AEROSPACE

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Thriving in space

The communications, food production, manufacturing, mining and transportation we'll need **PAGE 22**

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SHAPING THE FUTURE OF AEROSPACE

On-orbit servicing is one of the technologies that experts say will be required if humans are going to establish settlements in space.

Tethers Unlimited

AEROSPACE AMERICA

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Keith Button

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

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Adam Hadhazy

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

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Cat Hofacker

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

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Moriba Jah

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

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Debra Werner

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

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DEPARTMENTS

2020: the year we looked outward in a new way

At this writing, no one can say with absolute certainty that human society will ever manage to expand into space in a physical sense, whether aboard the O'Neill cylinders reportedly favored by Jeff Bezos and featured in the movie "Interstellar," or on the surface of Mars as Elon Musk proposes.

If either of those are going to happen, it's going to take an almost unimaginable variety and scale of technical and policy achievements over a span of decades.

Historians could look back on 2020, the year of the infamous covid-19 pandemic and the inaugural AIAA ASCEND gathering, as the moment we decided to explore our destiny more seriously than just the fun stuff of driving buggies in the desert and living in biospheres. This could be the year we pledged to take on the wider challenges toward dreams of an off-world economy and society.

In this month's cover story, we touched on some of the necessities. Take note that the experts in this piece are not just talking and pitching ideas. They are taking concrete steps, however small, toward potential breakout moments. The necessities they discuss are not the only ones. This magazine will be there to delve into other topics in future issues. There is one challenge in particular that I don't think receives enough ink or research dollars: We humans don't yet know whether or how our biology can exist for years on end beyond Earth's protective magnetosphere. And yet we are conceiving rockets and habitats and food experiments to get us out there.

Also, the policy realm must not be forgotten. The nations of the world haven't waged a coherent international response to the covid-19 pandemic or to climate change, so one wonders how humanity can possibly survive in outer space in the face of exotic threats that even science fiction writers have not yet imagined. Perhaps the value of NASA's Artemis Accords for the moon is the underlying recognition that we can't have the same discord in space as on Earth and expect to succeed.

So, that's reality as I see it in 341 words. If we do go, I hope it's because we choose to create a thousand Einsteins and Mozarts, as Bezos says, and not because we've ruined Earth. We won't survive long out there if we can't master sustainability here. These challenges don't bring me down, at least not for long. A great human drama is beginning to unfold, and I'm lucky enough to be here to help chronicle the start of it. ★

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

After the pandemic: 2 visions

Those were two fascinating opinion pieces ["Don't sideline environmental sustainability" and "The coming digital reality," June], especially read one after the other. Asteris Apostolidis looks forward to a world not much different from that of a few months ago, and urges planning for that future in a manner that would ally further, different calamities. He believes that the physical personal contact and experience, enabled by air travel, will be actively sought by future generations.

Dennis Bushnell's vision is quite different. Personal contact and physical experience will be unnecessary, with remote data and simulation taking their place. We'll just lie back and hook up.

But why bother? If the technology gets to a good enough level, why not avoid all those messy interactions with the physical world and other humans, and just dial it all back to, say, N64 level? All your associates could be avatars, much easier to get along with than real people, even those who are remote. No need to argue, no need to lose, no need to have a theory proved wrong.

No need for an aerospace industry.

No need to live, come to think of it.

I'm rooting for you, Mr. Apostolidis.

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More on UVC light

In two articles in September's Aerospace America, comments were made about validating the efficacy of ultraviolet C light to disinfect planes ["No-contact cleansing" and "Anti-covid leader"]. The shorter wavelength of UVC makes it particularly good for that but could be bad for classes of plastics. What was not asked is what effect does UVC light have either directly on the materials (plastics and fabrics) in the plane or through the ozone that might be generated. Furthermore, are there any compounds that result from the degradation of materials left on the surface that might be an issue with people? Hopefully, someone is also looking into these potential issues.

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Getting practical about avoiding space collisions

I was extremely excited to see Moriba Jah's article on probability dilution in the September 2020 issue ["Needed: Rules of thumb for avoiding collisions in space"]. I'm writing to supplement what Dr. Jah wrote with a little practical guidance for satellite navigators tasked with doing conjunction analysis.

"Probability" of collision is a deeply and provably unreliable risk metric. I know this because Ryan Martin, Scott Ferson and I proved it and published that proof in the Proceedings of the Royal Society in 2019 ["Satellite Conjunction Analysis and the False Confidence Theorem," July 17, 2019]. Given the typical uncertainties at play in present-day conjunction analysis, "probability" of collision consistently understates collision risk exposure by several orders of magnitude. If used as a plain risk metric, it offers satellite operators absolutely no viable path to controlling the rate at which collisions involving active satellites happen.

Moreover, this is not due to subjectivity in the prior, shaky assumptions in the likelihood, or any of the other usual statistical culprits. It is due to a straightforward mismatch between the mathematics of probability theory and the epistemic uncertainty to which it is being applied in conjunction analysis. This is a problem where Bayesian notions of "coherence" and engineering notions of reliability are fundamentally and provably incompatible.

There are many details and marginal errors to be run down in satellite conjunction analysis, but probability dilution is not merely one of them. It is the dominant source of error in conjunction analysis today. It is the thing that will completely invalidate your analysis, even if you get everything else right.

Fortunately, nobody is stuck with "probability" of collision as a risk metric. Robust alternatives are readily available. Ellipsoid overlap detection is an old standard, and it's provably reliable, though usually overconservative. Alternatively, navigators looking for a more flexible metric describing collision risk exposure can use plausibility of collision as computed using the "red fuzzy" approach presented in my 2016 AIAA paper on conjunction analysis ["A Corrector for Probability Dilution in Satellite Conjunction Analysis," SciTech Forum], or equivalently, the two-dimensional "Gaussian possibility distribution" presented in Dr. Jah's own 2019 AAS/AIAA paper with Emmanuel Delande and Brandon Jones ["A New Representation of Uncertainty for Collision Assessment," Advances in the Astronautical Sciences AAS/AIAA Spaceflight Mechanics 2019]. More efficient and general solutions are possible, but these references are offered to give satellite navigators adequate tools for immediate use.

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Let us hear from you

Send letters to letters@aerospaceamerica.org. Letters may be edited for length and clarity and may be published in any medium.

FLIGHT PATH

Your Ideas Matter. We're Listening.

Unprecedented year. That is a phrase I have heard many times this year. It goes beyond the pandemic-induced struggles surrounding health, the economy, and education. It also includes immense divisiveness in our nation, and that polarization is on the rise. In short, it is a trying time. No question.

Despite the fear, uncertainty, and restlessness, however, the space economy has continued to not only grow, it is gaining unforeseen momentum.

The proof is all around us. Private investments into remote sensing, space transportation, and technology continue to be strong. In May, we witnessed history as SpaceX's Dragon capsule ferried two astronauts to the International Space Station, opening a new era where U.S. astronauts are once again launched from American soil. NASA's Artemis program has kickstarted the industry with numerous hardware and technology development initiatives designed for a return to the moon, this time to stay.

New contract awards to companies like Axiom Space and Made in Space, combined with new cargo and crew transportation services, are starting to open low Earth orbit to commerce. National security space programs are driving advancement with new satellite and launch capabilities. And a new branch of the Armed Forces, the U.S. Space Force, now exists to protect U.S. and allied interests in space and to provide unique space capabilities.

While there is much to celebrate, this is not a time to rest on our laurels. To continue this high level of productivity and momentum into the future will be a tall agenda. That is what makes ASCEND, in my thinking, such a critical and timely event.

In just a few days, our community will gather to discuss the most audacious mission in the history of humankind – creating an off-world future. ASCEND is not like traditional aerospace conferences. It is about building and sustaining a vital platform committed to communication, collaboration, and forward progress.

In early 2019, we called upon some of the most creative leaders in our industry to serve as our guiding coalition. Each jumped at the chance to help us shape the ASCEND concept into reality. There was unanimous consent on one key differentiator – this will not be a traditional event with one-way conversations, it will be collaborative and intentional.

You will also see other fundamental differences. Participants will include collaborators from adjacent industries such as mining, infrastructure, construction, pharma, telecom, hospitality, and entertainment. To achieve a trillion-dollar space economy, we need to create new $100 billion markets. We won't get there talking amongst ourselves. Participants from adjacent industries will bring ideas, prospects, and challenges that we can collaborate on to build the future.

ASCEND is designed to be outcomes-focused. It is not enough just to share ideas. ASCEND goes beyond this stage. It is a living, ongoing, dynamic platform designed to carry ideas through to execution.

For example, in July, ASCEND used NASA's Sustained Plan for Lunar Exploration and Development as the impetus for a one-day event entitled "Economically Viable Lunar Settlements." A traditional panel session was followed by smaller group breakouts to identify technology gaps and economic considerations for creating such a lunar establishment.

Following the workshop, a group of volunteers developed a proceedings report, which now serves as an actionable blueprint for government and industry leaders to use as a reference for guiding future actions. This paper (**www.ascend.events/ensuring-economically-viable-lunar-settlements**) is available on the ASCEND website, and I strongly encourage you to take a look and share it with your colleagues.

As another example, ASCEND partnered with organizations – the National Society of Black Engineers, Society of Women Engineers, Society of Hispanic Professional Engineers, and the American Indian Science and Engineering Society – to create a series of webinars focused on diversity, equity, and inclusion in the aerospace workforce and share their unique perspectives. The recording (**www.ascend.events/news/ascendxwebinar-dei-pt2**) and key takeaways are available as a resource to you for building a more equitable culture.

The timing could not be better. New leaders and elected officials around the world will need to be consistently informed about the tremendous importance of the global space economy, science, cislunar and deep space exploration, and what it means to the future of humanity.

Ideas and collaborations birthed at ASCEND can make a difference, but it is not possible without you. You decide what interests you have and what role to take. We encourage you to participate and invite creative minds from adjacent industries to engage in this platform. As the dialogue evolves, you tell us what conversations and collaborations you want to see happen. Talk to us. We want to know.

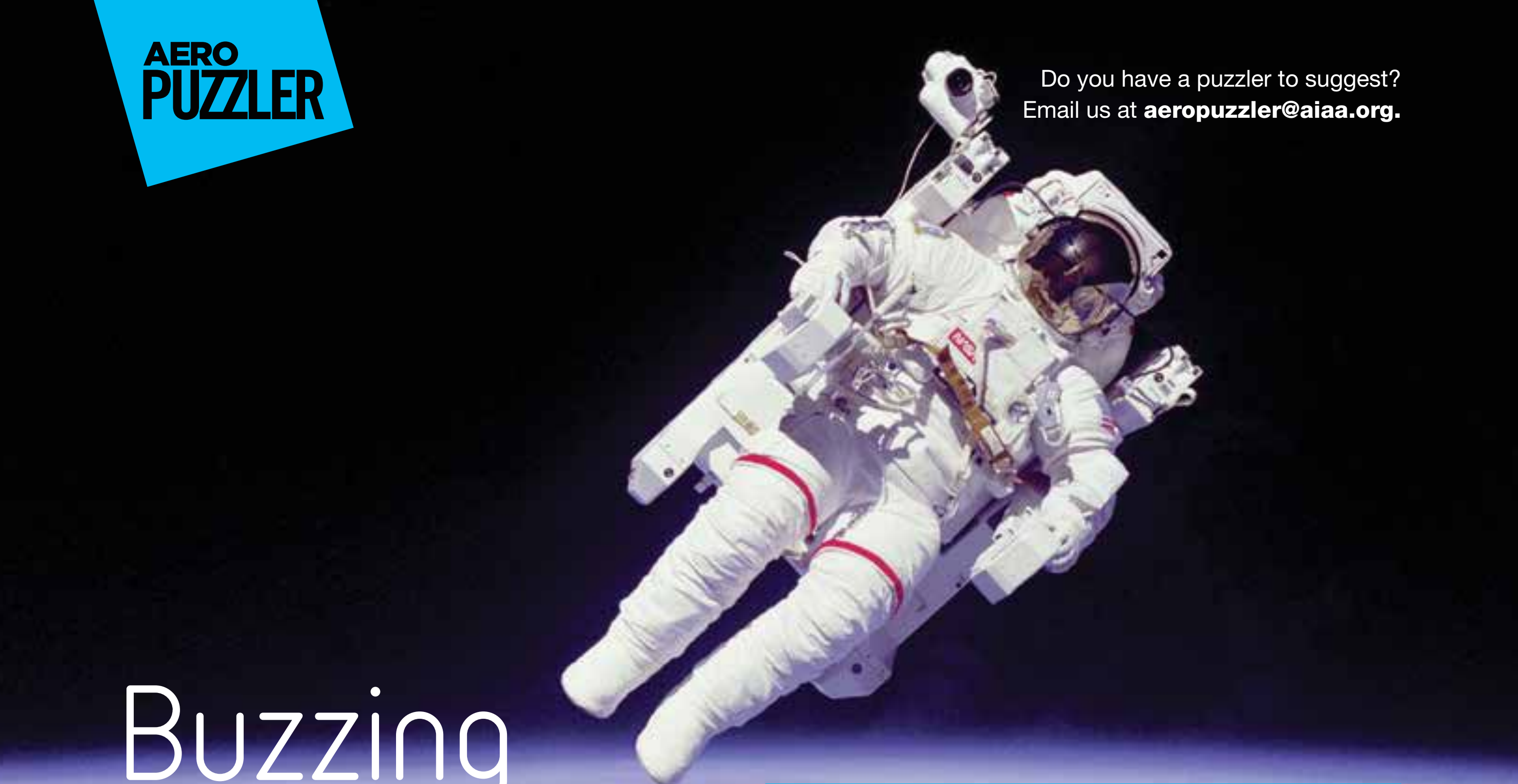
The space industry is on a dynamic trajectory. How fast and how far we progress depends on all of us as we collectively broaden involvement, participation in, and utilization of space. So meet us at ASCEND and bring your ideas. Become a part of this living, breathing platform for progress. We're listening.

Rob Meyerson
ASCEND Event Producer
CEO of Delalune Space
Former President of Blue Origin

For more information, visit www.ascend.events

AERO PUZZLER

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



Buzzing off course

Q: It's the near future, and you're aboard the Amazon International Space Station. You need to head over to the nearby Bayer Sustainability Lab to check on your crops, so you don your spacesuit and voice-controlled Human Maneuvering Unit, the latest iteration of which has achieved perfect navigation control. You tell the unit to make a straight beeline for Bayer. The unit laughs. "You'd better let me drive." You demand to know what's so funny. What will the unit say?

Draft a response of no more than 250 words and email it by noon Eastern Nov. 9 to aeropuzzler@aiaa.org for a chance to have it published in the December issue.

FROM THE OCTOBER ISSUE

FEELING THE PRESSURE: We asked you whether your ears would pop if you were flying within a perfectly sealed aircraft passenger cabin. Asteris Apostolidis, innovation strategy manager at Air France-KLM, and Clint Balog of Embry-Riddle Aeronautical University helped choose the winner.

WINNER: If you were inside a perfectly sealed aircraft passenger cabin, your ears would indeed not pop at all! The pop is just from the difference in air pressure from inside your ear to outside. The reason we design airplanes that maintain higher altitude pressure than sea level is to save weight and thus save fuel. If you were to maintain sea level air pressure (1 atm) on the inside of your airplane cabin, the air inside the fuselage would be "pushing outward" because of the much lower air pressure outside. For example at a cruise altitude of 35,000', the outside air pressure is only 0.24 atm, which would result in a differential pressure of 0.76 atm (about 11 psi) pushing out. By allowing the cabin air pressure to drop to a still breathable 8,000' pressure altitude (0.74 atm), you bring down the differential pressure to only about 0.5 atm, drastically reducing the thickness of the airplane skin and supporting structure required to keep the air in. One benefit of switching to carbon fiber fuselage on the Boeing 787 was the ability to have a lower cabin altitude of 6,000' without increasing the weight compared to a traditional aluminum fuselage, and thus less ear popping.

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

Satisfying electricity-hungry aircraft

BY KEITH BUTTON | buttonkeith@gmail.com

W.L. Gore & Associates, a Delaware materials company, has developed a new type of wire insulation that it says withstands chafing and electrically generated heat better than traditional wires, which could make the company's wire products especially suitable for the coming breed of high-voltage electric aircraft.

Damage to wires can lead to electric arcing between separate wires. At minimum,this arcing could knock out electronics, or in rare worst-case scenarios, spark fires or even explosions on conventionally fueled aircraft.

The insulation for Gore's new GWN3000 series aerospace wires — a modified form of what is commonly known as Teflon — creates a unique third category of wire, separate from the two traditional categories for aircraft, says Jim Carothers, product manager at Gore. Today, wires are coated with one of two kinds of composites: Either PTFE — short for polytetrafluoroethylene, also known as Teflon — and polyimide, or with XLETFE, which stands for cross-linked ethylene-tetrafluoroethylene. The PTFE-polyimide composite has higher tensile strength, abrasion resistance and cut-through resistance than XLETFE, while XLETFE is a better electrical insulator.

Gore says its new wire series beats PTFE and XLETFE on each of these performance measures.

Before the advent of electric aircraft, wiring typically had to accommodate 115 volts, and newer aircraft have made the jump to 270 volts. Gore's new wires can carry up to 600 volts and operate in temperatures up to 260 degrees Celsius, Carothers says.

The stakes ahead are particularly high for all-electric advanced air mobility concepts and distributed propulsion designs, especially designs that would carry people. Twenty years ago, losing power in a wire might mean knocking out the in-flight entertainment on a passenger plane, but aboard an all-electric aircraft, such a loss could cut power from a critical item like an actuator that's necessary for keeping the vehicle in the air, Carothers says.

"It's like the vascular system in a body," he says: Failure is more like a blood clot than a splinter.

To add durability for the two traditional categories of aerospace wire, wire manufacturers have resorted to increasing the thickness of the insulation, which adds size and weight to the bundles of wires contained in an aircraft. Gore's new wire series boosts durability without adding weight, the company says. The insulation material is also chemically inert, so it won't degrade when exposed to harsh chemicals or humidity.

Besides targeting electric aircraft, including drones, Gore is pitching its new wire series for aircraft that produce high vibration levels, such as rotorcraft that would be developed under the Pentagon's Future Vertical Lift program. ★

▲ **Parts of a next-**generation electric rotorcraft will require higher power, and W.L. Gore & Associates says its new wiring insulation will protect against overheating and chafing.
W.L. Gore & Associates

NASA

Cosmic explorer

More online aerospace america. aiaa.org

From his home in Maryland, John Mather's thoughts are often a million miles away — or more precisely, 1.5 million kilometers away at the second Lagrange point. From this gravitational position, the James Webb Space Telescope will look off into the cold of space with the Earth and the sun at its back, so that it can sense the weak infrared light from features of the early universe. If all goes as planned, Webb will be launched to this point next year to begin a $9.6 billion mission that Mather, a cosmologist and the project's top scientist, has been helping to plan for 25 years. I spoke to him via video call about why Webb has been worth waiting for. Here is our conversation, compressed and lightly edited. — *Cat Hofacker*

JOHN MATHER

POSITIONS: Astrophysicist at NASA Goddard Space Flight Center, since 1974; senior project scientist for the James Webb Space Telescope, since 1995; led the scientific proposals for the Cosmic Background Explorer, or COBE, satellite, 1974-1976; COBE study scientist and then project scientist, 1976-1998.

NOTABLE: 2006 recipient of the Nobel Prize in physics with George Smoot for his measurements of cosmic microwave background radiation via the Cosmic Background Explorer satellite, which confirmed the Big Bang theory. Led the team that defined the Webb telescope's science objectives and chose the instruments that will receive light from its mirrors.

AGE: 74

RESIDENCE: Hyattsville, Maryland

EDUCATION: Bachelor's degree in physics from Swarthmore College in Pennsylvania, 1968; doctorate in physics, University of California at Berkeley, 1974.

Q: If launch holds for Oct. 31, 2021, it is now one year and 29 days from the day we're speaking. Does that feel surreal?
A: Well, I just don't worry about it. You cannot worry about these things for 25 years. I'm just looking forward to having it up there, so we'll go onto the next thing to do.

Q: Have you started making your launch day plans?
A: We actually haven't all figured out where everyone will be, but it's pretty likely that I will be here in the Washington area, because shortly after launch scientists will be saying, "Is everything OK? What do we do now?" I don't want to be 24 hours by airplane from home when something like that might happen, so I think I probably have to give up watching the rocket go up. Soon after launch, scientists will be sitting there in control rooms with engineers and computer wizards to make sure that we're doing the right thing for the commissioning process: first unfolding the telescope and then focusing it and then setting up all the instruments. We are already doing rehearsals and detailed reviews of exactly what we are going to do at each minute of every day for the first six months after launch. We have a digital simulator of the observatory and send it commands to pretend that you're doing the real thing, pretend that something bad happens, and do you know how to respond?

Q: What's the big mystery we're trying to solve?
A: There's more than one mystery. They all fall into the category, for me anyway, of how did we get here from the Big Bang? What is the sequence of events that led from an expanding universe full of hot stuff to the expansion and turning around in places? With Webb, we will be seeing farther out into space and farther back in time. So we'll be able to see the first galaxies growing out of whatever was there. We will see the first stars turning on and the first stars blowing up. We will see some signs, we hope, of the first black holes forming and growing. After you see the first stars and galaxies growing and becoming more like modern ones, then we say, "Well, locally stars are being born today too, right? How is that working?" Over in the Orion Nebula, where you see Orion's sword has a big blob in the middle, that's a place where stars are being born today.

Mather got back to me later and noted that, actually, we see the nebula as it was about 1,300 years ago, the time it takes for light to reach us from Orion. — *C.H.*

You can't see them grow because they're inside dusty clouds that are opaque. Webb's infrared detectors will look inside those dusty clouds, around the dust rings to see stars and galaxies growing. We will also be looking at some places where we have signs of planets. We know there are planets around most stars, and some of them we can see already. Most of them are hard to see, but we will look where we know them to be. We know a pretty large catalog of stars that have planets that go in front of the star, causing the star to blink a little bit. We'll be looking especially at those because you can analyze the star light and say, "Well, some of it went through the planetary atmosphere on its way to our telescope. What's the chemistry of it?"

Q: You often phrase these science objectives as existential queries: Where do we come from and are we alone? So how do you boil these philosophical questions into the technical specifications of a telescope?
A: We go at it from both ends. You say, "Hey, scientists want the most observing capability you could possibly have because everything is unknown." And then we talked to our friends in engineering and they say, "Well, you can't have that. That's too hard for us." So we all agree about what we could build that would still be spectacular enough to be worth all this trouble. It's a kind of instinct; at first we think we can build it this big and this powerful, and then you try and maybe realize this isn't really going to fit after all. For a long time, we thought our telescope would be 8 meters across, and then we said, "That's too hard; how about 6.5 meters?" And now that we've got it just about finished, I think we must've been crazy to think we could get 8 meters in there. It's a very tight fit to get the 6.5-meter telescope into the top of the Ariane 5 rocket. It's folded up and it's still a snug fit. So you start off with a plan and engineers have to say, "I can't do that," and then we go back and say, "OK, scientists, are you still interested? Is this still the best thing that we could possibly build and is this still what you want?" And they of course said even if it's a little smaller, it's still super spectacular and they want it for sure.

Big science, but late

The main role of the James Webb Space Telescope will be to peer back 200 million years after the Big Bang at what scientists expect will be beautiful, hot swirling masses of gases in the process of becoming stars, planets and galaxies. Because the universe is flying apart, light from these features has been stretched to infrared wavelengths, which means Webb must be chilled to nearly absolute zero to image them.

By now, Webb should have been deep into this and other scientific work. But during construction, leaks were discovered in the valves that would pump propellant to the spacecraft's thrusters; its tennis-court-sized sunshield ripped during testing; engineers needed longer than expected to devise a way to fit the 6.5-meter primary mirror inside its launch vehicle's payload shroud and erect the mirror in space to the required precision. At best, Webb will reach space about 10 years later than planned, and its cost has increased to $9.6 billion, a figure that includes its first five years of operations.

— *Cat Hofacker*

Q: Was that reduction from an 8-meter to a 6.5-meter primary mirror disappointing? That translates to a decent amount of surface area you now don't have for capturing light.

A: Of course it's disappointing, but it's kind of obvious you have no choice. You just can't fit stuff in the rocket that's bigger than the payload fairing. You also contemplate how much is it going to cost us to build the mirrors and how long is it going to take us. We know what we're going to do and you can't possibly do the original plan, so do what you can with what you have and make it work.

Q: Even with the slightly smaller mirror, there's an awful lot to accomplish for what's estimated to be a five-year science mission. Can you achieve all you want to achieve with this telescope in five years, or do you think it'll end up going on longer?

A: We will run it as long as we have fuel to run it. It does need fuel for a couple of purposes: to stay where it's supposed to be in the Lagrange 2 orbit and also to point in the right direction. The sunshine actually pushes on the telescope and wants to turn it over, so we have to push back occasionally. We'll run it until we run out of fuel or something disastrous happens. What would be a catastrophic failure? There's nothing obvious we know. Other observatories have gyros that wear out or wheels that wear out. The gyros that we're using to measure the speed the spacecraft is turning are different from what they have on the Hubble, which had to be replaced. We're planning to keep on running Webb until we can't. We've got fuel for 10 years, at least, and if we're lucky, a lot more. So I'm not too worried about the five-year life; it's just that you can't promise something that you could never possibly test. We don't have a way that we know of to use it after the fuel is gone, so what we have to do is make sure it doesn't come back and hit the Earth.

▲ **The Orion Nebula** in an image from the Hubble Space Telescope. The James Webb Space Telescope's infrared detectors will "look inside those dusty clouds, around the dust rings to see stars and galaxies growing," Mather says.

NASA

"We calculated that if you were a bumblebee hovering at the distance of the moon, we could see the sunlight that you would reflect and the heat that you would radiate."

Q: Along with the change to the mirror, a coronagraph instrument was later added to detect distant planets. What drove that decision?

A: When we first conceived of the observatory, we didn't really know there were planets around other stars. It tells you how far back in time we started; in 1995 was our first conversation. That's when they were just beginning to find planets with the radial velocity technique from the ground. So as time went on we said, "Well, it would be really great if you have a coronagraph or something that would block the light of a star so you can see the little planets orbiting nearby, and so what should you do to have one?" You wouldn't want a telescope with a very different design, so very small changes were made at the instrument package just to say, "OK, well, look, we'll do what we can, but they're not allowed to make anything more difficult." When we get to designing a next observatory that's specially built to look for those planets, then they'll make some different choices.

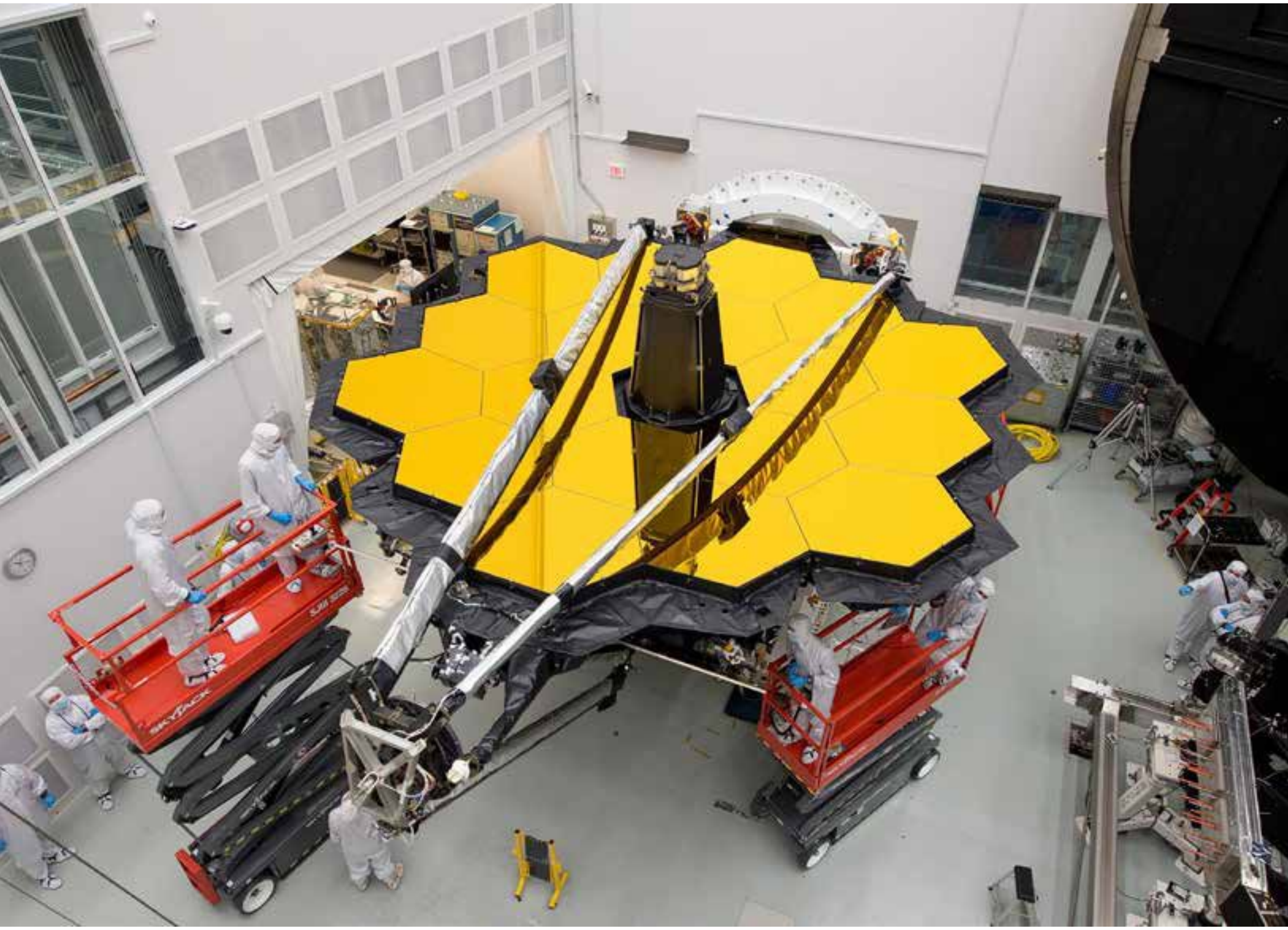
Q: So because Webb was conceived more than 25 years ago, how have the questions driving the science goals changed over time? And how do you make sure this design can answer not only those questions but the surprises that might await us?

A: What we know is certainly going to improve with time, so we had to ask, "What are you going to do with this observatory that nobody could ever do without it?" I ended up working with science teams to define, "What do you really want? What are the science objectives? Why are they so exciting that you should spend all this time and money on answering those questions?" In other words, what makes the Webb telescope special and unique? And it is two things: One is that it is very large, and one is that it can pick up the infrared light very well. Nobody had any plans to do anything like that with any other tool. Even if we've learned more about the subjects that we're looking at, we're still never going to get the information that the Webb telescope will. We said, "Well, suppose this doesn't work out. What else could you do?" And the answer is there's no way to get that information without that telescope.

Q: After 25 years of concepts and studies and construction, if someone came to you today and asked for an infrared telescope with the same objectives, would you do it differently?

A: It's certainly been a little bit longer trip than we were all planning. When we all started, we were very ambitious and very optimistic. We had a very optimistic boss at the time, former NASA Administrator Dan Goldin, who said, "Well, why didn't you just do it quicker?" It didn't turn out to be that you could. You're going to draw the sketches really quick, but you can't actually go through the process of building something that you're sure is going to work. If you want it to work, you really have to do it through every single test. It is sort of my lesson from life: If you do not test it, it will not work. And there's no such thing as taking a chance when there are hundreds and thousands of different ways that something could go wrong. If you don't check them all, one of them will get you. The test program that we do is 100% essential and it takes them forever. We've learned a few things about how to do the engineering, but there is actually no other way to get that information besides a big telescope that's cold in space. So you might do a different design. You might say, "Well, I have different mirror materials, a different way of unfolding it, a different way of cooling it down,

▼ **The honeycomb** primary mirror of the James Webb Space Telescope at NASA's Johnson Space Center in 2018, where the mirror and the science instruments (not pictured) were placed inside a cryovacuum chamber that replicated the freezing temperatures the telescope will operate in.
NASA



▲ **JWST in its launch** configuration at the Northrop Grumman clean room in California, where engineers in October completed the acoustic and vibration testing that replicated the forces the observatory will experience during launch. Plans call for enclosing the observatory in a protective container early next year and shipping it on a barge to French Guiana for fitting inside the payload fairing of an Ariane 5 rocket.
NASA

different design for the instrument package." All the details would be different if you started fresh, but the general idea has to be about the same.

Q: So paint me a picture of a future in which Webb has launched, the Nancy Grace Roman Space Telescope [formerly the Wide Field Infrared Space Telescope] has launched and Hubble is still operating. How do these telescopes work together?

A: What usually happens is somebody that's using one telescope says, "Look what I found; this is really important, and can I have some observing time on your telescope?" That's pretty likely. The Hubble has been running a long time, so I don't expect to get a lot of new surprises from it. The Roman telescope is pretty likely to show us a surprise because it takes pictures of huge areas of the sky all at once. It has a hundred times as much "bite" — meaning it can see 100 times as much sky at one time — as the Hubble can get or the Webb, so if there's anything special and unusual, it's likely to find it. We are expecting to get phone calls from astronomers to say, "Look what I found, please follow it up right now." Webb is bigger, collects more photons, is more sensitive at most of the wavelengths that we cover, but we would still get beautiful pictures. They will be different. Infrared sky really does look different from the ordinary visible sky, spectacular pictures we get with Hubble. We will be able to do those, and we'll be able to do them much more quickly, but we'll also get other pictures that you never could have seen.

Q: I remember hearing the first pictures of Hubble caused such a frenzy, they broke the internet. As a scientist, what's most exciting, these spectacular images or something else?

A: For me as a scientist, the exciting part is the discovery, the things that we didn't ever know were there before. Hubble certainly surprised us. The one that I really fastened on is that every galaxy has a black hole in the middle and nobody had ever guessed that. Nobody had any reason to expect it. Nobody had ever seen it; the Hubble had just enough power to see them. And so, oh golly, that changes everything. Then we certainly did not expect that it'd be able to image planets around other stars or start getting chemical

"We're planning to keep on running Webb until we can't. We've got fuel for 10 years, at least, and if we're lucky, a lot more."

analysis of those planets when they transit in front of their stars, but the Hubble did those things with the tools that were designed with something else in mind. It's my hope that we're going to get a similar number of surprises out of the Webb telescope, that something is going to be there nobody dreamed about.

Q: Given that it's taken much longer than planned to begin operations, what impact do you think Webb will have on future observatories?

A: We hope they're all positive, that the telescope works as planned and it does indeed discover things people are hoping to find, and then it opens up questions that we didn't even have before because we couldn't even ask them before. If we don't find a big surprise, I'll be disappointed, but you know, one way I think about this is this telescope is so incredibly powerful that it's hard to imagine how the universe has no surprises for us. We calculated that if you were a bumblebee hovering at the distance of the moon, we could see the sunlight that you would reflect and the heat that you would radiate.

Q: Do you worry at all that because Webb's costs have increased so much over time — to nearly $10 billion from the $1 billion originally estimated — that future observatories will be more limited in cost and maybe scope?

A: Yeah. People have up and down feelings about these things. When you're a graduate student, you can't possibly imagine how anyone would spend so much money on one thing, then you just get into the middle of it and you say, "Now I understand how that takes all that money and all that time." Really, it's actually people's time that we're getting; how many engineers and technicians does it take to build something that really will work? It's a lot. So I'm hoping that our next generation will be equally ambitious and say, "That is so important that it's worth money." I think it's important, and it is worth all that money, and I think the next generations will be as well. Our number one thing we have to do is prove that it can be done and that this amazingly difficult and complex thing will work. We do that, then I think people will be ambitious.

Q: It sounds similar to how the impact of the Apollo era is described. How did you feel that impact, personally?

A: I still feel it. I look around and so much of what we have today is because of the national push for excellence in science and engineering in the Apollo days. Apollo was the sort of visible piece of the Cold War, and it was the way that the nation could say we're going to invest in science and engineering. And so now we are the world leaders in so many areas that were sponsored by those people. So it affected my future. I got to go to school to be a scientist because we got to beat the Soviet Union. It's hard to remember my early childhood very well because I didn't keep a lab notebook, a diary; I wasn't a real scientist yet. But even when I was 8 years old, I would have heard about Darwin and Galileo, and I saw the planetarium show with the museum. "Oh, this is so exciting." And then there were television programs about the beginnings of knowledge. I didn't know how I was going to fit into that. I just thought quantum mechanics, relativity, that is the coolest thing; I just have to understand that. It still is strange and mysterious, and people do not have intuition about it. I thought if I can do anything like work on those topics, that will be cool.

Q: Webb is in some ways the continuation of your Nobel Prize-winning work with the Cosmic Background Explorer satellite. Webb is peering back 200 million years after the Big Bang; can we go even further?

A: We certainly can learn more about the Big Bang because we're already working on it. The cosmic microwave radiation that we've measured with a COBE satellite and got to go to Stockholm for has still one big territory that's unmeasured. It's called the polarization. A piece of the polarization of that radiation should come from the Big Bang itself. So that's as far as you can get in that direction, and if you ever understand that, you'll get as close as you can ever get to observing what the physicists called the unification of the forces. This is one of their holy grails: to see how the forces of physics connect. Quantum gravity is the basis of that. And we don't know what it is. So that's one big mystery. Then all the steps about how we turn the early universe into life. That's fascinating, too, and astronomers will work on their part. We can tell you when and how the atoms got to make a little planet like Earth with the right conditions. Then we'll hand over the job to biologists and other people to say, "The chemicals could have done this, and maybe that would have become alive." So I think eventually we'll have a story about that. That's not impossible that we'll have an understanding of it, even though the evidence has mostly disappeared. ★

Modeling structural strength

Production engineers are researching an improved version of the robotic layup technique that forms wings and other critical parts of airliners. At the moment, they won't have a way to assess the strength and flexibility of parts made with this new technique without lots of physical testing. Keith Button tells us about a possible solution.

BY KEITH BUTTON | buttonkeith@gmail.com

▲ **A steered** automated fiber placement gantry robot builds an aircraft part by laying strips of sticky resin-infused carbon-fiber tape, layer upon layer. The structure will be hardened in an autoclave.
MTorres

Building the carbon-fiber wing of a Boeing 787 or Airbus A350 starts with a robot arm slung from a gantry and gliding swiftly back and forth over a mold of the wing. The arm whirs and clicks like a PC printer head gliding over a sheet of paper — if the printer were large enough to hold the wing of an airliner. With this technique called automated fiber placement, or AFP, the robot lays down strips of sticky, resin-infused carbon-fiber tape, side by side and then layer upon layer, to build a 3D wing or fuselage structure that later will be hardened in a giant autoclave, a chamber that heats and pressurizes for curing.

Wings built from this robotic method are safety tested for strength and flexibility just as other variations of carbon-fiber wings and aluminum wings were before them: with physical stress tests. AFP robots are capable of building carbon-fiber structures with finely tuned strength and flexibility for specific points in an airplane, which has at least in theory opened up new design possibilities for stronger, lighter aircraft. But the endless structural variations that are theoretically possible from the AFP robots are limited by the cold, hard reality of expensive and time-consuming physical testing that is required for each iteration.

A University of Michigan aerospace engineering professor and a team of colleagues and students are building computer models to predict the strength of carbon-fiber composite wings, fuselages and other aerospace structures made with AFP techniques. If they are successful, airplane manufacturers will have a tool to help them know whether an AFP-made structure is as strong and flexible as designers intended it to be, without having to physically test that structure, opening up new design possibilities for stronger, lighter aircraft.

The professor, Anthony Waas, began developing the computer models about six years ago as manufacturers began making large aerospace structures with the method. An AFP robot can produce precisely the same patterns of carbon fiber every time, repeating the exact same wing or fuselage structure it was programmed to build over and over, and swiftly. While airplane builders are currently employing AFP, airplane designers have just scratched the surface of concepts made possible by AFP for stronger, lighter designs with precise degrees of flexibility or stiffness at specific points within the planes' structures.

Steered AFP expands possibilities

"We will see further and further and further improvements, and we are going to see amazing new capabilities; new designs; new structures; new everything, as time goes on," Waas says. "You can actually make the structure behave exactly the way you want it to behave for different loads: when it's in flight, when it's maneuvering, when it's lifting."

Those possibilities are expanding even more with a new variation on the automated fiber placement technique called steered AFP.

To build a large carbon-fiber structure for an airplane, AFP robots typically put down the 3-millimeter- to 1-centimeter-wide strips of tape in straight-line patterns for each layer, often many strips at a time in 20-centimeter-wide swaths with each pass over the mold. To create structural complexity and added strength in a carbon-fiber laminate, a robot might lay down the first layer in parallel strips at a 0-degree directional heading, followed by a second layer set at a 45-degree heading, then minus 45 degrees, then back to 0 degrees, and so on. The skin of a wing root might be made from 150 layers of tape to maximize strength, while the skin of the wing tip might require only 10 layers.

Steered AFP makes even more patterns and structural complexity possible.

With steered AFP, the robot can be programmed to lay down the parallel strips in curves, and therefore engineers can design lighter and stronger wings and other structures, along with added stiffness or flexibility, as the design may require at specific locations. The robot might steer circular patterns around the windows in a fuselage, for example, or for a wing lay down S-shaped patterns that are offset with each subsequent layer to tailor the design for added stiffness and strength.

From academia to industry

The expansive possibilities created by AFP and steered AFP techniques presented a problem for airplane builders and the companies trying to sell AFP robots to them: Without software that could reliably predict the strength and flexibility of all these newly possible carbon-fiber structures, each new structure would have to be physically tested. That could be expensive and time-consuming. Waas set out to develop his predictive computer models to solve this problem.

The issue is especially prominent for steered AFP, which is still in the research and development stage for aerospace applications, says Timothy Brooks, a former student of Waas' and now a research and development engineer in Boston for Nevada-based Aerion Supersonic. "One of the hardest problems you get is that as of today there doesn't really exist a standard process or procedure for certifying" steered AFP structures, he says.

To move steered AFP concepts from the academic and research realm into large-scale aircraft production, the industry will need computer modeling, which can provide a better understanding of the specific strength, flexibility and weakness of individual steered AFP structures. Predictive computer models would also represent a big step toward certifying aerospace structures for regulators

▲ **This composite** sample was made with the steered AFP (automated fiber placement) technique. A robotic tool lays carbon fibers in curved patterns to accommodate rounded windows and curves in wings or to lay down more varied patterns to support greater loads.
University of Michigan

without extensive physical testing, Brooks says.

Currently, traditional AFP is widely used by airplane makers, but "there's been very little exploration of moving away from that and looking at steered AFP laminates," Brooks says. "Figuring out how to build confidence in these laminates and predicting a lot of these mechanisms I think is crucially important to getting them adopted in future designs."

Waas chose a finite element method software called Abaqus, sold by Dassault Systèmes Simulia Corp. of Rhode Island, as the base for the computer models and software that he and his team of five graduate students and postdoctorals are developing. The software determines the strength of a structure, such as a wing, by solving millions of equations quickly. Specifically, the strength of every cell within a mesh overlay of the structure would be calculated, as would the strength of every cell for submeshes within that mesh, and so on.

Waas is adding physics to the software, analyzing how manufacturing defects in the robot-made carbon-fiber structures can fail down to the level of the matrix of interlocking 6-micrometer-diameter fibers. "If you know the details of the microstructure of the material, you can actually predict the strength," he says.

To predict the strength of a robotically manufactured aviation structure, Waas first has to identify robot-induced defects — the deviations from the perfect intended structure — and show how they affect structural strength. These defects can include points where strips of carbon fiber tape overlap, where ends of tape butt against each other, gaps of varying sizes between two abutting ends, an abutting-end gap in one layer of tape that aligns with a gap in a subsequent layer of tape, and gaps on different layers that nearly align.

The team has made physical samples of the types of potential defects from carbon-fiber tape, starting with 5-by-5-cm squares a few layers thick, hardened them in an oven, and then tested their tensile and compression strength. For tensile tests, the researchers clamped the samples into test frames powered by hydraulic pistons and gradually pulled them apart, measuring the strain leading up to the sample breaking and recording the cracking and breakage with high-speed cameras. The setup was similar for the hydraulic piston-driven compression tests. They compared the samples with defects to samples without defects and found that the degree of structural weaknesses caused by the defects depends on their type and distribution in the carbon-fiber samples. Also: Some of the defects actually add strength to the carbon-fiber laminate.

Testing bigger structures

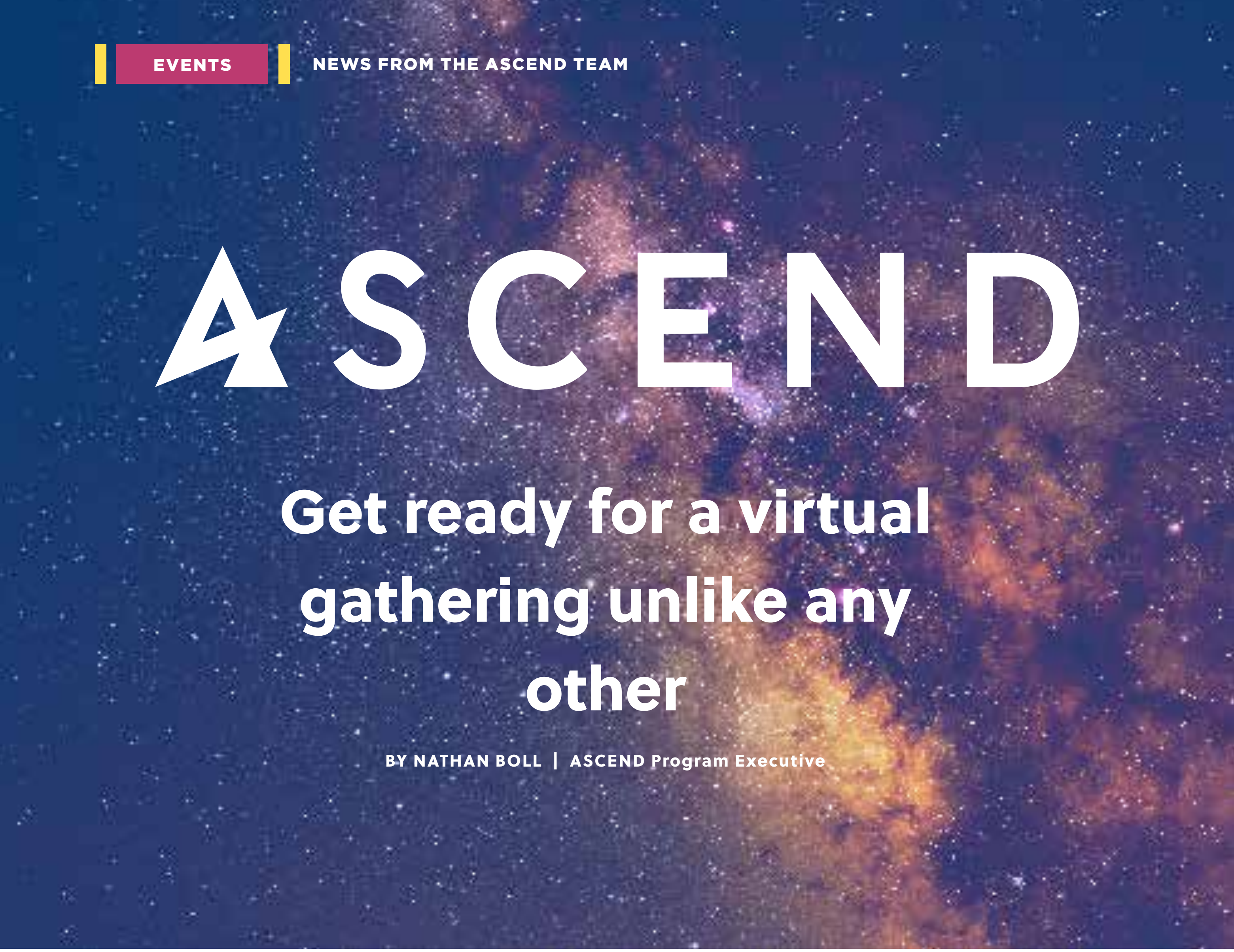
The team of engineers plans to test larger samples with more layers and more variations on the defects. In the latest testing, they examined 46-cm-wide squares. Next, the team will move on from testing small pieces of structures to larger pieces and then whole structures. The team has about 15 engineers working on the project, including the Michigan team, University of Texas at Arlington assistant professor Paul Davidson, representatives from two AFP robot makers — Electroimpact of Washington state and Spain-headquartered MTorres — and Japan-based carbon-fiber supplier Toray Industries.

Once the defect types and their effects on structural strength are cataloged and factored into the computer models, the models can take the defect "signature" of an individual AFP robot and precisely predict the strength of the carbon-fiber structures it will produce, Waas says. The robot's signature is predictable in a given structure it is programmed to make because the robot will do the same thing every time.

"The signature contains all of the types of imperfections that you might run into, and there aren't many; it's countable," Waas says. "The robot does a fantastic job; it really is very precise. But it can be precisely incorrect, or precisely off by a certain factor."

The next steps for Waas' team include validating the software with larger and more varied carbon-fiber structures, which involves making, breaking and analyzing many, many samples, he says.

"It takes time; this is done by hand by the students and post-docs," Waas says. "It's not easy push-a-button-and-the-results-come-out. It's a process." ★



ASCEND

Get ready for a virtual gathering unlike any other

BY NATHAN BOLL | ASCEND Program Executive

Even before the COVID-19 pandemic halted in-person events, ASCEND was going to be unlike traditional conferences. Rather than a forum focused on technological advances, we've designed ASCEND from the outset to encourage people to work across disciplines to advance space exploration, propel commercialization and ultimately pave the way for off-world civilizations.

"ASCEND will be a new kind of conference," says Tory Bruno, United Launch Alliance president and CEO and a member of the ASCEND Guiding Coalition. "It will incorporate formats that involve more discussion on thought-provoking topics, rather than the traditional, passive listening to papers and updates on important, but dry topics. ASCEND will have greater appeal and utility for early career professionals and students while also offering the depth and sophistication that can be appreciated by senior industry experts."

Now that ASCEND has moved online, it is likely to attract a far larger global audience than an in-person event would. It's also likely to bring in young professionals and students who might not have opportunities to travel to conferences.

"We are very excited about the potential of this new format to energize our community and reach people unaddressed in the past," Bruno says.

Similarly, Robert Lightfoot, vice president for strategy and business development at Lockheed Martin, ASCEND's Inaugural Cornerstone Founding Sponsor, calls ASCEND "a great opportunity to engage the next generation." Lightfoot, a member of the ASCEND Guiding Coalition, adds, "I need that next generation in my workforce like all of industry does."

ASCEND attendees will gather virtually 16-18 November to share technical and other insights, while hearing from dozens of speakers, including NASA Administrator Jim Bridenstine, U.S. Space Force Chief of Space Operations Gen. John W. "Jay" Raymond, and Marillyn Hewson, Lockheed Martin executive chairman.

ASCEND's Guiding Coalition, a who's who of U.S. government and space industry leaders, offered AIAA advice on top-level themes and helped invite conference speakers. Then, members of the space community contributed the vast majority of ASCEND programming through hundreds of papers and session proposals.

"Aerojet Rocketdyne is proud to be part of the first ASCEND event, which is taking a holistic look at the exploration, settlement and commercialization of space — from technical, business, policy and aspirational viewpoints," says Aerojet Rocketdyne's Jim Maser, the senior vice president in charge of the Space Business Unit and a member of the ASCEND Guiding Coalition. "Bringing together a diverse group of thought leaders to discuss and debate their ideas and views will help to move the whole industry forward."

Nonscientific aspects of creating a sustainable space economy, including building a diverse and inclusive workforce, are high on the ASCEND agenda. The event will highlight the achievements of space community women and minority leaders, providing recognition for their work and examples for future generations.

"While AIAA has long been a driver behind America's leading role in aerospace and space exploration, ASCEND will help propel innovation and professional collaboration to another level," says Boeing's Jim Chilton, the senior vice president in charge of the Space and Launch division, and a member of the ASCEND Guiding Coalition. "It's been exciting to see such interest in the broader range of topics and speakers, the new formats for engagement, and the opportunities for participation at every career level and from so many professional and technical disciplines. ASCEND will be a crucible for idea exchange, discussion, debate and friendship that will help shape future space exploration and the space economy."

ASCEND is an acronym that stands for Accelerating Space Commerce, Exploration and New Discovery. The event will be built around three overarching themes: accelerating the near-term commercialization of space; enabling the long-term human exploration and settlement of space; and exploring the security, policy and legal ramifications of space endeavors.

"The programming will focus on technology, exploration and the future of space," says Clay Mowry, Blue Origin vice president for global sales and an ASCEND Guiding Coalition member. "In these virtual times, it's more important than ever to stay connected with our industry on these critical topics."

ASCEND programming falls into three tiers. Macro sessions will explore overarching questions to help establish a shared vision of the future, behind which the technological, economic and industrial activities propelling the space economy can coalesce. Panelists will drill deeper during Meta sessions to identify the greatest opportunities and challenges of realizing that shared vision, while exploring how specific industries such as communications, construction and mining will help shape the off-world economy. Micro sessions will focus on the details — cutting-edge technical innovations, education and workforce development, legal and policy analysis, and much more — all aimed at addressing the challenges the community is likely to encounter as civilization expands farther in space.

To encourage conversation, networking and collaboration, ASCEND attendees can meet in virtual booths in the Engagement Zone. Also, The Aerospace Corp.'s virtual booth will offer a comprehensive look at Space Agenda 2021, a series of 28 policy papers from the Center for Space Policy and Strategy. Each paper offers an in-depth look at a space-related issue the United States will face during the next presidential term.

"The timing and themes of ASCEND afford the perfect opportunity to share ideas and have conversations around critical topics that define the future of space," says Steve Isakowitz, Aerospace president and CEO and ASCEND Guiding Coalition member.

"While everyone likes to attend conferences in person to network, AIAA deserves a lot of credit for turning on a dime to transform ASCEND into a virtual event that will offer tremendous value," Lightfoot says. ★

AT A GLANCE

WHAT: ASCEND, the event to drive the space economy forward, from the American Institute of Aeronautics and Astronautics

WHEN: 16-18 November

WHERE: Virtual gathering at ASCEND.events

WHO: Engineers, policymakers, entrepreneurs, inventors, security experts, educators, investors, government leaders, artists, economists, scientists, students, astronauts, lawyers, business executives and researchers

INAUGURAL CORNERSTONE FOUNDING SPONSOR: Lockheed Martin

SPONSORS: Aerojet Rocketdyne, The Aerospace Corp., Blue Origin, Boeing and United Launch Alliance

5 NECESSITIES FOR Thriving in space

Expanding civilization off Earth will require incredible breakthroughs. Resources must be mined on site and turned into fuel, drinking water and other supplies for settlers, who can't carry adequate food and health care infrastructure with them from Earth. Even with in situ resource utilization, the transportation challenges will be enormous, considering that to date humanity has delivered fewer than 600 people to space, and most of them no farther than Earth orbit. Only 24 have traveled to the moon's surface. Also, linking future settlers to each other and Earth will require high-throughput communications that today do not exist in deep space. **Debra Werner and Cat Hofacker** sought out an entrepreneur in each of these areas to point the way toward solutions.

BY DEBRA WERNER | werner.debra@gmail.com AND CAT HOFACKER | catherineh@aiaa.org

Communica-tions

MINA MITRY

Co-founder and CEO of Kepler Communications in Toronto

We've never built telecommunications infrastructure to support predominantly connectivity outside of the Earth, apart from the TDRSS [Tracking and Data Relay Satellite System] and EDRSS [European Data Relay Satellite System], which are government-led initiatives.

TDRSS is difficult to access and exorbitant in costs for any commercial user. EDRSS carries similar challenges. Even the EDRSS laser communications terminal is difficult to support on many missions because it consumes gross amounts of power and it's difficult to point. That's not conducive to the early markets that will adopt in-space connectivity.

So, one of the biggest challenges will be providing communications devices and infrastructures that are compatible with the small, low-cost machine architecture of many early users of in-space connectivity. I started Kepler Communications with three other engineers in 2015 to create a commercial replacement for TDRSS.

The path toward supporting off-world civilization begins with supporting these early users of in-space connectivity. Incremental markets formed using services in space will be the reason we're able to get off-world.

At Kepler, we're looking at concepts for lunar communications because of all the lunar initiatives taking place. If the concepts are for data-relay communications, then each bit or byte would travel from a point on the lunar surface through a few satellites to reach Earth.

Historically, most communications concepts have been led by the Deep Space Network or direct-to-Earth connectivity. The high data consumption that will inevitably come from more prevalent use of space will call for within-space networking to support the vast variety of user requirements.

The biggest challenge for lunar communications will be the radiation environment. It's encouraging that the MarCO satellites that relayed imagery from NASA's InSight lander in 2018 demonstrated the capabilities you can get from lower-cost small satellites.

Lunar satellites will need more radiation hardening for hardware and software. One of the biggest issues related to radios in orbit is single-event upset of a logic gate. That happens when a high dose of ionizing radiation turns a zero into a one inside a software-defined radio's signal processor, which deciphers the waveform. We would program the satellites to vote on which circuit has the right solution. That would allow us to overcome some of these radiation issues. It's like having three people vote on the right solution. If one is a little delusional, two out of three can agree on the answer.

Food production

ROBERT RICHTER

Director of environmental systems at Sierra Nevada Corp. in Colorado

Having enough food on board will be one of the biggest obstacles to sustaining people off the planet for long periods of time. Frequent resupply trips won't be feasible when crews are a two-year journey away on Mars. Being able to grow fresh produce onboard not only frees up valuable space and mass, but plants provide micronutrients that a lot of the dehydrated foods that make up the bulk of astronauts' diets lose over time as they sit on a shelf. We're also finding out in talking to a lot of these astronauts that there are psychological benefits. It's something green that reminds them of home.

The lack of gravity provides the biggest challenge to in-space food production. It's this balancing point of providing the right amount and mixture of water and nutrient solution to the roots to really get each plant to thrive. In 2012, the former company Orbitec, now fully integrated as SNC, designed the Vegetable Production System, or Veggie, as a simple way to achieve this. Each unit consists of a rectangular tray set into a plastic bellows that creates a microclimate within itself by keeping the roots and the shoots at a similar temperature. A Veggie can hold ap-

Astronauts aboard the International Space Station have grown various foods, including mizuna, red romaine lettuce and tokyo bekana cabbage. While this was an experiment, long space trips eventually will require crews to grow their own food.

NASA

proximately six plants, which are contained in little fabric pillows full of a clay media. Unlike a loose soil, the clay acts as a rigid sponge, allowing the plant roots to extract water through small openings without providing so much water that they drown. The plants also draw energy from a combination of overhead red, green and blue LED lights; the red and blue parts of the spectrum are what the plants absorb.

There are currently two Veggie units on ISS growing small amounts of produce. The next step is large-scale food production, for which you need to optimize the number of plants grown in what space is available to you. SNC's answer to this is the Astro Garden. Each rectangular unit consists of eight independent chambers, and units can be stacked on top of each other against the side of a spacecraft wall, such as the inflatable LIFE Habitat SNC is building.

If I were to forecast, I would say the next stepping stone is more plant-based proteins that simulate meat. And if you reach massive scales of production, some of these plants could eventually serve as a hybrid life support system by providing supplemental oxygen. As we go to Mars, you're going to see the evolution of technologies that are required for self-sustaining settlements.

Manufacturing

JOHN VELLINGER

President and CEO of Techshot in Indiana

One of the exciting opportunities for Techshot is biomanufacturing in space. We have bio-printed human heart cells and a meniscus in our 3D BioFabrication Facility or BFF, located aboard the International Space Station inside the U.S. National Laboratory.

Our near-term objectives are manufacturing tissue and biopharmaceuticals for people on Earth. In the long term, this technology could help doctors repair tissue damaged in space by radiation.

Whether it's an astronaut on an exploration mission in the next 10 years, or a citizen of a distant off-world civilization, each will be at risk of suffering severe radiation damage. One of our goals is to develop technology to print replacement adenoid and lymphoid immune tissue.

We would collect a space traveler's cells prior to launch (or perhaps at birth for someone born in space) to store in radiation-resistant enclosures. The Techshot Cell Factory would multiply the cells and produce the inks for 3D bioprinting in BFF.

For now, our biggest challenge is getting tissues and the cells up to the space station and back down. Thermal control is very important to living tissues. That means we need power to maintain thermal conditions for living tissues while they are being transported. There are only so many of those powered lockers available.

As commercial space stations come online, I think that's going to ease some of these constraints. We are working with Axiom, the company NASA selected to attach a commercial module to the space station in 2024, and other commercial space station builders to find room for more bioprinters and other microgravity research equipment. Everybody realizes this is a new era and a new opportunity.

We are working on a Multimaterial Fabrication Laboratory called FabLab, a 3D printer for plastic, metal, ceramics and electronics. Metal and electronics manufacturing is a critical technology for long-term exploration missions. The philosophy is: Make it; don't take it.

The challenge is having the right raw materials to make the most diverse set of electronic components. You obviously can't make everything. You have to select the raw materials you think are most likely to be utilized on an exploration mission. With the current FabLab prototype, we're back to the same issue: space constraints. We need room to test this stuff on board the space station.

The BioFabrication Facility and ADvanced Space Experiment Processor (the upper right white box) have bio-printed human tissue on board the International Space Station.

Techshot

▲ **An Orbit Fab refueling** satellite approaches the refueling port on an Xplore Xcraft spacecraft. Xplore Inc. plans to launch its first Xcraft in 2022 with one of these ports, called RAFTI, short for Rapidly Attachable Fluid Transfer Interface.
Bryan Versteeg/SpaceHabs.com

Mining

DANIEL FABER

Co-founder and CEO of Orbit Fab in California; former CEO of Deep Space Industries in California

The biggest challenge to building an off-planet resource economy is demand. Nobody is buying water and other space resources at the moment partly because nobody is selling them. I founded Orbit Fab two years ago with Jeremy Schiel to build gas stations in space to refuel satellites and extend their lives. We could see a demand for propellant in orbit. Initially, we will address the demand with propellant we lift off the Earth. We will create that supply chain. Then, if somebody can get propellant to us even a fraction cheaper by bringing it from an asteroid or the moon, we'll take that propellant and distribute it.

Earlier, at Deep Space Industries, we saw asteroids as the most promising prospective target for mining metals for off-world manufacturing and habitat construction and also for sale on Earth. We conducted a desktop scoping study of a mining operation for asteroids including extraction, processing, manufacturing and transportation. In terms of challenges, assessing diggability is the toughest. We can't get that from meteorite samples because the only samples we have are the ones that survived fiery passages through Earth's atmosphere. We don't know what the rocks are like in space and we don't have local verification to confirm the mineralogy. Every time we touch another planetary body or comet or asteroid, we learn something about the variability of those surfaces.

Six years ago, when the European Space Agency dispatched its Philae lander to close in on comet 67P at 3.6 kph, no one knew for certain what kind of surface it would encounter. The surface could have been sticky or solid rock or so fluffy the lander would disappear. What happened was the lander bounced and then the surface shattered and a crater opened up underneath. It was a creme brulee-type surface.

We may learn that black asteroids have specific properties and shinier ones have other properties. We need those correlations to know which rocks are easy to extract. We know that for mining operations on Earth, but even then we have to run pilot programs to make sure extraction processes work properly.

Transportation

JOEL SERCEL

Founder and CEO of Trans Astronautica Corp. in California

The biggest challenge to building an off-world future with hundreds, thousands and then millions of people living and working in space will be learning to harvest and use extraterrestrial resources to supply fully reusable spaceships. Humanity is on the verge of having reusable rockets that can carry large numbers of people to space affordably. But it will never be affordable for us to bring up all the rocket propellant, air and water that we will need for those people to live and work in space in a sustainable way. For that, we need to learn to harvest and use the resources of the moon and asteroids. Both SpaceX and Blue Origin are making great progress toward affordable, reusable rockets and spacecraft, but what they are doing is not enough.

I formed TransAstra several years ago to do the fundamental research and develop the technology to harvest water, methane and other resources from asteroids and lunar polar ices. The reusable vehicles that SpaceX and Blue Origin are developing will need rocket propellant and other consumables. TransAstra will supply them. The science is clear that many near-Earth asteroids are rich with the ingredients in rocket propellant: carbon, methane and water. The lunar poles are full of water ice and other valuable materials. TransAstra is developing the technologies and the systems to harvest those ices so they can be made into rocket propellant and sold in space to supply NASA, government and private spaceships. Mars is also known to have water, and the Martian atmosphere is primarily composed of carbon dioxide. With water and carbon dioxide, we can make liquid oxygen, liquid hydrogen and methane, the propellants SpaceX and Blue Origin will need.

Once we have reusable vehicles and can harvest propellant locally, travel in space can start to become so affordable that large scientific outposts and hotels will make economic sense on the moon. After that, we will build towns and cities in space supplied from the asteroids.

Here at TransAstra, we also plan to use water directly as propellant. We've invented a patent-pending solar thermal thruster called Omnivore that concentrates sunlight to turn water into superheated steam. Water propellant has key advantages in terms of logistics and ease of storage. But we can't use water directly as propellant to launch from planetary surfaces. The thrust isn't high enough.

In addition to Omnivore we have also invented, tested and applied for patents on other key innovations. These include the optical mining method to harvest asteroid resources and a rover-based process that uses radiation to harvest water from lunar polar regions. Finally, we have a breakthrough power system called Sun Flower to provide megawatts of low-cost electric power to support outposts and mining operations in lunar polar regions. ★

> "Once we have reusable vehicles and can harvest propellant locally, travel in space can start to become so affordable that large scientific outposts and hotels will make economic sense on the moon."
>
> — **Joel Sercel**, Trans Astronautica Corp.

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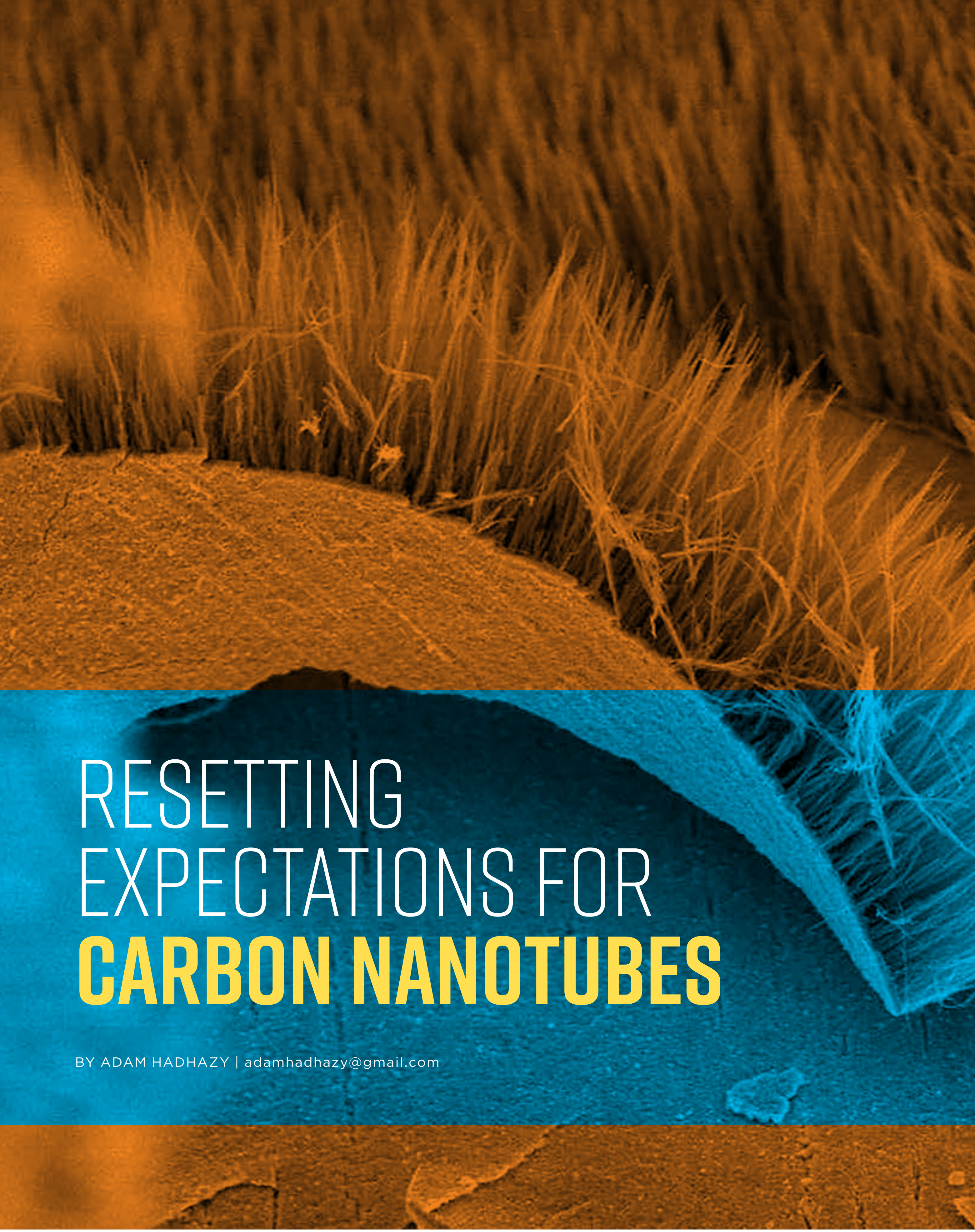
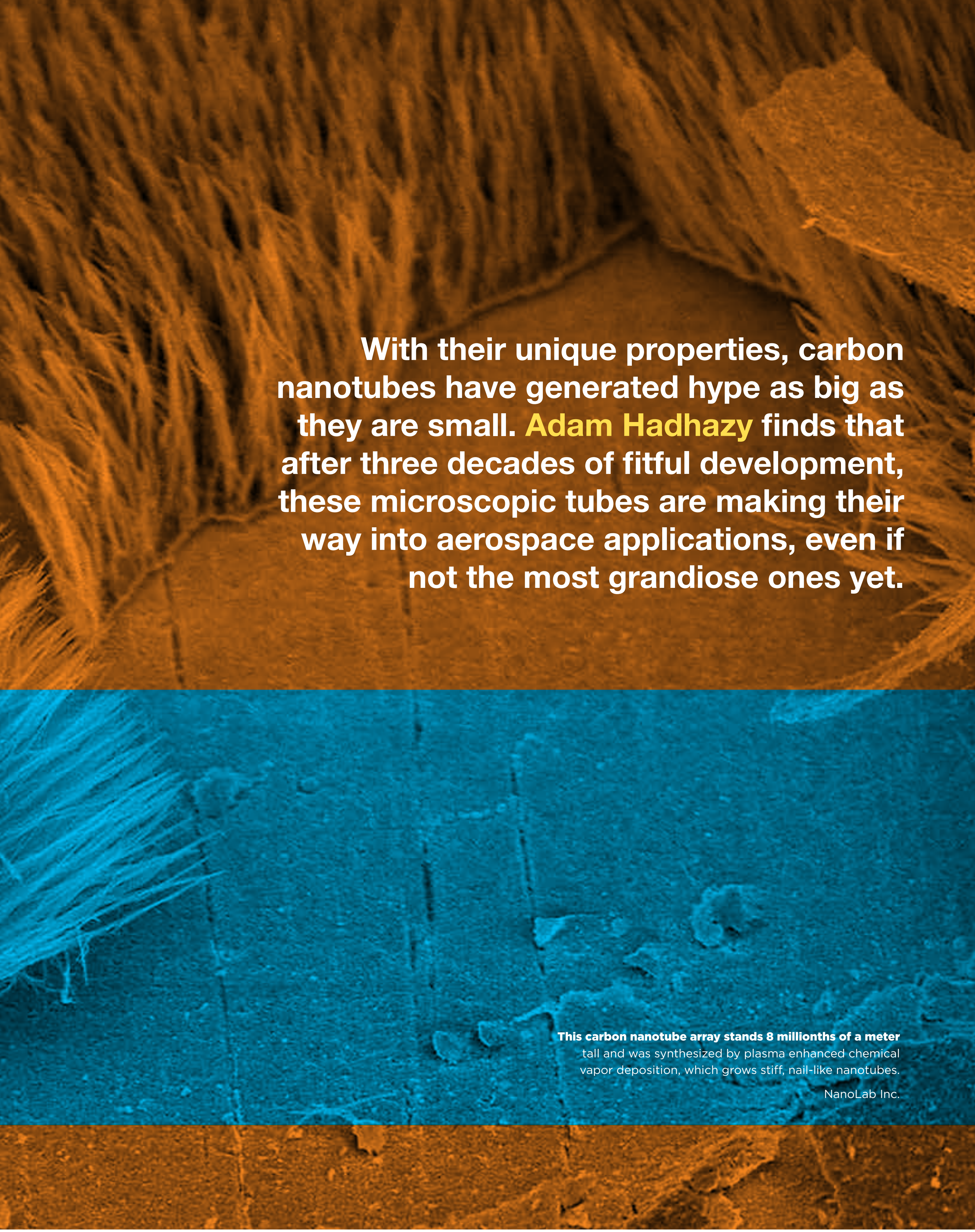


RESETTING EXPECTATIONS FOR **CARBON NANOTUBES**

BY ADAM HADHAZY | adamhadhazy@gmail.com



With their unique properties, carbon nanotubes have generated hype as big as they are small. Adam Hadhazy finds that after three decades of fitful development, these microscopic tubes are making their way into aerospace applications, even if not the most grandiose ones yet.

This carbon nanotube array stands 8 millionths of a meter tall and was synthesized by plasma enhanced chemical vapor deposition, which grows stiff, nail-like nanotubes.

NanoLab Inc.

If you shrank yourself by a factor of several hundred million and grasped a long carbon nanotube as if it were a steel rod, it would feel surprisingly light. If you slammed the slender, hollow tube against some nearby molecules, it would not break, even though its walls look delicate, a mere single atom thin. But be careful and don't touch the tube against something hot or electrified, because depending on how its atoms are arranged, it would conduct heat and current stunningly well and you'd be toast.

Materials scientists have been touting these and other properties of nanotubes since the early 1990s, promising a revolution in aerospace and other sectors. Lab tests show that carbon nanotubes have hundreds of times the tensile strength of an equivalent diameter span of steel, yet with just a sixth of steel's density. Bind nanotubes with resin into fibers, weave those fibers into sheets, and cure those sheets into shapes, and the resulting structures — superstrong and superlight compared to aluminum and conventional composites — would revolutionize performance and open new designs for aircraft and satellites. It might even be possible to make giant cables of nanotubes that could be unfurled from space toward Earth to create a space elevator, an ultradurable conduit for shuttling material up and down.

Flash forward 30 years, however, and none of that is remotely reality. Researchers are still laboring to retain the attractive properties displayed by individual nanotubes at size scales relevant to human technologies.

"The real challenge is how to take something at a molecular level and apply it and convert it into a macroscopic form that then delivers a system-level capability in a commercial environment," says Joe Sprengard Jr., president, CEO and co-founder of Veelo Technologies, an Ohio-based startup developing new materials — some based on nanotubes — for boosting the performance of next-generation aircraft.

For that reason, the first applications for carbon nanotubes are likely to be less grandiose than those originally envisioned three decades ago. They include heating devices that, ironically, would aid in manufacturing and repairing the conventional composites that carbon nanotube versions might someday replace. Others include airborne de-icing for wings and leading edges, along with durable sensors that could hold up in tough environmental conditions that aircraft encounter.

"We've finally learned how to work with these materials, getting them into the forms and scale that allow us to do meaningful things," says Michael Meador, who retired last year after a 36-year career at NASA, where he worked on nanomaterials as a manager for the agency's Game Changing Development Program at Glenn Research Center in Ohio.

"We're getting beyond the hype of the '90s," Meador adds. "Carbon nanotubes are not a one-size wonder material that's going to solve everyone's problems, but there's a lot of potential and they're close to reality."

Tiny but mighty

A carbon nanotube is actually a rolled-up version of graphene, another buzz-worthy substance that is intensively researched in materials science. The tubes' diameter is usually in the range of several tenths to a few tens of nanometers (billionths of a meter, or ten-thousandths the diameter of a human hair) for the common, single-walled variety of tube; concentrically nested tubes, or multiwalled tubes, can be significantly wider and are likewise being explored for their potential utility.

Reports of chemists observing narrow carbon tubules date back to the 1950s, but it was not until the early 1990s with the clear discovery of single-walled carbon nanotubes that interest in them skyrocketed.

Based on the angle of the lattice that the nanotube's carbon atoms form, the material can be highly conducting of electricity, semiconducting, or non-conducting. Carbon nanotubes are also about five times better at conducting heat than the industry workhorse, copper, and even exceed diamonds.

So why can't tubes be turned into materials that would simply be dropped into aerospace products? "Carbon nanotubes are finicky," Sprengard says.

For starters, while the raw manufacturing of carbon nanotubes has come a long way, with many companies producing the tubes for an array of niche commercial purposes, quality is sometimes a concern. High-end nanotubes — distinguished by their purity, uniformity and consistency within batches — remain relatively costly. "All carbon nanotubes are not created equal," says Sprengard. Nanotubes also do not behave like metals that can be simply melted down and molded into desired shapes; instead, nanotubes must be bound together in a matrix, for instance with resin, in order to transfer loads for structural purposes and to deliver their conductive properties at scale. Irksomely, though, nanotubes tend to agglomerate instead of evenly dispersing when added to another material; for instance, when adding the manufactured nanotubes (which in bulk look like a powder) to composites, the formulations grow too viscous and unworkable, limiting the numbers of tubes that can be added and ultimately the material property gains being sought.

Enhancing composite manufacture and repair

Yet progress is being made on all these fronts, with ever-improving manufacturing techniques and the use of dispersants to more evenly distribute nanotubes in their binders. The upshot is that non-structural applications in heating for conventional composite manufacture and de-icing are becoming increasingly well-developed and ready for service.

Sprengard knows the challenges presented by nanotubes well. In 2008, he formed a company called General Nano (later renamed Veelo) with two scientists at the University of Cincinnati who had figured out how to grow centimeter-long nanotubes, then the longest in the world, in a chemical vapor deposition chamber in their lab. The company initially sought to produce high-strength fibers from these long nanotubes, but years of effort could not economically deliver on that objective. Along the way, Sprengard and colleagues did learn some of the ins-and-outs of nanotubes, though, and pivoted to adding the tubes, now purchased in bulk powder form from outside vendors, into formulations for materials with other aerospace applications.

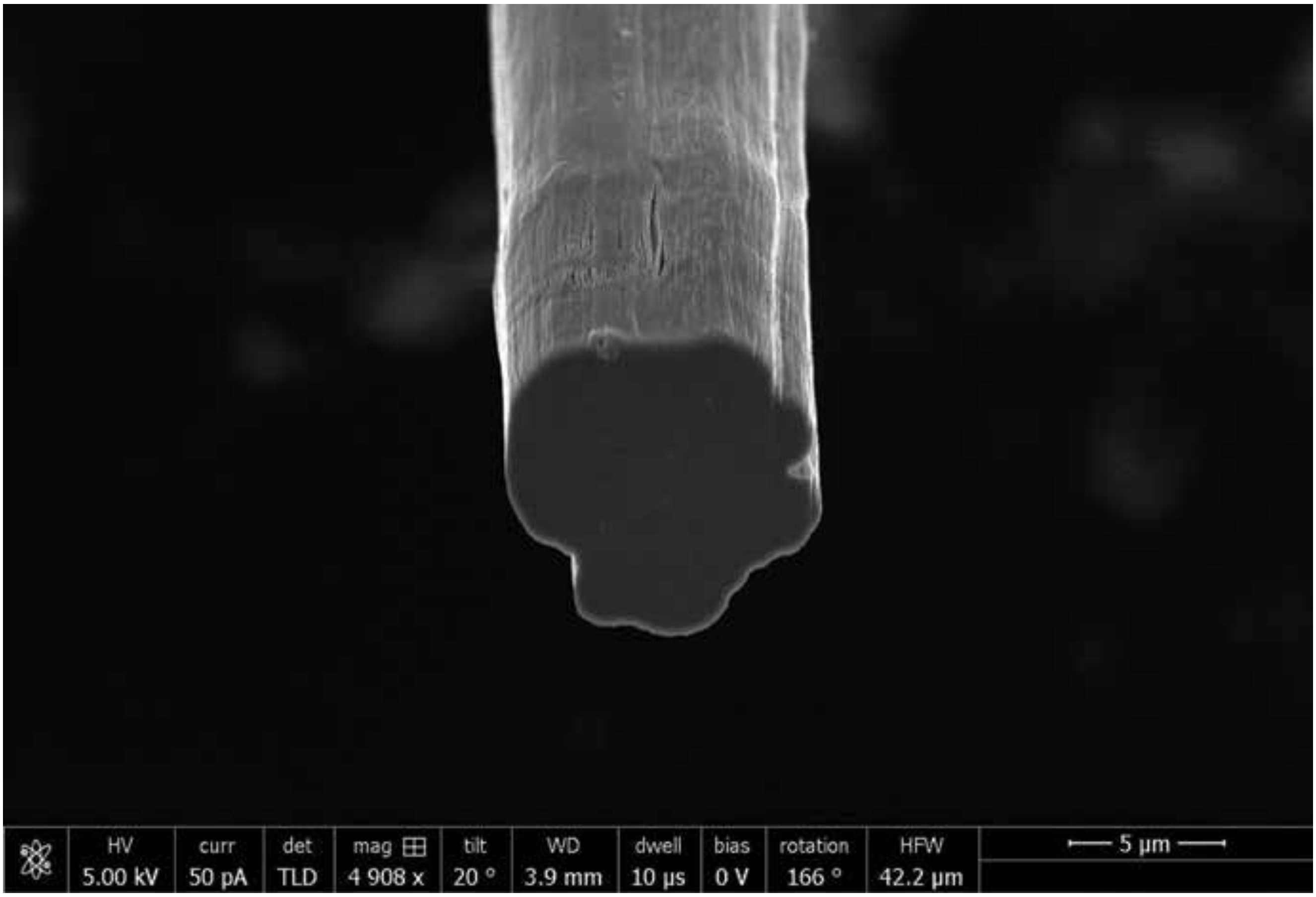
One such material formulation is silicon- and polymer-based heating blankets, which can aid in the manufacture and repair of composite materials reinforced by a different carbonaceous material, carbon fibers. These are a thousand times thicker than carbon nanotubes and are made of graphite. Carbon fiber-reinforced and other composites are a hot market these days in aerospace, with the materials increasingly taking the place of conventional structural metals. The Boeing 787 and the Airbus A350 XWB are cases in point, with around half of each airframe composed of composites.

Composites are composed of layers of material that must be fused together during a curing process at a few hundred degrees Celsius. For aircraft, the conventional approach has been to put components ranging from massive fuselages to tail fins in warehouse-sized ovens or, depending on the manufacturer, in autoclaves that both pressurize and heat the parts as part of the curing process. As a result, a large volume of air ends up being pointlessly and expensively heated.

"It's really super-inefficient," says Seth Kessler, founder of Massachusetts-based Metis Design Corp. which, like Veelo, is developing nanotube-based heating blanket alternatives to ovens and autoclaves, among other applications. Kessler points out that the energy consumption involved in running ovens and autoclaves is as much as half of the cost of manufacturing a composite part.

▼ A fiber made at Rice University in Texas consists of tens of millions of carbon nanotubes. The nanotubes are arrayed lengthwise in this image taken with a scanning electron microscope. The researchers say tests show the fibers are stronger than Kevlar.

Pasquali Research Group



The heating blankets Metis is working on, in collaboration with the Massachusetts Institute of Technology and MIT's funding support from Airbus, Embraer, Lockheed Martin, Saab AB, and other aerospace and defense organizations, would be put directly onto a component that needs curing, versus heating a component in a giant room. Simply adding an electric current heats the blanket — sort of like an electric blanket one might use for aching muscles. Because carbon nanotubes have excellent thermal conduction, the electrical energy required for this blanket-based curing is three orders of magnitude less than equivalent curing through standard manufacturing. "If you're taking the largest cost element of manufacturing composites and reducing it to less than a percent of its original cost," says Kessler, "that has tremendous implications for the cost of the part."

At MIT, materials scientists are investigating ultrathin film versions of carbon nanotube blankets that could be wrapped around a component of any size. Sprengard at Veelo emphasizes how these kinds of blankets could help in re-curing the often-nicked-up small sections of aircraft that need to be fixed. "Imagine your car: When it gets banged up, you go to the autobody shop," says Sprengard. "With [aircraft] composites, it's the same thing. You're constantly having to repair them. The plane flies and it's hit by a bird strike or a hailstorm, or a technician drops a hammer on it. You have to repair and re-cure that damaged area."

For these sorts of repairs, metal wire-based blankets have long been the norm. But besides being energy inefficient, these metallic blankets take longer to heat up and do not heat as evenly as carbon nanotube-doped blankets, Sprengard says.

The heating blankets are nowhere near mass-market yet, but Sprengard says Veelo counts numerous aerospace and defense firms as customers.

Ice be gone

The inherent material advantages to carbon nanotubes have further poised them as a key enabler for next-generation de-icing devices built into aircraft wings and other leading edges and surfaces to protect against ice buildup during flight.

Most de-icing today for commercial aircraft involves a chemical sprayed on wings before takeoff that cuts down on ice formation and on ducting hot air from the aircraft engines in flight to melt ice before it gets too thick and threatens performance. A newer kind of de-icing, incorporated in the Boeing 787, for example, involves conducting electricity into meshes of copper wire embedded under the skin to heat the leading edges. As with the curing blankets, this electrothermal de-icing arrangement leads to time-consuming and uneven heating as the metal slowly diffuses ice-eliminating warmth into the mesh gaps. Compared to metallic-based de-icing systems, carbon nanotube-based ones would

▼ **A VeeloHEAT** Blanket could help re-cure nicked-up small sections of an aircraft.
Veelo

heat up very rapidly, about 10 times faster for a given area, says Kessler. The nanotubes' remarkably low weight also shaves off hundreds of kilograms on an aircraft wing, for example. "Carbon nanotubes are much, much lighter than other electrothermal mechanisms," Kessler says. That lighter weight can also translate into far greater de-icing system coverage over a given expanse of an aerial vehicle.

Nanotube-based de-icing should ultimately require about 10 times less energy than conventional approaches, Kessler says. Furthermore, hardy nanotubes would not suffer from corrosion and could withstand much higher strain and deformation, flexing and returning to shape better than their copper counterparts.

The debut of nanotube-based de-icers on crewed military and commercial aircraft could be near. Embraer, the Brazil-based aerospace conglomerate, has tested the Metis-pioneered carbon nanotube de-icing heaters on the leading edge of a model of a horizontal tail in a wind tunnel. A different major commercial aircraft manufacturer and a major rotorcraft maker, both of which Kessler says he cannot disclose for proprietary reasons, have also purchased the heaters for testing, and the U.S. Navy is likewise interested. Metis ultimately licensed its electrothermal technology to Goodrich Deicing, part of Collins Aerospace, in 2017, and there have not been further announcements. Veelo, for its part, is also developing nanotube-based de-icers, and though Sprengard did not disclose customers at this time, he characterizes them as being in commercial aerospace and defense sectors.

In parallel, researchers are developing nanotube-based de-icers for unmanned aerial systems. Be-cause these aircraft have fewer regulatory hurdles, they could provide confidence that then translates to broader deployment. In this vein, the Ohio-based science and technology development company Battelle is continuing work on a product called HeatCoat [first reported in "De-icing with nanotubes," Aerospace America, July/August 2016]. Sponsored by the U.S. Special Operations Command, or SOCOM, HeatCoat is an ultrathin, lightweight, nanotube-doped layer sprayed onto surfaces underneath a regular coat of paint. Electrical leads connected to a drone's wiring system serve as a power source to disperse de-icing heat through the layer. Because HeatCoat is so close to the wing surface, it requires little energy to achieve de-icing, says Greg Kimmel, the national security business line manager for Battelle who is overseeing HeatCoat's continued development. Furthermore, because it's a spray-on layer, HeatCoat can be applied to components and areas with complex geometries, such as nosecones and engine intakes.

Over the past few years, Battelle has conducted ice tunnel and environmental tests with HeatCoat.

▲ **Heating blankets** made of nanotubes can aid in the manufacture and repair of composite materials reinforced by carbon fibers.
Veelo

Plans call for flight tests next year with a Navmar Applied Sciences Corp. TigerShark UAS, with the eventual goal of putting lightweight de-icers on MQ-9 Reaper drones — a mainstay hunter-killer for the U.S. Air Force.

A critical aspect of the ongoing development work has involved software controllers, which enable the heating device to autonomously activate when it detects ice buildup. "One of the complicated parts of de-icing systems, especially on unmanned aircraft, is knowing when you're in icy conditions so you don't run the system when you don't need to," says Kimmel. For drones operating on limited battery life, appropriate de-icer activation is important.

Knowing when things aren't right

Sensing is another area where the properties of nanotubes also make materials based on them promising candidates for development. Researchers at Metis and MIT came up with this concept of how a carbon nanotube-outfitted sensor embedded within an aircraft wing, for example, could register changes in a baseline level of electrical resistance caused by structural fatigue or damage. Accordingly, these devices could work very well as crack gauges, monitoring wing structural integrity. The data would be diagnostically helpful for both maintenance and post-mission repair. "You can easily correlate the

▲ **The Airbus** A350-1000 undergoing cold-weather testing. About half of its airframe is composed of composites, but none of them yet made of nanotubes.
Fiona Paton

change in resistance to the length of the crack needed to cause that change in resistance," says Kessler.

Analogs for such sensors that rely on metal foil have been around a long time, says Kessler, but carbon nanotube-based sensors would exceed their performance. "The nice thing about carbon nanotubes, they're really durable and inert," says Kessler. He and his colleagues have done tests subjecting carbon nanotube sensor prototypes to seawater and jet fuel exposure for a full year, among other extreme conditions, and the sensors have come out just fine. "Carbon nanotubes don't really care about the environment they're in at all," says Kessler.

The Air Force's F-15 fighter jet program is pursuing flight testing of the crack gauge sensors. Meanwhile, development is continuing for both strain and corrosion sensors.

Seizing upon strength and lightness

Perhaps the most obvious use case for carbon nanotubes, given their strength and lightness, would be in structural applications, especially for spaceflight. Reducing the weight of structural components, from the buses of satellites to the skins of rockets, would cut launch costs or translate into delivering significantly more useful mass to space.

"Every pound matters to us," says Emilie "Mia" Siochi, a research scientist with the Advanced Materials and Processing Branch at NASA's Langley Research Center in Virginia, who is coordinating agency efforts to devise structural carbon nanotube-based materials with academia and industry.

"When people say launch costs are $10,000 a pound, that's just to launch to low-Earth orbit," adds Siochi. "To go to the moon and Mars, that cost escalates."

The dream of structural nanotubes has certainly not been abandoned. Toward these mass- and cost-reduction goals, NASA started work two decades ago on developing new kinds of composites reinforced by nanotubes. The agency has targeted getting the nanomaterials to the point where they have approximately twice the tensile strength of the current material of choice, carbon fiber-reinforced composites. That, in turn, could enable a reduction in vehicle mass on the order of 50%. "It would be a game changer in terms of weight savings," says NASA's Meador.

"We're getting beyond the hype of the '90s. Carbon nanotubes are not a one-size wonder material that's going to solve everyone's problems, but there's a lot of potential and they're close to reality."

— Michael Meador, formerly at NASA

Mixing in nanotube powder to today's best composites to achieve even lower weight has proven problematic, however, due to agglomeration. A more promising tack, started in parallel about a decade ago, has been to weave nanotubes into fibers that could act as a drop-in replacement for carbon fiber in composite manufacturing. To that end, NASA has continued to award contracts to New Hampshire-based Nanocomp Technologies Inc., which produces nanotube yarns and sheets, among other products. NASA obtained hundreds of meters of this material to fashion a composite overwrap pressure vessel. The vessel contained cold gas as part of a thruster system. In 2017, that pressure vessel went to space aboard a sounding rocket launched from NASA's Wallops Flight Facility in Virginia; the launch marked the first flight test of a structural component made from a carbon nanotube composite material. The vessel ably withstood the loads of launching and landing. NASA is seeking to improve upon the achieved properties of the material — Siochi says strength has been boosted by around 2.5 times in the past few years — while maturing the processes needed for the large-scale, economical composite manufacture relevant for aerospace.

"People are used to building with metallics and carbon fiber composites, and both of those have decades of head start" on nanotubes, says Siochi. "We're trying to build up the confidence in this new material."

On Earth and beyond

Besides those applications already mentioned, nanotubes look set to appear in numerous other places that will impact aerospace. Many groups, for instance, are researching nanotubes for enhanced batteries, which are of course integral for advancing the state of electric aircraft. Computer engineers are also devising processor architectures that would incorporate nanotubes instead of silicon, with implications in particular for UAS and spacecraft.

Still other avenues of interest include shielding composites against electrostatic discharges and other electromagnetic interference. That need for protection extends beyond Earth's atmosphere as well. For example, and in an ahead-of-its-time use case, Nanocomp-built shields were incorporated into the Juno spacecraft ahead of its launch in 2011 to study Jupiter. The shielding has helped protect the main engine housing and attitude control motor struts from discharge events in the giant planet's intense radiation belts.

As for structures made of nanotubes, Siochi hopes to have those technologies ready soon enough to play a role in NASA's Artemis lunar landings, scheduled to start this decade, and from there, onward to becoming a major enabler of interplanetary exploration.

"I hope there is an opportunity to actually put something involving carbon nanotubes on the moon that helps us understand what it takes to be part of a system architecture, however small," says Siochi. "Then we can truly be part of the mission to Mars." ★

Weather alert

If consumers are going to receive packages by air to their doorsteps or hop onto aircraft to zip across town, engineers must figure out how to make these coming aircraft more resilient to bad weather than today's early versions. Dennis Bushnell of NASA's Langley Research Center in Virginia explains.

BY DENNIS M. BUSHNELL

Weather issues caused or contributed to approximately 35% of fatal general aviation accidents in the United States from 1982 to 2013, according to researchers from Northern Illinois University who in 2016 reviewed decades of accident data. Winds, especially updrafts and downdrafts, are the most prevalent cause. The delivery drones and other commercial unmanned aircraft systems under development today could be more prone to weather-related accidents or upsets, because many are smaller in size and weight than GA aircraft and therefore have lower inertia. Some of the coming advanced air mobility aircraft, which will include on-demand passenger aircraft, will be about the same size and weight as some GA aircraft and will be equally vulnerable.

All of them will fly at low altitudes, home to the worst of the weather, including snow, rain, fog, tornadoes, lightning, icing, excessive heat, hail, sleet, microbursts and wind shifts near thunderstorms. In fact, a study by the U.S. Army Research Laboratory concerning weather impacts on its Aerostar tactical unmanned aerial system notes that the manufacturer recommends against flying the aircraft in severe turbulence. Those conditions can amount to 5% to 70% of the time, depending on the time of day, region and season. Delivery drones and small on-demand passenger aircraft will be similarly vulnerable, and they will fly mostly over built-up areas in increasingly large numbers, constituting an increasingly worrisome safety hazard. They could be blown off course, possibly into buildings or other aircraft. All told, weather conditions can affect aircraft visibility, navigation, performance and controllability and reduce flight duration.

Therefore, for reasons of safety, operability, reliability, utilization and econometrics, designers should improve the next AAM and UAS vehicles so that they can fly in challenging weather.

Given that cost is a major metric for producing these vehicles, prospective solution spaces must be both effective and affordable. Also, the eventual replacement of automobiles with on-demand-mobility passenger aircraft will require operability in weather conditions at least to the extent that automobiles have. The usual conventional aeronautics approaches for weather issues include designing for service in all but extreme conditions and detecting and avoiding or flying around the extreme cases.

Attraction of electric vehicles

Increasingly, AAM concepts and UAS are electrically propelled, and the nearly two dozen reasons for this include significant improvements in nearly all of the air vehicle metrics — safety, acoustics, cost, vibration, aero and propulsive performance, maintenance and emissions.

The huge and ongoing decreases in costs of renewable energy generation and storage by some 85% in the last 10 years for photovoltaics and in the past eight years for storage point to the ongoing demise of coal and possibly gas going forward for electricity generation. In fact, nearly two-thirds of the new generation of electricity results from renewables, according to media coverage of IRENA, the International Renewable Energy Agency.

This bodes well for a shift to nearly emissionless electric propulsion for all transportation, whether on land, by sea or by air. Using energy sourced from renewables will have immense favorable implications and positive impacts on the climate. The scalability and relative ease of application of distributed electric propulsion have spawned a plethora of multi-to-many rotor vehicle configurations.

Weathersafe electrics

Many of the initial UAS designs are essentially "fair-weather" machines, not waterproofed for rain and moisture. Many are electric, operating off batteries sensitive to cold and heat, and are capable of flying in winds on the order of up to two-thirds of the maximum flight speed. Wind gusts can be up to the order of twice the average wind speed while AAM and UAS flights near buildings and trees or in urban canyons can encounter large-scale organized dynamic vorticity. Waterproofing and de-icing are probably essential for practical, safe operability in many areas and seasons.

The issue of battery sensivity to heat and cold could be addressed by a combination of insulation and regeneration of battery heat losses and added energy from external photovoltaic films or other energy sources operating a battery pack climate control system. For vehicles carrying passengers, the cabin environmental control system could be designed to include the battery enclosure. Flight in poor weather will, in general, require IFR equipage for visibility and air traffic control. The major remaining weather issues are wind and rain. Therefore, affordable solution spaces for these that are effective for relatively low speeds and inertia are of interest. Rain can affect flight by direct momentum exchange, by decambering wing surfaces and thereby inducing loss of lift and control authority, by increasing the vehicle mass, changing the center of pressure, by creating roughness and drag, and possibly by flow separation. Weather as a whole can affect controllability, speed, angle of attack and sideslip, and reduce range by requiring increased energy expenditure. The current major weather-related efforts with regard to AAM and UAS involve improvements in detailed local flight weather forecasting.

Maneuvering

Optons for enhancing AAM/UAS for safe maneuvering in wind and rain include:

- Increased onboard energy for thrust vectoring for controllability beyond what is available from the usual controls and to maintain speed/range. These increased energy and thrust vectoring capabilities could, in fair weather in the absence of significant weather effects, be utilized to extend the range and increase controllability for vertical takeoff and landing, VTOL, operations.
- Aero controls with morphing surfaces, flow control.

Of the preceding, thrust vectoring is probably the more effective overall approach. Thrust vectoring for lift can be achieved by tilting wings or just the nacelles, or by vectoring jet engine nozzles. These designs have been flown over the years on military aircraft and missiles, as well as on some lighter-than-air applications.

Options to enable thrust vectoring for enhanced AAM/UAS weather operability include:

- Gimbaled engines, nozzles and propulsors.
- Fluid injection into the exhaust stream to redirect momentum.
- Auxiliary thrusters.
- Exhaust/jet vanes for directing exhaust.

Power choices

In particular, electric propulsion handily enables thrust vectoring for enhanced operations in weather. This could be done either by vectoring extant distributed propulsion units or added units that could, when not needed for additional controllability in weather, be used for additional propulsion, for takeoff or for cruising. Overall, a system, capabilities and vehicle configuration tradeoff study should be conducted that includes the option of thrust vectoring for weather. Thanks to electric propulsion, thrust vectoring for enhanced operations in difficult weather is a viable approach. The design and operability of such wind and gust control systems should ensure suitable ride quality for AAM carrying passengers.

To maintain fair-weather cruise range when flying in difficult weather, additional vehicle energy capacity and requisite thrust vectoring for control are needed due to energy losses associated with flying in challenging conditions such as high winds. Electric propulsion can be enabled by two options: fuel cells and batteries. Compared to conventional internal combustion and gas turbine engines, propulsion fuel cells are more efficient but heavier. Batteries are more efficient than fuel cells, but much heavier, due to their much lower specific energy-density, expressed as power per kilogram. Currently, batteries power most electric vehicles, but hydrogen-powered fuel cells are available commercially and proffer some three-times greater range than the battery standard, lithium-ion. Some of that additional range capability could be traded for weather operability via thrust vectoring of distributed electric propulsors.

Advanced batteries are a work in progress, enabled and driven by massive markets for all transportation modes and much else. Going forward, batteries will be increasingly recharged by renewable energy generation, providing nearly emissionless propulsion. The near ultimate advanced battery would utilize atmospheric oxygen as part of the battery operation providing a theoretical energy-density nearly equal to hydrocarbon fuels and an expected initial nominal energy density approximately five times that of lithium-ion. This battery energy-density would be a considerable improvement over hydrogen fuel cells. The U.S. Department of Energy has tested Li-Air batteries with some 700 recharges. Perhaps nearer-term are a plethora of other advanced batteries: lithium-metal, solid-state, glass and others proffering twice to three times the range of lithium-ion designs. These are closing in on the range of hydrogen fuel cells. Therefore, compared to lithium-ion batteries, the increased energy-density of advanced batteries and hydrogen fuel cells would enable maintaining the Li-ion battery design range and employing distributed electric thrust vectoring, enhancing flight in poor weather. Additional opportunities to improve energy-density include utilization of the increasingly efficient solar photovoltaic films as a vehicle covering to recharge the batteries and provide electricity during cruise. These films could going forward double the efficiency values of photovoltaics via advanced materials and designs by producing two electrons per photon and exploiting much more of the solar spectrum. Another energy-density enhancing possibility would be to store fuel or electrical energy in the vehicle structure.

The potential ahead is enormous. The Vertical Flight Society lists about 200 AAM and UAS variants in development now. Also, the nascent financial aero markets for AAM and UAS would result in a doubling of the current civilian aero markets. It is early days yet for these vehicles and markets. Engineers and researchers are improving vehicle characteristics and capabilities. The major metrics for safety, operational capability, affordability, emissions and acoustics are becoming clearer.

Improved weather capability must feature prominently if the market is to progress as planned. ★

Dennis M. Bushnell is chief scientist of NASA's Langley Research Center in Virginia and an AIAA honorary fellow.

AIAA Bulletin

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We are frequently asked how to submit articles about section events, member awards, and other special interest items in the AIAA Bulletin. Please contact the staff liaison listed above with Section, Committee, Honors and Awards, Event, or Education information. They will review and forward the information to the AIAA Bulletin Editor.

Calendar

FEATURED EVENT

11–15 & 19–21 JANUARY 2021

Online Event

The world's largest event for aerospace research and development has expanded into eight days of programming over a two-week time frame. The new format offers a convenient, condensed daily schedule. The 2021 forum will explore the functional role and importance of diversity in advancing the aerospace industry.

aiaa.org/scitech

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2020			
16–18 Nov	ASCEND Powered by AIAA	VIRTUAL EVENT	31 Mar 20
25–26 Nov	AIAA Region VII/Sydney Section Student Conference	VIRTUAL EVENT	6 Oct 20
2021			
9–10 Jan	5th AIAA Propulsion Aerodynamics Workshop (PAW05)	ONLINE (http://learning.aiaa.org)	
11-15 & 19-21 Jan	AIAA SciTech Forum	VIRTUAL EVENT	8 Jun 20
21–22 Jan	1st AIAA CFD Transition Modeling Prediction Workshop	ONLINE (http://learning.aiaa.org)	
26–27 Jan	1st AIAA Stability and Control Prediction Workshop	ONLINE (http://learning.aiaa.org)	
28 Jan–4 Feb*	43rd Scientific Assembly of the Committee on Space Research and Associated Events	Sydney, Australia —HYBRID EVENT (cospar2020.org)	14 Feb 20
31 Jan–4 Feb*	31st AAS/AIAA Space Flight Mechanics Meeting	Charlotte, NC (http://space-flight.org)	
26 Feb–16 Apr	Design of Experiments: Improved Experimental Methods in Aerospace Testing Course	ONLINE (http://learning.aiaa.org)	
6–13 Mar*	2021 IEEE Aerospace Conference	VIRTUAL EVENT (www.aeroconf.org)	
Week of 15 Mar	AIAA Congressional Visits Day	VIRTUAL EVENT	
26–27 Mar	AIAA Region III Student Conference	Ann Arbor, MI	5 Feb 21

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

26–27 Mar	AIAA Region IV Student Conference	Stillwater, OK	1 Feb 21
3–4 Apr	AIAA Region VI Student Conference	Long Beach, CA (VIRTUAL)	6 Feb 21
8–9 Apr	AIAA Region II Student Conference	Tuscaloosa, AL	23 Feb 21
9–10 Apr	AIAA Region I Student Conference	New Brunswick, NJ	19 Feb 21
12–14 Apr*	55th 3AF Conference on Applied Aerodynamics (AERO2020+1)	Poitiers, France (http://3af-aerodynamics2020.com)	
15–18 Apr	AIAA Design/Build/Fly Competition	Tucson, AZ	
20–22 Apr	AIAA DEFENSE Forum	Laurel, MD	17 Sep 20
20–22 Apr*	Integrated Communication, Navigation, and Surveillance (ICNS) Conference	Herndon, VA (https://i-cns.org)	
5–7 May*	6th CEAS Conference on Guidance Navigation and Control (2021 EuroGNC)	Berlin, Germany (https://eurognc2021.dglr.de)	
31 May–2 Jun*	28th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (elektropribor.spb.ru/en)	
5–6 Jun	3rd AIAA Geometry and Mesh Generation Workshop (GMGW-3)	Washington, DC	
5–6 Jun	4th AIAA CFD High Lift Prediction Workshop (HLPW-4)	Washington, DC	
5–6 Jun	1st AIAA Ice Prediction Workshop	Washington, DC	
6 Jun	2nd AIAA Workshop for Multifidelity Modeling in Support of Design & Uncertainty Quantification	Washington, DC	
7–11 Jun	AIAA AVIATION Forum	Washington, DC	10 Nov 20
22–25 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
9–11 Aug	AIAA Propulsion and Energy Forum	Denver, CO	
6–10 Sep*	POSTPONED FROM 2020: 32nd Congress of the International Council of the Aeronautical Sciences	Shanghai, China (icas.org)	15 Jul 19
13–15 Sep*	3rd IAA Conference on Space Situational Awareness (ICSSA)	Madrid, Spain (http://reg.conferences.dce.ufl.edu/ICSSA)	15 Jun 21
27–30 Sep*	POSTPONED FROM 2020: 37th International Communications Satellite Systems Conference (ICSSC 2020)	Okinawa, Japan (kaconf.org)	15 May 19
25–29 Oct*	72nd International Astronautical Congress	Dubai, UAE	
15–17 Nov	ASCEND Powered by AIAA	Las Vegas, NV	

● AIAA Continuing Education offerings

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

AIAA Announces Class of 2021 Associate Fellows

AIAA is pleased to announce its Class of 2021 Associate Fellows.

"I am extremely excited for and proud of each member of the Class of 2021 Associate Fellows," said AIAA President Basil Hassan. "These individuals exemplify passion and dedication to advancing the aerospace profession and were selected because of their significant and lasting contributions to the field. Although this year's AIAA SciTech Forum will be unconventional, the Institute will take great pride in honoring this Class of Associate Fellows and celebrate their achievements in what remains a highly anticipated event. We truly look forward to doing so next year."

The grade of Associate Fellow recognizes individuals "who have accomplished or been in charge of important engineering or scientific work, or who have done original work of outstanding merit, or who have otherwise made outstanding contributions to the arts, sciences, or technology of aeronautics or astronautics." To be selected as an Associate Fellow an individual must be an AIAA Senior Member in good standing, with at least twelve years professional experience, and be recommended by a minimum of three current Associate Fellows.

"The AIAA Associate Fellows personify the innovation that drives our industry forward," said Dan Dumbacher, AIAA executive director. "The Class of 2021 Associate Fellows, representing industry, academia, and government, embodies the commitment, dedication, and ingenuity that are crucial for devising the best solutions to the complex questions raised in aerospace science. AIAA and the aerospace industry tremendously appreciate the long hours of dedication to society and the industry. We also recognize the families, friends, and colleagues that support the Associate Fellows helping drive our industry forward."

The Class of 2021 AIAA Associate Fellows are:

Ossama Abdelkhalik, Iowa State University

Douglas Abernathy, Lockheed Martin Corporation

Douglas Adams, Johns Hopkins University Applied Physics Laboratory

Nashat Ahmad, NASA Langley Research Center

Amr Ali, Pratt & Whitney

Darcy Allison, Raytheon Technologies

Guillermo Araya, University of Puerto Rico, Mayaguez

Vibhor Bageshwar, Honeywell Aerospace

Xiaoli Bai, Rutgers University

Caleb Barnes, Air Force Research Laboratory

Michael Barnhardt, NASA Ames Research Center

Tom Berger, U.S. Army Technology Development Directorate

Don Bingaman, VPE Aerospace Consulting, LLC

David Blunck, Oregon State University

Clifford Brown, NASA Glenn Research Center

Paul Bruce, Imperial College London

Shawn Buchanan, Northrop Grumman Corporation

Michael Buonanno, Lockheed Martin Corporation

George E. Cannon III, U.S. Air Force

Luciano Castillo, Purdue University

Oksan Cetiner-Yildirim, Istanbul Technical University

Swetaprovo Chaudhuri, University of Toronto

Han-Lim Choi, Korea Advanced Institute of Science and Technology

Bernd Chudoba, University of Texas at Arlington

Soon-Jo Chung, California Institute of Technology

Joseph Connolly, NASA Glenn Research Center

Richard Cook, NASA Jet Propulsion Laboratory

Peggy Cornell, NASA Glenn Research Center

Peter Curtis, Aerospace Aerodynamics Consultant

Phillip Jay Dellinger, Airbus Americas Customer Services, Inc.

Kyle DeMars, Texas A&M University

Tony Di Carlo, The Boeing Company

Adam Dissel, Reaction Engines, Inc.

Donald Drouin, The Boeing Company (retired)

Karthik Duraisamy, University of Michigan, Ann Arbor

Alicia Dwyer Cianciolo, NASA Langley Research Center

Trevor Sterling Elliott, University of Tennessee at Chattanooga

Kent Engebretson, Lockheed Martin Corporation

Patrick Enjuto, The Boeing Company

Timothy Eymann, Air Force Research Laboratory

Delmar A. Fadden, Flight Advantage LLC

Nathan Falkiewicz, MIT Lincoln Laboratory

David Faulk, Lockheed Martin Corporation

Silvia Ferrari, Cornell University

Krzysztof Fidkowski, University of Michigan

Preston D. Frazier, Northrop Grumman Corporation

Christopher Geiger, Lockheed Martin Corporation

Kenneth Goodrich, NASA Langley Research Center

Vijay K. Goyal, Lockheed Martin Corporation

Paul Gradl, NASA Marshall Space Flight Center

Walter A. Grady Jr., U.S. Air Force (retired)

Peter Grognard, von Karman Institute for Fluid Dynamics

Michael A. Gross, NASA Jet Propulsion Laboratory

Brian Gunter, Georgia Institute of Technology

Adam L. Hamilton, Southwest Research Institute

Kenneth R. Hamm Jr., NASA Ames Research Center

Joel M. Haynes, GE Aviation

Kenneth Hodgkins, International Space Enterprise Consultants (ISEC)

Charles Holland, Carnegie Mellon University Software Engineering Institute

Joseph Huwaldt, Dynetics, A Leidos Company

Samantha Infeld, Analytical Mechanics Associates, Inc.

Geoffrey Jeram, U.S. Army

Eric Johnsen, University of Michigan

Gregory H. Johnson, Lockheed Martin Corporation

Benjamin Jorns, University of Michigan

Chang-Kwon Kang, University of Alabama in Huntsville

Mary Beth Koelbl, NASA Marshall Space Flight Center

Jeffrey Komives, Air Force Futures and Concepts

David Krismer, Aerojet Rocketdyne
Chetan S. Kulkarni, KBR. Inc. / NASA Ames Research Center
Mrinal Kumar, Ohio State University
Paul Lambertson, The Boeing Company
Amy Lang, University of Alabama
Nicholas Lappos, Lockheed Martin Corporation
Johan Larsson, University of Maryland
Robert M. Lightfoot Jr., Lockheed Martin Corporation
Justin J. Likar, Johns Hopkins University Applied Physics Laboratory
David Loda, Oshkosh Corporation
Todd Lovell, Raytheon Technologies
Laura Mainini, Raytheon Technologies / Politecnico di Torino
Arthur N. Mallett, Jr., Dunmore Aerospace
Oliver Masefield, SolvAero Consulting GmbH
Lisa May, Lockheed Martin Corporation
Scott McHenry, Northrop Grumman Corporation (retired)
Joseph Miller, Air Force Research Laboratory
Knox Millsaps, Office of Naval Research
Toshiharu Mizukaki, Tokai University
Muthuvel Murugan, U.S. Army Research Laboratory
Jeffrey Newcamp, U.S. Air Force
Andrew Ning, Brigham Young University
David O'Brien, U.S. Army CCDC AvMC
Jacqueline O'Connor, Pennsylvania State University
Francisco Palacios, The Boeing Company
Robert Pearce, NASA Headquarters
Brian Pomeroy, Sierra Nevada Corporation
Jill Prince, NASA Langley Research Center
Laxminarayan L. Raja, University of Texas at Austin
Vipul Ranatunga, Air Force Research Laboratory
Zhuyin Ren, Tsinghua University
Jonathan Rogers, Georgia Institute of Technology
Michelle Rouch, Artwork by Rouch
Michael Ryschkewitsch, Johns Hopkins University Applied Physics Laboratory
Hiraku Sakamoto, Tokyo Institute of Technology
Paul Schifferle, Calspan Corporation
Sven Schmitz, Pennsylvania State University
Brett Schmuki, Lockheed Martin Corporation
Douglas Schwer, U.S. Naval Research Laboratory
Parthiv N. Shah, ATA Engineering, Inc.
Hao Shen, The Boeing Company
Brent Sherwood, Blue Origin
Jeremy Shidner, Analytical Mechanics Associates, Inc.
Eleni Sims, The Aerospace Corporation
John B. Stetson, Jr., Lockheed Martin Corporation
Brandon Stiltner, Charles Stark Draper Laboratory, Inc.
Leia Stirling, University of Michigan
Charles Svoboda, The Boeing Company
Brenton Taft, Air Force Research Laboratory
L. Dale Thomas, University of Alabama in Huntsville
Russel L. Thornock, The Boeing Company (retired)
Paolo Tortora, Alma Mater Studiorum - Università di Bologna
Kenneth Van Treuren, Baylor University
Panos A. Vitsas, International Test Pilots School
Justin Wagner, Sandia National Laboratories
Brad Wheatley, Lockheed Martin Corporation
Bradley Wheaton, Johns Hopkins University Applied Physics Laboratory
Viresh Wickramasinghe, National Research Council Canada
Craig Willis, Gulfstream Aerospace Corporation
Dee Wilson, General Atomics Aeronautical Systems, Inc
Moe Z. Win, Massachusetts Institute of Technology
Kunning G. Xu, University of Alabama in Huntsville
Jinkyu Yang, University of Washington
Peter Zaal, Metis Flight Research Associates/NASA Ames Research Center SimLabs
Matthew Zuber, Johns Hopkins University Applied Physics Laboratory
Thomas H. Zurbuchen, NASA Headquarters

AIAA Announces Candidates for 2021 Election

The Executive Nominating Committee has selected candidates for next year's election of AIAA President-Elect and the Council Nominating Committee has selected candidates for next year's openings on the AIAA Council of Directors.

Elections will be held 27 January–19 February 2021. Executive Nominating Committee Chair Paul Nielsen, Council Nominating Committee Chair John Blanton, and AIAA Governance Director Christopher Horton confirmed the names of the candidates who will appear on the 2021 ballot.

Integration and Outreach Activities Division

Director-Elect–Young Professionals Group

Alexandra Dukes, Lockheed Martin Space Systems
Kaela Martin, Embry-Riddle Aeronautical University
Cheryl O'Keefe, MIT Lincoln Laboratory

Regional Engagement Activities Division

Director–Region III

Peggy A. Cornell, NASA Glenn Research Center
Eric J. Ruggiero, GE Aviation

Director–Region VI

Melinda E. Tolle, Northrop Grumman Corporation
Oleg A. Yakimenko, Naval Postgraduate School

Technical Activities Division

Director–Aerospace Design and Structures Group

Jeanette L. Domber, Ball Aerospace & Technologies Corp.
Masoud Rais-Rohani, University of Maine

Director–Aerospace Sciences Group

M. Christopher Cotting, U.S. Air Force Test Pilot School
Lesley A. Weitz, The MITRE Corporation

The Executive Nominating Committee is pleased to present the slate of candidates for President-Elect for the 2021 election.

Laura J. McGill, Raytheon Missiles and Defense
George C. Nield, Commercial Space Technologies, LLC

MAKING AN IMPACT

AIAA Diversity Scholars Program

Where They Are Now

The AIAA Diversity Scholars Program was established in 2018 by the AIAA Diversity and Inclusion Working Group to provide opportunities for underrepresented university students who have an interest in aerospace the chance to attend an AIAA forum or event. Since then, 156 scholarships have been awarded to university students. Here is a peek at what some of our alumni have accomplished since being a part of the program.

Sarah Adewumi
University of Maryland Eastern Shore
Since being a Diversity Scholar, I have utilized the tools provided to me at the SciTech Forum to propel me to succeed in the STEM industry. I am now a 3x intern for NASA (NASA Langley Research Center, NASA Glenn Research Center, and NASA Ames Research Center) and am graduating early with my bachelors degree in Aviation Science with a concentration in Management. I am extremely grateful to the AIAA Diversity Scholars Program for granting me the opportunity to have been welcomed into the Aerospace industry, and I can honestly say my life changed after the SciTech Forum experience.

Sarah Ketchersid
Embry-Riddle Aeronautical University, Daytona Beach
Since receiving the scholarship, I was also able to intern over the summer with Northrop Grumman in Melbourne, FL, as a vehicle engineering design intern. Being a Diversity Scholar and having a chance to attend IAC 2019 was monumental for me, and allowed me to solidify my goals for the future. I had no idea what to expect from the industry, and the networking, technical papers, and mentors that I still keep in contact with gave me both hope and motivation to keep pushing forward, especially with the dampener COVID-19 has put on everything.

Gustavo Fujiwara
University of Illinois
Since receiving the scholarship, I have started a full-time job at Amazon Prime Air working on developing a Drone for Package Delivery, where I am currently working within the Aircraft Design team.

Payton Barnwell
Florida Polytechnic University
Since becoming an AIAA diversity scholar, accepted a full time offer at The Spaceship Company where I am now an Aero-Thermal Flight Sciences Engineer who also sits at the Mission Control console for SS2/WK2 [SpaceShipTwo/White Knight Two] flights. Being named an AIAA Diversity Scholar expanded my network of aerospace professionals exponentially and gave me mentors & friends that I'll have for years to come.

Dayana Abdullah-Smoot
Texas Southern University
It was an honor to be accepted in the Diversity Scholar Program during the Fall of 2018. This November I will be graduating with my PhD in Environmental Toxicology from Texas Southern University and I hope to find a job working with Environmental Control and Life Support System. Being in the Diversity Scholar Program has boosted my confidence, encouraged me to step out of my comfort zone and opened my eyes to a world of possibilities I could have never imagined.

Celina Arellano Correa
University of California, Merced
Receiving the scholarship to attend the AIAA SciTech Forum definitely helped define what I wanted to pursue in the future, it allowed me to see the endless opportunities within the aerospace industry and gave me the opportunity to expand my network. Since receiving the scholarship I have completed a research fellowship at UC Irvine's Advanced Power and Energy Program.

Kaylen Woods
Pennsylvania State University
The AIAA Diversity Scholarship actually changed my career path entirely. I always tell people "a really amazing aerospace conference" led to me changing my major!

When I came to Orlando for the forum, I was a sophomore in Astrophysics from Penn State. I didn't really know a lot about the aerospace industry, but I knew that It would be a chance to network and a chance to learn about a lot of new areas of science and engineering I hadn't heard of before.

While I was there, I learned about the field of Space Weather, which is a field I am heavily pursuing now as a senior in college. I switched my major to Atmospheric Science and kept my minor in Astrophysics to best prepare myself for a future in this field. Since then, I have had an internship at UCLA working on Martian Space Weather, and this past summer, I was a NASA intern in the Heliophysics department. The Diversity Scholarship opened up my eyes to opportunities like these and has really prepared me for my next steps!

A'liyah Fleeks
Harris-Stowe State University
Being selected as an AIAA Diversity Scholars changed my life for the better. I am now currently a Co-Op Systems Engineering Intern for Lockheed Martin Space and will be returning as a Summer 2021 Systems Engineering Intern. I am grateful for this program because it was the kickstart to my dreams!

Rupal Nigam
University of Michigan
Since receiving the scholarship, I have started my PhD program at the University of Illinois, Urbana Champaign. Receiving the Diversity Scholarship helped me establish valuable connections and gain deeper insight into the space industry, all of which have supported me in accomplishing the above.

Jennifer Esparza
Iowa State University
As a diversity scholar for the 2019 AIAA AVIATION Forum, I had the amazing experience of getting to know Aurora Flight Sciences. In fact, the experience was so amazing that I spent the summer of 2020 interning for them! Through my internship, I learned more about the aerospace industry as well as a little more about myself. While I have all intention to jump into the industry to work full-time after I complete my undergraduate degree, it is because of the Aviation Forum and Aurora Flight Sciences that I have decided to pursue my Masters degree shortly after. Being a scholar has helped set flight to my future education and career goals!

Rebeca S. Griego
California State University, Long Beach
I was awarded the AIAA Diversity Scholars Scholarship in October 2019 and I was able to attend IAC 2019! The opportunity was truly amazing and helped me grow both academically and professionally. Thanks to AIAA and attending IAC 2019 I was able to start doing an independent research project in orbital debris. In addition, through networking at the event, I was able to find a Summer 2020 internship with Jacobs at NASA's Johnson Space Center's Orbital Debris Program Office.

"As a society, we need to support, invest in, and grow the untapped capacities and potential of underrepresented communities," said AIAA Executive Director Dan Dumbacher. "We must bring those views, those perspectives, and those talents to address some of the aerospace industry's most vexing challenges. We are thrilled that The Boeing Company has agreed to sponsor the AIAA Diversity Program for future events."

Diversity scholarship applications are now open for the virtual AIAA SciTech Forum in January 2021. For information visit aiaa.org/get-involved/committees-groups/Diversity-and-Inclusion/Diversity-Scholars-Program.

2020 Best Professional and Student Technical Papers

AIAA technical committees (TCs) and integration and outreach committees (IOCs) have selected the best professional and student technical papers presented at recent AIAA forums. With a standard award criteria and selection process from the respective committees, the following technical papers were selected as the "best," and the authors were presented with a Certificate of Merit. The papers can be found online at the AIAA Aerospace Research Central (arc.aiaa.org), marked as "Best Paper."

BEST PROFESSIONAL PAPERS

2018 AIAA Hypersonic Best Paper
"Turbulence Dynamics in the Merging Process of Supersonic Streamwise Vortices" (AIAA 2018-5161) by Fabrizio Vergine, San Jose State University; Davide Vigano and Luca Maddalena, University of Texas at Arlington

2019 AIAA Aerospace Power Systems Best Paper Award
"Solar Power for Deep-Space Applications: State of Art and Development" (AIAA 2019-4236) by Andreea Boca, Clara A. MacFarland, Robert S. Kowalczyk, NASA Jet Propulsion Laboratory, California Institute of Technology

2019 AIAA Adaptive Structures Best Paper
"Off-Design Sonic Boom Performance for Low-Boom Aircraft" (AIAA 2019-0606) by David S. Lazzara, Todd Magee, Hao Shen, James H. Mabe, Boeing Research & Technology

2019 AIAA Aircraft Operation Best Paper Award
"Approach for Representing the Aircraft Noise Impacts of Concentrated Flight Tracks" (AIAA 2019-3186) by Alison Yu and R. John Hansman, Massachusetts Institute of Technology

2019 AIAA Applied Aerodynamics Best Student Paper
"Experimental Validation of the Unsteady CFD-generated Airwake of the HMS Queen Elizabeth" (AIAA 2019-3029) by Neale A. Watson, Mark D. White, Ieuan Owen, University of Liverpool, United Kingdom

2019 AIAA Atmospheric and Space Environments Best Paper Award
"High Ice Water Content in Tropical Cyclones during NASA/FAA Radar Flight Campaigns with Comparison to Numerical Simulations (AIAA 2019-3304) by Fred Palmer, Steve Harrah, and George Switzer, NASA Langley Research Center; Justin Strickland and Patricia Hunt, Analytical Mechanics Associates, Inc.

2019 AIAA Atmospheric and Space Environments Best Paper
"Remote Sensing of Spacecraft Potential at Geosynchronous Orbit using Secondary and Photo Electrons" (AIAA 2019-0311) by Miles T. Bengtson and Hanspeter Schaub, University of Colorado

2019 AIAA Atmospheric Flight Mechanics Best Paper
"Effects of Model Simplification on Wind Reconstruction During Open-Loop Longitudinal Flight" (AIAA 2019-1599) by Hunter G. McClelland and Craig A. Woolsey, Virginia Polytechnic Institute and State University

2019 AIAA Structures Best Paper Award/ Collier Research Hypersizer
"Experimental and Numerical Study on the Low Velocity Impact Damage of a Shear Dominated Composite Laminate" (AIAA 2019-1269) by Shiyao Lin and Anthony M. Waas, University of Michigan

2019 AIAA Computational Fluid Dynamics Conference Best Paper Award
"Geometry Modeling for Unstructured Mesh Adaptation" (AIAA 2019-2946) by Michael A. Park, William Kleb, and William T. Jones, NASA Langley Research Center; Joshua A. Krakos and Todd Michal, The Boeing Company; Adrien Loseille, INRIA; Robert Haimes, Massachusetts Institute of Technology; and John F. Dannenhoffer, Syracuse University

2019 AIAA Design Engineering Best Paper
"An Exploratory Design Tool for Lattice Airplane Wing Components" (AIAA 2019-3067) by Patrick Riley and Samar Malek, United States Naval Academy

2019 AIAA Electric Propulsion Best Paper Award
"High Power Demonstration of a 100 kW Nested Hall Thruster System (AIAA 2019-3809) by Sarah W. H. Shark, Aerojet Rocketdyne; Scott J. Hall, Vantage Partners, NASA Glenn Research Center; Benjamin A. Jorns, University of Michigan; Richard R. Hofer and Dan M. Goebel, NASA Jet Propulsion Laboratory

2019 AIAA Fluid Dynamics Best Paper Award
"Oscillating Shock Impinging on a Flat Plate at Mach 6" (AIAA 2019-3077) by Gaetano M. D. Currao, Liam P. McQuellin, and Andrew J. Neely, UNSW Canberra, Australia; Fabian Zander, David R. Buttsworth, and Ingo Jahn, University of Southern Queensland, Australia; Jack J. McNamara, Ohio State University

2019 AIAA Ground Testing Best Paper Award
"Characterization of Laminar Separation Bubbles using Infrared Thermography" (AIAA 2019-2808) by Dallyn W. Wynnychuk and Serhiy Yarusevych, University of Waterloo

2019 AIAA Guidance Navigation and Control Best Paper
"Vision-Based Navigation for the NASA Mars Helicopter" (AIAA 2019-1411) by David S. Bayard, Dylan T. Conway, Roland Brockers, Jeff Delaune, Larry Matthies, Håvard F. Grip, Gene Merewether, Travis Brown, and Miguel San Martin, NASA Jet Propulsion Laboratory

2019 AIAA High Speed Air Breathing Propulsion Best Paper
"Using Computational Flow Imaging to Optimize Filtered Rayleigh Scattering Measurements of an Isolator Shock Train" (AIAA 2019-4016) by Robin L. Hunt, Cody R. Ground, Robert A. Baurle, and Paul M. Danehy, NASA Langley Research Center

2019 AIAA Hybrid Rockets Best Paper Award
"Real Time Deep Throttling Tests of a Hydrogen Peroxide Hybrid Rocket Motor" (AIAA 2019-4266) by Alessandro Ruffin, Technology for Propulsion and Innovation; Enrico Paccagnella, Marco Santi, Francesco Barato, and Daniele Pavarin, University of Padova

2019 AIAA Inlets, Nozzles, and Propulsion System Integration Best Paper Award
"Development of a Ducted Propulsor for BLI Electric Regional Aircraft – Part I: Aerodynamic Design and Analysis" (AIAA 2019-3853) by Kenneth A. Brown, Jonathan Fleming, Matthew Langford, and Wing Ng, Techsburg, Inc.; Kyle Schwartz, AVEC, Inc.; Cory Combs, Ampaire, Inc.

2019 AIAA High Speed Air Breathing Propulsion Best Paper
"Study of Parasitic Combustion in an Optically Accessible Continuous Wave Rotating Detonation Engine" (AIAA 2019-0473) by Fabian Chacon and Mirko Gamba, University of Michigan

2019 AIAA Nuclear and Future Flight Best Paper Award
"Applications of Nuclear Thermal Propulsion to Lunar Architectures" (AIAA 2019-4032) by Christopher B. Reynolds, University of Michigan; James F. Horton, Claude. R. Joyner II, Timothy Kokan, and Daniel J. H. Levack, Aerojet Rocketdyne

2019 AIAA Liquid Propulsion Best Paper Award
"Additive Manufacturing and Hot-fire Testing of Liquid Rocket Channel Wall Nozzles Using Blown Powder Directed Energy Deposition Inconel 625 and JBK-75 Alloys" (AIAA 2019-4362) by Paul R. Gradl, Christopher S. Protz, and Tal Wammen, NASA Marshall Space Flight Center

2019 AIAA Modeling and Simulation Best Paper
"The Suitability of Objective Motion Criteria for Rotorcraft Manoeuvres" (AIAA 2019-0180) by Michael Jones, German Aerospace Center

2019 AIAA Modeling and Simulation Best Paper Award
"Free-Wake Based Nonlinear Aeroelastic Modeling of UAV Scale Cycloidal Rotor" (AIAA-2019-3245) by Atanu Halder and Moble Benedict, Texas A&M University

2019 AIAA Multidisciplinary Design Optimization Best Paper Award
"High-Fidelity Multidisciplinary Sensitivity Analysis Framework for Multipoint Rotorcraft Optimization" (AIAA 2019-1699) by Li Wang, NASA Langley Research Center; Boris Diskin, National Institute of Aerospace; Robert Biedron and Eric Nielsen, NASA Langley Research Center; Valentin Sonneville and Olivier Bauchau, University of Maryland

2019 AIAA Propellants and Combustion Best Paper Award
"Influence of Cross-Frequency Interactions on Nonstationary Thermoacoustic Oscillations in a Rich-Burn Gas Turbine Combustor at Elevated Pressure" (AIAA 2019-3949) by Mitchell L. Passarelli and Timothy M. Wabel, University of Toronto; Krishna Venkatesan and Arin Cross, GE Global Research; Adam M. Steinberg, Georgia Institute of Technology

2019 AIAA Plasmadynamics and Lasers Best Paper Award
"Dual-Pulse Laser Ignition Using Oxygen REMPI Preionization" (AIAA 2019-3117) by Carter Butte, Colorado State University; Ciprian Dumitrache, Centrale Supélec EM2C, France; Azer P. Yalin, Colorado State University

2019 AIAA Pressure Gain Combustion Best Paper
"Operational Stability Limits in Rotating Detonation Engine Numerical Simulations" (AIAA 2019-0748) by Daniel Paxson, NASA Glenn Research Center; and Doug Schwer, Naval Research Laboratory

2019 AIAA Sensor System and Information Fusion Best Paper
"Autonomous Wildfire Monitoring Using Airborne and Temperature Sensors in an Evidential Reasoning Framework" (AIAA 2019-2263) by Alexander A. Soderlund, Mrinal Kumar, and Chao Yang, Ohio State University

2019 AIAA Solid Rockets Best Paper Award
"Numerical Simulations of Air Inclusions Using ROBOOST Simulation Tool" (AIAA 2019-3959) by Fabrizio Ponti and Stefano Mini, University of Bologna, Forli, Italy; and Adriano Annovazzi, Avio Space Propulsion, Rome, Italy

2019 AIAA Shahyar Pirzadeh Memorial Meshing Visualization and Computational Environments Best Paper Award
"Verification of Unstructured Grid Adaptation Components" (AIAA 2019-1723) by Michael A. Park, Aravind Balan, and W. Kyle Anderson, NASA Langley Research Center; Marshall C. Galbraith, Philip C. Caplan, and Hugh A. Carson, Massachusetts Institute of Technology; Todd Michal, Joshua A. Krakos, and Dmitry S. Kamenetskiy, Boeing Research & Technology; Adrien Loseille and Frédéric Alauzet, INRIA Paris-Saclay; Loïc Frazza, Sorbonne Universités; and Nicolas Barral, Imperial College London

2019 AIAA Space Architecture Best Paper Award
"Space Habitat Reconfigurability: TESSERAE platform for self-aware assembly" (IAC-19.E5.1A.12x52608) by Ariel Ekblaw, Dava Newman, and Joseph Paradiso, Massachusetts Institute of Technology; and Anastasia Prosina, Stellar Amenities

2019 AIAA Spacecraft Structures Best Paper
"Analysis of the Column Bending Test for Bending of High Strain Composites" (AIAA 2019-1746) by Ajay Sharma, TJ Rose, Andrew Seamone, and Francisco López, University of Colorado; and Thomas Murphey, Opterus R&D

2019 ASME/Boeing Structures & Materials Award Best Paper
"Effect of Automated Fiber Placement (AFP) Manufacturing Signature on Mechanical Performance" (AIAA 2019-0516) by Minh Hoang Nguyen, Avinkrishnan Ambika Vijayachandran, Paul Davidson, and Anthony Waas, University of Michigan; Damon Call and Dongyeon Lee, Toray Composites American

2019 ASME Aerospace Division Propulsion Technical Committee Best Paper Award
"GRCop-42 Development and Hot-fire Testing Using Additive Manufacturing Powder Bed Fusion for Channel-Cooled Combustion Chambers" (AIAA 2019-4228) by Paul R. Gradl, Chris Protz, Ken Cooper, and Chance Garcia, NASA Marshall Space Flight Center; David Ellis and Laura Evans, NASA Glenn Research Center

2020 AIAA Aircraft Design Best Paper Award
"Development of an Efficient Mach=0.80 Transonic Truss-Braced Wing Aircraft" (AIAA 2020-0011) by Neal Harrison, Michael Beyar, Eric Dickey, and Kirshna Hoffman, Boeing Research and Technology; Gregory Gatlin and Sally Viken, NASA Langley Research Center

2020 AIAA Aerodynamic Measurement Technology Best Paper Award
"Extending the Frequency Limits of 'Postage-Stamp PIV' to MHz Rates" (AIAA 2020-2018) by Steven J. Beresh, Russel Spillers, Melissa Soehnel, and Seth Spitzer, Sandia National Laboratory

2020 AIAA Applied Aerodynamics Best Paper Award
"Examination of Pitch-Plunge Equivalence for Dynamic Stall over Swept Finite Wings" (AIAA 2020-1759) by Daniel J. Garmann and Miguel R. Visbal, Air Force Research Laboratory

2020 AIAA Gas Turbine Engines Best Paper Award
"Conjugate Heat Transfer Study of Innovative Pin-Fin Cooling Configuration" (AIAA-2019-0634) by Mohammad A. Hossain, Munevver E. Asar, Ali Ameri, and Jeffrey P. Bons (affiliations not provided)

2020 AIAA Thermophysics Best Paper Award
"Modeling Heatshield Erosion due to Dust Particle Impacts for Martian Entries" (AIAA 2020-0254) by Grant Palmer, Eric Chin, Matthias Ihme, Dirk Allofs, and Ali Gulhan, AMA, Inc. NASA Ames Research Center

BEST STUDENT PAPERS AND STUDENT PAPER COMPETITIONS

2019 AIAA Aerospace Power Systems Best Student Paper Competition Award
"Hydrogen Loss Effects on Mircoreactors for Space and Planetary Nuclear Power Production" (AIAA 2019-4452) by Vedant Mehta and Patrick McClure, Los Alamos National Laboratory; and Dan Kotlyar, Georgia Institute of Technology

2019 AIAA Atmospheric Flight Mechanics Student Paper Competition
"Beneficial Effect of the Coupled Wing-Body Dynamics on Power Consumption in Butterflies" (AIAA 2019-0566) by Madhu Sridhar, Chang-kwon Kang, and David Brian Landrum, University of Alabama in Huntsville

2019 AIAA Computational Fluid Dynamics Student Paper Competition – 1st Place
"Sensitivity computation of statistically stationary quantities in turbulent flows" (AIAA 2019-3426) by Nisha Chandramoorthy and Qiqi Wang, Massachusetts Institute of Technology

2019 AIAA Computational Fluid Dynamics Student Paper Competition – 2nd Place
"A Novel Flux Reconstruction Method for Diffusion Problems" (AIAA 2019-3063) by Philip E. Johnson and Eric Johnsen, University of Michigan; H.T. Huynh, NASA Glenn Research Center

2019 AIAA Computational Fluid Dynamics Student Paper Competition – 3rd Place
"Assessment of low-dissipative shock-capturing schemes for transitional and turbulent shock interactions" (AIAA 2019-3208) by David J. Lusher and Neil D. Sandham, University of Southampton

2019 AIAA David Weaver Thermophysics Best Student Paper
"Investigation of Galileo Probe Entry Heating with Coupled Radiation and Ablation" (AIAA 2019-3360) by Aaron J. Erb, Thomas K. West, and Christopher O. Johnston, NASA Langley Research Center

2019 AIAA Hybrid Rockets Best Student Paper Award
"Experimental Findings on Pre- and Post-combustion Chamber Effects in a Laboratory-scale motor" (AIAA 2019-4336) by Flora Mechentel, NASA Jet Propulsion Laboratory; and Brian J. Cantwell, Stanford University

2019 AIAA Propulsion Education Best Student Paper Award
"Development and Experimentation of a Laboratory-Scale Pulse Detonation Engine (PDE)" (AIAA 2019-3808) by Austin P. Murray, Tyler L. Smith, Eric D. Pittman, Grant A. Risha, and Jeffrey D. Moore, Pennsylvania State University, Altoona

2019 AIAA Solid Rockets Best Student Paper Award
"Comparative Analysis and Justification of Optimal Rocket Motor Selection in NASA USLI by Applying Newton's Second Law to a Variable Mass Body" (AIAA 2019-4138) by Brandon Roberts, UT Space Institute; M. Sam, John A. Brand II, and Trevor S. Elliott, University of Tennessee at Chattanooga

2019 AIAA Space Architecture Best Student Paper Award
"SIRONA: Sustainable Integration of Regenerative Outer-space Nature and Agriculture (ICES 2019-302) by Heather Hava, Larissa Zhou, Elizabeth M. Lombardi, Kaixin Cui, Heeyeon Joung, Sarah Aguasvivas Manzano , Abby King, Hayley Kinlaw, Kyri Baker, Andrew Kaufman, and Nikolaus Correll (affiliations not provided)

2019 AIAA Walter R. Lempert Student Paper Award in Diagnostics for Fluid Mechanics, Plasma Physics, and Energy Transfer
"Single-Exposure Field-of-View Extension Using Multiplexed Structured Image Capture" (AIAA 2019-0832) by Cary Smith, Jacob Harrold, Zhili Zhang, and Mark Gragston, University of Tennessee

2020 AIAA Guidance, Navigation and Control Graduate Paper Competition
"Fast Trajectory Optimization via Successive Convexification for Spacecraft Rendezvous with Integer Constrains" (AIAA 2020-1616) by Danylo Malyuta, University of Washington

2020 AIAA Harry H. and Lois G. Hilton Student Paper Award in Structures
"High-efficiency and High-fidelity Numerical Predictions of Low Velocity Impact and Compression after Impact of Laminated Composites" (AIAA-0724) by Shiyao Lin, University of Michigan

2020 AIAA Jefferson Goblet Student Paper Award
"Granular jamming as a variable stiffness mechanism and biomimetic inspiration for morphing aerostructures" (no paper number) by J. David Brigido, PhD student, Bristol Composites Institute (ACCIS)

2020 AIAA Lockheed Martin Student Paper Award in Structures
"A Methodology to Investigate Skin-Stringer Separation in Postbuckled Composite Stiffened Panels" (AIAA-0477) by Luc Kootte, Delft University of Technology

2020 AIAA Meshing Visualization and Computational Sciences Best Student Paper
"Advancing Layer Surface Mesh Generation" (AIAA 2020-0902) by Jasmeet Singh, University of British Columbia; and Carl Ollivier-Gooch, British Columbia University

2020 AIAA Multidisciplinary Design Optimization Student Paper Competition (1st Place)
"Windowing Regularization Techniques for Unsteady Aerodynamic Shape Optimization" (AIAA-2020-3130) by Steffen Schotthöfer, Beckett Yx Zhou, Tim A. Albring, and Nicolas R. Gauger, Technical University of Kaiserslautern

2020 AIAA Multidisciplinary Design Optimization Student Paper Competition (2nd Place)
Simultaneous layout and topology optimization of curved stiffened panels (AIAA 2020-3144) by Sheng Chu, Scott Townsend, and Carol Featherston, Cardiff University; and Hyunsun A. Kim, University of California, San Diego

2020 AIAA Multidisciplinary Design Optimization Student Paper Competition (3rd Place)
"Advances in the Pseudo-Time Accurate Formulation of the Adjoint and Tangent Systems for Sensitivity Computation and Design" (AIAA 2020-3136) by Emmett Padway and Dimitri J. Mavriplis, University of Wyoming, Laramie

2020 AIAA Plasmadynamics and Lasers Best Student Paper
"Complementary Laser Diagnostics of Metastable N2(A3 u+,v) Molecules in Nonequilibrium Plasmas and in High-Speed Flows" (AIAA 2020-1743) by Elijah Jans, Ilya Gulko, Xin Yang, Terry Miller, and Igor V. Adamovich, Ohio State University

2020 AIAA Southwest Research Institute Student Paper Award in Non-Deterministic Approaches
"Toward reliable digital twins via component-based reduced-order models and interpretable machine learning" (AIAA-2020-0418) by Michael Kapteyn, Massachusetts Institute of Technology

2020 AIAA/CEAS Aeroacoustics Best Student Paper Award
"Investigating the numerical stability of using an impedance boundary condition to model broadband noise scattering with acoustic liners " (AIAA 2020-2547) by Michelle Rodio and Fang Q. Hu, Old Dominion University; and Douglas M. Nark, NASA Langley Research Center

2020 American Society for Composites Student Paper Award
Morphing Composite Cylindrical Lattices: Thermal Effects and Actuation (AIAA-0247) by Ciarán McHale, Bernal Institute, School of Engineering, University of Limerick

Final Freitag Awards Presented

The Joseph Freitag Sr. Awards were recently presented to **Laurenz Siebold**, **Johannes Klösel**, and **Tim Lietzenmayer** of the Daimler Ausbildung and Training School, Stuttgart, Germany. Each student was awarded 1,200 EUR.

The faculty of the Daimler school selected students from those who have been accepted to have a higher education to receive the award based on the criteria that characterized the life of Freitag: educational achievement, self-initiative, craftsmanship approach, team player, and determination and perseverance.

AIAA would like to thank the Freitag family for their generous donation of the remainder of the Joseph Freitag Sr. Memorial Fund to the AIAA Foundation, which helps advance AIAA's mission to help aerospace professionals and their organizations succeed.


Laurenz Siebold


Johannes Klösel


Tim Lietzenmayer

Obituaries

AIAA Associate Fellow McRonald Died in June

Angus D. McRonald died on 5 June. He was 91 years old.

McRonald served for five years in the U.K. RAF Volunteer Reserve as a student pilot, learning to fly before he could drive. He graduated with a B.S. in physics from the University of Aberdeen in 1950, and began his career in England at the Atomic Weapons Research Establishment (AWRE).

In 1954, McRonald moved to the Australian government's Weapons Research Establishment (WRE) in Adelaide. In 1962, McRonald began a post in Sydney with the Australian Atomic Energy Commission. His love of aerospace inspired him to learn Russia for translating technical articles. In 1963, he was employed at the National Physical Laboratory in England.
In 1965, he began work at the Jet Propulsion Laboratory (California) in the wind tunnel and shock tube area. McRonald earned a master's and Ph.D. in aerospace engineering from the University of Southern California and became an American citizen. At JPL, much of his career was spent in mission analysis and design, providing planetary trajectory and launch approval support for Voyager, Galileo, Ulysses, Cassini, MER, New Horizons, Mars 96, and Mars 98 missions. His original analysis included aero-braking, aero-gravity assist, aerocapture and hypersonic ballutes.

Following retirement from JPL in 2000, he continued to consult on JPL and NASA projects. During his 35 years at JPL, McRonald was very active with the AIAA San Gabriel Valley Section. An AIAA member since 1965, he was recognized with the AIAA Sustained Service Award in 2009.

AIAA Associate Fellow McCool Died in July

Alexander 'Mac' A. McCool Jr., 96, died on 14 July.

After high school, Mr. McCool served as a first class petty officer and machinist mate in the U.S. Navy, serving at various Naval Air stations. He received a bachelor's degree in Mechanical Engineering at the University of Louisiana at Lafayette and a master's degree in Engineering at Louisiana State University in 1951.

After college, he was employed by the Army Corps of Engineers in Vicksburg, MS. He transferred to the Ordinance Corps, U.S. Army in 1954 in Huntsville, where he worked in the Guided Missile Development Division at Redstone Arsenal as a propulsion engineer. He developed propulsion systems for early U.S. space launch vehicles. As chief of Engine Systems Analysis with the Army's Ballistic Mission Agency, he was a key participant in the propulsion design of the Jupiter rocket, which placed the Explorer satellite into orbit.

In 1960, McCool transferred to NASA Marshall Space Flight Center to work with the Wernher von Braun team. He was heavily involved in the design of the propulsion systems for the Saturn launch vehicles. In 1969, as Chief of the Systems Project in NASA Marshall's Astronautics Laboratory, he directed project engineering for the Saturn/Apollo and Skylab programs. In the 1970s, as the Director of Structures and Propulsion Laboratory, McCool assumed the leadership role in the early development of the space shuttle's main engine and in the early 1980s, he managed the in-house development, test, and flight phases of the space shuttle solid rocket boosters. After the Challenger accident in January 1986, McCool was selected to lead the Solid Rocket Boosters recovery activity at the Kennedy Space Center. His expertise made him a valuable commodity at NASA, where he was named Director of the Safety, Reliability, Maintainability, and Quality Assurance Office at the Marshall Space Flight Center.

Mr. McCool retired in 2004 after over 50 years of service. He volunteered as an emeritus docent at the U.S. Space and Rocket Center. He was recognized by AIAA with the von Braun Award for Excellence in Space Program Management in 2005.

AIAA Associate Fellow Goodyer Died in September

Michael Goodyer, age 86, died on 6 September in his UK home.

He was accepted as an apprentice to Armstrong Siddeley Motors Ltd studying automobile and aeronautical engineering, and gained his HNC in Mechanical Engineering in 1954, before attending the College of Aeronautics, Cranfield in 1956, where Goodyer gained his M.Sc with a specialization in aircraft propulsion in 1958 before returning to now Bristol Siddeley Engines Ltd as Section Leader of the performance section.

In 1963 his long association with Southampton University began with his appointment as a Research Fellow to the Department of Aeronautics and Astronautics. Promoted to Lecturer in 1966, he gained his Ph.D. in Experimental Aerodynamics in 1968 and remained in this post until his promotion to Senior Lecturer in 1978, Reader in Experimental Aerodynamics in 1985, Deputy Head of Department in 1993, and ultimately held the Acting-Head of Department position at his retirement 33 years later in 1995.

Goodyer's innovative proposals for the use of cryogenically cooled fluids in wind tunnels, allowing smaller scale and potential for magnetic suspension, resulted in a NASA consultancy from 1970 to 1991. In the 1970s, Goodyer's work with the practical application of cryogenic cooling for high Reynolds number aerodynamic testing and his inventive work on a stagnation pressure probe won him several NASA awards. In 1984 he received the NASA Medal for Exceptional Scientific Achievement and in 1990 the NASA Space Act Award for his scientific contribution to the National Transonic Facility (NTF) at NASA Langley Research Center. Data from NTF and the European Transonic Wind-tunnel have been used in many legacy program and are still in use today advancing the design of military and commercial air vehicles.

Throughout the 1980s and 1990s Goodyer was in high demand as a visiting lecturer and spent time in Japan, Taiwan, Australia, and China. He also acted as a consultant to many institutions, including British Aerospace, Vickers, the Royal Aircraft Establishment and the European Transonic Wind-tunnel (ETW) group.

In 1990 he became an AIAA Associate Fellow, and in 1994 a Fellow of the Institute of Mechanical Engineers and of the Royal Aeronautical Society.

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REGION IV - SOUTH CENTRAL

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Edward Laverdure *Deputy Director, Education*
Humberto Silva *Deputy Director, Education*
James Walker *Deputy Director, Finance*
Mark Melanson *Deputy Director, Honors & Awards*
Douglas Yazell *Deputy Director, International*
Svetlana Hanson *Deputy Director, Membership*
David Fox *Deputy Director, Public Policy*
Edgar Bering *Deputy Director, STEM K-12*
Isaias Chocron *Deputy Director, Technical*
Alexander Foster *Deputy Director, Young Professionals*

Albuquerque

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Andrea Loper *Career and Professional Development Officer*
Humberto Silva *Education Officer*
Stephen Seiffert *Honors & Awards Officer*
Erin Pettyjohn *Membership Officer*
Nicholas Morley *Programs Officer*
Mark Fraser *Public Policy Officer*
Terry Caipen *Secretary*
Elfego Pinon *STEM K-12 Officer*
Robert Malseed *Treasurer, Newsletter Editor*
Svetlana Poroseva *University Liaison Officer*
Paul Delgado *Vice Chair*
Kyle Lynch *Young Professional Officer*

Houston

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Svetlana Hanson *Chair Emeritus*
Elizabeth Sheridan *Council Member*
Sarah Shull *Council Member*
Wanda Sigur *Council Member*
Jared Wissel *Communications Officer*
Megan Smith *Career and Professional Development Officer*
Michael Martin *Education Officer*
Benjamin Wichmann *Honors & Awards Officer*
Douglas Yazell *History Officer*
Laura Sarmiento *Programs Officer*
Shen Ge *Publicity Officer*
Wayne Rast *Public Policy Officer*
William O'Neill *Secretary*
Edgar Bering *STEM K-12 Officer*
Ami Halbur *Technical Officer*
Jackelynne Silva-Martinez *Technical Officer*
Thomas Bryan *Treasurer*
Patrick Rodi *Vice-chair, Technical*
Joel Godinez *Website Editor*
Joshua Kivijarv *Young Professional Officer*

North Texas

James Sergeant *Chair*
Mike Fox *Advisory Committee*
Kevin Kramer *Advisory Committee*
Paul Park *Advisory Committee*
Erasmo Pinero *Advisory Committee*
Michael Smith *Advisory Committee*
Robert Wetherall *Advisory Committee*
Justin Kanarick *Secretary*
Dana Johnson *Treasurer*

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Subramanyam Gollahalli *Honors & Awards Officer*
Jamey Jacob *Newsletter Editor*
Michael Frey *Programs Officer*
Andrew Arena *Secretary*
Prakash Vedula *Treasurer*
Richard Gaeta *Vice Chair*
Andrew Arena *Website Editor*

Southwest Texas

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James Crean *Membership Officer, Public Policy Officer*
Thomas Moore *Secretary*
Joan Labay-Marquez *STEM K-12 Officer*
George Hindman *Vice Chair, Technical Officer*

White Sands Space Harbor

Stephen McDougle *Chair*
Robert Cort *Education Officer, Honors & Awards Officer*
Joe Bullington *Vice Chair*

REGION V - MID WEST

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Kristen Gerzina *Deputy Director, Finance*
Andrew Carlson *Deputy Director, Honors & Awards*
Enanga Fale *Deputy Director, Membership*
Colin Campbell *Deputy Director, Public Policy*
Arjun Rao *Deputy Director, Public Policy*
Karolyn Evans *Deputy Director, STEM K-12*
James Horkovich *Deputy Director, Technical*
Christopher Stevens *Deputy Director, Young Professionals*

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Vinay Dayal *Programs Officer*
Albert Ratner *Programs Officer*
Sridher Kaminani *Secretary*
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Brian Gulliver *Chair Emeritus*
Merri Sanchez *Immediate Past Chair*
Tracy Copp *Council Member*
Duncan Hills *Council Member*
Mark Kettles *Council Member*
John Marcantonio *Council Member*
Durga Niroula *Council Member*
Sally Hanley *Communications Officer*
William Carter *Education Officer*
Carolyn Overmyer *Honors & Awards Officer*
John Reed *TC Liaison*
Marshall Lee *Membership Officer*
Adrian Nagle *Newsletter Editor*
Christopher Zeller *Programs Officer, Technical Officer*
Joe Rice *Public Policy Officer*
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Taylor Lilly *Treasurer*
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Tyler Walston *Young Professional Officer*

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David Peters *Advisor*
Chris Tavares *Advisor*
Andrea Martinez *Communications Officer*
Paul Bent *Career and Professional Development Officer*
Charles Svoboda *Education Officer*
Patrick Padilla *Honors & Awards Officer*
Colin Thiele *History Officer*
Alexander Friedman *Membership Officer*
Lawrence Brase *Other*
Robert Dowgwillo *Programs Officer*
Frank Youkhana *Public Policy Officer*
James Guglielmo *RAC Representative*
Abigail Sevier *Secretary*
Raymond Cosner *Retirees Section Officer*
Bradley Sexton *Special Projects Officer*
Jackie Blumer *STEM K-12 Officer*
John Schaefer *Technical Officer*
Alec Herzog *Treasurer*
Sanjay Jayaram *Vice Chair*
Stephen Clark *Young Professional Officer*

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Jeffrey Doom *State Representative - South Dakota*
Michael Ward *Technical Officer*
Frank Hoffmann *Treasurer*
Nicholas Janak *Vice Chair*
Andrew Carlson *Website Editor*

Wichita

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Linda Kliment *Education Officer*
Robert Stuever *Honors & Awards Officer*
Balaji Kartikeyan *Chandrasekaran Secretary*
John Franken *Student Liaison*
Eddie Irani *Treasurer*
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Julie-Elisa Acosta *Young Professional Officer*

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Matthew Angiulo *Deputy Director, Public Policy*
Elishka Jepson *Deputy Director, STEM K-12*
Bradley Williams *Deputy Director, Young Professionals*

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Chris Coyne *Publicity Officer*
Patrick Clark *Public Policy Officer*
Christopher Watenpool *Secretary*
Robert Jensen *STEM K-12 Officer*
Keerti Bhamidipati *Treasurer*
Kasthuri Sivagnanam *University Liaison Officer*
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Joseph Piotrowski *Vice Chair, Young Professional Officer*

China Lake

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Ying-Ming Lee *Membership Officer, Newsletter Editor*
Steven Goad *Public Policy Officer*
Edward Jeter *Secretary*
William Sturgeon *Treasurer*
Michael Petersen *Vice Chair*

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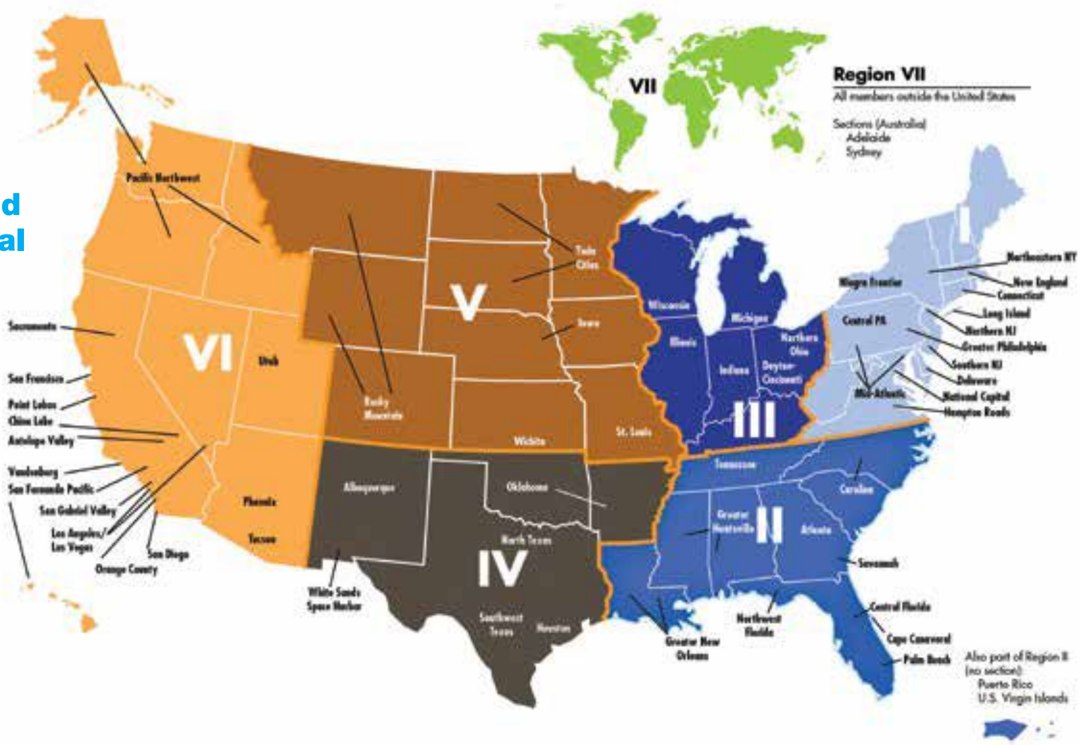
Jeffery Puschell *Advisor*
Marsha Weiskopf *Advisor*
James Kowalski *Career and Professional Development Officer*
Edwin Williams *Career and Professional Development Officer*
Robert Baker *Education Officer*
Arpie Ovsepyan *Education Officer*
Dennis Wonica *Enterprise Program*
Aldo Martinez *Honors & Awards Officer, Membership Officer*
Seth Potter *Professional Society Liaison*
David Ramirez *Professional Society Liaison*
Marty Waldman *Las Vegas Chapter Representative*
Vahik Khodagolian *Other*
Kenneth Lui *Programs Officer*
Jordan Chilcott *Public Policy Officer*
Khushbu Patel *STEM K-12 Officer*
Gary Moir *Technical Officer*
Marilyn McPoland *Treasurer*
Fred Lawler *Vice Chair*
Lisa Kaspin-Powell *Website Editor*

AIAA Sections and Geographical Regions



Orange County
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Janet Koepke *Advisor*
Robert Koepke *Advisor*
Lotfi El-Bayoumy *Chair Emeritus*
Abdulmageed Abdulrahman *Council Member*
John Moussan *Council Member*
Philip Ridout *Council Member*
Dino Roman *Council Member*
Philip Schulze *Council Member*
Erol Kilik *Career and Professional Development Officer*
H. Welge *Membership Officer, RAC Representative*
Kamal Shweyk *Public Policy Officer*
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Binay Pandey *STEM K-12 Officer*
Edward Rocha *STEM K-12 Officer*
Clyde Helms *Technical Officer*
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Jonathan Hart *Website Editor*
Bradley Williams *Young Professional Officer*

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Rachel Horzewski *Advisor*
Christian Pierre *Advisor*
Simon Shuham *Advisor*
Adiel Guinzburg *Honors & Awards Officer*
Melanie Kwong *Liaison*
Scott McComb *Liaison*
Adriana Blom-Schieber *Membership Officer*
Alexandru Stere *Public Policy Officer, Education Officer*
Paul Vijgen *RAC Representative*
Abhiram Krishnan *Secretary*
Karl Rein-Weston *Retirees Section Officer*
Elana Slagle *STEM K-12 Officer*
Grant Funk *State Representative - Alaska*
Joseph Nwizugbo *Student Liaison*
Adam Ragle *Student Liaison*
John Dixon *Technical Symposium Chair*
Cristian Romero *Technical Symposium Chair*
Christopher Roberdeau *Treasurer*
Bradley Camburn *University Liaison Officer*
Mike Myers *University Liaison Officer*
Nancy Squires *University Liaison Officer*
Matthieu Masquelet *Vice Chair*
Patrick Remy *Website Editor*
Megan Harrington *Young Professional Officer*
Brent Pomeroy *Young Professional Officer, Technical Symposium Chair*

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Keith Jenkins *Council Member, Technical Officer*
Jeonglae Kim *Council Member*
Eric Nichols *Council Member*
Richard Kale *Secretary*
Brianna Grembowski *STEM K-12 Officer*
Scott Wertel *Treasurer*
Scott Fouse *Vice Chair*
Garrick Williams *Young Professional Officer*

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Stephen Tackett *Secretary*
Daniel Bursch *Treasurer*
Lara Magallanes *Vice Chair*
Jae-Jun Kim *Website Editor*

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James Hornick *Chair Emeritus, Council Member*
L. Jane *Hansen Council Member, Treasurer, Website Editor*
Brett Hoffstadt *Communications Officer, Secretary*
Stephen Reiff *Public Policy Officer*

San Diego
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Irving Hernandez *Education Officer*
Kevin Burns *History Officer*
Cesar Martin *Public Policy Officer*
Robin Jacobson *Secretary*
Rich Kenney *STEM K-12 Officer*
Diego Chavez *Student Liaison*
Brenda Williamson *San Diego Student Liaison*
Kimberly Painter *Treasurer*
Mark Anderson *University Liaison Officer*
Allen Plotkin *University Liaison Officer*
Nick Candrella *Vice-chair, Long-range Planning*
Lindsey Sweeney *Vice-chair, Technical*
Jin Oh *Website Editor*
Zachary Annala *Young Professional Officer*

San Fernando Pacific
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Ryan Reynolds *Membership Officer*
Misak Zetilyan *Public Policy Officer*
Corinne Cho *STEM K-12 Officer, Website Editor*
Melissa Onishi *Treasurer*
Anita Sengupta *Young Professional Officer*

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Richard Kwan *Council Member*
Ramuhalli Krishna *Education Officer*
Swati Saxena *Honors & Awards Officer*
Thomas Lombaerts *Programs Officer*
Derek Lang *STEM K-12 Officer*
Watson Attai *Treasurer*
Gedi Minster *Minster Vice Chair*
Sheen Kao *Communications Officer*
Tyler Miles *Young Professional Officer*

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TBD Chair
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Sevan Kenderian *Programs Officer, Website Editor*
Mar Vaquero *Programs Officer*
Alejandro Levi *Public Policy Officer*
Gerald Hintz *Treasurer*
Jill Hardash *Young Professional Officer*

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Michelle Rouch *Chair*
Alexis Hepburn *Career and Professional Development Officer*
Corey Bullens *Honors & Awards Officer*
Rajka Corder *Membership Officer*
Jeffrey Jepson *RAC Representative*
Steven Smith *Secretary*
Elishka Jepson *STEM K-12 Officer*
Mehrdad Rouhani *Treasurer*
Teresa Clement *Vice Chair*
Eric Hoffman-Watt *Website Editor*
Michael Hotto *Young Professional Officer*

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Catherine Beck *Chair*
Scott Stebbins *Chair Emeritus*
John McCrea *Council Member*
Collin Wagner *Membership Officer*
Michael Miller *Membership Analytics Officer*
Jessica Widrick *Outreach Officer*
Michael Stevens *Programs Officer*
Charles Vono *Public Policy Officer*
Ryan Clawson *Secretary*
John Metcalf *Treasurer*
Jacob Hopkins *Vice Chair*
Trevor Floyd *Website Editor*
Justin Wettstein *Young Professional Officer*

Vandenberg
Michelle Itzel *Chair, Secretary*
Christopher Menino *Honors & Awards Officer, Membership Officer*
Steve Boelhouwer *Newsletter Editor*
Jasmine Toye *Programs Officer, Young Professional Officer*
Thomas Stevens *STEM K-12 Officer*
Thomas Nadobny *Treasurer*
Eva McLaughlin *Education Officer*
Evan Agarwal *University Liaison Officer*
Curtis Brooks *Vice Chair*

REGION VII - INTERNATIONAL
Cees Bil *Director*
Roelof Vos *Deputy Director, Europe*
Joao Luiz Azevedo *Deputy Director, South America*

Adelaide
Patrick Neumann *Chair, Membership Officer*
Saman Aghdam *Council Member*
Mark Bateup *Council Member*
Warrick Miller *Council Member*
Melanie Ward *Council Member, Young Professional Officer*
Steven Pietrobon *Secretary*
Natalie Hayman *Student Liaison*
Rey Chin *Treasurer and University Liaison*
Alice Gorman *Vice Chair*
RaviTeja Duggineni *Website Editor*

Sydney
Nimish Shete *Chair*
Sudip Bhattrai *Council Member*
Arnab Dasgupta *Council Member*
Diego Exposito *Brioso Council Member*
David Jarrett *Council Member*
Matthew Vella *Council Member*
Michael Spencer *Honors & Awards Officer*
Nathan Long *Membership Officer*
Andrew Neely *STEM K-12 Officer*
Cole Scott-Curwood *Student Liaison*
Divya Jindal *Treasurer*
Gareth Vio *University Liaison Officer*
Tjasa Boh *Whiteman Vice Chair - Canberra*

TEXAS A&M UNIVERSITY
Department of
Aerospace Engineering

The College of Engineering at Texas A&M University invites applications for a full-time tenured professor and department head for the Department of Aerospace Engineering with an 11-month academic appointment beginning fall of 2021. The college is seeking a dynamic, innovative, and visionary leader who can continue to advance the department. The successful applicant will be an innovative thinker with a strategic vision for guiding the department to a higher level of excellence and who can communicate this vision to a constituency that includes academia, government, industry, and former students. The candidate must have notable accomplishments and experience in research, academic or industry leadership, teaching and scholarship.

Candidates must demonstrate a vision for supporting, directing, and enhancing the goals of the department. This leadership position includes opportunities for research and teaching as well as expanding the department's interdisciplinary research and interaction with autonomous systems, life sciences, Army Futures Command, smart manufacturing initiatives, innovative energy alternatives, and unconventional energy.

The department head will:

- Demonstrate leadership, mentoring and administrative skills;
- Continue a successful distinguished research and academic record commensurate with the title of tenured full professor;
- Promote continued growth of the department in research excellence and graduate education;
- Lead and motivate high standards for continued excellence and innovation in undergraduate education;
- Build commitment and support for the department from a wide variety of constituent groups such as former students, industry and government labs;
- Provide effective budget management and promote an environment of integrity to stimulate faculty, staff and students to succeed at the highest levels;
- Organize successful fundraising through the pursuit of research funding opportunities (grants and contracts), scholarship and endowments through strengthening relationships with diverse stakeholder groups.

Department Information: As one of fifteen departments within the Texas A&M University College of Engineering, the Department of Aerospace Engineering is proud to be among the top Aerospace Engineering programs in the United States, providing unique cutting-edge educational and research opportunities, including space exploration, national defense, air transportation, communications and sustainable energy. The department is comprised of more than 50 faculty (eight faculty are NAE members), 600+ undergraduate students and almost 200 graduate students who work on projects such as building shape-shifting supersonic aircraft, hypersonic technologies, virtual reality space simulation environments, space missions, a 15,000-pound thrust re-startable hybrid rocket system, autonomous systems technologies for next generation air and space missions, surface aquatic autonomous drone, and shape-memory alloys into an emergency response tourniquet. The department emphasizes balance between basic and applied research with a wide range of strengths and depth in fundamental analytical, computational, and experimental methods. The laboratory and experimental facilities are excellent. Recent teaming with the Army Futures Command, Air Force Research Laboratories and Jet Propulsion Laboratory expand the existing research portfolio.

Qualifications: Candidates must have an earned doctorate in Aerospace Engineering or a closely related field. Evidence of credentials that merit appointment at the rank of full professor with tenure including a distinguished research and academic record commensurate with the title of tenured full professor.

Application Instructions: Applicants should submit a cover letter, curriculum vitae, teaching statement, research statement, diversity statement and a list of four references (including postal addresses, phone numbers and email addresses) by applying for this specific position at apply.interfolio.com/79193. Applicants should also submit a three-page statement summarizing his/her personal vision and goals for the Department of Aerospace Engineering's education and research, as well as his/her philosophy of academic leadership for achieving those goals. Full consideration will be given to applications received by February 1, 2021. Applications received after that date may be considered until the position is filled. It is anticipated the appointment will begin fall 2021.

Contact: Dr. Robin Autenrieth, Department Head and A.P. & Florence Wiley Professor, Aerospace Engineering Department Head Search Committee Chair, Texas A&M University, aerodhsearch@tamu.edu.

Texas A&M University is committed to enriching the learning and working environment for all visitors, students, faculty, and staff by promoting a culture that embraces inclusion, diversity, equity, and accountability. Diverse perspectives, talents, and identities are vital to accomplishing our mission and living our core values.

Equal Opportunity/Affirmative Action/Veterans/Disability Employer committed to diversity.

Embry-Riddle Aeronautical University Presidential Fellows Cluster Hiring Initiative

Embry-Riddle Aeronautical University has an ambitious agenda for the next five years, focused on expanding its research capabilities, graduate programs, and facilities and recruiting highly-talented faculty. The University strives to expand its presence in aerospace and aviation research and to be recognized globally in select signature areas while growing its discovery-driven undergraduate programs. In support of this agenda, multiple Presidential Fellow positions will be filled.

Presidential Fellows will hold a Distinguished Faculty position in one of the Colleges across the three campuses in Daytona Beach, Prescott, or Worldwide. The appointments come with tenure and will be available as early as January 2021.

The University invites nationally renowned candidates in the areas of Aviation Cyber Security, Aviation Data Science and Business Analytics, Flight Research, Unmanned Aerial Systems (UAS) and Autonomous Systems to apply. Candidates for these positions are expected to have an exemplary record of sustained funded research, supervision of doctoral students, an excellent publication record, and experience in building new research programs and leading major labs or centers.

Candidates should have an earned terminal degree in a related field and have the credentials for Associate or Full Professor rank. Women and underrepresented minorities are especially encouraged to apply.

Candidates must specify a preferred home department, college, and campus as well as any desired joint appointment. Candidates must submit: (1) a cover letter; (2) a Curriculum Vitae; (3) teaching philosophy; (4) a research plan; and (5) the names and contact information of at least three references.

Candidate materials should be submitted online by applying to requisition #190373 at http://careers.erau.edu.

Any questions should be directed to the University's Associate Provost for Research, Dr. Remzi Seker at sekerr@erau.edu or 386.226.7409.

FACULTY OPENING
Stanford University
Department of Aeronautics and Astronautics

Stanford University

The Department of Aeronautics and Astronautics at Stanford University invites applications for a tenure track faculty position at the Assistant or untenured Associate Professor level.

Research advances in the fundamental areas of aerospace engineering are critical for future air and space transportation systems that will provide efficiency, safety, and security, while protecting the environment. We are seeking exceptional applicants who will develop a program of high-impact research, contribute to an innovative undergraduate curriculum, and develop graduate courses at the frontier of areas such as: novel lightweight structures concepts, structural materials and integrated systems, aerospace system design, autonomous aerospace vehicle technologies, and breakthroughs in aerospace propulsion concepts. We will place higher priority on the impact, originality, and promise of the candidate's work than on the particular area of specialization within Aeronautics and Astronautics.

Evidence of the ability to pursue a program of innovative research and a strong commitment to graduate and undergraduate teaching is required.

Candidates whose research programs in Aeronautics and Astronautics will involve the development of sophisticated computational and/or mathematical methods may be considered for an appointment with an affiliation with the Institute for Computational and Mathematical Engineering (https://icme.stanford.edu/).

All candidates should apply online at https://aa.stanford.edu/job-openings. Applications should include a brief research and teaching plan, a detailed resume including a publications list, three letters of reference, and the names and addresses of at least two more potential referees. Applications will be accepted until the position is filled; however, the review process will begin on January 4, 2021.

Stanford is an equal employment opportunity and affirmative action employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability, protected veteran status, or any other characteristic protected by law. Stanford also welcomes applications from others who would bring additional dimensions to the University's research, teaching and clinical missions.

AUBURN UNIVERSITY
SAMUEL GINN COLLEGE OF ENGINEERING

Multiple Open Rank Tenure-Track Faculty Positions

The Department of Aerospace Engineering at Auburn University invites applications for multiple **open rank tenure-track faculty positions (Assistant, Associate or Full Professor)**. Applications are invited in all areas related to aerospace engineering. Candidates are strongly encouraged to apply with expertise in: aerodynamics and propulsion; computational fluid dynamics; flight dynamics; and space systems and payloads. Candidates will be expected to fully contribute to the department's mission through (i) the development of a strong, nationally recognized, funded research program, (ii) teaching aerospace engineering related courses at both the undergraduate and graduate level, and (iii) professional service. Successful candidates will have a demonstrated track record of scholarship, a creative vision for research, an active interest in engineering education, and strong communication skills. For applications at the rank of Associate or Full Professor, an emphasis will be placed on the strength and caliber of the candidate's existing research program and the candidate's ability and desire to provide mentorship and leadership to a young, enthusiastic, and rapidly growing department. Candidates must have an earned Ph.D. in aerospace, mechanical engineering, or a closely related field at the time of employment.

The Department of Aerospace Engineering at Auburn University is in the midst of unprecedented growth with undergraduate enrollment increasing by over 50% in last six years to 535 students. This growth has been complemented by aggressive faculty hiring with the department now consisting of four full professors, one associate professor, eight assistant professors and two lecturers. Our current focus is on the development of world-class research programs and growth of the graduate student body from its current size of 72 students to a goal number of over 100 graduate students within the next five years. The department is part of the Samuel Ginn College of Engineering, which has a total enrollment of over 6,500 students and is home to several nationally recognized research centers, which among others would include National Center for Additive Manufacturing Excellence (NCAME), Center for Polymer, Advanced Composites (CPAC), Center for Advanced Vehicle and Extreme Environment Electronics (CAVE3), Auburn University Small Satellite Program, and Cyber Research Center. Auburn University's proximity to the aerospace, defense, and government enterprises located from Huntsville, AL down to the Florida Space Coast presents a unique opportunity for the department to emerge from this growth phase as one of the premier aerospace engineering departments in the country. Additional information about the department may be found at: www.eng.auburn.edu/aero/.

Auburn University. (www.auburn.edu/) is one of the nation's premier public land-grant institutions. In 2020, the college of engineering was ranked 29th among public universities by U.S. News and World Report. Auburn maintains high levels of research activity and high standards for teaching excellence, offering Bachelor's, Master's, Educational Specialist, and Doctor's degrees in engineering and agriculture, the professions, and the arts and sciences. Its 2020 enrollment of 30,737 students includes 24,505 undergraduates and 6,232 graduate and professional students. Organized into twelve academic colleges and schools, Auburn's 1,450 faculty members offer more than 200 educational programs. The University is nationally recognized for its commitment to academic excellence, its positive work environment, its student engagement, and its beautiful campus. Auburn (https://www.auburnalabama.org) residents enjoy a thriving community, recognized as one of the "best small towns in America," with moderate climate and easy access to major cities or to beach and mountain recreational facilities. Situated along the rapidly developing I-85 corridor between Atlanta, Georgia, and Montgomery, Alabama, the combined Auburn-Opelika-Columbus statistical area has a population of over 500,000, with excellent public school systems and regional medical centers.

Candidates should log in and submit a cover letter, CV, research vision, teaching philosophy, statement on diversity, equity and inclusion, and three references at www.auemployment.com/postings/19572. Cover letters may be addressed to: Dr. Brian Thurow, Search Committee Chair, 211 Davis Hall, Auburn University, AL 36849. To ensure full consideration, candidates are encouraged to apply before December 1, 2020 although applications will be accepted until the positions are filled. The successful candidate must meet eligibility requirements to work in the U.S. at the time the appointment begins and continue working legally for the proposed term of employment.

Auburn University is understanding of and sensitive to the family needs of faculty, including career couples. See "Guidelines for Dual Career Services" www.auburn.edu/academic/provost/policies-guidelines/#guidelines

Auburn University is an EEO/Vet/Disability Employer

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1920

Nov. 1 Aeromarine West Indies Airways starts the United States' first international passenger service, between Key West, Florida, and Havana, after winning the rights to an international airmail contract from the U.S. Postal Service. Aeromarine flies repurposed Curtiss F5L flying boats. While most early airlines fail within a few months, Aeromarine prospers for four years flying passengers to Cuba and later to the Bahamas and, in the summer months, across Lake Erie to Canada. The secret to its success is Prohibition. Some Americans are willing to pay high fares in order to fly to countries that permit alcohol sales. R.E.G. Davies, **Airlines of the United States Since 1914**, pp. 22-24.

1 **Nov. 16** Queensland and Northern Territory Aerial Services Ltd., or Qantas, is founded in Winton, Australia, by Hudson Fysh and Paul McGinness. Operations start two years later on Sept. 2, 1922. Eventually they move the headquarters to Longreach. David Baker, **Flight and Flying: A Chronology**, p. 306.

1945

2 **Nov. 6** U.S. Navy Ensign Jake West makes the first jet aircraft landing on an aircraft carrier in a Ryan FR-1 Fireball fighter with mixed powerplants, a turbojet in the aft fuselage, and a reciprocating engine at the front. The record is unintentional as the aircraft piston engine failed, forcing West to land under jet power alone. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 51.

Nov. 7 The first postwar aircraft world speed record is set in a flight off England by Royal Air Force Group Capt. H.J. Wilson in the jet-powered Britannia, a Gloster Meteor F.4, which he flies at 975 kph. The previous record recognized by the Federation Aeronautique Internationale was 754 kph, set in 1939 by Flugkapitan Fritz Wendel in a Messerschmitt Me 109R. Records set in experimental aircraft during the war are not recognized by the FAI. David Baker, **Flight and Flying: A Chronology**, p. 306.

3 **Nov. 28** The Short Brothers' Short Sandringham is introduced as the latest in the line of S.23-type Empire flying boats. Unlike the earlier models, the Sandringham carries passengers on both the upper and lower decks for a total seating capacity of 24; it also has a dining room, pantry, kitchen, bar and sleeping cabins. **The Aeroplane**, Dec. 7, 1945, p. 671.

Nov. 22 Pan American Airways becomes the first airline to operate the new Lockheed Constellation, a four-engine pressurized airliner. The triple-tailed Constellation soon becomes the symbol of the luxurious post-World War II era of international air travel. David Baker, **Flight and Flying: A Chronology**, p. 307.

1970

Nov. 4 The Concorde supersonic transport, 001, French prototype, is flown for the first time to Mach 2, by Aerospatiale chief test pilot André Turcat. The flight from Toulouse's Blagnac Aerodrome marks the beginning of tests that will lead to contract negotiations with 16 airlines holding options on purchasing 75 of the airplanes. **Aviation Week**, Nov. 9, 1970, p. 16; **New York Times**, Nov. 5, 1970, p. 94.

Nov. 9 Ofo, short for Orbiting Frog Otolith, and a second payload, the RM Radiation-Meteoroid Satellite, are launched into orbit on a four-stage Scout booster from Wallops Island, Virginia. The primary purpose of the 132.5-kilogram Ofo is to obtain information on the functioning and adaptability in weightlessness of the inner ear that controls balance by studying two male bullfrogs on board. Scientists chose frogs for flight because their inner ear mechanism is similar to humans and because they are small animals. The data is obtained through microelectrode sensors implanted in the frogs. **NASA Release 70-132**.

Nov. 10 The Soviet Union launches its Luna 17 lunar probe from Baikonur, Kazakhstan, and on Nov. 17 the craft lands on the moon's Sea of Rains and releases a self-propelled vehicle. Powered by solar energy and batteries, the eight-wheeled Lunokhod 1 carries scientific instruments and radio and TV transmitters. **New York Times**, Nov. 18, 1970, p. 1.

4 **Nov. 16** The Lockheed L-1011 trijet makes its first flight from the company's facility at Palmdale, California. The flight is early in the morning to avert possible strong winds in the high desert. This also enhances the performance of the plane's Rolls-Royce RB.211-22 engines. **Aviation Week**, Nov. 16, 1970, p. 33 and Nov. 23, 1970, p. 16.

5 **Nov. 17** A Lunar Roving Vehicle two-person training model, the 1-G trainer, is delivered by Boeing to representatives of NASA's Marshall Space Flight Center at Santa Barbara, California. The trainer is a flight version for the Apollo 15, 16 and 17 missions but weighs twice as much. **NASA Release 70-201**.

Nov. 26 A broken section of a propeller spinner from Charles Lindbergh's Spirit of St. Louis aircraft that made the first solo crossing of the Atlantic on May 30, 1927, is donated to the Smithsonian Institution by Stanley Vaughn of Columbus, Ohio. Vaughn had been the factory manager for Curtiss Aeroplane and Motor Co. and had kept the broken spinner for 45 years. **New York Times**, Dec. 9, 1970, p. 46.

1995

6 **Nov. 28** A McDonnell-Douglas MD-11 makes the first automated landing of an airliner using engine thrust alone. **NASA Release 95-39**.

Nov. 28 The Gulfstream V long-range business jet is flown for the first time. Powered by two Rolls-Royce BR700-710A1-10 turbofans featuring full authority digital engine controls, the Gulfstream V features an improved supercritical wing that gives the aircraft a maximum range of 12,000 kilometers. Up to 19 passengers can be carried. **Aviation Week**, Dec. 4, 1995.

7 **Nov. 29** The latest version of the McDonnell Douglas F/A-18 Hornet multirole fighter for the U.S. Navy, the F/A-18E/F Super Hornet, completes its first flight. Longer than the earlier versions of the Hornet, the Super Hornet can carry 33% more fuel, increasing its range 50% to a maximum of 3,200 km. It is designed to replace the Grumman F-14 Tomcat and features upgraded radar and avionics as well as stealth features. **Boeing.com**


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Jon Proctor

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CONTINUED FROM PAGE 64

Simply put, these operators should be required to compensate for their withholding of information by performing correction maneuvers to keep their satellites on gravity-only trajectories. These are the paths the spacecraft would follow were it not for nongravitational influences. The process of joining the timetables would begin with a satellite operator choosing one of Earth's gravitational models, approximating the actual regions of varying gravitational strength around our planet, in which to orbit their satellites. The operator would periodically provide astrodynamicists with a new set of initial conditions at a specific time, and ensure that its satellites move along the subsequent gravity-only trajectories plus or minus some tolerance that would also be made known to humanity. The operator could then keep all of the proprietary, export-controlled, sensitive characteristics of its satellites to itself, while still enabling space safety and sustainability.

To be sure, not all satellites have the same control authority and level of operational accuracy and precision, but these can be quantified and, as long as they are made known, the remainder of operators sharing these increasingly congested orbital neighborhoods can plan accordingly. For transparency and as a confidence-building measure, satellite owners and operators would be encouraged to provide evidence of their past trajectories so others could compare and contrast these to the agreed-to trajectory control thresholds. Operators need not all choose the same Earth gravitational model. Each operator could choose what is most convenient for them in terms of minimizing their own operational costs, so long as they make this publicly known and stick to it. In a demonstration of leadership, Amazon, for example, has expressed support for implementing this solution for its Project Kuiper, a satellite constellation that would provide global internet.

This approach could eventually lead to performance-based standards for required satellite control accuracy and precision in order to obtain licenses to launch and operate these satellites. The timetables would include satellites whose owners choose to share their satellite data, and also those who don't. For them, we can all rest easier knowing that Isaac Newton is in the driver's seat with gravity-only trajectories. ★

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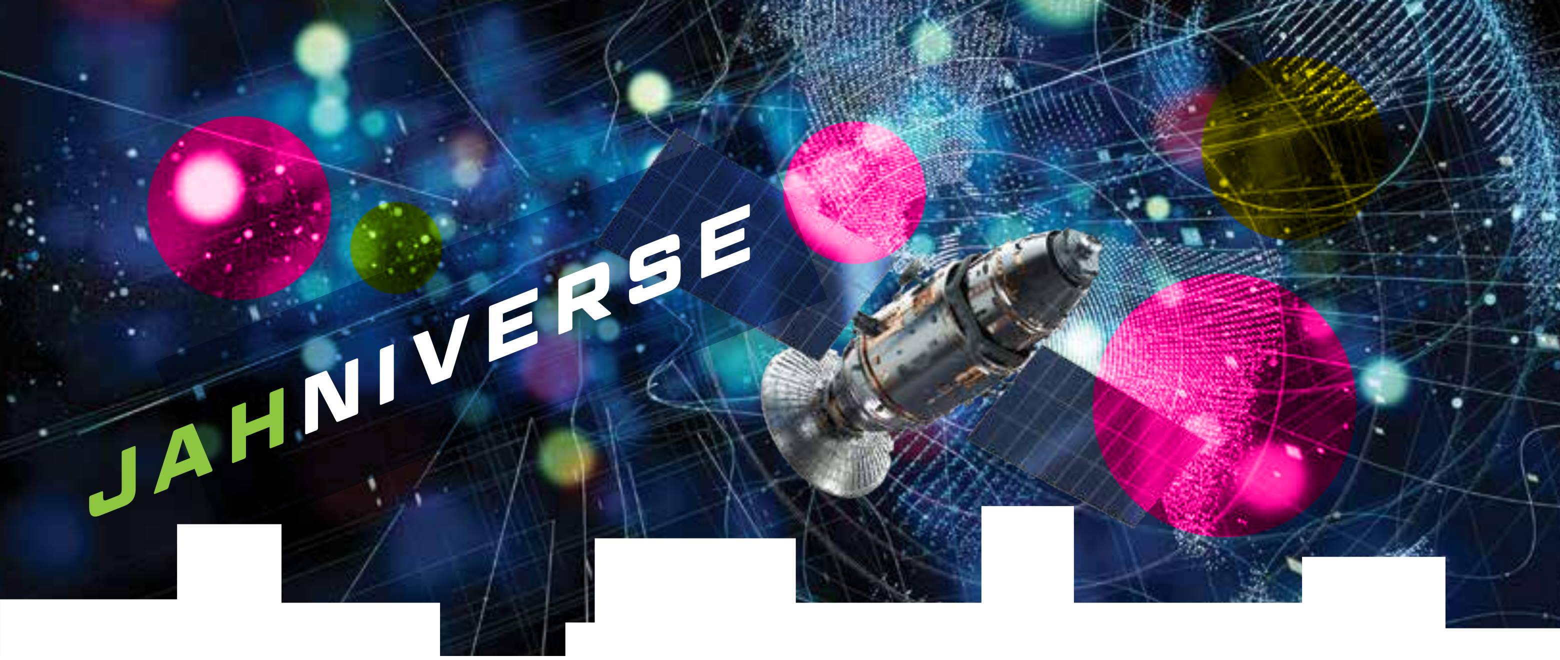

Don't want to share your satellite details? That should cost you

BY MORIBA JAH

Moriba Jah is an astrodynamicist, space environmentalist and associate professor of aerospace engineering and engineering mechanics at the University of Texas at Austin. He holds the Mrs. Pearlie Dashiell Henderson Centennial Fellowship in Engineering and is an AIAA fellow. He also hosts the monthly webcast "Moriba's Vox Populi" on SpaceWatch.global.

Given the vast number of satellites that space operators are starting to launch, humanity risks exceeding the orbital carrying capacity of the space environment unless we do better at coordination. We would all benefit from establishing orbital timetables that would predict the locations of specific satellites at specific times in the future, not unlike a European train schedule.

These timetables would help everyone plan their satellite movements in a shared environment and aid in creating norms of behavior underscoring safety and sustainability. We could predict and take steps to avoid collisions well into the future.

For those operators willing to share their satellites' details, adding their spacecraft to the timetables would be relatively straightforward. Astrodynamicists like myself could model the nongravitational forces that these objects will experience, and maybe even request their planned maneuvers so we can anticipate their deliberate motion. The starting point would be Newton's principle of determinacy, which states that if we know an object's initial position and velocity, we can predict where it will be for all time. Gravity is an equal-opportunity accelerator because no matter what an anthropogenic space object looks like, is shaped like, or made of, the portion of acceleration due to gravity is the same. From there, we would consider a satellite's size and shape and the characteristics of its materials, which together with the natural effects of radiation, particle interaction and electromagnetism determine how the spacecraft will actually move. The results would be highly accurate predictions. The trains would run on time.

Unfortunately, adequate transparency is the missing ingredient in my proposal to create railroad-like timetables for satellites. Many satellite owners and operators closely hold detailed information about their spacecraft, including specific physical characteristics, functions and operational details. That information is often considered proprietary or subject to export control rules for national security reasons. So, we can't at the moment fully predict where their satellites will be, and therefore we can't include them in the proposed timetables unless something is done.

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