National Airport, Arlington, VA on Tuesday, 19 May 2020, at 1:00 PM.

Christopher Horton,
AIAA Governance Secretary

# Recognizing Top Achievements – An AIAA Tradition

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


**AIAA acknowledges the following individuals who were recognized between November 2019 and January 2020.**

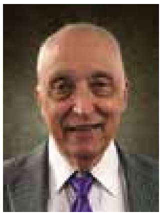
### Presented at the Society for Gravitational and Space Research (ASGSR) Meeting, 20–23 November 2019, Denver, Colorado

*Space Processing Award*

**Issam A. Mudawar**
**Purdue University**
*Recognizing decades of research and advances in fluid-based heat transfer in aerospace applications, including the Flow Boiling and Condensation Experiment in ISS.*

### Presented at the AIAA SciTech Forum, 6–10 January 2020, Orlando, Florida

*2020 Dryden Lecture in Research*



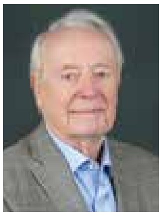
**Raphael T. Haftka**
University of Florida (Emeritus)
*Lecture: "Evolution of optimization, experiments, and uncertainty quantification with increasing computing power."*

*2020 Durand Lecture in Public Policy*

**Robert D. Braun**
University of Colorado Boulder
*Lecture: "Space Technology: An investment in our future."*

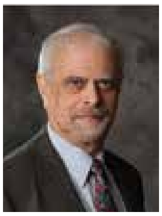
(left to right) **Cole Anderson**, Oregon State University, awarded the **Abe Zarem Graduate Award in Aeronautics** for his paper titled "A Test Rig for Wing Flutter Suppression via Distributed Propulsion"
**Johnie Sublett**, Georgia Institute of Technology, awarded the **Abe Zarem Graduate Award in Astronautics** for his paper titled "Design and Testing of a Fault-Tolerant Space Suit"
**Dimitri Mavris**, Sublett's faculty advisor at Georgia Institute of Technology

*2020 AIAA Diversity and Inclusion Award*



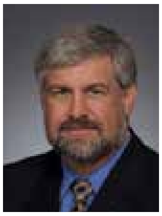
**Charles Wilson**
MIT Lincoln Laboratory (retired)
*For zealously pursuing AIAA's Diversity and Inclusion initiative, hosting special events and collaborating with organizations to promote progress in diversity for AIAA and with the AIAA New England Section team.*

*2019 AIAA/ASEE John Leland Atwood Award*



**Azad M. Madni**
University of Southern California
*For exemplary leadership in aerospace systems engineering education and research, and for lasting contributions to the aerospace industry as thought leader, author, educator, researcher and mentor*

### *2020 AIAA de Florez Award for Flight Simulation*



**Edward L. Burnett**
Lockheed Martin Aeronautics (retired)
*For his outstanding contributions to the nation's most advanced military aircraft through the art of modeling and simulation to enhance controllability and performance.*

### *2020 AIAA Gardner-Lasser Aerospace History Literature Award*

**Jeremy R. Kinney**
National Air and Space Museum
*"Reinventing the Propeller: Aeronautical Specialty and the Triumph of the Modern Airplane"*

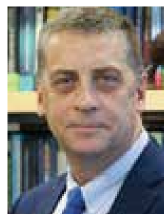
### *2020 History Manuscript Award*

**Glen R. Asner**
Historical Office, Office of the Secretary of Defense

**Anthony Waas** and **Royan J. D'Mello**, University of Washington
**Marianna Maiaru**, University of Massachusetts, Lowell
**Robert W. Koon**, Lockheed Martin
**Thomas Sutter, Folusho Oyerokun,** and **Tsukasa Harrington**, GE Aviation
**Anoush Poursartip**, Convergent Manufacturing Technologies
*Integrated Computational Modeling For Efficient Material And Process Design For Composite Aerospace Structures* (AIAA 2020-0655)

**Stephen J. Garber**
NASA History Division, NASA Headquarters
*Manuscript: Untethering Spaceflight: A History of U.S. Space Exploration Policy 1999-2004*

### *2020 AIAA Intelligent Systems Award*



**Jonathan P. How**
Massachusetts Institute of Technology
*For outstanding and sustained contributions to the decision making and control of intelligent autonomous aerospace vehicles*

### *2020 AIAA Mechanics and Control of Flight Award*

**Christopher N. D'Souza**
NASA Johnson Space Center
*For seminal contributions to the theory and practice of autonomous guidance, navigation, and control of space vehicles*

### *2020 Pendray Aerospace Literature*

**Russell M. Cummings**
**U.S. Air Force Academy**
*For being the lead author on a ground-breaking undergraduate text that introduces computational fluid dynamics to aeronautical engineering students.*

### *2020 AIAA Structures, Structural Dynamics, & Materials Award*

**Stephen P. Engelstad**
Lockheed Martin Aeronautics
*For outstanding contributions as an industry leader in R&D and DOD applications of new aeronautics computational mechanics and composites structure/certification technologies.*

### *2020 AIAA Summerfield Book Award*

**Steve A. Brandt**
U.S. Air Force Academy

**Randall J. Stiles**
Colorado College (retired)
**John J. Bertin**
U.S. Air Force Academy
**Ray Whitford**
Royal Military College of Science, Shrivenham, England
*AIAAA Education Series Book: Introduction to Aeronautics: A Design Perspective, Third Edition*

### *2020 AIAA Survivability Award*

**Charles F. Frankenberger**
Naval Air Warfare Center Weapons Division
*For technical and leadership excellence in propulsion system survivability enhancement and executing multi-service test programs to evaluate and improve overall aircraft survivability.*

### Presented at the 2020 Transformative Vertical Flight Conference/ International Powered Lift Conference (IPLC), 21–23 January 2020, San Jose, California

### *2020 AIAA F. E. Newbold V/STOL Award*

**Justin D. Paines**
**Joby Aviation**
*For his leading role in the development of the revolutionary STOVL Flight Control System for the Joint Strike Fighter.*

***Thank you to all the nominators and supporters of these awards***

**MAKING AN IMPACT**

# Design Competitions

Our industry is continuously evolving to meet the challenges of today and tomorrow, and we know that some of the most cutting-edge answers come from university students. AIAA student members from across the world respond to these challenges by forming teams of up to 10 people and submitting designs to one of AIAA's design competitions. These competitions solicit members of industry to design a Request for Proposals (RFP) that outlines a specific design problem that students will work together to solve.

In 2019, the Student Activities Committee (SAC) issued design competition RFPs covering missile systems, space systems, aircraft, and engine design, and over 500 students answered the call and produced reports responding to the RFPs. Several AIAA Technical Committees (TC) supplied industry professionals to judge the students' proposals, and student members received valuable feedback and critique of their designs.

Out of the 73 proposals submitted across all design competitions, 18 team and individual proposals were selected as the best of the best. Students on the winning teams were invited to present their proposals to TCs and answer questions from industry professionals about their designs at the 2019 AIAA Propulsion and Energy Forum and the 2020 AIAA SciTech Forum. Industry feedback is valuable to students so they can continue their research and design long after the competitions have concluded.

RFPs for 2020 design competitions have been released in the areas of missile systems design, aircraft design, space systems design, and engine design. Information about AIAA's design competitions can be found at aiaa.org/get-involved/students-educators/Design-Competitions.

*For more information about how to become involved with AIAA's educational outreach or make a donation, please visit aiaa.org/get-involved or contact Merrie Scott, merries@aiaa.org.*


# National Capital Section Presents Future City 2020 Special Award

*By Bruce Cranford*

From 15 to 19 February, regional Future City winners from 40 middle schools and afterschool organizations (e.g., scouts, 4H, boys/girls clubs) nationwide and Canada participated in the Future City National Finals in Washington, D.C. Regional winning teams received an allexpensepaid trip to the National Finals. In its 28th year, this year's Future City theme was "Clean Water: Tap Into Tomorrow," and middle school students were asked to create cities of the future, first on a computer and then as large tabletop models. Working in teams with a teacher and volunteer engineer mentor, students create their cities using the SimCity 3000 TM video game donated to all participating schools by Electronic Arts, Inc., of Redwood City, CA. Students wrote an abstract and an essay on using engineering to solve an important social issue. Then they presented and defended their cities before engineer judges at the competition. Over 45,000 students from more than 1,350 schools participated in 2019–2020.

The students created detailed and often fantastic cities of tomorrow that give intriguing insight to how young minds envision their future. At the same time, their bold designs and innovative concepts provide a refreshingly optimistic appreciation of how our nation can realistically deal with the many challenges facing its cities, including the power of public spaces.


**TOP:** Judges Ananthakrishna Sarma and Nitin Raghu. **BOTTOM:** Mill Middle School, Buffalo, New York Team. Photographs by Bruce Cranford

As part of the Future City's program, the AIAA National Capital Section (NCS) presented the 18th annual Special Award for the Best Use of Aerospace Technology to the city named Iberis (Team Members: Marc Vredenburg, Eric Ma, Vrushali, Kulkami, Sunya Afrasiabi, Cyrus Clabeaux, Seamus Coleman, Oscar Guzzino, Kaitlyn Guitt, Kendra Harrington, Elion Isenberg, Lillie Klaiman, Alexander Kydrytski, Lilia Miliotto, Theodore Poulin, Jack Pronobis, Drwain Skalski. Educator: Randall Gammiero, Mentor: Jeffrey Harrington, Mill Middle School, Buffalo, New York [Western Region]). The AIAA NCS congratulates the team for their outstanding efforts in winning this award. Bruce Cranford, NCS Social Media chair, presented the award on 18 February 2020. The award consisted of a savings bond for each student team member, and a plaque highlighting the award for each member of the team.

Part of the NCS STEM activities is to include science fair judging for middle and high schools in the greater Washington D.C. Metropolitan Area.

The AIAA NCS wishes to thank the NCS judges for the Best Use of Aerospace Technology: Dr. Ananthakrishna Sarma, Technical Fellow at Leidos, and Nitin Raghu, NCS Chair and Senior Consultant at Deloitte. For more information and a list of all the winners, visit futurecity.org.

# News

## AIAA Welcomes Four New Corporate Members

***Please join us in welcoming four new corporate members!***

**Centennial Software, LLC**
Broomfield CO
This privately held small business conducts embedded platform development and maintenance work. They have the ability to build firmware, test plans, programmable logic boards, offer assistance with debugging, planning, new product development, upstreaming using a variety of tools such as Xilinx Vivado, SDK, SDSoC and PetaLinux Tools, Eclipse, GNU and proprietary software.

**BRPH**
Melbourne FL
BRPH is a full-service architecture and engineering design firm with all services in-house. More than simply designers, they solve the world's toughest challenges with precision, creativity, and a little bit of fun. With 53 years of experience designing projects for a full spectrum of industries, ranging from multi-million-dollar launch pads to over a million-square-foot manufacturing facilities and everything in between. Some of their aerospace projects include the P-109 aircraft maintenance hangar, Kodiak Launch Complex, Delta IV Launch Complex 37 modifications, Commercial Crew and Cargo Processing Facility and The Kennedy Space Center.

**Brulin Holding Company, Inc. (BHC)**
Indianapolis IN
BHC is a specialty chemical manufacturer under the brand names of Brulin and Patco Food Safety. These respective brands operate divisions in commercial floor care, healthcare, food service, industrial where they provide process cleaning solutions for space & aerospace, precision metal, automotive, medical and optics and are production intermediates, providing a turnkey super concentrated chemical blending program.

**Jet Propulsion Laboratory (JPL)**
Pasadena CA
JPL is a federally funded research and development center and NASA field center. Founded in the 1930s, the JPL is currently owned by NASA and managed by the nearby California Institute of Technology (Caltech) for NASA spacecraft "robotic spacecraft, though it also conducts Earth-orbit and astronomy missions. It is also responsible for operating NASA's Deep Space Network.

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# CALL FOR NOMINATIONS

## AIAA-ASC James H. Starnes Jr. Award

**In honor of James Starnes**, a leader in the fields of structures and materials, the James H. Starnes Award recognizes significant contribution to and demonstrated promotion of the field of structural mechanics over an extended period of time emphasizing practical solutions, and acknowledges high professionalism and the strong mentoring of and influence on colleagues, especially younger colleagues.

The award consists of an engraved bronze medal, a certificate of citation and a $2,000 USD cash prize.

This award is presented at the AIAA SciTech Forum, January 2021, in Nashville, Tennessee.

**Nomination Deadline: 1 June 2020**

**The award is sponsored by the American Society of Composites (ASC) and American Institute of Aeronautics and Astronautics (AIAA)**

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For award details and nomination forms, please visit **aiaa.org/starnesaward**

Dwight Clayton, Louisville Regional Airport Authority (LRAA) Director of Engineering and Dirk Speas

### 2020 Speas Airport Award Presented

Sponsored jointly by AIAA, the American Association of Airport Executives (AAAE), and the Airports Consultants Council (ACC), the Jay Hollingsworth Speas Airport Award is presented annually to the nominee(s) judged to have contributed most significantly in recent years to the enhancement of relationships between airports and/or heliports and their surrounding environments via exemplary innovation that might be replicated elsewhere. The award was presented to the Louisville Regional Airport Authority for their work in seeking "to maintain operational capabilities while enhancing community relations with neighborhoods and reducing environmental impacts of obstruction mitigation" at the 2020 ACC/AAAE Airport Planning, Design and Construction Symposium in February.

# Obituaries

## AIAA Associate Fellow Scott Died in August 2019

**Steven S. Scott**, NASA Goddard Space Flight Center (GSFC) Chief Engineer, passed away on 14 August 2019.

Mr. Scott completed a Bachelor's of Physics from Lebanon Vallley College and two Master of Science degrees.

After joining GSFC in 1990, Mr. Scott worked on a large number of technical assignments, developmental efforts, projects and programs, including as a Systems Assurance Manager, the Software Systems Manager for the EOS (Earth Observing System) Chemistry and Special Flights Project, the Total Ozone Mapping Spectrometer (TOMS-EP) Project, and serving as the Lead Systems Engineer for the LANDSAT-7 Project.

He also served as the Software Systems Manager for the specification, design, implementation, and testing of all the Flight Software for LANDSAT-7. He assembled a team to develop the Failure Detection and Correction Software for LANDSAT when the contractor development effort was delayed. He also led teams of engineers in the development of On-Orbit Operations and Telemetry and Command Handbooks and Procedures. In 1999 he was assigned as the Chief Systems Engineer for Earth Explorers, Earth Science System Pathfinders (ESSP), and Earth Probes Projects. He also served as a Senior Systems Engineer on Aura (EOS Chemistry), GOES (Geostationary Orbital Environmental Satellite), and served as the GOES NOPQ Software Systems Manager until May 2000.

Mr. Scott was involved with the specification of flight and ground software for the TDRSS (Tracking and Data Relay Satellite System) program. He wrote all the software and flight computer specifications for the GOES NOPQ procurement. Based on his expertise, he supported other projects in a consulting role in the area of software management and development.

As GSFC Chief Engineer in the Applied Engineering and Technology Directorate, Mr. Scott had the responsibility for the planning, management, and evaluation of engineering activities, projects, and programs to meet Goddard's mission requirements. Mr. Scott participated in thousands of spacecrafts, ground system, and instrument reviews as well as on Tiger Teams and troubleshooting activities.

Because of his expertise in flight software, ground software, and operations, Mr. Scott served as the first Software Discipline Chief Engineer/Software Technical Fellow for the NASA Engineering and Safety Center while continuing to perform his duties as the GSFC Chief Engineer. He also served as the NASA Engineering and Safety Center (NESC) Center Chief Engineer for Goddard Space Flight Center for several years.

Early in his career, Mr. Scott served as a technical representative and translator of technical data packages on many projects in the United States and China, were he was the Lead Engineer for installing a complete Hybrid Circuit Production facility at the East China Institute of Photo-Electron IC. In addition, Mr. Scott worked for UNISYS as a Senior Software Engineer where he worked on Space Station Work Package Three and the Flight Telerobotic Servicer Mission.

As well as being an AIAA Associate Fellow, Mr. Scott was a member IEEE, ACM, ASQ, APS, INFORMS. He had been a member of the AIAA Software Technical Committee.

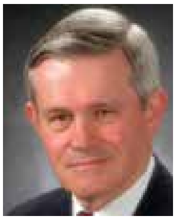
## AIAA Senior Member Reitter Died in December 2019

**LeRoy M. Reitter**, 94, passed away 17 December 2019.

Mr. Reitter enlisted in the U.S. Marine Corps and served tours of duty in World War II and in the Korean Conflict. He graduated from the University of Illinois.

A career aerospace engineer with McDonnell Aircraft Corp. and then McDonnell-Douglas Corp., Mr. Reitter was an administrative engineer for McDonnell at Cape Canaveral, FL, during the Mercury and Gemini manned space programs. In two manned space program halls of fame, Mr. Reitter retired from McDonnell in 1981.

## AIAA Fellow Franklin Died in January



**James A. "Jack" Franklin**, internationally known V/STOL controls expert, died on 22 January.

After completing his Ph.D. in aerospace and mechanical sciences at Princeton University, Franklin began working at NASA Ames Research Center in 1970. He was a member of the Flight Dynamics and Controls Branch, where he initially specialized in STOL flying qualities, using an approximation of the speed/flight-path angle equations of motion to posit different responses to attitude and thrust inputs depending on aerodynamic characteristics of such aircraft and quantifying the effects of the differences on flying qualities by doing a number of manned experiments in the Flight Simulator for Advanced Aircraft at Ames. He and his coworkers at Ames and Canada's National Research Council validated these results in flight experiments with both the Augmenter Wing and QSRA aircraft at Ames.

From 1975 to 1984, Franklin was promoted to chief of the Flight Dynamics and Controls Branch. He led the branch in an expansion of research to include helicopter dynamics and control, which included transferring a CH-47 research fly-by-wire helicopter to Ames. At the same time, he also continued his personal research, focused on flying qualities issues with VTOL aircraft. In 1980 the Vertical Motion Simulator at Ames was completed to continue this research for both helicopters and V/STOL aircraft, and Franklin undertook an examination of VTOL control laws, using a new nonlinear inverse design scheme that was pioneered in the Flight Dynamics and Controls Branch. Concurrently, he began the process of acquiring a YAV-8B Harrier aircraft for flight verification at Ames of simulator results.

Returning to a full research position in 1985, Franklin worked on a series of simulator and flight experiments with his colleagues. He formed a collaborative research program with the British Royal Aeronautical Establishment at Bedford, who also were building a modified Harrier to explore the same flying qualities issues. After flight verifications, Franklin tested the flight control concept developed by this collaborative effort in a new series of simulations focused on the aerodynamic models of two competing Joint Strike Fighter variants. Ultimately, this control system design was selected by NAVAIR in 2002 as the basis for what is now the Lockheed-Martin F-35B. For this work, along with the 30 years of research preceding it, Franklin was awarded the AIAA F.E. Newbold V/STOL Award in 2010.

In 2002, Franklin authored an AIAA Education series book, Dynamics, Control, and Flying Qualities of V/STOL Aircraft. He was also the author of a NASA report on the history of flight research at Ames, along with numerous papers and technical memoranda. In addition, Franklin taught a graduate course in flying qualities at Stanford, one of a series of courses developed by Fred Schmitz.

## AIAA Associate Fellow Smith Died in February

**Hubert C. "Skip" Smith**, an Associate Professor Emeritus of Aerospace Engineering at Penn State University, died on 15 February. He was 89.

Smith received a B.A. in Liberal Arts from Gettysburg College, and a B.S. and M.S. in Aeronautical Engineering from Penn State University. In 1978 he received a Ph.D. in Systems Engineering from the University of Virginia. He also served for two years as a U.S. Air Force officer, and additional ten years in the Air Force Reserve, rising to the rank of Captain. From 1959 to 1965, he worked for the Air Force in a civilian capacity as an Aircraft Project Engineer.

Following graduate studies in 1967, Smith joined the faculty of the Aerospace Engineering Department at Penn State University as an Assistant Professor. He was also a Visiting Professor of Aeronautical Engineering at Embry-Riddle Aeronautical University (1983–1984 and 1991–1992). Twelve years prior to retiring in 1999, he was Director of Undergraduate Studies in Aerospace Engineering at Penn State, and spent much of his time throughout his career advising and working with students. A highlight of his career was helping several teams receive awards in the National General Aviation Design Competition sponsored by NASA and the FAA. His passion was making sure his students were successful. As such, several student groups presented him with trophies in appreciation for his dedicated devotion to his craft of teaching.

During Smith's tenure at PSU, he authored several books, including The Illustrated Guide to Aerodynamics, books on performance flight testing, and an engineering textbook. He also authored over 60 articles relating to aeronautical engineering

A pilot since 1952, and owner of several planes, he was an instrument-rated commercial pilot, a glider pilot, and a certified flight and ground instructor. He served for 20 years as a FAA-designated Aviation Safety Counselor and spoke at numerous FAA safety seminars and other aviation gatherings. Smith was frequently interviewed by newspapers and TV stations on current aviation events. In 2005, he was given the prestigious Wright Brothers Master Pilot Award by the FAA.

As well as being an AIAA Associate Fellow, he was a member of the American Society for Engineering Education (ASEE), the Aircraft Owners and Pilots Association, the Experimental Aircraft Association, and a past member of the Society of Automotive Engineers (SAE), and the National Transportation Research Board. He held a number of national awards for educational achievement from AIAA (Piper General Aviation Award, 1996), ASEE, and SAE, as well as local awards for outstanding teaching and advising from both Penn State and Embry-Riddle Universities.

# 1920

**April 8** A specially constructed airplane carries a horse from Los Angeles to Santa Barbara, California, to enter an exhibition. This is one of the earliest known use of an airplane to carry a horse. **Flight**, April 15, 1920, p. 430.

**April 23** Cie Franco Roumaine de Navigation Aerienne is formed in Paris to open regularly scheduled commercial air service between France and Eastern Europe. The first flight, from Paris to Prague, takes off on Sept. 20. R.E.G. Davies, **A History of the World's Airlines**, p. 30.

**April 25** Six former members of the U.S. Army Air Services volunteer to fly and fight for the newly re-formed Poland as members of the Kosciuszko Squadron. They enter combat, attacking advanced units of the Bolshevik army and are instrumental in the capture of Kiev. David Brown, **Flight and Flying: A Chronology**, p. 133.

# 1945

**April 1** Japan's Ohka suicide solid-fuel rocket-propelled aircraft hit major targets for the first time when they damage the battleship USS West Virginia and three other ships, including the British aircraft carrier Indefatigable. On April 12, another Ohka sinks the American destroyer USS Mannert L. Abele. David Brown, **Flight and Flying: A Chronology**, p. 302.

**April 19** The De Havilland Sea Hornet DH. 103 prototype makes its first flight. It subsequently becomes the British Royal Navy's first twin-engined single-seat fighter operated from aircraft carriers. The Sea Hornet is a long-range fighter with a top speed of 750 kph (467 mph) and folding wings, designed for operations against Japan. A.J. Jackson, **De Havilland Aircraft Since 1909**, pp. 438-440.

**April 19** The International Air Transport Association forms in Havana. Luis Machado of Cuba's Expreso Aereo Inter-Americano is elected its first chairman. R.E.G. Davies, **Airlines: A History of the Jet Age**, p. 29.

**April 23** A BOAC Avro Lancastrian leaves from the United Kingdom on a proving flight to New Zealand, to prepare for inauguration of the company's U.S.-Australia-New Zealand high-speed service. The flight is made in 3.5 days, a record time for the 22,000-kilometer journey, even though 24 hours are spent on the ground. The average flight speed is 350 kph. **The Aeroplane**, May 4, 1945, p. 514.

**April 23** Two Bat missiles are fired against Japanese ships in Balikpapan Harbor, Borneo, from Navy PB4Y Liberators, marking the first known combat use of automatic homing missiles during the war. The 3-meter-long glide bomb, capable of carrying a 450-kilogram payload to ranges of 24-48 kilometers, was developed by the National Bureau of Standards in 1942 as an anti-ship weapon. F.I. Ordway III and R.C. Wakeford, **International Missile and Spacecraft Guide**, pp. 117-118.

**April 25** The last U.S. bombing raid in Europe occurs when Boeing B-17 Fortresses bomb the Skoda Works at Pilsen, Czechoslovakia. During this operation, the last German plane, an Me-262, is shot down. **The Aeroplane**, May 18, 1945, p. 583.

**April 26** Famed German aviator Hanna Reitsch flies Gen. Ritter von Greim from Berlin Gatow to Berlin, where he replaces Hermann Goering as commander of the Luftwaffe. Von Griem, who was commander of the von Richthofen Fighter Group, is one of Germany's best-known fighter pilots. David Brown, **Flight and Flying: A Chronology**, p 302.

**April 28-29** Some 250 British Avro Lancasters conduct "mercy raids" on the Netherlands by dropping hundreds of tons of food and supplies on the airports of Rotterdam and Leyden and on The Hague. **The Aeroplane**, May 4, 1945, p. 507.

**COMPILED BY** FRANK H. WINTER and ROBERT VAN DER LINDEN

# 1970

**April 1** This is the 10th anniversary of the launch of Tiros 1, short for Television Infrared Observation Satellite, which NASA considers to be the first weather satellite. It was carried into orbit by a Thor-Able rocket from Cape Canaveral Air Force Station, Florida. Although Tiros 1 operated for only 75 days, it provided the first accurate weather forecasts based on data gathered from space. NASA, **Aeronautics and Astronautics, 1970**, p. 107.

**April 5** Trans World Airlines starts its Boeing 747 wide-body "Jumbo Jet" San Francisco-to-New York service. The jet carries 335 passengers. **Aviation Week**, April 13, 1970, p. 32.

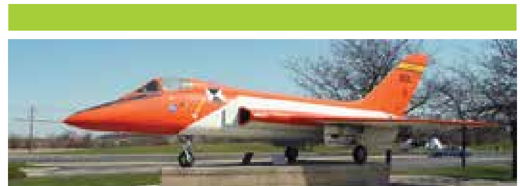
**April 8** The Nimbus 4 satellite to study Earth's atmosphere and a piggyback Topo 1 topographic satellite to map the Earth from space are launched by a thrust-augmented Thor-Agena rocket from Vandenberg Air Force Base, California. **Aviation Week**, April 13, 1970, p. 19.


**April 10** The McDonnell Douglas A-4M Skyhawk flies its first test flight. This is the last version of the Skyhawk series to be built; it's specifically for the U.S. Marine Corps and has such improvements as an uprated Pratt & Whitney J52-P-408A engine, doubled ammunition capacity and enlarged canopy for improved visibility. **Aviation Week**, April 27, 1970, p. 105.

**April 17** Apollo 13 astronauts James Lovell, Fred Haise and John Swigert return to Earth following a 143-hour mission around the moon and an accident that nearly cost them their lives. Launched from the Kennedy Space Center, Florida, on April 11, the Apollo 13 command module was 56 hours into the flight and 330,000 kilometers from Earth when the astronauts heard a "pretty large bang," accompanied by fluctuations in electrical power. There was a temporary loss in communications and upon its restoration, Swigert said, "OK, Houston. Hey, we've got a problem here." The accident was due to a rupture of Service Module Oxygen Tank 2. **Aviation Week**, April 20, 1970, pp. 14-19.

**April 24** The People's Republic of China launches its first satellite, designated Chicom 1 by North American Aerospace Defense Command, from the rocket facility at Shuang Cheng Tsu, and makes China the fifth nation to place a satellite into Earth orbit, although few details are released. It weighs approximately 173 kilograms and carries a radio transmitter that broadcasts the patriotic song "Dong Fang Hong" ("The East is Red"). **Aviation Week**, May 4, 1970, p. 24; **Washington Star**, April 25, 1970, p. A1.

**April 27** The Soviet Union orbits eight Cosmos satellites with a single launch vehicle in an attempt to deploy a navigational and communication satellite system. **Aviation Week**, May 4, 1970, p. 27.



**April 27** The Douglas F5D Skylancer aircraft flown by Apollo 11 astronaut Neil Armstrong in training is to be retired and eventually will be turned over by NASA to the Ohio Historical Society for display in the future Armstrong Museum at Wapakoneta, Armstrong's birth place. NASA, **Aeronautics and Astronautics, 1970**, p. 153.

# 1995

**April 12** Former NASA Administrator T. Keith Glennan dies at the age of 89. Glennan was appointed by President Dwight Eisenhower and consolidated the National Advisory Committee for Aeronautics with several other programs to create NASA. He was NASA's first administrator, holding the job from 1958 until 1961. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 639.

**April 27** The U.S. Air Force Space Command declares the Global Positioning System of 24 satellites fully operational. Carnegie Mellon University, **GPS History, Chronology, and Budgets**, p. 246.

# TERIK WEEKES, 29

Chief engineer, Elroy Air

**When Terik Weekes was a baby on the island of Nevis in the Caribbean, his parents would drive him to the nearby airport where he would fall asleep as he watched the planes take off and land. Weekes has loved aircraft ever since. He attended Embry-Riddle Aeronautical University in Florida and now works for Elroy Air, a cargo drone startup in San Francisco. He leads design and construction of Chaparral, a hybrid-electric autonomous aircraft that would ferry express packages, spare parts, disaster relief and military supplies nearly 500 kilometers, or roughly the distance between San Francisco and Los Angeles.**

**Learning about aircraft** ▶ In high school I took a cooperative education opportunity at Honeywell Aerospace in Phoenix that motivated me to become an engineer. I graduated from Embry-Riddle in 2013, with a bachelor's degree in aerospace engineering. While at Embry Riddle, I gained exposure to unmanned aircraft by leading a team competing with the Association for Unmanned Vehicle Systems International's Student Unmanned Aerial Systems Competition as well as interning at DynaWerks, an unmanned aerial systems company in Daytona Beach, Florida. I spent the next three years with the test and integration team at Airware, a drone analytics company, where I met Clint Cope [Elroy Air co-founder and vice president, engineering] who later invited me to join Elroy Air.

**From power system to first flight** ▶ I started at Elroy Air in February 2017. The first months were spent trying to find a power system and configuration for the aircraft. We iterated on the design, tested propulsion concepts, developed a subscale model, and prototyped a payload system until we had a concept that made sense from both business and performance perspectives. In August 2018, we finalized the outer mold line of the prototype aircraft and on Aug. 14, 2019, we flew the first Chaparral prototype. Chaparral is significant because it is designed as a fully autonomous system from loading to delivery. It is a cost-effective and fuel-efficient aerial logistics system that requires little infrastructure. There are plenty of situations where this is desperately needed, such as the many natural disasters we see more commonly today.

**Aviation in 2050** ▶ Aircraft with hybrid and electric propulsion systems will share the sky with traditional fuel aircraft. The configuration and appearance of those electrified aircraft will be different in ways we do not know yet. Much like how there were several generations of jet aircraft. I believe the same will be true for electric and hybrid electric aircraft. It is hard to predict what the 2050 generation of electrified aircraft will look like. Unmanned aircraft will be prevalent, performing routine tasks such as cargo delivery. Coupled with electrification, this will allow for lower cost and lower-impact transportation. Most exciting for me will be the impact on logistics. The same one- or two-day delivery times that we take for granted today in the U.S. will be lower cost and accessible in developing nations and difficult-to-access regions where transporting goods via boat or truck may be more resource-intensive or high-risk. ★

BY DEBRA WERNER | werner.debra@gmail.com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