

Predicting bad vibes

U.S. Sen. Jerry Moran on FAA, NASA

Leaping from automation to autonomy

# AEROSPACE

★ ★ ★ A M E R I C A ★ ★ ★

## SPARKING THE SPACE ECONOMY

A flexible glass produced in space shows promise as a catalyst for building an economy in space. **PAGE 16**



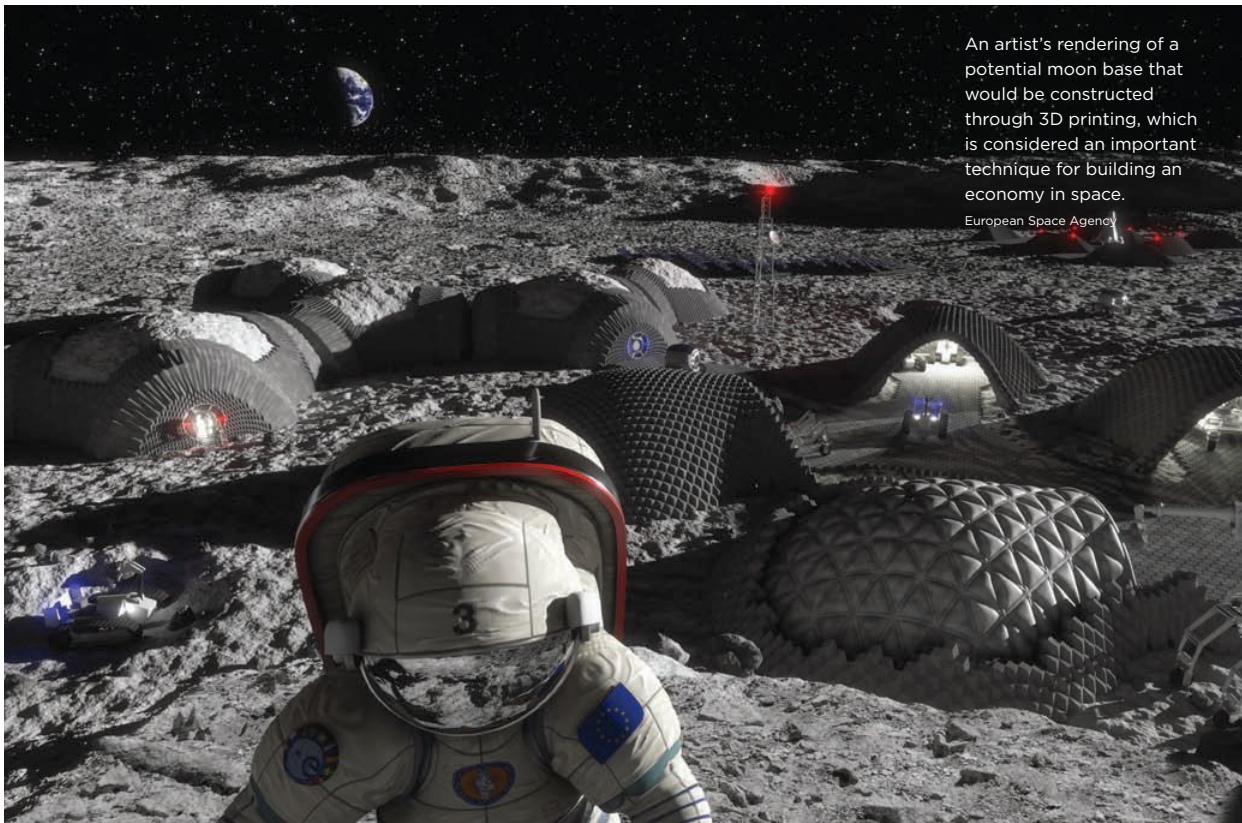
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An artist's rendering of a potential moon base that would be constructed through 3D printing, which is considered an important technique for building an economy in space.  
European Space Agency

# 16

## Manufacturing in space

A fiber optic material called ZBLAN could be the product that jump-starts the space economy.

By Debra Werner

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## Dream Chaser's new champion

Janet Kavandi, a former astronaut and former director of NASA's Glenn Research Center, takes charge of Sierra Nevada Corp.'s Space Systems division.

By Amanda Miller

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## Planes vs. cars

While autonomous aircraft appear to be building on the advances of self-driving cars, operating in more dimensions carries special challenges.

By Adam Hadhazy

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## Defending Earth from asteroids

A partnership between governments and the nascent commercial space industry would guarantee the reliability and rapid response necessary, says a former NASA mission planner.

By Don Nelson

The logo features a stylized sunburst or fan shape at the top with the year '2020' in the center. Below this, the words 'AEROSPACE SPOTLIGHT' are written in a bold, sans-serif font, followed by 'Awards Gala' in a large, elegant script font. The entire logo is framed by horizontal lines and decorative diamond shapes.

2020

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**AIAA**  
SHAPING THE FUTURE OF AEROSPACE

# AEROSPACE

★ ★ ★ AMERICA ★ ★ ★

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### Christine Fisher

Christine writes about technology, space and science. Her work can also be found on Engadget.com.

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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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### Amanda Miller

Amanda is a freelance reporter and editor based near Denver with 20 years of experience at weekly and daily publications.

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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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Daniel Alvarez, space mission program manager at Millennium Space Systems

# The burgeoning space economy

The fresh determination by NASA and a host of startups to build products in space could require rethinking our standard nomenclature about matters of space.

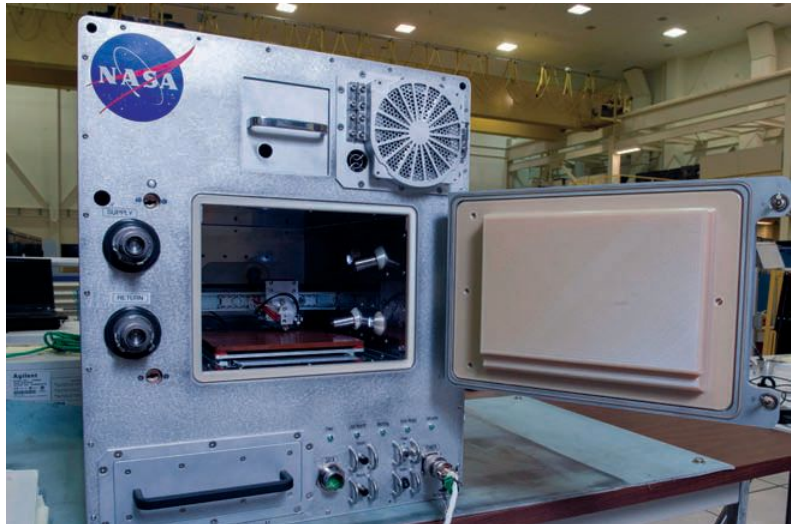
Consider the term “space economy.” In the traditional sense, the U.S. and other space-faring nations have nurtured a vibrant economy for decades. Governments commission construction of satellites and hire companies to launch them. The “new space” companies, which aren't so new anymore, build satellites and rockets to their liking, and governments can choose to become customers or not. There are bustling markets for a host of products and services, including communications bandwidth through orbit; weather forecasting data; banking and mapping software and apps derived from the timing and navigation signals of GPS and similar constellations; and images from privately owned imaging constellations. All this government spending and private-sector revenue added up to \$360 billion globally in 2018, according to Bryce Space and Technology, a Virginia-based analysis and engineering firm.

To give you a gauge, that's about half of the annual U.S. defense budget. That's a lot of money, but there's room for growth, and the meaning of the term “space economy” needs to expand to match. For a small band of entrepreneurs, the term now refers to a whole set of aspirations ranging from the bold to the fantastic. Bold would be making a product in space and returning it to Earth in high enough volume that revenues from sales exceed the sizable costs of getting materials to space, making a product and delivering it to customers on Earth. Our cover story takes a deep look at one promising possibility, a fiber optic product that can't be made in high quality on Earth due to gravity but whose zero-gravity version should outperform conventional fibers.

On the fantastic front is the idea of gathering natural resources in space and making products out of them for customers away from Earth. The best of those who are working toward such fantastic goals are careful not to overstate matters. The sizable technical challenges ahead need to be embraced and conquered. As Justin Kugler of the Silicon Valley company Made In Space puts it: The space economy will “eventually include building satellites and vehicles in space that never touch the ground, but we're a ways yet from that!”

The route to the fantastic must run through the bold.

All this brings to mind another term: space exploration. Without a doubt, there's still plenty of exploration to be done by humans and by robotic probes in space, but humanity seems to be pushing to make the transition from pure exploration (call it the Lewis and Clark phase) to exploration plus economy building. ★



▲ This machine dubbed the “Refabricator” on the International Space Station prints plastic parts and recycles old parts into new ones. NASA and manufacturer Tethers Unlimited of Washington say reusing waste could cut costs of future space missions. NASA



*Ben Iannotta*

Ben Iannotta, editor-in-chief, [beni@aiaa.org](mailto:beni@aiaa.org)

# Cosmic mystery

**Q:** I am leftover from the beginning of time. Without me and my spots, galaxies could not have formed. I'm everywhere in the cosmos, but not uniformly. My wavelengths were small, but you sense them as stretched. A spacecraft was launched decades ago to take my temperature and look for my spots. What am I, and how did this spacecraft find me?

---

Draft a response of no more than 250 words and email it by midnight Jan. 12 to [aeropuzzler@aiaa.org](mailto:aeropuzzler@aiaa.org) for a chance to have it published in the February issue.

## FROM THE DECEMBER ISSUE

### FLIGHT-TEST FEED-

**BACK:** We asked you what devices had been removed from a prototype jet that led the test pilot to say the aircraft was difficult to control in certain configurations and wanted to stall sooner than it should. He assessed "a Cooper-Harper of 7 to 8" at times.

**WINNER:** The engineer was referring to wing vortex generators. These devices on the upper surface of a wing are used to control flow separation along the aft portion of the wing. If they are removed, the flow will separate at a lower angle of attack, and the plane would stall sooner. It would be desirable to not have vortex generators because they produce drag.

David G. Hull  
AIAA associate fellow and member emeritus  
Austin, Texas  
[dghull@mail.utexas.edu](mailto:dghull@mail.utexas.edu)



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

# AIAA CONGRESSIONAL VISITS DAY

WEDNESDAY, 18 MARCH 2020

## Advocate for Aerospace on Capitol Hill

Every year, AIAA members—engineers, scientists, researchers, students, educators, and technology executives—travel to Washington, DC, for a day of advocacy and awareness with national decision makers. Spend a day meeting with new and established congressional members and their staff.

Your participation, enthusiasm, and passion remind our lawmakers that aerospace is a key component of an economically strong and secure nation. If you are interested in the future of your profession, the advancement of technology, the furthering of scientific research, and the strengthening of our nation's security, this event is for you!

*Travel subsidies are available*

“ Participating in CVD was like getting a bird's-eye view of a grand and magnificent national aerospace project. I knew that my contribution might be small, but being a voice of the aerospace community filled my heart with immense pride and humility at the same time. ”

**RUCHIR GOSWAMI**

PhD Candidate  
Iowa State University

REGISTER NOW

[aiaa.org/CVD2020](http://aiaa.org/CVD2020)

**AIAA**  
SHAPING THE FUTURE OF AEROSPACE

# Work with Us to Raise the Profile of the Aerospace Community

**A**s Chair of the AIAA Public Policy Committee (PPC), I'm excited to highlight our policy-related successes from this past year and also take the opportunity to make members aware of how you can participate in AIAA's public policy activities.

Last February, at the beginning of the 116th Congress, AIAA sponsored an educational briefing covering the importance of government investment in aerospace and its potential to affect the industry and the nation's economy. The "Aerospace 101" session was attended by roughly 90 House and Senate staffers. Then in March, we held the 21st annual Congressional Visits Day (CVD) program. It was our largest and most successful CVD to date with approximately 175 members, representing 36 states and 37 sections, attending and visiting about 275 offices on Capitol Hill. More impressive was that over 60 percent of the participants were students.

The objective of our CVD program is to increase awareness of the long-term importance of science, engineering, and aerospace technology to the nation through face-to-face meetings with members of Congress, congressional staff, key administration officials, and other decision makers. I believe that objective was especially met in 2019 given the positive legislative developments that transpired from our advocacy efforts and strong relationships. The first of those developments was the passage of the Hidden Figures Congressional Gold Medal Act, which appropriately recognizes the notable women who contributed to NASA's success during the Space Race and highlights their broader impact on society. AIAA endorsed the legislation from the outset and leveraged the membership to call on lawmakers to support it. The second development was the overwhelming interest in our congressional activities leading up to the International Astronautical Congress (IAC 2019). Over the course of the summer, the Institute hosted three different issue briefings and two receptions designed to generate interest in the IAC and support for the nation's space programs. The third development was the introduction of the NASA Authorization Act of 2019—a key issue covered during CVD. The bill provides policy direction for NASA and its various programs and missions. During the drafting of this important legislation, congressional committees sought inputs from AIAA, and the PPC was able to provide feedback on behalf of the Institute. These activities demonstrate how AIAA is viewed as a valuable resource to lawmakers in the development of aerospace policy.

Related to the NASA authorization bill, AIAA held its initial policy breakfast in late November and it was a rousing success. More than 50 aerospace community members attended the off-the-record event and learned more about the legislation from a

panel of senior Senate staffers. The new initiative is designed to connect our members and nonmembers with government stakeholders and other thought leaders. The breakfast series also provides a great opportunity for participants to network with key representatives across government, industry, and academia. Our second event will cover another issue of relevance and will take place later this winter.

I am very proud of the PPC's work this past year, but I would be remiss if I didn't stress the importance of the broader membership's involvement in our policy-related activities to achieve our goals. There are three primary avenues for AIAA members to contribute: key issue suggestions, policy papers, and CVD.

Each year, the PPC establishes key issues that become the focal points of the Institute's engagement with congressional decision makers, the administration, and state and local officials. The key issues provide the supporting pillars of the CVD program, drive panel sessions at our annual forums, underpin our state-level advocacy efforts, and form the basis of smaller focused events and activities. These issues are intended to raise the profile of the broad aerospace community and generally align with one of our current policy pillars: R&D and Innovation, Funding Stability and Competitiveness, and Workforce Development and Enhancement. The PPC collects key issue input year-round. Consider submitting key issue suggestions through the AIAA website or your local section.

The second way for members to contribute is by authoring or contributing to a policy paper. AIAA policy papers are prepared to convey educational and informational material and may express opinions of and recommendations for action by the government to address issues of interest or concern to our members. They are a mechanism by which AIAA members contribute to crafting or influencing government solutions to problems. There are four types of policy papers: Information Papers, Opinion Papers, Institute Position Papers, and White Papers.

Lastly, members can contribute by attending the aforementioned CVD program. This year's event will be held on 18 March. Registration is currently open and I encourage you to sign up. There is no fee to attend, and headquarters is offering limited subsidies to help defray the cost of travel expenses. Members and AIAA sections are also encouraged to promote our key issues by visiting their members of Congress during district work periods, which offers a better chance of meeting the lawmaker face-to-face.

In closing, the PPC welcomes all member involvement in AIAA's public policy activities, and we need member engagement to continue to grow our impact. For more information on these activities and how you as a member can contribute, please visit the **Advocacy** section of the AIAA website: [aiaa.org/advocacy](http://aiaa.org/advocacy). ★

**Tim Dominick**, AIAA Public Policy Chair

Sen. Jerry Moran questions NASA Administrator Jim Bridenstine at a budget review hearing.

NASA

# Q & A

## Budget maker



More online  
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[aiaa.org](http://aiaa.org)

U.S. Sen. Jerry Moran grew up two hours from Wichita, Kansas, the self-styled “Air Capital of the World” and home of manufacturing giants Textron and Spirit AeroSystems. As a Senate appropriator, he is now one of the legislators who decide how to spend U.S. taxpayer dollars on aerospace, including those that go to the FAA and also, via the subcommittee he leads, to NASA and NOAA. With power comes hard decisions, including whether Congress should fund NASA’s Artemis lunar landing program and require an overhaul of the FAA aircraft certification process after the Boeing 737 MAX crashes. I discussed these priorities and more with Moran by phone from his office in Washington, D.C.

— Cat Hofacker

### JERRY MORAN

**POSITIONS:** Since 2018, chair of the Commerce, Justice, Science and Related Agencies subcommittee of Senate Appropriations that drafts funding legislation for NASA and NOAA; co-chair of the Senate Aerospace Caucus since 2014; U.S. senator from Kansas since 2011; member of U.S. House from Kansas, 1997-2011; Kansas state senator 1989-1996.

**NOTABLE:** Introduced the Aviation Funding Stability Act that would fund FAA programs in the event of a government shutdown; co-sponsored with Sen. Mark Warner, D-Va., the Aeronautics Innovation Act, which would increase NASA aeronautics funding over the next five years and establish research initiatives including additional X-planes.

**AGE:** 65

**RESIDENCE:** Manhattan, Kansas

**EDUCATION:** Bachelor of Science in economics and a law degree, both from the University of Kansas

**FAVORITE QUOTE:** The Kansas state motto, “Ad Astra per Aspera,” which translates to “to the stars through difficulties.”

## IN HIS WORDS

### Balancing (and passing) budgets

A continuing resolution is damaging to everybody, all the federal agencies and investments that are made. A continuing resolution whereby Congress cannot get its act together to reach a conclusion about next year's funding is especially damaging to science, to exploration of space, to things that are long-term projects. So one of the things that is always important in the appropriations process is there has to be give and take between various members of our committee, members of the United States Senate, the House and the White House. There has to be working together to get a result because in the absence of a result, we fall back to either a government shutdown or we fall back to a continuing resolution that freezes spending from one year to the next. The people who are on the Appropriations Committee are generally very interested in cooperation, looking for an end result — not just a statement. We've tried to put ourselves in positions that are advantageous to working with others in the Senate, in the Congress, to reach a result.

### 2024: "A great goal for this country"

My experience is with the Apollo Program and what it meant to me at a much younger age than today: a fascination not just with space, but with science. I've seen time and time again with people who were young and are now involved in science or space or aeronautics. The lunar landing had a consequence on their lives; it captured their attention. That is part of the reason that I'm interested in space exploration, accelerating the date for a lunar landing. At a time in which our country is so divided, it's hard to find consensus on things; we have tremendous challenges with other countries in the world in regard to technology and our national security. A lunar landing in this time frame would help bring the country together. It would advance science for our national security purposes and demonstrate to the world that, again, the United States is a leader in space exploration. I would never attribute motives to others, but this is something that I hope does not become partisan. It's not about the fact that the president, the vice president are promoting it. This is either a good idea or not. And while I applaud the administration for championing an early arrival on the moon, I wouldn't want anybody to take away from that that this is a political statement. Certainly not a political statement by me; don't think it's necessarily a political statement by the administration. It's trying to urge us to go places that we need to go, and we need to get there sooner because we have such competition and the challenges are so great. So part of it is science and moving forward in the world of technology, and part of it to me is an opportunity to bring the country together.

### Wanted: cost estimate for Artemis lunar program

I've encouraged the administration, I've asked NASA Administrator Bridenstine, I've asked the Office of Management and Budget, have visited with others at the White House, saying, "We need to see those numbers." I wish we had a five-year plan now; I think it would be valuable to us as appropriators. I'm not interested in investing in something that I don't have a sense for what the next amount of money, what the next investment requirement is. I wish we had something that we don't have, which is numbers today. As we negotiate with the House over this issue, it's fair to all of us —

"So part of [Artemis is about] science and moving forward in the world of technology, and part of it to me is an opportunity to bring the country together."

Republicans, Democrats, House and Senate — to have an idea of what the administration's cost estimates are for Artemis. There's a lot of uncertainty. I mean, there's a reason that they're hard to come by, but it would be useful to have, both as a practical matter of how we look at what's next, but also just provide some certainty to someone like me that's a supporter of Artemis to know what it is that's expected in the future. I am continuing to encourage those numbers to be made available as quickly as possible, and it is a matter of educating not just myself, but all of my colleagues and then analyze those numbers and see if they make sense.

### Standing by Artemis

I would not withdraw my support for the concept of a lunar landing [should the estimated cost be higher than hoped]. The question is at what time frame does that lunar landing occur? If we aren't allocated sufficient resources within our appropriations subcommittee, or if the costs are significantly more than what was expected or what's been talked about, then that creates a problem with the time frame in which that landing could occur. Every appropriations process involves establishing priorities. I think it's important for me and my colleagues to hear from a wide array of those involved in space, in aeronautics, in STEM education. There's a significant number of components, of money, that is spent within the NASA budget. The Senate Appropriations Committee knows it's a priority to have funding for STEM education, for example, or aeronautics. Those are components that we don't want to walk away from, and we will have to work hard to find the right balance. That will take information, testimony, hearings from Administrator Bridenstine, but also from others outside NASA and within NASA.

### Partnering with industry

So many of the things that the private sector will learn and accomplish in aeronautics are things that translate well into NASA. The transfer of information, the understanding of the science involved is valuable to both the public and private sector. We know that we can do more,



we can better protect taxpayer dollars and we could advance science and technology in the United States by that public-private partnership. This is a concept that makes sense today, particularly as the expense of aspects of aeronautics just continue to increase. We face a world in which other countries are much more robust in their support for science and technology, and we do so at a risk to our innovation economy, and we do so at a risk to our national security.

### Hypersonics

Our global competitors are advancing rapidly in their development of these technologies. It is important not only for the speed, but for the application of what we learned in the process of getting that speed, what that means elsewhere to development of innovative ideas and modes of transportation in this country. My impression is that we face significant challenges in the amount of resources that China and others are putting into this arena, and it is important for us, as best we can, to keep up. We also have a robust private sector that is advantageous, so you cannot compare one country to another because our private sector is fully engaged, and together we can accomplish these things. But we are challenged to stay at the forefront, due to the resources that other countries are putting into their programs.

### 737 MAX fallout

I think it's premature for me to reach a conclusion of what went wrong. I'm still looking for more answers. I recognize that the ODA [Organization Designation Authorization] process is critical to the industry

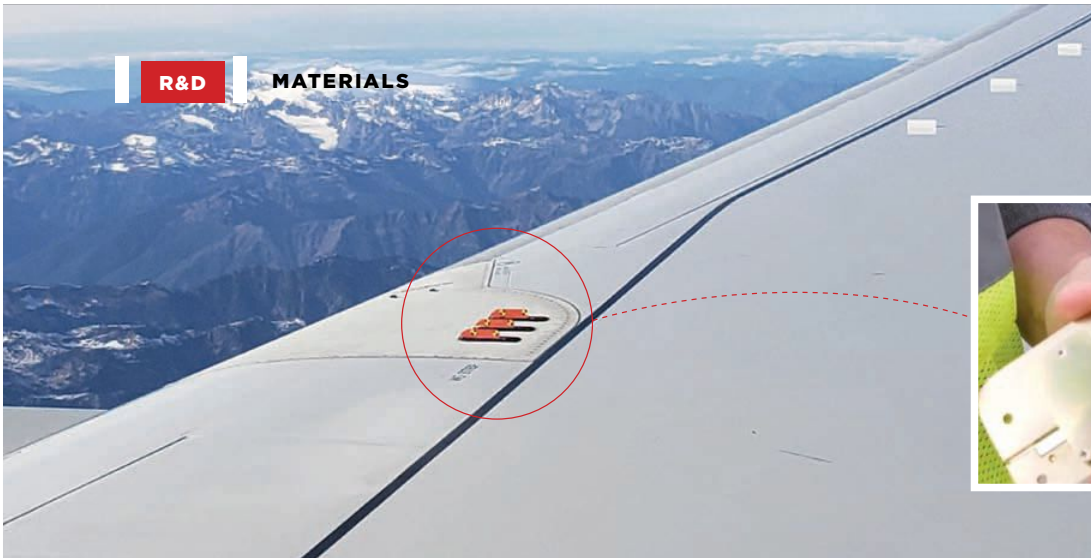
remaining competitive. It is a question of how do we move forward rapidly but never jeopardizing safety. I'm anxious for this MAX issue to be resolved, for us to know what all of the experts have concluded so that we can find that correct balance in safety and advancing technology. Depending upon what the result of this investigation shows, the private sector has a role to play. The private sector has a lot of stake. In determining what role the FAA and the private sector play, I think it takes both of them: strong oversight but a continued presence by the private sector in the process.

### The return of the MAX

When it's certified, its safety has improved, I don't think I have any qualms about flying in a 737 MAX. My expectation is that the traveling public, the consumer, will be generally satisfied once the FAA and other international regulators reach the conclusion that the fix, whatever that is, has occurred and the problem has been solved. There is still a significant amount of credibility from consumers in that regulatory process. All eyes are on the FAA. If there was disagreement between regulators, the FAA and others internationally, I don't think that solves the problem, the consumer issue, the sense of security and safety. There can't be a debate. This issue has to be resolved in a way in which there is no longer debate about "Has it been fixed correctly? Is the plane now safe?" ★

The first of four RS-25 engines is mounted on the core stage of a NASA Space Launch System rocket at the Michoud Assembly Facility in Louisiana. NASA is developing SLS with industry partners Boeing and Aerojet Rocketdyne to power the first Artemis mission to the moon.

NASA



# Testing vortex generators that get out of the way

BY CHRISTINE FISHER | christine@cfisherwrites.com

**V**ortex generators, or VGs, the tabs often fixed to the leading edge of aircraft wings, play a critical role during takeoff and landing, improving control and reducing stall speeds. But at cruise, they do little more than add drag.

NASA's Glenn Research Center in Ohio and Boeing may have a solution: VGs that lie flat during cruise and stand vertically for takeoff and landing. The key is a unique SMA, short for shape memory alloy, developed at Glenn that doubles as a sensor and an actuator.

Typically, SMAs change shape when heated. This SMA, a blend of nickel, titanium, hafnium and zirconium, does the exact opposite; it changes shape when cooled. The SMA is formed into a rod about .25 centimeter in diameter, and placed along the base of the VG, where it acts like a hinge.

As an aircraft climbs toward its cruising altitude, the air temperature drops and the SMA twists, causing the VG to rotate and lie flush with the wing. As the aircraft descends, the air temperature increases. That causes the SMA to twist back, and the VG rotates to its vertical position.

In November, NASA and Boeing conducted the first flight tests of what they're calling Shape Memory Alloy Reconfigurable Technology Vortex Generators, or Smart VGs. They swapped three standard VGs on a wing of Boeing's 777-200 ecoDemonstrator aircraft with Smart VGs.

By the time the ecoDemonstrator reached cruise at about 40,000 feet, the atmospheric temperature had cooled enough, between minus 20 degrees Celsius and minus 60, to activate the SMA, which

caused the Smart VGs to lie flat on the wing. As the ecoDemonstrator descended into warmer temperatures, above 0 degrees Celsius and around 15,000 feet, the SMART VGs began to deploy and stand back up.

"There's no application of heat, there's no batteries, there's no power supply to the vortex generators," says Othmane Benafan, Glenn's lead engineer on the project. "The environment is doing the trick, and it's doing it by cooling them."

The Smart VGs could reduce drag on commercial aircraft by 0.2 to 0.5 percent, Boeing and NASA predict. "Over years, over the fleet, that translates to a huge number," says Benafan.

If the Smart VGs were used on 100 Boeing 777s, over the course of a year, they could save 3 million gallons (11.4 million liters) of fuel, the equivalent of removing 3,800 cars from the road for one year, Boeing estimates.

"We're preparing this technology so it could potentially be used for new airplanes and it could be retrofitable for older airplanes," says E. Tad Calkins, a Boeing associate technical fellow.

For now, this is purely a research effort. Boeing will use data from the ecoDemonstrator test flights, which wrapped up in late December, to chronicle how the Smart VGs react to different flight conditions and determine if they meet design requirements. Boeing says it is still too difficult to predict when these might arrive on any of its aircraft.

"These do show promise, so I think NASA and Boeing would be optimistic that perhaps one day they will find their way onto an airplane," says Boeing spokesman Paul McElroy. ★

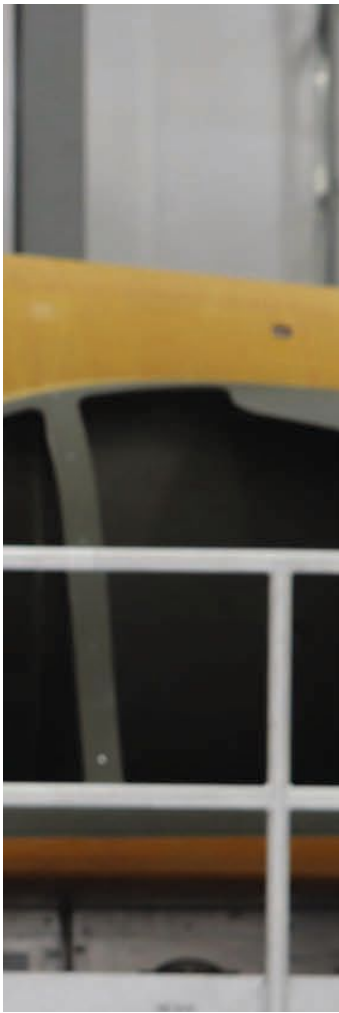
▲ **Three Smart Vortex Generators** deployed on the wing of NASA's ecoDemonstrator. A rod made of shape memory alloy on the bottom of a vortex generator (inset) acts as a hinge when cooled, forcing the Smart VG to lie flat at cruise. Boeing



# Astronaut Kavandi's new mission

**Janet Kavandi arrived at the Space Systems headquarters of Sierra Nevada Corp. in September to lead its space work as senior vice president of programs. Space Systems is in the midst of an ambitious growth plan as it prepares to launch cargo to the International Space Station and is vying for roles in human spaceflight, including NASA's proposed Artemis lunar missions. In an interview at the unit's headquarters in Colorado, **Amanda Miller** asked Kavandi about these initiatives, how she became an astronaut and about milestones for women in aerospace.**

BY AMANDA MILLER | [agmiller@outlook.com](mailto:agmiller@outlook.com)



▲ **Janet Kavandi,** in front of the primary structure for Sierra Nevada Corp.'s first Dream Chaser cargo vehicle in October. Sierra Nevada Corp.

**W**hen they went searching for a new linchpin of their company's Space Systems business area, Eren Ozmen and her husband Fatih chose Janet Kavandi, a three-time space shuttle astronaut and one of the foremost U.S. spaceflight safety experts.

Kavandi's flying days are over, but here at Sierra Nevada Corp.'s Space Systems headquarters in Louisville, Colorado, she tells me, "I'm here because I still think about flying in space." She says she's determined "to enable humanity to do more things in the exploration of space."

As senior vice president for programs, Kavandi reports to Fatih Ozmen, the acting executive vice president of Space Systems. Kavandi's passion for spaceflight and arrival in Louisville are perhaps most notable for this reason: SNC is on a tight deadline of less than two years to launch Dream Chaser, a cargo craft that looks like a mini-version of the shuttle orbiters that Kavandi flew aboard and which lands on a runway like the shuttle orbiters. Her mission, in part, will be to fulfill a NASA contract to resupply the International Space Station six times with one or perhaps both of the Dream Chaser vehicles NASA is helping to fund. She oversees SNC's spacecraft and space technology manufacturing programs, including the descent brake landing mechanism for the Mars 2020 rover scheduled for launch in July. The rover project and other efforts have swelled the Space Systems business area to facilities in five states.

### Next line of business

Kavandi speaks with the thoughtful demeanor that one would expect of an astronaut with a doctorate in analytical chemistry, whose dissertation discussed pressure-indicating paints for wind tunnel tests and who operated the robotics to put together parts of the International Space Station.

She was cautious during our discussion, one of her first in-depth interviews since arriving in September from NASA's Glenn Research Center in Ohio, where she was director for three years. U.S. law forbids her for a year after leaving federal employment from saying anything to influence NASA. "I'm basically just trying to educate myself on the company as quickly as I can — learning the business, learning the objectives of what the owners want for their business," Kavandi says, referring to the Ozmens, naturalized U.S. citizens from Turkey.

Several months ago SNC began assembling the first of its Dream Chaser orbital spacecraft that will fly to the ISS autonomously and glide back for a runway landing at Kennedy Space Center's Launch

and Landing Facility in Florida. That's the same shuttle landing facility where Kavandi landed three times.

"I always admired this design and think that is something I'd really like to be a part of — to see that launch and land successfully. Part of the first year will be dedicated toward making that happen," Kavandi says. Dream Chaser is "a good candidate to get us into space reliably and not from the government — the government will contract it; they won't own it. I just think it's a very elegant solution to getting back and forth from space. And I think it could be a safer option of transporting cargo and potentially humans."

NASA rejected the crewed Dream Chaser design for the Commercial Crew program in 2014 in favor of the SpaceX Crew Dragon and the Boeing CST-100 Starliner. Neither of those craft have yet carried a crew. Meanwhile, SNC hasn't given up the dream of someday doing so with Dream Chaser.

Safety of the crew would, of course, be paramount for NASA, and this is an area where Kavandi has personal experience. "Should we ever have a contract to provide a crewed option, then, of course, that would be foremost in my mind, since that was my history," Kavandi says.

When the orbiter Columbia disintegrated over Texas in 2003 on its way back to Florida, Kavandi was the lead casualty assistance calls officer in charge of 25 astronauts who notified the families of those who had died in the catastrophe. The "CACOs" helped the families arrange memorial services and manage publicity after the accident.

Even with such risks, Kavandi remains enamored by spaceflight. "I spent a lot of time in the government [on spaceflight], and in the time that I have left in my useful life as a working citizen, I would like to contribute on the outside in that same way."

She thinks the Artemis astronaut missions to the moon, proposed by NASA, will open up new opportunities in the astronaut career field, especially because NASA wants to go in a "sustainable way," rather than collecting samples and then abandoning human exploration for another 50 years. The undertaking would be complex, but Kavandi states the goal simply: "Figure out how to survive," she says. "It would be to go and learn how to live on another planetary surface that has a very dusty environment. It's got no atmosphere. It's got intense radiation from the sun. You have to learn how to make your own water, grow your own food in some sort of shelter, use the — ISRU, they call it — in-situ resource utilization on the surface of the moon, maybe find the water that's in ice form at the poles and use that to make oxygen or melt it for consumable water."

All that will require trustworthy equipment, the



## SNC HISTORY

Sierra Nevada Corp. set up the headquarters of its Space Systems business area in Louisville, Colorado, near the aerospace hub of Boulder, after acquiring two small space companies in 2008, one of which, SpaceDev, already had a facility there. The SpaceDev acquisition “added tremendous space heritage with products that had flown on more than 300 spacecraft over 20 years,” according to SNC’s company timeline. SNC’s owners Eren and Fatih Ozmen are married Turkish immigrants who bought the company in 1994, then just a small defense firm in Nevada. They’ve since acquired 14 more companies in the aviation, space and technology sectors, not counting those companies’ subsidiaries.

long-term target being not the moon but a red speck in the sky visible from the lunar surface. “The trick will be: OK, so these things broke. We’ll bring them back, we’ll redesign them, we’ll put them back on the surface. When they don’t break anymore, then we’re ready to push things to Mars.”

The red planet brings out the futurist in Kavandi: “If we want to ensure the survivability of the species in the long run, in case there is this comet or meteorite or something out there that we can’t avoid, and it smacks us like what happened to the dinosaurs — most of life was extinguished on the planet — so if we want to make sure that the human species might survive something like that, we could be on two planets, then we have a better chance that way. But it won’t be fast, and it won’t be in 10 years. It would be in a long period of time that we hopefully colonize, to a small extent, Mars.”

But first, the Ozmens want a role in Artemis. Space Systems has delivered a mockup to NASA of

its design for a habitat module that could one day expand the moon-orbiting Gateway where astronauts would stay before venturing to the lunar surface. In November, NASA announced that SNC is also one of the companies that will get to bid on Commercial Lunar Payload Services contracts to robotically deliver cargo to the surface of the moon.

### Leading in the private sector

Kavandi worked at NASA from the time of her selection as an astronaut in 1994 until shortly before moving to Colorado from Ohio, where she was director of Glenn, a center known especially for its space propulsion research and development.

At SNC, part of her oversight role will include the Propulsion and Environmental Systems unit that builds SNC’s Vortex engines for the Dream Chaser spacecraft. SNC also is developing a version of the Vortex engines with the U.S. Air Force as an upper stage for launch vehicles.

After so many years in government, I wondered if she was feeling culture shock by now working for a NASA and Defense Department contractor. “It’s not quite as foreign as I thought it might be because my last role was running a NASA center, which is essentially running a business. You don’t have to make a profit, per se, but you do have to run it as if you were running a business. You can’t have a deficit. You have to manage your people. You have to manage your budget. You have to make good strategic decisions on where you invest and what you want your future to look like.”

### Reaching space

Asked about her determination to become an astronaut, Kavandi conjures a memory. “I attribute it to some time I spent with my father. We lived in the country. We could see the stars at night. We could look up and wonder what it would be like to be in space. And there were satellites going over, and there were the first people flying in space at the time, and I think we talked about what it would be like to be up there and looking back at the Earth and what we might see.”

She knew that NASA — at the time the only option for an American who wanted to go to space — had two kinds of astronauts: military test pilots or scientists with doctorates. “I had to think about it from a Ph.D. scientist or engineer perspective, but not a test pilot, because there were no female test pilots” at the time in the U.S. “So I knew I had to have a Ph.D.” She went and got it from the University of Washington in 1990. She started applying to be a NASA astronaut while she earned her doctorate and was selected in 1994.

Kavandi’s career might have played out differently were it not for a high school teacher. “The



reason I chose chemistry was because of a particular instructor that I had who I just really enjoyed. She was a female, for one thing, and she was very strong-willed and strong-minded, and she was very blunt and very intelligent, and I just really liked her. I wanted to study under her, and so I chose chemistry in part because of her.”

Now that she has been to space, this has affected her view of Earth. As determined as she is to propel humanity into space, “another passion is helping to preserve the natural habitats that we have left on the planet,” she says. She is loving Colorado, and so is the Kavandi family. “My daughter is actually an environmental biologist, and she’s looking to come out here, too, because she sees a lot of potential use for a biologist here with that background. And also my son is already getting a job and moving out this way too.” Her husband, an airline pilot, “can live anywhere,” she adds.

▲ **A mockup of Sierra Nevada Corp.’s design for a human habitat module of the proposed lunar Gateway.**  
Amanda Miller

### Women’s firsts

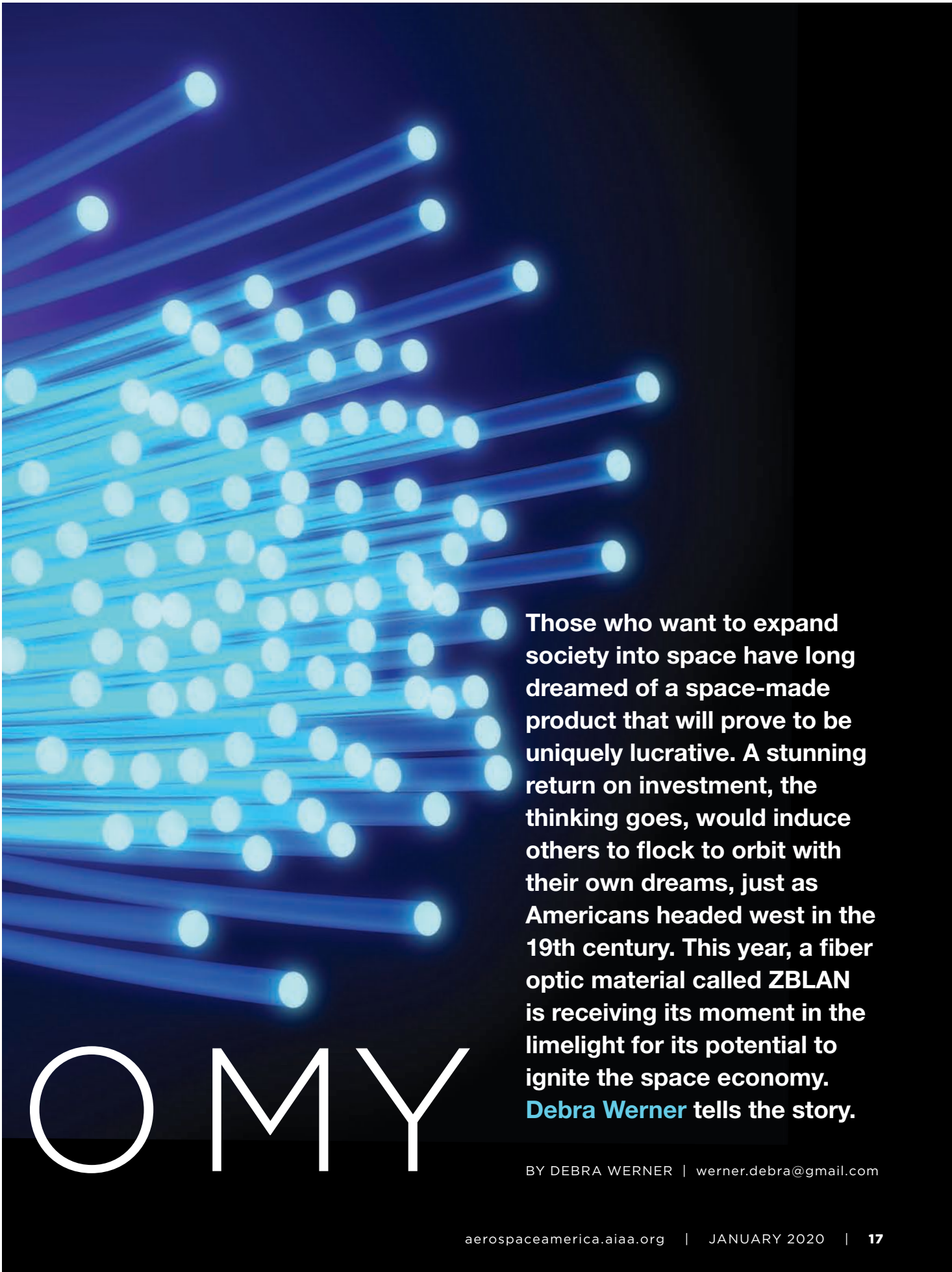
This year NASA conducted humanity’s first two-woman spacewalk, or extravehicular activity. “Eventually,” Kavandi says, such milestones “will not be a big deal. That’s where we have to get to, is a state where it’s not a big deal.” She sees progress. “Like I mentioned, when I was first thinking about being an astronaut, I had to think about it from a Ph.D. scientist or engineer perspective.” There were no women test pilots, “but now there are,” she notes. “When I chaired the Astronaut Selection Board, I selected two female test pilots because they were available, and they were outstanding candidates. And so, whereas before it was not an option, there are so many options now that women have, that we don’t even think about it.”

Women remain pioneers: “People who go into those fields help make it better for the people who follow them.” ★

COVER STORY



***SPARKING THE***  
**SPACE**  
**ECON**



Those who want to expand society into space have long dreamed of a space-made product that will prove to be uniquely lucrative. A stunning return on investment, the thinking goes, would induce others to flock to orbit with their own dreams, just as Americans headed west in the 19th century. This year, a fiber optic material called ZBLAN is receiving its moment in the limelight for its potential to ignite the space economy. **Debra Werner** tells the story.

# OMY

BY DEBRA WERNER | [werner.debra@gmail.com](mailto:werner.debra@gmail.com)

At Made In Space in Silicon Valley, CEO Andrew Rush handed NASA Administrator Jim Bridenstine a palm-sized spool of clear fiber made of ZBLAN, short for zirconium barium lanthanum aluminum sodium fluoride.

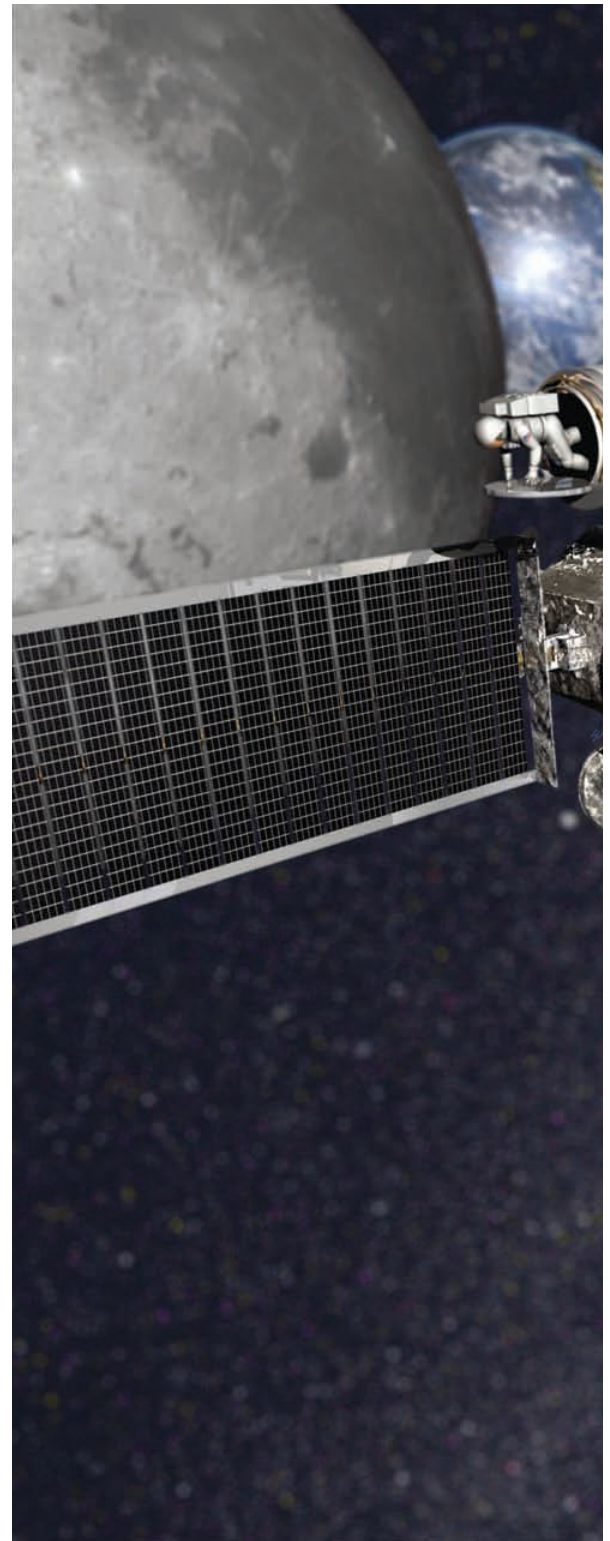
ZBLAN is among a group of glasses discovered by accident in 1974 by French scientists Marcel and Michel Poulain at the University of Rennes. In the years since, manufacturing challenges have relegated ZBLAN to specialty optical applications such as laser-generating mediums and optical fibers for medical endoscopy and scientific spectroscopy.

Enter Made In Space and its two rivals in the ZBLAN field, FOMS, short for Fiber Optics Manufacturing in Space, of San Diego and Physical Optics Corp. of Torrance, California. The three are racing to be first to commercialize ZBLAN fibers by making them in orbit, as each company has so far done only in small batches aboard the International Space Station.

True believers think that space-made ZBLAN fibers could gradually replace silica fibers as the product of choice for modernizing or expanding the millions of kilometers of fiber optic cables back on Earth. This would require mastering production of long fibers in space facilities sized for commercial production.

Such an outcome would mark an unusual twist in the long search for a product that will spark creation of an economy in space. Such visions often center on additive manufacturing or 3D printing. Rockets, space habitats and other equipment could, in theory, be made this way instead of launching them assembled from Earth. Material ranging from human tissue to composites would be laid down a layer at a time with techniques tailored to take advantage of microgravity.

The ZBLAN in Bridenstine's hand last August was not made that way. A machine crafted by Made In Space produced this particular batch on the ground



as a prelude to the firm's campaign to produce fiber aboard the ISS through a process known as pulling. The end of a glass rod is melted, and as it melts, a drop breaks away, pulling behind it a fiber about the width of a human hair that is wound around a spool as it solidifies.

#### **Beating silica**

Fiber optic engineers have long been intrigued by



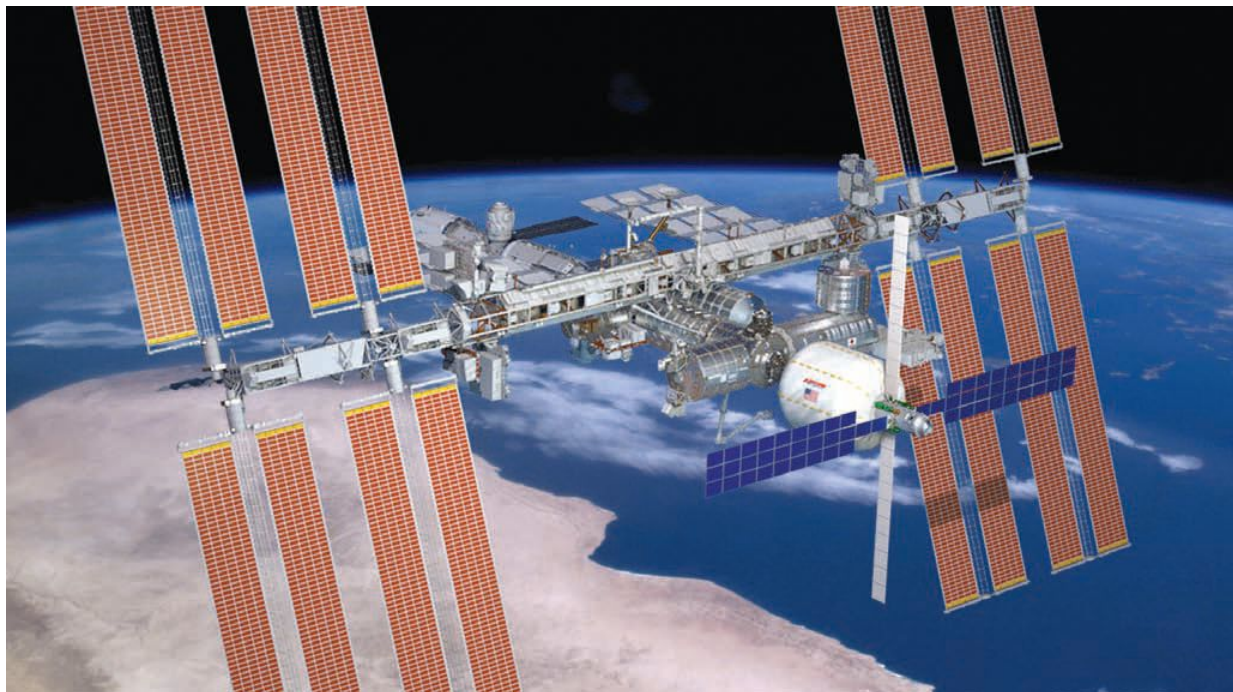
ZBLAN because, in theory, fibers made of the material should be clearer over a wider range of frequencies than today's silica fibers. The improved frequency range comes from the fact ZBLAN incorporates lightweight elements and heavy elements rather than just silica. Being clearer, the laser-encoded bits and bytes of our television programming, web pages and phone calls would travel much farther with less signal loss. Laser

repeaters might only be needed after thousands of kilometers instead of hundreds of kilometers with silica, says Dmitry Starodubov, chief scientist at FOMS.

All told, ZBLAN fiber could transmit signals up to 100 times more efficiently than silica optical fibers, says Michael Roberts, the interim chief scientist for the ISS U.S. National Laboratory, a nonprofit organization formerly known as CASIS,

▲ **Concept image of** Lockheed Martin's refurbished multi-purpose logistics module prototype.

Lockheed Martin



short for the Center for the Advancement of Science in Space. His organization helped the three competitors send their manufacturing equipment to the space station.

Theoretical superiority is one thing. ZBLAN, it turns out, can't be produced in high volumes on Earth, because gravity makes it hard to combine ZBLAN's elements into a uniform material. The heavier elements settle, the lighter elements rise to the top and crystals form as the material solidifies. Humidity also causes defects and crystals that reduce clarity and make the fibers brittle.

So far, none of the competitors have managed to consistently produce long strands of high-quality ZBLAN. "If the companies can produce ZBLAN in space repeatedly, there is a ready and growing market for the higher-quality fibers," says Lynn Harper, integrative studies lead for NASA's Emerging Commercial Space Office. Harper, who is based at NASA's Ames Research Center in Silicon Valley, co-authored a series of NASA studies about promising microgravity research.

The companies plan to achieve the desired consistency by tweaking their machine designs and trying again in an iterative approach. Rush of Made In Space compares the strategy to developing a new version of the iPhone, but with some key distinctions: "We don't have the capital Apple has, our hardware is orbiting Earth and you can only go up there a couple of times a year."

So far, Made In Space has sent a microwave-oven-size ZBLAN device to ISS four times. The company plans to send an upgraded version to the

station this year. Made In Space isn't saying how much ZBLAN it produced in orbit. The company is still trying to prove the on-orbit manufacturing technology works before gradually scaling it up to produce longer ZBLAN fibers. "I would love to have a 1,000-kilometer-class ZBLAN manufacturing plant in orbit in two years, but there's a lot of steps between here and there," says Rush.

Starodubov of FOMS announced at an optical fibers conference in November that the company produced its first strands of high-quality ZBLAN aboard ISS in its suitcase-size machine. Astronauts inside the station installed the machine in the U.S. Destiny Lab by hooking up cables and screwing in bolts. FOMS controlled the equipment remotely from NASA's Marshall Space Flight Center in Alabama. The company says it produced tens of meters of ZBLAN close to the desired uniformity. "If we can make it just a little bit better, the current market price of the specialty fiber would be \$200 per meter or about \$6 million for 30 kilometers or 1 kilogram," Starodubov says. "Then we can grow our orbital manufacturing for years to come."

### Commercial space stations

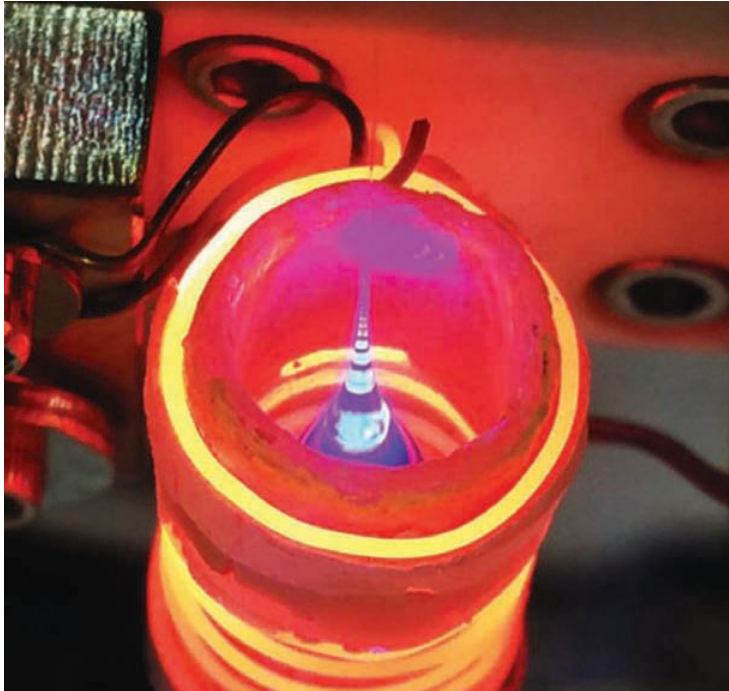
At some point, the ZBLAN pioneers will need an alternative to the space station's diminutive Destiny module, which at 8.4 meters long and 4.2 meters wide is about the volume of a small apartment. Also, it's not clear how long ISS will be available for research. The Trump administration called in 2018 for ending funding for its portion of the station after 2024 but has backed off that stance. Legislation

▲ **Bigelow Aerospace's** B330 (white module) would be a prototype inflatable space habitat to provide laboratory space for private companies in low Earth orbit.

Bigelow Aerospace

▶ **A NASA astronaut** installs the first 3D printer in the Microgravity Science Glovebox on the International Space Station.

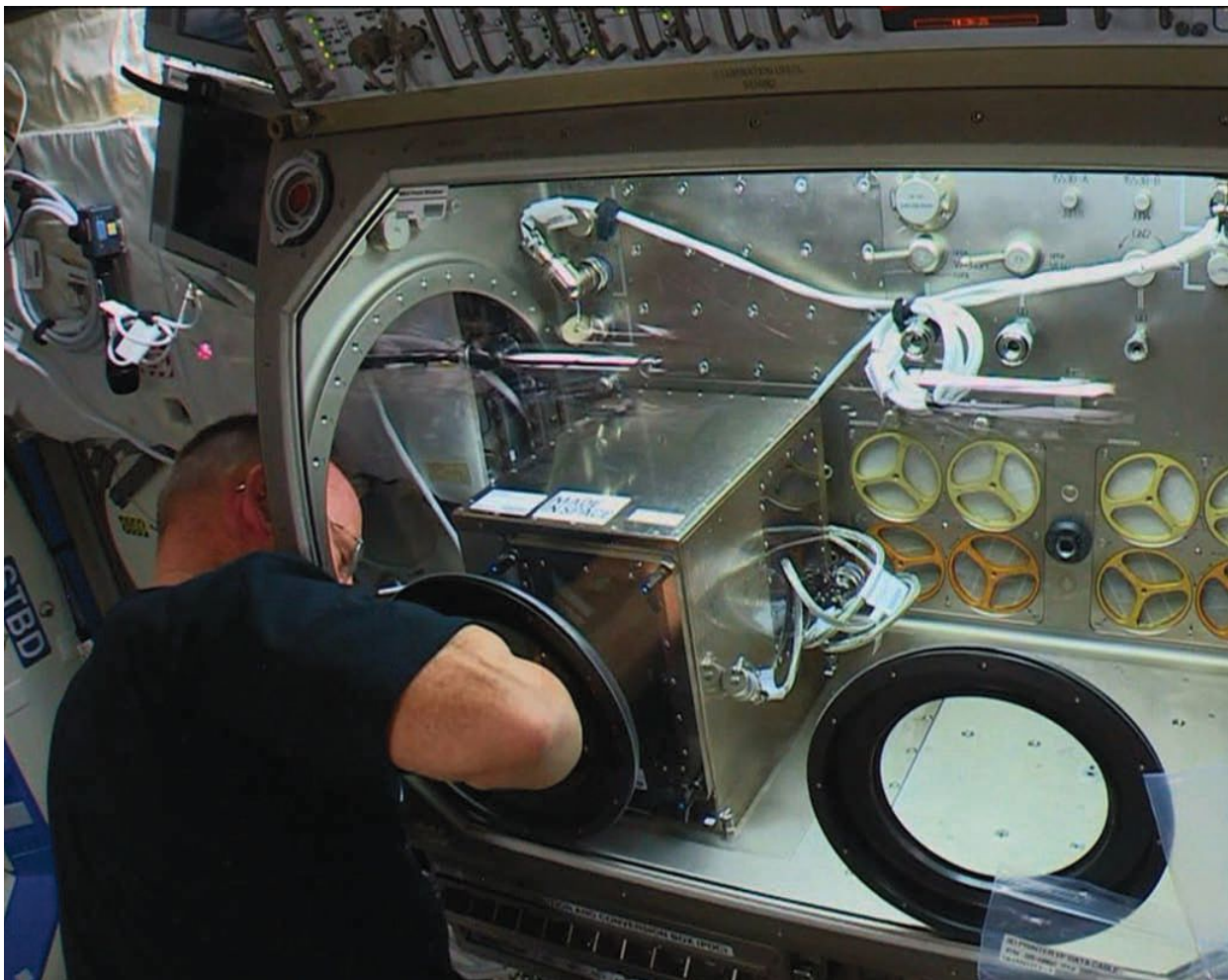
NASA

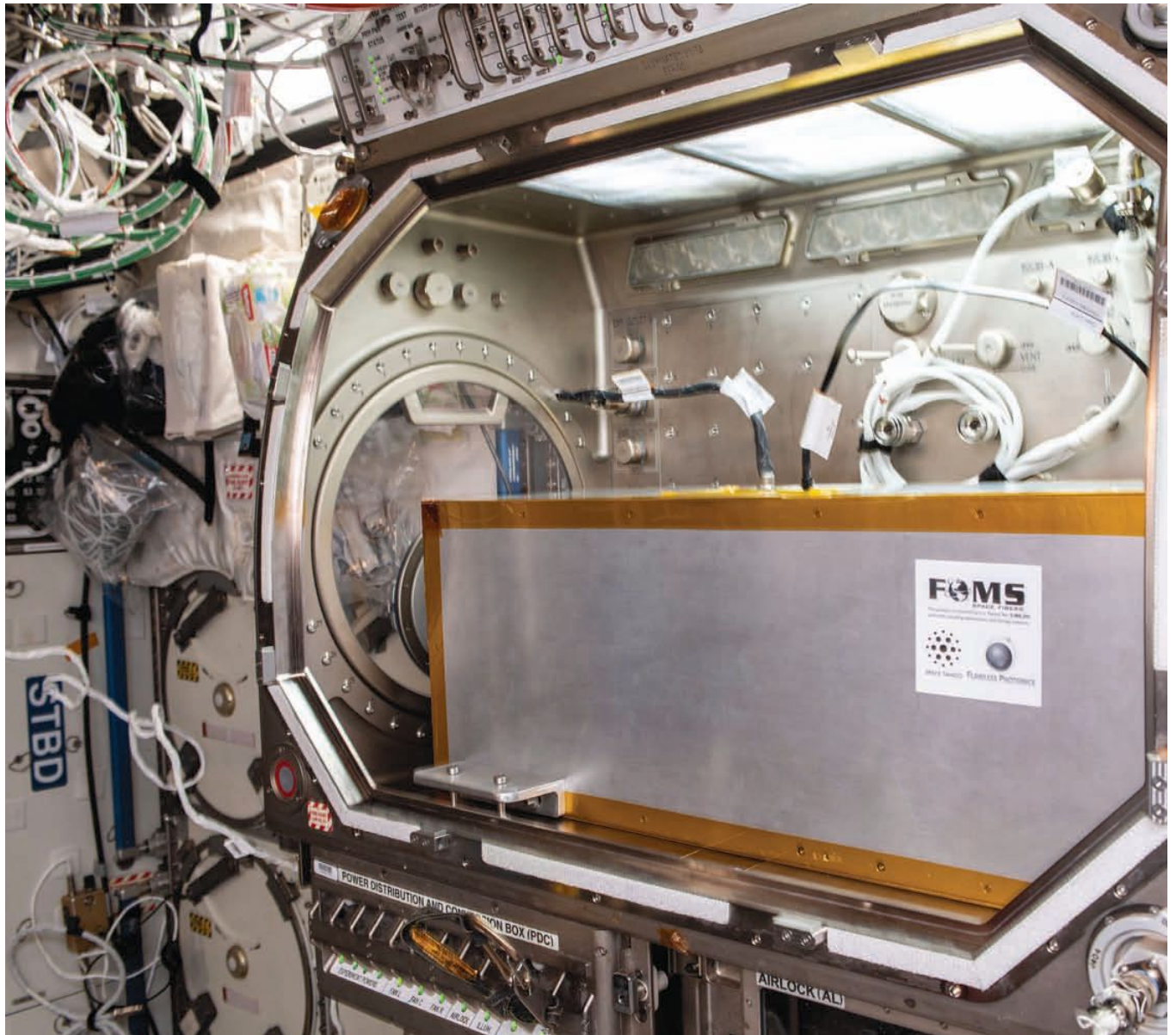


◀ **ZBLAN fiber is “pulled”** — a method of manufacturing — in a ground experiment. The blue light is the illuminated preform cone.  
FOMS

pending in Congress would extend station funding until 2030.

Bridenstine's NASA is trying to lay out a clear path between ISS and commercial space stations through a program called NextSTEP, short for Next Space Technologies for Exploration Partnerships. Among other things, NextSTEP invites companies to match at least 20% of the money they win from NASA to design and develop free-flying commercial space stations and a commercial space station that would be attached to the ISS Harmony module. NASA plans to spend about \$561 million on these programs over the next four years. NASA intends to





“If the companies can produce ZBLAN in space repeatedly, there is a ready and growing market for the higher-quality fibers.”

— **Lynn Harper** of NASA’s Emerging Commercial Space Office

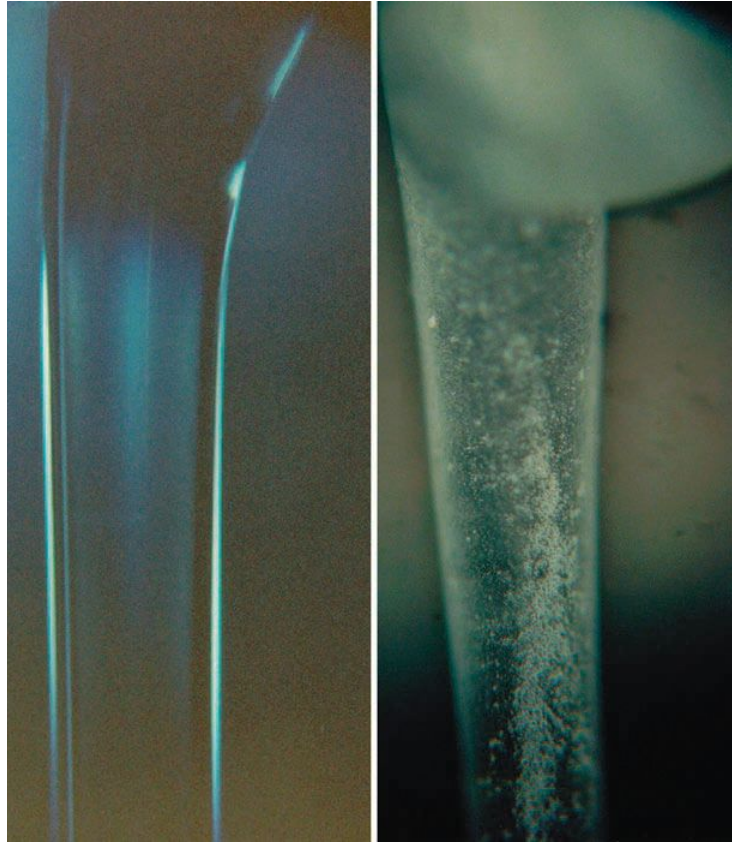
pick one company to link its space station with ISS by 2024. It’s not clear how many companies NASA will select to build the free-flying space stations.

Among the contenders, Bigelow Aerospace in September showed off a prototype station built in part with NextSTEP dollars. The Bigelow B330, named for its 330-cubic-meter volume, would be a larger version of the Bigelow Expandable Activity Module that docked with ISS in 2016 and which astronauts continue to float in and out of. The station’s walls would be made of a proprietary flexible material that expands to shape when pressurized. Bigelow wants to dock the B330 with ISS and later fly it on its own.

Nanoracks of Texas in 2017 signed a NASA NextSTEP contract to study the concept of turning



▲ This FOMS printer produced the company's first strands of ZBLAN aboard the ISS.  
NASA



◀ ZBLAN fibers pulled in Earth's gravity (right) have surface defects that would degrade an optical signal. Smoother fibers on the left came from zero-gravity experiments aboard NASA's KC-135 low-gravity aircraft.  
NASA

a spent upper stage into a space station called the Nanoracks Outpost. The initial NextSTEP contracts are small, but they put companies in the running for follow-on contracts to develop and eventually build commercial space stations geared for different audiences. One space station might be set up for astronauts or tourists while another is optimized for manufacturing equipment to pull ZBLAN fiber or 3D-print satellite antennas. The manufacturing facility in orbit could be crew-tended, meaning equipment would be controlled remotely and people would visit to perform repairs or maintenance.

For any of these space stations to succeed in creating a new orbital infrastructure, the U.S. government must provide significant funding like it did for the U.S. Interstate Highway System in the 1950s and '60s, says Adrian Mangiuca, commerce director at Nanoracks. "A bunch of transcontinental truckers didn't get together and say, 'Let's self-fund the American highway system because we want to get fruit from California to New York in three days,'" says Mangiuca. Instead, the U.S. government paid for the infrastructure. Creating an infrastructure in space will be similar, but this time Nanoracks and others will own the infrastructure in exchange for helping to fund and extend it. The U.S. government and industry will have to work together, through

what Mangiuca calls "a whole-of-nation" approach to creating a low Earth orbit economy.

### Vying with additive manufacturing

As hopeful as ZBLAN's fans are, they like to emphasize that building a space economy does not rest entirely on any single product. "When you remove gravity from the equation, you unlock a different universe of physics," says Ioana Cozmuta, CEO and co-founder of G-Space, a Silicon Valley startup developing software to quantify gravity's effect on materials. "I compare it to the time when the semiconductor industry was transformed because people recognized the benefit of ultra-low temperatures. It unlocked a new universe of physics."

Companies plan to produce several classes of optical fibers in orbit, and NASA managers remain bullish about the potential for additive manufacturing to act as a springboard for the nascent space economy for one simple reason. They've seen the impact of 3D printing in factories on the ground. "It's one of the most disruptive technologies I've seen in my 30-plus years of aerospace," says John Vickers, NASA principal technologist for advanced materials and manufacturing.

As an example, he notes that Rocket Lab, the Huntington Beach, California, startup, says it can print the combustion chamber, injectors, pumps

**These ceramic parts were**

3D-printed with simulated lunar regolith as part of an experiment led by the European Space Agency into how 3D printing could figure into building a lunar base. Austrian company Lithoz worked with ESA on the project.

ESA



and main propellant valves for one of its Rutherford engines in 24 hours. Vickers estimates that 10 years ago, a Rutherford engine would have taken months or even years to manufacture.

Made In Space sent the first 3D printer to the space station in 2014. The microwave-oven-size printer churns out spare parts and tools for astronauts. Made In Space also makes money operating a second printer on ISS, the Additive Manufacturing Facility. NASA and other customers pay Made In Space to print objects in the latest microwave-size machine.

Beyond spare parts and tools, NASA sees additive manufacturing as a path to constructing space telescopes and communications antennas too large to fit in rocket fairings.

Archinaut One is a good example. Made In Space is preparing to launch the refrigerator-size satellite in 2022 with an on-board 3D printer and robotic arm. Once in low Earth orbit, Archinaut One will attempt to additively manufacture a solar array stretching 20 meters from tip to tip and plug the array into a Northrop Grumman instrument. Northrop Grumman and Made In Space won't elaborate on the job of the Northrop Grumman instrument except to say it will be tested in space for the first time.

In-space manufacturing and assembly means you can design satellites for their intended role in orbit rather than building them specifically to “fold up origami-style inside a launch fairing and survive intense forces and vibrations,” says Justin Kugler, Made In Space vice president for advanced programs and concepts.

In addition to creating structures in orbit, NASA expects future planetary habitats to be additively manufactured. To demonstrate the potential, NASA awarded \$701,000 last May to two teams that relied on additively constructed shelters out of materials like the soil and rocks found on the moon and Mars. It was the second round of the 3D-Printed Habitat Challenge, where competitors robotically built one-third-scale semi-permanent shelters.

Additive manufacturing technology is progressing so quickly, it should have its own Moore's Law, Vickers says. A few years ago, 3D printers were known for manufacturing small plastic parts. Those early printers have given way to larger machines employing new techniques for printing metals and composites.

Whether the catalyst turns out to be additive manufacturing or ZBLAN, or a mix of both, true believers are sure the space economy is coming. Rush of Made In Space predicts it will “blossom from a factory to an industrial park to cities in space.” ★



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# ACHIEVING AUTONOMY



Following in the tire tracks of autonomous cars, the development of self-flying aircraft continues. As similar as the challenges are in some regards, **Adam Hadhazy** discovered that aircraft engineers must largely forge their own solutions.

BY ADAM HADHAZY | adamhadhazy@gmail.com



**B**ack during World War I, starting up a fighter plane with hand-propping meant someone pushing downward as hard as he could on the propeller and jumping back in fear for his life. Today, a pilot starts an F-35 by simply pushing buttons. The first pilots had to navigate through sight alone, relying on the positions of celestial objects to maintain a heading. Nowadays, GPS-connected navigation systems automatically guide a plane from here to there.

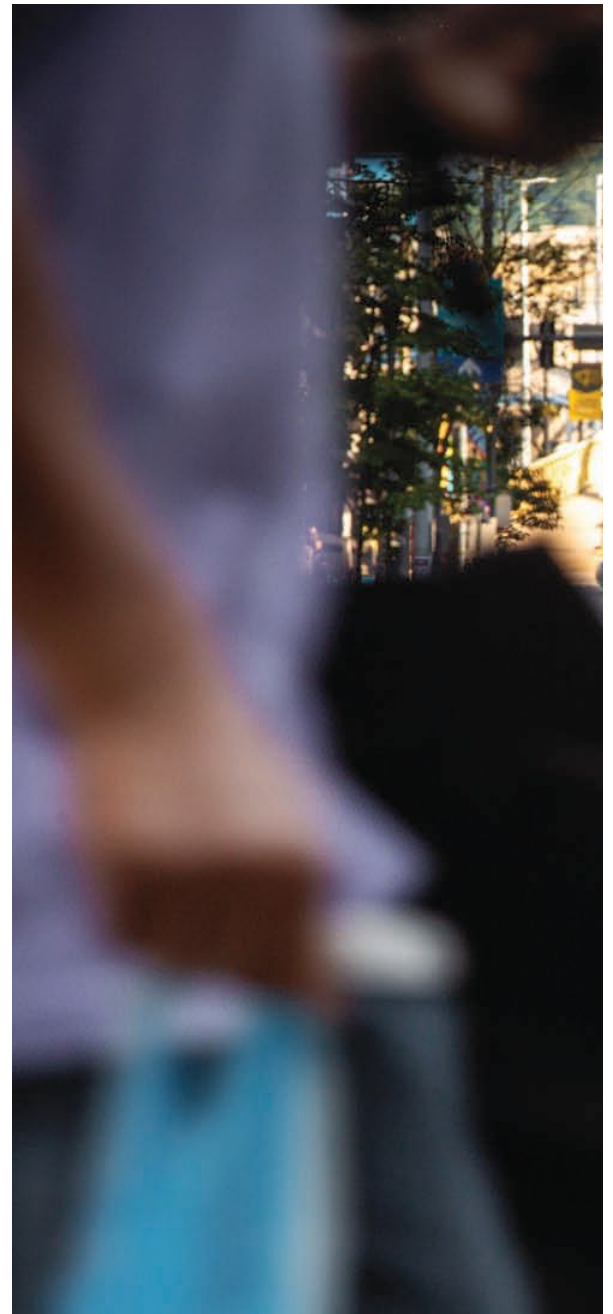
Over the last decade-plus, this technological trend from the laboriously and precariously manual to the conveniently automatic has begun reaching into the eyebrow-raising realm of autonomy in the world of automobiles and aircraft. With autonomy, decision-making and execution become no longer the sole or even partial purview of human operators; vehicles must think and act for themselves, keeping occupants safe while ensuring the safety of bystanders.

Self-driving cars are the most obvious manifestation of this “Nightrider”-ish trend toward smart vehicles. Heavily researched and pursued by big tech companies like Google and Uber, pioneering car manufacturers like Tesla, along with established industry titans including Toyota and Ford, autonomous cars have already logged tens of millions of kilometers in cities around the world. Most of that kilometerage has been for training purposes, but the vehicles have also ferried some intrepid, early-adopter passengers, while Tesla owners routinely let their vehicles run in “autopilot,” a semi-autonomous mode that handles street driving with ease.

Far behind this curve and with far less fanfare, autonomous aircraft are also in the works. Aviation industry leaders — including the three biggest manufacturers Boeing, Airbus and Embraer — all recognize the promise and arguably requirement for this revolution in air travel. Most ongoing efforts focus on urban air mobility, small, personal air taxis for urban environments, with an eye toward full-fledged autonomy for conventional long-haul commercial flight.

In some respects, self-flying aircraft are building on the advances already achieved by ground vehicle developers, says Arne Stoschek, who himself worked on autonomous cars prior to becoming project executive for Wayfinder, an autonomous flight software and hardware initiative at Airbus’ A<sup>3</sup> innovation center in Silicon Valley. “We step on the shoulders of giants,” Stoschek says, thanks to “the huge investment that the car industry did.”

But as he and others point out, in key respects, aircraft will have to make their own way dealing with challenges unique to their aerial operational environment. Navigating these challenges will determine

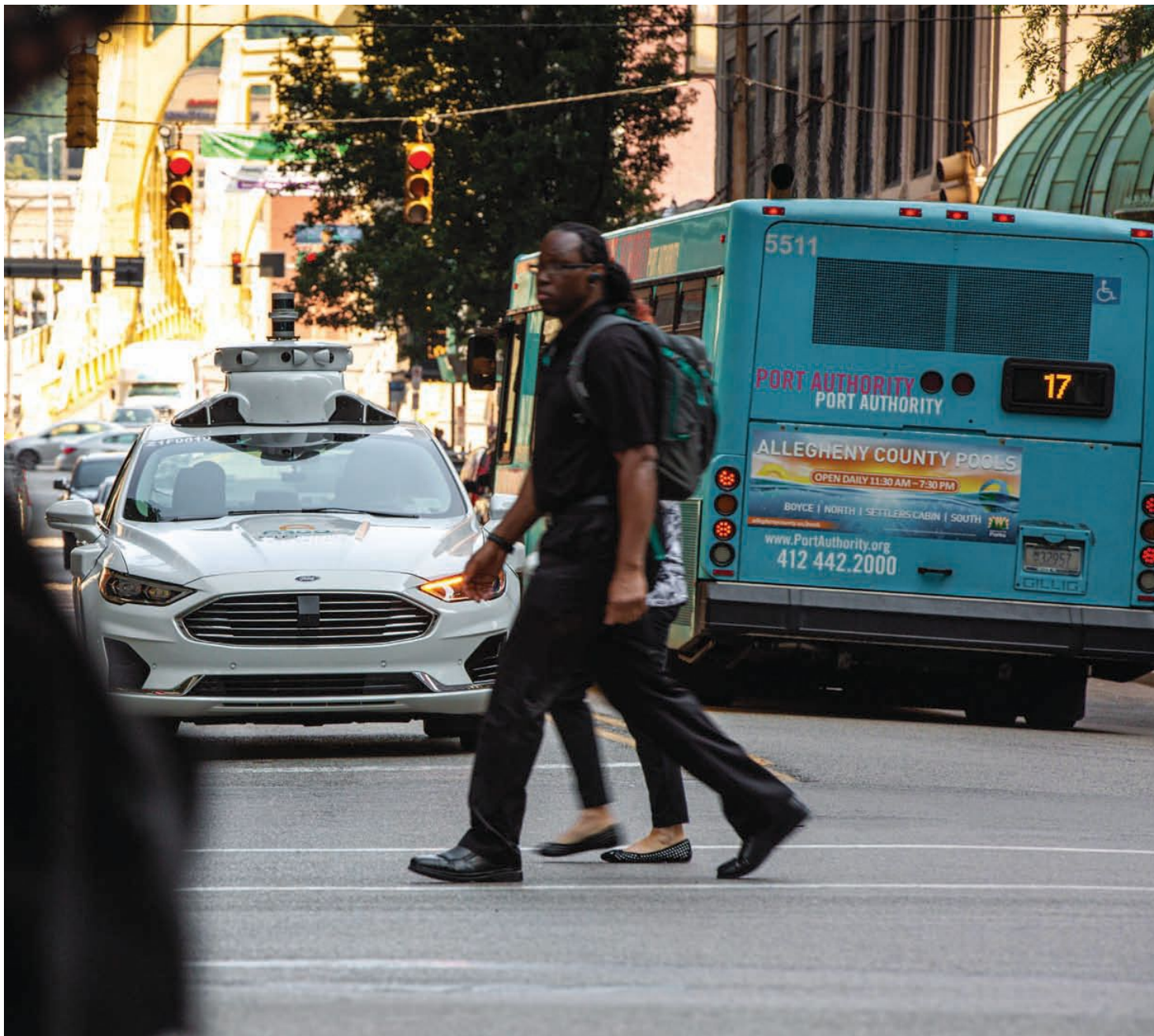


when and if autonomous vehicles take to the skies in appreciable numbers — before, alongside or after their self-driving counterparts come to dominate streetscapes as many expect.

The pressure is on for self-flying to become viable sooner rather than later. A prime motivator: looming pilot shortages, given the widely expected doubling in the number of commercial airliners over the next couple decades. Mark Cousin, A<sup>3</sup>'s CEO, estimates that 600,000 pilots will need to be trained in the next 20 years, although “we’ve only trained 200,000 pilots since the start of commercial aviation.”

Raising the stakes further is that the consequences of failure are terribly severe for aircraft compared to cars.

“There is no such thing as a fender-bender between aircraft,” says Jack Langelaan, who studies



autonomous flight as an associate professor of aerospace engineering at Penn State. “You can have a minor collision between two automobiles—nobody gets hurt, no nothing. But if two aircraft collide in the sky, they’re coming down somewhere, and potentially on top of passersby that are completely uninvolved in the whole situation.”

### Self-driving or self-flying?

Asked which will prove ultimately harder, developing self-driving cars or self-flying aircraft, researchers demur, pointing to the apples-and-oranges nature of the question.

In laying out the obvious, cars operate in a two-dimensional environment, essentially, while aircraft operate in three dimensions. Speed is another key difference, at least when considering conventional

airplanes’ approximately 900-kph cruise speeds to cars’ 100-plus-kph highway speeds. Air taxis and delivery drones with their rotor-based propulsion and low-altitude, short-haul trips, would operate at speeds more akin to cars.

Finally, unlike cars, airliners would not have an option of slamming on the brakes or even significantly slowing in case of obstacles; collision (read: disaster) avoidance comes down to evasive maneuvers that must still preserve airworthiness.

“To sum it up,” says Stoschek, “the big difference is it’s a 3D problem, it’s basically 10 times faster than cars, and you cannot stop if things go wrong.”

### Seeing the road, seeing the sky

Although operational environments profoundly differ, both kinds of autonomous vehicles, ground-

▲ **Human drivers** benefit from visual cues from pedestrians and other drivers, something that developers of autonomous vehicles, like this Ford from Pennsylvania-based Argo AI, must account for.

Argo AI

# “THE BIG DIFFERENCE IS IT’S A 3D PROBLEM, [FLYING IS] BASICALLY TEN TIMES FASTER THAN CARS, AND YOU CANNOT STOP IF THINGS GO WRONG.”

— Arne Stoschek, A<sup>3</sup> by Airbus

craft and aircraft, will still rely on conceptually the same sorts of sensors — cameras, radar and lidar — to perceive surroundings in real time. Both vehicle types will feed that data into artificial intelligence systems that, having been trained through so-called machine learning, will identify, characterize and evaluate external phenomena. The vehicles’ AI will then rapidly decide on and execute any changes in speed, heading and so forth necessary to navigate safely and efficiently from point A to point B.

So far, so similar. But again, the disparate worlds the transportation vessels operate in will require tailored solutions.

Where aircraft have it easy compared to cars is that, except for when in proximity to landing and takeoff zones, the sky is a relatively big, open space. Other flying objects of significant speed and heft to pose significant collision concern are — freak bird strikes aside — other aerial vehicles. Such vehicles can communicate with each other directly to help maintain safe distances. Aircraft are also monitored and coordinated by air traffic control, which itself will have to eventually become largely autonomous to accommodate projections for the high volumes of air taxis and drones in cities, notes Parimal Kopardekar, an expert in autonomy and air space management, principal investigator of the Unmanned Aircraft Systems Traffic Management project, director of NASA’s Aeronautics Research Institute at Ames Research Center in California.

Cars, on the other hand, must deal with orders of magnitude more complexity on roads. This is especially evident in congested urban quarters, where multiple nearby vehicles interweave with myriad pedestrians, bicyclists, skateboarders, construction signs, temporary barriers, litter, blithely jaywalking pigeons — you name it.

Huei Peng, a professor of mechanical engineering at the University of Michigan and director of Mcity, the university’s automated vehicle research center, points out that aside from other cars, these

objects will not have any ability to communicate with or coordinate their movements with self-driving cars. “They don’t talk to you,” Peng says, meaning cars must be keenly reactive and flexible in navigating their object-addled arenas.

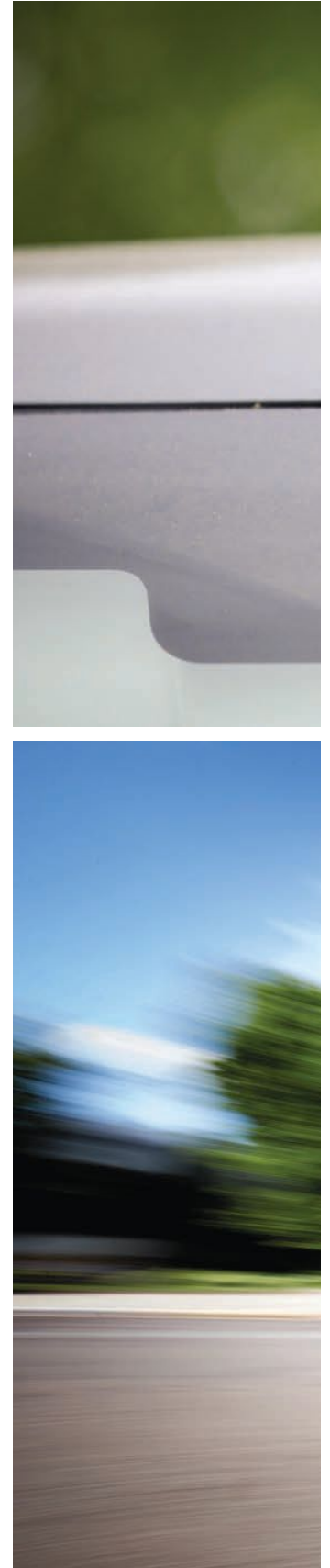
## Making sense of the world

In terms of seeing and sensing environments, sensors are already highly advanced, says Langelaan; matching or exceeding human visual capabilities, for instance with pixel density, is not a problem. Instead, the biggest challenge is on the artificial intelligence side of the equation with regard to analyzing, interpreting and ultimately making sense of the deluge of data in order to snappily decide and aviate safely.

“You can have a 4K camera with a gazillion pixels on it,” says Langelaan. “But you need to process every single one of those pixels to figure out what the camera is telling you. It’s this problem of taking sensor data and turning it into useful information.”

The difficulties inherent to data processing are amplified considerably in off-nominal situations, where objects on a roadway or in the sky do not behave as expected — often due to the whims and peculiarities of human operator behavior. For example, a car could be rolling forward out of a McDonald’s parking lot into a roadway entrance. Is the driver merely trying to see out into the road better before attempting to enter? Or is the driver in fact already pulling onto the road, wolfing down fries, completely unaware of the other vehicle already in the roadway? A human driver could notice if the other driver was eating or had his head down, likely looking at a phone, and assume that this other driver is in fact dangerously not paying attention. Self-driving systems struggle making these sorts of everyday inferences. “For a robot to know what human intent is has been really tricky to figure out,” says Langelaan.

In the sky, a partial solution for gauging intent would be to train artificial intelligence to identify types of aircraft as well as their orientations, which





together prescribe a range of possible physical behaviors. (Algorithms in self-driving cars can do this to an extent, for instance, by differentiating between a pedestrian and a bicycle, and churning out predictions about the paths and velocities each is likely to take compared to the other in terms of presenting a possible collision hazard.) For instance, if a particular kind of fixed-wing aircraft — whether human-piloted or autonomous — has a certain tilt, then it must be turning. An entirely different set of such inferences would apply for quadrotor-powered drones and air taxis, given their radically different aerodynamics, notes Langelaan.

“That would be a really cool thing if [autonomous aircraft] could do it,” says Langelaan. “Humans do it all the time if we’re playing with a baseball versus a frisbee. You know the thing behaves very differently, and we can account for that when we go to catch it.”

### The human advantage

In that last point, Langelaan hits on a critical deficiency of all autonomous systems: the fact that all they do is drive or fly. They lack the sort of rich life experience of a human pilot, who has seen and interacted with countless objects and phenomena outside of the typical aviation environment. That broad world sense enables a person to usually and quickly diagnose what an anomaly is, however unexpected or bizarre, and take appropriate action. Consider landings. “If everything is hunky-dory,” says NASA’s Kopardekar, “it’s not an issue” for autonomous systems. But what if there’s an object on the runway? Humans can gauge the threat level innately, drawing on their vast knowledge outside of aviation. “It’s very easy for humans to figure out that’s just a dry leaf, not a big rock,” says Kopardekar.

Of course, in most cases, landings are routine affairs — enough so that already today, they are

### ◀▲ A driverless shuttle

carries passengers at the University of Michigan’s research campus. The project examined how passengers, drivers of other vehicles and pedestrians interacted with the shuttle. The lidar sensor on the driverless shuttle maps the vehicle’s surrounding environment.

University of Michigan

# “THERE IS NO SUCH THING AS A FENDER-BENDER BETWEEN AIRCRAFT.”

— Jack Langelaan, Penn State

becoming increasingly automated. Autopilot programs can approach land and start taxiing when an airport has a so-called CAT III ILS (Instrument Landing System). In this system, instruments at the airport and aboard the aircraft communicate with each other. The airport transmits information from runway radar arrays for aircraft position guidance, with localizer radio antennae continually serving up data on the aircraft's lateral deviations from the desired centerline. Another instrument, the glide slope antenna, measures the aircraft's vertical distance from the ground so the aircraft maintains the right descent angle (usually 3 degrees above the horizon) for reaching the intended runway touchdown point. Yet fewer than a hundred airports worldwide — typically with low-visibility issues — have plumped for the expense of a CAT III ILS, according to Harvest Zhang, head of software for A3's Wayfinder.

Stoschek, Zhang and colleagues are looking to “teach” aircraft to perform landings without these sorts of automated landing systems. One such effort involves the Airbus ATTOL (Autonomous Taxi, Take-Off and Landing) project, which has outfitted an A320 test aircraft with the kinds of sensors, actuators and computers an actual autonomous aircraft would use. The effort is a collaboration with the aforementioned Wayfinder program, whose goal is to develop a common, certifiable set of software and hardware that will scale for autonomous fliers, from air taxis to jumbo jets.

The Wayfinder computer system consists of an artificial neural network that uses so-called deep learning to understand and perform programmed tasks. In plain English, that means a computer system that learns in a manner akin to humans by poring over examples, at first discerning basic, common elements in the examples and then build-



ing up those elements into concepts of increasingly greater complexity. For runways, that means first recognizing basic line edges and colors, then compiling that information to discriminate the tarmac from surrounding terrain, for instance. The examples presented to such a computer system include not only true runways, but thousands upon thousands of images of simulated runways. So far, the neural network can robustly identify runways in real-life images at distances of several kilometers and with encouraging accuracy, given the still-early nature of the research and development.



▲ **The CityAirbus** demonstrator is designed to fly autonomously in cities, but Airbus says a human will pilot the aircraft until it is certified and the public is comfortable with autonomous aircraft.

Airbus

To an extent, those are baby steps still for the landing portion of autonomous flight, but Stoschek and others point to how rapidly autonomous car development has proceeded. “Fifteen years ago, we would say autonomous cars was pretty nuts,” says Stoschek. “Now it’s a reality. Every day that I drive to work to Airbus in Silicon Valley, I see several autonomous cars driving around me.”

#### **The leap to full autonomy**

Before the switchover to full autonomy can occur, Peng of the University of Michigan warns about a

significant chasm that both cars and aircraft will have to bridge, and into which both vehicle types are in some ways alarmingly descending. In short, partial autonomy — where human operators might be suddenly forced to intervene, should the highly automated or autonomous system not know how to react — is dangerous. Peng describes this as “you want the human to come in and save the world when something goes wrong.”

Trouble is, the human operators have likely had little to do, perhaps for hours, beyond blandly monitoring vehicle operations. A person will lack the



necessary situational awareness, not to mention adequate time to take action, if thrust into an anomalous, emergency scenario.

Breaking the problem down further, Peng says there are five levels of autonomy widely recognized for cars. Everything operated manually is Level 0, including basic cruise control that a human operator switches on and off (not unlike air conditioning, say). Level 1 involves minimal driver-assistance technologies, like adaptive cruise control and lane keeping. In Level 2, the options of accelerating, braking and steering can be turned over to the vehicle, enabling it to, for instance, slam the brakes to avoid an imminent collision.

This Level 2 of semi-autonomy is the vanguard today, for example with Tesla Autopilot. Two fatal accidents have infamously highlighted safety lapses, though statistical data does bear out that Auto-

▲ **The Vahana** demonstrator, which took its last flight in November, had three types of sensors: cameras, lidar and radar.  
A<sup>3</sup> by Airbus

pilot use results in fewer crashes than human drivers per miles driven. In the latest dataset (Q2 of 2019), Tesla reported one accident per every 3.27 million miles (5.26 million kilometers) driven with Autopilot engaged. For Tesla vehicles without Autopilot or other active safety features engaged, that rate rose to one accident per every 1.41 million miles (2.27 million kilometers) driven. Both methods were significantly safer than the National Highway Traffic Safety Administration's data indicating one car crash per every 498,000 miles (801,500 kilometers) driven in the United States.

Where things could trend in the wrong direction is in Level 3 conditional autonomy, Peng says. Level 3 cars handle all driving aspects themselves in certain operating conditions but expect a driver to remain alert and fully engaged during operation (just in case). Aircraft have already entered the equivalent of Level 3, Peng says, with the Boeing 737 MAX 8, the fourth generation of the 737 introduced in 2017. Two fatal crashes — Lion Air Flight 610 in 2018 and Ethiopian Airlines Flight 302 in 2019 — were linked to erroneous activation of the anti-stall system MCAS, short for Maneuvering Characteristics Augmentation System. The software autonomously lowers the aircraft's nose if the aircraft appears at risk of stalling, according to speed, altitude and angle-of-attack sensors. Pilots did not know how to disengage MCAS after it had seized control and continued pointing the nose down until the aircraft crashed. The MAX fleet remains grounded as software fixes are sought and better training procedures established.

"The Level 3 option is just not a good idea," says Peng. He thinks car companies — as well as aircraft manufacturers — have to fully develop Level 4 autonomy, with no human intervention called for over an entire journey, before autonomy comes to rule the roads and skies. "Companies should offer Level 1, Level 2, then boom, Level 4," Peng adds.

All the technological development will not matter, of course, if human operators' trust cannot be earned. Humans will have to have faith in the machine in order to let go of the steering wheel and stick; come Level 5, the top level of autonomy, those human interfacing control elements won't even exist anymore, and vehicles will look more like mobile lounges.

How will the developers of autonomous vehicles ever know what they have made is in fact safe "enough"? Stoschek offers a guiding principle.

"Early on in my career, I asked one very experienced engineer who was actually in charge of the designing of safety systems, 'How do you know when a system is safe'? And the answer was, 'When I would put my kids and my family' on it," Stoschek says. "I really, really kept that in my mind." ★

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# BAD VIBRA

Designers of hypersonic vehicles need to be confident that unsteady flows around their vehicles won't produce vibrations that will damage the vehicles or their payloads. Accurately predicting the pressure generated by these unsteady flows and modeling how hard this pressure shakes a vehicle could give U.S. engineers that confidence. [Katya Casper](#) of Sandia National Laboratories in New Mexico describes her research toward making this a reality.



# TIONS

▲ A typical wind tunnel model is shown in the 18-inch-diameter test section of the Hypersonic Wind Tunnel at Sandia National Laboratories. The tunnel has interchangeable nozzles so it can operate at Mach 5, 8 or 14.

Sandia National Laboratories/  
Randy Montoya

When a vehicle reaches hypersonic speeds of Mach 5 or greater, pressure fluctuations in the air flow can zip across the surface within the otherwise smooth

laminar flow. These turbulent spots can grow and conglomerate into an unsteady turbulent layer that vibrates the vehicle. If the structural loads from these vibrations are strong enough, they can damage the vehicle and any sensitive electronics or payloads inside it.

With U.S. development of hypersonic systems now a top defense priority, and private companies determined to one day create hypersonic passenger aircraft, the need to understand exactly how much vibration is imparted by these turbulent spots has become even more pressing. Engineers must be able to predict where turbulent spots will form and anticipate the intensity of the resulting vibrations and loading.

The origins of turbulent spots and the resulting structural response have been understood in low-speed flows for many years. But they are known to be driven by differing physics in hypersonic flows. This was the void my colleagues and I continue to pursue filling under a research initiative begun in 2007. The experiments began at Purdue University during my graduate studies and then moved to the Hypersonic Wind Tunnel at Sandia National Laboratories in New Mexico.

At Purdue, we started out mapping the pressure field beneath a single hypersonic spot to contrast its behavior with the pressure field of a low-speed turbulent spot. We did this by installing arrays of pressure instrumentation on the wind tunnel wall in order to study the development of a large spot over several meters. A traditional wind tunnel model would not have been the right choice at this point in the project. The models are typically only a half meter long, so the spots that form on those models are too small to map the pressure fluctuations beneath them with high spatial resolution.

With the pressure measurements from the tunnel wall obtained at a rate of hundreds of kilohertz, we characterized how a single spot formed from hypersonic instabilities in the boundary layer. For the first time, the shape and magnitude of a hypersonic spot pressure field was mapped. This mapping showed that the hypersonic instabilities were an integral part of the spot at these high speeds, and these instabilities persisted at the edges of the growing disturbances.

We then needed to study the physics of how these instabilities break down during transition from laminar flow to form turbulent spots and understand how those physics differ between low

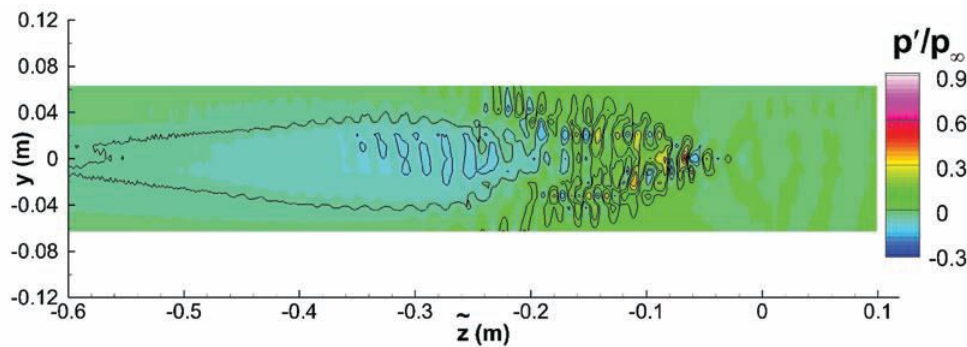
Structural components, whether on a flight vehicle or a wind tunnel model, possess certain inherent frequencies of structural response. When these structural frequencies correspond to those frequencies induced by the passage of turbulent spots, the flight component can be strongly excited.

and hypersonic speeds. This transitional breakdown can be a prime contributor to unsteady loading and vehicle vibration. We needed to measure spot growth and propagation on a relevant geometry, specifically a cone-shaped wind tunnel model that is representative of many hypersonic vehicles. We installed dense arrays of high-frequency pressure instrumentation on a model that traveled between

the Purdue and Sandia tunnels in a collaborative research effort. We also visualized the density gradients in the flow over the model with high-speed cameras using a technique called schlieren imaging. With both the pressure measurements and flow visualization, we detected turbulent spots passing over the models in milliseconds and captured the spot evolution as it developed from the breakdown

▼ **Hypersonic turbulent** spots were measured passing over the nose of a sounding rocket designed and launched by Sandia National Laboratories from a Hawaii test site in April 2019. Sandia National Laboratories





◀ **The pressure footprint** of one hypersonic turbulent spot at Mach 6. As turbulent air flows over a vehicle, thousands of such spots occur every second causing severe vibration. Sandia National Laboratories/ Katya Casper

of hypersonic instabilities.

Ultimately, for our flight predictions, we need to know the statistics and distribution of how these spots form as the boundary layer transitions from smooth laminar flow to unsteady turbulence. The spot formation rates and distributions were measured over a range of conditions between Mach 5 and Mach 14. With this data and the pressure mapping beneath a single spot, Sandia was able to develop computational models of the pressure loading on a hypersonic vehicle during transitional flow.

With a physical basis established for the behavior of hypersonic turbulent spots, we began to contemplate how a structure on a flight vehicle might respond to their passage. We decided to start with a very simple geometry. A 1-millimeter-thick carbon composite panel was embedded into the surface of a conical wind tunnel model. The thin panel was designed to vibrate from the flow passing over it so the interaction of the boundary layer with the panel response could be studied in detail. The incoming flow was characterized with high-speed imaging and pressure sensors, and the panel response was measured with accelerometers on the interior.

Structural components, whether on a flight vehicle or a wind tunnel model, possess certain inherent frequencies of structural response. When these structural frequencies correspond to those frequencies induced by the passage of turbulent spots, the flight component can be strongly excited.

To investigate this worst-case scenario, spots were periodically generated at frequencies that either matched or were offset from a structural natural frequency. When the spots passed at a rate that coincided with the natural structural vibration of the panel, the amplitude of the vibrations of the test article soared to levels 200 times greater than when the frequencies were not aligned.

In reality, a broad range of forcing frequencies will be generated by a transitional boundary layer in which thousands of spots pass by within a second. The frequency of the excited structural vibrations of

the panel can be correlated to the rate of turbulent spot passage in the transitional boundary layer. To date, we have mapped out the turbulent spots and the vibrations they cause on this simple cone geometry, and we have modeled the results with our computational code. Next, we want to map this effect on geometries representing more realistic flight configurations.

Wind tunnels ultimately are a simulation of flight conditions. To test out our models of structural response to turbulent spot passage, there was no substitute for actually flying. In April and August 2019, we conducted analogous experiments by instrumenting the nose shroud of a rocket in Sandia's High Operational Tempo Sounding Rocket Program, or HOT SHOT.

HOT SHOT launches inexpensive sounding rockets carrying scientific experiments and prototypes of flight technology. The data help researchers improve technologies, validate that they are ready for use and deploy them faster than with conventional validation techniques.

In flight, we measured hypersonic turbulent spots passing over the nose of one of the rockets and the resulting structural response. The turbulent spots looked very similar to the spots that were measured in the wind tunnel — however, the data is more sparsely sampled because of telemetry limitations that cap how much data can be collected in flight. By comparing the flight measurements to our database of wind tunnel measurements, we have a good understanding of what our flight data would look like if we had additional bandwidth in flight. The flight experiment also measured the structural response of the nose and internal payloads to the turbulent spot passage. That data are now being used to test flight codes to see if the response of the structure to the unsteady flow above it can be correctly estimated in a real flight environment.

If our work continues to progress as hoped over the next few years, we will have developed an important new tool for predicting the vibration environments of future hypersonic vehicles. ★



**Katya Casper** is an aerospace engineer at Sandia National Laboratories in New Mexico. She is principal investigator for a variety of high-speed experimentation projects and a member of the Aerosciences Group tasked with predicting the thermal and aerodynamic environment a vehicle will see in flight. She received a Bachelor of Science degree in aerospace engineering from North Carolina State University in 2007; a Master of Science in aeronautics and astronautics from Purdue University in 2009; and a doctorate in aeronautics and astronautics from Purdue in 2012. Casper received AIAA's 2019 Lawrence Sperry Award for the research described in this article.



# More than government work

**Defending Earth from “city killer” asteroids will require a partnership between governments and the burgeoning commercial space industry. Retired NASA mission planner **Don A. Nelson** makes the case.**



▲ **The European Space Agency** wants to create a network of automated telescopes to detect asteroids. The first one, nicknamed Flyeye and seen in this illustration, is being built on a mountain in Sicily. Don Nelson writes that private companies and governments should collaborate on solutions to protect the Earth from potentially catastrophic asteroid hits.  
European Space Agency

Americans would rather stop asteroids from hitting Earth than go to the moon or Mars, according to a poll published last June by the Associated Press-NORC Center for Public Affairs Research at the University of Chicago. The potential for a cataclysmic asteroid impact on our home planet is so credible that NASA established a Planetary Defense Coordination Office in 2016 to coordinate efforts of U.S. agencies, international counterparts, and professional and amateur astronomers around the world. The European Space Agency also established a Near-Earth Object Coordination Centre that conducts searches for near-Earth asteroids.

To date, approximately 20,000 near-Earth asteroids have been discovered, of which 800 have been classified by NASA as possible impact risks, because they are greater than 500 feet (152 meters) in size and their orbits bring them within 4.7 million miles (7.6 million kilometers) of Earth's orbit.

The trouble is, size alone doesn't determine destructive power. The density and the angle of entry into the atmosphere determine how much kinetic energy is generated. It is these small asteroids that are the most concerning. They impact Earth at a greater frequency and far too often are not discovered until a few days before their impact.

The small undetected asteroid that broke up over Chelyabinsk, Russia, on Feb. 15, 2013, created a shock wave that shattered glass and injured about 1,200 people. It would have been far worse if it had been an iron core asteroid with a high entry angle into the atmosphere. Or consider Asteroid 2008TC3, estimated to be 4 meters and discovered the day before it broke up on Oct. 7, 2008, and scattered at least 600 extremely hot fragments over the Nubian Desert. Had this occurred over a dry forest region, the outcome would have been far different.

Or last March, BBC News reported that a "space rock" exploded in the atmosphere the previous December but that the event went largely unnoticed because the explosion was over the Bering Sea. Last July, our planet reportedly had a near miss with a city-killer asteroid.

And yet, on its Planetary Defense webpage, NASA says, "No known asteroid poses a significant risk of impact with Earth over the next 100 years." The statement is true, but the key word is "known." Surprises from smaller asteroids happen fairly regularly.

Consider these questions: Is there a credible asteroid threat that requires the immediate development of a planetary defense system? Can the requirements for the system be defined? Can this system be built and operated without significant government funding? This old retired NASA engineer believes the answer to each of these questions is yes.

The three requirements for the defense system are: rapid deployment, reliability and affordability. Such an asteroid defense system must be able to detect the threat, provide rapid access to inspect the object and categorize the degree of danger and the ability to neutralize it.

The three requirements for the defense system are: rapid deployment, reliability and affordability. Such an asteroid defense system must be able to detect the threat, provide rapid access to inspect the object and categorize the degree of danger and the ability to neutralize it.

It would be cost prohibitive for the U.S. and partner governments to develop stand-alone launch vehicles and deflection devices for this purpose. Rather, the

▼ **SpaceX's Starship** could launch quickly and inexpensively enough to meet requirements for commercial operations and planetary defense. This is a Starship test vehicle at SpaceX's Texas launch site. SpaceX

need for planetary defense must be a participating part of the developing 21st-century commercial space transportation system programs. For cost-effective and reliable commercial space operations, the private-sector transportation system must include reusable launchers and space tugs based in orbit. These vehicles will for that reason meet the defense system requirements for rapid launch and access to the threat. Future civil, military and commercial satellites in addition to their primary function could be equipped with sensors to identify asteroid threats. Since there are no new technology requirements demanded of the vehicles for planetary defense, they can be developed by the private sector with minimum or no government funding.

Rapid deployment can be achieved only with reusable launch vehicles. There may not be an inventory of expendable launchers available when an asteroid threat is discovered. Also, expendable launchers cannot achieve the required reliability because of undetected manufacturing errors on vehicles whose first flight is the only flight. Reusable launchers and space-based vehicles have the potential to achieve a failure rate equivalent to commercial aircraft.

Affordability is a function of flight rate and launch operations costs. Where operations cost will be a fixed value, flight rate will be a function of the economy and missions needed. To stay in business there must be significant flight rate to cover operations overhead. This may require a business model similar to the one considered by Lockheed Martin for its 1990s-era



VentureStar reusable, commercial launch vehicle proposal. One cost estimate for the fleet was \$8 billion in 2014 dollars. NASA and other U.S. government customers were expected to guarantee a specific number of payloads or launches. Unfortunately the VentureStar had unsolvable development problems. It remains true, however, that reusable launchers must be used to contain operations costs.

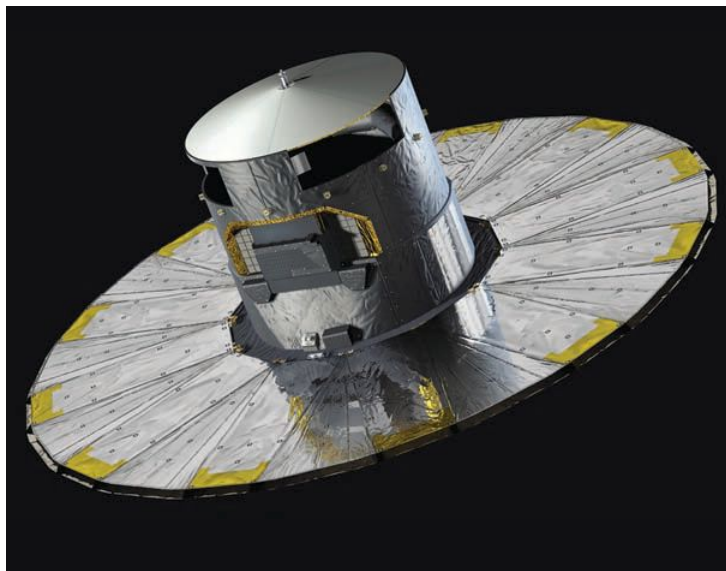
There are two launcher concepts that can meet the cost and rapid-deploy requirements for commercial operations and planetary defense: the SpaceX Starship vehicle (formerly the Big Falcon Rocket) and a space shuttle-inspired freighter concept that I and others have advocated. In my opinion, both concepts should be developed.

SpaceX recognizes the importance of reusability. The company's Starship vehicle will consist of a first stage called the Super Heavy rocket that will return and land on six legs, plus a reusable second stage, the Starship spacecraft. Together they are being sized for service to orbit and deep space missions to Mars, with the launch pad height approximately that of the Saturn V. Super Heavy would be powered by 35 Raptor engines powered by subcooled liquid methane and liquid oxygen. Starship will provide passenger, cargo and tanker service to orbit and beyond. SpaceX has an ambitious first launch date of 2020. It will incorporate design components from the highly successful Falcon launch vehicle program.

The Commercial Space Shuttle, or CSS, Freighters would be designed to: support near-Earth space transportation requirements, provide the capability to deploy payloads for deep space exploration and support humanity's need to obtain deep space resources. Its payload landing capability makes it unique for this requirement.

These freighters would incorporate the many existing technologies that can correct the deficiencies of the space shuttle fleet that was decommissioned in 2011. The launch cost will be significantly lower than those of an expendable launch vehicle, primarily because of increased reliability, no continuous manufacturing overhead and lower insurance costs for the CSS freighters (for more information, see [www.spacetrans21.org](http://www.spacetrans21.org)).

Each CSS freighter will incorporate the airframe profile of the shuttle orbiters, but unlike the orbiters, a CSS will operate autonomously. Passengers will be flown only on missions requiring their presence. For these missions, they will be provided escape pods for launch, on-orbit and entry anomalies. Launch pad assembly of the freighter will reduce operations cost and turnaround time. Rapid turnaround is a freighter feature that reduces operations' cost, provides the capability for timely intercepts of threatening asteroids and supports U.S. Air Force rapid-deploy mission requirements.



Space-based tugs, first proposed in the 1990s, would be an essential element for a cost-effective 21st-century space transportation system. When a dangerous asteroid is spotted, a tug could be dispatched to classify its composition and provide the delivery systems for deflection or destruction. NASA's Marshall Space Flight Center in Alabama and the Russian Space Agency had concepts, but the lack of an affordable launch vehicle prevented their development.

There are several options for asteroid-detection satellites. NASA in 2015 picked a proposed space telescope called NEOCam for study. It would survey the sky for potentially hazardous asteroids and gather infrared light to characterize their physical properties, such as diameters.

Another option would be to place asteroid-detection sensors on satellites with multifunctions. Consider, for example, Europe's Gaia satellite which is the process of mapping the positions and movements of the stars to create a 3D map. Gaia also watches for asteroids, and it has discovered three previously unknown ones. This supports the notion that asteroid detection can be one of many functions of a satellite mission and would not have to drive up manufacturing and operating costs. Gaia also shows that asteroid detection can and must be an international project.

NASA is correct in that there are no known city-killer asteroids. However, the alarming increase in near-Earth asteroids that whiz dangerously by is a warning sign that asteroid planetary defense must not be ignored. The technology exists to develop an asteroid planetary defense system supported by the commercial space programs. The only lacking element for an asteroid planetary system is leadership. ★

▲ **The Gaia satellite is** collecting data to make a 3D map of the Milky Way, but it's also spotting asteroids, including three previously undetected ones.

European Space Agency



### Don A. Nelson

retired from NASA in 1999 after a 36-year career.

An aerospace engineer, he worked on the Gemini, Apollo and Skylab projects and was a member of the space shuttle design team. Email [caae@wt.net](mailto:caae@wt.net). He is coordinator for the Commercial Space Shuttle Freighter advocacy group, [www.spacetrans21.org](http://www.spacetrans21.org).

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- › AI-Enabled Autonomy
- › Leveraging Innovation to Advance Missile Defense
- › Technological Overmatch: The Critical Role of DoD Labs and DARPA
- › USD R&E Enterprise

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This ITAR-restricted course, to be held after the forum on 8 May, aims to provide a foundation for evaluating trust in autonomous systems. State-of-the-art research, methods, and technologies for achieving trusted autonomous systems will be reviewed with current applications.

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# Calendar

**FEATURED EVENT**



**5-7 MAY 2020**

**Laurel, MD**

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

[aiaa.org/defense](http://aiaa.org/defense)

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
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**2020**

4-5 Jan	3rd Sonic Boom Workshop	Orlando, FL	
4-5 Jan	Design of Experiments: Improved Experimental Methods in Aerospace Testing Course	Orlando, FL	
4-5 Jan	Design of Electrified Propulsion Aircraft Course	Orlando, FL	
4-5 Jan	Fundamentals of Drones: UAV Concepts, Designs and Technologies Course	Orlando, FL	
4-5 Jan	Integrated CubeSat Engineering	Orlando, FL	
4-5 Jan	Integrating Program Management, Systems Engineering, and Six Sigma	Orlando, FL	
4-5 Jan	Missile Guidance Course	Orlando, FL	
4-5 Jan	Systems Thinking for Modern Aerospace Complexity	Orlando, FL	
5 Jan	75+ Years of Hypersonics Development: History, Resources, References, and Insights	Orlando, FL	
5 Jan	Additive Manufacturing: Structural and Material Optimization Course	Orlando, FL	
5 Jan	Introduction to Digital Engineering Course	Orlando, FL	
5 Jan	A Unified Approach for Computational Aeroelasticity Course	Orlando, FL	
6 Jan	Class of 2020 AIAA Associate Fellows Induction Ceremony	Orlando, FL	
6-10 Jan	AIAA SciTech Forum	Orlando, FL	11 Jun 19
14-16 Jan*	2nd IAA Conference on Space Situational Awareness	Washington, DC ( <a href="http://icssa2020.com">icssa2020.com</a> )	
21-23 Jan*	International Powered Lift Conference (IPLC 2020)	San Jose, CA ( <a href="http://vtol.org/events/2020-transformative-vertical-flight">vtol.org/events/2020-transformative-vertical-flight</a> )	19 Aug 19

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

25–28 Jan*	Aircraft Noise and Emissions Reduction Symposium (ANERS)	Bordeaux, France (Contact: <a href="mailto:aerospace-europe2020.eu">aerospace-europe2020.eu</a> )	31 July 19
27–30 Jan*	66th Annual Reliability & Maintainability Symposium (RAMS®)	Palm Springs, CA ( <a href="http://www.rams.org">www.rams.org</a> )	
7–14 Mar*	2020 IEEE Aerospace Conference	Big Sky, MT ( <a href="http://aeroconf.org">aeroconf.org</a> )	
10–12 Mar*	23rd AIAA International Space Planes and Hypersonic Systems and Technologies Conference	Montréal, Québec, Canada	22 Aug 19
18 Mar	AIAA Congressional Visits Day	Washington, DC	
23–25 Mar*	55th 3AF Conference on Applied Aerodynamics — “Turbulent Flows in Aerodynamic Applications”	Poitiers, France ( <a href="http://3af-aerodynamics2020.com">http://3af-aerodynamics2020.com</a> )	18 Nov 19
16–19 Apr	AIAA Design/Build/Fly Competition	Wichita, KS ( <a href="http://aiaa.org/dbf">aiaa.org/dbf</a> )	
5–7 May	AIAA DEFENSE Forum	Laurel, MD	8 Oct 19
8 May	Trusted Autonomous Systems Course	Laurel, MD	
19 May	2020 AIAA Fellows Dinner	Crystal City, VA	
20 May	2020 AIAA Aerospace Spotlight Awards Gala	Washington, DC	
25–27 May*	27th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia ( <a href="http://elektroprigor.spb.ru/en/conferences/142">elektroprigor.spb.ru/en/conferences/142</a> )	
13–14 Jun	1st AIAA CFD Transition Modeling Prediction Workshop	Reno, NV	
13–14 Jun	6th AIAA Workshop on Benchmark Problems for Air Frame Noise Computations (BANC-VI)	Reno, NV	
14 Jun	2nd AIAA Workshop for Multifidelity Modeling in Support of Design and Uncertainty Quantification	Reno, NV	
15–19 Jun	AIAA AVIATION Forum	Reno, NV	7 Nov 19
23–26 Jun*	ICNPAA 2020: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic ( <a href="http://icnpaa.com">icnpaa.com</a> )	
15–22 Aug*	43rd Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events (COSPAR 2020)	Sydney, Australia	14 Feb 20
24–26 Aug	AIAA Propulsion and Energy Forum	New Orleans, LA	11 Feb 20
14–18 Sep*	32nd Congress of the International Council of the Aeronautical Sciences	Shanghai, China ( <a href="http://icas.org">icas.org</a> )	15 Jul 19
26–27 Sep*	CEAS-ASC Workshop 2019 on “Advanced Materials for Aeroacoustics”	Rome, Italy	
12–16 Oct*	71st International Astronautical Congress	Dubai, UAE ( <a href="http://mbrsc.ae/iac2020">mbrsc.ae/iac2020</a> )	
29 Oct–1 Nov*	37th International Communications Satellite Systems Conference (ICSSC 2019)	Okinawa, Japan ( <a href="http://kaconf.org">kaconf.org</a> )	15 May 19
16–18 Nov	ASCEND	Las Vegas, NV ( <a href="http://ascend.events">ascend.events</a> )	17 Mar 20

● AIAA Continuing Education offerings

\*Meetings cosponsored by AIAA. Cosponsorship forms can be found at [aiaa.org/Co-SponsorshipOpportunities](http://aiaa.org/Co-SponsorshipOpportunities).

## MAKING AN IMPACT

# Footsteps to the Future at Purdue

By Geoffrey Andrews, Member, STEM K–12 Outreach Committee

Purdue University Space Day, held 8 November, celebrated its 24th year by setting new records for attendance and volunteer participation. This free one-day space camp has taken place at Purdue University every fall since 1996, teaching engineering and science principles to schoolchildren in grades 3–8 via fun, hands-on activities centered on space exploration. This year 855 children from around the Midwest attended the program, which was staffed by more than 400 students and volunteers. Each participant received an AIAA career

booklet to keep them inspired to continue their studies in aerospace.

The theme of the day was “Footsteps to the Future,” a nod to both the 50<sup>th</sup> anniversary of the historic Apollo 11 moon landing and to NASA’s ambitious plans to return to the moon by 2024. The students were challenged to complete activities such as designing a paraglider wing for a model Gemini capsule, improvising an emergency air filter like the astronauts of Apollo 13, and building water rockets and balloon buggies.



This year, retired astronaut Jose Hernandez (STS-128) was Purdue Space Day’s guest of honor, talking to the students about his life’s journey to the astronaut corps and participating in various activities throughout the day. Plans are already underway for the 25<sup>th</sup> annual Purdue Space Day, which will be held in October 2020 – for more information, contact [PSD@purdue.edu](mailto:PSD@purdue.edu).

*For more information about how you can get involved with AIAA’s educational activities, please contact Merrie Scott, at [MerrieS@aiaa.org](mailto:MerrieS@aiaa.org).*



## AIAA Diversity Scholars Attend IAC

Twenty-five AIAA Diversity Scholars attended the 70th International Astronautical Congress (IAC 2019) in Washington, DC, in October. Scholars attended plenary and technical sessions, Exhibit Hall programs, special sessions geared specifically for the scholars, as well as trip to the Boeing Long Bridge Facility.

The AIAA Diversity Scholarship aims to combat underrepresentation in the industry by providing students from underrepresented groups with the opportunity to attend AIAA forums and receive additional targeted programming

that may help them succeed in the aerospace industry. This program is a collaboration of the AIAA Foundation and The Boeing Company.

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

## AIAA Region VII-Australia Student Conference Took Place in December



Group photo of winners with Cees Bil, Region VII Regional Director.

From 4 to 5 December, the AIAA Region VII Student Paper Conference, collocated with the 11th Asia-Pacific International Symposium on Aerospace Technology (APISAT), took place at the Gold Coast. Fourteen undergraduate AIAA student members, pursuing studies in Australia, India, Indonesia, Japan, and Italy, presented original research on a variety of topics. Their papers and presentations were evaluated by industry peers with many years of experience in the aerospace sector.

Judges collated their results and announced the winners. Reilly Palmer of the University of Queensland in Brisbane, Queensland (Australia) won first place with his paper “Hypersonic Vehicle for Space Access Using Hydrocarbon Fuel”; Lachlan Noller of the University of Southern Queensland in Toowoomba, Queensland (Australia) won second place with his paper “Restart of a 2D Hypersonic Inlet at Mach 6 using Slot Injection”; and Reece Otto of the University of Queensland in Brisbane, Queensland (Australia) won third place with his paper “Adjoint-based Grid Adaptation for CFD of High-speed Flows.” The first-place winner is invited to compete in the AIAA International Student Conference, which takes place at the AIAA SciTech Forum.

## News

### Aerospace Conference Spans Across the Asia-Pacific

Australia hosted the 11th Asia-Pacific International Symposium for Aerospace Technologies (APISAT 2019), at the Gold Coast, 4–5 December 2019. The Royal Aeronautical Society Australian Division and Engineers Australia entered into a formal partnership to organize the event, which also included many AIAA members.

"This is the 3rd time that Australia has proudly hosted APISAT. It provides a wonderful opportunity for students, researchers, and professionals in aerospace to meet and share their ideas. The conference agenda and poster sessions push the boundaries of our understanding of the science and applications for aerospace technology," said Cees Bil, conference chair.

Michael Spencer, a committee member from the AIAA Sydney Sec-



**LEFT TO RIGHT:** Michael Lagana, AIAA University Programs Coordinator; Cees Bil, AIAA Associate Fellow, RAeS (Aust.), Conference Chair; Michell Gee, Director, Sir Lawrence Wackett Centre, RMIT University & keynote plenary speaker; and Michael Spencer, AIAA Associate Fellow, session chair for spacecraft presentations.

tion, was a session chair for a series of presentations on spacecraft design. And the AIAA Region VII Student Conference was incorporated at the event alongside the APISAT agenda. Conference speakers and attendees came from universities and aerospace research institutes in various countries including Australia, China, Japan, Poland, South Korea, and the United States.

Bil commented, "It is good to see interests in aerospace science, industry and innovation are thriving. 2019 is a special anniversary year for celebrating

aerospace: this is the 50th anniversary of the Apollo 11 lunar landing and the centenary anniversary of the first flight along the 'kangaroo route', hopping from London across Europe and South Asia to Australia. The symposium showed that the interests and applications for aerospace science and technology continue to inspire and drive new research activities and attract follow-on generations of aerospace researchers, scientists and engineers."

Next year's APISAT will be held in Jeju Island, Korea.

## YOUR INSTITUTE, YOUR VOTE POLLS OPEN 29 JANUARY

Your vote is critical to shaping the future of AIAA!

**TO VOTE ONLINE:** Visit [aiaa.org/vote](http://aiaa.org/vote). If you have not already logged in, you will be prompted to do so. Follow the on-screen directions to view candidate materials and cast your ballot. Vote by 21 February 2020.

**TO REQUEST A PAPER BALLOT:** Contact Survey & Ballot Systems at 952.974.2339 or [support@directvote.net](mailto:support@directvote.net) (Monday – Friday, 0800 – 1700 hrs CDT). All other questions, contact AIAA Member Services at 703.264.7500, or (toll-free, U.S. only) 800.639.2422.

VOTING CLOSES  
21 FEBRUARY 2020

[aiaa.org/vote](http://aiaa.org/vote)



## 2020 AIAA Sustained Service Award Winners Announced

AIAA is pleased to announce the winners of the 2020 Sustained Service Awards, which recognize sustained, significant service and contributions to AIAA by members of the Institute.



**Nancy F. Andersen**  
Johns Hopkins  
University Applied  
Physics Laboratory

*For sustained and diverse leadership contributions*

*to AIAA through the Ground Testing Technical Committee, CASE, the Engineering and Technology Management Group, the Board of Directors, and the Council of Directors.*



**Brett A. Bednarczyk**  
NASA Glenn  
Research Center

*For over 25 years of exceptional service to AIAA, the AIAA SciTech Forum,*

*the SDM Conference, and the Structures Technical Committee.*



**Cassandra A. Dellinger**  
Dellinger  
Technologies

*For sustained and dedicated service to AIAA's Region II*

*(South East) and its student members as Deputy Director of Education and Regional Student Conference Chair.*



**L. Michael Freeman**  
University of  
Alabama

*For sustained and dedicated service to AIAA's Region II (South East) and*

*to the University of Alabama Student Branch members as faculty advisor.*



**Jeffrey W. Hamstra**  
Lockheed Martin  
Corporation

*For outstanding and exemplary leadership of the Propulsion and*

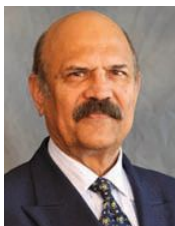
*Energy Group and long-standing support of technical activities within the Institute.*



**Christopher H. Jenkins**  
Montana State  
University

*For over five decades of dedicated service to the Institute*

*through distinguished leadership advancing the causes of the Gossamer and Spacecraft Structures Technical Committees.*



**Mohammad Javed Khan**  
Tuskegee University

*For sustained and dedicated service to the AIAA technical programs and to*

*the Tuskegee University Student Branch members as faculty advisor.*



**Joseph R. Marshall Jr.**  
BAE Systems

*For over 25 years of continuous service to AIAA through Computer*

*Systems Technical Committee leadership positions with a career focus on standardizing electronics for spaceborne systems.*



**Eric J. Pencil**  
NASA Glenn  
Research Center

*In recognition of sustained contributions to*

*AIAA at the section, region, and national levels.*



**Denise S. Ponchak**  
NASA Glenn  
Research Center

*For outstanding leadership to AIAA technical activities, the*

*development and management of highly successful conferences, and the funding of scholarships for future aerospace professionals.*



**Oleg Yakimenko**  
Naval Postgraduate  
School

*In recognition of significant and sustained contributions to*

*AIAA at the local, regional, and national levels.*

For more information on this award, please visit [aiaa.org/awards](http://aiaa.org/awards).

## Call for Content Issued for AIAA's New Space Conference ASCEND

AIAA has issued a Call for Content ([ascend.events/experience/call-for-content](https://ascend.events/experience/call-for-content)) for ASCEND, a new outcomes-focused, transdisciplinary conference dedicated to the space economy.

ASCEND, happening 16–18 November 2020 in Las Vegas, Nevada, will focus on three macro themes:

- Accelerating the near-term commercialization of space
- Enabling the long-term human exploration and settlement of space
- Exploring the security, policy, and legal ramifications of space endeavors

Scientists, engineers, economists, educators, legal professionals, artists, investors, and entrepreneurs are among the wide range of experts invited to submit content. ASCEND will explore emerging space-related applications and opportunities across all industries such as aerospace, agriculture, construction, entertainment,

hospitality, manufacturing, mining, pharmaceuticals, and telecommunications.

Call for Content categories include, but are not limited to:

- Defining the space economy
- Education, outreach and workforce development
- Information systems and software
- National science priorities
- National security space
- Propulsion
- Space exploration architectures and enabling infrastructures
- Space life sciences and systems
- Space policy and law

- Space resource utilization
- Space traffic management and integration
- Transformative research and technologies

Subject-matter experts may submit to lead an engagement session, or present technical papers on their work in progress, completed research, and case studies. Submissions will be accepted at [ascend.events/cfc](https://ascend.events/cfc) through **17 March 2020**.

Contact *Nathan Boll*, [nathanb@aiaa.org](mailto:nathanb@aiaa.org), for more information about submissions. To register, visit [ascend.events](https://ascend.events).



**Issam Mudawar** (left), Purdue University, was the recipient of the 2019 AIAA Space Processing Award for “Recognizing decades of research and advances in fluid-based heat transfer in aerospace applications, including the Flow Boiling and Condensation Experiment in ISS.” The award, which honors significant contributions in space processing or in furthering the use of microgravity for space processing, was presented by **Sunil Chintalapati** (right), AIAA Microgravity and Space Processes Technical Committee Chair, at the American Society for Gravitational and Space Research (ASGSR) Meeting in November.

## Obituaries

### AIAA Associate Fellow Stull Died in August

**Dr. Frank D. "Don" Stull**, age 87, died on 9 August.

Dr. Stull graduated from Rensselaer Polytechnic Institute in 1953 (where he had been in the Air Force ROTC program), and received his commission as a 2nd Lieutenant in the U.S. Air Force.

He joined Westinghouse Electric as an engineer in the Management Training program before he was called to active duty and assigned to Wright-Patterson Air Force Base (WPAFB) as a test engineer providing in-house experimental support for the General Electric Aircraft nuclear propulsion program. Upon serving his two years of active duty at WPAFB he stayed on as a civilian project engineer in the Propulsion Laboratory, conducting analytic studies for the nuclear ramjet (PLUTO) and nuclear rocket (ROVER) programs. He was

selected by the Propulsion Laboratory to attend the Oak Ridge School of Reactor Technology in 1958 and upon returning to the Propulsion Laboratory was promoted to Group Leader with the Electro-Jet Nuclear Branch, responsible for the development of electric thrust devices for the Air Force.

After two years with the Atomic Energy Commission in Cincinnati, OH, Dr. Stull returned to the Propulsion Laboratory in 1962 as Assistant Chief of the Ramjet Component Branch conducting analytic studies on scramjet propulsion for the original Aerospace Plane program, and went on to obtain his M.S. Degree in Mechanical Engineering in 1959 and his Ph.D. Degree in Mechanical Engineering in 1972, both from Ohio State University. During his career he served as Chief of the Ramjet Technology Branch, Research Specialist for the Ramjet Engine Division, and Technical Advisor to the Advanced Propulsion Division. He made significant contributions in the 6.1 and 6.2 ramjet/scramjet field including such projects as the

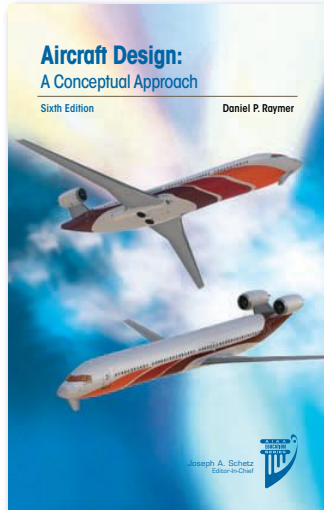
dual-mode scramjet, dump combustors, swirl combustors, combustor pressure oscillations in ramjet engines and the successful ramjet powered missile, ASALM, and flight test program.

In 1985 Dr. Stull was detailed to work on the DARPA Copper Canyon program which eventually led to the National Aerospace Plane program (NASP). Additionally he led the computational fluid dynamics effort in analyzing hypersonic propulsion systems and was a member of the NASP High Speed IPT Team. Upon retiring in 1994 after 40 years, he joined the Universal Technology Corporation, working as a consultant in the area of hypersonic propulsion for an additional 12 years.

Over the years, Dr. Stull served on many high-level national and international panels and committees as a recognized ramjet/scramjet propulsion expert. In 1998 he was awarded the Bondarjuk Medal by the Russian Federation of Aerosport for Dr. Stull's significant contribution to ram/scramjets research and international collaboration.

# NEW EDITION AVAILABLE

AIAA's #1 Selling Textbook



## Aircraft Design: A Conceptual Approach

Daniel Raymer

ISBN: 978-1-62410-490-9

Member: \$84.95

List: \$114.95

**Winner of the  
Summerfield  
Book Award**

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

### WHAT'S INCLUDED

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

- › Preliminary sizing
- › Configuration layout
- › Aerodynamics
- › Performance
- › Structures
- › Cost analysis
- › Stability and control
- › And much more!
- › Propulsion

### WHAT'S NEW?

- › Expanded and updated explanation of the fast-moving technologies in aircraft design.
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- › New chapter entitled “Electric Aircraft,” presenting technologies, design-to-guidance, and rules of thumb, and offers electric aircraft performance and sizing equations derived in a format familiar to those designing conventionally-powered airplanes.

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Additional awards include Co-Winner of the First AFADL S.D. Heron Award in 1964, Co-Inventor of the "Dual Mode Supersonic Combustion Ramjet Engine" in 1972, Outstanding Professional Achievement Award by the Engineering & Sciences Foundation of Dayton in 1976, the NASA Group Achievement Award in 1991, and the AIAA Lifelong Member Service Award for 50 years of sustained contribution in 2011.

## Former AIAA Member Spilker Died in September

**James Spilker Jr.**, a central figure in the technical development of the Global Positioning System (GPS) and an adjunct professor of aeronautics and astronautics at Stanford, died on 24 September. He was 86.

Spilker studied at College of Marin before transferring into Stanford University's undergraduate program in 1953. He earned his B.S., M.S., and Ph.D. degrees in electrical engineering at Stanford, where he became an expert in transistor electronics and communications theory.

Spilker's first job out of college was with Lockheed Research Labs in Palo Alto, where he invented the delay-lock loop process, an optimal receiver for tracking satellites. Spilker then joined Ford Aerospace to help build a multi-satellite communications system for the military. From there, he and two Ford colleagues co-founded Stanford Telecommunications, Inc., building the company from three employees to 1,300 by 1999. Throughout the 1960s, Spilker would author or co-author key papers on signal timing technologies that would later make possible the precise tracking of satellites necessary for triangulating a user's position on the ground.

In the early 1970s when Brad Parkinson approached Spilker about collaborating on the original GPS architecture. Spilker focused his efforts on improving both the accuracy and the economics of GPS to make the technology affordable.

Spilker and Parkinson co-authored *Global Positioning System: Theory and Applications* in 1996 (AIAA), the standard text for GPS. Spilker's popular textbook

*Digital Communications by Satellite*, first published in 1977, has seen 10 printings.

In 2001, Spilker joined Parkinson at Stanford as a consulting professor of aeronautics and astronautics. In 2005, he co-founded the Stanford University Center for Position, Navigation and Time, where he continued to work on satellite navigation.

Spilker was elected to the National Academy of Engineering, the Air Force GPS Hall of Fame and the Silicon Valley Engineering Hall of Fame, and was a Life Fellow of the IEEE and a Fellow of the Institute of Navigation. He also shared the Goddard Memorial Trophy with his collaborators on GPS. In 2015, he won the Thomas Edison Award from the IEEE. In 2019, Spilker was honored along with Parkinson and industry engineers Hugo Fruehauf and Richard Schwartz with the 2019 Queen Elizabeth Prize for Engineering (QEPrize) for their pioneering work in the development of GPS.

## AIAA Associate Fellow Atwell Died in October

**William (Bill) Atwell** passed away at the age of 80 on 11 October.

Atwell received a B.S. in Physics/Math (English minor), and an M.S. in Physics/Math from Indiana State University, and was a Ph.D. candidate in Nuclear Engineering at the University of Florida.

Atwell was an internationally recognized expert in the field of radiation physics with 40+ years of experience in the areas of space radiation environments, high-energy particle transport through materials, active and passive dosimetry, spacecraft, satellite, and anatomical modeling/shielding analysis, radiation detection instrumentation, biological and physical effects, and related data analyses. He was one of the original members

of the NASA Johnson Space Center (JSC) Space Radiation Analysis Group. His radiation research supported the NASA JSC Medical Sciences, Space & Life Sciences, and Engineering Directorate; NASA Jet Propulsion Laboratory; NASA Langley Research Center; and the European Space Agency (ESA)/German Space Agency.

Atwood authored over 250 technical and scientific publications, and was a science advisor/mentor for M.S./Ph.D. students at the University of Maryland, the University of Virginia, Colorado State University, USC, and Texas A&M University. He was the recipient of the Astronaut's Silver Snoopy Award, Tech Fellowship, and numerous NASA, NATO, AIAA, and SAE/Aerospace awards and commendations. He was a chair of the AIAA Life Sciences and Systems Technical Committee and he received a 2004 Sustained Service Award for "his outstanding contributions and dedications to promote AIAA goals at the Houston Section and national level."

## AIAA Associate Fellow Etherington Died in October

**Richard (Dick) Etherington**, age 89, passed away 24 October 2019.

Etherington earned his B.S. in Aeronautical Engineering from the University of Kansas in 1952. He began his professional career with Beech Aircraft in Wichita.

In 1968, he joined Lear Jet where he was Director, Technical Design and Configuration Development, designing business jets until he retired in 1995. Etherington loved all things related to airplanes, including owning and flying them, designing them, talking about them, reading about them, and building and flying models.

## Register Now for CVD 2020!

Registration is open for any AIAA member who would like to attend the 2020 Congressional Visits Day program, which will take place on 18 March in Washington, DC. AIAA is offering limited subsidies to assist members in their efforts to attend. Details about the event can be found at [aiaa.org/CVD2020](http://aiaa.org/CVD2020).

# AIAA Student Branches, 2019-2020

AIAA has over 230 student branches around the world. Each branch has a chair elected each year, and a faculty advisor who serves long term to support that branch's activities. Like the professionals, the student branches invite speakers, take field trips, promote career development, and participate in projects that introduce students to membership with AIAA and their professional futures. The branches, and their officers in particular, organize branch activities in addition to their full-time schoolwork, and their advisors clearly care deeply about their students' futures. Please join us in acknowledging the time and effort that all of them take to make their programs successful.

FA = Faculty Advisor  
SBC: Student Branch Chair

## REGION I

### Boston University

(New England)  
FA: Sheryl Grace  
SBC: Pien van Westendorp

### Brown University

(New England)  
FA: TBD  
SBC: TBD

### Carnegie Mellon University

(Mid-Atlantic)  
FA: TBD  
SBC: TBD

### Catholic University of America

(National Capital)  
FA: Diego Turo  
SBC: Virginia Boras

### City College – New York

(Long Island)  
FA: Prathap Ramamurthy  
SBC: Mazen Alhirsh

### Clarkson University

(Northeastern New York)  
FA: Kenneth Visser  
SBC: Colin Branigan

### Columbia University

(Long Island)  
FA: TBD  
SBC: Robert Sasse

### Cornell University

(Niagara Frontier)  
FA: Dmitry Savransky  
SBC: Christopher Chan

### Dartmouth University

(New England)  
FA: TBD  
SBC: TBD

### Drexel University

(Greater Philadelphia)  
FA: Ajmal Yousuff  
SBC: Derek Marshall

### George Washington University

(National Capital)  
FA: David Dolling  
SBC: Daniel Livshen

### Hofstra University

(Long Island)  
FA: TBD  
SBC: TBD

### Howard University

(National Capital)  
FA: Nadir Yilmaz  
SBC: Paa Sey

### Lehigh University

(Greater Philadelphia)  
FA: Terry Hart  
SBC: Ethan Imler

### Manhattan College

(Long Island)  
FA: John Leylegian  
SBC: Amber Perez

### Massachusetts Institute of Technology

(New England)  
FA: David Darmofal  
SBC: Blake Berk

### National Institute of Aerospace

(Hampton Roads)  
FA: TBD  
SBC: TBD

### New Jersey Institute of Technology

(Northern New Jersey)  
FA: Edward Dreyzin  
SBC: TBD

### New York Institute of Technology

(Long Island)  
FA: James Scire  
SBC: TBD

### NYU Tandon School of Engineering

(formerly Polytechnic Institute of Brooklyn)  
(Long Island)  
FA: TBD  
SBC: TBD

### Northeastern University

(New England)  
FA: Andrew Gouldstone  
SBC: Karl Swanson

### Old Dominion University

(Hampton Roads)  
FA: Colin Britcher  
SBC: Forrest Miller

### Pennsylvania State University

(Central Pennsylvania)  
FA: Robert Melton  
SBC: Nathan Osikowicz

### Princeton University

(Northern New Jersey)  
FA: Michael Mueller  
SBC: Michael Whitmore

### Rensselaer Polytechnic Institute

(Northeastern New York)  
FA: Farhan Gandhi  
SBC: Richard Healy

### Rochester Institute of Technology

(Niagara Frontier)  
FA: Daniel Kaputa  
FA: Agamemnon Crassidis  
SBC: Allen Snyder

### Rowan University

(Southern New Jersey)  
FA: John Schmalzel  
SBC: Pietro Sparacio

### Rutgers University

(Northern New Jersey)  
FA: Javier Diez  
SBC: Ruchita Sinha

### Southern New Hampshire University

(New England)  
FA: David Guo  
SBC: Rasheed Blake

### State University of New York – Buffalo

(Niagara Frontier)  
FA: Paul Schifferle  
SBC: Marianne Cites

### Stevens Institute of Technology

(Northern New Jersey)  
FA: Siva Thangam  
SBC: Pablo del Puerto

## The Yvonne C. Brill Lectureship in Aerospace Engineering

This premier lecture emphasizes research or engineering issues for space travel and exploration, aerospace education of students and the public, and other aerospace issues such as ensuring a diverse and robust engineering community.

Candidates should have a distinguished career involving significant contributions in aerospace research and/or engineering and will be selected based on technical experience, originality, and influence on other important aerospace issues such as ensuring a diverse and robust engineering community.

The award includes a \$1,000 cash prize and a \$1,000 travel stipend.

The lecture will be held at the National Academy of Engineering building in Washington, DC, in October 2020.



Yvonne Brill receiving the National Medal of Technology and Innovation from President Obama at the White House in 2011.

**NOMINATION DEADLINE: 1 FEBRUARY 2020**

For more details and nomination form, please visit

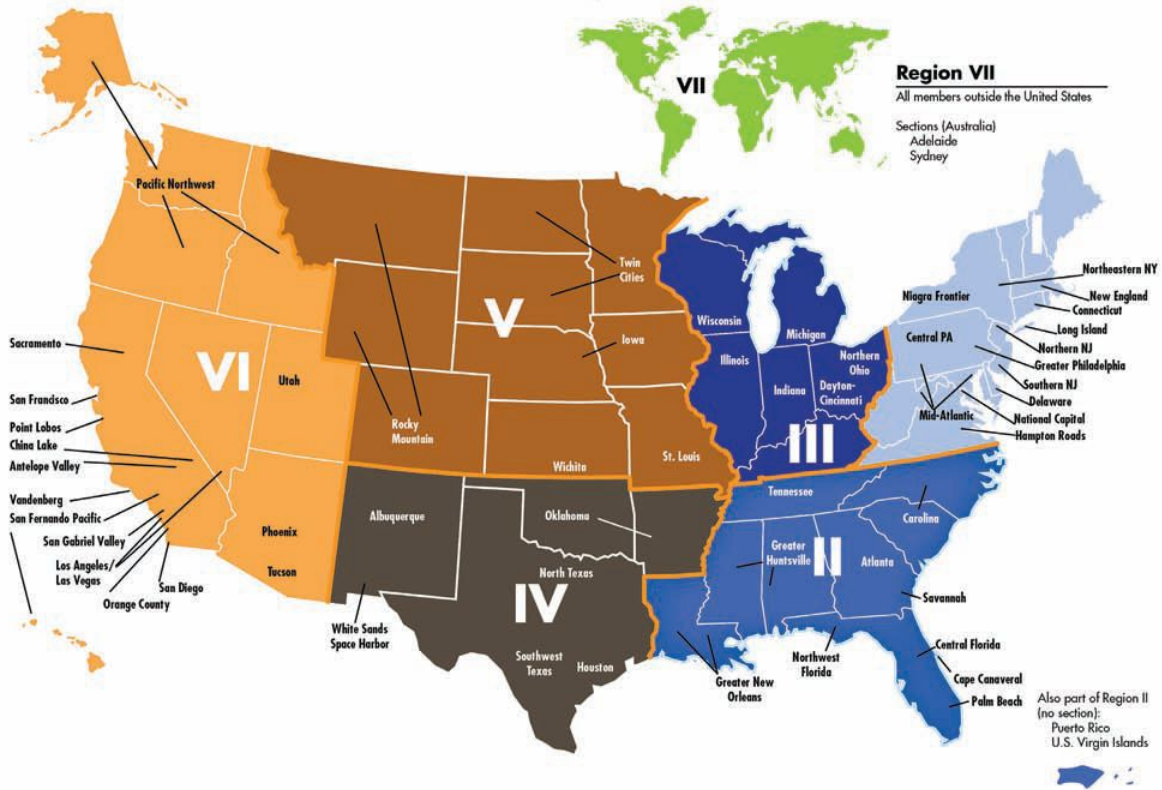
**[aiaa.org/brill](http://aiaa.org/brill)**



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AIAA SECTIONS AND GEOGRAPHICAL REGIONS



**Stony Brook University**  
(Long Island)  
FA: Sotirios Mamlis  
SBC: Le Si Qu

**Syracuse University**  
(Northwestern New York)  
FA: John Dannenhoffer  
SBC: Charles Keppler

**United States Military Academy/West Point**  
(Mid-Atlantic)  
FA: David Fobar  
SBC: TBD

**United States Naval Academy**  
(Mid-Atlantic)  
FA: Jeffrey King  
SBC: Ian Hardy

**University of Connecticut**  
(Connecticut)  
FA: Chih-Jen Sung  
SBC: Cody Corey

**University of Delaware**  
(Delaware)  
FA: TBD  
SBC: TBD

**University of Maine**  
(New England)  
FA: Alexander Friess  
SBC: TBD

**University of Maryland – Baltimore County**  
(Mid-Atlantic)  
FA: Charles Eggleton  
SBC: Micah Nissly

**University of Maryland – College Park**  
(National Capital)  
FA: Norman Weresley  
SBC: Quinn Kupec

**University of Massachusetts – Lowell**  
(New England)  
FA: Marianna Maiaru  
SBC: Jake Wilson

**University of Vermont**  
(New England)  
FA: TBD  
SBC: TBD

**University of Virginia**  
(National Capital)  
FA: Christopher Goyne  
SBC: Rikia Freeman

**Vaughn College of Aeronautics and Technology**  
(Long Island)  
FA: Amir Elzawawy  
SBC: Syed Misbahuddin

**Villanova University**  
(Greater Philadelphia)  
FA: Sergey Nersesov  
SBC: John Harding

**Virginia Polytechnic Institute and State University**  
(Hampton Roads)  
FA: Mayuresh Patil  
SBC: Abby Caslin

**Wentworth Institute of Technology**  
(New England)  
FA: Haifa El-Sadi  
SBC: Kylee Julia

**West Virginia University**  
(Mid-Atlantic)  
FA: Christopher Griffin  
SBC: Matthew Andrews

**Worcester Polytechnic University**  
(New England)  
FA: John Blandino  
SBC: Jarod Romankiw

**Yale University**  
(Connecticut)  
FA: Mitchell Smooke  
SBC: Rowan Palmer

**REGION II**  
**Alabama A&M University**  
(Greater Huntsville)  
FA: TBD  
SBC: TBD

**Athens State University**  
(Greater Huntsville)  
FA: J Wayne McCain  
SBC: Katherine Brewer

**Auburn University**  
(Greater Huntsville)  
FA: Norman Speakman  
SBC: Tristan Macke

**Duke University**  
(Carolina)  
FA: Kenneth Hall  
SBC: Miles Burnette

**East Carolina University**  
(Carolina)  
FA: Tarek Abdel-Salam  
SBC: Jacob Rose

**Embry-Riddle Aeronautical University – Daytona Beach, FL**  
(Central Florida)  
FA: Habib Eslami  
SBC: Thomas Van Veldhuisen

**Florida A&M University**  
(Northwest Florida)  
FA: Chiang Shih  
SBC: TBD

**Florida Institute of Technology**  
(Cape Canaveral)  
FA: David Fleming  
SBC: Archit Srivastava

**Florida International University**  
(Palm Beach)  
FA: George Dulikravich  
SBC: Matthew Barreto

**Florida State University**  
(Northwest Florida)  
FA: Chiang Shih  
SBC: Austin Robertson

**Georgia Institute of Technology**  
(Atlanta)  
FA: Dimitri Mavris  
SBC: Savas Mavridis

**Kennesaw State University**  
(Atlanta)  
FA: Adeel Khalid  
SBC: Cindy Vo

**Louisiana State University**  
(Greater New Orleans)  
FA: Keith Gonthier  
SBC: Marie Allain

**Mississippi State University**  
(Greater Huntsville)  
FA: Robert Wolz  
SBC: Savannah Metz

**North Carolina A&T State University**  
(Carolina)  
FA: Michael Atkinson  
SBC: Donovan McGruder

**Polytechnic University of Puerto Rico**  
(Palm Beach)  
FA: Jose Pertierra  
SBC: Hector Marini

**Tuskegee University**  
(Greater Huntsville)  
FA: Mohammad Khan  
SBC: Maya York

**University of Alabama at Birmingham**  
(Greater Huntsville)  
FA: Roy Koomullil  
SBC: Jordan Whitson

**University of Alabama at Huntsville**  
(Greater Huntsville)  
FA: Brian Landrum  
SBC: Jacob Clark

**University of Alabama at Tuscaloosa**  
(Greater Huntsville)  
FA: Weihua Su  
SBC: Peyton Strickland

**University of Central Florida**  
(Central Florida)  
FA: Seetha Raghavan  
SBC: Mikaela Black

**University of Florida**  
(Central Florida)  
FA: Richard Lind  
SBC: Max Chern

**University of Memphis**  
(Tennessee)  
FA: Jeff Marchetta  
SBC: William Bowen

**University of Miami**  
(Palm Beach)  
FA: Ryan Karkkainen  
SBC: Lei Wang

**University of Mississippi**  
(Greater Huntsville)  
FA: Erik Hurlen  
SBC: Annie Richardson

**University of Puerto Rico**  
(Palm Beach)  
FA: Guillermo Aray  
SBC: Harrison Rivera

**University of South Alabama**  
(Greater Huntsville)  
FA: Carlos Montalvo  
SBC: Andrew Givens

**University of South Carolina**  
(Carolina)  
FA: Michael Van Tooren  
SBC: TBD

**University of South Florida**  
(Central Florida)  
FA: TBD  
SBC: TBD

**University of Tennessee**  
(Tennessee)  
FA: James Coder  
SBC: Christopher Busic

**University of Tennessee Space Institute**  
(Tennessee)  
FA: Trevor Moeller  
SBC: Katherine Stamper

**Vanderbilt University**  
(Tennessee)  
FA: Amratur Anilkumar  
SBC: Alexander Barnett

### REGION III

**Air Force Institute of Technology**  
(Dayton/Cincinnati)  
FA: Marc Polanka  
SBC: Matthew Fuqua

**Case Western Reserve University**  
(Northern Ohio)  
FA: Paul Barnhart  
SBC: Genevieve Timmermann

**Cleveland State University**  
(Northern Ohio)  
FA: Nicole Strah  
SBC: Dan Londrigo

**Illinois Institute of Technology**  
(Illinois)  
FA: Boris Pervan  
SBC: Zoey Krevitz

**Indiana University-Purdue University Indianapolis (IUPUI)**  
(Indiana)  
FA: Hamid Dalir  
SBC: William Conover

**Kettering University**  
(Michigan)  
FA: TBD  
SBC: TBD

**Lawrence Technological University**  
(Michigan)  
FA: Andrew Gerhart  
SBC: Brent Bartone

**Miami University**  
(Dayton/Cincinnati)  
FA: Ryan Clark  
SBC: Dylan Shumway

**Michigan State University**  
(Michigan)  
FA: Patton Allison  
SBC: Jonathan Swavely

**Milwaukee School of Engineering**  
(Wisconsin)  
FA: William Farrow  
SBC: Zachary Runte

**Ohio Northern University**  
(Dayton/Cincinnati)  
FA: Jed Marquart  
SBC: Zane Myers

**Ohio State University**  
(Dayton/Cincinnati)  
FA: Ali Jhemi  
SBC: Austin Karr

**Ohio University**  
(Dayton/Cincinnati)  
FA: Dennis Irwin  
SBC: Alex Polacek

**Purdue University**  
(Indiana)  
FA: Li Qiao  
SBC: Neal Ottinger

**Rose-Hulman Institute of Technology**  
(Indiana)  
FA: Calvin Lui  
SBC: Samantha McCuaig

**Trine University**  
(Indiana)  
FA: James Canino  
SBC: Caroline Hipskind

**University of Akron**  
(Northern Ohio)  
FA: Alexander Povitsky  
SBC: Rishabh Gadi

**University of Cincinnati**  
(Dayton/Cincinnati)  
FA: George Black  
SBC: Matthew Ha

**University of Dayton**  
(Dayton/Cincinnati)  
FA: Sidaard Gunasekaran  
SBC: Kathleen Mae Abel

**University of Illinois-Chicago**  
(Illinois)  
FA: Kenneth Brezinsky  
SBC: Kathleen Mae Galicia

**University of Illinois at Urbana-Champaign**  
(Illinois)  
FA: Laura Villafane-Roca  
SBC: Ari Jain

**University of Kentucky**  
(Dayton/Cincinnati)  
FA: Alexandre Martin  
SBC: Christopher Sanders

**University of Kentucky-Paducah**  
(Dayton/Cincinnati)  
FA: Sergiy Markutsya  
SBC: Lexi Parks

**University of Michigan at Ann Arbor**  
(Michigan)  
FA: Ella Atkins  
SBC: James Stieber

**University of Notre Dame**  
(Indiana)  
FA: Thomas Juliano  
SBC: Michael Rogers

**University of Wisconsin at Madison**  
(Wisconsin)  
FA: Matthew Allen  
SBC: Andrew Marek

**University of Wisconsin at Milwaukee**  
(Wisconsin)  
FA: Ryoichi Amano  
SBC: Abdel Rahman Salem

**Western Michigan University**  
(Michigan)  
FA: Peter Gustafson  
SBC: Avery Maurer

**Wright State University**  
(Dayton/Cincinnati)  
FA: Rory Roberts  
SBC: Hunter Gilliland

**Youngstown State University**  
(Northern Ohio)  
FA: Kevin Disotell  
SBC: David Irwin

### REGION IV

**New Mexico State University**  
(White Sands/Space Harbor)  
FA: Andreas Gross  
SBC: Noah Kohler

**Oklahoma State University**  
(Oklahoma)  
FA: Andrew Arena  
SBC: Timothy Runnels

**Rice University**  
(Houston)  
FA: Andrew Meade  
SBC: Wyatt Crider

**Texas A&M University – College Station**  
(Houston)  
FA: Gregory Chamitoff  
SBC: Jared Blunt

**University of Arkansas-Fayetteville**  
(Oklahoma)  
FA: Po-Hao Huang  
SBC: TBD

**University of Houston**  
(Houston)  
FA: Edgar Bering  
SBC: Daniel Kolodziejczyk

**University of New Mexico**  
(Albuquerque)  
FA: Svetlana Poroseva  
SBC: Patrick Arite

**University of Oklahoma**  
(Oklahoma)  
FA: Thomas Hays  
SBC: Alexandria Caudill

**University of Texas at Arlington**  
(North Texas)  
FA: Zhen-Xue Han  
SBC: Chelsi Nelson

**University of Texas at Austin**  
(Southwest Texas)  
FA: Renato Zanetti  
SBC: TBD

**University of Texas at Dallas**  
(North Texas)  
FA: Arif Malik  
SBC: TBD

**University of Texas at El Paso**  
(White Sands/Space Harbor)  
FA: Jack Chessa  
SBC: TBD

# NOMINATIONS NOW BEING ACCEPTED

The **Daniel Guggenheim Medal** is awarded for notable achievements in the advancement of aeronautics. The medal is regarded by many as the greatest honor that can be presented for a lifetime of work in the aeronautical field.

This medal is jointly sponsored by AIAA, the American Society of Mechanical Engineers, SAE International, and the Vertical Flight Society. The award is generally presented at the AIAA Aerospace Spotlight Awards Gala in Washington, DC.



### Past Recipients Include:

Orville Wright  
William Boeing

William Durand  
Donald Douglas

Igor Sikorsky  
Charles Stark Draper

### Nomination Deadline: 1 February 2020

For more information and for nomination forms, please visit [guggenheimmedal.org](http://guggenheimmedal.org)



**University of Texas at San Antonio**  
(Southwest Texas)  
FA: Christopher Combs  
SBC: Austin Rendon

**REGION V**

**Colorado School of Mines**  
(Rocky Mountain)  
FA: Angel Abbud-Madrid  
SBC: Brianne Treffner

**Colorado State University-Fort Collins**  
(Rocky Mountain)  
FA: Xinfeng Gao  
SBC: Brennan O'Connor

**Iowa State University**  
(Iowa)  
FA: Anupam Sharma  
SBC: Megan Runyan

**Kansas State University**  
(Wichita)  
FA: TBD  
SBC: TBD

**Metropolitan State University of Denver**  
(Rocky Mountain)  
FA: Jose Lopez  
SBC: Randy Owen

**Missouri University of Science and Technology**  
(St. Louis)  
FA: Kakkattukuzhy Isaac  
SBC: Annika Highley

**North Dakota State University**  
(Twin Cities)  
FA: Yildirim Suzen  
SBC: TBD

**Saint Louis University**  
(St. Louis)  
FA: Michael Swartwout  
SBC: Rebecca Lolocono

**United States Air Force Academy**  
(Rocky Mountain)  
FA: Barrett McCann  
SBC: TBD

**University of Colorado at Boulder**  
(Rocky Mountain)  
FA: Donna Gerren  
SBC: James Guthrie

**University of Colorado at Colorado Springs**  
(Rocky Mountain)  
FA: Lynnane George  
SBC: Ryan Kight

**University of Iowa**  
(Iowa)  
FA: Kamran Samani  
SBC: Joseph Jalowiec

**University of Kansas**  
(Wichita)  
FA: Ronald Barrett-Gonzalez  
SBC: Joe Ruis

**University of Minnesota**  
(Twin Cities)  
FA: Yohannes Ketema  
SBC: Robert Halverson

**University of Missouri at Columbia**  
(St. Louis)  
FA: Craig Kluever  
SBC: James Fritsch

**University of North Dakota**  
(Twin Cities)  
FA: TBD  
SBC: TBD

**University of Wyoming**  
(Rocky Mountain)  
FA: TBD  
SBC: TBD

**Washington University in St. Louis**  
(St. Louis)  
FA: Swami Karunamoorthy  
SBC: Jonathan Richter

**Wichita State University**  
(Wichita)  
FA: Scott Miller  
SBC: Colton Wagner

**REGION VI**

**Arizona State University**  
(Phoenix)  
FA: Timothy Takahashi  
SBC: Omar Alavi

**Boise State University**  
(Pacific Northwest)  
FA: TBD  
SBC: TBD

**Brigham Young University**  
(Utah)  
FA: Andrew Ning  
SBC: Jon Rice

**California Institute of Technology**  
(San Gabriel Valley)  
FA: TBD  
SBC: Luis Pabon Madrid

**California Polytechnic State University, Pomona**  
(San Gabriel Valley)  
FA: Subodh Bhandari  
SBC: Andres Hernandez

**California Polytechnic State University, San Luis Obispo**  
(Vandenberg)  
FA: Aaron Drake  
SBC: TBD

**California State University, Fresno**  
(Antelope Valley)  
FA: Deify Law  
SBC: Kyle Sweeney

**California State University, Fullerton**  
(Orange County)  
FA: Salvador Mayoral  
SBC: TBD

**California State University, Long Beach**  
(Los Angeles-Las Vegas)  
FA: Eric Besnard  
SBC: Ian Clavio

**California State University, Northridge**  
(San Fernando Pacific)  
FA: Peter Bishay  
SBC: Mathan Vasu

**California State University, Sacramento**  
(Sacramento)  
FA: Ilhan Tuzcu  
SBC: TBD

**Embry-Riddle Aeronautical University, Prescott**  
(Phoenix)  
FA: David Lanning  
SBC: Elizabeth Mitchell

**Northern Arizona University**  
(Phoenix)  
FA: TBD  
SBC: TBD

**Oregon State University**  
(Pacific Northwest)  
FA: Roberto Albertani  
FA: Nancy Squires  
SBC: Amy Caldwell

**Portland State University**  
(Pacific Northwest)  
FA: Andrew Greenberg  
SBC: Kathleen Joslyn

**San Diego State University**  
(San Diego)  
FA: Allen Plotkin  
SBC: Diego Chavez

**San Jose State University**  
(San Francisco)  
FA: Periklis Papadopoulos  
SBC: Fernando Ferreira-Velaquez

**Santa Clara University**  
(San Francisco)  
FA: Christopher Kitts  
SBC: Karla Raigoza

**Stanford University**  
(San Francisco)  
FA: Stephen Rock  
SBC: Harsh Patel

**University of Alaska, Fairbanks**  
(Pacific Northwest)  
FA: Michael Hatfield  
SBC: Michael Radotich

**University of Arizona**  
(Tucson)  
FA: Jekan Thangavelautham  
SBC: Amanda Fordyce

**University of California, Berkeley**  
(San Francisco)  
FA: George Anwar  
SBC: Parker Trautwein

**University of California, Davis**  
(Sacramento)  
FA: Ronald Hess  
FA: Case Van Dam  
SBC: Andrew Arends

**University of California, Irvine**  
(Orange County)  
FA: Haitham Taha  
SBC: Grant Tsuji

**University of California, Los Angeles**  
(Los Angeles/Las Vegas)  
FA: Jeff Eldredge  
SBC: Oliver Lam

**University of California, Merced**  
(Sacramento)  
FA: YangQuan Chen  
SBC: Tommy Hang

**University of California, San Diego**  
(San Diego)  
FA: Mark Anderson  
SBC: Laura Morejon Ramirez

**University of Idaho**  
(Pacific Northwest)  
FA: TBD  
SBC: TBD

**University of Nevada, Las Vegas**  
(Los Angeles/Las Vegas)  
FA: William Culbreth  
SBC: Sophia Leon

**University of Nevada, Reno**  
(Sacramento)  
FA: Jeffrey LaCombe  
SBC: Barry Jones

**University of Southern California**  
(Los Angeles/Las Vegas)  
FA: Geoffrey Spedding  
SBC: Randi Arteaga

**University of Utah**  
(Utah)  
FA: TBD  
SBC: TBD

**University of Washington at Seattle**  
(Pacific Northwest)  
FA: Behcet Acikmese  
SBC: TBD

**Utah State University**  
(Utah)  
FA: Stephen Whitmore  
SBC: Bryson Jaipean

**Washington State University**  
(Pacific Northwest)  
FA: Jacob Leachman  
SBC: Daniel Falslev

**Weber State University**  
(Utah)  
FA: TBD  
SBC: TBD

**REGION VII**

(All student branches outside of the United States)

**Beihang University**  
FA: Zhiqiang Wan  
SBC: Jing Pu

**British University in Egypt**  
FA: Talat Refai  
SBC: TBD

**Cairo University**  
FA: TBD  
SBC: TBD

**Carleton University**  
FA: Steve Ulrich  
SBC: Carmen Huang

**Chulalongkorn University**  
FA: Joshua Staubs  
SBC: Supakorn Suttiruang

**Concordia University**  
FA: Hoi Dick Ng  
SBC: TBD

**Ecole Polytechnique de Montreal**  
FA: TBD  
SBC: TBD

**Emirates Aviation College**  
FA: TBD  
SBC: TBD

**Ghulam Ishaq Khan Institute of Engineering Sciences and Technology (GIKT)**  
FA: TBD  
SBC: TBD

**Hindustan University**  
FA: TBD  
SBC: TBD

**Hong Kong University of Science and Technology**  
FA: Larry Li  
FA: Wei Shyy  
SBC: Marco Clark

**Indian Institute of Technology, Kanpur (IIT)**  
FA: Ajoy Ghosh  
SBC: TBD

**Institute of Space Technology, Pakistan**  
FA: Shuja Rehman  
SBC: Abdul Munem Khan

**Istanbul Technical University**  
FA: Gokhan Inalhan  
SBC: TBD

**Khalifa University of Science, Technology, and Research**  
FA: Ashraf Al-khateeb  
SBC: Nouf Al Suwaidi

**Korea Advanced Institute of Science and Technology**  
FA: Jiyun Lee  
SBC: Yujoo Kang

**McGill University**  
FA: TBD  
SBC: TBD

**Middle East Technical University**  
FA: TBD  
SBC: TBD

**MLR Institute of Technology**  
FA: TBD  
SBC: TBD

**Monash University**  
FA: Daniel Edgington-Mitchell  
SBC: Sweta Balakrishna

**Moscow Aviation Institute**  
FA: TBD  
SBC: TBD

**Nagoya University**  
FA: TBD  
SBC: TBD

**Nanjing University of Aeronautics and Astronautics**  
FA: TBD  
SBC: TBD

**Northwest Polytechnical University**  
FA: TBD  
SBC: TBD

**Queen's University**  
FA: TBD  
SBC: TBD

**Royal Melbourne Institute of Technology**  
FA: Cees Bil  
SBC: Thang Nguyen

**Royal Military College of Canada**  
FA: Ruben Perez  
SBC: TBD

**Ryerson Polytechnic University**  
FA: Sayed Hashimi  
SBC: TBD

**Sapienza Universita di Roma**  
FA: Giuliano Coppotelli  
SBC: Filippo Russomando

**Technion Institute of Technology**  
FA: TBD  
SBC: TBD

**United Arab Emirates University**  
FA: Emad Elnajjar  
SBC: TBD

**Universidad Autonoma de Baja California**  
FA: Juan Antonio Paz  
SBC: Christian Sanchez

**Universidad Autonoma de Chihuahua**  
FA: Eloy Normando Marquez Gonzalez  
SBC: Fernando Fernandez

**Universidad de San Buenaventura**  
FA: Ruben Salazar  
SBC: TBD

**Universidad Pontificia Bolivariana**  
FA: TBD  
SBC: TBD

**Universita degli Studi di Napoli Federico II**  
FA: Francesco Marulo  
SBC: TBD

**Universitat Stuttgart**  
FA: TBD  
SBC: TBD

**University of Adelaide**  
FA: Rey Chin  
SBC: Natalie Hayman

**University of New South Wales (Sydney)**  
FA: Danielle Moreau  
SBC: Arfin Trisakti

**University of Palermo**  
FA: TBD  
SBC: TBD

**University of Queensland**  
FA: TBD  
SBC: TBD

**University of Sydney**  
FA: Gareth Vio  
SBC: Cole Scott-Curwood

**University of Toronto**  
FA: TBD  
SBC: TBD

**Von Karman Institute of Fluid Dynamics**  
FA: TBD  
SBC: TBD



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## 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: dynamics and controls; flight dynamics; space systems and hardware; and aerospace structures, materials and manufacturing. 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 or materials 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 50% in last five years to nearly 500 students. This growth has been complemented by aggressive faculty hiring with the department now consisting of four full professors, ten assistant professors and three 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 70 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 6,000 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](http://www.eng.auburn.edu/aero).

Auburn University ([www.auburn.edu](http://www.auburn.edu)) is one of the nation's premier public land-grant institutions. In 2019, 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 2019 enrollment of 30,460 students includes 24,594 undergraduates and 5,866 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 ([www.auburnalabama.org](http://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, and three references at: <http://aufacultypositions.peopleadmin.com/postings/3927>. 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 January 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 an EEO/Vet/Disability Employer



TEXAS A&M UNIVERSITY  
Department of  
Aerospace Engineering

The Department of Aerospace Engineering, College of Engineering at Texas A&M University invites applications for five full-time tenured or tenure-track faculty positions with a 9-month academic appointment, and the possibility of an additional summer appointment contingent upon need and availability of funds, beginning September 1, 2020. Applicants will be considered for the faculty titles of assistant, associate and full professor. Candidates should have expertise in:

- **Reactive Flow, Computational or Experimental**, computational combustion, computational propulsion, numerical algorithms and code development; experience using numerical simulations on high-performance computing and computers to understand and study reactive flows, all fluid regimes of interest, and/or experimental studies of fundamental reactive flow and combustion, as applied to energy, safety, and propulsion; experience with shock and detonation tubes or other instrumentation and diagnostics for high studies of reactive flows. (<http://apply.interfolio.com/71367>)
- **Flight Systems**, aerodynamics, hypersonic flow, high temperature materials, boundary layer stability, turbulence modeling, wind tunnel testing, computational fluid dynamics and vehicle design. (<http://apply.interfolio.com/71267>)
- **Human Spaceflight Systems**, spacecraft systems and human factors, digital human modeling and simulation, aerospace materials (e.g. woven fabrics), embedded systems, structural dynamics, partial gravity fluid physics, environmental life support systems, displays and controls, additive manufacturing, aerospace systems engineering/robotics, design for extreme environments, and spacecraft/habitat design. (<http://apply.interfolio.com/71277>)

The successful applicants will be required to teach, advise and mentor graduate students; develop an independent, externally funded research program; participate in all aspects of the department's activities; and serve the profession. Strong written and verbal communication skills are required. Applicants should consult the department's website to review our academic and research programs (<http://aerospacengr.tamu.edu/aerospacengr>).

Applicants must have an earned doctorate in aerospace engineering or a closely related engineering or science discipline. Applicants should submit a cover letter, curriculum vitae, teaching statement, research statement, diversity statement (optional) and a list of four references (including postal addresses, phone numbers and email addresses) by applying for the specific position provided in the above links. Full consideration will be given to applications received by December 30, 2019. Applications received after that date may be considered until positions(s) are filled. It is anticipated the appointment(s) will begin fall 2020.

The vision of Department of Aerospace Engineering at Texas A&M is a nationally and internationally renowned program that attracts the world's top faculty and students and promotes a passion for learning and applying the knowledge of science and engineering to lead in providing solutions to the most challenging problems in the field. The sixty-one tenured/tenure-track faculty include eight members of the National Academy of Engineering and seven endowed positions. The student body is made up of 630 undergraduates and 175 graduate students. The department is committed to an extensive suite of facilities to enable leading research. The graduate and undergraduate programs are ranked 6th and 7th, respectively, among public institutions by U.S. News & World Report.

Texas A&M University is committed to creating 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/Minorities/Disability Employer committed to diversity.

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**UNITED STATES AIR FORCE ACADEMY**  
**ASSISTANT PROFESSOR OF AERONAUTICAL ENGINEERING**  
**(#19-57DFAN)**

The Department of Aeronautical Engineering anticipates hiring an Assistant Professor beginning June 22, 2020. The initial appointment will be for three years. Reappointments are possible. Applications are invited from candidates who can contribute to the United States Air Force Academy mission by interacting with cadets, both in and out of the classroom. Successful candidates will demonstrate the potential for teaching excellence, academic service, and sustained intellectual contributions in one or more of the following: airbreathing propulsion, fluid dynamics, flight mechanics, aircraft structures, and aircraft design. Duties will include instruction ranging from introductory to advanced undergraduate engineering courses, research, academic advising, mentoring cadets, and fulfilling department duties and other service to the institution. An earned doctorate (completed no later than June 22, 2020) in Aeronautical, Aerospace, Mechanical or a related engineering field is required. To Apply: Go to [www.usajobs.gov](http://www.usajobs.gov). Type in "Professor" in the "Keywords" box and "USAF Academy" in the Location box and click "Search." Scroll down until you locate this position. *Applications must be received by February 16, 2020. U. S. citizenship required.*



**Faculty Position in Astronautics and Space Applications**

**Embry Riddle Aeronautical University, Daytona Beach Department of Aerospace Engineering**

The Department of Aerospace Engineering at Embry-Riddle Aeronautical University (ERAU) in Daytona Beach, Florida has an ambitious agenda for the next five years, which is focused on expanding its graduate programs, research capabilities, facilities, and recruiting highly talented faculty. In support of this agenda, the University has invested in a new 50,000 square foot engineering building, the John Miles Engineering and Aerospace Innovation Complex (MilesPlex), housing several research laboratories and a new state-of-the-art subsonic wind tunnel, which were completed within the last two years.

The Department invites applications for a tenure-track/faculty position at the rank of Assistant, Associate, or Full Professor. Successful applicants for the Assistant rank should demonstrate a potential to establish and grow a strong research program and to excel at teaching and mentoring undergraduates and graduate students. Applicants for the Associate rank should have an exemplary record of teaching and scholarly activities including externally funded research. Appointment at the Professor rank will be considered for individuals with exceptional qualifications and national recognition. The preferred area of expertise is astronautics and space applications. However, applicants in all areas of Aerospace Engineering will be considered.

Current research thrust areas of the Department include: autonomous, guidance, navigation and control, unmanned and autonomous robotic systems, urban air mobility, computational fluid dynamics, sensor fusion, spacecraft aerodynamics, flow control, alternative propulsion, air-breathing hypersonic and rocket propulsion, manufacturability, composites, microsystems, smart materials, structural health monitoring, computational structural mechanics, and design optimization.

The Department, the largest in the nation with an enrollment of over 1650 full-time students, offers Bachelor, Master, and Ph.D. degrees, including 95 students in our Ph.D. program. The undergraduate program is currently ranked #4 (tie) and the graduate program is ranked #29 (tie), by *U.S. News and World Report*. ERAU, the world's largest, fully accredited university specializing in aviation and aerospace, offers more than 70 Baccalaureate, Master, and Ph.D. degree programs in Arts & Sciences, Aviation, Business, and Engineering. ERAU's eastern campus is located at Daytona Beach and serves a diverse student body of approximately 6,400 undergraduates and 650 graduate students.

Candidates should have an earned Doctorate in Aerospace Engineering or a closely related field. Women and underrepresented minorities are especially encouraged to apply. Applicants must submit a single document that includes: (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. For more information about the position and application process, please visit our careers site, <http://careers.erau.edu>, and search for requisition no. 190360. For full consideration, candidates are encouraged to apply before January 20th, 2020. Screening of the applications will start upon receipt and will continue until the positions are filled.

# 1920 1945

**Jan. 21** The British Royal Air Force sends a squadron of de Havilland D.H. 9 light bombers to quell a revolt in British Somaliland. The British quickly expel Mohammed bin Abdullah Hassan, the founder of the Dervish movement who led a 20-year war against European colonialism. David Baker, **Flight and Flying: A Chronology**, p. 131; **Derek O'Connor Hunt for the Mad Mullah**, Historynet.com.



**Jan. 24** Five Breguet 16 aircraft leave Paris for Dakar, Senegal, under the command of French Maj. Joseph Vuillemin. Only three aircraft make it as far as Algeria. Of these, only Vuillemin's completes the flight across the Sahara with a stop in Timbuktu, arriving in Dakar on March 31. David Baker, **Flight and Flying: A Chronology**, p. 131.

**Jan. 24** Flying the first Vickers Vimy, G-EAAV, Capt. F.C.G. Broome and Capt. S. Cockerell of the British Royal Air Force seek to win the Daily Mail's prize for the first flight from Cairo to Capetown. They leave Brooklands, England, and proceed south before making a crash landing in Tanganyika one month later. David Baker, **Flight and Flying: A Chronology**, p. 131.

**Jan. 3** Fifty-seven Boeing B-29s attack the Japanese city of Nagoya with incendiary bombs. It is the first of three raids to test the effectiveness of incendiaries against Japanese cities, which have mostly wood structures. While the results of this raid are inconclusive, subsequent fire bombings prove devastating, especially against Tokyo. David Baker, **Flight and Flying: A Chronology**, p. 300.

**Jan. 9** Boeing test pilot Elliott Merrill breaks the U.S. coast-to-coast record when he flies a prototype Boeing C-97 Stratofreighter 3,739 kilometers (2,323 miles) from Seattle to Washington, D.C., in six hours, three minutes, at an average speed of 616 kph (383 mph). The aircraft carries a total payload of 9,000 kilograms. **The Aeroplane**, Jan. 19, 1945, p. 79; **The Aeroplane**, Feb. 16, 1945, p. 192.



**Jan. 20** Aerodynamicist Robert T. Jones of the National Advisory Committee for Aeronautics, forerunner of NASA, formulates the swept-back wing configuration to overcome shock-wave effects at critical Mach numbers. By March he verifies the concept in wind tunnel experiments at Langley Memorial Aeronautical Laboratory in Virginia; he is unaware of parallel work in wartime Germany. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 49.



**Jan. 24** Germany test-launches an A-4b rocket, a V-2 with wings to make it glide an estimated 160 kilometers farther than the wingless V-2. The A-4b climbs to an altitude of 250,000 feet at 4,345 kph, then glides down before crashing. No more tests are done. Frank H. Winter, **Rockets Into Space**, p. 50.

**Jan. 26** Powered by two Westinghouse 19 XB-2B turbo jet engines of 5,182 newtons (1,165 pounds) thrust each, the first McDonnell XFD-1 Phantom jet fighter completes its initial flight. The Phantom is built for carrier operations with the U.S. Navy and has a top speed of 783 kph. Rene J. Francillon, **McDonnell Douglas Aircraft Since 1920**, pp. 380-383.

# 1970

**Jan. 1** The Apollo 11 lunar landing is considered the biggest news story of 1969, in an Associated Press poll, while astronaut Neil Armstrong is voted the top newsmaker. **Washington Star**, Jan. 1, 1970, p. A3.



**Jan. 3** Photos of a falling meteorite are taken by automatic cameras at Hominy, Oklahoma, and Pleasanton, Kansas, field stations of the Prairie Network operated for NASA by the Smithsonian Astrophysical Observatory. The meteorite entered Earth's atmosphere at 56,300 kph, creating a trail that is visible for nine seconds. **Boston Globe**, Jan. 20, 1970.

**Jan. 4** The Lunar Science Institute in Houston is dedicated by NASA Administrator Thomas O. Paine and other NASA officials. The institute, whose name will be changed to the Lunar and Planetary Institute in 1978, is open to all scientists, including those from Iron Curtain countries, and geologist William Rubey of the University of California is named the first director. **Houston Post**, Jan. 5, 1970.



**Jan. 5-9** The Apollo 11 Lunar Science Conference is held at the Marshall Space Flight Center in Alabama during which the results are presented of the first systematic studies of lunar samples from the mission. The studies have been made by 500 scientists from nine countries. NASA, **Astronautics and Aeronautics, 1970**, pp.4-6.

**Jan. 8** Col. Douglas Frost of the U.S. Air Force sets a flight endurance record of 10 hours for the Ling-Temco-Vought A-7A Corsair subsonic light attack aircraft. Frost piloted two round-trip flights from Edwards Air Force Base, California, to New Mexico, covering a total flight distance of 8,047 kilometers. NASA, **Astronautics and Aeronautics, 1970**, p. 7.

# 1995

**Jan. 8** The U.S. and Australia are to jointly begin the construction of a top-secret communications station at Australia's Woomera rocket range, the Associated Press reports. The station is to be used for space and defense programs. NASA, **Aeronautics and Astronautics**, 1970, p. 7.

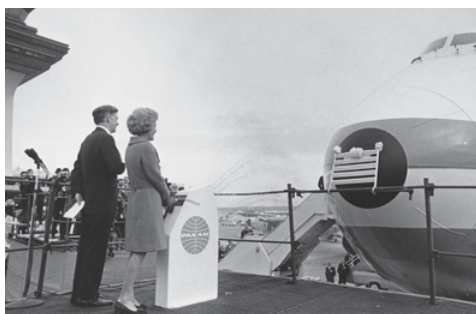
**Jan. 9** The importance of studying asteroids is cited in the Jan. 9 issue of the journal *Science* by Hannes O. Alfvén of the Royal Institute of Technology in Stockholm and the University of California and Gustaf O.S. Arrhenius of the Scripps Institute of Oceanography. Among some of the reasons given is that the asteroid belt "represents an intermediate stage in the formation of the planets." Therefore, "in order to understand how the solar system originated it may be essential to explore the asteroids." *Science*, Jan. 9, 1970, pp. 139-141.

**Jan. 9** Astronaut Neil Armstrong receives an honorary Doctor of Engineering degree from Purdue University in Indiana, one of many such honorary degrees conferred upon the first man on the moon. *Washington Post*, Jan. 10, 1970.

**Jan. 10** Soviet cosmonaut Pavel Ivanovich Belyayev, who commanded the historic Voskhod 2 mission that included the first spacewalk in 1965, dies in Moscow. The spacewalk was conducted by his crewman, Alexei Arkhipovich Leonov. Belyayev also served as the first commander of the cosmonaut corps. *Washington Star*, Jan. 11, 1970, p. D6.



**Jan. 12** Blanche Scott, who was possibly the first American woman aviator, dies in Rochester, New York, at age 84. Scott made a solo flight in Hammondsport, New York, on Sept. 6, 1910, in a Curtiss Pusher aircraft and became the first woman to ride in a jet in 1948, a Lockheed TF-80C piloted by Chuck Yeager. *Washington Post*, Jan. 14, 1970, p. C-6.



**Jan. 15** The Boeing 747, the first wide-body airplane and the first plane dubbed a "jumbo jet," is christened by first lady Pat Nixon. On Jan. 22, the aircraft begins passenger service on Pan-Am's New York-London route. *New York Times*, Jan. 14, 1970, p. A-6.

**Jan. 15** William Thomas Piper Sr., the president and director of Piper Aircraft Corp. since 1929 and known as "the Henry Ford of aviation" since he built more aircraft than anyone else in the world, dies at Lock Haven, Pennsylvania, at age 89. Originally an oil producer, Piper became interested in the development of light aircraft and purchased the Taylor Aircraft Co. After this company was destroyed by fire, he established the Piper Aircraft Corp. in an abandoned silk mill at Lock Haven. During World War II, some 5,000 Piper aircraft were flown for reconnaissance, liaison and ambulance duties. Piper flew his own aircraft until the late 1950s. *Flight International*, Jan. 22, 1970, p. 107.

**Jan. 23** NASA launches the Oscar 5, short for Orbiting Satellite Carrying Amateur Radio, as a piggyback on the second stage of a Thor Delta from Vandenberg Air Force Base, California. The amateur radio satellite was built by students of the University of Melbourne in Australia. NASA, **Aeronautics and Astronautics**, 1970, p. 23.

**Jan. 24** The world's largest fishing boat, insulated with polyurethane foam that was developed as insulation in the Saturn V second stage fuel tank, is launched at San Diego. NASA, **Aeronautics and Astronautics**, 1970, p. 27.



**Jan. 6** The 36-inch telescope on NASA's Kuiper Airborne Observatory, while flying over Recife, Brazil, collects data that leads scientists to determine the comet Chiron is between 160 and 300 kilometers wide. The comet orbits the sun once every 50 years. NASA, **Aeronautics and Astronautics**, 1991-1995, p. 620.



**Jan. 9** Soviet Cosmonaut Valery Polyakov sets a space endurance record after spending his 367th day in orbit on the Mir space station. NASA, **Aeronautics and Astronautics**, 1991-1995, p. 622.

**Jan. 24** The Faisat commercial communications satellite operated by Final Analysis Inc. is launched into orbit by a Soviet booster. NASA, **Aeronautics and Astronautics**, 1991-1995, p. 628.

# DANIEL ALVAREZ, 31

Space mission program manager at Millennium Space Systems, a Boeing company



Daniel Alvarez created entire cities with Legos, K'nex and Tinker Toys when he was a child. He built a 1-megavolt Tesla coil in eighth grade and a Stirling engine while earning bachelor's degrees in mechanical engineering and business economics management at the California Institute of Technology. From college, Alvarez went directly to Boeing's Satellite Development Center in El Segundo, California, to work as a mechanical design engineer. Now, Alvarez leads a multidisciplinary team building satellites for Boeing's Millennium Space Systems company, which specializes in small satellites for national security.

**Landing a job** ▶ When I graduated college, I was excited by the opportunity to work at Boeing's Satellite Development Center based mostly on the company's reputation as a premier engineering firm. The more I learned about satellites, however, the more enthralled I became by the fact that something could be engineered to withstand the mechanical stress of a rocket launch, the extreme temperature conditions of space, the threat of micrometeoroids, a harsh radiation environment, and yet still perform a multitude of missions that make our lives better. Whether using Legos or aerospace-grade aluminum, to me there are few things more fulfilling than tackling a problem and creating a solution of value. This is the passion that drove me to be an engineer and continues to drive me to this day.

**Communications, first and foremost** ▶ About 90% of my job as a program manager involves communication. I communicate with my team to ensure alignment on objectives and priority, balancing technical performance, cost, schedule and risk. I strongly believe continual communication across every facet of the team is a key enabler for healthy programmatic execution, building trust and identifying risks early. This also applies to other program stakeholders, like customers and executive management. Communication builds trust that the program is being properly managed with customer interests in mind, while meeting the business objectives of the company. Although the details of my specific work are restricted, I take pride in knowing that it ultimately helps keep America safe. I believe the world is a better place when the United States is in a position of strength. I am grateful to play a small role in that.

**Space in 2050** ▶ I think that space-based innovation will continue to make the world a much better place. Very soon, many of the megaconstellations of satellites that are being conceived today will be operational, providing low-cost communication and internet to help developing nations all over the world. Lasers will drastically improve the speed and bandwidth of space-based communication and the United States will maintain the space-based technological advantage it has had since the space race. I believe the U.S. space program will still be the envy of the world and will offer a strategic advantage. I think we will have reusable rockets and spaceships capable of interplanetary travel. I don't know if we'll have a Martian colony by 2050, but certainly there will be a flag in the Martian atmosphere, and I think that flag will be an American flag. ★

BY DEBRA WERNER | [werner.debra@gmail.com](mailto:werner.debra@gmail.com)

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