CLIMATE CHANGE 18
Spotting polluters from space

Q&A 10
NASA's Robert Cabana

FUTURE OF FLIGHT 38
DARPA's control-tech X-plane

AEROSPACE
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PIE FROM THE SKY

Why the drone delivery revolution has unfolded more slowly than hoped and what is next. **PAGE 28**

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Roksenhorn/Wikipedia

A drone catapults at Zipline Inc.'s California test site.

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Drone delivery

Safety and public acceptance are among the issues that have prevented companies and the government from launching full-scale programs to deliver all types of consumer goods to homes and businesses.

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Q&A with Kennedy Space Center's director

Robert Cabana talks about the new NASA, Kennedy's transformation and commercializing space.

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Spotting methane from space

The private sector is launching satellites to monitor the gas, a role that traditionally has fallen to government agencies.

By Adam Hadhazy

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Flow control X-plane

DARPA is looking for a group to devise electrodes or other devices that create targeted currents of air and lead to new aircraft designs.

By Jan Tegler

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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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Debra Werner

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

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A tale of two FAAs

One FAA is the one we see in our cover story about the emergence of drone delivery services. This FAA is strategic, meticulous and cautious, almost to a fault. The other FAA is the one that certified the Boeing 737 MAX aircraft. That FAA exhibited an odd lack of curiosity about a bold software innovation and its implications.

Let's look first at the drone delivery market. FAA invites companies to prove reliability by delivering items to customers under pilot projects and initial services. While that's happening, the FAA and NASA are figuring out how to affordably manage what could someday be thousands of delivery drones and other unmanned aircraft in the skies simultaneously. The private sector will play a large role in managing flights, but under detailed rules set by FAA.

The slow pace and complexity of this rollout has been maddening, for sure, but there is an upside to this caution. Once drone delivery is normalized, we in the United States can be confident that drones or their payloads won't fall on our heads, crash into us when we're flying or become weapons for terrorists. Risks can never be eliminated entirely, but those that remain will be acceptable. Entrepreneurs might even look back on this era as one of tough love: Serious injuries or deaths could justifiably ruin a company or set drone delivery back by years. The FAA is helping the industry avoid those scenarios.

We're witnessing a healthy tension between regulators and the regulated.

Now, imagine if the MAX certification process had been as vigorous, thorough and tense as the FAA's work to shepherd the drone-delivery market into existence. Almost certainly, the plane's automated anti-stall software would not have been considered a good candidate for the FAA's Organization Designation Authorization process, in which Boeing officials were permitted to assess the technology's readiness to fly. With a different culture in place, someone at the FAA surely would have discovered the human factors and systems engineering issues raised by the Maneuvering Characteristics Augmentation System and dug into them. Relying on software to compensate for the MAX's tendency to stall was an untried strategy for a commercial aircraft carrying hundreds of souls.

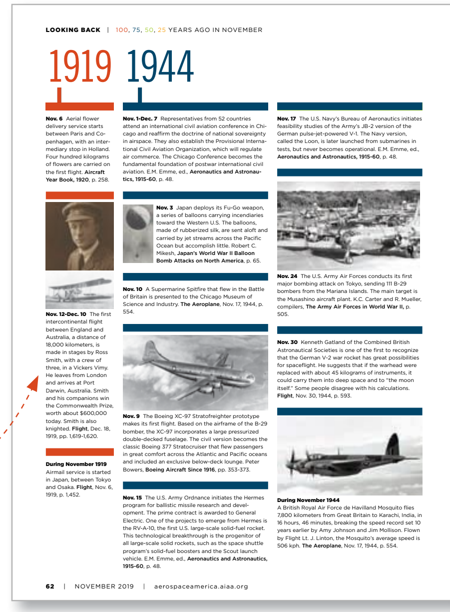
Instead, even when tragedy struck a second time, bringing the MAX's death toll to 346, the FAA lagged much of the world in grounding the planes.

Effective innovation depends on vigorous tension between regulators and the regulated. The FAA in our cover story is the one we need for the post-MAX era. ★

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

CORRECTION

Andrew Lucas



LOOKING BACK | 100, 75, 50, 25 YEARS AGO IN NOVEMBER

1919 1944

Nov. 6 Aerial flower delivery service starts between Paris and Copenhagen, with an intermediary stop in Holland. Four hundred kilograms of flowers are carried on the first flight. **Aircraft Year Book, 1920**, p. 258.

Nov. 12-Dec. 10 The first intercontinental flight between England and Australia, a distance of 18,000 kilometers, is made in stages by Ross Smith, with a crew of three, in a Vickers Vimy. He leaves from London and arrives at Port Darwin, Australia. Smith and his companions win the Commonwealth Prize, worth about $600,000 today. Smith is also knighted. **Flight**, Dec. 18, 1919, pp. 1,619-1,620.

During November 1919
Airmail service is started in Japan, between Tokyo and Osaka. **Flight**, Nov. 6, 1919, p. 1,452.

Nov. 1-Dec. 7 Representatives from 52 countries attend an international civil aviation conference in Chicago and reaffirm the doctrine of national sovereignty in airspace. They also establish the Provisional International Civil Aviation Organization, which will regulate air commerce. The Chicago Conference becomes the fundamental foundation of postwar international civil aviation. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 48.

Nov. 3 Japan deploys its Fu-Go weapon, a series of balloons carrying incendiaries toward the Western U.S. The balloons, made of rubberized silk, are sent aloft and carried by jet streams across the Pacific Ocean but accomplish little. Robert C. Mikesh, **Japan's World War II Balloon Bomb Attacks on North America**, p. 65.

Nov. 10 A Supermarine Spitfire that flew in the Battle of Britain is presented to the Chicago Museum of Science and Industry. **The Aeroplane**, Nov. 17, 1944, p. 554.

Nov. 9 The Boeing XC-97 Stratofreighter prototype makes its first flight. Based on the airframe of the B-29 bomber, the XC-97 incorporates a large pressurized double-decked fuselage. The civil version becomes the classic Boeing 377 Stratocruiser that flew passengers in great comfort across the Atlantic and Pacific oceans and included an exclusive below-deck lounge. Peter Bowers, **Boeing Aircraft Since 1916**, pp. 353-373.

Nov. 15 The U.S. Army Ordnance initiates the Hermes program for ballistic missile research and development. The prime contract is awarded to General Electric. One of the projects to emerge from Hermes is the RV-A-10, the first U.S. large-scale solid-fuel rocket. This technological breakthrough is the progenitor of all large-scale solid rockets, such as the space shuttle program's solid-fuel boosters and the Scout launch vehicle. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 48.

Nov. 17 The U.S. Navy's Bureau of Aeronautics initiates feasibility studies of the Army's JB-2 version of the German pulse-jet-powered V-1. The Navy version, called the Loon, is later launched from submarines in tests, but never becomes operational. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 48.

Nov. 24 The U.S. Army Air Forces conducts its first major bombing attack on Tokyo, sending 111 B-29 bombers from the Mariana Islands. The main target is the Musashino aircraft plant. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II,** p. 505.

Nov. 30 Kenneth Gatland of the Combined British Astronautical Societies is one of the first to recognize that the German V-2 war rocket has great possibilities for spaceflight. He suggests that if the warhead were replaced with about 45 kilograms of instruments, it could carry them into deep space and to "the moon itself." Some people disagree with his calculations. **Flight**, Nov. 30, 1944, p. 593.

During November 1944
A British Royal Air Force de Havilland Mosquito flies 7,800 kilometers from Great Britain to Karachi, India, in 16 hours, 46 minutes, breaking the speed record set 10 years earlier by Amy Johnson and Jim Mollison. Flown by Flight Lt. J. Linton, the Mosquito's average speed is 506 kph. **The Aeroplane**, Nov. 17, 1944, p. 554.

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An incorrect photo accompanied a Looking Back item for Nov. 12-Dec. 10 on Page 62 of the November issue. Above is a Vickers Vimy G-EAOU. The restored aircraft is displayed at Adelaide International Airport, Australia.

ASCEND: Thinking Big, Solving Problems, and Helping New Ideas Take Flight

Humans have always been driven to explore and push boundaries, and expanding humanity off Earth is the next opportunity. Space investments have grown exponentially in the past five years, with small satellites making imaging and sensing from space more accessible to new markets like agriculture, construction, insurance, and others. NASA is now investing heavily in the Artemis program to return humans to the moon and then on to Mars. These investments, along with government and commercial investments in space transportation, will provide the infrastructure needed to begin thinking long term about space settlement. Now is the time to start thinking about what it will be like to live and work on another planet or in space. What are the challenges and what disciplines need to be considered?

Bringing multidisciplinary players to the discussion is one reason why AIAA created ASCEND (**www.ascend.events**), a new, outcomes-focused, transdisciplinary platform built by space professionals to grow the space economy. It will be a place where scientists, engineers, economists, medical professionals, educators, legal professionals, artists, investors, and entrepreneurs gather to network, share ideas, and develop solutions.

ASCEND stands for Accelerating Space Commerce, Exploration and New Discovery. It will debut 16–18 November 2020 in Las Vegas. At ASCEND, you will explore emerging space-related applications and opportunities across aerospace and other industries such as manufacturing, mining, pharmaceuticals, and telecommunications. You will also access the strengths of AIAA—the technical panels and sessions that bring together and educate experts from industry, government, and academia.

ASCEND programming is being led by a Guiding Coalition of industry leaders and experts. Dava Newman, Apollo Professor of Aeronautics and Astronautics at MIT and a Guiding Coalition member, said "ASCEND is inclusive, hands-on, and outcomes-oriented. It's the conference of the future."

We're introducing ASCEND programming in various venues throughout the year. At IAC 2019 in October, we hosted a panel of space industry founders for a discussion on lessons learned from space startups. In March, we're traveling to Austin, TX, to host the "ASCEND: Creating Our Off-World Civilization" panel at South by Southwest (SXSW). We competed against 4,400 entrants to claim a spot at this internationally renowned annual event.

The SXSW panel will include Ariel Ekblaw (MIT Media Lab), Sandy Magnus (former astronaut and member of the ASCEND Guiding Coalition), Kathryn Denning (York University), and Wanda Sigur (former vice president at Lockheed Martin). They will address how to deal with the inherent human challenges—both physiological and psychological—to living and working off-Earth. They'll discuss the technical and design solutions needed, as well as our ethical responsibility as this journey unfolds, and how we ensure we meet it.

> ASCEND is inclusive, hands-on, and outcomes-oriented. It's the conference of the future.

Now is a pivotal time to build the framework for how we're going to live and work off-planet, and we need creative and open-minded people to take on work that will have a tangible impact on our future. AIAA created ASCEND for YOU, and you can become a part of this transformative conversation by answering the Call for Content (**www.ascend.events/cfc**). We are looking for participants to host debates, lead workshops and, of course, present technical papers. Submissions are due on **17 March**.

Together we ASCEND!

Rob Meyerson
Executive Producer, ASCEND
Former President, Blue Origin

AERO PUZZLER

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

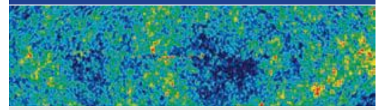
Burning clean

Q: Tell us why the following is true or false: The Space Shuttle Main Engines and a hypothetical air-breathing hypersonic aircraft are both fueled by liquid hydrogen, so therefore their only emissions would be water vapor.

Draft a response of no more than 250 words and email it by midnight Feb. 12 to aeropuzzler@aiaa.org for a chance to have it published in the March issue.

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

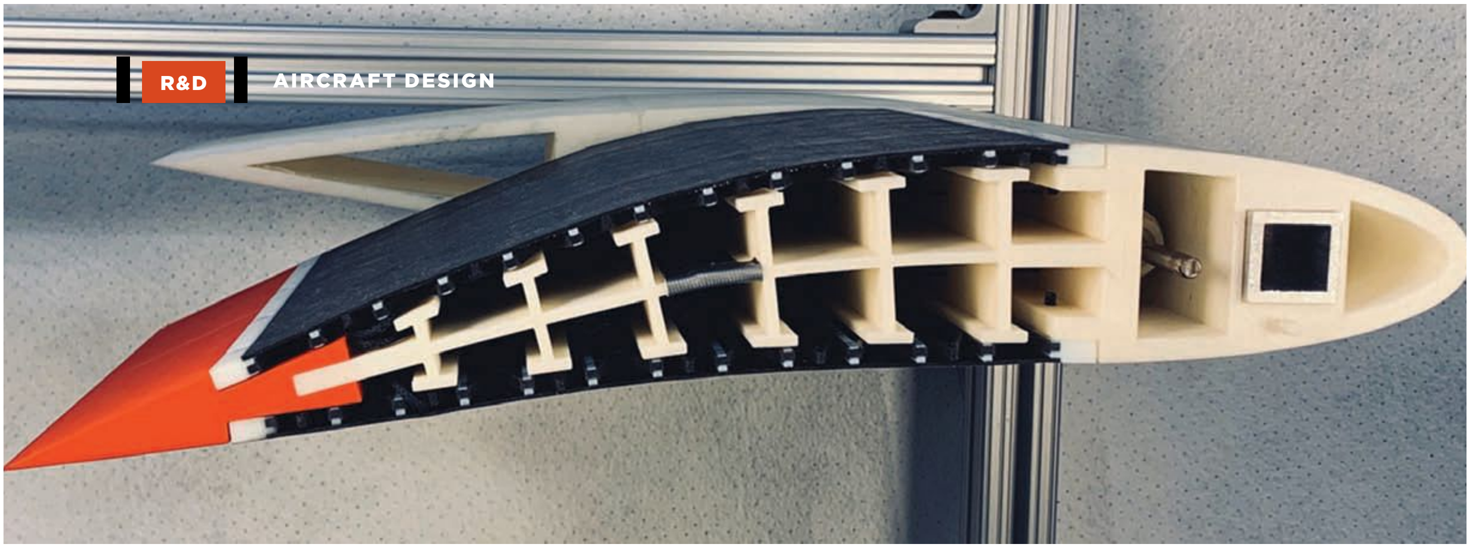
FROM THE JANUARY ISSUE



COSMIC MYSTERY: I'm leftover from the beginning of time; I have spots; a spacecraft was launched to look for my spots and take my temperature. What am I? Your responses were reviewed by John Mather, who shared the 2006 Nobel Prize in Physics with fellow astrophysicist George Smoot for their work with NASA's Cosmic Background Explorer spacecraft.

WINNER: You are the remnant radiative energy from the time our universe began! Cosmic Background Radiation (CMB), as you are called, represents the thermal energy left over from this "Big Bang!" We can't see you with our human eyes, you're way too cold at 2.725 Kelvin…so we use microwave detectors to capture you and your spots! We first became aware of you as "noise," blaming pigeons' droppings of all things! But our Penzias & Wilson & team soon found your ever-presence, garnering a Nobel Prize for their astounding and serendipitous discovery! Decades later, the Cosmic Background Explorer (COBE) mapped you in the sky, followed years later by the Wilkinson Microwave Anisotropy Probe, with many surprises in store (lumpiness, asymmetry, & gravitational waves, oh my)! Now with a telescope named after Planck, we have found your fluctuations that hint at dark matter and energy hiding an astonishing 95% of our universe! COBE's very first "baby universe" picture of you used a trio of instruments: "a Diffuse Infrared Background Experiment (DIRBE) to search for your cosmic infrared background radiation, a Differential Microwave Radiometer (DMR) to map this cosmic radiation sensitively, and a Far Infrared Absolute Spectrophotometer (FIRAS) to compare the spectrum of the cosmic microwave background radiation with a precise blackbody." We can't wait to find what you'll reveal to us in the decades to come!!!

José Camberos, Dayton, Ohio
AIAA associate fellow, Dayton-Cincinnati section; team lead for design of aerospace systems for hypersonics at the U.S. Air Force Research Lab; jose.camberos@us.af.mil



Inspired by fish

▲ **The fishbone-like** structure inside this wing section flexes to adjust the camber, or curvature, of the wing.
University of Maryland

BY CHRISTINE FISHER | christine@cfisherwrites.com

Researchers at the University of Maryland have devised a wing section whose camber, or curvature, can be morphed by bending a fish-inspired skeleton core.

Today's aircraft adjust their camber by extending or retracting ailerons and flaps. The gaps between these surfaces and the wing create drag, and because these control surfaces are rigid, the camber cannot be adjusted as precisely as might be possible with the new method.

The origins of this bioinspired concept can be traced to work done nearly a decade ago by Benjamin Woods, then a doctoral student at the University of Maryland and now a lecturer at the University of Bristol in the United Kingdom. He devised the FishBAC, short for Fish Bone Active Camber.

"The idea was to have a flexure to do the bending and get the camber and have the spines go off to create the shape you would need for the airfoil surface," explains Norman Wereley, the University of Maryland professor whom Woods studied under and who is now the chair of the Department of Aerospace Engineering at Maryland.

At the time, Wereley wanted to combine the FishBAC with the morphing aircraft skins that are his research specialty, but the complex geometric substructure within the skin seemed too complex to affordably make a model or models for testing. Inside the skin, ribs made of hard plastic connect with a geometric grid of soft plastic to form a flexible honeycomb that is covered with an elastomer surface. The skin stretches in one direction without losing any dimension in the other direction, called a zero Poisson's ratio.

Suspecting that advances in 3D printing might have bent the cost curve for making models, Wereley last year tasked two undergraduate students, Ben Stutzke and Vivek Uppoor, with designing and printing the proof of concept shown on this page.

Printing the FishBAC core was relatively straightforward. More complex, just as expected, were the skins that attach to the leading and trailing edges of the wing and stretch over the FishBAC.

The honeycomb substructure, a tear-resistant layer and the surface of the skin were printed as one piece.

"You can only do that with multimaterial 3D printing, and it gives it a lot of strength," Stutzke says.

3D printing also meant they could make the prototype small, just 42 centimeters from root to wingtip, but still highly detailed. The miniature size constrained costs and printing time.

In a wind tunnel test, with wind speeds reaching 24 meters per second, the prototype morphed without fluttering, proving its feasibility.

Next, Stutzke and Uppoor plan to try a pushrod actuation method. At the moment, the camber is adjusted by turning spools of string attached to a series of tendons running through the FishBAC.

Eventually, they'd like to test the wing on a small unmanned aircraft.

"With the morphing camber system, we can morph 90% of the wing," says Stutzke. That provides more control authority, especially on very low-aspect-ratio wings, meaning those that are short and squat.

"It's all smooth curves," adds Uppoor. "Therefore, there's not going to be as much break in airflow, and because of that, you can have a higher efficiency flight." ★

Robert Cabana at an event at NASA's Kennedy Space Center in Florida.
NASA/Aubrey Gemignani

Commanding commercialization

More online
aerospace america.aiaa.org

Robert Cabana has one New Year's resolution: launch U.S. astronauts on U.S. rockets. As director of NASA's Kennedy Space Center, Cabana is ultimately responsible for the Commercial Crew program that's tasked with that challenge and is managed at his center. That's not all his job entails, of course. The launch pads at KSC host a variable roster of NASA, government and commercial launches, a reality that Cabana hardly dared dream of when he began KSC's transformation from space shuttle launch site to multiuser spaceport almost 10 years ago. Now, the center could be a model for an agency that's increasingly relying on industry. I sat down with Cabana in his office at KSC to discuss this commercial future. *— Cat Hofacker*

ROBERT CABANA

POSITIONS: Director of Kennedy Space Center since October 2008; director of NASA's Stennis Space Center, 2007-October 2008; NASA astronaut, 1986-2000; pilot in the U.S. Marine Corps, 1976-2000, when he retired at the rank of colonel.

NOTABLE: Flew four space shuttle missions between 1990 and 1998, the last of which was the first assembly of a U.S. module on the International Space Station; as NASA's chief astronaut from 1994 to 1997, he made crew assignments for future shuttle missions and gave input on the design and development of spacecraft; flew A-6 Intruders with the 2nd Marine Aircraft Wing in Cherry Point, North Carolina.

AGE: 71

EDUCATION: Bachelor of Science in mathematics from the U.S. Naval Academy, Maryland, 1971

RESIDENCE: Cocoa, Florida

IN HIS WORDS

The end of an era, but a "fresh start"

The last shuttle flight was in July 2011, when Atlantis landed. When it came to an end, it was depressing. Not only had the shuttle program ended, but just prior to that, the Constellation program that was a new exploration program to replace it had been canceled. We went from a workforce of 15,000 down to 7,500 in two years. In fact, Atlantis landed on a Thursday in July 2011. The very next day, 2,000 contractors got pink slips and walked out the door. So there was this real low, but there aren't many times in your life when you can define what you want your future to be. Most of the time we end up in positions where we just keep something else going and improve on it or try and make it better. But we had a fresh start, if you will.

The "seed" of KSC's transformation

I really credit a lot of it to the year that I spent at the Stennis Space Center in Mississippi. Stennis, in addition to being the center where all the propulsion testing gets done for NASA, is also a "federal city." It supports the U.S. Navy; it supports universities; it supports businesses. Seeing that you could operate on a federal facility in more than just a federal way, supporting pure government programs, that helped plant a seed, if you will, that hey, how can we redefine ourselves here at the Kennedy Space Center? It was an iterative process. We set out some goals and then we added to it, and we continued to evaluate it every year to get it to where it is. At one point I said to somebody, "You can see so clearly what you want the future to be, and it's so hard making it happen." It took so much longer than I thought it would take. And they said, "I can't believe you did it as fast as you did, considering you're the federal government." Looking back on it now, when I looked at what our strategic plan was and where we thought we would be, we far exceeded what we had planned in getting it done sooner. You can just feel the vibrancy here on the Space Coast, because it's not just the commercial stuff going on — it's Artemis taking us back to the moon; it's big rockets; it's Commercial Crew, it's satellite launches; it's everything that's going on. And it's not just here at Kennedy or Cape Canaveral Air Force Station; it's the entire Space Coast. This is a happening place.

The new NASA

I definitely think it's a lasting change. This is how we're operating. This is our future. It's not us alone. It's not just NASA; it's NASA in partnership with our commercial partners, our international partners. The International Space Station is a great model for how we move forward, but now bring in the commercial aspect of that also, in addition to just having our international partners. As we expand the boundaries of our human existence beyond Earth, we need to do it as the people of planet Earth, in a cooperative way.

Enabling commercialization, not ensuring it

It's not my goal to guard against them [the companies] being successful or not. I want to enable them to be successful. I want to provide the tools, the resources, the facilities that they need to be successful, but I can't make them successful. When the shuttle program ended and we evaluated all the facilities that we had, first off: We couldn't afford to pay for everything. As we moved into SLS [Space Launch System] and Orion, now the Artemis program, we took an initial look: What do we need for SLS and Orion? Obviously, we have to keep all those facilities. If we didn't need it for that, then we looked at will it support commercial operations? Or, if it doesn't support commercial operations and we don't need it for SLS or Orion, let's raze it, let's tear it down and get it off our books, because we can't afford to keep it. When we went out with a notice of availability for a lot of these facilities, a number of companies that won an award and wanted to take it over and maintain and operate it, pay a lease, whatever, were not successful. We had one company that was taking over a parachute facility, and unfortunately they didn't win as many government contracts as they thought they were going to win, and they had to downsize and go back to just where their primary operations were, and they couldn't expand and grow the company like they had thought. So that didn't work out. We had another company that was doing nondestructive inspections — NDI. They tried to make a go of it for about a year and a half and eventually were not successful. It's not our job to make the company successful; it's to provide the environment that enables them to be successful.

> **"When we were flying the shuttle, there was schedule pressure to get things done. There's always going to be a demand to get it done on time. But the bottom line is we're dealing with human spaceflight here, and I've made a commitment to the crews that we'll fly when we're ready to fly."**

Role of government versus industry

I think there are things that commercial companies can do quicker and easier sometimes than the way the government does it. We can learn from that decision velocity and a few other things, but there are some things meant for the government to do also. When I look at the cost of exploration, of going to Mars, that's a national goal that enables industry to be a part of it, that grows our understanding, that grows our economy, that grows our knowledge. That's an admirable thing to lead in. It's way too expensive for any one company to take that on. It needs to be a

▲ Engineers, technicians and crane operators practice moving Space Launch System solid rocket booster test segments at NASA's Kennedy Space Center in Florida.
NASA/Glenn Benson

national initiative. I think it's really important that we continue to explore, that we establish a presence beyond our home planet. It's really important that we enable commercial operations, also, as we do that. I look at Commercial Crew right now, and we talk about it being commercial, but it's really just another way of doing a government procurement. We did it through Space Acts, meeting goals and stuff, and eventually went to a firm-fixed-price contract for a service. Without the International Space Station right now, there would be no destination in space for Commercial Crew. The government is key in helping enable that. A true commercial venture is: I have an idea, I go out and get venture capital, I build it, people like it, they buy it, it works, and I make a profit. But Commercial Crew, we're looking at kind of a government-subsidized program, if you will, right now, and there's nothing wrong with that; that's the government's role. But eventually, just as aviation was more or less government-subsidized in the early days, that's kind of what we're doing with commercial space right now. Eventually, I believe it will become commercialized and fully commercial.

The future of ISS

What's really going to help us here is getting Commercial Crew flying. It's going to be huge when we can increase the number of people on the International Space Station to actually do more science, to bring [people] other than professional career astronauts up to the space station to do science on the space station. That is really important, and that's one of the main reasons I want to get Commercial Crew flying on time, so that we can gain that extra knowledge on the space station. At some point it's going to have to come down, but until we have a transition, I definitely think we need to keep the International Space Station on orbit as a destination for Commercial Crew and for doing these commercial operations in space. But I also think we need to

encourage the development of a pure commercial space station where NASA can just be one of many customers, as opposed to being totally in charge.

Improving crew safety

There's a huge difference between the shuttle and a capsule on top of a rocket. For one thing, we're going to have a demonstrated abort capability on both of these vehicles. The shuttle had multiple "black zones" where, depending on what the failure was, there was no way to save the crew. We've designed into both of these vehicles no black zones. They can safely get the crew off the rocket from T-0 to main engine cutoff on orbit and safely get the crew back, and that's huge, having that demonstrated capability to ensure that. We're not going to fly until we're ready to fly. That's the bottom line. There's always pressure. I don't care what you're flying or what you're doing. When we were flying the shuttle, there was schedule pressure to get things done. There's always going to be a demand to get it done on time. But the bottom line is we're dealing with human spaceflight here, and I've made a commitment to the crews that we'll fly when we're ready to fly. You talk about the model that we have today [with Commercial Crew], one of the differences is it's insight rather than oversight. We don't have direct oversight over the contractor, but we have insight into what the contractor is doing. They have very specific requirements; they have to show that they meet those certifications in order to fly. So, we've got a very good partnership with both SpaceX and Boeing, working together with them to ensure that they are meeting those requirements. When it's safe to fly, we'll fly. We've got a long way to go on both vehicles to meet those certifications.

College graduates turned new employees

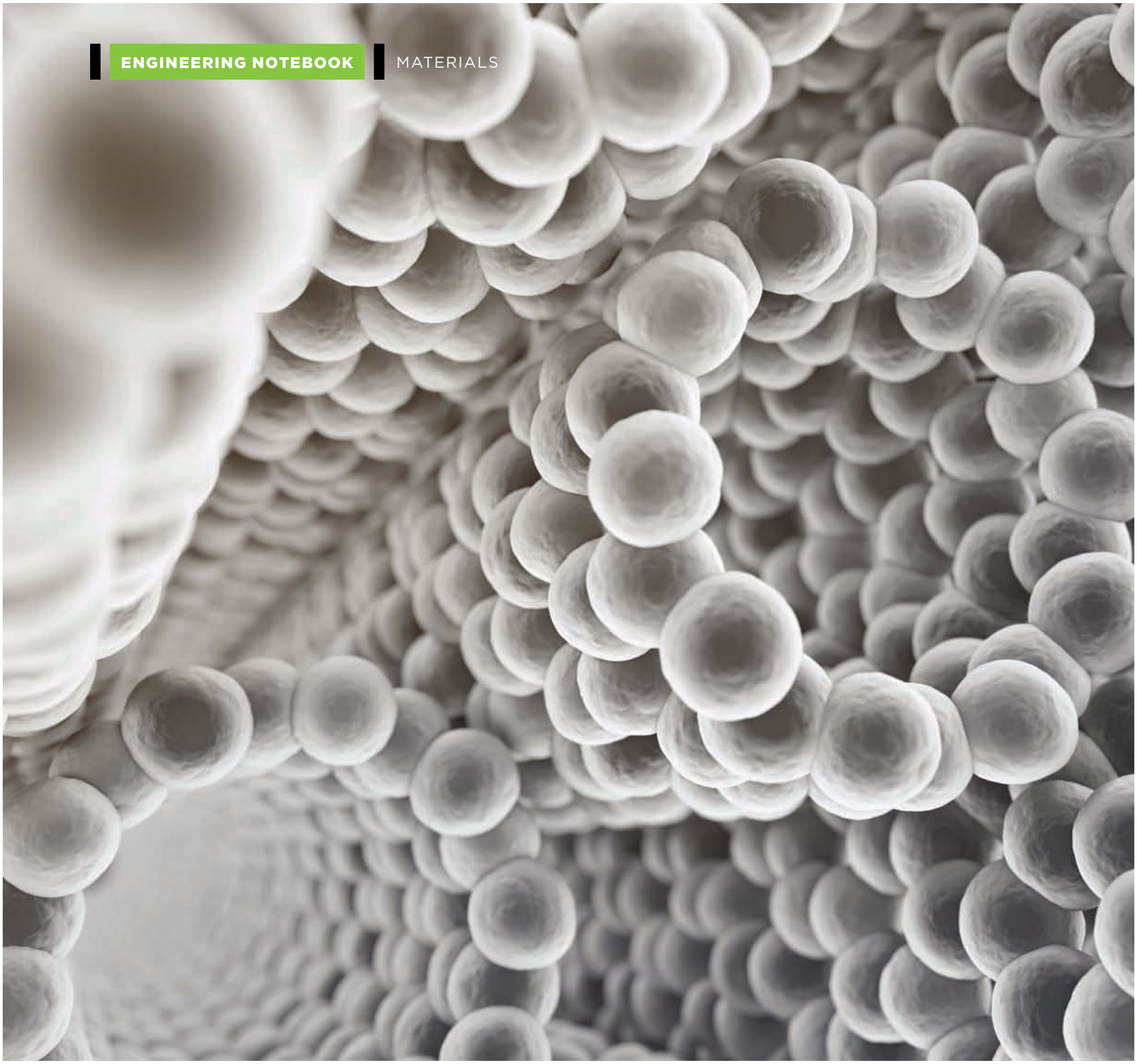
I have a requirement on our team that half of our new hires have to be fresh-outs. So I'm trying to bring down — I'm not doing too well — the average age here. It is coming down a little bit. Knowledge capture is really important, pairing people up with young folks and sharing that knowledge, operational experience. I went and I had an all-hands here a while back, and I asked for a show of hands, "How many were here when we lost Columbia?" I'll bet it was only a fourth of the audience that raised their hand. That says a lot. How we feel about things is based on our experience and our environment. I don't want to lose those lessons learned from Columbia and Challenger and Apollo 1. It's important that we don't forget that. I don't want to learn those lessons a second time, or a third time, or a fourth time. But we have to share the things that we do right, also, how we operate. But I will tell you, the fresh-outs, the kids that are coming aboard — and they are kids, by my standards — they have so much talent, and they have tools that we never had. I've got interns writing software to launch SLS and Orion. That's awesome.

The next decade

I want to continue to carry forward this multiuser spaceport that we've established. I think it's phenomenal when you look at what we're supporting here: the government launches as well as all the commercial operations that have taken place here at KSC. It's a partnership between industry and government; it's a partnership between KSC and the state, working with the state of Florida; it's a partnership between the Kennedy Space Center and the 45th Space Wing [of the U.S. Air Force] and the FAA. A lot of agreements had to get put in place to help enable what we are doing today, so I definitely want to see that go forward and continue to grow and solidify. I also think there's things we can do better. There's a few more agreements I'd like to see in place. There's ease of operations. I want to continue to work on the bureaucracy, if you will, of what it takes in order to operate and launch here on a government facility in a commercial nature. I want to ensure that the infrastructure that was built back in the 1960s is able to support the growth of this spaceport as it continues to grow, and so we need to make sure that that's in place. But overall, [there's] not a whole lot that I want to change; I just want to improve on some stuff.

Back to the moon, on to Mars

No. 1 goal in this decade is in the very first quarter of the first year this decade getting crews to the International Space Station on a U.S. rocket. The goal is sustainable operations in a lunar environment. There's nothing easy about keeping humans alive in space, in a harsh environment like the lunar environment or the Martian environment. That's this next 10 years; it's getting established sustainable human operations in a lunar environment. Humans, they need air to breathe, they need CO_2 scrubbed; you've got to give them food to eat; you've got to take care of their trash; you've got to provide a pressurized environment. That's a huge challenge for this next decade, but I've got to say, we have bipartisan support in both houses of Congress for what we're doing, we've got a $1.3 billion increase to our budget to help us get back to the moon by 2024, and we're going to continue to need increases like that as we go forward. We have huge support right now to make this happen. Now is the time. We're going to do this. We are very capable. If you think in May of 1961, Alan Shephard did a suborbital flight in a small little capsule on a Mercury Redstone [rocket], just over eight years later we're walking on the moon. That is phenomenal. Even with half of 1% of the federal budget, we can do this. I think this nation can do anything it sets its mind to, given the resolve and the support. ★



Out-of-oven curing

Carbon nanotubes, the long cylindrical molecules that have enthralled engineers with their strength, also happen to conduct electricity that can produce heat. Keith Button spoke to MIT researchers who want to tap this characteristic to change the way aircraft structures are made.

BY KEITH BUTTON | buttonkeith@gmail.com


iStock

Aerospace engineers at the Massachusetts Institute of Technology have devised a method for curing aircraft composite materials by incorporating carbon nanotube molecules in them and electrifying them to generate heat.

Normally, composite wings, fuselages and other components must be heated for hours in ovens to solidify them into shape. With the out-of-oven process, the MIT team has "demonstrated that we can bake the cake in one hour, as opposed to three hours," says Brian Wardle, the MIT professor who leads the research team.

So far, only small patches of materials have been cured, but if the method can be scaled up and proven for a wide range of materials and shapes, then airplane manufacturers could adopt the technique to speed up their processes and reduce energy costs.

The new technique came to the engineers through serendipity. In 2010, MIT and Metis Design Corp., a Boston aerospace company headed by Seth Kessler, a colleague of Wardle's, started a project for the U.S. Navy. MIT and Metis designed and built an embedded wing de-icer for unmanned Triton aircraft, the Navy's maritime surveillance drones.

For this de-icer, the engineers knew that carbon nanotubes, the long carbon molecules thousands of times thinner than a human hair, conduct electricity well. Feeding electricity to them could warm the aircraft's wings and melt ice or keep it from building up. They applied thin, black sheets of nanotubes to the leading edge of a composite wing as they fabricated it. Then the whole unit was cured in an oven.

To prove the technique, they fed electrical current to the sheets through electrodes. The sheets conducted the electricity to other electrodes to complete the circuit and produce ice-melting heat. Dozens of ice tunnel tests have been run on the de-icer, but it hasn't been fielded yet, Kessler says.

The engineers had an epiphany from this experience: "Why can't we use that heat to actually do the manufacturing?" Wardle recalls the team wondering.

Wings with benefits

Incorporating carbon nanotube heaters into the manufacturing of carbon fiber reinforced plastics could have some immediate benefits for airplane builders, Wardle says. They wouldn't need giant ovens to contain large wings or fuselages. And because the nanotubes heat up immediately when electric current is applied, the manufacturers wouldn't have to wait hours for the air or gas inside an oven to heat up.

Once the planes are built, pilots, mechanics and airplane operators could benefit from carbon nanotubes baked into wings and other airplane structures. The nanotubes might measure strain or structural damage, for example. As a strain gauge, bending or twisting the carbon nanotube mesh would cause the resistance of electric current passing through the nanotubes to change: Tension would increase resistance and compression would decrease it. A sensor could discern that change and measure strain on the wing, says Lawrence Drzal, a professor and director of the Composite Materials and Structures Center at Michigan State University in East Lansing, Michigan. He is not involved in the MIT research but is aware of it. For structural damage, a sensor could pick up on permanent changes in the electric current passing through the carbon nanotubes when connections are removed between them because of damage to the wing. Carbon nanotubes might also offer lightning protection to the skin of an aircraft, diffusing the energy of a strike, Drzal says.

Testing the concept

In 2012, the engineers began a series of experiments to see if the heat from electrified sheets of nanotubes would be enough to cure composites. "In a sense, a lot of the really hard stuff was already worked out from the prior technology," Wardle says, referring to the de-icing work. For the Navy drones, the engineers had figured out issues like how and where to place electrodes to best control the heating. They had also worked out how much the sheets of nanotubes could be bent or folded over and still create heat as required.

Now, they decided to test the nanotube heating on the thermoset carbon-reinforced plastics that some airplane wings and fuselages are made from.

To test their curing technique on this material, the engineers needed to make their own sheets of carbon nanotubes that conducted electricity well. The nanotubes on these sheets had to be dense, aligned in the same direction and touching. They grew their own nanotubes on a 4-by-5-centimeter silicon wafer, producing what was in essence a nanoscale carpet of fibers sticking straight up. They laid a piece of Teflon film over the nanotubes and then rolled a rod over the film to press the nanotubes flat in the same direction. The nanotubes stuck to the Teflon and came off the silicon wafer, creating a nanoscale structure resembling a cloth.

Next, they needed to make electrodes that would be attached to the sheet to create their carbon nanotube heater. They took a rectangular Teflon-nanotube sheet and attached strips of copper mesh running down two ends of the rectangle, perpendicular to aligned nanotubes.

With their heater ready, they needed to see how well it would cure thermoset material compared to the traditional oven method. They stacked together

16 layers of prepreg thermoset sheets, which are sticky like duct tape, each 4-by-5-cm wide. Then they topped the stack with their Teflon-nanotubes sheet and ran electric current through the Teflon-nanotubes sheet to heat it up. They built a second 16-layer stack of the prepreg sheets and heated it an oven. For both stacks, they raised the temperature to 121 degrees Celsius for three hours, then to 177 degrees Celsius for two hours, following the schedule recommended by the maker of the prepreg. Later tests would show that nanotube heaters could cure the material three times faster than an oven.

Once the curing was finished, the engineers compared how completely the nanotubes-heated and oven-heated samples cured. They found that the degrees of cure — with 100% being fully cured — were about 93% for the oven-made sample and 93% to 99% for the nanotube-made sample.

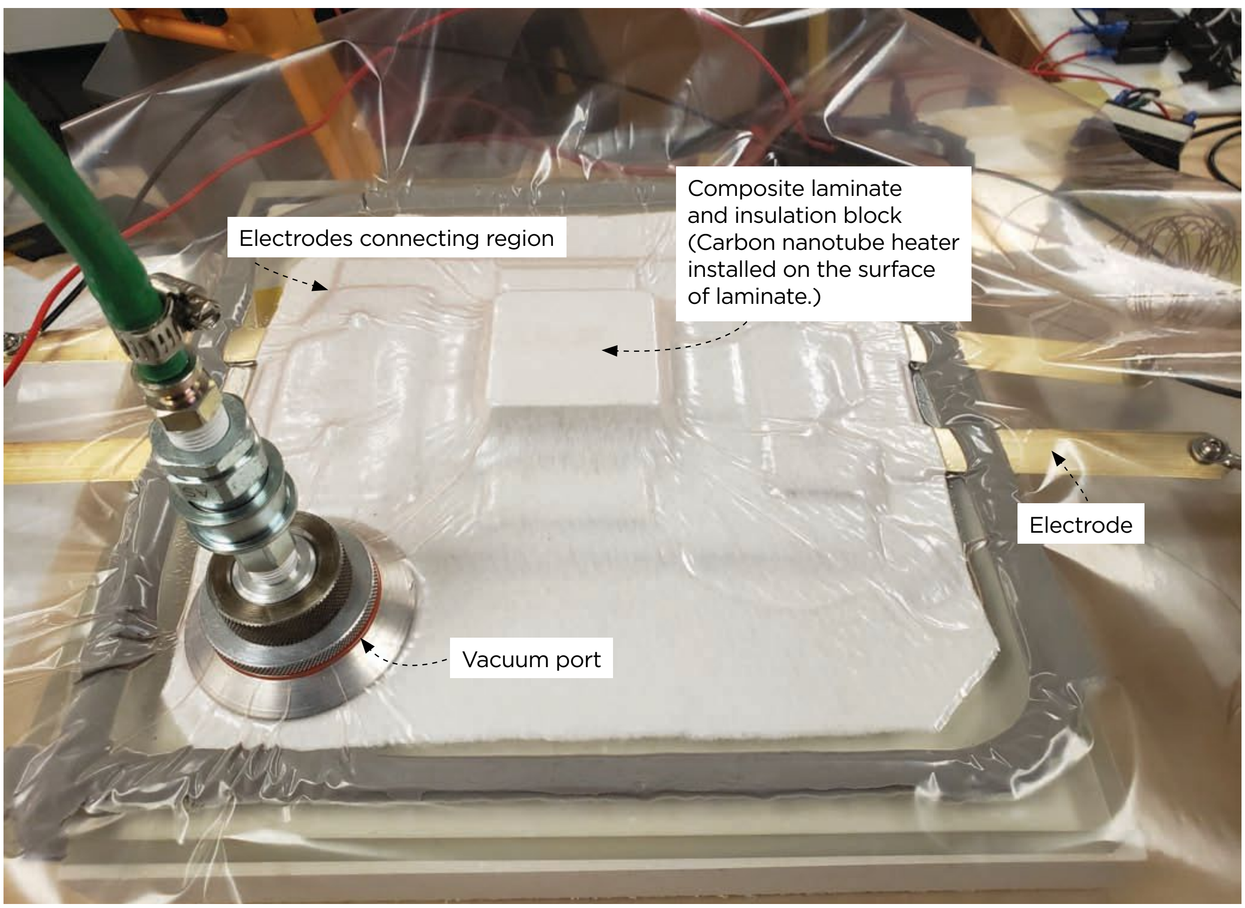
With the out-of-oven process, the MIT team has "demonstrated that we can bake the cake in one hour, as opposed to three hours."

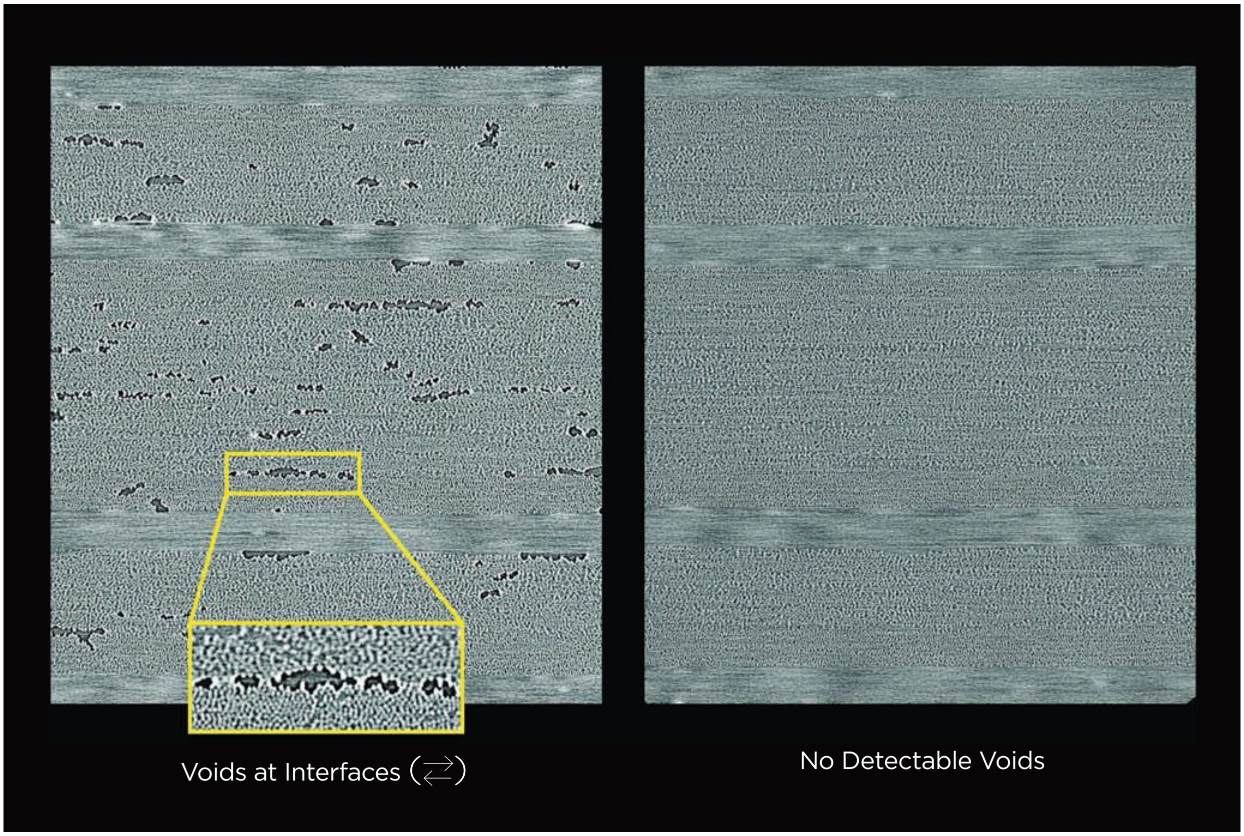
– Brian Wardle, MIT professor

Recent testing

In 2018 and 2019, MIT engineers decided to find out how nanotube heating compared to traditional curing methods for thermoplastics, another type of carbon-reinforced material. This material is typically formed into airplane parts such as ribs, engine

A vacuum bag set up to test out-of-oven curing with carbon nanotubes.
MIT





▲ **Cross-sections of** composites show that those produced by nanotube heaters, right, are in some cases better than those made by pressurized ovens, left, which exhibited voids.
MIT

pylons or wing leading edges. Manufacturers traditionally cure prepreg sheets of this material in a hot press or pressurized oven, where it melts and then hardens as it cools.

For this testing, the engineers wanted to try commercially available nanotube sheets for the heaters instead of making their own, because the sheets would be easier to adopt for large-scale production in the future. But first, they needed to make sure the commercial sheets wouldn't melt or disintegrate at the high temperatures — at least 400 degrees Celsius — needed to cure the thermoplastics.

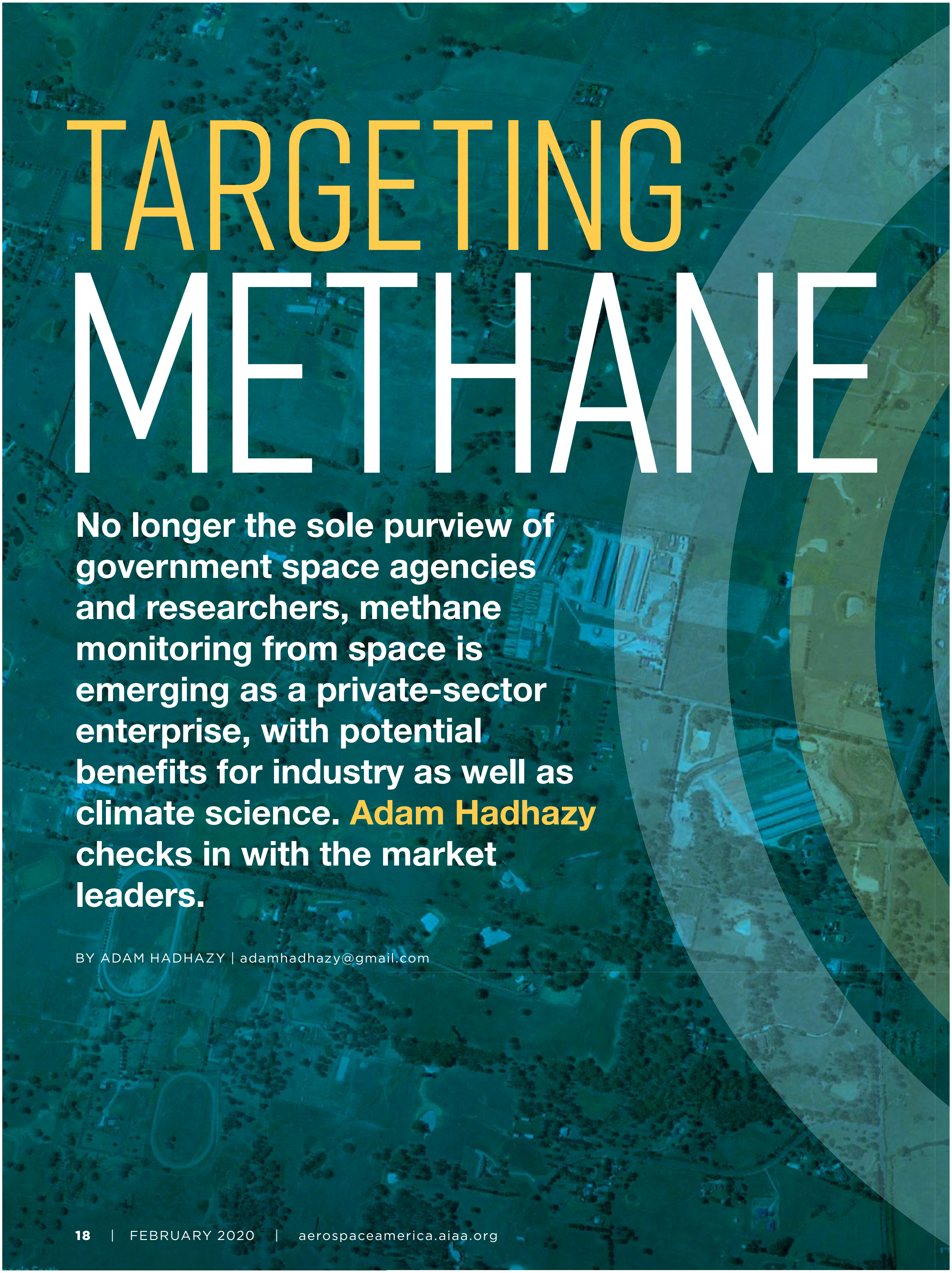
The engineers ran electric current through patches of the nanotube material, each 2-by-1.5-cm across, to heat them to between 556 and 562 degrees Celsius. The patches were not affected.

They were then confident that the commercial nanotube sheets would not melt or disintegrate, but they still needed to make sure that their process would result in cured thermoplastic patches that were just as strong as those made by the traditional heating methods. So they made three sets of samples that they could compare: samples made by the nanotube heaters, in a pressurized oven and in a hot press.

The team divvied up the work. The MIT engineers made 18- and 24-ply composites with the nanotube heater as the top layer. Meanwhile, Teijin Carbon America — the U.S. subsidiary of a Tokyo-based carbon-fiber manufacturer and maker of the prepreg thermoplastic composite material — cured 18- and 24-ply composites, both in a pressurized oven at the University of Dayton Research Institute and with a hot press at its plant in Kettering, Ohio.

Now, the engineers had to figure out how the samples from the three manufacturing methods compared structurally. They calculated the percentage of crystalline structures in the samples to see how well the samples had hardened. They also scanned the samples with an X-ray microscope to look for voids, which signify structural weakness and can lead to cracks when a component is squeezed, bent or sheared. The engineers found that the samples produced by the nanotube heaters were just as structurally sound, or better in some cases, as those made by the pressurized oven and the hot press.

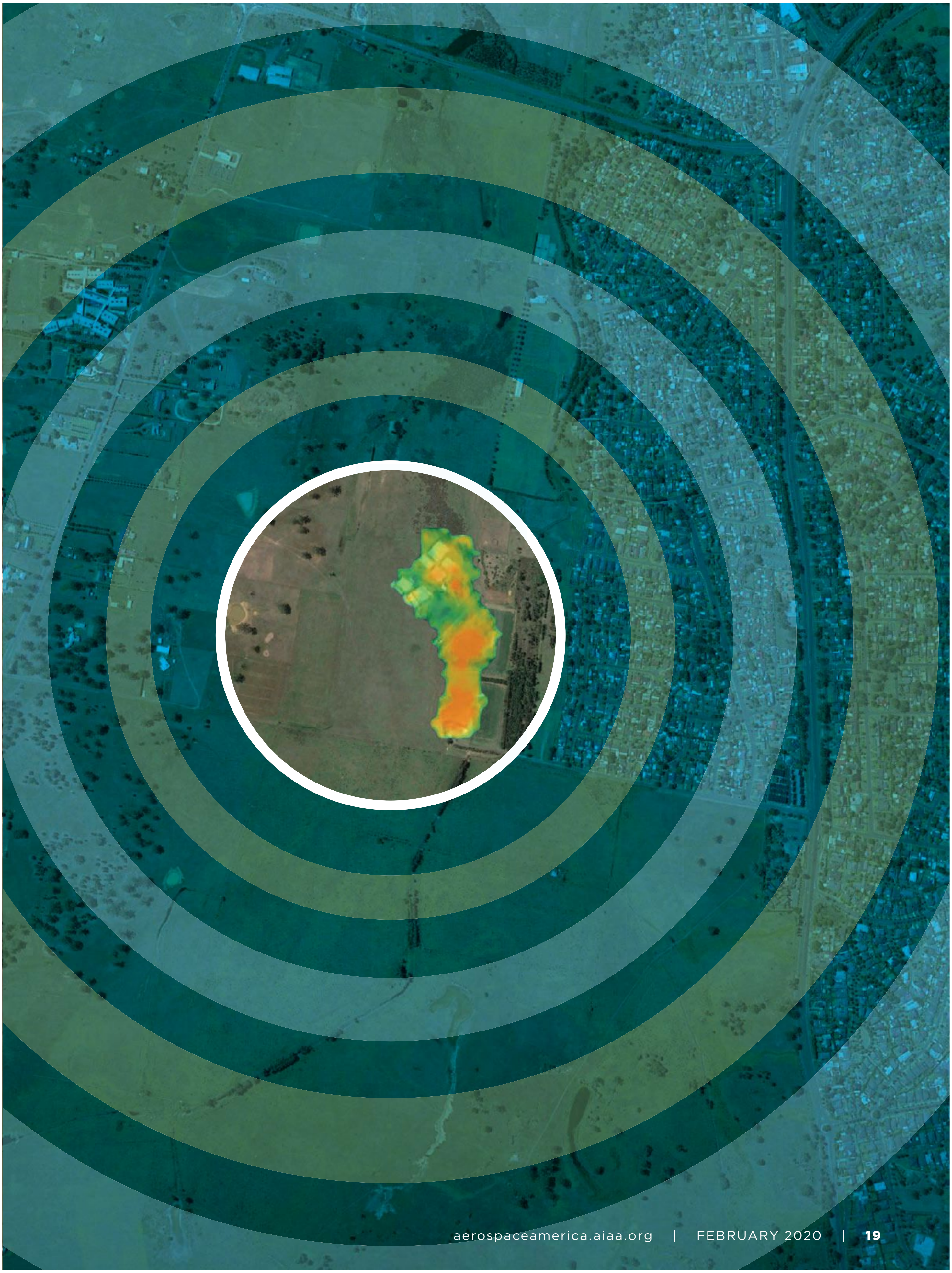
More work lies ahead, such as to find out exactly how quickly composites can be cured. "The question is: How far can you go? The heaters heat really fast. The polymer can cure really fast as well," Wardle says. The MIT and Metis engineers didn't try to optimize the curing period with the nanotube heaters, so adjusting the temperature recipe could probably cut the cure time in a half again, Wardle predicts. ★



TARGETING METHANE

No longer the sole purview of government space agencies and researchers, methane monitoring from space is emerging as a private-sector enterprise, with potential benefits for industry as well as climate science. Adam Hadhazy checks in with the market leaders.

BY ADAM HADHAZY | adamhadhazy@gmail.com



In the fight against climate change, carbon dioxide looms as the top villain, but the baddest guy in any story often has a formidable top lieutenant — like Darth Vader to Emperor Palpatine in "Star Wars," or Saruman to Sauron in "The Lord of the Rings." For carbon dioxide, the accomplice is methane.

Colorless and odorless, methane is familiar to many of us as the principle component of natural gas. The largest single-sector contributor to global methane emissions from human activity is production of oil and gas, stemming from leakage during drilling and fracking, and the vast pipeline infrastructure that transports liquid and gaseous petroleum products, spanning 4.2 million kilometers in the U.S. alone. Other key methane sources include landfills, wastewater treatment plants and the agricultural industry, of which an infamously major component is burps from cattle and other livestock. All told, climate scientists deem methane responsible for about a quarter of the human-caused global temperature increase of 0.9 degrees Celsius (1.6 degrees Fahrenheit) since the late 19th century, with carbon dioxide accounting for the remaining 75%.

While carbon accordingly grabs the headlines, methane is increasingly getting its due. A flurry of new satellites custom-built to detect the gas in the atmosphere highlight the rising interest in better comprehending methane's contribution and inspiring leakers to see the economic value in cleaning up their acts.

Historically, methane monitoring from orbit has been the purview of national and international governmental space agencies. Now for the first time, the private sector — namely Bluefield Technologies, a Silicon Valley startup, and Montreal-based GHGSat — as well as the nonprofit sector, led by the Environmental Defense Fund in New York, is getting involved. Though helping save the planet from a climatic catastrophe is certainly one motivation, for the private-sector entrants, profit motive is another. Oil and gas could, in the case of the for-profit companies, subscribe to the monitoring because of their economic incentives to rein in product loss, along with meeting new and future regulatory mandates, for instance in jurisdictions such as California. As for the regulators themselves, they could parse the satellite data to identify facilities in need of physical inspection or closer monitoring moving forward, as well as check against any self-reporting of emissions by industry.

The science case for remote methane monitoring from space, meanwhile, rests on the significant uncertainty still surrounding the relative contributions from methane's various sources, both natural and artificial. Ballpark, humans are estimated as being responsible for 60% of global methane emissions, with natural sources — such as wetlands — spewing out the remainder, though with significant variability over spans of years. To wit, and adding to the mystery: a leveling-off of atmospheric methane concentrations numbers that, according to global ground-based measurements, lasted from about 2000 to 2006, followed by a resumption of methane's historically steep, year-on-year rise since.

"We want to understand the global methane budget," says Riley Duren, a research scientist at the University of Arizona and an engineering fellow at NASA's Jet Propulsion Laboratory in California, which has developed methane sensors for use on terrestrial aircraft, as well as on rovers on Mars. "The jury's still out on what the exact causes are of the observed changes in the methane growth rate, which is important for understanding the future trajectory of the planet."

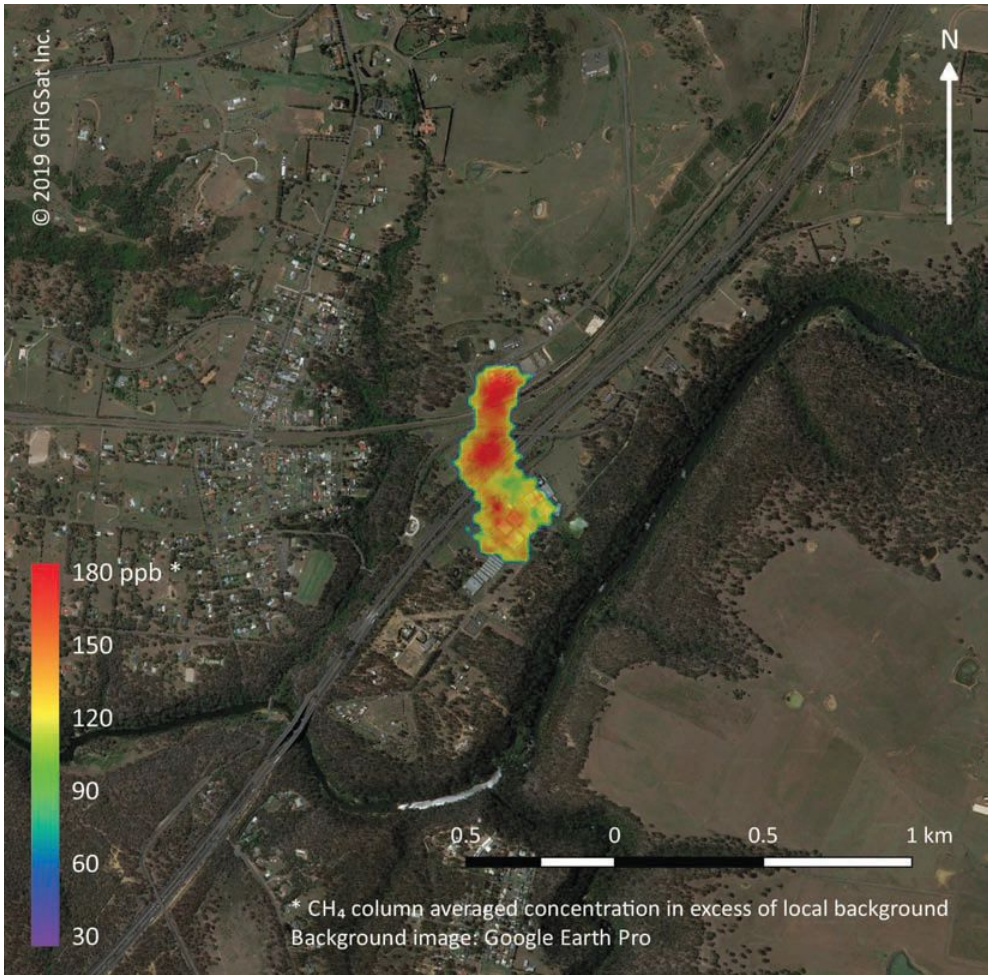
Bringing methane into focus

Pound-for-pound, methane is actually the more potent of the nefarious greenhouse gas duo, trapping around 80 times as much heat as carbon dioxide over a 20-year time span. Yet because carbon dioxide molecules outnumber methane in the atmosphere by 200 to 1 and persist for longer, CO_2 remains the substance of greater concern versus CH_4.

Over the past million years or so, the global average atmospheric methane concentration has cycled between about 400 and 800 parts per billion. Today, that figure has skyrocketed to about 1,860 ppb and is still going up by about 10 ppb annually, according to the Global Greenhouse Gas Reference Network established by NOAA.

Along with similarly stunning increases in carbon dioxide concentrations, efforts are ongoing by governments and private industry to slow or even reverse the methane trend. Satellites can significantly aid in this objective by providing global coverage of methane plumes, capturing broad-scale, natural phenomena as well as (often human-made) point sources. Satellites can see into countries and unpopulated regions without adequate conventional monitoring by ground sensors or aircraft. These conventional methods, while highly accurate, are ultimately costlier than satellites, because they must be tended to by human workers. Manual methane checking also has poorer temporal coverage, argues Yotam Ariel, CEO of Bluefield, one of the satellite monitoring startups. As a result, Ariel says that three out of every four methane leaks are missed by oil and gas operators. With adequate-sized constellations, however, satellites could provide scientists, regulators and clients with daily reports on methane emissions at pre-selected sites of interest, helping

High-altitude balloon test of the Bluefield methane sensor at 100,000 feet. Bluefield plans to begin launching a constellation of methane-monitoring satellites.
Bluefield



▲ **A methane hot spot** over a coal mine in Camden, Australia. Red and orange indicate highest concentrations of methane in parts per billion. GHGSat says it collects data as its satellite makes 10-20 passes over a site.
GHGSat

all parties identify where and when emissions are happening, and thus how to curtail them.

Toward this end, Bluefield is developing a roughly backpack-sized microsatellite targeted for launch in 2020, with goals for more spacecraft to follow. "With about eight satellites, that will get us to daily measurements pretty much anywhere in the world," says Ariel.

Bluefield's competitor, GHGSat, has similar goals. The Canadian company, founded in 2011, pioneered private-sector methane monitoring in 2016 by launching a proof-of-concept, 15-kilogram, microwave oven-size satellite — nicknamed Claire. Two more satellites, dubbed Iris and Hugo, are slated for launch in 2020, with more to come to match projected demand.

"We have clear demand for at least 10 satellites, and that's our next step," says company president Stephane Germain.

Both companies plan to collaborate with the Environmental Defense Fund's satellite, called MethaneSAT, targeted for launch in 2022. Unlike the data gleaned by the Bluefield and GHGSat spacecraft, which will be available only to subscribing organizations, MethaneSAT data — and eventually image-processing algorithms and other technical details — will be publicly available for free. The specific purpose of MethaneSAT is to document methane emissions from oil and gas facilities, enabling operators to reduce their emissions, and for regulators and the public to keep track. "Our goal is to quantify emissions from the entire oil- and gas-production sector, which has never been done before," says Ritesh Gautam, a senior physical scientist working on MethaneSAT. In that vein, the Environmental Defense Fund hopes that its satellite will prompt the industry to slash global methane pollution from the oil and gas industry by 45% come 2025.

MethaneSAT will canvass the planet in approximately 200-kilometer-wide swaths, targeting areas of oil and gas production. The satellite's spatial resolution will be about 1 kilometer by 1 kilometer — sufficient to localize a methane "hot spot," though not enough to narrow the source to a specific plume from an oil and gas well pad, say, or an exact site of a pipe leak.

That is where Bluefield and GHGSat come in.

"GHGSat and us, we can zoom in even further and be very granular and specific about what is emitting," Ariel says. The companies have announced their intended spatial resolutions as 20 and 20 meters and 25 by 25 meters, respectively. This level of resolution is sufficient for clients keen on quickly diagnosing and sealing leaks. "A client just needs to know about which well pad or wellhead or storage tank is emitting, and then someone has to go there anyway to fix it," he says.

In effect, MethaneSAT will serve as a wide-angle lens, while Bluefield and GHGSat spacecraft serve as zoom lenses. In this way, all three satellites' makers believe they can continue the positive trend of refining spatial resolution, demonstrated over the brief history of methane detection from space. Timeline-wise, Duren of JPL groups methane detection satellite instrumentation into three generations. The first generation was the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY, or SCIAMACHY, part of the payload aboard the European Space Agency's ENVISAT satellite that launched in 2002 and which offered a coarse resolution of 30 km by 60 km. The second generation of instruments is on satellites still flying. These include the Japan Aerospace Exploration Agency's Greenhouse Gases Observing Satellite, or GOSat, launched in 2009 and which has 10 km by 10 km resolution, as well as TROPOMI, short for TROPOspheric Monitoring Instrument, aboard ESA's Sentinel-5 Precursor, launched in 2017 and whose pixel sizes are 7 km by 3.5 km. "Today, TROPOMI is the state-of-the-art for methane monitoring from space," says Duren.

One destination, different paths

Engineers at Environmental Defense Fund, Bluefield and GHGSat all believe they can monitor methane even better than the satellites that have come before in part due to advances in machine vision and learning algorithms. The three parties are predictably mum on the specifics about their particular algorithms for sorting the methane signal from the noise of other atmospheric gases and especially aerosols, the particulates often associated with methane plumes from oil and gas production. The algorithms additionally factor in variables such as cloud cover and ground reflectivity.

The three satellites also share in common a basic sensing principle of collecting sunlight — specifically, infrared-wavelength light — reflected from Earth's surface that then passes through methane and whatever else happens to be in the air column between the ground and the sensor. Yet all three go about this passive sensing differently.

MethaneSAT will rely on spectroscopy, splitting apart the received light via a grating to tease out the

"OUR GOAL IS TO QUANTIFY EMISSIONS FROM THE ENTIRE OIL- AND GAS-PRODUCTION SECTOR, WHICH HAS NEVER BEEN DONE BEFORE."

— Ritesh Gautam, Environmental Defense Fund

▲ **Two GHGSats** in orbit in an artist's rendering.
GHGSat

telltale infrared absorption signature of methane. The sensitivity goal for MethaneSAT is to measure a 0.1% increase in methane concentrations at ground level — the equivalent of 2 ppb. (For comparison, TROPOMI is sensitive to a 12-ppb increase and SCIAMACHY 30 ppb, Gautam says.) The Environmental Defense Fund contracted Ball Aerospace last September to build the detector instrument, the raison d'être of the approximately 350-kg (770-pound) satellite, whose bus manufacturer has yet to be announced.

GHGSat will also carry a spectrometer, but a newly patented type based on a Fabry-Perot interferometer. A common optical device, the interferometer consists of two parallel planes of reflective material between which incoming light bounces, with a portion of the light filtering through the material with each partial reflection. The upshot is a single beam of light turned into multiple beams that then interfere with each other, producing a distinctive pattern on a detector that indicates (in this case) the identity and quantity of the gas in question. In GHGSat's version of the device, a wide angle of light is accepted, versus the typically isolated single wavelength. As a result, multiple absorption lines are registered by an infrared camera, boosting confidence in a methane detection, Germain says.

Bluefield takes a different approach. Instead of dispersing light, where there is some loss of spectral information, the company's sensor channels reflect infrared light through two glass capsules: one empty and one filled with methane. Correlating the two resulting images allows for matching the methane signature, should it be present in the reflected light, across a complete methane spectral signature of some 20,000 absorption lines, versus the 20 or so lines of other methods, enabling detection of smaller leaks and cutting down on misidentifications, Ariel says. This so-called gas filter technique has a strong heritage, having already flown on a dozen NASA satellites for various gas detection applications. To miniaturize the sensor for a microsat, Bluefield tested prototypes on helicopters and high-altitude balloons. The sensor's

builder and the satellite bus manufacturer have yet to be announced.

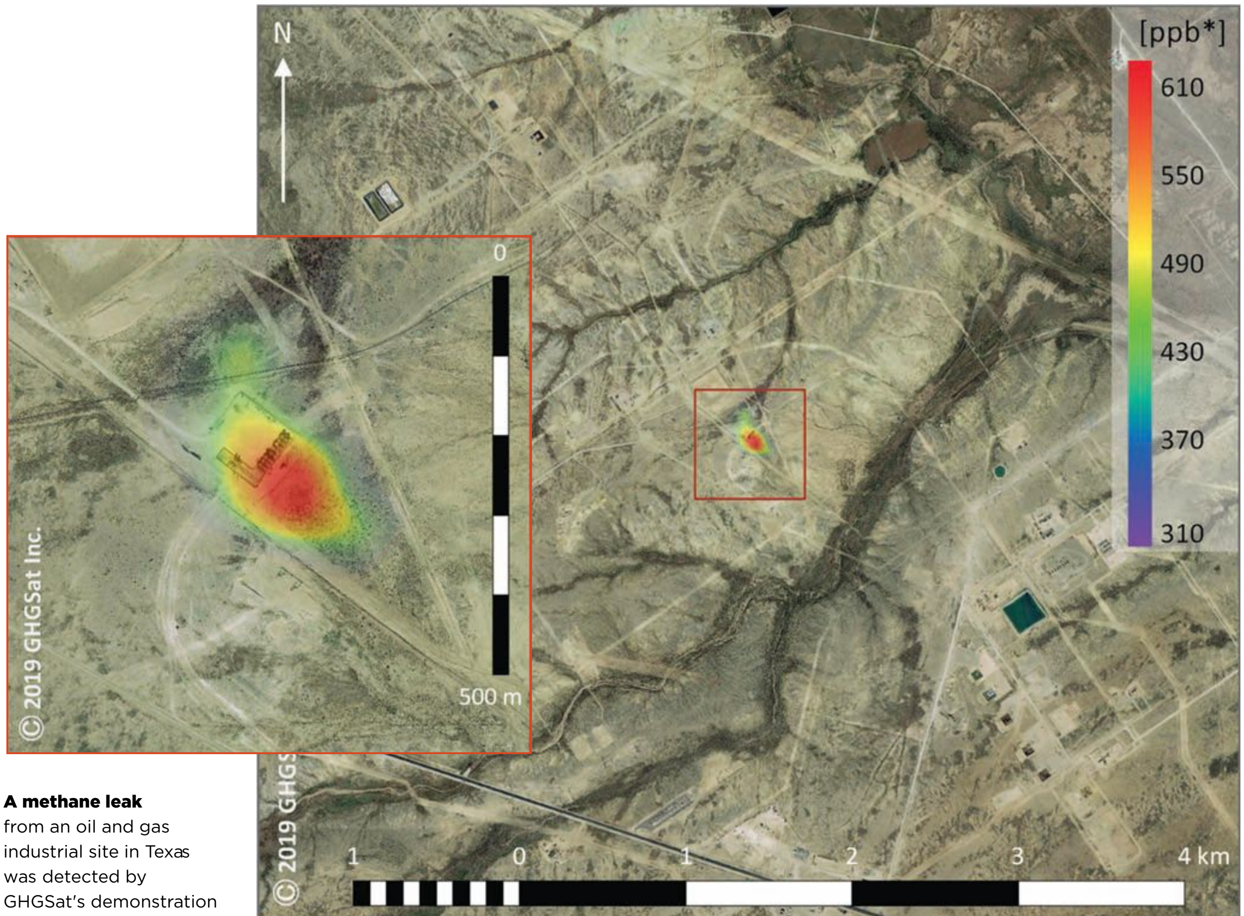
Methaneconomics

All three satellite makers believe the economic motivation for their data will be high. The International Energy Agency, based in Paris, has estimated that the oil and gas industry can cut its global methane emissions by 75%, with as much as two-thirds of that drop achievable at zero net cost, based on the saving of saleable gas otherwise pointlessly lost to the atmosphere.

According to a 2018 Environmental Defense Fund-funded study in Science magazine, in which ground-based measurements were validated by aircraft observations, the leak rate from the oil and gas system within the United States stands at 2.3% — a volume of natural gas valued at $2 billion and enough to supply 10 million homes. Studies from NASA have put that dollar figure even higher, estimating losses from $5 billion to as much as $10 billion annually due to methane leakage.

"WE WANT TO UNDERSTAND THE GLOBAL METHANE BUDGET. THE JURY'S STILL OUT ON WHAT THE EXACT CAUSES ARE OF THE OBSERVED CHANGES IN THE METHANE GROWTH RATE, WHICH IS IMPORTANT FOR UNDERSTANDING THE FUTURE TRAJECTORY OF THE PLANET."

— Riley Duren, University of Arizona and NASA's Jet Propulsion Laboratory



A methane leak from an oil and gas industrial site in Texas was detected by GHGSat's demonstration satellite. The company is targeting potential customers in other sectors, including agriculture and hydropower.
GHGSat

Beyond the oil and gas sector, GHGSat and Bluefield anticipate numerous other customer opportunities. These include coal mining operations with methane venting and seepage; hydropower facilities accounting for methane rising from reservoirs; waste management companies seeking to place gas collectors at landfills; and again, the agricultural sector, from methane emissions-rich rice paddies to dairy producers rolling out new feeds to curtail bovine belching. As the marketplace for satellite-based methane monitoring matures and diversifies, Ariel expects that new sorts of clients will want access, including the investment banks and hedge funds that help finance oil and gas projects.

Climate scientists, meanwhile, will benefit from the deluge of data. Better constraining certain sector emissions could clarify if, as some researchers argue, increasing methane spewing from tropical wetlands — possibly due to feedback from increasing global temperatures — is behind the rising emissions since circa 2006, or whether the advent of fracking, which dramatically boosted natural gas production, is chiefly responsible.

More players will look to get in the game as well. One such interested organization is Planet, a San Francisco-based Earth-imaging company, which the University of Arizona's Duren is advising. Last September, Planet announced, alongside Michael Bloomberg and the state of California, an initiative to develop a new generation of satellite technologies for detecting carbon dioxide and methane. Meanwhile, NASA is working on Geostationary Carbon Observatory, its first satellite to measure methane near Earth's surface, penciled in for an early 2020s launch.

Bluefield's Ariel and GHGSat's Germain say they look forward to seeing increased competition, further stressing that they welcome it even with each other. "As we mature and they mature," says Ariel, "we will see more and more companies go into methane detection. If you look, there are quite a few imaging satellite companies, and they're not saturating the market."

"In the end," says Germain, "I think that all parties serving this market will need to both compete and collaborate in order to achieve the impact we all want: reductions in greenhouse gas emissions on a global scale." ★

PIE FROM THE S

The fact that the skies aren't yet filled with delivery drones is deceiving. The revolution has been slow in coming, but in a few places, it's beginning to happen. Daniel Dubno explores the path ahead for delivery entrepreneurs.

BY DANIEL DUBNO | dan@dubno.com

Drone delivery to consumers once seemed like pie in the sky. Good news: Drones now deliver pie from the sky. Unfortunately, this service only flies to some fjords near Reykjavik during the relatively placid summer months, and the only available pie flavor, I'm told, is rhubarb. To be fair, a wide assortment of other food choices is available for drone delivery from AHA, Iceland's largest e-commerce website, which in 2017 began delivering pies, burgers, beer, pizza, snacks and such via drones supplied by Tel Aviv, Israel-based Flytrex corporation.

Food isn't the only thing coming from the skies. Last October, drones delivered non-prescription drugs and gift items to customers in Christiansburg, Virginia, through a consortium whose members include drone development company Wing (a spinoff from Google's "X" research group), FedEx Express and Walgreens. Just days later, in November, United Parcel Service's Flight Forward drone division and San Francisco-based drone manufacturer and delivery company Matternet flew prescriptions from a CVS store in Cary, North Carolina, to nearby customers too sick to travel to the pharmacy. A few kilometers away, in Raleigh, North Carolina, lifesaving blood and medical supplies now routinely wing their way across the campus of WakeMed Hospital. Drone delivery services have also sprouted up in Australia, China, Finland, Ghana, Rwanda, Switzerland and the United Kingdom.

Yet when you hear rotor blades humming, do not assume the rotors beating beat for you. At least, not yet. What unites these delivery services is that each is either a test or a limited initial commercial service approved under conditions carefully proscribed by aviation regulators. The U.S. is a particularly sought-after market due to its strong consumer culture, but visions of drones plying the skies like FedEx or UPS trucks remains a lofty goal.

The barriers to routine deliveries in the U.S. are complex but can be summarized simply. "First, safety has to be the priority, and second, the interaction with the public and public acceptance has to be positive," says Mark Blanks, who directs the Virginia Tech Mid-Atlantic Aviation Partnership. Virginia Tech is a collaborator within the state of Virginia's experimental drone delivery test effort, approved by the FAA, that includes Wing, FedEx Express, Walgreens and others.

Now, after a slow start and a nudge from Congress, the FAA is working side by side with drone makers, delivery companies and NASA technologists to assure that these aircraft won't pose unacceptable risks to the public, whether they be on the ground or aboard other aircraft flying at low altitudes.

Taming the "Wild West"

In a memorable appearance on "60 Minutes" in 2013, Amazon CEO Jeff Bezos predicted that autonomous deliveries were probably "four or five

years away." He allowed the public to see several drone delivery prototypes in flight and confidently envisioned that legions of drones would soon whisk Amazon packages through the skies. Bezos was right about the timing of the first test deliveries but was overly optimistic about when drone deliveries would become widespread in the United States. Bezos' genius for predicting future trends did not help him foresee challenges autonomous delivery drones would create for government regulators.

Consider the 2016 Consumer Electronics Show in Las Vegas that I attended. The lower-floor convention hall overflowed with every imaginable variation of drone design, including some to carry packages for the exploding web economy. Amid this hubbub of whizzing rotors, the small section where the FAA had set up an information zone in the Las

▼ Food is loaded into a box, below left, so that a drone can carry it to golfers at the King's Walk golf course in North Dakota.

Flytrex

Vegas convention hall was conspicuously quiet. The electronics industry was selling a drone-filled "Wild West," but few flocked to the FAA booth for advice, and the government sheriffs of air safety showed little outward evidence of being swept up by the fervor and emotion of it all.

Behind the scenes, however, the FAA was being pressured to solve some tricky problems. Four years earlier, influence from drone operators had led Congress to pass the FAA Modernization and Reform Act of 2012 (signed by President Barack Obama) that instructed the FAA to establish regulations to permit commercial drone flights. One problem was that these craft tend to be larger than consumer drones, making them potentially lethal. The FAA had to figure out how to deconflict thousands of future flights to avoid collision and catastrophe. A particular worry was that delivery drones might crash into each other or other low-flying aircraft, such as tour helicopters, crop dusters or airplanes taking off or landing.

In February 2016, a month after that CES show, additional pressure from companies including Amazon and Google led the FAA to draft guidelines for regulating safe commercial drone flights above populated areas. During the summer of that year, the FAA released Part 107 of the Federal Aviation Regulations, which established rules for operating nonhobbyist drones weighing less than 55 pounds (25 kilograms). Flights were limited to daylight or twilight hours in the visual line of sight of an operator and no higher than 400 feet, but the rules also provided an opening for the drone visionaries. The FAA pointed out to me that these rules continue to provide "flexibility for the FAA, at its discretion, to waive some limitations." In fact, the agency has pages and pages of waivers, including approvals for police departments and film crews to fly at night with ground observations over specific areas.

Nevertheless, the limits ruled out an immediate explosion of services like those envisioned by Bezos and others. To give the sector a boost, the Trump White House in 2017 issued a memorandum to Transportation Secretary Elaine Chao instructing the FAA to establish Unmanned Aircraft Systems Integration Pilot Programs. Participants in these IPPs are making limited commercial test deliveries and other flights at sites across the United States. Initially, 10 regional IPPs were selected, comprised of state agencies, drone manufacturers, flight companies and other businesses. One IPP consortium dropped out, leaving nine programs. Flytrex, participating in North Carolina's IPP, estimates it will

▲ **This Prime Air delivery** drone lifts off vertically and then its protective shroud and propellers shift for horizontal flight.

Amazon

▼ **A prescription is** loaded on a drone in Cary, N.C., as part of a trial involving UPS Flight Forward and CVS. The prescription was delivered to a customer.

UPS

▲ **Drone-maker Wing** collaborated with FedEx on package delivery.

Wing

deliver takeout food by drone beginning in the first few months of 2020, within the suburb of Holly Springs.

Failing safely

Regulators have been concerned about what would happen if a drone's battery failed in flight or the craft experienced a catastrophic loss of control or a package came untethered. A commercial delivery drone weighing up to 25 kilograms and falling from hundreds of feet would likely damage property and possibly injure or kill people. Even a small package from a significant height could be lethal. Six years ago, in Jersey City, New Jersey, a construction worker's tape-measure weighing just half a kilogram reportedly fell from 500 feet and killed a person standing underneath.

Commercial drone manufacturers developed redundant batteries, installed multiple navigation computer sensors and control chips, and designed software to detect failure and make the craft automatically land safely in such circumstances. For its delivery service, Flytrex modifies commercial DJI Matrice 600 Pro drones, originally designed for aerial photography. Although the top-of-the-line drone already incorporates a wide range of safety technologies, Flytrex customized an automatic parachute as well. Though eager to keep details from competitors, Flytrex's co-founder Yariv Bash says, "Our independent system identifies when the drone is flipping or falling and then cuts off the motors and ejects the parachute."

Beginning in 2003, and throughout the evolution of commercial delivery drone design, standards organization ASTM International's Committee on Unmanned Aircraft Systems suggests safety technologies for delivery drones. They include software, control systems, battery designs, manufacturing methods and parachute safety mechanisms that experts from the standards group believe should be on such drones. Bash says the specter of delivery drones falling from the sky needs to be placed in perspective. "Remember that any alternative, which usually includes a human driving a 1-ton car, is much more dangerous," he says.

Perfection is no more possible for drone deliveries than in other forms of air travel. In at least one case, another parachute design did not work as planned. Last May, a 22-kg Matternet delivery drone, operated by Swiss Post, crashed 50 meters from a group of children in a wooded area of Zurich, after reportedly having been buffeted by wind gusts. Swiss Post, the national postal service, which was routinely delivering medical supplies by drone, temporarily suspended the service after the failure, although no injuries were reported. An investigation determined the parachute failed as it was deployed when a connecting rope was severed. Future Matternet drones, according to media reports, will be securely connected to their parachute by two ropes reinforced with

metal braiding. The drone's existing emergency landing whistle will also be made louder.

▲ **A drone tested** at a North Dakota golf course.

Flytrex

Exploding demand

The drone tidal wave is building. The FAA has so far registered about 1.5 million small unmanned aircraft, including some delivery drones, an FAA official tells me, and demand is building for even more aircraft. Each of these drones must give other aircraft wide berth, avoid private planes, low-flying gliders, free-flying balloons and erratic medevac operations.

Given the expected volume of flights, automated management will be essential. The FAA devised an early version of such an automated management strategy to cope with the many requests to permit commercial drones, and now also recreational drones, to fly in the controlled airspace near 600

"First, safety has to be the priority, and second, the interaction with the public and public acceptance has to be positive."

— Mark Blanks, Virginia Tech Mid-Atlantic Aviation Partnership

airports. The core of the strategy is the Low Altitude Authorization and Notification Capability, an online portal backed by computers and software that authorizes or rejects a requested route in seconds. Those requests don't go directly to LAANC (pronounced "lance") or the FAA, however. A drone operator logs onto an app provided by one of 13 unmanned aircraft service suppliers, which are companies authorized by the FAA to manage requests that are analyzed by the LAANC computers. Drone operators, the FAA and others can also see real-time flight tracks displayed on these apps.

Beyond the drone realm, the FAA is shifting to a next-generation air traffic control strategy of computerized guidance that will permit controllers to reduce separation among passenger and commercial aircraft in the air and on the ground. Drones, however, won't get that same human touch as the FAA expands LAANC and what the agency calls a "complementary" concept known as UTM, short for Unmanned Aircraft Systems Traffic Management. NASA's Ames Research Center in Silicon Valley is developing a research version of UTM for the FAA to demonstrate automatic management of drone flights beyond visual line of sight or in airspace outside the purview of air traffic controllers. UTM also will rely on private service suppliers under a business plan to be decided.

Ron Johnson, project manager at Ames, suggests that UTM drone operations could someday incorporate "localized weather predictions into flight planning, using cellphone networks to enhance drone traffic communications, relying on cameras, radar and other ways of seeing" to ensure drones fly safely.

For UTM to work, drone operators and the FAA need to know who is flying where. One reason is deconfliction, but the FAA also wants to distinguish "good drones" from "bad drones," one FAA official says, referring to the possibility of a drone controlled by terrorists attempting to deliver bombs or toxins.

▼ **A prescription is** delivered to a customer's home in the North Carolina trial.

UPS

This led the FAA to release a proposed rule in December that would require drones to transmit their unique serial numbers and locations with a time stamp over the internet from takeoff through landing. Under this Remote ID rule, a separate category of Remote ID service suppliers authorized by the FAA would receive this flight data in real time from subscribing drone operators.

The FAA is receiving pushback to this proposed rule and as of late January had received 6,000 comments during the public response period that runs through March 2, an FAA official says. The FAA official notes that public input prompted changes to Part 107 when it was proposed, suggesting that a final Remote ID rule might look quite different.

The FAA drafted the rule recognizing that privacy would be an issue. If an operator wanted to keep a customer's flight confidential, the service supplier would generate a random code to conceal the aircraft's identity to all but the FAA and law enforcement authorities. Data privacy is a related concern, because the service suppliers would be required to store drone flight data for six months in case authorities need to review it to hold a reckless drone operator accountable.

The expense of internet connectivity is another issue. DJI, the world's largest consumer drone maker, in January published a critique on its website, saying the FAA "has proposed a complex, expensive, and intrusive system." DJI wants the FAA to shift to requiring radio broadcasts from the drones, saying this technology would be "cost-free and easy-to-use."

For these and other reasons, drone delivery has rolled out more slowly than the visionaries hoped. Looking out my Manhattan window right now, not a single drone is in sight. But the evidence shows that this revolution is indeed coming.

When I was young, we waited sometimes for hours on the beach in Coney Island for the Good Humor man. Eventually, you would see him lug a box of ice cream bars across the sand and he would deliver joy. There is a sunny day coming, when someone on the beach will say, "Kids, look to the sky!" Down a line will come bars of ice cream and perhaps, for me, a banana split with three scoops, whipped cream, strawberry syrup, just like I ordered it. Plus, a spoon. ★

"Our independent system identifies when the drone is flipping or falling and then cuts off the motors and ejects the parachute."

— Yariv Bash of Flytrex

▼ A drone delivers a package in Iceland.
Flytrex

FUTURISTIC FLOW CON

For the history of fixed-wing flight, pilots have controlled their aircraft by moving flight control surfaces into or out of the air rushing by their craft. DARPA thinks there's a better way, and with help of aerodynamicists and an X-plane, it aims to prove it. Jan Tegler tells the story.

BY JAN TEGLER | wingsorb@aol.com

TROL

The red lines down the center of the vertical tail of Boeing's ecoDemonstrator 757 are active flow control actuators. The flight test was part of NASA's Active Flow Control Enhanced Vertical Tail Flight Experiment.

Boeing

Replacing flaps, rudders, elevators and ailerons with electrodes or other devices to create targeted currents of air could give aircraft designers new flexibility and enhance fuel efficiency. Over the decades, researchers in the U.S. and abroad have tested a variety of such concepts in labs, wind tunnels and cautiously on aircraft.

Now DARPA is searching for a team to build an X-plane that will maneuver primarily with this kind of control.

The program is called CRANE, short for Control of Revolutionary Aircraft with Novel Effectors. Announced by DARPA last August, the goal is to fly a conventionally piloted or unmanned X-plane by fiscal 2024. Later this year, competitors from industry and academia will hear whether they have been selected to participate in a $21 million conceptual design phase. One or two of those winners will be invited to continue working beyond this initial phase, and in 2022 DARPA plans to select a single team to build and fly the X-plane.

The new control technology could empower designers to create aircraft with seamless outer mold lines, meaning without moveable flight control surfaces and the gaps, hinges and rivets that come with them. These create drag, hamper fuel economy and increase the radar cross section.

DARPA doesn't want to push the competitors toward a specific design for the X-plane, however. "I purposely haven't shown cartoons of a nominal airplane because I didn't want people to lock into a picture or concept," says DARPA's Alexander Walan, the aerodynamicist who directs the CRANE program.

▼ **A closeup of the** Magma experimental drone on the runway.
BAE Systems

“I purposely haven’t shown cartoons of a nominal airplane because I didn’t want people to lock into a picture or concept.”

— Alexander Walan, director of DARPA’s CRANE program

As far as the public record shows, no one has flown a full-sized aircraft with one of the new technologies as its primary means of directional control. Doing so in four years will be a big challenge, and Walan says that’s the point.

“I would argue that if it had been done, DARPA wouldn’t be interested,” he says. The word “Revolutionary” in the CRANE name refers partly to the fact that flying without mechanical control surfaces “allows you to think about shapes that aren’t necessarily classic aircraft shapes,” he adds.

The trick for CRANE will be demonstrating the effectiveness of the new approach in the real world, not just in wind tunnels, on small scale models or in cautiously orchestrated flight tests.

DARPA would not identify the competing teams, but aerodynamicists and engineers affiliated with some competitors agreed to speak to me about technologies that could end up on the X-plane.

Basic principle

The new approaches have come to be collectively known as active flow control, or AFC, although technically speaking conventional flight control surfaces also perform active flow control. The various technologies distort the flow around the vehicle to achieve control without changing the shape of the vehicle. Fundamentally, the techniques “generate forces and moments that can help maneuver the vehicle,” explains Michael Amitay, director of the Center for Flow Physics and Control at Rensselaer Polytechnic Institute, who is on one of the teams.

Consider, for example, how a conventional aircraft performs a roll. Traditionally, that would be done by employing ailerons. Raising an aileron on one wing decreases lift while lowering the aileron on the other increases lift. The difference in lift causes the airplane to roll. “If you want to do that with AFC, on one side you can accelerate flow and on the other side you can decelerate flow,” Amitay explains.

With AFC, momentum might be added to the airflow at a specific location on a wing or fuselage by blowing air into the flow out of orifices in the fuselage. Conversely, momentum could be subtracted by sucking air out of the flow. Blowing and suction can also create or shape aerodynamic wakes that Amitay describes as virtual control surfaces.

“On one wing you blow a jet of air that moves the wake downward,” Amitay says. “On the other side you blow a jet to move the wake upward — virtual ailerons.”

Blowing can create virtual elevators and flaps too. If the wings have rounded trailing edges, air will follow their curvature, a tendency known as the Coanda Effect. Blow air over the top of a rounded trailing edge and you create a downward wake. Blow

▲ **Tufts to indicate wind** flow are attached to the surface of a full-size tail of a 757 commercial airliner that has been equipped with air-blowing orifices called sweeping jets that blow air across the rudder surfaces.

NASA

air from below and you create an upward wake. The wakes can change the pitch of an aircraft, raising or lowering its nose just as flaps and elevators do.

Left or right yaw motion, produced by rudders on conventional aircraft, is harder to create with AFC, but it can be done by vectoring the thrust of an engine. “Picture exhaust gases coming out from a jet engine,” Amitay says. “You can blow or pull the exhaust gas to one side or the other side and manipulate it.”

Imagine a plane flying at an angle steep enough to cause the air flowing over it to separate from its wings or body. This can lead to a stall, but “if you can activate something that is a local disturbance, like a jet of air that adds momentum, that can cause the flow to reattach. That’s active flow control,” Amitay says.

Also, air flowing around a vehicle exhibits variations in density, pressure, velocity and temperature. Engineers are learning to tap these instabilities with their AFC technology. “We can change lift and drag significantly by amplifying or diminishing natural instabilities,” says aerospace engineer Mo Samimy of Ohio State University’s Aerospace Research Center, which is also part of a team proposing for CRANE.

An example would be the transition from laminar flow to turbulent flow caused by instabilities. An aircraft might trigger or suppress this transition with synthetic jets, depending on what the pilot wants the aircraft to do. Suppressing instabilities on one wing, but not the other, would induce a roll or cause the nose to rise, depending on the combination of jets that were fired, says Matthew McCrink, a colleague of Samimy’s and a research scientist at Ohio State.

The options

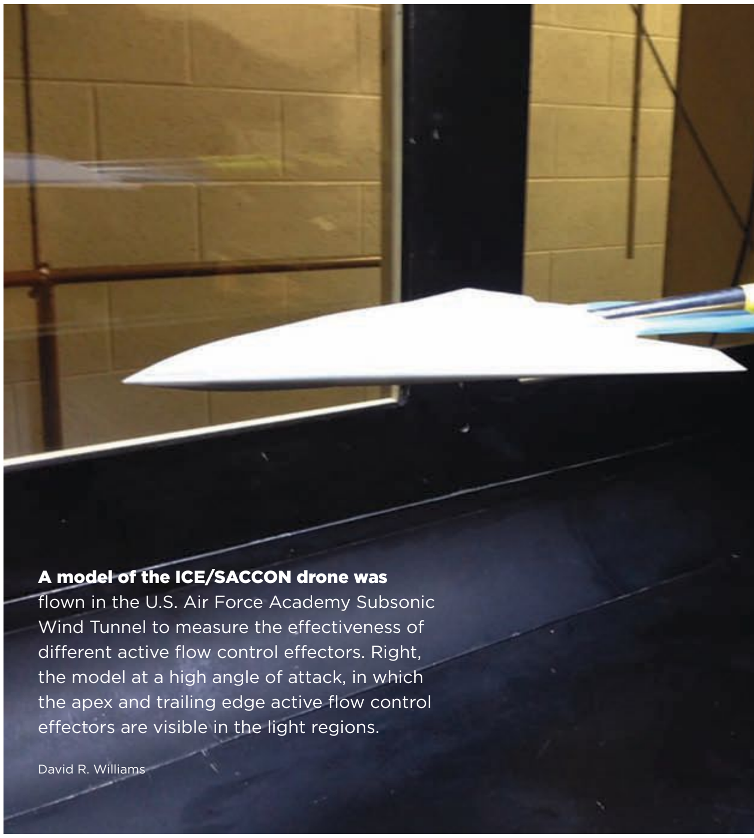
Fluidic oscillators are one kind of active flow control actuator. Small quantities of air are funneled internally from the aircraft’s engines to orifices — slots, trapezoids or other shapes — in a process known as bleed air extraction. This air is injected into the flow at various locations on an aircraft.

Two separate teams of researchers within the NATO Applied Vehicle Technology Task Group tested this technique on experimental drones for directional control. In 2018, Lockheed Martin Skunk Works flew a drone called ICE, short for Innovative Control Effectors. Last year, BAE Systems and the University of Manchester flew their Magma drone. Each blew air through slots in the trailing edges of their wings to maneuver. Magma also blew air into its engine exhaust nozzle from small jets to vector thrust for maneuvering.

The only full-sized aircraft known to have tested modern AFC was the Boeing-NASA ecoDemonstrator 757 that was flown in 2015. Devices called sweeping jets blew compressed air from the auxiliary power unit in the rear of the fuselage in arcs across the plane’s vertical tail in an attempt to improve aerodynamic efficiency. “You have steady air coming into these orifices that are shaped almost like a trapezoid. They’re designed in a way that it causes the flow to move side to side at high frequency, sweeping a larger area than a steady jet will, and that makes it more efficient,” Amitay says.

The concept is similar to the windshield fluid nozzles on cars, says Jim Gregory, director of Ohio State University’s Aerospace Research Center. “Instead of emitting a steady stream, they spread the fluid out over a much wider area. We can use the exact same geometry and apply that to flow on an aircraft.”

Then there are synthetic jets, so called because they create streams of air artificially with electronics, rather than with air bled from an engine or another source of compressed air. The design details vary, but millimeter-wide holes would be arrayed



A model of the ICE/SACCON drone was flown in the U.S. Air Force Academy Subsonic Wind Tunnel to measure the effectiveness of different active flow control effectors. Right, the model at a high angle of attack, in which the apex and trailing edge active flow control effectors are visible in the light regions.

David R. Williams

on the surface of the aircraft, and those holes open into centimeter-wide cavities, each with a thin metallic diaphragm at the bottom. Voltage can be turned on and off rapidly to each diaphragm, or in some designs the polarity can be reversed. This makes the diaphragm oscillate inward and outward. When the diaphragm shifts inward, the vacuum effect draws air in through the hole, and when it shifts outward, air is expelled into the flow. "These really do work almost exactly like your lungs and diaphragm," says McCrink of Ohio State.

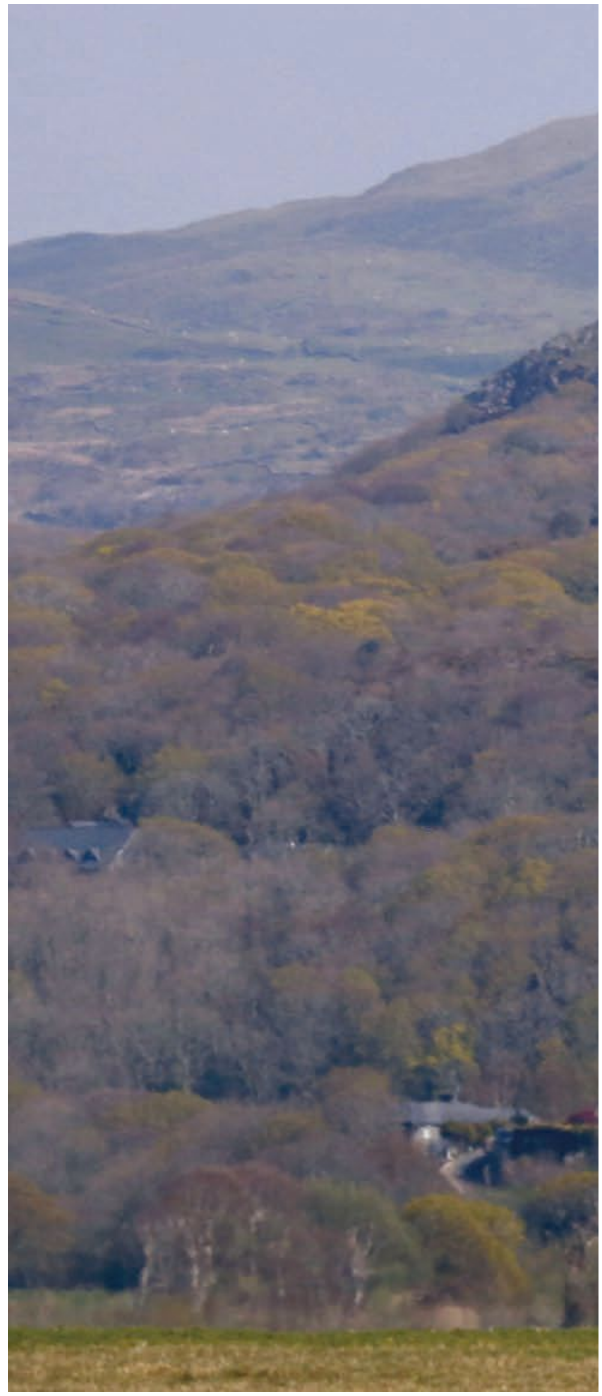
Yet another option are plasma actuators that discharge pulses of electricity into the air through electrodes. Heat from the electricity turns the air into plasma that interacts with the instabilities in the flow. "We generate perturbations with [the] right frequency range and let the instabilities amplify the perturbations so that we can manipulate the flow and change it the way we desire," explains Samimy of Ohio State in an email. He has been experimenting with two types of plasma actuator, one that pulses up to 20,000 times a second and another that pulses up 200,000 times a second. "Higher frequency doesn't mean it's better," he cautions.

"Initially we tried using as many actuators as we could. One of the Boeing people asked what happens if one of the [actuator] jets fails in flight? So we turned every other jet off and performance went up. This knowledge helped us minimize the number of jets and save power."

— Michael Amitay, Rensselaer Polytechnic Institute

Time to fly

DARPA believes the time is right for the boldest AFC test yet.



An engineer braces himself against strong winds inside the National Full-Scale Aerodynamic Complex at NASA's Ames Research Center in California. He is holding a wand emitting smoke to visualize "in flight" air flow across a full-size airliner tail.
NASA

Researchers have managed to create AFC actuators that require less electricity or bleed air to achieve the same effects. "You simply could not integrate an AFC system onto most aircraft when you're using 10% [of available aircraft electricity or bleed air]," notes Daniel Miller, senior fellow for Air Vehicle Systems and Sciences at Skunk Works. "As we're now looking at 1%, things are starting to snap into place quite nicely."

Amitay of Rensselaer recalled his participation in the Boeing-NASA ecoDemonstrator project: "Initially we tried using as many actuators as we could," he says. "One of the Boeing people asked what happens if one of the [actuator] jets fails in flight? So we turned every other jet off and performance went up. This knowledge helped us minimize the number of jets and save power."

The newest techniques for AFC, including synthetic jets and plasma actuators, have only been tested in wind tunnels or computer simulations. AFC enabled by bleed-air extraction has flown but only on relatively small unmanned aircraft. Researchers don't yet know how effective AFC will be when incorporated on larger aircraft that must fly with a range of aerodynamic loads in varying atmospheric and electromagnetic conditions.

Samimy notes that electromagnetic interference from plasma actuators could interfere with aircraft electronics and that heat, cold, rain, ice or snow can affect the orifices that most actuators employ.

With these and other challenges to be overcome, Walan acknowledges that a CRANE X-plane might only demonstrate AFC in specific portions of the vehicle's flight envelope. "Some of the potential benefits of AFC on a tailless airplane, for example, might be significantly reduced takeoff or landing roll. That might be part of a demonstration. Or perhaps someone wants to do a combat drone approach at a higher Mach number. They may have conventional surfaces for takeoff and landing and use AFC to enhance maneuverability up and away."

Miller of Skunk Works says an attention grabber would be "something done on a next-generation tailless platform demonstrating appropriate levels of directional control power in a mission scenario."

The prospect of a tailless aircraft with a seamless outer mold line and its stealthy advantages are never far from a conversation about the CRANE program. But Miller points to the importance of redundant flight control systems for a demonstration's flight safety. "My feeling is that AFC will provide

the directional control power but you'll have on board some kind of redundant conventional flight control system present for a back-up mode."

He adds that efficient actuators paired with sensors and control algorithms capable of managing their operation will be needed to create designs that incorporate AFC for full-spectrum maneuvering.

Walan describes this challenge as closing the flight control loop, and he says more work lies ahead to achieve that. "Every time you deflect a traditional control surface 2 degrees it always has the same effect, and we have decades of experience with them," he notes. "With AFC, if you have multiple controllers, the order in which you turn those on and off, and the flight conditions — there's a lot more variability,"

DARPA has stressed the use of existing subsystems such as engines, wheels and brakes to simplify the design of an AFC X-plane, noting that the 2024 first-flight goal doesn't leave much time to invent new ideas or refine actuators. Walan suspects the X-plane will be subsonic due to the complexities of shock waves that come with supersonic flight.

Ohio State's McCrink concludes that the expression "DARPA hard" applies to CRANE and active flow control but says it's the "right type" of ambition. "If you shoot the moon on this one, I think you'll hit it." ★

▲ **The Magma** experimental drone flies with a type of active flow control called fluidic oscillators.

BAE Systems

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Calendar

FEATURED EVENT

5–7 MAY 2020

Laurel, MD

This Secret/NOFORN event provides a venue for leaders from government, military, industry, and academia to advance and accelerate modernization, informed by the Office of the Under Secretary of Defense for Research and Engineering's priorities.

aiaa.org/defense

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2020			
7–14 Mar*	2020 IEEE Aerospace Conference	Big Sky, MT (aeroconf.org)	
10–12 Mar*	23rd AIAA International Space Planes & Hypersonic Systems and Technologies Conference	Montréal, Québec, Canada	22 Aug 19
18 Mar	AIAA Congressional Visits Day	Washington, DC	
20 Mar–17 Apr	Fundamentals of Airplane Performance, Stability, Dynamics, & Control Online Short Course	Online (aiaa.org/events-learning/online-education)	
23–25 Mar*	55th 3AF Conference on Applied Aerodynamics — "Turbulent Flows in Aerodynamic Applications"	Poitiers, France (http://3af-aerodynamics2020.com)	18 Nov 19
24 Mar–12 May	Design of Modern Aircraft Structures Online Short Course	Online (aiaa.org/events-learning/online-education)	
27–28 Mar	Region III Student Conference	Columbus, OH	31 Jan 2020
27–28 Mar	Region IV Student Conference	Stillwater, OK	31 Jan 2020
28–29 Mar	Region VI Student Conference	Portland, OR	3 Feb 2020
2–3 Apr	Region V Student Conference	Wichita, KS	15 Feb 2020
3–4 Apr	Region I Student Conference	State College, PA	16 Feb 2020
6–7 Apr	Region II Student Conference	Tuscaloosa, AL	21 Feb 2020
16–19 Apr	AIAA Design/Build/Fly Competition	Wichita, KS (aiaa.org/dbf)	
21–22 Apr*	AIAA SOSTC Improving Space Operations Workshop 2020	Suitland, MD (https://isow.space.swri.edu)	
5–7 May	AIAA DEFENSE Forum	Laurel, MD	8 Oct 19
8 May	Trusted Autonomous Systems Course	Laurel, MD	

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

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	6th AIAA Workshop on Benchmark Problems for Air Frame Noise Computations (BANC-VI)	Reno, NV	
13–14 Jun	Design for Advanced Manufacturing: Aviation Lightweighting Course	Reno, NV	
13–14 Jun	Design of Unmanned Aircraft Systems Course	Reno, NV	
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	14 Feb 20
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	Las Vegas, NV (ascend.events)	17 Mar 20
2021			
11–15 Jan	AIAA SciTech Forum	Nashville, TN	8 Jun 20

● AIAA Continuing Education offerings

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

AIAA Announces Its Class of 2020 Fellows and Honorary Fellows

AIAA has selected its Class of 2020 AIAA Fellows and Honorary Fellows. The new Fellows and Honorary Fellows will be inducted on 19 May and then recognized on 20 May at the AIAA Aerospace Spotlight Awards Gala at the Ronald Reagan Building and International Trade Center in Washington, D.C.

Honorary Fellow is the highest distinction conferred by AIAA and recognizes preeminent individuals who have had long and highly contributory careers in aerospace and who embody the highest possible standards in aeronautics and astronautics.

The 2020 Honorary Fellows are:

Robert D. Briskman, Telecommunications Engineering Consultants
Wesley G. Bush, Northrop Grumman Corporation (retired)
Jason L. Speyer, University of California, Los Angeles

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

The 2020 Fellows are:

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, Laboratoire EM2C - CNRS
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

In 1933, Orville Wright became AIAA's first Honorary Fellow. Today, AIAA Honorary Fellows and AIAA Fellows are the most respected names in the aerospace industry. For more information on AIAA's Honors Program, or the AIAA Honorary Fellows or Fellows Program, please contact Patricia A. Carr at 703.264.7523 or patriciac@aiaa.org.

2020 AIAA Election Results

AIAA is pleased to announce the results of its 2020 election of Chief, Regional Engagement Activities Division (READ) and Chief, Technical Activities Division (TAD). The Chief, READ, was elected by the regional directors. The Chief, TAD, was elected by the technical group directors and the division committees.

Regional Engagement Activities Division

Daniel T. Jensen, *Rolls-Royce Corporation*

Technical Activities Division

Jeffrey W. Hamstra, *Lockheed Martin Corporation*

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

2020 International Student Conference Winners Announced

The AIAA International Student Conference took place on 6 January in conjunction with AIAA SciTech Forum. Students who won first place at one of the 2019 AIAA Regional Student Conferences presented their papers at this professional technical conference, which offers students a chance to showcase their research at an event where they can also network with potential employers and colleagues. The winners were announced at an awards breakfast on 7 January.

Undergraduate Category

Collin O'Neill, Ohio State University, "Active Flow Control in a Compact High-Speed Inlet/Diffuser Model"

Master's Category

Stephanie Cottier and Christopher Combs, University of Texas at San Antonio, "Spectral Proper Orthogonal Decomposition Analysis of Shockwave/Boundary Layer Interactions"

Team Category

Kunal Gangolli, Athreya Gundamraj, Wyatt Hoppa, and Shrivathsav Seshan, Georgia Institute of Technology, "Implementation and Verification of a Versatile GN&C and Flight Software Architecture for an Active Control Launch System"

Dates for the 2020 Regional Student Conferences can be found on the Calendar (pp 48–49). For more information about the student conferences, contact Michael Lagana at michaell@aiaa.org or 703.264.7503.

Thank you to Lockheed Martin Corporation for sponsoring the 2020 conference.

LOCKHEED MARTIN

Diversity Scholars

Fifteen AIAA Diversity Scholars attended AIAA SciTech Forum, 6–10 January 2020. The AIAA Diversity Scholarship aims to directly combat underrepresentation in the industry by providing students from underrepresented groups the opportunity to attend AIAA forums and receive additional targeted programming that may help them succeed in the aerospace industry.

This program is a collaboration of the AIAA Foundation and the sponsor Aurora Flight Sciences. Scholars, seen above with Aurora Flight Sciences representatives, attended the plenary, Forum 360, and technical sessions, as well as the Rising Leaders in Aerospace events and other special sessions geared specifically for the scholars.

Diversity scholarships will be offered for select AIAA forums throughout the year. The scholarship welcomes applications from students in all disciplines with an interest in aerospace, including but not limited to STEM fields, communications, law, industrial design, journalism, and political science. Please visit **aiaa.org/Diversity-and-Inclusion** for more information.

The Class of 2020 AIAA Associate Fellows were inducted at the AIAA Associate Fellows Induction Ceremony and Reception on 6 January at the Hyatt Regency Orlando in conjunction with AIAA SciTech Forum.

2020 AIAA Key Issues and Recommendations

The aerospace and defense (A&D) industry is critical to our nation's well-being, providing major contributions to education, our economic prosperity, our national defense and homeland security, and our quality of life. A&D professionals are conducting research and working on initiatives that will soon return American astronauts to the moon and then on to Mars, growing a commercial space economy, integrating UAS more effectively into the national airspace, developing new supersonic aircraft, and modernizing our hypersonic capabilities among many other critical endeavors. There is much to be excited about and it is imperative for government, industry, and academia to continue working together to imagine and create capabilities that transform our society.

According to the Aerospace Industries Association, in 2018 the A&D sector:

- Received $105.9 billion from the federal government for research and development
- Supported more than 2.5 million jobs (881,575 directly employed, 1.67 million in the supply chain), representing nearly 20 percent of the nation's manufacturing workforce
- Generated nearly $929 billion in economic output, of which $459 billion is attributed to the industry's supply chain
- Created $348.3 billion in value-added goods and services, contributing $324 billion to the U.S. GDP
- Paid out $237 billion in wages and benefits, with an average wage of $92,742
- Exported $151 billion in goods, with a positive trade balance of $89.5 billion (reducing the U.S. trade deficit by 10 percent)

AIAA, the world's largest aerospace technical society, urges lawmakers to enact and sustain policies that will enhance a robust and world-leading A&D sector. We strongly believe the accompanying key issues and associated actionable recommendations are crucial to the continued health of our industry, as well as the continued competitiveness, security, and growth of our nation.

As we strive to represent our nearly 30,000 individual members, 95 corporate members, and the broader aerospace community, we welcome and encourage feedback—our objective motive is to strengthen the profession and serve as a valued resource for decision makers.

Funding Stability and Competitiveness

The A&D industry has experienced growth in recent years because of a strong commercial market and increased government spending; however, major challenges exist because of mounting budget deficits, trade policy uncertainties, a lengthy acquisitions process, and foreign competitors investing heavily in military modernization, commercial development, and scientific research. The current unpredictable fiscal environment creates short-term perspectives, which increase the risk of the delay of new aerospace initiatives and the curtailment or termination of important programs. The technologies and products developed for A&D applications have been at the heart of the American technology boom driving significant improvements to economic growth and quality of life. A return to a regular appropriations process – last accomplished in the late 1990s – coupled with a long-term perspective is needed immediately so that the nation can best plan for and execute initiatives critical to a secure and economically robust future.

Recommendations:

- Provide sustained investment for foundational and applied research in federal laboratories and universities at levels consistent with maximizing economic growth and technological leadership – this early investment is necessary to deliver new technologies within 5–10 years.[1]
- Provide the DOD with stable and predictable funding that supports efficient and effective multi-year acquisitions and operations.
- Streamline the certification and defense acquisition processes by tailoring oversight requirements to risk.[2,3,4,5]
- Provide long-term authorizations and appropriations to fund all NASA directorates properly in a balanced and predictable manner to meet short- and long-term program and mission requirements.
- Accelerate the establishment of policies for advancing the development and integration of new aerospace technologies into society, such as drones and supersonic aircraft.[2,6]
- Expand support for small businesses to foster technical innovation and facilitate the transition of those new products up the supply chain to support civil and military capabilities.
- Continue to review and roll back restrictive export controls that hinder U.S. A&D global competitiveness.

R&D and Innovation

Since the dawn of aviation and through the advent of the space age, the United States has been the world leader in aerospace technologies. The federal government has played an important role in supporting research and development (R&D) efforts by academia, industry, and government labs leading to a myriad of scientific discoveries and innovations.[1] While there has been a recent uptick in federal funding for R&D and the United States still represents nearly half of global aerospace R&D spending, our foreign competitors continue to invest significantly in technologies critical to aerospace and defense. Sufficient and sustained R&D investments are therefore crucial to maintain our preeminence in this sector and to create more high-paying jobs.

Recommendations:

- Support robust, long-term federal civil aeronautics and space research and technology initiatives1 funded at a level that will ensure U.S. leadership.
- Invest in computational modeling and simulation technologies, as well as experimental ground and flight-testing capabilities, to advance basic and applied research and development of new military and commercial products.
- Ensure sufficient and stable funding for federal programs in critical areas to accelerate innovation and technology transition to operational applications.
- Create programs that enable greater interaction and cooperative arrangements between federal research laboratories, academia, and industry to foster innovation and growth.
- Offer incentives for research by large corporations and small businesses including the commercialization of that research into new products and services.
- Streamline the government A&D product development process by tailoring risk acceptance to better align with timeliness and lifecycle cost management.
- Ensure that federal agency R&D budgets provide sufficient funding to maintain long-term U.S. technical leadership in critical areas such as autonomy, hypersonics[4], and space.
- Re-energize the Small Business Innovation Research (SBIR) program with adequate funding and adequate government resources to execute the Commercialization Readiness Program, emphasizing new initiatives that address barriers in bringing SBIR/STTR technologies to the marketplace.

Workforce Development and Enhancement

The U.S. A&D sector enjoys a prominent position in terms of global competitiveness and technical superiority; however, the sector faces a skills gap that will threaten our future standing in the world. A large percentage of the workforce is or will soon be eligible for retirement. While demand for highly skilled workers has reached levels not seen since the 1960s, the A&D industry faces a number of significant hiring and retention challenges: achieving greater workforce participation by women and ethnic minorities, retaining qualified and trained personnel facing recruitment by other industries, processing background checks without long delays for classified work[7], and hiring well-qualified international workers without impediment. Federal and state policies can enable significant progress in addressing each of these challenges.

Jobs today are heavily reliant on technology, yet our education system is largely not preparing students to be STEM-literate and adaptable to rapidly changing technologies.[8] Additionally, many schools are underfunded, teachers receive inadequate support, and there is an absence of direct mentoring. These factors have helped create a national workforce crisis. Industry leaders and policymakers alike must tackle this crisis sooner rather than later to address the forecasted demand for skilled technical workforce.[8]

Recommendations:

- Pass legislation, such as the Higher Education Act, that enhances the pipeline of STEM-competent workers into the U.S. economy, including initiatives aimed at underrepresented communities.8
- Promote educational and training programs for both the existing workforce and new entrants, as well as encourage the recruitment and professional development of K-12 STEM teachers through federal incentives and grants.[8]
- Support programs that specifically focus on technical jobs, improve the pipeline from high schools, and provide grants for these activities.
- Incentivize industry and the military to engage directly with recruiting military personnel transitioning to the civilian workforce such as creating a standard to process and categorize military skill sets.
- Pass visa legislation that welcomes and retains highly educated international professionals who earn advanced STEM degrees from U.S. colleges and universities.
- Reform the security review process to streamline investigations, prioritize mission critical investigations, increase oversight, and promote reciprocity among agencies while protecting sensitive information and utilizing advanced technology to manage risk appropriately.[7]

ENDNOTES

1 Aeronautics R&D: A Key to Economic Prosperity (2018)
2 UAS: Expanding Transportation and Driving Growth (2018)
3 FAA NextGen: Modernizing Our Nation's Skies (2018)
4 Hypersonics: A Game-Changing Technology (2018)
5 Aircraft Certification: Accelerating Innovation in Civil Aviation (2018)
6 Supersonic Flight Over Land: High-Speed Flight for the 21st Century (2018)
7 Security Clearance Reform: Reducing Backlogs to Meet Government Needs (2019)
8 STEM Pipeline (2019)

Papers can be found at: aiaa.org/advocacy/Policy-Papers/Information-Papers

Attend CVD 2020!

Registration is open for AIAA members who would like to attend the 2020 Congressional Visits Day (CVD) program. Attendees will gather on 18 March in Washington, DC, to promote the Institute's Key Issues. A training webinar will be held 6 February, and a formal in-person training will take place 17 March in Washington, DC. **Register at aiaa.org/cvd2020. For more information, contact Steve Sidorek at steves@aiaa.org or 703.264.7541.**

News

MAKING AN IMPACT

AIAA and Blue Origin Partner to Launch Experiments Designed by High School Students into Space

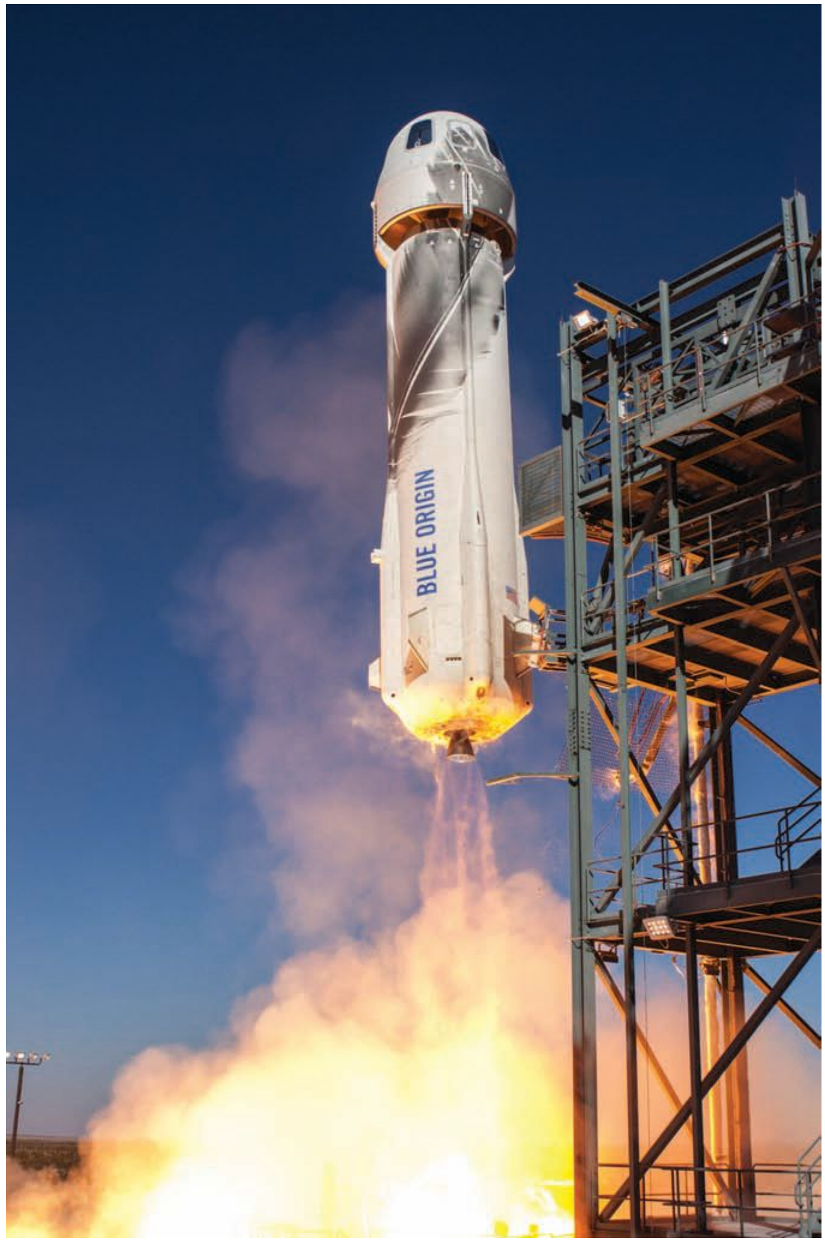
AIAA and Blue Origin have partnered to create Design/Build/Launch (DBL), a new competition designed to launch experimental payloads to study the effects of short-duration microgravity.

AIAA and Blue Origin invite high school students to develop creative research proposals in the fields of microgravity science or space technology and pair the experiment with a public outreach plan to share the excitement of space with others. The top proposal will be launched on Blue Origin's *New Shepard* rocket and receive a $1,000 grant to prepare and develop the experiment for flight.

"There's no better way to learn than by doing," said Dan Dumbacher, AIAA executive director. "These students have an amazing opportunity to contribute to space research while learning how transformative aerospace can be."

AIAA and Blue Origin representatives will judge the submitted proposals on the basis of scientific/technical merit, outreach creativity, and feasibility. The winning payload is expected to fly on *New Shepard* in 2021. Postflight, the students will be recognized and have the opportunity to deliver their final report at ASCEND, an AIAA event dedicated to the space economy.

"Blue Origin is passionate about the future of living and working in space. Through payloads on our reusable *New Shepard* vehicle and our non-profit, Club for the Future, we are inspiring students to pursue careers in STEM and inviting them to visualize their own possibilities in space," said Dr. Erika Wagner, payload sales director for Blue Origin.



Timeline:
Proposals Due: 3 April 2020

Announcement of Winning Team: 22 May 2020

Experiment Flies: 2021

Final Report Presentation at ASCEND: November 2021

Who can enter?
All active high school students, between 9th and 12th grade (or equivalent homeschooling levels) at the time of their submission. Multiple students may collaborate on a single proposal, and a lead faculty advisor must be named to receive the payload development award. The competition is open to both U.S. and international students. Please see **aiaa.org/dbl** for more information.

For more information about how you can get involved with AIAA's educational activities, please contact Merrie Scott, at MerrieS@aiaa.org.

AIAA Publications Announcements

Smits Honored with Awards

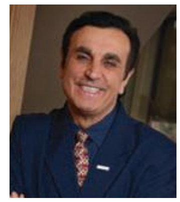
Alexander Smits, Eugene Higgins Professor of Mechanical and Aerospace Engineering Emeritus at Princeton University, was honored with two awards for his work. He won the 2019 APS Fluid Dynamics Prize, which recognizes and encourages outstanding achievement in fluid dynamics research. The prize includes a $10,000 prize and Dr. Smits was honored "For transformative contributions to the measuring and understanding of wall turbulence in extreme Reynolds and Mach number regimes, for pioneering research on bio-inspired propulsion, and in recognition of exemplary technical leadership, mentoring, and community service."

Dr. Smits was also awarded the G K Batchelor Prize for 2020. Sponsored by the *Journal of Fluid Mechanics*, the prize is awarded every four years at the International Congress of Theoretical and Applied Mechanics.

The prize is given for Professor Smits' "seminal contributions to our understanding of the structure of wall turbulence at very large Reynolds and Mach numbers, especially through the design of innovative experiments and measurement devices, and also for pioneering work on bio-inspired propulsion and on drag reduction using modified surfaces. Some of his most influential contributions are concerned with the behavior and scaling of wall turbulence at extreme conditions, most notably its asymptotic behavior at high Reynolds numbers, as well as its response to perturbations, especially shock waves, and to changes in Mach number. He has also inspired interest in biomimetic flows, including propulsion, energy harvesting and vortex dynamics, often with the practical objective of improving the efficiency of fluid-based systems."

Dr. Smits is the Editor-in-Chief of the *AIAA Journal*. Among his other honors, he has also been recognized with the 2004 AIAA Fluid Dynamics Award, the 2014 AIAA Pendray Aerospace Literature Award, and the 2014 AIAA Aerodynamic Measurement Technology Award.

Givi to Give Elsevier Distinguished Lecture in Mechanics

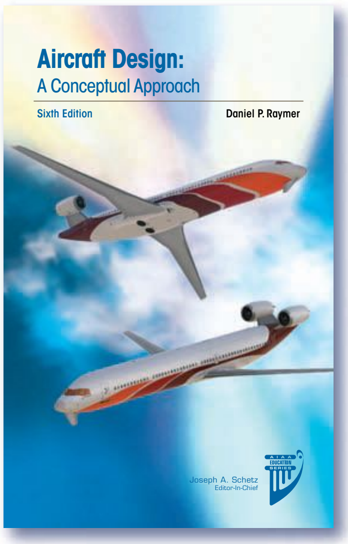


Peyman Givi, Distinguished Professor of Mechanical Engineering and the James T. MacLeod Professor in the Swanson School of Engineering, University of Pittsburgh, has been invited to give the upcoming 13th Elsevier Distinguished Lecture in Mechanics on "Quantum Information and Deep Learning for Turbulent Combustion Modeling & Simulation." Dr. Givi is an AIAA Fellow and the deputy editor of *AIAA Journal*.

The lecture will take place on 2 April 2020 at the University of Pittsburgh. For further information, contact Meagan Lenz (MEL171@pitt.edu).

NEW EDITION AVAILABLE

AIAA's #1 Selling Textbook



This best-selling textbook presents the entire process of aircraft conceptual design—from requirements definition to initial sizing, configuration layout, analysis, sizing, optimization, and trade studies. Widely used in industry and government aircraft design groups, *Aircraft Design: A Conceptual Approach* is also the design text at many major universities around the world. A virtual encyclopedia of engineering, it is known for its completeness, easy-to-read style, and real-world approach to the process of design.

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This encyclopedic book covers every topic necessary to the understanding of aircraft design building from first principles to a set of tools allowing the reader to actually do a realistic job of aircraft conceptual design. Topics include:

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Daniel Raymer

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- Rewritten introductory material to make the textbook even more "user-friendly."
- New chapter entitled "Electric Aircraft," presenting technologies, design-to guidance, and rules of thumb, and offers electric aircraft performance and sizing equations derived in a format familiar to those designing conventionally-powered airplanes.

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AIAA
SHAPING THE FUTURE OF AEROSPACE

Obituaries

AIAA Senior Member Smith Died in April 2018

Lawrence "Fred" Smith died in April 2018.

Smith served as a flight engineer and gunner on a B17 doing bombing runs over Germany and Russia in World War II. After the war he worked on his Bachelor's Degree in Engineering at the Spartan School of Aeronautics. He served as a flight engineer again in Korea before he was assigned to Tinker AFB. While at Tinker, he worked on his Master's degree from the University of Oklahoma, and was an associate professor.

Smith worked for the U.S. government as an engineer until 1985 when he retired and then went to work for Boeing in Oklahoma City. After almost 10 years he retired from Boeing.

AIAA Fellow Michael Holden Died in December

Michael S. Holden, Vice President of the Aeronautics Sector at CUBRC in Buffalo, NY, was internationally recognized principally for his extensive research in supersonic and hypersonic flows. Dr. Holden served in many capacities for AIAA and published over 125 papers through AIAA conference proceedings and journal articles.

Dr. Holden obtained his Ph.D. from Imperial College for experimental research and analysis associated with shock wave/boundary layer interaction and separated regions in the hypersonic flow regime. In 1964, this work continued with the 48-inch and 96-inch shock tunnels at Cornell Aeronautical Laboratory, and culminated with the Large Energy National Shock-tunnels (LENS) I, II, and XX, which he conceptualized, and oversaw construction and operational systemization of those new major ground test facilities at CUBRC.

His work contributed greatly to the design and development of U.S. ballistic and scramjet powered weapon systems, space capsules, and the Space Shuttle and space planes. Through his work on AIAA technical committees, conference panels, and as a distinguished lecturer, Dr. Holden provided the industry with a unique level of leadership.

Although his professional work was in the area of high-speed flow, he was equally recognized for his pioneering work in training winter Olympic teams in low-speed wind tunnels. As an avid skier himself, he advocated allowing the Olympic athletes to train in the Calspan facilities after attending the 1980 Winter Olympics in Lake Placid. Each year, he donated his time to train downhill racers, then ski jumpers, and bobsleigh, skeleton, and luge teams. This work was then expanded to include the Paralympic athletes. Many of the medalists and their coaches attributed their success to the training they received from Dr. Holden.

Dr. Holden was featured in many national magazines from *Popular Mechanics* to *Sports Illustrated* for the innovative training that he initiated. He developed special test equipment and data analysis, and invented fixtures to suspend the athletes in the tunnel. In addition to refining stance and movement, his work resulted in the development and refinement of equipment and clothing. *WIRED* magazine referred to Dr. Holden as "Team USA's Physicist."

In 2011 Dr. Holden was recognized with the AIAA Ground Testing Award for unique contributions in the development and construction of hypervelocity ground test facilities and their application to experimental research over a wide range of problems in hypersonic flow. He was also involved with the AIAA Fluid Dynamics TC and the HyTASP Program Committee

AIAA Fellow Glassman Died in December

Irvin Glassman died on 14 December. He was 96. Professor Glassman was the Robert H. Goddard Professor (Emeritus) of Mechanical and Aerospace Engineering at Princeton University. He retired from Princeton in 1999 after 49 years on the faculty.

Professor Glassman served as a research scientist in the U.S. Army during World War II and was honorably discharged in 1945. He received his Bachelor's of Engineering (1943) and Doctorate of Engineering (1950) from Johns Hopkins University.

He was considered one of the world's leading authorities on combustion as applied to problems in energy production, pollution, propulsion, and fire safety. In 1972, Professor Glassman founded Princeton University's Center for Energy and Environmental Studies. He was editor and founder of the journal *Combustion Science and Technology* and published more than 250 articles as well as two major books, including *Combustion*, considered the leading book in his field. He was elected to the National Academy of Engineering in 1996, received an honorary Doctorate of Science from Princeton University in 2009.

In 2018 Professor Glassman was awarded the Daniel Guggenheim Medal, which honors innovators who make notable achievements to aeronautics, for his contributions to the fields of combustion and propulsion. Among his other honors, he was also awarded the 1998 AIAA Propellants & Combustion Award.

Professor Glassman was most proud of his legacy as a teacher. His course on combustion engines was voted the most popular in a poll of Princeton University students. More than twenty of his graduate students awarded Ph.D.s are faculty members at major universities. Through his interest in others, kindness, and positive outlook, he became not only a teacher, but a lifelong mentor to many of his academic "children."

AIAA Associate Fellow Walker Died in January

Wright Brothers Institute (WBI) Executive Director **Dr. David Walker** died on 8 January 2020.

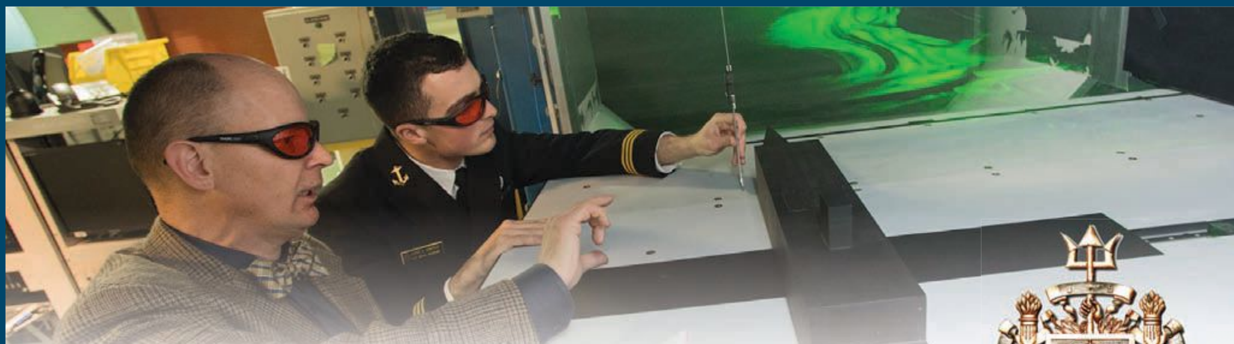
Dr. Walker earned his Bachelor and Master of Science degrees in Aerospace Engineering from the University of Texas at Austin. Upon graduation, he was commissioned as a 2nd Lieutenant in the United States Air Force. Over the course of his career, he flew 65 different types of aircraft and accumulated over 2,700 flying hours. A Distinguished Graduate of USAF Test Pilot School at Edwards AFB, CA, he served as an Experimental Test Navigator and an Experimental Test Weapons System Officer for the F-15E.

Following his graduation from Air Command and Staff College, he earned his Ph.D. in Aeronautical Engineering from the Air Force Institute of Technology at Wright-Patterson AFB. He returned to Edwards, where he first served as the Chief of Instructor Training and Curriculum Development at the Test Pilot School and later became the school's Deputy Commandant. After graduating from Air War College, he served as Deputy Chief of the Common Systems Division and the Chief of the Agile Combat Support Division in the Directorate of Global Power Programs at the Pentagon. Returning to Wright-Patterson as a Colonel, he served as the Director of Air Vehicles at the Air Force Research Laboratory (AFRL).

He then moved back to Edwards, where he commanded the Operations Group of the 412th Test Wing of the USAF Flight Test Center. His final assignment in his active duty career took him back to AFRL in Wright-Patterson, where he served as the Vice Commander. Upon his retirement in 2006, he entered the Senior Executive Service (SES) and became the Director of Materials and Manufacturing at AFRL. He returned to the Pentagon, where he worked as the Associate Director of Programs in Plans and Programs, Associate Deputy Assistant Secretary of the Air Force for Acquisition Integration, and finally as the Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering. His last assignment as an SES was as the Research and Development Portfolio Director in the Office of Naval Research.

With his long history with aerospace technology and innovation, he became the Executive Director of the Wright Brothers Institute (WBI) in Dayton, OH, in June 2019. He was passionate about what WBI and the Air Force Research Laboratory could accomplish in the coming months.

Dr. Walker's multi-service expertise helped WBI rapidly connect technology developed inside AFRL to men and women in uniform. The Air Force Small Business Innovation Research (SBIR) Office, Air Force Life Cycle Management (AFLCMC) and Air Force Special Operations Command (SOCOM) are some of the Air Force organizations leveraging WBI's innovation and commercialization practices.



Open faculty positions in the Aerospace Engineering Department

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The USNA Aerospace Engineering Department invites applications for multiple faculty positions at varying levels of rank and experience in Astronautics and Aeronautics. Our department has a proven record of teaching excellence and impactful research with strong inter-agency sponsorships and collaborations. We currently seek candidates with expertise in the areas of RF communication systems; spacecraft and ground station development and operations; satellite on-board command and data handling; air vehicle design and engineering; and prototype aircraft development, testing, and evaluation. Three positions are currently open, with specific online application instructions for each:

- **Assistant Professor of Astronautics**, a tenure-track position (https://www.usna.edu/HRO/jobinfo/AsstProfAero-AY20.php)
- **Robert A. Heinlein Chair in Aerospace Engineering**, a Distinguished Visiting Professorship in Astronautics (https://www.usna.edu/HRO/jobinfo/HeinleinDVP-AY20.php)
- **David F. Rogers Chair in Aerospace Engineering**, a Distinguished Visiting Professorship in Aeronautics with emphasis on air vehicle engineering and design (https://www.usna.edu/HRO/jobinfo/RogersDVP-AY20.php)

USNA is a unique institution of higher learning located in picturesque Annapolis, Maryland. As a historic naval officer accession program and premier undergraduate college, USNA has its own distinctive niche among America's top educational institutions. We've been ranked #4 "Best Undergraduate Engineering" and #1 "Top Public School" by *US News and World Report* and #5 "Best Science Lab Facilities" by *Princeton Review*. Our talented faculty are committed "to develop Midshipmen morally, mentally, and physically and to imbue them with the highest ideals of duty, honor and loyalty in order to graduate leaders who are dedicated to a career of naval service and who have potential for future development in mind and character, to assume the highest responsibilities of command, citizenship, and government." To meet this challenge, we recruit from all segments of society to find faculty, instructors, and support staff who model the highest professional standards.

We are invested in building a diversified workforce committed to providing a multi-disciplinary, hands-on approach to student learning and leadership development. We believe that individuals from diverse backgrounds strengthen our programs and build an equitable and inclusive environment that augments student success. We encourage qualified applicants from all backgrounds and experiences to apply for consideration.

Every year, more than a million people tour "the Yard" to experience what we already know—that USNA is a special place, with special people, working toward a special purpose. Those selected for employment will find challenging and rewarding work, state-of-the-art facilities that inspire academic and scholastic excellence, outstanding Federal benefits and support programs, and exceptional quality-of-life.

All positions are currently open and will remain open until filled. For more information, visit the USNA Human Resources webpage at https://www.usna.edu/HRO/jobs/faculty.php or contact CDR Jeff King, Chair of the Aerospace Engineering Department, at jking@usna.edu or 410-293-6401.

1920

Feb. 5 Britain's Royal Air Force College is established at Cranwell to train the next generation of officers to defend the empire. David Baker, **Flight and Flying: A Chronology**, p. 132.

Feb. 7 Noted French aviator Joseph Sadi-Lacointe sets a speed record for aircraft when he pilots a modified Nieuport-Delage 29V fighter to 171 mph (275 kph) over a 1-kilometer course. The aircraft is the latest fighter to join the French Air Force and just missed service in World War I. The biplane fighter is powered by a single 320-horsepower Hispano Suiza 8Fb V-8 engine. Kenneth Munson, **Aircraft of World War I**, p. 148.

Feb. 14 The first Rome-to-Tokyo flight begins, piloted by Italian Lt. Arturo Ferrarin. He wins the race, which begins with 11 competitors and is flown in stages. **Flight**, June 10, 1920, p. 629.

1945

Feb. 7 Consolidated Vultee's XP-81 escort fighter prototype makes its initial flight, becoming the first turbopowered aircraft to fly in the U.S. The plane is designed to have a nose-mounted GE TG-100 turboprop and a rear-mounted GE I-40 turbojet in the fuselage, but on this flight, a conventional Packard V-1650 piston engine is installed as the TG-100 is not ready. The aircraft is designed as a potential long-range escort for Boeing B-29 raids against Japan. It has a top speed of 800 kph (500 mph) and a range of 2,000 kilometers (1,250 miles). Delays with the TG-100 eventually force the cancellation of the program as better jet aircraft become available. John Wegg, **General Dynamics Aircraft and Their Predecessors**, p. 179.

Feb. 13-15 Dresden, Germany, is devastated by a British Royal Air Force and U.S. Army Air Forces bombing operation that nearly destroys the city and kills thousands of people. About 1,300 British and American heavy bombers strike the medieval city in four raids over two days, dropping 3,500 metric tons of explosives and incendiaries. The raid targets German communications and marshaling yards, as well as factories and workers, to interrupt the flow of civilians and disrupt German military reinforcements to the Eastern Front. Mark Clodfelter, **Beneficial Bombing: The Progressive Foundations of American Air Power, 1917-1945**, pp. 148-151, 175, 176.

Feb. 20 The U.S. war secretary approves plans for the establishment of the White Sands Proving Ground in New Mexico. The site opens in July and is the nation's primary long-range missile test range. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, pp. 49-50.

Feb. 21 Britain's Hawker Sea Fury, which becomes the last piston-engined fighter to serve in first-line Royal Navy squadrons, makes its first flight. The Sea Fury is a naval version of the Royal Air Force's Fury with folding wings and a tailhook. It features a massive Bristol Centaurus 18 radial engine that gives the aircraft a top speed of 740 kph. It is one of the fastest piston-engined aircraft built during World War II although it is flown in operations only in 1947, two years after the end of the conflict. Francis K. Mason, **Hawker Aircraft Since 1920**, pp. 303-315.

Feb. 25 The Bell XP-83, a pressurized turbojet-powered long-range escort fighter, makes its first flight with Bell test pilot Jack Woolams at the controls. The XP-83 is a developed version of America's first jet aircraft, the P-59 Airacomet. It is larger than the XP-59 and features a bubble canopy, a laminar flow wing and two more powerful GE XJ33 centrifugal flow jet engines, each producing 4,000 pounds (17,792 newtons) of thrust, twice the power of the Airacomet. Despite its top speed of 840 kph, its performance and maneuverability do not meet expectations and the program is canceled after only one is built. A.J. Pelletier, **Bell Aircraft Since 1935**, pp. 61-62.

Feb. 28 Germany's manned, rocket-propelled Bachem Ba 349 Natter (Viper) defense interceptor is test flown for the first time, but its pilot, Senior Lt. Lothar Siebert, is killed. At about 500-feet altitude, the cockpit cover fell off with the headrest attached to it; it is believed the pilot died instantly from a broken neck. Three subsequent manned launches are conducted, and the Natter is approved for operational deployment. W. Ley, **Rockets, Missiles, and Space Travel**, p. 415.

During February 1945 U.S. Army Ordnance, in cooperation with Western Electric, initiates the Nike missile project to develop an air-defense missile for use against high-speed, high-altitude bombers beyond the range of conventional artillery. The first test flight of the Nike is made at White Sands Missile Range, New Mexico, in 1952, after which the Nike-Ajax becomes America's main-line anti-aircraft defense, with Nike batteries posted around cities throughout the U.S. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, pp. 49, 69-70.

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1970

Feb. 3 NASA launches its 1,500-kilogram SERT II, short for Space Electric Rocket Test, vehicle from Vandenburg Air Force Base, California, with a Thorad-Agena rocket. When SERT II reaches a low Earth orbit of 1,008 kilometers, it deploys solar panels. The primary objective of this mission is to operate electric ion thrusters over six months. SERT I, launched in a suborbital mission on July 20, 1964, proved that ion engines could produce thrust in space. Therefore, SERT II is to prove the system at full thrust and over a longer duration. The engine produces 27-millinewton thrust that is to increase the spacecraft's apogee by about 97 km. NASA, **Astronautics and Aeronautics, 1970**, pp. 38, 51; **Aviation Week**, Feb. 23, 1970, p. 24.

Feb. 5 NASA launches the latest model of the Aerobee sounding rocket, the 12.5-meter Aerobee 170, with its Nike booster, from Wallops Island in Virginia, carrying a 95-kilogram scientific payload. The primary purpose of the mission is to flight-test the vehicle and its new telemetry instrumentation. NASA, **Astronautics and Aeronautics, 1970**, p. 41.

Feb. 7 The Intelsat-III F-6 communications satellite launched by NASA for ComSatCorp on Jan. 14 begins its full-time commercial service with 995 circuits carrying telephone and telegraph messages among 17 Earth stations in the Atlantic area. NASA, **Astronautics and Aeronautics, 1970**, p. 45.

Feb. 10 The U.S. Patent Office grants Patent No. 3,495,260 to Goddard Space Flight Center engineers Charles Laughlin and Roger Hollenbaugh for an air traffic control system using a satellite. This system is to be tested with an Applications Technology Satellite in 1972 and is designed to transmit aircraft positions to ground stations and relay the data to all aircraft via satellite. **New York Times**, Feb. 14, 1970, p. 70.

Feb. 11 Japan launches its first satellite, Ohsumi, becoming the fourth nation to orbit a spacecraft with its own booster. The 38-kilogram Ohsumi is carried by a four-stage Lamda 4S-5 rocket from the Kagoshima Space Center at Uchinora. Ohsumi contains a small radio transmitter, battery, thermometer and accelerometer in its nosecone and has four antenna spikes protruding from the cone. NASA, **Astronautics and Aeronautics, 1970**, pp. 48-49.

Feb. 13 NASA's Marshall Space Flight Center in Alabama announces the establishment of its Space Shuttle Program Office with Robert F. Thompson as its manager. NASA, **Astronautics and Aeronautics, 1970**, p. 51.

Feb. 15 Air Chief Marshal Lord Hugh Dowding, chief of Britain's Royal Air Force Fighter Command from 1936 through the battle of Britain in 1940, dies at age 87. Dowding learned to fly in 1913 in a Vickers biplane. He became a pilot during World War I and a temporary brigadier-general by 1917 when he was given the command of the southern training brigade. In 1933 he was promoted to air marshal and appointed commanding officer of the newly created RAF Fighter Command. Dowding is generally given the credit for Britain's victory in the Battle of Britain. **Aviation Week**, Feb. 23, 1970, p. 74.

Feb. 16 Apollo 11 astronautics Neil Armstrong, Buzz Aldrin and Michael Collins receive the 1970 Goddard Memorial Trophy at the 13th annual Goddard Memorial Dinner. **Aviation Week**, March 16, 1970, p. 13.

Feb. 25 The Boeing nuclear air-to-surface Short-Range Attack Missile is tested at Holloman Air Force Base, New Mexico, after an airdrop from the weapons bay of a B-52 bomber. The missile has a range of 93 kilometers. **Aviation Week**, March 16, 1970, p. 22.

Daniel Mennerich

During February 1970 The February issue of Astronautics and Aeronautics presents a progress report on the planned construction of a dedicated building for the National Air and Space Museum. President Lyndon Johnson authorized the NASM in July 1966 but refrained from asking Congress for construction funding until after the Vietnam War. The NASM was an outgrowth of the original National Air Museum, established in 1946. The new building is dedicated in 1976. NASA, **Astronautics and Aeronautics, 1970**, p. 69.

1995

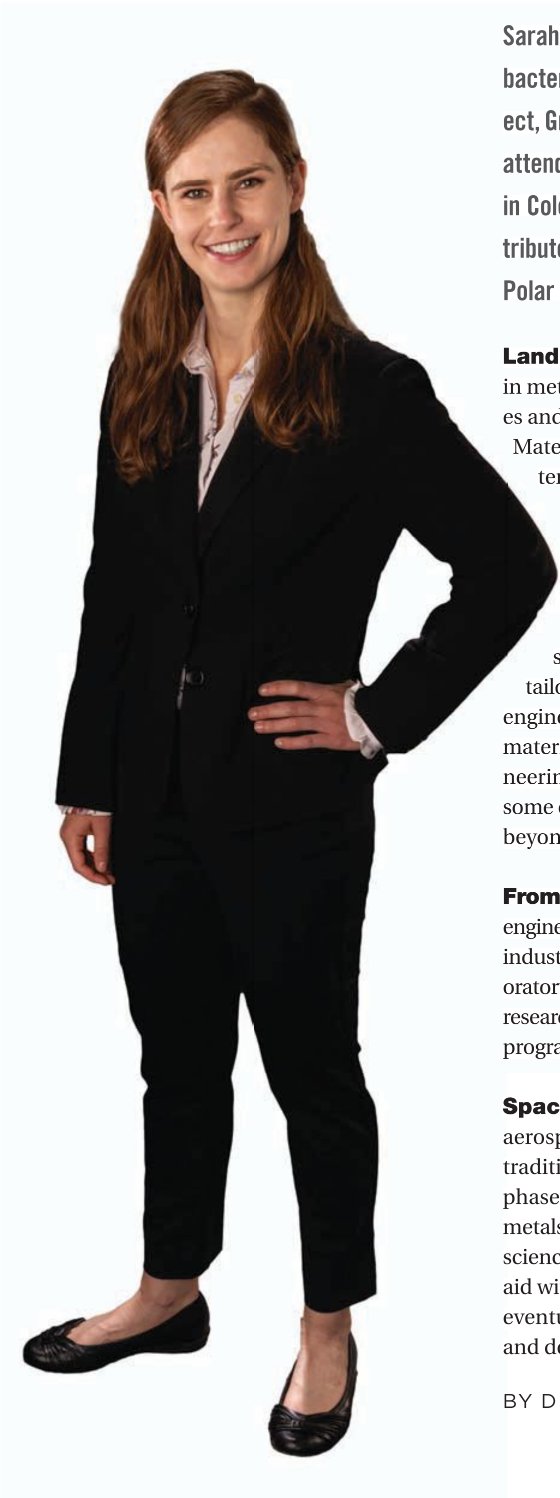
Feb. 3 The space shuttle Discovery, STS-63 mission, makes America's first close contact with a Russian spacecraft, Mir, since the Apollo-Soyuz mission of 1975. The mission is a dress rehearsal for seven planned docking missions to Mir. The flight is also the first time that a space shuttle is flown by a woman, Eileen Collins, and the second time a Russian has flown aboard a U.S. spacecraft, Vladimir Titov. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 631, 723.

Feb. 10 A prototype of the Antonov An-70 collides with An-72 during the An-70's fourth test flight near Gostomel, Ukraine. All aboard the An-70 — seven crew members — die in the crash. **Aviation Safety Network**; **FlightGlobal.com**, March 21, 1995.

TRAJECTORIES | CAREER TURNING POINTS AND FUTURE VISIONS

SARAH GRUNSFELD, 23

Materials and process engineer at Ball Aerospace



Sarah Grunsfeld became enamored with science in middle school. While culturing bacteria found in and around her home in Seabrook, Texas, for a science fair project, Grunsfeld became fascinated with the environment's impact on organisms. She attended the Massachusetts Institute of Technology before joining Ball Aerospace in Colorado. At Ball, Grunsfeld helps develop and evaluate new materials and contributes to programs including the Ozone Mapping and Profiler Suite on NOAA's Joint Polar Satellite System, the latest generation of polar-orbiting weather satellites.

Landing a job ▸ Through a variety of internships, including analyzing amino acids in meteorites at NASA's Goddard Space Flight Center in Maryland and growing viruses and templating nanoparticles for catalyst reactions at MIT's Belcher Biomolecular Materials Lab, I realized that I was interested in understanding and improving materials to expand upon what biology and evolution have made possible. I did an internship at HRL Laboratories, a research center in Malibu, California, where I had the opportunity to develop 3D-printed ceramics for aerospace applications. It is incredible how the underlying molecular structures of the materials around us can be combined and organized in ways that allow us to create materials that can survive the ordeal of traveling multiple times faster than the speed of sound, or materials that allow us to create synthetic bones for highly tailorable medicine. I completed my undergraduate degree in materials science and engineering at MIT with a focus on additive manufacturing and how it can improve material properties and the overall functioning of engineered parts. All facets of engineering are inherently limited by materials. If we can improve those materials, or in some cases develop entirely new materials and advance their processing, we can reach beyond the current capabilities in any industry.

From laboratory to Joint Polar Satellite System ▸ As a materials and process engineer, I work on a variety of different programs, supporting both the defense and space industries. I split my time between developing and evaluating new materials in the laboratory, supporting the advanced Ozone Mapping and Profiler Suite, supporting internal research to implement novel additive manufacturing technologies on current and future programs, and assessing how additive will impact the aerospace industry in the future.

Space in 2050 ▸ I foresee additive manufacturing becoming a large part of the aerospace industry, enabling us to build parts that are currently unachievable with traditional manufacturing technologies and allowing us to innovate at the concept phase and increase part functionality. New, stronger and more capable 3D-printed metals and even 3D-printed ceramics will dominate the market, allowing us to pursue science to further understand our own planet, solar system and beyond. Software will aid with intelligent data-driven designs and integration of multicomponent systems, eventually leading to machine learning algorithms that can optimize the materials and designs for next-generation aerospace systems. ★

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