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Given NASA's troubled cyber record, experts urge fresh attention to station's cybersecurity. **PAGE 20**

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The International Space Station's solar arrays and the Milky Way over the Earth in a long-exposure photograph taken from the orbiting lab.

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Protecting ISS

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By Debra Werner

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Cat Hofacker

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

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

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

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Debra Werner

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

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For ISS and air travel alike, layered defenses are best

This will sound odd, but our cover story about cybersecurity and the International Space Station brought to mind my one and only flight during the covid-19 pandemic.

On Sept. 6, my wife and I were among the 689,630 passengers who flew domestically in the United States that day, about a third of what would be expected any other year. We were on our way back to Northern Virginia from California, after saying goodbye to our younger daughter who is a first-year college student. We dropped our rental car at LAX and headed toward the shuttle bus, where a sign declared a strict 12-person limit for the ride to the terminals. We doubled up our masks and stepped aboard with a handful of fellow travelers who, like us, wore masks. At one stop, a man hopped on maskless, and just like that, a new risk, however small, was injected into our travels. This was true, despite the fact we were headed for an aircraft cabin that would be treated with adenosine triphosphate to verify an operating-room lack of pathogens after cleaning, according to the airline, and that would quickly run air through high-efficiency particulate air filters.

Human behavior, it seems, remains the great wild card in safety. This is true no matter how much science and technology we apply to flying across country during a pandemic or securing the ISS crew and their experiments from cyber intrusions.

The best defense is a layered one of education, monitoring and engagement. If the man on the shuttle bus was bound for a plane, he would be required to don a mask in the terminal. If he got through the terminal, he would not be permitted to board the plane without wearing a mask.

NASA's information security apparatus needs the equivalent of this layering. As our cover story shows, ISS is cordoned off from the public internet, but contractors, workers and components must cross in and out of this bubble. That might not be so concerning, except that last year NASA scored a 2 out of 5 on a government information security scale, level 5 representing "optimized" information security in which "policies, procedures, and strategies are fully institutionalized," according to the NASA Office of Inspector General.

Somewhere at NASA, there could well be the information-security equivalent of a man hopping on a shuttle bus without a mask. Humans are fallible. This will happen. A level 5 agency would catch this, but a level 2 agency might not.

As for our flight home, it was eventless. We sat in first class seats for distancing and because they cost what coach seats normally do. I did not crane my neck, but as far as I could tell everyone kept their masks on. About one in 10 passengers wore face shields too, and we were among them. I can't say I was not a little nervous for the next 14 days, but seeing all the signage, the fellow travelers in masks, and the cleanliness of the plane made me confident, though not cocky. I would fly again if the reason were good enough.

NASA needs to achieve the equivalent in its information security posture. ★

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

The United States Must Prioritize A&D Industry Investment

The United States must take a hard look at where we want our nation to be after the coronavirus pandemic is over. Will we cede our technological leadership in aerospace and defense to other countries? Now is the time for action. We must support our country's aerospace and defense industry by increasing investments in research and adequately funding its programs and mission.

The aerospace and defense (A&D) industry is critical to our economic and national security, and it will be an essential part of our rapid recovery from the pandemic. Work in the A&D sector has enabled our prosperity and propelled us to preeminence. During other periods of national crisis such as World War II, the Cold War, and 9/11, the sector steadily developed transformative technology that changed the world and made our homes a safer and more comfortable place to live.

Many of the technologies we use every day either began or were refined in the aerospace industry. It's a long list that includes weather satellites to help predict sunny days or dangerous storms, GPS satellites to help us find our way, and 3-D printing. U.S ingenuity is demonstrated with the recent launch of the Mars Perseverance Rover and the engineering triumph of Apollo. Such pursuits leads to technological and scientific knowledge that benefits us all.

But it is not guaranteed. The United States has taken for granted its role as the world's aerospace leader in the 51 years since the first lunar landing. In the face of increased competition, both policymakers and the general public must continue to support the A&D industry through the current crisis and for the long term.

According to the Aerospace Industries Association, the A&D industry more than carries its weight. In 2018, the industry supported more than 2.5 million jobs, representing nearly 20 percent of the nation's manufacturing workforce. A job in this sector pays well with an average wage of $92,742. The industry also generated nearly $929 billion in economic output, of which $459 billion is attributed to the industry's supply chain. Moreover, $151 billion in exported goods reduced the U.S. trade deficit by 10 percent.

The A&D community has risen to the challenge and quickly responded on a global level to the COVID-19 pandemic. Companies developed and transported PPE equipment such as masks and gowns to help protect frontline medical responders as they treat patients, rapidly designed new ventilator solutions and delivered them to hospitals nationwide, contributed component parts to ventilator manufacturers, assisted with supply chain and global sourcing needs, donated meals to help combat food insecurity, accelerated hundreds of millions of dollars-worth of payments to small business suppliers, and more. All on a timeline never seen before.

COVID-19 is weakening this resilient U.S. industry. Enormous revenue losses, large-scale unemployment in aviation, erosion of military capabilities, and the breakdown of essential supply chains composed of small and mid-sized companies are creating a dire situation that cannot easily be reversed unless steps are taken now.

Commercial and civil space activities have slowed just as low Earth orbit and lunar exploration efforts were expanding. Many NASA programs are built on private–public partnerships that are in danger of collapse without a strong private sector. While the Department of Defense has maintained readiness, weapon system development programs for current and future threats have been impacted and national security risks are increasing as the pandemic continues.

Therefore, we call upon decision makers to support the people and the companies of the A&D industry by increasing investments in research and providing adequate funding for programs and mission. Such action will lead to new technological advancements, a healthy workforce pipeline, and sustained U.S. leadership.

The A&D industry's well-earned reputation for innovation and exploration will fuel the U.S. recovery and create opportunity and economic growth. It must be utilized to help return the country to a prosperous, safe, and exciting future for all Americans. Otherwise, our competitors will gladly take advantage of this opportunity. Our future is well worth the investment. ★

Dan Dumbacher
AIAA Executive Director

2020 Election: Space Policy Platform Paper

The Institute's Public Policy Committee has developed a space policy platform paper in advance of the 2020 election. The paper highlights the importance of our space activities and the need for continued investments in space-related federal programs. More specifically, it calls for a continuity of policies and programs that are meeting their objective to maintain constancy of purpose, as well as a whole-of-government approach to build on past successes. Read the paper on pages 30-31.

Feeling the pressure

Q: If you were flying inside a perfectly sealed aircraft passenger cabin, would your ears pop when ascending or descending? Explain why or why not, and why designers accept some ear popping.

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

FROM THE SEPTEMBER ISSUE

NOT SO DICEY: We asked you where on the French Riviera a simulation expert was headed to celebrate her success at predicting the outcome of some hypersonic test flights.

WINNER: Monte Carlo! In project management, we sometimes do quantitative risk analysis with a tool like the Risky Project application. We load our project schedule or budget and our risk assumptions into the application, and it performs a Monte Carlo analysis by running project simulations hundreds or thousands of times, much like our French simulation expert "flying" her prototype maneuverable hypersonic aircraft many times! One output can be a graphical representation of the probability of completing the project by a certain date or within a certain budget.

Bob Morin, AIAA senior member
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Morin is a senior principal project manager at Mission Support & Test Services, which operates the U.S. Department of Energy's Nevada National Security Site.

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

Anti-space debris tech poised for testing

BY CAT HOFACKER | catherineh@aiaa.org

Few hypothetical scenarios give satellite operators greater headaches than that of their dying or defunct spacecraft colliding with another object in low-Earth orbit, creating a cloud of debris.

While some companies would like to refuel or service failing satellites or tug them out of orbit with other spacecraft, one executive is offering what he calls "the simplest, dumb-as-a-brick" solution: a 70-meter-long polymer tether that would unfurl from a dying or defunct satellite on command. The tape would conduct electricity and increase the surface area of the spacecraft in the thin veil of the atmosphere, slowing the satellite and causing it to sink and burn up sooner than it otherwise would.

Tethers Unlimited of Washington state unveiled this tether, dubbed the Terminator Tape, in 2009, and has since received a handful of orders. CEO Rob Hoyt is confident that number will soon increase, given the exponential increase of LEO satellites forecast in the coming years and the product's low price point; a Terminator Tape module costs between $50,000 and $75,000.

"A satellite up above 700 kilometers without any kind of end-of-life deorbit solution, that satellite might be up there for several hundred or a thousand years," he said. With a Terminator Tape, that goes down to "within 10 years."

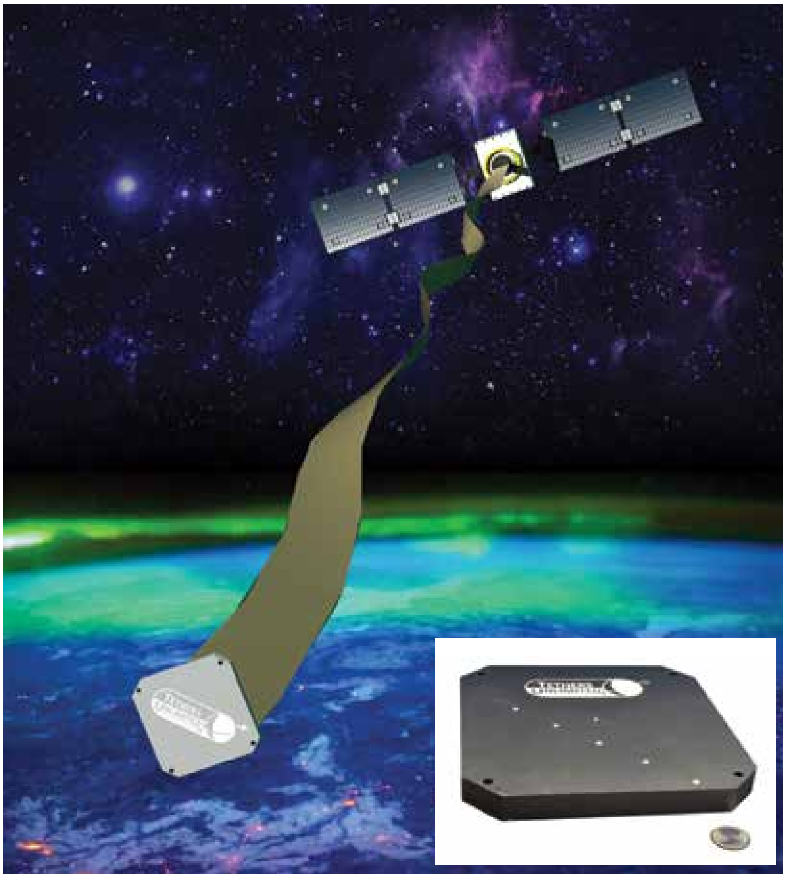
A technology demonstration scheduled to launch next month now aims to compare how long it takes the tape to deorbit a satellite versus natural orbital decay. For the mission, dubbed DragRacer, Boeing subsidiary Millennium Space Systems will launch two identical six-unit satellites, meaning each is 60 centimeters long, one equipped with Terminator Tape and the other without it.

Here's how the mission will unfold: Technicians at Millennium Space Systems in February bolted a notebook-sized Terminator Tape module to the side of the Alchemy satellite, which is scheduled to be shipped to New Zealand by the end of October together with its twin, Augury, for installation atop a Rocket Lab Electron launch vehicle for a planned liftoff on Nov. 8.

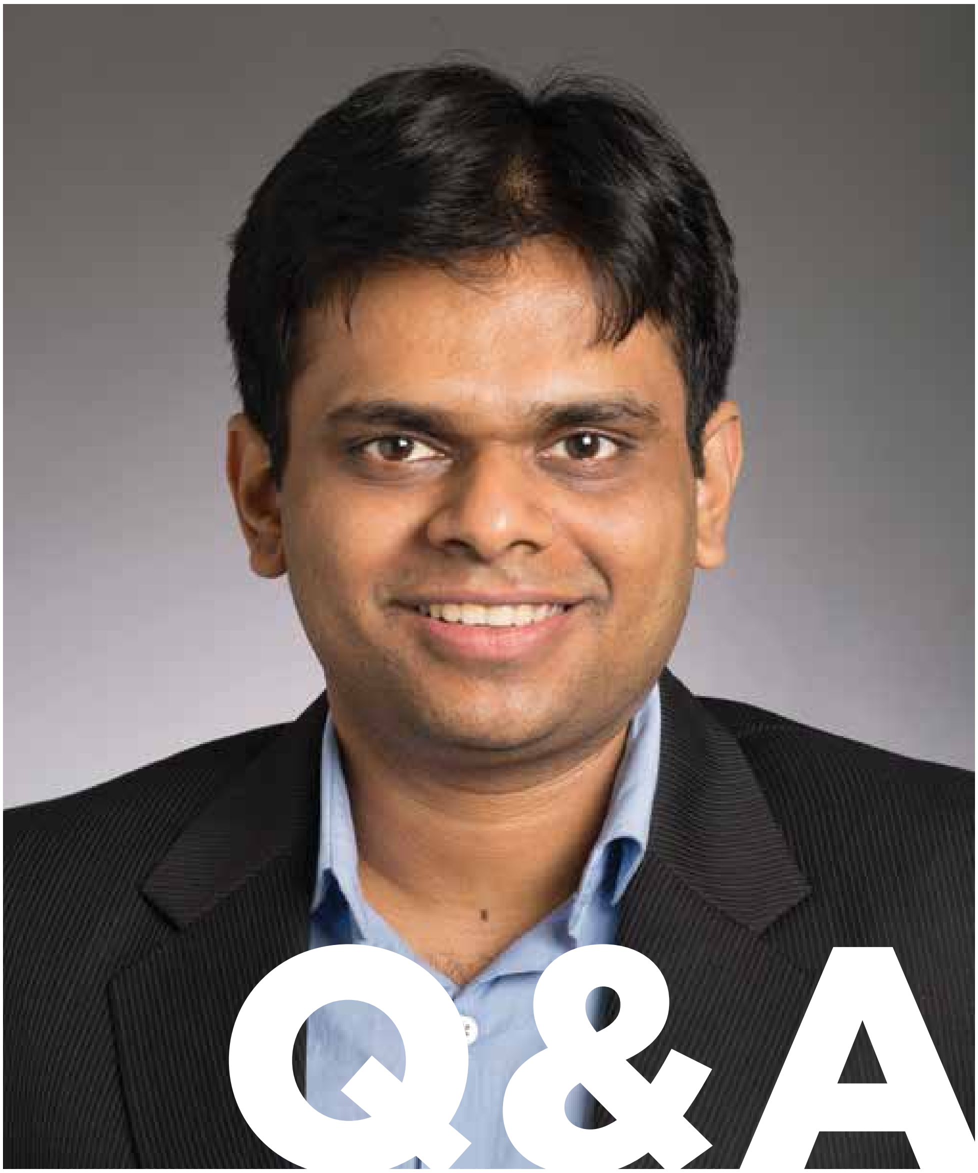
About two hours after launch, the satellites will be released from their payload fairing into a 500-kilometer sun synchronous orbit. An internal timer in the Terminator Tape will go off, prompting the 70-meter conducting tape to unfurl. The Earth's gravity will pull the tape vertically, the increased surface area dragging Alchemy down, while an electromagnetic current running down the tape interacts with the Earth's ionosphere, creating additional drag. In the weeks to come, Millennium will monitor the telemetry of both satellites via the U.S. Space Surveillance Network and radar maps from LeoLabs, awaiting Alchemy's demise.

Millennium Space Systems estimates that the Terminator Tape will drag Alchemy down to burn up in the atmosphere within 45 days, while Augury will slowly decay over the course of five to seven-and-a-half years.

In the future, Tethers Unlimited plans to release longer and wider versions of the tape tailored for larger satellites at much higher orbits. The nanosat version on DragRacer is designed for satellites up to 100 kilograms orbiting as high as 750 kilometers, and a version with a 20-meter tether is available for smaller spacecraft. ★



▲ **A 70-meter** conducting tape unfurls from a Terminator Tape module (inset), shortening how long it takes the spacecraft to sink and burn up in Earth's lower atmosphere. The upcoming DragRacer mission will launch two identical cubesats, one with Terminator Tape and one without, and compare the deorbit times side by side.
Tethers Unlimited



Carnegie Mellon University

Unlocking electrification

Whether it's reducing carbon emissions or limiting costly jet fuel consumption, there's a lot to love about the idea of powering aircraft exclusively or in part with batteries. But the holy grail of purely electric passenger travel has remained frustratingly out of reach for decades, largely because delivering the required energy with today's battery technology would make such aircraft impossibly heavy. Venkat Viswanathan, a professor at Carnegie Mellon University, is one of the researchers attempting to design a new class of batteries that would be lighter and would deliver more power. I called Viswanathan at his home office in Pennsylvania to discuss the challenges and external trends influencing electric flight. — *Cat Hofacker*

VENKAT VISWANATHAN

POSITIONS: professor of mechanical engineering at Carnegie Mellon University, 2014-present; technical consultant to Pratt & Whitney on batteries for hybrid-electric aircraft, 2018-present; postdoctoral researcher at MIT focusing on next-generation lithium-ion batteries, 2013-2014.

NOTABLE: Selected this year for MIT Technology Review's "Innovators Under 35" list for his work on high-energy, high-power batteries for electrical vertical takeoff and landing vehicles, or eVTOL. 2019 recipient of a Young Investigator Award from the U.S. Office of Naval Research, which consists of a three-year grant to study batteries under cold temperatures.

AGE: 34

RESIDENCE: Pittsburgh

EDUCATION: Bachelor of Science in mechanical engineering, Indian Institute of Technology, 2008; doctorate in mechanical engineering, Stanford University, 2013

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IN HIS WORDS

Wanted: industry backing

If you look at the scale of investment in electric aircraft, it's minuscule. A lot of these arguments are very similar to the arguments that people were making in 2003 when Tesla was founded: Electric vehicles can never be long range, can never charge fast and so on. It takes extraordinary willpower for some set of entrepreneurially minded people to be able to move the needle. We're nowhere near the spending levels needed for driving this innovation and driving the technology forward. Part of it is also a challenge of where this development should reside. The traditional people who think about batteries don't think about aviation, and the people who think about aviation typically don't think about batteries. What's needed is similar to the Tesla Effect, which is you need some company or something with a very strong, sustained effort to begin the electrification of aircraft to sort of bootstrap the traditional, more established people into this dimension. Otherwise, it's very unlikely that we'll see the kind of disruption that we saw in the vehicle space in the aviation space.

Moore's law vs. Wright's law

There's actually been quite a lot of improvements in battery technology. But we frequently sort of compare it to Moore's law and then ask the question, "Why haven't batteries progressed?" Now, there's actually a very interesting recasting of Moore's law in the form of what's called Wright's law. The idea is that if you start making more of something, you learn how to make it better. So you will both learn how to do new things in a way, but also there's a critical mass of people innovating and so on. It turns out that most energy technologies grow at roughly the same pace with the scale of production. For batteries, now that we're seeing massive exponential scales of production, unit costs will start to go down. Now, at some point, you hit some limits of what's possible with the chemistry of materials. Batteries will eventually approach that limit. We're not there yet. I would say in the Moore's law analogy, we're probably in the 1980s or 1985, maybe. And there are still sort of 20 more years, or something like that; 10 more years, 20 more years of growth where we know the trajectory to getting better and better and better.

▲ The electric motors for NASA's X-57 Mod II vehicle and their propellers are powered up and spun for a test. The X-57 Maxwell is an Italian Tecnam P2006T aircraft NASA is modifying to fly electric in three configurations to lay the groundwork for certification standards for future electric aircraft. The Mod II is the first of the configurations.

AFRC TV / Steve Parcel

> "A lot of these arguments are very similar to the arguments that people were making in 2003 when Tesla was founded: electric vehicles can never be long range, can never charge fast and so on."

Reusability

The central technical problem comes to the question of single-use fuels compared to batteries that are used multiple times. Fuel you just burn once and then you emit the CO2, and then you move on with life. It's easy to make energy sources that can be single use, so those can be very high-energy density, meaning lots of energy is stored per volume, and a higher density number is better. The reuse is what makes the energy density of batteries much lower than regular fuels. So depending on what state-of-the-art numbers you take, you get an energy source that's roughly 10 times heavier than jet fuel, for instance. So now you can then ask the question, "Well, if that was the case, how are electric cars able to solve this problem?" What engineers have done is essentially make these cars heavier, so any electric vehicle is much heavier than the comparable internal combustion engine vehicle because the lower energy density of batteries means you need more of them. For aircraft, the problem comes from the fact that you need to generate lift. That's when the weight hits you. The extra weight essentially forces you to ask for so much more power and so much more energy, which will need more batteries. And then you basically can't close the design. So it's a runaway train: You need more and then you add more, and then you need more, even more, and so on.

Power conundrum

Batteries are closed systems, which means that nothing comes in or comes out. When you have a closed system, you usually have this fundamental energy-power tradeoff. The easiest way in which you can visualize this is if you have an energy source, what happens is if you want very high power, then essentially you want to run very high currents through it. And because power is voltage times the current, to increase the power you need to increase the current. Now, when you increase the current, the amount of available energy loses a part that goes into heat. So as you try and increase the power, which is increasing the current, then you lose energy because of the fact that your resistive part of the energy loss now becomes much higher. You can then ask the question, "Could I do something smarter? Could I now make it such that I put more of the energy-

An illustration of Lilium's tilt jet aircraft with 36 engines embedded in the wing flaps. The electric engines face downward to propel the aircraft during takeoff, then rotate 90 degrees during flight.
Lilium

containing components — which in a battery is the anode and the cathode — in the battery?" When you're discharging the battery, you want to move ions from the anode to the cathode. Now, if you have more material on the cathode, in order to get all of the energy out you need to move the ion to all parts of the cathode, and you want to do that very fast because you want to get very high power. So one popular way in which you can make better batteries is to put more of the material; you can think of them as sheets stacked on top of each other, and you can make a bigger sheet. Then what happens is when the ions are moving, it's easy for them to move, and then they can access the front part [of the battery]. But then it's very hard for them to access the end part. So once you make thicker and thicker electrodes, you get less and less power.

Batteries compared to combustion

The energy content inside a tank of gasoline is way more than the energy that is stored in a battery pack, but the electric drivetrain is more efficient, as batteries are more efficient at converting chemical energy into useful work than burning fuels. So you need less overall energy to be able to move an electric vehicle than what you would need with the internal combustion engine counterparts. In that same way, an electric aircraft will need less energy, so as a result will need less energy density than the equivalent jet fuel-powered aircraft. But of course, that assumes that the weight of the battery pack doesn't play a huge role. Jet engines need economies of scale because the bigger they are, the more efficient they are, and then you have two of them for redundancy, for safety. Essentially, you oversize it so much because it should be able to fly with just one, whereas electric motors are essentially still invariant: They're equally efficient when they're small as when they are very large. Which means that you can do these kinds of distributed propulsion concepts like the NASA X-57 plane, where instead of having just two engines, you have these 14 motors across the wing, and that then brings some aerodynamic efficiency and so on. There may be other ways in which you can get improvements.

Why lithium

The term lithium-ion is used for a broad range of technologies. Basically anything that uses lithium as the main carrying ion would technically fall under lithium-ion. Many of the things that people call "beyond lithium-ion" also still use lithium-ion. So solid state and all these things, it's still lithium-ion as the working ion. In that sense, in the broader definition of lithium-ion, I think it's nearly impossible for it to be any other ion because lithium is the lightest, and it's the most electro positive, which means you'll get the highest voltage out of your cell for the least amount of weight. To do that, you need to maximize the voltage and you need to minimize the weight. Lithium is the best for that at this point. Now having said that, the conventional way in which the term "lithium-ion" is used is that it refers to the kind of lithium-ion that we use today, which consists of graphite and some oxide cathode material. And then anything beyond that typically is called "beyond lithium-ion." So battery chemistries that are changing the anode from graphite to silicon or lithium metal, those are seen as beyond lithium-ion, but they still use lithium-ion as the working ion from one side to another.

Exotic alternatives

Those would be lithium-ion based, but there are still battery chemistries even in lithium-ion that haven't been explored, which I think would significantly move the needle. The are several very interesting ideas that are known to be much, much higher in energy density than current lithium-ion. If we look at single-use batteries, there are battery chemistries that would give something like 800-plus watt-hour per kilogram energy density. To compare, today's best automotive cells provide around 250 watt-hours per kilogram. So that's a significant step up, but we haven't been able to make these single-use batteries rechargeable, so the economics just won't work out. You need the battery to last several thousand cycles.

Rechargeability

The rechargeability question really comes hand in hand with the use case model, which is basically, "Would you fast charge the battery or would you slow charge the battery and swap the battery in an aircraft?" It seems to be that both are still on the table. So a plane lands, you charge the battery, and then it takes off again. That means the battery would have to be recharged in 30 minutes or so. Or you take it out and then you swap the battery and then slow charge the battery. The lifespan is hugely dependent on whether you fast charge or whether you slow charge. If you slow charge, then you have easily several thousands of cycles that are possible. Now, if you fast charge, then that comes down to a few hundred cycles. That's the challenge that basically ties back to the use case, and of course the economics of the use case, which means that if you swap then you need more than one battery pack because the other battery is not being utilized for some time. That will also have a role to play.

Sorry, no electric 747

We have many, many solutions that we know for a fact can easily electrify flying taxi concepts for whatever distance it is you think you want: 100 miles, 200 miles, etc. Whether we have it today is, of course, up for debate, but we'll have it. There's no technological barrier to making it work; it's simply just now finding the kinks and figuring them out. Now, if you think of something like a Boeing Dreamliner or the equivalent Airbus A380 aircraft, it gets very tricky. Then you'll have to ask the question of how many passengers and how long. There is a limit beyond which it is essentially not feasible with any known technology today, of any known battery chemistry today — which means battery defined in the fashion of how we think about battery today. There are some hard limits. What that number is is a little bit tricky to exactly estimate. I couldn't crisply tell you the boundary, but I think there will be an envelope of things that would be possible, and then beyond which it will not be possible. It's safe to say that a wide-body aircraft that's carrying something like 300 passengers would be essentially impossible with any known battery technology today.

Steady progression

It's going to be a staged development: urban air mobility, and then short haul, maybe seaplanes, other kinds of small commuter aircraft; and then from there to maybe some more regional planes, and then eventually maybe something like a coast-to-coast type of thing. There's a long way to go in terms of certifying aircraft. The systems have to get very, very high levels of reliability. Both the short haul and the urban air mobility are sort of ideal playgrounds to set up that certification process and thinking about these battery systems as propulsive batteries as opposed to how they're seen today, which is that they are just for auxiliary power. For a vertical takeoff and landing aircraft capable of carrying a few passengers, the requirements and size of the battery pack would not be significantly different from that of a battery pack inside a typical electric vehicle, for example a Tesla Model 3, which means that the leap is not so large. We know how to manage these battery packs safely. Then from there, you can go to better battery system safety certification. You also need consumer faith and consumer adoption and so on. People should feel safe flying these things. So if these things come and become ubiquitous, then there will be a step change.

Lithium fire risk

If you think about it, it's crazy that we go and pump flammable gasoline into our cars, and we feel totally safe. It's very unlikely that, during use, a lithium-ion battery would have any sort of safety issues. The risk is mostly during charging; so if you charge your battery pack, that's when you're more likely to face these issues. But it's the fear of the unknown, and that's a fear that any new technology must face. So there's still a while to go for this to get to the level where people are feeling comfortable and excited. ★

Meet NASA's Kathy Lueders

The veteran manager tasked with steering NASA into a new era of human spaceflight

BY CAT HOFACKER | catherineh@aiaa.org

When NASA Administrator Jim Bridenstine called Kathy Lueders in June and asked if she wanted to run the agency's roughly 200-person Human Exploration and Operations Mission Directorate, she said yes for at least two reasons.

She would remain involved with the Commercial Crew launch program that, for six years, she shepherded from a troubled effort to one that in May delivered two astronauts to the International Space Station inside a SpaceX capsule for a nine-week stay.

The other reason, and possibly the bigger one, was the scope of the challenge that Lueders, an industrial engineer by training, would get to embrace.

"I sat and thought about what's going on with the rest of HEO right now, and realized we have a crapload of missions going on," she told me in a Zoom interview during AIAA's virtual Propulsion & Energy forum in August.

That schedule includes missions that will determine whether NASA succeeds at firmly establishing commercial flight to and from the International Space Station and returning American astronauts to the moon, this time to stay.

Summing all that up as a "crapload" is classic Lueders, and the word isn't an understatement. In addition to the roster of uncrewed missions for which HEO provides launches under its Launch Services Program, the directorate plans to launch people to space and bring them home at least seven times in four years. Now that SpaceX has demonstrated its Crew Dragon and is set to complete its first regular flight this month, Boeing must do so with its Starliner; if all goes as planned, routine flights with both vehicles will begin in 2021.

Looming on the schedule, after the Artemis-1 uncrewed inaugural launch of a Space Launch System rocket, will be a crewed launch around the moon called Artemis-2 ahead of the planned moon landing, which NASA is determined to complete before the end of 2024. The Artemis-3 lunar landing will be the most challenging, with a timeline that NASA and U.S. lawmakers labeled as aggressive even before the coronavirus pandemic forced the agency to shift most of its workforce to telework for the foreseeable future.

Covid-19, in fact, is often on Lueders' mind. In March, confirmed cases in Louisiana and Mississippi prompted NASA to halt construction for two months on the core stages of SLS rockets at the Michoud Assembly Facility in Louisiana and testing at nearby Stennis Space Center in Mississippi; the first SLS launch is scheduled for November 2021.

"It was tough for the team because they've, over the last year, doubled down and were hitting all of their development goals up to that point, really showing great progress. I think the team's been heroic over the last few months, as we came back."

She was referring to how NASA and its contractors

▲ **NASA's Lueders** speaks to reporters after SpaceX boosted two astronauts on their way to the International Space Station in May, marking a breakthrough for the Commercial Crew launch program that Lueders managed for six years. Now head of the agency's Human Explorations and Operations Mission Directorate, Lueders oversees NASA's human spaceflight programs, including Commercial Crew.
NASA/Kim Shiflett

have resumed the Green Run test campaign, green referring to the first time engineers will power up the core stage for the inaugural SLS flight. To guard against additional transmission of the virus, Green Run testing at Stennis was paused for two months. Rather than lose time, managers looked at the SLS development schedule and realized they could continue software development and testing remotely without violating any covid-19 restrictions, and in this way they kept the Green Run on schedule. In May, NASA approved personnel to start returning to Stennis, donned in the proper personal protective equipment. As of this writing, the campaign was preparing for its final test, scheduled for this month. This will be a hot fire test of the flight model's four RS-25 engines, the same kind that powered the space shuttle orbiters. The engines will run for eight minutes, just as they will on the inaugural flight, when they must propel an uncrewed Orion crew capsule to orbit.

Since May, SLS testing has proceeded apace, minus another temporary halt in late August when Tropical Storm Laura made landfall on the Gulf Coast. "I sometimes tell people 'Let me know when the locusts show up,'" Lueders chuckled, "because so far we're dealing with covid, technical issues, we got a couple hurricanes heading for the Louisiana coast. Everything's getting thrown at us right now." As of September, no storms had done damage.

To Lueders, the SpaceX launch and the splashdown of the Crew Dragon capsule in August underscored that big challenges can be overcome. That mission was called Demo-2, because it was the second and final demonstration required before NASA would clear the Crew Dragon design for routine flights. A setback came about a year before the launch, when the capsule originally designated for that flight was destroyed during testing at the company's landing site in Florida, because a fuel leak caused an explosion. Reaching that conclusion required pausing some preparations so NASA and SpaceX could conduct a detailed investigation. Then came the pandemic, which forced NASA and SpaceX to quickly adapt their processes to include social distancing and personal protective equipment. They limited the number of personnel on site at Kennedy Space Center in Florida and required those interacting with the two astronauts to wear masks and gloves to reduce any chance of virus transmission. That same flexibility will be required during preparations for the upcoming Artemis missions, the first of which will be the 2021 inaugural flight of the SLS design.

▼ **NASA crews transport** the first completed core stage for a Space Launch System rocket, shown here with coverings over its four RS-25 engines, to Stennis Space Center in Mississippi in January. Not long after, engineers began the Green Run campaign, eight tests of the new rocket components that will culminate with the firing of the core's four engines.
NASA

"We know now that we can" do what's required to safely launch humans, or at least their vehicle, to space "while we as a nation and the world" work to tame the pandemic, Lueders said. "They just don't give up, and they're moving so hard toward these missions. We'll see where we end up."

Lueders thinks the team can still make the November 2021 date for SLS, "but it doesn't help at the beginning of the campaign to be using some of your margin for hurricanes and covid," she said. In the uncrewed test, an SLS will boost an Orion capsule on its way around the moon, which Orion will orbit for six days.

Also, at least two contractors must be selected to make competing versions of lunar landers, in hopes that at least one will be ready in time to meet NASA's deadline of returning U.S. astronauts to the moon by the end of 2024. The U.S. House of Representatives approved $628 million for lander development in fiscal 2021, far short of the $3 billion that NASA requested.

"Obviously getting a third of the money makes it tough, but we also know we're not done yet," Lueders said, referring to the fact that the Senate has yet to pass its fiscal 2021 spending bill. In the meantime, the three companies awarded a combined $967 million in April are working "gangbusters" to refine their lander designs and establish the certification criteria before the February downselect. At least two designs will be chosen for further funding, but having one ready in time depends in part on the amount of funding granted when House and Senate appropriators reconcile the two bills.

The best the agency can do for now, Lueders said, is prepare for every contingency.

"I've learned in my career that you can go lay out the best plan, but don't get too fixated with that because lots of things can happen during development," she said. "So what we're really trying to do right now is lay out the pieces, get all the pieces going, lay out our initial plans for the missions. And then as we see the progress of all the different pieces as they're developing, we'll go lay in the timing of all the different pieces." ★

Seeing deep inside engines with X-rays

Argonne National Laboratory outside Chicago is creating a research program that will empower investigators to apply the sensing qualities of X-rays to the challenge of seeing what goes on inside scramjets, rotating detonation engines and other hypersonic propulsion concepts. The program's architects, Brandon Sforzo, Prithwish Kundu and Pinaki Pal, describe the technology's heritage and its time- and cost-saving benefits.

BY BRANDON SFORZO, PRITHWISH KUNDU AND PINAKI PAL

A jet engine's ability to lift us into the skies begins with a spray of fuel. The injected liquid joins with a stream of pressurized air and burns within the engine's combustor, generating thrust — and you're ready for takeoff.

Every engine, jet or otherwise, today benefits from the engineering community's ever-growing understanding of this fuel injection process, a multiphase interaction so complex that it offers continual opportunities to tune performance. At the U.S. Department of Energy's Argonne National Laboratory in Lemont, Illinois, we have a long history of studying this dynamic in automotive systems, by projecting powerful X-rays at spraying hardware and turning the resulting measurements into computational models.

Over the past year, we've begun to explore how these same techniques can be applied to the aerospace world. In partnership with industry, academia and other government agencies, we're developing a unique research program that will help build not only the next generation of gas turbine engines, but emerging technologies, such as rotating detonation engines, to propel rockets and hypersonic jets.

X-ray vision for propulsion

Computer algorithms can help us capture and predict the intricacies of fuel sprays, but a model is only as good as the real-world data that shapes it. For that, we turned to Alan Kastengren, the physicist who oversees the 7-BM beamline, a pathway for X-ray light to be directed from the Advanced Photon Source, a ring-shaped particle accelerator at the Lemont campus. This beamline is one of approximately 60 specific pathways, each dedicated to a unique methodology for X-ray diagnostics, across a wide range of scientific disciplines, at the APS, one of DOE's Office of Science User facilities. The 7-BM beamline is optimized for high-resolution fluid dynamics measurements, which means scientists and engineers can train a variety of X-ray sensitive detection equipment on fuel sprays and hardware to characterize what happens to the atomized liquid at the earliest phases of injection into the combustor.

The Vehicle Technologies Office in the DOE's Office of Energy Efficiency and Renewable Energy funds the fuel spray research program relevant to gasoline and diesel direct injection.

Fuel spray studies at many other research institutions have relied on laser illumination to view liquid sprays prior to combustion, but visible light lasers are limited in a couple of ways. First, they cannot peer directly into the hardware at the point where fuel is being injected. Second, laser light tends to scatter when it hits many fuel droplets, much as sunlight is blocked by passing clouds. The extremely intense X-rays at the Advanced Photon Source don't interact with the droplets the same way that laser light does. So, the beamline can help measure the distribution of fuel close to where it gets injected.

Stitching together thousands of time-resolved images, we can reconstruct across milliseconds how fuel droplets are formed and ripped apart, how they splash on the inner surface of the device, and where they move from there. In a study published in December by the American Society of Mechanical Engineers, Sforzo and four co-authors examined spray nozzle hardware and geometries provided by the National Jet Fuels Combustion Program, finding that the injected fuel behaved differently than expected based on previous characterization work.

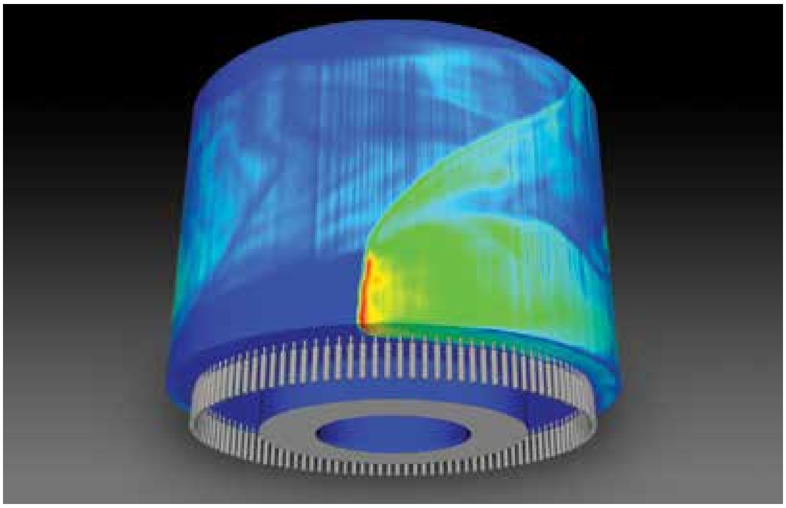
This behavior hasn't been studied very thoroughly until now. Armed with the novel data, computational fluid dynamics experts in industry and research community can construct much more robust and realistic modeling boundary conditions — the parameters within which a simulation will run. Boundary conditions set the context for a given gas turbine simulation: the pressure, velocity and temperature at which the fuel is injected, for example, or the cone angle of the spray, which has an effect on fuel distribution. Furthermore, the quantitative validation data serves as a cross-check on the predictive performance of developed models. Taken together, all of these factors have a cascading effect on the performance of a jet engine, which is why computational modeling is critical in pinpointing the most efficient engine designs and fuels.

Predicting the future of fuel

One of the biggest computational challenges for gas turbine applications is that the size of each combustion simulation is significantly larger than any automotive one. Our numerical simulations generate terabytes of data. To analyze these terabytes, we turned to supercomputing resources such as the Theta system at the Argonne Leadership Computing Facility, another Office of Science user facility. In a 2018 study, our high-fidelity model compared two jet fuels with respect to lean blowout, in which the combustor's flame extinguishes when the supply of fuel goes down.

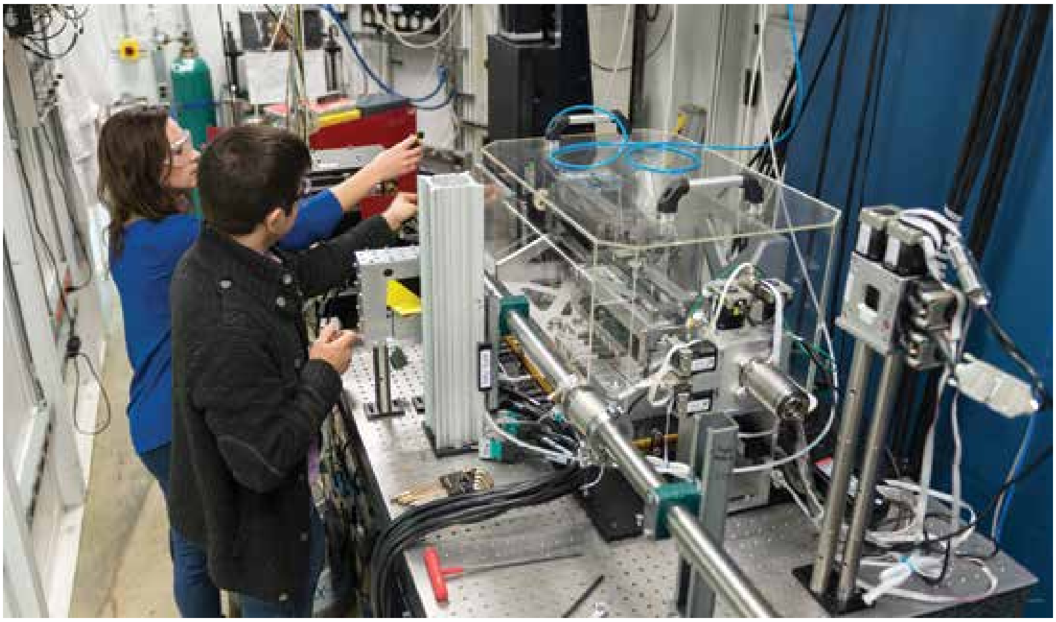
This kind of predictive modeling saves engineers time and money by steering them toward the engine design parameters that are likely to work best, helping to avoid building a test engine that's bound to send everyone back to the drawing board. But the computer simulations themselves involve a significant cost because they often run for months on a supercomputer.

To speed up the process, we are turning to a form of artificial intelligence known as deep learning. Deep neural networks "learn," in a hidden manner, to be efficient representations of physical phenomena from



▼ **The red in this** simulation produced by Argonne National Lab represents the hot detonation area that circles clockwise inside a rotating detonation engine.

Argonne National Laboratory



Argonne National Laboratory

▲ **Argonne researchers** Katarzyna Matusik and Brandon Sforzo prepare an experiment to investigate fuel injector design at the Advanced Photon Source outside Chicago.

voluminous data, which can improve the efficiency of predictive modeling. With these compact representations, we can turn terabytes of observational data into physics-informed surrogate models that run very quickly, instead of running thousands of computational fluid dynamics simulations. We're using novel deep learning techniques in collaboration with the Raytheon Technologies Research Center of East Hartford, Connecticut, for example, to enable faster optimization of combustor and turbine cooling designs for modern aero-engines, while reducing the computational expense of fluid dynamics models.

A foundation for hypersonic flight

In the near term, the insights we gain from this novel combination of X-ray experiments and computational modeling can help engineers and designers maximize the efficiency and performance of next-generation gas turbine engines. And given that the combustor lies at the heart of any propulsion system, our work also applies to the longer-term vision of hypersonic flight and the development of advanced rotating detonation engines, RDEs, for rocket propulsion.

Unlike a conventional gas turbine engine, which combusts fuel at a constant pressure, an RDE confines a continuously rotating shock wave in a ring-shaped channel, creating elevated pressures that result in self-sustaining ignition of the fuel. This detonative mode of combustion could power engines that are smaller and lighter, but with a higher thrust than their current counterparts.

So far, the promise of RDEs far outstrips their viability; they are chaotic, dynamic systems in which the combustion phenomena are difficult to control. Working in collaboration with the Air Force Research Laboratory and Convergent Science Inc., our group has developed high-fidelity numerical modeling tools that can accurately predict the combustion characteristics of RDEs operating with practical hydrocarbon fuels in a computationally efficient manner and help researchers bring one closer to reality.

We also partnered with NASA's Langley Research Center in Virginia to implement tabulated combustion models — accelerated using deep neural networks — to model hypersonic propulsion for aircraft, such as scramjets. By the completion of the project at year's end, the algorithms we develop will be integrated with NASA's in-house computational fluid dynamics code, VULCAN-CFD, supporting hypersonic propulsion device development.

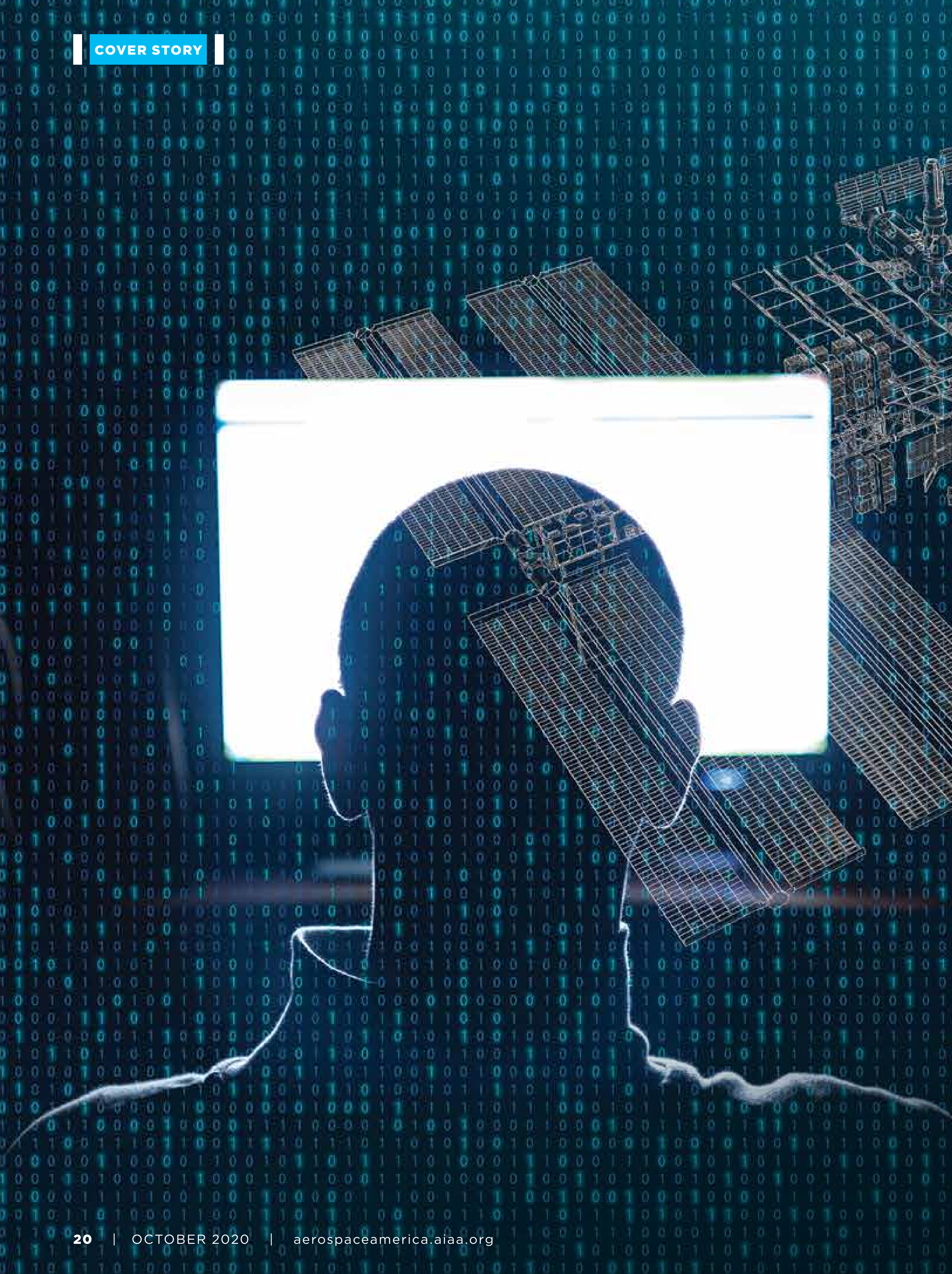
At AIAA's SciTech 2020 Forum, we convened the first meeting of an advisory committee with several technology experts and program managers from original equipment manufacturers and government agencies to provide guidance on the most meaningful research avenues going forward. We are designing a common testbed for our unique experiments, where we can examine these important physics under even more realistic conditions, which will in turn strengthen the computational models.

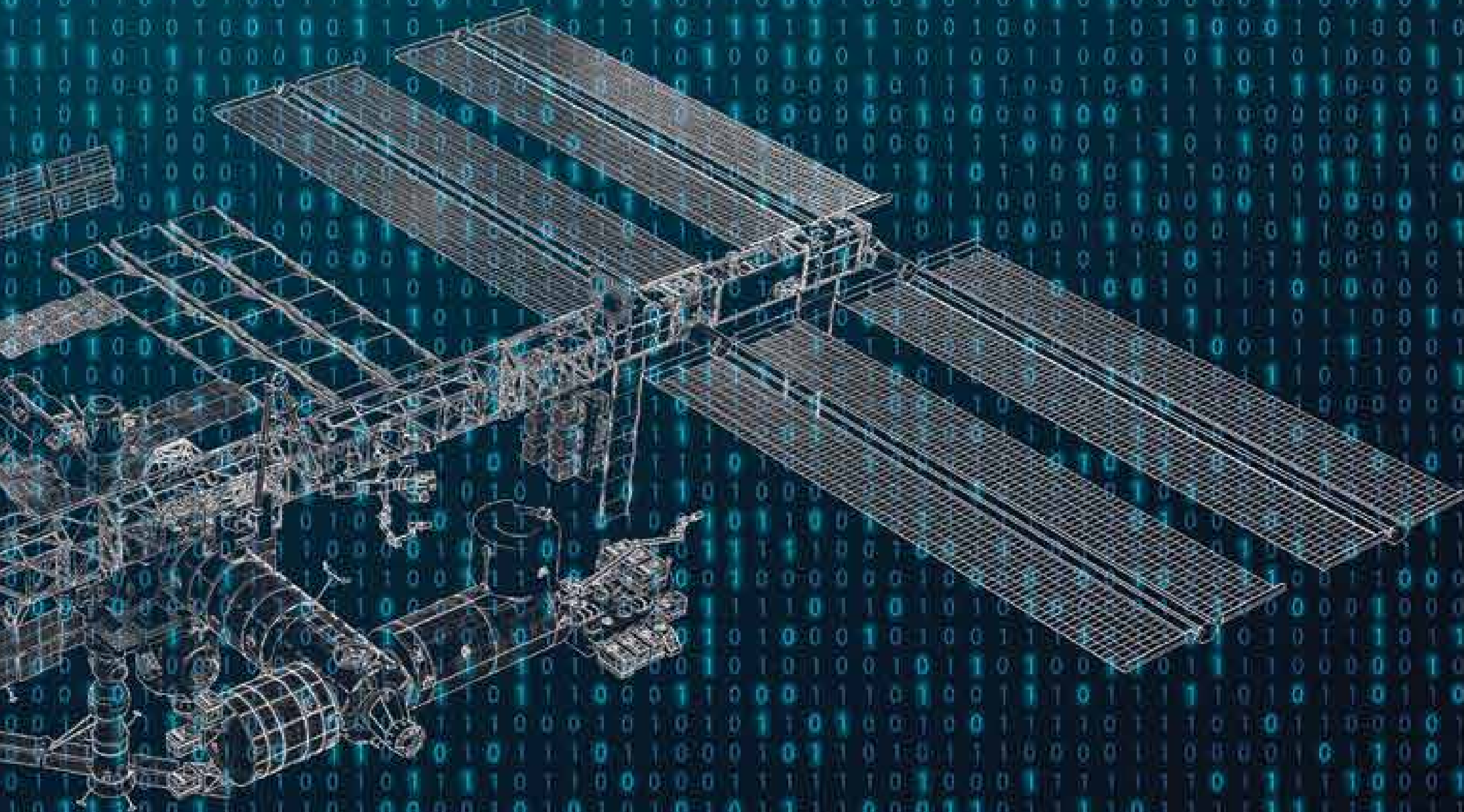
By building a bridge between the current expertise and capabilities for automotive fuel combustion and those for almost any aerospace application, we are laying the foundation for a new era of aerospace propulsion research. The most exciting developments in this effort are yet to come. ★

Brandon Sforzo is a mechanical engineer at Argonne National Laboratory. He conducts fuel spray research for automotive and aerospace applications.

Prithwish Kundu is a research scientist at Argonne National Laboratory focusing on turbulent combustion modeling and its applications to propulsion.

Pinaki Pal is a research scientist at Argonne National Laboratory focusing on computational fluid dynamics, turbulent combustion modeling, machine learning, computational science and high-performance computing.





PROTECTING ISS

NASA's cybersecurity track record has been a troubled one, but as far as the public record shows, the troubles have not reached the International Space Station. What should NASA do to keep it that way? Sarah Wells spoke to cybersecurity experts to find out.

BY SARAH WELLS | sarahes.wells@gmail.com

While it is easy — and even romantic — to imagine the International Space Station as a safe haven from Earthly pressures, the orbiting lab is, in reality, digitally connected to our terrestrial world, and therefore vulnerable, at least in theory, to the kind of targeted and malicious cyber threats we face on Earth from anyone with a grudge and a keyboard.

Of course, ISS is not connected directly to the internet. Before birthday wishes, photos and social media are allowed into NASA's network and bounced to the station via the geosynchronous Tracking Data Relay Satellite System, they are checked by NASA and mirrored by a computer at NASA's Johnson Space Center in Texas. With their NASA-provided laptops, U.S. crew members can remotely view this computer's desktop and control it via the laptop's track pad.

Still, the public prominence of the station has made the ISS a potentially juicy target for hackers worldwide — though likely not in the catastrophic, careening-out-of-orbit way that we might see in an action movie. More likely, experts believe, are data thefts and efforts to undermine the prestige of the ISS partner nations, probably carried out by finding a way around this secure computer.

The closest to anything like that came in 2011, when an unencrypted notebook computer containing ISS command and control algorithms was stolen, though NASA maintained that there was never an operational risk to the station. Nevertheless, NASA's poor cybersecurity record throughout other parts of the agency has independent experts and retired officials counseling even greater vigilance to protect ISS, especially with 90% of the workforce working remotely since March.

"We must recognize that while basic cyber hygiene practice is relatively doable under normal circumstances, these are not normal times," said Diana Burley, a cybersecurity researcher at American University in Washington, D.C., in a September congressional hearing.

Even before the pandemic, internal audits and reports by NASA'S Office of the Inspector General and the congressional Government Accountability Office indicated that NASA had repeatedly fallen short on cybersecurity of its computer networks and the proper data hygiene of its employees.

After repeated attempts for comment from NASA's associate chief information officer for cybersecurity and privacy, Mike Witt, and others in the Information Security Office in charge of NASA's cyber posture, I was able to connect with Renee Wynn, who was on the receiving end of some of those reports before

▲ **NASA astronaut** Mike Hopkins (foreground) and Japan Aerospace Exploration Agency astronaut Koichi Wakata monitor the situation as a cargo spacecraft unberths from the International Space Station in 2014.
NASA

retiring in April after five years as NASA's chief information officer.

Arriving as NASA's CIO in 2015, Wynn says she found independent scrutiny essential for identifying where NASA's corporate information technology has fallen short, and she acknowledges that it has indeed fallen short.

"One of the big challenges for NASA is that it invented some of the IT [the agency] needed to launch super cool science missions," she explains. And some of that IT, for example, communications software for receiving data from the Voyager space probes, has continued to be used well after what many would consider its prime. In the 1970s when these probes were launched, cybersecurity was not a top concern, says Wynn.

As for technology not tied up in nearly half-century long missions, Wynn says the importance of shoring up — or introducing — cybersecure technology and policies has become a priority in recent

years. But devising the best way to do so has not been without its challenges.

To understand how to best plug NASA's cybersecurity holes, Wynn says that under her watch the agency took a risk-based-assessment approach and began to evaluate a variety of scenarios and risks of all programs, including the human spaceflight program that operates the ISS.

"We certainly found a green field of opportunity" for improving security, she says.

Despite Wynn's efforts, in 2018, the NASA-funded Jet Propulsion Laboratory in California had 500 megabytes of undisclosed data stolen through an unsecured and unmonitored Raspberry Pi, a credit-card-sized hobbyist computer. NASA and cybersecurity reviewers from other agencies have released little information about the incident, but we do know the hacker used the Raspberry Pi to access NASA's Deep Space Network, which routes commands to spacecraft beyond Earth orbit and receives scientific data back from them. They also penetrated an internal communications network that connects JPL with other NASA centers and contractors. A 2019 NASA audit report says that Johnson, the center responsible for ISS, disconnected from the infected internal network altogether.

"Johnson officials were concerned the cyber attackers could move laterally from [the internal network] into their mission systems, potentially gaining access and initiating malicious signals to human space flight missions that use those systems," according to the report, "Cybersecurity Management and Oversight at the Jet Propulsion Laboratory."

▲ **The International** Space Station photographed from a Soyuz spacecraft after undocking. On board the Soyuz were two NASA astronauts and a Russian cosmonaut. The international delegations that work on ISS add another layer of complexity to preventing cybersecurity intrusions.
NASA/Roscosmos

While NASA reports that no serious damage was done during this breach, records suggest that the agency has continued to struggle with cyber threats. In an independent review of federal records between 2018 and 2019, Atlas VPN, an online privacy company based in New York, reported that cybersecurity incidents at NASA were up 360% from 2018, with a total of 1,468 cyber incidents in 2019. This assessment is echoed by concerns voiced in a NASA inspector general report issued in June, "Evaluation of NASA's Information Security Program," which cited the agency for poor implementation and maintenance of cybersecurity infrastructure and protocols at its various centers.

NASA's Office of Inspector General explained to me in an email that these shortcomings threaten "the confidentiality, integrity, and availability of NASA information maintained in those [computers and databases.]"

Source of the problem

Although analyses to date have not specifically named the ISS as a concern, cybersecurity researchers I spoke to say there could be as-yet-undiscovered weaknesses at the root of the agency's tangle of information computer networks, software and personnel, that might leave the station vulnerable.

As for how NASA amassed a poor cyber record, Emmanuel Lesser, a software product assurance engineer at the European Space Agency who researches cybersecurity solutions for satellites and deep space probes, thinks he knows, and it has to do with history.

"The kind of security implemented in space systems was security through obfuscation," he says. Lesser explains that major science and technology organizations, like NASA, that were building advanced hardware, software and craft for space exploration simply believed that malicious actors would find it too hard to obtain the communications protocols or appropriate transmitters necessary to hack their computers, let alone to understand the information once they got it. "They really believed [they were] not worth the effort to hack."

But, while the sheer complexity of spacecraft and their communications networks may have been enough to safeguard them in the past, hackers can learn a lot about those technologies from information that's available online, and they can add to that knowledge with each breach. This has left NASA rushing to catch up to modern cyber threats that stretch from its ground-based operations all the way, at least in theory, to the ISS.

In the June report, NASA's Office of Inspector General contends that this lack of security does not necessarily come from a lack of funding or lack of overall infrastructure capabilities, but instead from a more human problem: inconsistent management.

Part of the cause for this, says Wynn, is the diversity of protocols and organizational structure in different parts of the agency itself. During her tenure, she recognized that she would need solutions tailored for the specific needs of the different programs.

While some offices proved to be challenging to work with, the station managers were not.

"I immediately found partnership with the human space program," says Wynn, including managers of the ISS. When coming to discuss the cyber risks of the program, Wynn says she was prepared for resistance but instead "found people were already thinking about it and really putting some great ideas into practice."

Part of what drove this early adoption of cyber posture, Wynn suggests, is the concern for astronaut safety among those in the human spaceflight program. For them, cybersecurity was another critical element of that safety.

Challenges ahead

Of course, a desire for security is one thing, finding it is another. Bhavani Thuraisingham, who directs the Cyber Security Research and Education Institute at the University of Texas in Dallas, says that securing a spacecraft such as ISS is far more complicated than, for example, securing a retail store.

"The retail industry, like many industries, uses computers, iPads, and smartphones that are all integrated into databases and your operating system," says Thuraisingham. Targeting one piece of technology within a network of devices, say the microprocessor of a single iPad, is equivalent to an attack on the whole information network — from the iPad fleet to the financial databases they might be connected to — because of its interconnectivity, she says. This means that these networks are truly only as powerful as their weakest link.

So, retail stores are continually updating their software and devices for security. That's much harder to do with spacecraft far from Earth whose weaknesses might be outdated code or low-memory capacity for cybersecurity upgrades, says Gregory Falco, a security researcher at Stanford University.

The good news is that ISS is close to Earth, relatively speaking, and astronauts can regularly update its computers.

Teleworking targets

NASA is already contending with delays to its missions because of the widespread teleworking prompted by the coronavirus pandemic. Now, the agency must also contend with how that teleworking affects its cybersecurity, agency Inspector General Paul Martin told the House space subcommittee in September.

About 90% of NASA's employees and contractors have been working remotely since March, Martin said during the hearing. He said, "phishing attempts have doubled and malware attacks have increased exponentially."

This increase is not unique to NASA, said Diana Burley, a cybersecurity researcher at American University in Washington, D.C. Larger numbers of employees logging in from their home networks increase the number of points through which hackers can attempt to gain information from government agencies and companies, and employees who may be "distracted, frightened, and fatigued" with juggling work and personal responsibilities may be easier targets.

"Employees are worried about meeting their basic needs and are less likely to attend to seemingly lower priorities like cybersecurity," Burley told lawmakers.

— Cat Hofacker

▲ **Linking the** International Space Station to Earth requires flight controllers, software and hardware at NASA's Johnson Space Center in Texas.
NASA

In fact, ISS is certainly not stuck in the 1960s — or even '90s — when it comes to technology, says Pamela Melroy, a retired Air Force colonel and NASA astronaut who piloted or commanded three space shuttle missions to ISS. Melroy, now director of space technology and policy at Nova Systems in Australia, spoke during the virtual DefCon in August in a session titled "Cybersecurity Lessons Learned From Human Spaceflight." Hardware and software updates have even been made in recent years to accommodate new commercial spacecraft, she noted, the first of those being Northrop Grumman's Cygnus cargo capsules and SpaceX's Dragon and Crew Dragon capsules.

But with added complexity and capability, points out Thuraisingham, comes the possibility of cybersecurity breaches or mishaps. For example, the process from designing specialized hardware and software for a new spacecraft all the way through docking it at ISS can mean the participation of not only many NASA centers but private-sector partners as well. Any misstep in the process can create weak points, says Thuraisingham, and assigning blame can be nearly impossible.

And, of course, there is the international aspect of the space station. Nations aboard the station include Canada, Japan, Russia and those represented by the European Space Agency. While the astronauts do work together to transport cargo and crew to and from the station and share dinners together in com-

"It can sometimes be challenging for scientific institutions like NASA to look beyond their bigger mission — the advancement of science — to see how specialized hardware or software might be used nefariously for other purposes."

— Gregory Falco, Stanford University

mon areas, scientific experiments are carried out in separate, national modules and follow information security protocols from their respective agency CIOs, says Wynn, the former NASA CIO.

While comradery and respect among these international space agencies is critical to the station's overall mission of peaceful scientific cooperation in space, these differences in security protocols could nonetheless leave room for miscommunication or accidental introduction of nefarious code to ISS.

But, as Melroy explained in her DefCon talk, even if infected software were to be introduced to the station, say through a computer laptop, this wouldn't likely lead to stationwide infections because computers on ISS are never connected to other station networks or computers. In fact, this is true for many communications and scientific devices on the station for just these security reasons.

This similarly makes it unlikely for a phishing email with malware hidden in its links to infiltrate the station. These emails and personal communications are originally accessed through a secure computer on Earth and mirrored safely to laptops on the space station, similar to how you can trick your internet provider into thinking your computer is located in the United Kingdom by using a VPN. The next thing you know, you're watching another country's Netflix selections. Likewise, by using the station's laptops to remotely access the proxy computer on Earth, astronauts can check their email or other personal accounts a few times a day, says Melroy.

The threats

Wynn says that phishing attacks do not necessarily keep those in the CIO office up at night worrying about threats to ISS and human spaceflight. But that does not mean the station is completely out of harm's way, either.

When it comes to the actual damage these hackers could do to ISS, Steve Lee, AIAA's aerospace cybersecurity program manager, says there are three main types of attackers to look out for.

"I would say, if you had a pie chart of this sort of thing, some significant portion, maybe a quarter or a third, would be [industry] insiders and com-

▲ **The Canadarm2** robotic arm, guided by an astronaut on the ISS, prepares to capture a Cygnus supply spaceship made by Northrop Grumman. Hardware and software aboard ISS has been updated in recent years to accommodate new commercial spacecraft.
NASA

petitors." Lee says these types of bad actors, which may likely be behind the data breach at JPL in 2018, are not in the hacking game for chaos or prestige, but instead to steal trade secrets and make money. Similarly, Lee says another big piece of the pie is opportunistic hackers armed with ransomware or malware to corrupt or steal information. And the remaining sliver, no more than 20%, is terrorists and nation states, says Lee.

Regarding nation states, "What they're doing is super strategic, super targeted and, frankly, super surgical," says Lee. China and Iran, two nations not represented on ISS, are often top suspects for threats like these, he says.

No wise person entirely disregards the possibility of terrorists trying to hack ISS, but as yet there is no evidence that they would have motivation for such an attack, Lee says.

What seems more likely than a catastrophic attack would be one that undermines the integrity of NASA and ISS partners by stealing or corrupting experiment results, says Falco. Even if not aimed directly at the ISS, a breach that threatens data accuracy or NASA's reputation could result in an overall loss of public trust, funding and, ultimately, NASA's place in space leadership, worries Falco.

"I think the biggest risk is that we lose trust in the organizations trying to make space exploration real," says Falco.

It can sometimes be challenging for scientific institutions like NASA to look beyond their bigger mission — the advancement of science — to see how specialized hardware or software might be used nefariously for other purposes, Falco says. Hiring cybersecurity experts who can see around and through this mystique will be essential to protecting it.

While Thuraisingham says that this tug of war between hackers and the guardians of technology is destined to be eternal, there are steps that can be taken to secure space communication networks, spacecraft and computers.

In addition to better management from NASA, Lesser, the ESA researcher, says that it will also be important to future-proof security upgrades such as encryption. Even though today's modern encryption techniques can go toe-to-toe with hackers, the rise of quantum computing suggests that, without innovations, tomorrow's hackers will be able to cut right through conventional encryption. But, if ISS is indeed decommissioned in 2028, Lesser says this threat is unlikely to reach the station.

For ISS, Thuraisingham also suggests implementing security strategies that do not rely on encrypted communication signals to transmit commands to and from space, but instead depend on physical data available only on the station itself, for example, exact positioning or velocity measurements. Physical, immutable data like this would make spoofing encryption keys much harder. This, along with artificial intelligence algorithms designed to learn and anticipate hackers' patterns, could be another step forward.

Ultimately, putting more tools in NASA's cybersecurity toolbox is about more than protecting communications, data and science. It's about maintaining the public's trust — and funding — for scientific endeavors that aim to expand the understanding of our universe and ourselves.

"There's going to be a lot of players in the coming decade," Falco says. Those players will include private companies seeking to shuttle tourists and scientific instruments into space and national organizations like NASA and the space agencies of other nations. Falco says these players must work together to ensure they "have the security toolsets" to build these critical safety nets. ★

*Staff reporter **Cat Hofacker** contributed to this report.*

2020 ELECTION:

SPACE POLICY PLATFORM PAPER

The importance of United States space activities to the modern economy, our way of life, and our global stature cannot be understated. American space preeminence – a singular source of national pride – is established through international partnerships in civil space exploration and satellite services; a blossoming commercial industry; essential military satellites for navigation and timing, surveillance, early warning, communications; and the critical nature of space in our innovation ecosystem.

KEY POINTS

The United States must continue to lead in space with sustained policies, programs, and investment (funding) that have bipartisan support. Space has historically been a unifying issue and there is, in general, consensus and strong support in the country and Congress for national space programs.

Continuity of policies and programs that are meeting their objectives and adding value to the nation's technological advancement, scientific knowledge, and strategic security is necessary to maintain "constancy of purpose" and prevent excessive cost and delay. This includes robust government support of basic research that identifies new technologies and frontiers in science. Such research is often the source of technological breakthroughs that fuel America's engine of innovation.

A whole-of-government approach is essential to build on successful past policies and programs. Examples include the creation of $1.7 trillion in economic value since the Global Positioning System (GPS) was made available for civilian and commercial use; the establishment of the moon as a focal point for civil and commercial space in service of national leadership goals; and the interagency Science & Technology Partnership Forum that collaborates on cross-cutting space technology strategies.

U.S. space leadership can be defined in terms of three principal sectors: civil, commercial, and national security. In addition to sustaining the programs-of-record, new government investments in advancing space domain awareness, accelerating the pace of satellite production and deployment, and on-orbit servicing, assembly, and manufacturing infrastructure are needed to ensure the United States has both the actionable information and the industrial capacity to maintain leadership in each sector.

CRITICAL SECTORS

The benefits of U.S. leadership in civil space are wide ranging, as often exemplified by NASA and NOAA programs in space science, human exploration, weather and climate monitoring, and Earth remote sensing. NASA has also led one of the most successful and technically complex modern international partnerships: the International Space Station (ISS). Now NASA envisions a return to the moon and future human exploration of Mars through national capabilities like the Space Launch System (SLS) rocket, Orion crew module, the Lunar Gateway, and new industry partnerships for lunar surface operations.

The commercial space sector has traditionally been dominated by private satellite operators for global telecommunications. Collecting and transmitting data around the world at the speed of light remains an important and lucrative business. Advances in launch technology; the miniaturization of satellite systems, such as CubeSats and other "small sats"; and the increasing use of public-private partnerships by government agencies are accelerating the growth of new entrants into the space economy and the creation of new transportation and satellite services that were previously only available through large national programs. This enables both private and government customers to obtain more value from space-based services.

The modern U.S. defense enterprise is wholly dependent on national security space capabilities, ranging from communications and precision navigation for air, land, and sea; to strategic and tactical early warning; to intelligence collection and treaty compliance monitoring. However, near-peer adversaries, such as Russia and China, threaten those critical assets with new anti-satellite weapons and increasingly sophisticated denial and deception operations. This is all intended to either prevent overhead collection or deny our forces access to the data generated by U.S. satellite assets. Deterring threats to U.S. space infrastructure requires new strategies and operations unique to the space environment.

THEMES TO BE ADDRESSED

AIAA has identified several key themes in U.S. space policy that must be addressed to ensure ongoing global leadership, maintain space superiority over our adversaries, and expand the benefits of this highly technological sector for our society.

Continued, balanced investment in human space exploration, scientific research, and space technology development is essential to increase our understanding of both the Earth and the universe, create the space technologies needed to sustain economic growth and increase value to society, and inspire our youth to study scientific disciplines and pursue the variety of careers available.

Constancy of purpose in human space exploration enables the first crewed missions beyond low Earth orbit in 50 years. The United States must continue successful international partnerships – including the ISS – to retain critical experience and leverage the capabilities NASA has developed for a return to the moon, such as SLS, Orion, Gateway, Commercial Lunar Payload Services, and other programs.

Civil space situational awareness and space traffic management capabilities are fundamental to safety of operations, attribution of space events, and sustainable, industry-friendly space practices. These practices should be based on shared values of open access for people and markets for peaceful purposes. The White House and Congress should prioritize giving the authority and transitioning resources to civil management, which will enable the U.S. Space Command to focus on its core missions.

U.S. ambitions in space science, exploration, and defense depend on policies **enabling innovations for national strategic benefit** and the continued **reduction of barriers to entry for entrepreneurial ventures and early innovators**. Examples include maintaining a U.S. National Laboratory in low Earth orbit as an incubator for new businesses and space technologies; reviewing and assessing the constraints that export controls and licensing requirements impose on space businesses; and granting and incentivizing the use of urgently needed, streamlined acquisition authorities, such as Other Transaction Authorities, commercial services contracts, and joint ventures.

The United States must also **strengthen our coalitions and partnerships with our allies in civil and defense space** to promote our values and ensure freedom of movement in space. Examples include continued implementation of the Artemis Accords; creating a common approach and international standards for space situational awareness and space traffic management in which peaceful missions can navigate cooperatively and as freely as maritime traffic; collaboration on debris mitigation and hazard avoidance; and engaging stalwart military allies, like the Five Eyes intelligence partnership and the NATO alliance, on topics of mutual interest for our national security space strategy.

SPACEPLANE CATAYLYST

No one without the right clearance knows exactly what the U.S. Air Force's X-37B spaceplanes do in orbit, but it must be a lot given the cumulative years they've spent up there. The vehicles are sparking a resurgence of interest in spaceplanes as a necessary ingredient for expanding society to space. Debra Werner tells the story.

BY DEBRA WERNER | werner.debra@gmail.com

Less than five minutes after liftoff in May, the United Launch Alliance webcast cut away from the Atlas V rocket before its payload shroud opened to expose its cargo: a U.S. Air Force X-37B spaceplane carrying orbital experiments housed inside its payload bay. The online audience was treated to Boeing, ULA, Air Force and U.S. Space Force leaders thanking first responders for their work during the covid-19 pandemic.

The Air Force, which owns two X-37Bs, and the Space Force, which flies them, like to offer tantalizing glimpses but few details of the autonomous spaceplanes that have spent about eight years in orbit over six missions. The spaceplanes make cameos in the first Space Force recruitment videos released in May, coming in for landing and on a runway surrounded by people in hazmat suits with sensors to check for noxious vapors.

Air Force Secretary Barbara Barrett lauded X-37B's unique capabilities as an experimental platform during a May webinar put on by the Space Foundation but said little about what it tests, aside from identifying a handful of NASA and military research laboratory experiments. Boeing declined my requests for interviews on the X-37B or the merits of spaceplanes in general, and its customer, the Air Force, said "coordinating an interview will take time" and had not scheduled one as of Sept. 21.

In spite of the mystery, the U.S. National Aeronautics Association announced in August that it had selected the X-37B, which it called "the world's only reusable, autonomous spaceplane," to have its name engraved on the prestigious Robert J. Collier Trophy, whose most famous past recipient is the GPS constellation.

The vehicles are serving as an advertisement for the type of spaceplane likely to play an increasingly important role as entrepreneurs, Fortune 500 companies and NASA managers seek to extend the Earthly economy, and someday possibly even our society, into orbit.

"You can count on spaceplanes flying people and cargo to the edge of space or to low-Earth orbit and back very soon," predicts Bobby Braun, solar system exploration director for NASA's Jet Propulsion Laboratory in California and a former NASA chief technologist. "Spaceplanes are here, and they're here to stay."

By edge of space and soon, he means Virgin Galactic's SpaceShipTwo, an air-launched suborbital spaceplane that the company plans to launch with customers for the first time in 2021. On the orbital side, he means Sierra Nevada Corp.'s Dream Chaser. Like an X-37B, it will be boosted toward space atop a conventional rocket inside a payload fairing. If all goes as planned, Dream Chaser will transport cargo for NASA to and from the International Space Station starting in 2021.

▲ **The Dream Chaser test** vehicle touches down at Edwards Air Force Base in California after being dropped from a helicopter at an altitude of 12,400 feet.

Defining spaceplanes

Spaceplane discussions often begin with definitions. Not everyone considers X-37B, SpaceShipTwo and Dream Chaser spaceplanes. Some preserve the term for single-stage-to-orbit vehicles that take off from a runway, travel to orbit and return to a runway.

Others include air-launched spacecraft as long as they have wings to maneuver and glide through Earth's atmosphere on the way back from orbit to a runway.

If vehicles that fit those definitions are eventually built and flown hundreds of times with minimal repair and maintenance between flights, they could slash the cost of space transportation and speed point-to-point travel on Earth.

Few expect significant savings with spaceplanes launched atop throwaway rockets that can cost $100 million or more.

Space pioneers will need 10 to 100 times more flights to orbit, "if you are serious about blowing open a low-Earth-orbit economy," says Adam Dissel, president of Reaction Engines Inc., the U.S. subsidiary of the United Kingdom air and space propulsion company that aspires to crack the spaceplane riddle. "You've got to move to more aircraft-like operations," he says. But imagine if an aircraft took off and landed safely 98% or 99% of the time. Those figures are the best one can expect from most of today's expendable or partially reusable rockets, and that's not nearly good

▲ **Virgin Galactic's** SpaceShipTwo Unity is released from its carrier aircraft for a glide flight in New Mexico.
Virgin Galactic

enough for carrying precious cargo. "We have to move the needle on reliability," Dissel cautions.

In addition to cost and reliability, there are convenience and comfort to consider.

"I'm partial to vehicles that land on runways instead of having to recover people somewhere else with helicopters and boats," says Janet Kavandi, SNC's senior vice president for space systems business and a former NASA space shuttle astronaut.

Spaceplanes can adjust their angle of atmospheric reentry to reduce the forces on passengers or cargo.

"Depending on the design of the capsule, coming back from orbit you might pull 8 or 9 G's," Braun says. "If you're in Dream Chaser, it's more like 2 G's."

(In fact, Dream Chaser is designed for atmospheric reentries of 1.5 G's.)

▼ **Personnel attend to** the U.S. Air Force X-37B Orbital Test Vehicle 4 in Florida in 2017 after it spent 717 days in space.
U.S. Air Force

Spaceplane advocates also bring up maneuverability.

"Because it has wings, it could do interesting things in terms of changing its orbit by using lift and drag in a way that a simple capsule would have a hard time doing," says Peter Garretson, retired Air Force lieutenant colonel and now a senior fellow for defense studies at the American Foreign Policy Council in Washington, D.C.

On the return trip, if there is a problem at one airport, a spaceplane can adjust its trajectory to glide toward another airport.

Stefan Powell, co-founder and chief technology officer of Dawn Aerospace, a New Zealand space transportation startup, says compared with rockets, spaceplanes will be "in every way a safer, more reliable, more efficient way of transportation."

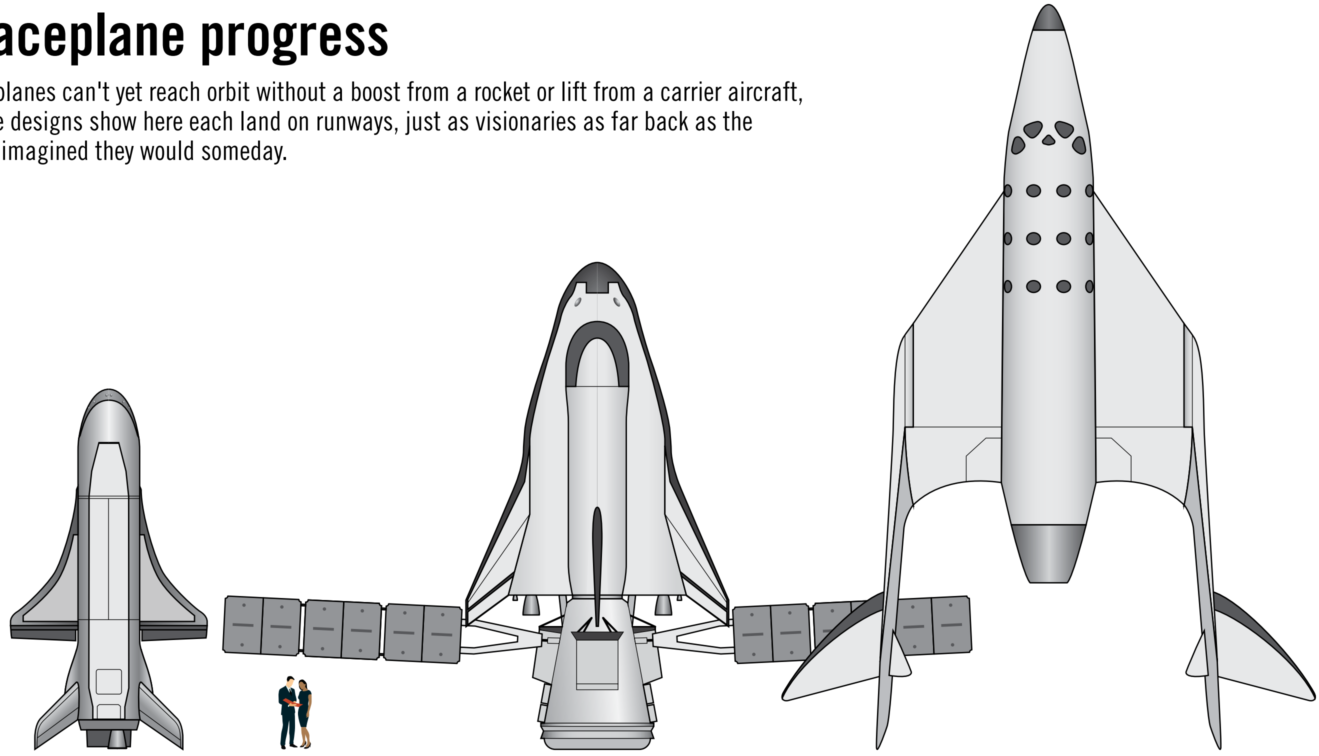
Zero to Mach 25

That's the promise. To date, in spite of tens of billions of dollars spent by governments and corporations and decades of research and development around the world, no one has flown a single-stage-to-orbit spaceplane or even managed to release a spaceplane from an aircraft and send it to orbit.

Instead, astronauts, satellites and cargo are typically boosted toward orbit on lightweight rockets filled with propellant that claims up to 90% of their takeoff weight. But reaching orbit in a single-stage spaceplane and landing with a quick turnaround comes with sizable challenges. Such vehicles would have to be durable enough to survive multiple reentries in Earth's atmosphere, and they would need efficient propulsion

Spaceplane progress

Spaceplanes can't yet reach orbit without a boost from a rocket or lift from a carrier aircraft, but the designs show here each land on runways, just as visionaries as far back as the 1950s imagined they would someday.



X-37B Orbital Test Vehicle
U.S. Air Force

Length: 8.9 meters

Wingspan: 4.5 meters

Launch vehicle: ULA Atlas V or SpaceX Falcon 9

Flight mode: Vertical launch to LEO, horizontal landing

Load: Classified cargo

Status: Two Boeing-built X-37B Orbital Test Vehicles have orbited Earth for more than eight years cumulatively and there is no end in sight for operations of the autonomous spaceplane.

Dream Chaser/Shooting Star
Sierra Nevada Corp.

Reentry vehicle length: 9 meters

Wingspan: 7 meters

Cargo Module: 4.6 meters long

Launch vehicle: United Launch Alliance Vulcan Centaur

Flight mode: Vertical launch to LEO, horizontal landing

Load: 5,000 kg pressurized and 500 kg unpressurized

Status: Sierra Nevada Corp. plans to launch Dream Chaser Tenacity and its Shooting Star cargo module to the International Space Station in 2021, in what would be the design's first orbital flight.

Virgin Galactic SpaceShipTwo
Virgin Galactic

Length: 18.3 meters

Wingspan: 8.2 meters (excluding lateral fins)

Carrier aircraft: The SpaceShip Co.'s WhiteKnightTwo

Flight mode: Air-dropped from WhiteKightTwo jet at 50,000 feet, followed by rocket ignition.

Load: 2 crew, 6 passengers

Status: Virgin Galactic has flown a dozen powered and glide test flights of SpaceShipTwo VSS Unity in preparation to carry passengers to the edge of space in 2021. VSS Unity's first passenger soared to an altitude of nearly 90 kilometers in the vehicle after it was released from the carrier aircraft, Scaled Composites' WhiteKnightTwo, in 2019.

Graphic by John Bretschneider

▲ **An X-37B Orbital** Test Vehicle is prepared for launch in 2010 at the Astrotech facility in Titusville, Fla. Half of the Atlas V 5-meter fairing is visible in the background.

for takeoff, ascent through the atmosphere and spaceflight because wings and landing gear add weight.

"What propulsion system is viable from a velocity of zero to Mach 25?," asks Dallas Bienhoff, founder of Cislunar Space Development Co., a Virginia startup, and former Boeing space architect and project manager. "And what materials are viable for reentry without requiring months for inspection and repair like the space shuttle?"

This is his way of suggesting that no one has answered those questions with certainty. Engineers are beginning to tackle those challenges. The highest profile effort is underway at Reaction Engines, which designed Skylon, a single-stage-to-orbit spaceplane powered by SABRE, for Synergetic Air-Breathing Rocket Engine. SABRE's key innovation is a precooler, a heat exchanger to chill and compress incoming air before funneling it into the engine. Instead of carrying liquid oxygen on board like most rockets flying today, SABRE would pull oxygen from the air, vastly reducing its takeoff weight.

"That's now a savings I can pass onto a vehicle that can afford the weight penalties of wings, landing gear or more robust structural margin," says Dissel.

To make air breathing work, though, the air must be cooled. An aircraft traveling beyond Mach 3.5 or Mach 4 would make its surrounding air hot enough to melt engine components. SABRE's precooler, tested on the ground in 2019 at speeds as high as Mach 5, solves the problem by reducing the temperature of incoming air and injecting the heat pulled from the air into its SABRE engine. "It's a usable bit of energy to help run your engine," Dissel says.

The next step for Reaction Engines is to demonstrate the SABRE engine cycle on the ground, proving it can move thermal energy from the air to the engine.

Other startups have competing designs for spaceplanes and spaceplane propulsion.

Polaris Raumflugzeuge, a spinoff of DLR, the German Aerospace Center, performed the first flight in April of a 2.5-meter model of Aurora, a flying wing propelled by a kerosene-fed turbojet engine. Eventually, the company would like to scale up the design to carry people and launch satellites. But Aurora initially would be limited to suborbital flights, and an expendable upper-stage would have to be added to loft satellites into orbit.

New Zealand's Dawn Aerospace is developing Mk-II Aurora, a 4.8-meter-long air-launched spaceplane scheduled to begin flight tests with a jet engine later this year. If all goes as planned, Dawn Aerospace will add a rocket motor for further testing in 2021.

Flying testbed

Meanwhile, the X-37Bs have proved that an autonomous spaceplane can remain in orbit for years at a time; the design's longest mission was 780 days. How the design operates, the U.S. Defense Department won't say beyond disclosing its dimensions and the fact that it is powered by gallium arsenide solar cells that charge lithium-ion batteries.

Over multiple flights, X-37Bs have tested advanced guidance, navigation and control, thermal protection, avionics, high temperature structures and seals, conformal reusable insulation, lightweight electromechanical flight systems, advanced propulsion, advanced materials and autonomous orbital flight, reentry and landing, according to an Air Force fact sheet.

During the first three flights, the Air Force demonstrated technologies for long-duration reusable space vehicles with autonomous reentry and landing systems, an Air Force spokesman said by email.

Secret spaceplane, secret flights

When the X-37B began flying in 2010, the U.S. Air Force said little about what it was testing. Gradually, the Air Force began sharing details about a few of the technologies tested on board the spaceplane and later returned to the ground for inspection. Here's what we know about the first six flights.

FLIGHT DESIGNATION	LAUNCH DATE AND SITE	ROCKET AND LAUNCH SITE	LANDING DATE AND LOCATION	MISSION DETAILS	SOURCE
Orbital Test Vehicle (OTV) 1	April 22, 2010	Atlas V from Cape Canaveral Air Force Station	Dec. 3, 2010 Vandenberg Air Force Base (224 days)	Checkout of technologies for long-duration reusable space vehicle capable of autonomous reentry and landing. Tire blowout during landing.	Air Force Public Affairs: The primary focus for the first three OTV missions was vehicle checkout and demonstration of a number of technologies required for long-duration reusable space vehicles with autonomous reentry and landing capabilities.
OTV-2	March 5, 2011	Atlas V from Cape Canaveral Air Force Station	June, 16, 2012 Vandenberg Air Force Base (468 days)	Technology checkout continued.	Air Force Public Affairs
OTV-3	Dec. 11, 2012	Atlas V from Cape Canaveral Air Force Station	Oct. 17, 2014 Vandenberg Air Force Base (674 days)	Technology checkout continued.	Air Force Public Affairs
OTV-4	May 20, 2015	Atlas V from Cape Canaveral Air Force Station	May 7, 2017 Kennedy Space Center Shuttle Landing Facility (717 days)	In-orbit validation testing of Aerojet Rocketdyne's XR-5A Hall Thruster and NASA materials testing. Vehicle operated in a higher inclination orbit than prior missions.	Aerojet Rocketdyne press release
OTV-5	Sept. 7, 2017	Falcon 9 from Kennedy Space Center Launch Complex 39A	Oct. 27, 2019 Kennedy Space Center Shuttle Landing Facility (780 days)	Small satellites onboard. Air Force Research Laboratory payload to test oscillating heat pipes.	U.S. Air Force news article
OTV-6 and U.S. Space Force 7	May 17, 2020	Atlas V from Cape Canaveral Air Force Station	Still in orbit as of late September	First mission with a trunk-like service module to provide extra room for payloads including Air Force Academy Falconsat-8, NASA tests of materials and seeds, U.S. Naval Research Laboratory space solar power technology.	U.S. Air Force fact sheet

The fourth flight in 2015 housed an Aerojet Rocketdyne Hall-effect thruster and NASA research on the effect on various materials of long-term exposure to temperature extremes and space radiation.

Three cubesats piggybacked on and were released from the fifth X-37B, which reached its highest-inclination orbit. An Air Force Research Laboratory satellite to test oscillating heat pipes, tubes containing liquid to help cool electronic devices, also flew on Orbital Test Bed-5, as the flight was known.

The sixth flight, launched in May and still in orbit as of late September, houses more experiments than any of the prior missions. One is — or was, if it's been released already — the FalconSat-8, a 136-kilogram U.S. Air Force Academy satellite to test thrusters, cameras, antennas, reaction wheels, carbon nanotube cables and a flywheel energy storage device. (The X-37B released a small satellite on May 30, but space watchers aren't certain that was FalconSat-8, and the Air Force had not answered my question as of Sept. 21.) NASA also sent another materials-testing experiment and a payload to show how space radiation affects food seeds. In addition, the U.S. Naval Research Laboratory is conducting an experiment to turn solar power into radio frequency microwave energy, which someday could be transmitted to the ground, to another spacecraft or to a lunar or Martian habitat.

"We've gained a lot of information in the decade we've been operating" X-37Bs, according to Randall Walden, who runs the Air Force Rapid Capabilities Office that manages the X-37B program, speaking in an August webinar put on by the Mitchell Institute for Aerospace Studies in Virginia. "It's provided unique and relevant insight into some of the newer technologies that would actually go to space and informs how they would build those systems," he said.

Air Force officials don't reveal all the technology they are examining on board X-37B, but the ability to test satellite technologies and bring them home to examine would be particularly useful for reconnaissance or missile warning.

▲ **The X-37B Orbital Test** Vehicle 5 in its payload shroud at NASA's Kennedy Space Center in Florida in 2017.
Boeing

"You can count on spaceplanes flying people and cargo to the edge of space or to low-Earth orbit and back very soon. Spaceplanes are here, and they're here to stay."

— Bobby Braun, NASA's Jet Propulsion Laboratory

"You're looking at programs that are going to cost billions of dollars and take a long time," says Brian Weeden, program planning director for the Secure World Foundation, a Washington think tank. "Being able to flight test individual components or technologies ahead of time makes a lot of sense."

The military doesn't disclose the X-37B's orbit or the orbits of the cubesats it has launched over the years. Hobbyist observers equipped with telescopes have spotted the spaceplanes at altitudes of 270 to 450 kilometers and inclinations of 37 to 55 degrees, meaning they travel over latitudes between 55 degrees south and 55 degrees north, says Jonathan McDowell, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.

The X-37B is not likely to be testing electro-optical cameras because it does not travel in a sun synchronous orbit where consistent lighting would make it easier to detect changes by comparing images. Instead, observers suspect the spaceplane could test radars, hyperspectral imagers or some type of signals intelligence device, meaning a sensor to detect electronic signals coming from sources like ground-based radars.

"I honestly don't know, but my guess is that it's testing technologies for ground surveillance, intelligence and reconnaissance," says Weeden, former director of a U.S. Air Force orbital analyst training program.

Dream Chaser and SpaceShipTwo

Compared with the X-37B, the other two spaceplanes nearing takeoff, SNC's Dream Chaser and Virgin Galactic's SpaceShipTwo, are open books.

Dream Chaser will carry up to 5,500 kilograms of pressurized and unpressurized cargo in its 9-meter-long lifting body and 4.6-meter-long trunk called Shooting Star. The first flight of Tenacity, the first orbital Dream Chaser as opposed to the engineering test vehicle, is scheduled to travel to the International Space Station on a United Launch Alliance Vulcan Centaur rocket in 2021.

Each Dream Chaser is designed to make 15 or more flights and to fit a variety of launch vehicles including the Atlas V. Under the Commercial Resupply Services 2 contract NASA awarded to SNC in 2016, Dream Chaser will remain docked to the International Space Station for as long as 75 days before disposing of 3 metric tons of trash, about half a metric ton more than Northrop Grumman's Cygnus capsule, to burn up in the atmosphere and delivering up to 1,925 kilograms of cargo to the runway at the Kennedy Space Center's Shuttle Landing Facility on Florida's Merritt Island. Although NASA is hiring Dream Chaser to transport cargo, the spaceplane was designed originally to carry astronauts. It could eventually serve as an orbiting laboratory or a government or commercial transport vehicle.

"We're focused on getting this particular vehicle to the space station and back," says John Wagner, a retired U.S. Air Force colonel and SNC's vice president for national security space. "Once we show everyone we can do this, cargo to station is just the beginning. Then, we envision other opportunities for Dream Chaser including crewed missions."

As for Virgin's SpaceShipTwo Unity, it is poised for takeoff in early 2021 with founder Richard Branson on board to attest that the experience of traveling to the fringes of space lives up to the Virgin brand's reputation for customer service.

Prior to welcoming Branson on board, Virgin Galactic plans to conduct two powered test flights from Spaceport America in New Mexico of the 18.3-meter-long carbon-fiber vehicle with twin tail booms that fold down to act like wings in the atmosphere.

Suborbital tourism is Virgin Galactic's first market, but the company's long-term goal may be high-speed point-to-point transportation. Virgin Galactic and its subsidiary, The Spaceship Co., are working with NASA and Boeing, one of the firm's investors, to develop commercial planes able to travel Mach 3.

While that is not as fast as the hypersonic spaceplanes that could someday deliver passengers from New York to Tokyo in a couple of hours, it would speed the journey.

"If you can achieve low-Earth orbit, you can get anywhere," Braun says. ★

A long-exposure photograph of an airliner flight deck.

Tomorrow's connected cockpit is taking shape now

In the coming years, the FAA and equivalent authorities around the world must establish an air transportation network that can welcome futuristic aircraft and hitherto unseen flight volumes. The FAA's NextGen air transportation network is a good start, but more is needed. Gregg Leone and Emily Stelzer of the MITRE Corp.'s Center for Advanced Aviation System Development in Virginia give us a glimpse of the future.

BY GREGG LEONE AND EMILY STELZER

The future of aviation is upon us. Over the next decade, thousands of urban air mobility vehicles and package delivery drones will course through the low altitudes. Up higher, jet aircraft will rebound from the pandemic to set records once again for passenger-kilometers traveled. Commercially operated rockets will roar toward space from new spaceports, and they will fly back in stages or in their entirety through this increasingly bustling airspace.

Accommodating these new airborne vehicles, their missions and the accompanying increase in number of vehicles will require vigorous and ongoing innovation by the FAA in its operation of the U.S. National Airspace System, as the United States fills its role in the global aviation ecosystem.

Today's NAS must be adapted into a fully interconnected system from surface to space. This is the only way to safely maximize the throughput of passengers, packages and cargo. Staying organized will require aircraft and spacecraft, whether conventionally piloted or uncrewed, to exchange their intents, their trajectories and a host of other information with each other and with air traffic controllers in real time.

As the operator of FAA's research and development center, we at the MITRE Corp. know that the information revolution occurring across the world offers unprecedented opportunities for making this level of data exchange possible. The required connectivity would be delivered through a mixture of publicly and privately owned infrastructure incorporating advances in satellite and cellular communication technology. We are researching ways to accelerate this transformational shift to a more fully interconnected NAS, a key being to develop a new class of fully integrated flight decks, or cockpits, for all passenger jets.

A foundation for success

The good news is that there is a strong foundation on which to build ubiquitous information exchanges. Today, air travelers are beginning to reap the benefits of that foundation, the Next Generation Air Transportation System, the ambitious modernization of the NAS launched two decades ago. NextGen brings multiple new capabilities, one being Automatic Dependent Surveillance-Broadcast, ADS-B, a communications protocol in which a radio aboard each aircraft broadcasts the aircraft's GPS position and other data to the ground and to any nearby aircraft equipped with an ADS-B In receiver. Due in part to ADS-B, controllers can now use traffic flow and scheduling software to adjust trajectories while aircraft are en route, a process called trajectory-based operations. There is also Data Comm, the text-based digital communications link between pilots and air traffic controllers. Data Comm has begun reducing the need for radio-based voice communications between pilots and controllers.

A test pilot glances at an electronic flight bag display in preparation for landing.
DLR

▲ Data Comm on a flight deck display.
Alaska Air

In addition to reducing radio congestion, Data Comm enables controllers to deliver enhanced ATC services to pilots that are not feasible with voice communications.

These foundational capabilities have set the stage for the integrated flight deck of tomorrow, in which even more information will be exchanged over broadband satellite and 5G-based LTE networks to come.

Enabling a fully shared environment

By tapping into the power of these commercial communication infrastructures, we'll be able to create a common operational "now-cast" of the NAS, one that encompasses shared weather, flight, traffic flow, aircraft intent and tracking information. This data would be shared in real time but also stored for researchers or investigators in the sector's never-ending effort to improve safety. In real time, air traffic control organizations could use machine learning and artificial intelligence to generate actionable recommendations to realize new safety initiatives. Airlines will be able to analyze and monitor aircraft performance more fully to tailor operational solutions and reduce operational risks. The aircraft software would consume data to continually improve decision support through machine learning. Autonomous aircraft would rely on this situational awareness to safely operate in the airspace.

The use of shared infrastructure and services will also allow the NAS to evolve on pace with technology and the needs of the most demanding users or providers.

Evolving flight deck requirements

It all begins on the coming integrated flight deck.

As a foundation, MITRE is working with the FAA to explore new concepts for all airspace users that will improve route efficiency, reduce emissions, and provide a transportation system that is more resilient to interruptions caused by bad weather or other events. Time-based management tools will provide pilots with strategic target times for reaching certain points along their intended route. Trajectory-based decision support tools will enable controllers to provide crews with dynamically generated trajectory adjustments to meet a specific air traffic management goal for the flight.

Our research has shown that a connected flight deck could accelerate the realization of these types of operations. Shared and real-time access to mission support, weather and traffic data will enable pilots and controllers to execute these operations. Air-to-ground trajectory exchange will permit the ground automation software to produce trajectory adjustments in both time and spatial dimensions, adjustments that are not possible with legacy radar surveillance and voice communications. Real-time situational-awareness and safety analytics will guarantee the operations provide increased benefits while maintaining the highest possible safety.

Mobile technology on the flight deck

Airlines have already issued iPads or Microsoft Surface tablets to pilots, and we think they can make greater use of them in the future. Today, pilots exchange data with the airline dispatcher on tablets and receive information from the aircraft's avionics.

Some pilots access moving maps that show where they are on a taxi route using these tablets or other mobile devices. In the most state-of-the-art avionics, pilots can make changes to their flight plans and directly upload those changes to their flight management computer.

Since tablets and smartphones are now commonplace in the cockpit, at MITRE we are exploring how these compact, yet powerful machines might be used in other ways. For instance, we are examining how they can support air-ground trajectory exchange when that capability is not available in the aircraft's avionics. We are also studying how mobile applications might enable improved departure-time planning for business jet operators, as well as how these portable devices might provide the information pilots need to engage in higher-precision aircraft spacing operations.

All of these explorations will ultimately yield a more integrated and effective aircraft operating environment that can better meet future needs. Mobile devices and technology may provide a key bridge between the flight deck and air traffic controllers in the future. These devices provide more computing power and storage than the aircraft's avionics and could provide additional capabilities that are not available on installed avionics. Mobile devices can connect via Internet Protocol and cellular networks, and this could prove to be the most cost-effective conduit to bring the gigabytes of aircraft data to data-hungry smart systems being developed by airlines and air traffic service providers.

A shift to shared infrastructure

The potential of this sort of connectivity is boundless.

Today, most aviation communications occur within an aviation-specific communication infrastructure. Because this infrastructure serves a relatively small user base (tens of thousands), it is not keeping pace with state-of-the-art communication capabilities being exploited by other industries (that serve tens of millions). However, if aviation leveraged commercial broadband communications services, it would be possible to establish many more useful connections among airspace users, air traffic controllers, researchers and value-added service providers to vastly expand the amount and type of data that can be shared — all at lower cost.

By using the IP-based infrastructure the commercial sector provides, the aviation industry would reap the benefits of the continual upgrades of that infrastructure. And, because this commercial infrastructure boasts a vast customer base, these services can be provided at lower cost than those in a private, aviation-specific infrastructure.

Just as the Internet of Things has given us the ability to operate our garage doors or check our thermostats from the office or while traveling, it has the power to give pilots access to vast amounts and types of data, from multiple sources.

The integrated flight deck: tomorrow's connected aircraft

Currently, global air traffic control organizations implement one-to-many command-and-control processes, in which pilots rely primarily on instructions from air traffic controllers to guide their operations. And even that process is segmented, with different facilities and controllers managing different regions of airspace.

Tomorrow, the pilot of a connected aircraft will connect with global information sources beyond a specific air traffic controller's airspace in a many-to-many communication system. With greater connectivity, and more sharing of information, both air traffic control organizations and airspace users will build an enhanced flight trajectory — an end-to-end picture of the flight's planned path in space and time — that can be shared with all stakeholders. This connected aircraft will be made possible at a global level following the International Civil Aviation Organization's proposed Flight & Flow Information for a Collaborative Environment.

Access to other flight-specific information will be possible as well. For instance, pilots may be able to access information about airspace constraints, runway closures or even the upstream metering schedule for their arrival airport.

Even further, the flight deck's connectivity will extend beyond FAA. Pilots might access feeds from NOAA for up-to-the-minute weather information. They may receive notifications that urban air mobility aircraft or low-altitude drones are flying nearby or that commercial space launch vehicles are transiting the airspace. Or perhaps they will receive an alert directly from a space vehicle making an emergency reentry into low-Earth orbit to clear the nearby airspace.

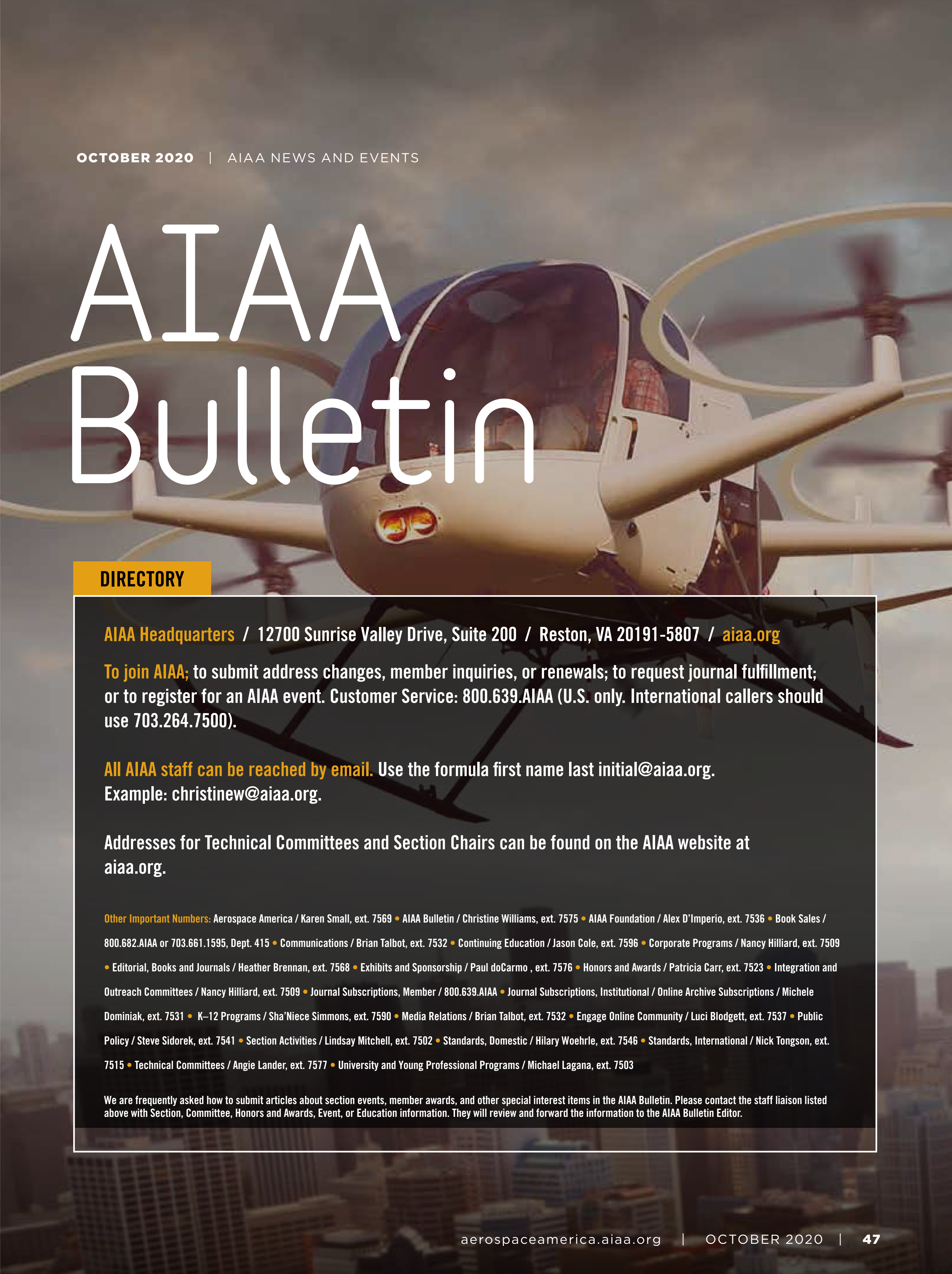
With the enhanced situational awareness the integrated flight deck provides, flying will be safer and more efficient.

Connectivity from surface to space

The connected flight deck is just one example of the power of open data sharing that will enable the next leap in air transportation. Ultimately, FAA envisions that all aerospace aircraft, traffic management stakeholders and regulatory entities will be interconnected. As the operations of low-altitude drones, urban air mobility vehicles and commercial spacecraft expand, ubiquitous information exchange will become crucial to the safety and efficiency of the entire air transportation enterprise. ★

Emily Stelzer is the National Airspace System future vision and research manager at MITRE's Center for Advanced Aviation System Development. She oversees enterprise aerospace planning and concept exploration around NAS concepts, architecture, integration and evolution. She has a doctorate in engineering psychology.

Gregg Leone is vice president and director of the Center for Advanced Aviation System Development at MITRE Corp. in Virginia. He leads MITRE's domestic and international civil aviation, and aerospace and transportation strategy efforts, and works closely with FAA and the global aviation community on next-generation transformation and integration.



AIAA Bulletin

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Addresses for Technical Committees and Section Chairs can be found on the AIAA website at aiaa.org.

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

Calendar

FEATURED EVENT

16–18 NOVEMBER 2020

Online Event

ASCEND is the most forward-thinking space event in the world. It's the center of gravity for the space community—bringing technical and business leaders together to solve problems that affect our entire planet and beyond. Join us at ASCEND to build the future of space in cyberspace.

www.ascend.events

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2020			
7 & 9 Oct	Sustainable Aviation Course	Online (aiaa.org/events-learning/online-education)	
11–15 Oct*	39th Digital Avionics Systems Conference (DASC)	VIRTUAL EVENT (https://2020.dasconline.org/)	
12–14 Oct*	71st International Astronautical Congress (The CyberSpace Edition)	(iac2020.org)	
14 Oct–11 Nov	Electrified Aircraft Propulsion Technologies: Powering the Future of Air Transportation Course	Online (aiaa.org/events-learning/online-education)	
15–16 Oct	Young Professionals, Students, and Educators Conference	VIRTUAL EVENT (aiaaypse.com)	25 Sep 20
19–28 Oct	Design for Advanced Manufacturing: Aviation Lightweighting Course	Online (aiaa.org/events-learning/online-education)	
20 Oct–12 Nov	Taking the Next Steps in Your Aerospace Career Course	Online (aiaa.org/events-learning/online-education)	
21 Oct	ASCENDxSummit: Space Policy and Education	VIRTUAL EVENT (www.ascend.events)	
16–18 Nov	ASCEND Powered by AIAA	VIRTUAL EVENT	31 Mar 20
25–26 Nov	AIAA Region VII/Sydney Section Student Conference	VIRTUAL EVENT	6 Oct 20
2021			
9–10 Jan	5th AIAA Propulsion Aerodynamics Workshop (PAW05)	VIRTUAL EVENT	
11–15 Jan	AIAA SciTech Forum	VIRTUAL EVENT	8 Jun 20
19–20 Jan	1st AIAA Stability and Control Prediction Workshop	VIRTUAL EVENT	

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

21–22 Jan	1st AIAA CFD Transition Modeling Prediction Workshop	VIRTUAL EVENT	
28 Jan–4 Feb*	43rd Scientific Assembly of the Committee on Space Research and Associated Events	Sydney, Australia (cospar2020.org)	14 Feb 20
31 Jan–4 Feb*	31st AAS/AIAA Space Flight Mechanics Meeting	Charlotte, NC (http://space-flight.org)	
6–13 Mar*	2021 IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
26–27 Mar	AIAA Region III Student Conference	Ann Arbor, MI	
26–27 Mar	AIAA Region IV Student Conference	Stillwater, OK	
3–4 Apr	AIAA Region VI Student Conference	Long Beach, CA (virtual)	
8–9 Apr	AIAA Region II Student Conference	Tuscaloosa, AL	
9–10 Apr	AIAA Region I Student Conference	New Brunswick, NJ	
12–14 Apr*	55th 3AF Conference on Applied Aerodynamics (AERO2020+1)	Poitiers, France (http://3af-aerodynamics2020.com)	
15–18 Apr	AIAA Design/Build/Fly Competition	Tucson, AZ	
20–22 Apr	AIAA DEFENSE Forum	Laurel, MD	17 Sep 20
5–7 May*	6th CEAS Conference on Guidance Navigation and Control (2021 EuroGNC)	Berlin, Germany (https://eurognc2021.dglr.de)	
31 May–2 Jun*	28th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (elektropribor.spb.ru/en)	
5–6 Jun	3rd AIAA Geometry and Mesh Generation Workshop (GMGW-3)	Washington, DC	
5–6 Jun	4th AIAA CFD High Lift Prediction Workshop (HLPW-4)	Washington, DC	
5–6 Jun	1st AIAA Ice Prediction Workshop	Washington, DC	
6 Jun	2nd AIAA Workshop for Multifidelity Modeling in Support of Design & Uncertainty Quantification	Washington, DC	
7–11 Jun	AIAA AVIATION Forum	Washington, DC	10 Nov 20
22–25 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
9–11 Aug	AIAA Propulsion and Energy Forum	Denver, CO	
6–10 Sep*	POSTPONED FROM 2020: 32nd Congress of the International Council of the Aeronautical Sciences	Shanghai, China (icas.org)	15 Jul 19
27–30 Sep*	POSTPONED FROM 2020: 37th International Communications Satellite Systems Conference (ICSSC 2020)	Okinawa, Japan (kaconf.org)	15 May 19
25–29 Oct*	72nd International Astronautical Congress	Dubai, UAE	
15–17 Nov	ASCEND Powered by AIAA	Las Vegas, NV	

● AIAA Continuing Education offerings

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

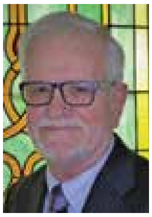
Recognizing Top Achievements - An AIAA Tradition

AIAA is committed to honoring you—the very best! For over 80 years, AIAA has been committed to ensuring that aerospace professionals are recognized and celebrated for their achievements, innovations, and discoveries that make the world safer, more connected, more accessible, and more prosperous. From the major missions that reimagine how our nation utilizes air and space to the inventive new applications that enhance everyday living, aerospace professionals leverage their knowledge for the benefit of society. AIAA continues to celebrate that pioneering spirit showcasing the very best in the aerospace industry.

AIAA celebrates the following individuals who were recognized between July and September 2020.

Scheduled to have been presented at the 50th International Conference on Environmental Sciences (ICES), 12–16 July 2020, Lisbon Portugal, which was cancelled

2020 AIAA Jefferies Aerospace Medicine and Life Sciences Research Award



James M. Waligora
NASA Johnson Space Center (retired)
For pioneering human performance studies and engineered countermeasures critical for safe and productive extravehicular activity on programs spanning Apollo to the International Space Station.

Presented at the 2020 AIAA Propulsion and Energy Forum, 24–26 August 2020, Virtual Event

2020 AIAA Aerospace Power Systems Award

Charles W. Bennett
Lockheed Martin Corporation
For sustained excellence in the design and deployment of energy storage systems for unique space environments and applications.

2020 Energy Systems Award

Alan Williams
University of Leeds
For pioneering contributions to energy systems for enhanced efficiency and reduced pollution using experiments and modeling, and for education and services to industry and government.

AIAA Wyld Propulsion Award

Alec D. Gallimore
University of Michigan
For groundbreaking achievements and leadership in technology and workforce development that has contributed significantly to increased utilization of spacecraft electric propulsion systems.

2020 AIAA Air Breathing Propulsion Award

Heinz Pitsch
RWTH Aachen University
For seminal contributions to the fundamental understanding, theory, and computational modeling of turbulent combustion

2020 AIAA Propellants & Combustion Award

Meredith B. Colket, III
United Technologies Research Center (retired)
For pioneering contributions in the development of endothermic fuels leading to demonstration of the X-51 and coordinating technology programs supporting certification of alternative jet fuels.

Thank you to all the nominators and supporters of these award winners.

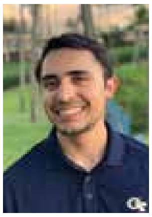
AIAA Announces Winners of Prestigious Zarem Graduate Student Awards

AIAA is pleased to announce the winners of the Zarem Graduate Student Awards for Distinguished Achievement.

Nathan Crane, who graduated in 2020 with his M.S. in Aerospace Engineering from the Georgia Institute of Technology, won the **aeronautics award** for "Preliminary Active Subspace Investigation of a Commercial Supersonic Design Space." He has been invited to present his paper at the ICAS 2021 Congress.

Aaron Afriat and **Sandeep Baskar** jointly won the **astronautics award** for "Atmospheric Breathing Solid-Fuel Ramjet for Martian Descent Missions." Afriat is a graduate research assistant at the Purdue Energetics Research Center and Master's student in Mechanical Engineering at Purdue University under Professor Steven Son. Sandeep Baskar graduated from Purdue with two bachelor's degrees, in Aerospace Engineering and Applied Physics, in spring 2020. Their paper will be presented in the graduate portion of the student paper competition at the virtual IAC 2020.

AIAA Honorary Fellow Dr. Abe Zarem established the Zarem Graduate Awards for Distinguished Achievement to recognize graduate students in aeronautics and astronautics who have demonstrated outstanding scholarship in their field.



Crane

Crane is currently an Aerospace Technologist at NASA Langley Research Center. He graduated with his B.S. in Aerospace Engineering from Embry-Riddle Aeronautical University, Daytona Beach in 2018, and his M.S. in Aerospace Engineering from the Georgia Institute of Technology in 2020. While at Georgia Tech, he was a part of the Aerospace Systems Design Laboratory, where his research concentrated on commercial supersonic conceptual design and aerodynamics. He completed a thesis focusing on incorporating high fidelity analysis into the supersonic conceptual design process while concurrently reducing computational time.

"Although I grew up not knowing any engineers, I decided early in my childhood that I wanted to pursue aerospace engineering and design aircraft," he said. "After many years working to earn the opportunity to study and research aircraft design, it is an incredible honor to be awarded for my work in aeronautics. It is a great feeling to know that I have contributed to the field and encourages me to continue my passion into the future."

Crane's faculty advisor, Dimitri Mavris, is the Director of the Aerospace Systems Design Laboratory at the Georgia Institute of Technology.

Afriat and Baskar

Afriat's research focuses on additively manufacturing and characterizing high-performance, environmentally friendly propellants. His interests lie in designing the next generation of spacecraft engines, and eventually pioneering the exploration of Mars. He received his B.S. in Aeronautical and Astronautical Engineering with concentrations in Propulsion and Systems Design from Purdue University in May 2019.

"My remote background as a Caribbean Islander filled me with childhood dreams of space exploration that I can now proudly say I have partaken in," he said. "Organizations like AIAA, through recognitions and worldwide spread of technical information, enabled me and others alike to strive for our dream; something I am incredibly thankful for. I believe that this wealth of information, while bringing us closer together as a scientific community, also brings humanity ever closer to spreading beyond Earth's horizon."

After receiving his B.S. degrees in the spring, Baskar is now a Flight Dynamics Analyst at Dynetics. His undergraduate work and internship experience involved trajectory analysis, vehicle design, and mission design. His work at Dynetics focuses on trajectory optimization and mission design for the Artemis Human Lander System project. Unsurprisingly, his interests are in the realm of human spaceflight and astrodynamics to assist in human exploration of deep space.

Afriat's and Baskar's faculty advisor was Stephen Heister, Raisbeck Distinguished Professor in the School of Aeronautics and Astronautics and a professor of Mechanical Engineering at Purdue.

For more information on the Abe M. Zarem Graduate Awards for Distinguished Achievement, please contact Michael Lagana at michaell@aiaa.org or 703.264.7503.

2020 AIAA Young Professionals, Students, and Educators (YPSE) Conference

The AIAA Mid-Atlantic Section will hold the AIAA Young Professionals, Students, and Educators (YPSE) Conference 15–16 October in a fully virtual environment. Technical presentations will be made in areas of interest to the aerospace community by young professionals (age 35 and under), graduate, undergraduate, high school students, and educators are sought. The featured keynote speaker is Dr. Sandra Magnus, deputy director of Engineering in the Office of the Secretary of Defense for the Under Secretary of Research and Engineering. Please register at **aiaaypse.com**.

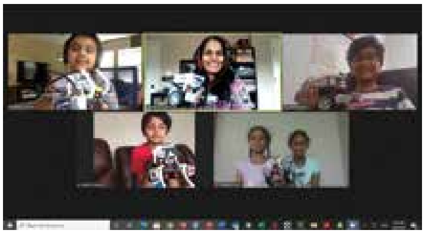
MAKING AN IMPACT

AIAA Foundation Classroom Grant Program

The AIAA Foundation Classroom Grant program, sponsored by The Boeing Company, provides opportunities for educators to encourage and support STEM activities in their classrooms. Since 1998, close to 1,400 grants have been awarded, creating rewarding activities for more than 181,000 students in the classroom. Each school year, grants of up to $500 are awarded to worthy projects that significantly influence student learning. Each grant supports a clear connection to STEM subjects with an emphasis on aerospace. Applicants must be current AIAA Educator Associate Member (and the membership is free!), and each school is limited to two grants per calendar year.

Sumitha Tharasingh of Shiksha School of Austin, TX, said, “Lego education kits are excellent resources to teach students project-based or hand-on STEM concepts. Every week [my students] learn and execute a new concept and project/program. And at the end of the semester, they are assigned an Independent Project that they finish and present. The excitement on their faces when reporting data during an experiment and or presenting their project is priceless. … However, the materials are expensive; for example, a Lego education EV3 Mindstorms kit is $439.90, the Space Challenge Set it $249.95, and a Simple and Powered Machines kit coast 199.99. … The [grant] … goes into buying these materials. Especially very valuable during COVID, I loaned out a few kits to students to work safely from home.”

Andrea Diamond of Steam Enrichment Academy in Southern California noted, “I’ll be beginning my virtual classroom next week with my new pilot program Mission2Mars. … I’ll be using my new microscope with an adapter to display magnified images on my shared computer monitor in my virtual classroom. As an Earth Space Physics specialist, my students’ age range is 5-12 years old as I service multiple school districts. For some children this will be the first time they enter the microscopic world! By studying Tardigrades as an analog here on Earth we can learn about whether or not life as we know it existed on Mars. We will explore what makes these tiny organisms so hardy, able to exist in harsh extreme environments such as space. This will aid us in our exploration answering questions such as, ‘Did life exist off-Earth? Is there life now off-Earth? Can there be potential life off-Earth?’”



Rodney Meadth of the Providence Engineering Academy (Santa Barbara, CA) used his classroom grant “to help fund a design-build-fly project with our 11th and 12th grade students. Despite the challenges that came with COVID-19 and distance learning, our talented students continued on from their homes without missing a beat, using collaborative CAD and spreadsheet tools to design their powered aircraft according to the aerodynamic theory they had already learned beforehand. The airframe materials and electronic systems were fully provided for by the generous grant, ensuring a high-quality experience for these junior engineers, who came together in person at the end of the semester to fly their remote-controlled creations. We are proud to announce that two of our female graduates have gone from this project directly into related studies, one in mechanical engineering and the other in aeronautical engineering.”

“We are using the grant for building a basic understanding of flight principles. Students will benefit from being exposed to engineering flight concepts at an early age and build their understanding as they advance” explained **Susan Stewart**, STEAM-Technology teacher at Excellence Charter School in Parker, CO. “Younger students will explore paper airplanes and Styrofoam gliders, while upper elementary students will explore flight concepts with balsa wood gliders. Middle school students will take the challenge of building 3D printed gliders and paper rockets. Designing their own rocket launchers and wind tunnel will allow students to test their prototypes.”

For information about the classroom grant program, please visit **aiaa.org/get-involved/students-educators/aiaa-foundation-classroom-grant-program** or contact Sha’Niece Simmons, Sha’NieceS@aiaa.org. If you would like to become an AIAA Educator Associate, please visit **aiaa.org/get-involved/educator**.

News

The Craft of Making Spacecraft at Skykraft

By Michael Spencer, AIAA Associate Fellow, AIAA Sydney Section

FAR LEFT: Skykraft constellation project, inspired by New Space, for better air traffic management. **LEFT:** Guest speaker Dr. Doug Griffin, Chief Engineer, Skykraft;

Like other organizations around the world, the AIAA Sydney Section has adapted to meet the requirements of mandated social distancing and commenced a program of online informational and motivational lectures for its members and the public. On 11 August, Ms. Tjasa Boh Whiteman, Vice-Chair, AIAA Sydney Section, hosted **Dr. Doug Griffin**, Chief Engineer at Skykraft, for an online discussion on his career history in a space engineering career. The lecture is part of a program intended to inform and motivate anyone interested in current and next-generation aerospace career opportunities.

Griffin completed a doctorate in aerospace engineering under the auspice supervision of renowned hypersonics researcher Dr. Ray Stalker. After completing research studies in Australia, he moved overseas to pursue space engineering opportunities in Big Space programs. He worked his way up to Head of the Systems Engineering Group at RAL Space in the UK, developing instrument payloads for various ESA/NASA missions such as Herschel and Solar Orbiter.

After fifteen years, he changed careers and transitioned from Big Space to New Space. Griffin returned to Australia and joined the university space engineering program under Professor Russell Boyce, the UNSW Canberra Space director. UNSW Canberra Space developed new programs and facilities to enable space mission design, space systems engineering and systems testing, and space operations management to cover the full life cycle of small satellites. The transition from managing small elements of overseas Big Space projects to managing the total engineering efforts of small satellites inspired by New Space has helped catalyze Australia's new space economy.

UNSW Canberra is the first Australian university to manage a multi-mission space program over the full life cycle of development and operations, for five satellites in four discrete space missions:

- The Buccaneer Risk Mitigation Mission (BRMM) was successfully launched from Vandenberg AFB in 2017. The 3U cubesat was jointly developed with scientists from Defence Science Technology (DST) and validated the space mission design and engineering capabilities of UNSW Canberra Space.
- UNSW Canberra Space has been collaborating with the Royal Australian Air Force to design and build three spacecraft. The M1 mission, a single 3U cubesat, was launched by a Falcon 9 from Vandenberg AFB in December 2018 during a record-breaking event with the highest number of satellites launched from a single U.S. launcher. The M2 Pathfinder mission, a 3U cubesat, was launched in June 2020 by Rocket Lab from its New Zealand facility as a risk reduction mission for the follow-on M2 Mission. The M2 mission is a single 12U payload planned for launch in 2021, subject to COVID-19, which will separate into two formation-flying 6U cubesats.

The engineering successes of the UNSW Canberra Space projects inspired the establishment of Skykraft as a company to continue to support UNSW in the design and manufacture of small satellites and future satellite constellations for a broad range of space-based services. Griffin recently changed employment, moving from UNSW Canberra to join Skykraft as the Chief Engineer. The designs for small satellites may seem less challenging than the large satellites funded in Big Space projects. However, New Space innovations and reduced launch costs make it viable to deploy small satellites into constellations, with a similar accumulative mass to the large satellite projects, and provide novel space-based services to a global user base.

The audience to the AIAA Sydney Section event heard how Griffin started his career as a space engineer within a large organization of multinational teams, working on inspiring but rigidly designed space missions that are only possible in the big-budget projects of Big Space. Today, his work in smaller space missions on New Space projects provides him with increased scope to personally practice innovation and agility and be intimately responsible for designs and engineering over the entire life cycle of space missions. Griffin works with the opportunities and lessons learned gained from space projects in both worlds, including experiences working with significant members in the Australian AIAA membership. Dr. Stalker and Dr. Boyce are two of the three Australians who are recognised as AIAA Fellows.

2020 Election: Space Policy Platform Paper

The Public Policy Committee has released a space policy platform paper in advance of the 2020 election. The paper highlights the importance of our space activities and the need for continued investments in space-related federal programs. AIAA has identified several themes that must be addressed to ensure ongoing global leadership, maintain space superiority over our adversaries, and expand the benefits of this highly technological sector for our society. Read the paper on pages **30-31**.

K-5 STEM Outreach Materials

The Air Force Research Laboratory at Eglin Air Force Base, FL, and the AIAA Northwest Florida Section are committed to creating equitable STEM education opportunities for public school students in Florida. This summer, two STEM outreach programs were developed to better serve Florida classrooms by AIAA Educator Associate Catherine Sprague and AIAA Associate Fellow Dr. Angela Diggs.

The senior of the two curricula, I LOVE Science! is a STEM outreach program serving grades K-5 that has recently been revised to reflect Florida's current Science standards and the newly adopted B.E.S.T. Math and English Language Arts standards. I LOVE Science! cultivates student learning with dynamic, hands-on math and science activities appropriate for any elementary school classroom. The newest member of the curricula, I LOVE Robotics!, was created this summer to serve students in grades K-5. Each I LOVE Robotics! lesson includes the most current Florida standards for Math, Science, Computer Science, and English Language Arts. Using the LEGO Education WeDo 2.0 robotics kits, 2nd-5th grade students build and program LEGO robots to explore and demonstrate various STEM concepts. Kindergarten and first grade lessons include hands-on activities with Duplo or LEGO bricks. Both curricula include literacy activities to meet the growing demand for academic literacy, promote crosscurricular learning, and increase functionality of the curriculum for self-contained classrooms in response to the COVID-19 pandemic.

AIAA members from the Northwest Florida Section have over a decade of experience with the I LOVE Science! curriculum and are excited to begin to implement the new I LOVE Robotics! curriculum. Please email nwfl.aiaa@gmail.com with questions. To access lesson plans, student materials, and instructional support resources, please visit the Northwest Florida AIAA Engage website at https://engage.aiaa.org/northwestflorida/home and click on the "I LOVE Science" or "I LOVE Robotics" link on the left side.

Celebration of Excellence: Gohardani Presentation Award

By: Amir S. Gohardani

Five years ago when the Gohardani Presentation Award in Aeronautics and Astronautics was initially launched by the Springs of Dreams Corporation, a nonprofit organization in Southern California, there were many skilled presenters interested in the aerospace industry who at a regional level went unrecognized. Principally, a key intent of this award was to celebrate presentation skills among those interested in aeronautics and astronautics. In partnership with the AIAA Orange County Section in Southern California, this award found a home and ever since, it has been presented to two of the most thought-provoking and exceptional all-around presentations delivered during the AIAA Aerospace Systems and Technology (ASAT) Conference. Some of the award selection criteria relate to content, reasoning, organization, timing, management, style, clarity, interactivity, engagement with the audience, and overall feedback of the presentation. With a monetary prize in addition to a certificate of excellence, awardees join a talented pool of presenters including students, seasoned professionals, and rising stars in the aerospace sector. Since its inception, the Gohardani Presentation Award in Aeronautics and Astronautics has been presented to ten excellent speakers. The 2019 Gohardani Presentation Award was presented to Emma Chao and Isaiah Navarro.

Emma Chao
A graduate of the University of Nevada, Las Vegas, Chao received her Bachelor's in Mechanical Engineering in 2019 and graduated summa cum laude with minors in Mathematics and French. In 2020, she received her Master's in Mechanical Engineering with a concentration in Aerospace Engineering. Her Master's thesis work under Dr. William Culbreth focused on discrete vortex modeling of a flat plate in aerodynamic flutter. During her college career, she was heavily involved with her university's AIAA student branch as an executive board member and later their graduate advisor. She has led several design teams in competitions such as AIAA Design/Build/Fly and the UTA 3D Printed Aircraft Competition. Chao was also selected as an AIAA Diversity Scholar in 2018. After her graduation, she will begin working full-time at Lockheed Martin Skunk Works in Palmdale, CA, in the Aerodynamics Department.

Isaiah C. Navarro
Currently, employed with the Northrop Grumman Corporation as an engineer, Navarro is the volunteer Chief Executive Officer and Founder of Military Children's Charity, a nonprofit organization he incorporated in 2010. Following his graduation from Mater Dei High School, Navarro completed two Bachelor's of Science degrees in Aerospace Engineering and Mechanical Engineering from the UC Irvine (UCI) in 2017. He served as the UCI Rocket Project Manager during his undergraduate senior year. Navarro completed his Masters of Aerospace and Mechanical Engineering, with a concentration in Fluid Mechanics, in December 2019 from UCI. Isaiah's master's thesis is entitled "Quasi-One Dimensional Flow Through a Nozzle With a Shock."

AIAA Announces Section Award Winners

AIAA has announced its 2019–2020 section awards winners. The section awards honor particularly notable achievements made by member sections in a range of activities that help fulfill the Institute's mission.

Section awards are given annually in five categories based on the size of each section's membership. Each winning section receives a certificate and a cash award. The award period covered is 1 June 2019–31 May 2020. The Institute believes that vital, active sections are essential to its success.

The Outstanding Section Award is presented to sections based upon their overall activities and contributions through the year. The winners are:

Very Small: First Place: Delaware, Daniel Nice (Northrop Grumman Corporation), section chair; **Second Place: Vandenberg,** Michelle Itzel (Millenium Engineering and Integration Company), section chair; **Third Place: Wisconsin**, Michael Carkin (Sierra Nevada Corporation), section chair

Small: First Place: Northwest Florida, Eugen Toma, section chair; **Second Place: Palm Beach,** Randy Parsley (Pratt & Whitney-Rocketdyne), section chair; **Third Place: Long Island**, David Paris, section chair

Medium: First Place, Tucson, Michelle Rouch (Artwork by Rouch), section chair; **Second Place: Antelope Valley,** Jason Lechniak (NASA)**,** section chair; **Third Place: Wichita,** Wilfredo Cortez (Department of Defense), section chair

Large: First Place: St. Louis, James Guglielmo (The Boeing Company), section chair; **Second Place (tie): Cape Canaveral**, Elizabeth Balga (The Boeing Company), section chair; **Second Place (tie): San Diego,** Kimberly Painter (NAVAIR), section chair

Very Large: First Place: Greater Huntsville, Charles Simpson, section chair; **Second Place: Hampton Roads,** Tyler Hudson (NASA), section chair; **Third Place: Los Angeles-Las Vegas,** Chandrashekhar Sonwane (Aerojet Rocketdyne), section chair

The Career and Professional Development Award is presented for section activities that focus on career development, such as time management workshops, career transition workshops, job benefits workshops, and technical versus management career path workshops. The winners are:

Very Small: First Place, Delaware, Timothy McCardell (Northrop Grumman Corporation), career and professional development officer; **Second Place: Wisconsin**, Michael Carkin (Sierra Nevada Corporation), section chair; **Third Place: Point Lobos**, Giovanni Minelli (Naval Postgraduate School), section chair

Small: First Place: Northwest Florida, Ryan Sherrill, career and professional development officer; **Second Place: Long Island,** David Paris, section chair; **Third Place: Savannah,** Andrew Clemens (Gulfstream Aerospace Corporation), career and professional development officer

Medium: First Place: Antelope Valley, Joseph Piotrowski (Millenium Engineering and Integration), young professional officer; **Second Place: Wichita**, Eddie Irani (Spirit Aerosystems), programs officer

Large: First Place (tie): Cape Canaveral, Elizabeth Balga (The Boeing Company), section chair; **First Place (tie): Orange County**, Erol Kilik, career and professional development officer; **Second Place: St. Louis**, Paul Bent (The Boeing Company), career and professional development officer

Very Large: First Place: Hampton Roads, Elizabeth Ward (NASA) and Hyun Jung Kim (National Institute of Aerospace), career and professional development officers; **Second Place (tie): Greater Huntsville**, Nishanth Goli, section vice chair; **Second Place (tie): Los Angeles-Las Vegas**, Chandrashekhar Sonwane (Aerojet Rocketdyne), section chair

The Communications Award is presented to sections that have developed and implemented an outstanding communications outreach program. Winning criteria include level of complexity, timeliness, and variety of methods of communications, as well as frequency, format, and content of the communication outreach. The winners are:

Very Small: First Place: Delaware, Christina Larson (Northrop Grumman Corporation), communications officer; **Second Place: Vandenberg,** Steve Boelhouwer (Mantech International), newsletter editor; **Third Place (tie): Adelaide**, Patrick Neumann (Neumann Space), section vice chair and then section chair; **Third Place (tie): Point Lobos**, Giovanni Minelli (Naval Postgraduate School), section chair

Small: First Place: Savannah, Michael Hay (Gulfstream Aerospace Corporation), section secretary; **Second Place: Sydney,** Nimish Shete (Boomi), section vice chair and then chair; **Third Place: Long Island**, David Paris, section chair

Medium: First Place: Tucson, Michelle Rouch (Artwork by Rouch), section chair; **Second Place: Phoenix,** Michael Mackowski, section chair; **Third Place: Antelope Valley,** Jason Lechniak (NASA)**,** section chair

Large: **First Place: St. Louis,** Andrea Martinez, publicity officer; **Second Place (tie): Cape Canaveral,** Jacob Shriver (NASA), communications officer**; Second Place (tie): Northern Ohio,** Edmond Wong, communications officer

Very Large: **First Place: Hampton Roads,** John Lin (NASA), newsletter editor; **Second Place: Greater Huntsville,** Nishanth Goli, section vice chair; **Third Place: Rocky Mountain**, Adrian Nagle (Ball Aerospace), newsletter editor

The Membership Award is presented to sections that have supported their membership by planning and implementing effective recruitment and retention campaigns. The winners are:

Very Small: **First Place: Delaware,** Zachery Gent, membership officer; **Second Place: Vandenberg**, Christopher Menino, membership officer; **Third Place: Point Lobos**, Giovanni Minelli (Naval Postgraduate School), section chair

Small: **First Place (tie): Northwest Florida,** Jill Barfield (Okaloosa County School System), membership officer; **First Place (tie): Savannah**, Michael Hay (Gulfstream Aerospace Corporation), section secretary; **Third Place: Long Island**, David Paris, secton chair

Medium: **First Place: Tucson,** Rajka Corder (Raytheon Missile Systems), membership officer; **Second Place: Wichita**, Vicki Johnson (Spirit Aerosystems, Inc), membership officer; **Third Place, Antelope Valley**, Chris Coyne (U.S. Air Force), publicity officer

Large: **First Place: St. Louis,** Nic Moffitt, membership officer; **Second Place: Orange County**, Robert Welge (Robert's Engineering Development), membership officer; **Third Place: San Diego,** Nick Candrella (Naval Air Warfare Center), section secretary

Very Large: **First Place: Los Angeles-Las Vegas,** Aldo Martinez Martinez, membership officer; **Second Place: Greater Huntsville,** Theresa Jehle, membership officer; **Third Place: Rocky Mountain,** Marshall Lee (Sypris Electronics), membership officer

The Public Policy Award is presented for stimulating public awareness of the needs of aerospace research and development, particularly on the part of government representatives, and for education section members about the value of public policy activities. The winners are:

Very Small: **First Place: Delaware,** Di Ena Davis, public policy officer; **Second Place: Vandenberg**, Michelle Itzel (Millenium Engineering and Integration Company), section chair; **Third Place, China Lake**, Steven Goad, public policy officer

Small: **First Place: Northwest Florida,** Michael Kelton (U.S. Air Force), public policy officer; **Second Place: Palm Beach,** Kevin Simmons (The Weiss School), public policy officer; **Third Place: Utah,** Scott Stebbins, section chair

Medium: **First Place: Antelope Valley,** Patrick Clark (Lockheed Martin Aeronautics), public policy officer; **Second Place: Tucson,** Michelle Rouch (Artwork by Rouch), section chair; **Third Place: Wichita**, Vicki Johnson (Spirit Aerosystems, Inc), membership officer

Large: **First Place: Northern Ohio,** Victor Canacci (Jacobs Technology Inc), public policy officer; **Second Place: Cape Canaveral,** Helen Petrucci, public policy officer; **Third Place: St. Louis**, Frank Youkhana (The Boeing Company), public policy officer

Very Large: **First Place: Greater Huntsville,** Naveen Vetcha (ERC Incorporated), public policy officer; **Second Place: Hampton Roads,** Steven Dunn (Jacobs Technology Inc) and Jake Tynis (Analytical Mechanics Associates), public policy officers; **Third Place: Rocky Mountain,** Tracy Copp (Ball Aerospace), public policy officer

The STEM K–12 Award is presented to sections that have developed and implemented an outstanding STEM K–12 outreach program that provides quality education resources for K–12 teachers in the STEM subject areas. The winners are:

Very Small: **First Place: Delaware,** Kelly Storrs (Northrop Grumman), STEM K–12 outreach officer; **Second Place: Vandenberg**, Thomas Stevens (U.S. Air Force), STEM K-12 outreach officer; **Third Place:**

China Lake, Michael Petersen (NAVAIR), section vice chair

Small: First Place: Northwest Florida, Judith Sherrill, STEM K-12 outreach officer; **Second Place: Palm Beach,** Shawna Christenson, STEM K–12 outreach officer; **Third Place: Savannah,** Jessica Swann (Gulfstream Aerospace Corporation), STEM K–12 outreach officer

Medium: First Place: Tucson, Elishka Jepson (Raytheon Missile Systems), STEM K–12 outreach officer; **Second Place: Antelope Valley**, Jason Lechniak (NASA), section chair and Robert Jensen (Sierrra Lobo, Inc), STEM K-12 officer

Large: First Place: St. Louis, Jackie Blumer (Greenville Junior High School), STEM K–12 outreach officer; **Second Place: San Diego**; Rich Kenney (AeroED Group), STEM K-12 Officer; **Third Place: Orange County,** Janet Koepke, Binay Pandey, and Ed Rocha, STEM K–12 outreach officers

Very Large: First Place: Hampton Roads, Karen Berger (NASA) and Amanda Chou (NASA), STEM K-12 outreach officers; **Second Place: Greater Huntsville,** Ragini Acharya (Raytheon Technologies), STEM K-12 outreach officer; **Third Place: Los Angeles-Las Vegas,** Dean Davis, STEM K-12 officer

The Section-Student Branch Partnership Award recognizes the most effective and innovative collaboration between the professional section members and student branch members.

Very Small: First Place: Delaware, Daniel Nice (Northrop Grumman Corporation), section chair; **Second Place: Vandenberg**, Anthony Touchette (U.S Air Force), program officer; **Third Place: Wisconsin**, Robert Michalak (Sierra Nevada Corporation), university liaison

Small: First Place: **Northwest Florida**, Judith Sherrill, STEM K-12 outreach officer; **Second Place: Palm Beach**, Kevin Simmons, public policy officer, and Randy Parsley (Pratt & Whitney-Rocketdyne), section chair; **Third Place: Sydney**, Cole Scott-Curwood (University of Sydney), student branch representative

Medium: First Place: **Tucson,** Teresa Clement (Raytheon Technologies), section vice chair; **Second Place; Wichita**, Linda Kliment (Wichita State University), education officer; **Third Place: Antelope Valley**, Robert Jensen (Sierrra Lobo, Inc), STEM K-12 officer, and Kasthuri Sivagnanam, university liaison

Large: First Place: St. Louis, Charles Svoboda (The Boeing Company), education officer; **Second Place, San Diego**, Kimberly Painter (NAVAIR), section chair; **Third Place, Atlanta**, Aaron Harcrow, membership officer

Very Large: First Place, Los Angeles-Las Vegas, Chandrashekhar Sonwane (Aerojet Rocketdyne), section chair; **Second Place: Pacific Northwest**, Adriana Blom-Schieber (Boeing Commercial Airplanes); **Third Place (tie): Dayton/Cincinnati,** Aaron Altman (AFRL) and Krista Gerhardt (U.S. Air Force), eduction officers; **Third Place (tie) Greater Huntsville,** Brittany Searcy, university liaison; **Third Place (tie): Hampton Roads,** Manual Diaz (National Institute of Aerospace), Forrest Miller (Old Dominion University), and Julie Deutsch (Virginia Tech), student branch liaisons

The Young Professional Activity Award is presented for excellence in planning and executing events that encourage the participation of the Institute's young professional members, and provide opportunities for leadership at the section, regional, or national level. The winners are:

Very Small: First Place: Delaware, Taylor Coleman (University of Delaware), young professional officer; **Second Place: Wisconsin**, Michael Carkin (Sierra Nevada Corporation), section chair; **Third Place: Vandenberg**, Anthony Touchette (U.S Air Force), program officer

Small: First Place: Northwest Florida, Ryan Sherrill, young professional officer; **Second Place: Utah,** Jacob Hopkins, young professional officer; **Third Place (tie): Savannah**, Scott Terry (Gulfstream Aerospace Corporation); **Third Place (tie): Sydney,** Divya Jindal, young professional officer

Medium: First Place: **Antelope Valley**, Joseph Piotrowski (Millenium Engineering and Integration) and Patrick Clark (Lockheed Martin Aeronautics), public policy officer; **Second Place: Tucson,** Michael Hotto, young professional officer; **Third Place: Wichita**, Julie-Elisa Acosta (Spirit Aerosystems), young professional officer

Large: First Place: St. Louis, Stephen Clark (The Boeing Company), young professional officer; **Second Place: San Diego**, Zachary Annala, young professional officer; **Third Place: Atlanta,** Jeremy Young (Generation Orbit), young professional officer

Very Large: **First Place: Los Angeles-Las Vegas**, Moises Seraphin, young professional officer; **Second Place (tie): Greater Huntsville,** Lindsey Blair, Young Professional Officer; **Second Place (tie): Rocky Mountain**, Alexandra Dukes (Lockheed Martin Space Systems), young professional section officer

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The Outstanding Activity Award allows the Institute to acknowledge sections that held an outstanding activity deserving of additional recognition. The winners are:

Very Small: **Delaware**, Daniel Nice, section chair. **First State, First Step Viewing.** As E-week was winding down, the screening of the aerospace documentary "First State, First Step" was the one last hoorah of the week for the AIAA Delaware Section. This event was a joint sponsored event, with the students of ASAE at the University of Delaware. With approximately 30 people in attendance, Michael Oates, director and moderator of the film, revealed the impact such a small state had on the space race and how it helped to put the first humans on the moon. The video captured the contributions of the many people who helped, from those who sewed the space suits to the leaders of Gore and ILC, and the engineers involved. The close-up view of those involved in that era really stirred up an effervescence of energy as we look the moon and beyond once again. Following the screening, a Q&A session was held with ILC Dover marketing director, Daniel Klopp, and the film director.

Small: **Northwest Florida**, Eugen Toma, section chair. **Transit of Mercury**. While the planet Mercury passes in front of the sun at regular intervals, the morning of 11 November 2019 presented a unique opportunity as the passing was visible during the daytime from northwest Florida. Dr. John Fay set up his telescope with solar filter at Lincoln Park in Valparaiso, FL, where scouts from Cub Scout Pack 52, students from Edge Elementary, and anyone else who was interested could watch Mercury's transit. The transit was a unique opportunity as the next visual passing of Mercury from Florida will not occur until 2049. The event was well attended by the Scouts, their families, and their leaders. For Tiger Scouts that attended, this event satisfied an elective requirement toward the "Sky is the Limit" merit badge.

Medium: **Wichita**, Wilfredo Cortez, section chair. **AIAA Young Professionals Tour Series**. The AIAA Young Professionals Tour Series served to provide young professionals with a glimpse into their local industry. Cortez worked with local industry to coordinate tours of production lines, labs, wind tunnels, and museums. These tours served to show young professionals local company capability, the history of flight, and testing capabilities in the Wichita vicinity. The tours also allowed companies to showcase their capabilities and attempt to recruit new talent. Young professionals could view companies of interest before deciding to apply for a job there.

Large: **St. Louis**, James Guglielmo, section chair. **A Practical Guide to Wind-Tunnel Testing Lecture and Tour**. The event was presented in two parts. In Part 1, Mathew Rueger presented A Practical Guide to Wind Tunnel Testing, held in a cafeteria on the Boeing campus. His lecture provided an overview of the concepts of wind-tunnel testing, types of tests and facilities, and recent trends. The evening concluded with an open forum discussion of the use of CFD and wind tunnels in the development of flight vehicles.

Part 2 was a tour of the Boeing Polysonic Wind Tunnel (PSWT). The name "Polysonic" derives from the ability to provide test conditions in the subsonic, transonic, supersonic, and hypersonic flow regimes. Over its 60-year history, the PSWT has played a key role in the development of major programs such as Gemini, F-4, F-15, F-18, Delta Rocket, X-51, and more. PSWT staff members Mark Kammeyer, Rob Spencer, Tom vonHatten, and Rob Whiting led four groups of 15-20 guests each through the facility, which is a 4-foot blow-down wind tunnel. The wind tunnel tour lasted almost three hours.

Very Large: **Rocky Mountain**, Merri Sanchez, section chair. **Apollopalooza**. Wings Over the Rockies Museum invited the section to participate in Apollopalooza – a weeklong regional celebration of the 50th anniversary of the moon landing and future human space exploration. The section staffed a membership table throughout the week. Adjacent to the membership table, they organized a felt storyboard and asked students to tell their space exploration story by making felt shapes of planets, astronauts, and spacecraft. Every morning they challenged visitors (kids, parents ,and grandparents alike) to design, build, and test a sturdy, but lightweight "lunar lander" of gumdrops and toothpicks. Over 200 "engineers" participated. They also offered two-hour "Orbital Confusion" workshops for high school students and a half-day workshop for teachers as part of "Apollo University," a weeklong continuing education program.

Honorable Mention: **Greater Huntsville,** Charles Simpson, section chair**. AIAA Greater Huntsville Inaugural Remembrance Event.** The Greater Huntsville Section held an inaugural Remembrance Event to honor the section's departed members who are memorialized in the US Space & Rocket Center (USSRC) Saturn V courtyard. The section began a program during the 2017 section year to purchase an inscribed memorial brick in the Saturn V Courtyard for departed section members. This Remembrance Event was the first ceremony to be held at the courtyard to bring AIAA members, coworkers, family, and friends together to remember our departed colleagues.

Obituaries

AIAA Fellow Gregorek Died in October 2019

Dr. Gerald M. "Jerry" Gregorek, 88, died on 3 October 2019. He was a student and faculty member of the Department of Aeronautical and Astronautical Engineering at Ohio State University for over 66 years. He was an inspiration to his students as a teacher and innovative researcher of aerodynamics, aircraft flight-test, and airfoil design, and high-speed vehicle design.

Dr. Gregorek served in the U.S. Air Force during the Korean War as a B-29 flight engineer, then headed to Ohio State to study aeronautical engineering. He had a long career that includes serving as chair of the Department of Aeronautical and Astronautical Engineering from 1991 to 1999, director of the Aeronautical and Astronautical Laboratory, and director of the OSU Don Scott Airport.

He had a lifelong passion for education and his talent as a model airplane builder was transformed into model rocket building, education, and competition. During his son David's illness, Dr. Gregorek used his model building talent to engage Dave in spacemodelling. He became the advisor to the newly formed Columbus Society for the Advancement of Rocketry, and he organized the first USSR space modeling competition. He represented the United States in international competitions as a member of the USA Space Modeling Team and served as a contest official for many national and world rocketry championships.

An AIAA Fellow, Dr. Gregorek was recognized with the AIAA Piper General Aviation Award (1983) and the AIAA Faculty Advisor Award (1987). He was a member of AIAA technical committees including the Aircraft Operations Technical Committee and the Aircraft Design Technical Committee. He was a member of the Supersonic Wind Tunnel Association, American Society of Engineering Education, International Astronautical Federation, Federation Aeronautique International, Experimental Aircraft Association, and received many national and international recognitions from these and other professional societies. The OSU Department of Mechanical and Aerospace Engineering established the Gerald M. Gregorek Excellence in Teaching Award in his honor.

AIAA Senior Member Glassman Died in July

Keith F. Glassman passed away at the age of 58 in an automobile accident.

Accomplished in the field of aircraft structural dynamics, he entered the profession at age 17 when he entered the Aerospace Engineering program at MIT. Mr. Glassman joined AIAA during that freshman year at MIT, and maintained continuous membership throughout his career. He completed his studies at the Parks College of Engineering, Aviation, and Technology in Saint Louis, MO.

Mr. Glassman began his government service in August 1991 and joined the Fleet Readiness Center Southwest in March 1999 where he then served as a member of the U.S. Navy's F/A-18 Fleet Support Team as a Structural Engineer. Throughout those years, Mr. Glassman was a member of the team of scientists and engineers that planned and developed modifications to the F/A-18 airplane and assisted the depot in developing repair procedures. Last year he was recognized with another Special Act award from the Navy, the first having been awarded in 1995.

Mr. Glassman was a strong believer that aerospace engineering professionals should be recognized for their discoveries and achievements, and after having served as the chair of the AIAA San Diego Section, he became head of the Honors and Awards Committee and organized the annual awards banquet for two decades. For the last three years, he did the same for the San Diego County Engineering Council, which held the annual National Engineers Week banquet. Mr. Glassman also initiated and managed the annual AIAA Aerospace Heritage Night, where distinguished scientists and engineers from the San Diego Section shared their life stories and were recognized for their lifetime achievements.

Mr. Glassman was recognized with the Outstanding Contribution to the AIAA San Diego Section Award in 1998 and again in 2012; and while serving as the Section Professional Development Officer, he received the Career Enhancement Award five times. From 2007 to 2009 Mr. Glassman was AIAA Deputy Director of Region VI for membership, and he shared his passion for aerospace engineering by participating in countless outreach activities, and was enthusiastic at promoting STEM at various K-12 schools. In 2010 and 2011 he received awards for participating in the Naval Science Enrichment Program (NSEP) STEM outreach to local schools.

AIAA Associate Fellow Kutter Died in August

Bernard Kutter passed away unexpectedly on 12 August.

After graduating from the University of Washington in 1987, Mr. Kutter worked at United Launch Alliance (ULA) and its predecessors for more than 32 years.

Mr. Kutter was the manager of Advanced Programs for ULA and a major force in NewSpace. He was described by ULA CEO Tory Bruno as "a cornerstone of our Advanced Programs team, shaping the future of space technology and sharing that vision with many inside and outside of ULA." He was considered to be a brilliant engineer and was pivotal in the design and oversight of ULA's new Vulcan rocket, the successor to the venerable Atlas V and Delta Heavy IV rockets and ULA's first ground-up rocket design. Mr. Kutter was also an architect of ULA's "Cislunar 1000" plan, which aims to put 1000 people into space by 2045. He additionally hosted the popular cislunar workshops sponsored by ULA for members of the space community.

Mr. Kutter was an active member of AIAA and was part of the AIAA Space Transportation Technical Committee. He presented AIAA papers and served on AIAA panels. As Mr. Kutter said on his Linkedin profile, "I want to help humans use space to better our lives and enhance our understanding of the universe."

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1920

1 **Oct. 14** Hubbard Air Services, founded by Eddie Hubbard and William Boeing, opens the first international airline service from the United States when Hubbard pilots his Boeing B-1 flying boat from Seattle to Victoria, British Columbia. The 128-kilometer route cuts a day off the time it takes to move the trans-Pacific mail by ships from Asia. Robert van der Linden, **Airlines and Air Mail**, pp. 21-22.

2 **Oct. 20** French aviation and rocketry pioneer Robert Esnault-Pelterie wins his case against the claim of the Farman brothers for his invention of the joy stick, which controls pitch and roll in airplanes. **Aeronautics**, Oct. 28, 1920, p. 314; Frederick C. Durant III and George S. James, eds., **First Steps Toward Space**, pp. 5-21.

3 **Oct. 20** An aircraft exceeds 300 kph for the first time when French aviator Sadi Lecointe flies a Nieuport-Delage NiD 29V Bis single-seat biplane fighter 302 kph during high-speed trials. David Baker, **Flight and Flying: A Chronology**, p. 135.

1945

4 **Oct. 2-3** As part of Operation Backfire, the first British-captured V-2 rockets are test-fired by a German crew under British supervision at Cuxhaven, Germany. F.I. Ordway III and M.R. Sharpe, **The Rocket Team**, pp. 305-306.

5 **Oct. 4** Australia's Qantas airlines starts its postwar service, from Australia to Singapore, with the Short C-class Empire flying boat Coriolanus. On its first return flight, the flying boat carries home 34 Australian former prisoners of war. David Baker, **Flight and Flying: A Chronology**, pp. 306.

Oct. 11 A full-scale WAC-Corporal upper atmospheric sounding rocket is launched by the U.S. for the first time, attaining an altitude of 235,000 feet at White Sands Proving Ground in New Mexico. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 51.

Oct. 24 Pan American's Douglas DC-4 flagship America arrives at Hum, Scotland, starting the first commercial transatlantic service operated by land plane. It carries 11 passengers, a crew of seven and 450 kilograms of mail. **The Aeroplane**, Nov. 2, 1945, pp. 515-516.

1970

Oct. 11 A Boeing 747-B airliner makes the design's first flight from Snohomish County Airport, Washington. Thirteen airlines have ordered 42 of the improved model of the standard 747. **Aviation Week**, Oct. 19, 1970, p. 34, and Nov. 2, 1970, p. 28.

Oct. 14 The Soviet Union launches its Intercosmos 4 satellite from Kapustin Yar to study solar ultraviolet and X-ray radiation and their effects upon the upper atmosphere. **Aviation Week**, Nov. 2, 1970, p. 19.

Oct. 15 The Soviet Union orbits its Meteor 6 meteorological satellite from Plesetsk Cosmodrome. It is designed to study clouds and weather changes. NASA, **Astronautics and Aeronautics, 1970**, p. 337.

Oct. 20 NASA's Nimbus 4 weather satellite, launched April 8, relays the temperature of steam emitted from Mount Rainier, the first time volcanic temperatures are relayed through a satellite. NASA, **Astronautics and Aeronautics, 1970**, p. 343,

6 **Oct. 20-27** Zond 8 is launched by the Soviet Union from the Baikonur Cosmodrome and travels around the moon, taking photos of the lunar surface and the Earth and moon at different distances. Zond's closest approach to the moon is 1,120 kilometers. The Soviets will announce that the spacecraft brought back "photographs needed for studies of the geological and morphological qualities of the Moon." **Baltimore Sun**, Oct. 28, 1970; **Aviation Week**, Oct. 26, 1970, p. 25.

Oct. 21 The moon was formed as a separate planet outside Earth orbit and was later captured by Earth, according to calculations published by scientist S. Fred Singer of the U.S. Department of Interior and astronomer L.W. Bandermann of University of Hawaii in the journal Science. NASA, **Astronautics and Aeronautics, 1970**, p. 345.

Oct. 23 The Soviet Union launches its Cosmos 374 into an unusually high orbit and high apogee. On Oct. 30, Cosmos 375 is launched. Subsequently, as tracked by Britain's Royal Aircraft Establishment, it is determined that both satellites are involved in a weapons test in which they were exploded together with many fragments also detected, the explosive charge possibly released by a third satellite, Cosmos 373. It is now known that Cosmos 374 failed at a two-revolution intercept and was destroyed. **Aviation Week**, Nov. 30, 1970, p. 17; Mathew Mawthorpe, **The Militarization and Weaponization of Space**, p. 118.

Oct. 29 NASA and the Soviet Academy of Sciences agree on joint efforts to design compatible space docking and rendezvous equipment. This leads to the Apollo-Soyuz Test Program that culminates with the first international crewed space mission in 1975. **NASA Release 70-210**.

7 **During October 1970** The Condor air-to-surface missile makes its first full-system test when it scores a direct hit from a Grumman A-6A Intruder aircraft, the U.S. Navy says. The test includes rocket propulsion, data link and guidance equipment. **Aviation Week**, Oct. 12, 1970, p. 15.

1995

8 **Oct. 10** In the search for increased combat maneuverability in fighter aircraft, NASA test-flies a modified McDonnell Douglas F-18 Hornet equipped with controllable nose strakes. The Actuated Nose Strakes for Enhanced Rolling project features two movable panels measuring 1 meter by 15 centimeters designed to improve the yaw of the aircraft at high angles of attack. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 659.

Oct. 16 Ozone is detected in the atmosphere of Ganymede, one of Jupiter's moons, after scientists study spectrograph results from the Hubble Space Telescope. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 659.

9 **Oct. 20** The space shuttle Columbia is launched on a 16-day research trip carrying the Microgravity Laboratory Spacelab. While in orbit, Columbia is struck by space debris, chipping a window and leaving a 1-centimeter dent in the cargo bay door. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 660.

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France National Library

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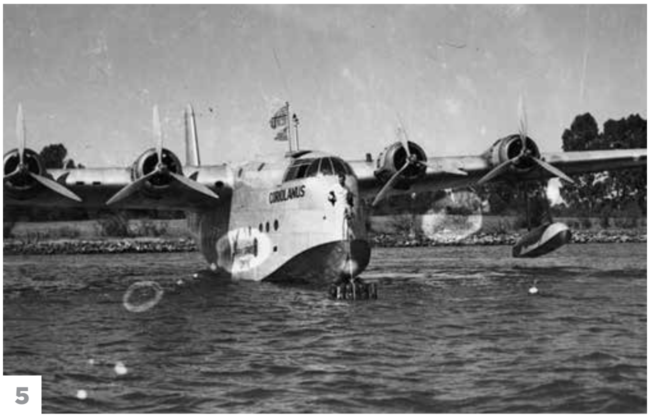

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Tenure-Track Faculty Position, Aerospace Engineering

The Department of Aerospace Engineering at The Pennsylvania State University invites nominations and applications for a tenure-track faculty position starting in Fall 2021. The position is intended for the rank of Assistant Professor, although exceptional applicants at more senior ranks may also be considered.

Outstanding candidates working in all subject areas relevant to aerospace engineering will be considered. The department is seeking new faculty to both bolster its current areas of strength (including aerodynamics, aeroacoustics, avionics, autonomy, materials and structures, and rotorcraft) and to grow its reach into new areas of expertise (including novel vehicle design and expanded areas in space systems). Applicants should articulate their plans to setup a research program attracting outside research sponsorship, contributing to the aerospace industry, and resulting in published research findings. Further, applicants should describe how they will collaborate with the disciplinary strengths already in place within the department in support of cross-disciplinary collaborative research and in support of the department's undergraduate and graduate programs.

The Department of Aerospace Engineering at Penn State is strongly committed to our educational mission. Successful candidates should demonstrate interest in teaching undergraduate and graduate courses.

Applicants must have an earned doctorate in aerospace engineering or a related field by the start date. Responses received before October 23, 2020 are assured full consideration, but the search will remain open until the position is filled. Applicants should submit electronically a **single** pdf file that contains a cover letter, a CV, a statement of research and teaching interests, and the names and contact information for at least three references.

Apply online at **https://apptrkr.com/1999962**

The Department of Aerospace Engineering enjoys an excellent international reputation in aeronautics and astronautics. The department currently has 21 full-time tenured/tenure-track faculty members, more than 250 juniors and seniors, and more than 120 graduate students. Annual research expenditures exceed $6 million.

Penn State at University Park is a land-grant institution located within the beautiful Appalachian Mountains of central Pennsylvania. State College and nearby communities within Centre County are home to roughly 100,000 people, including over 40,000 students, and offer a rich variety of cultural, recreational, educational, and athletic activities. State College is a wonderful community in which to raise a family and has an excellent public school system.

We especially encourage applications from individuals of diverse backgrounds, as the department seeks to grow in the diversity of its faculty. Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to minorities, females, veterans, disabled individuals, and other protected groups.

CAMPUS SECURITY CRIME STATISTICS: Pursuant to the Jeanne Clery Disclosure of Campus Security Policy and Campus Crime Statistics Act and the Pennsylvania Act of 1988, Penn State publishes a combined Annual Security and Annual Fire Safety Report (ASR). The ASR includes crime statistics and institutional policies concerning campus security, such as those concerning alcohol and drug use, crime prevention, the reporting of crimes, sexual assault, and other matters. The ASR is available for review at https://police.psu.edu/annual-security-reports.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status. If you are unable to use our online application process due to an impairment or disability, please contact HR Services at vacancypsu.edu or 814-865-1473.

Employment with the University will require successful completion of background check(s) in accordance with University policies.

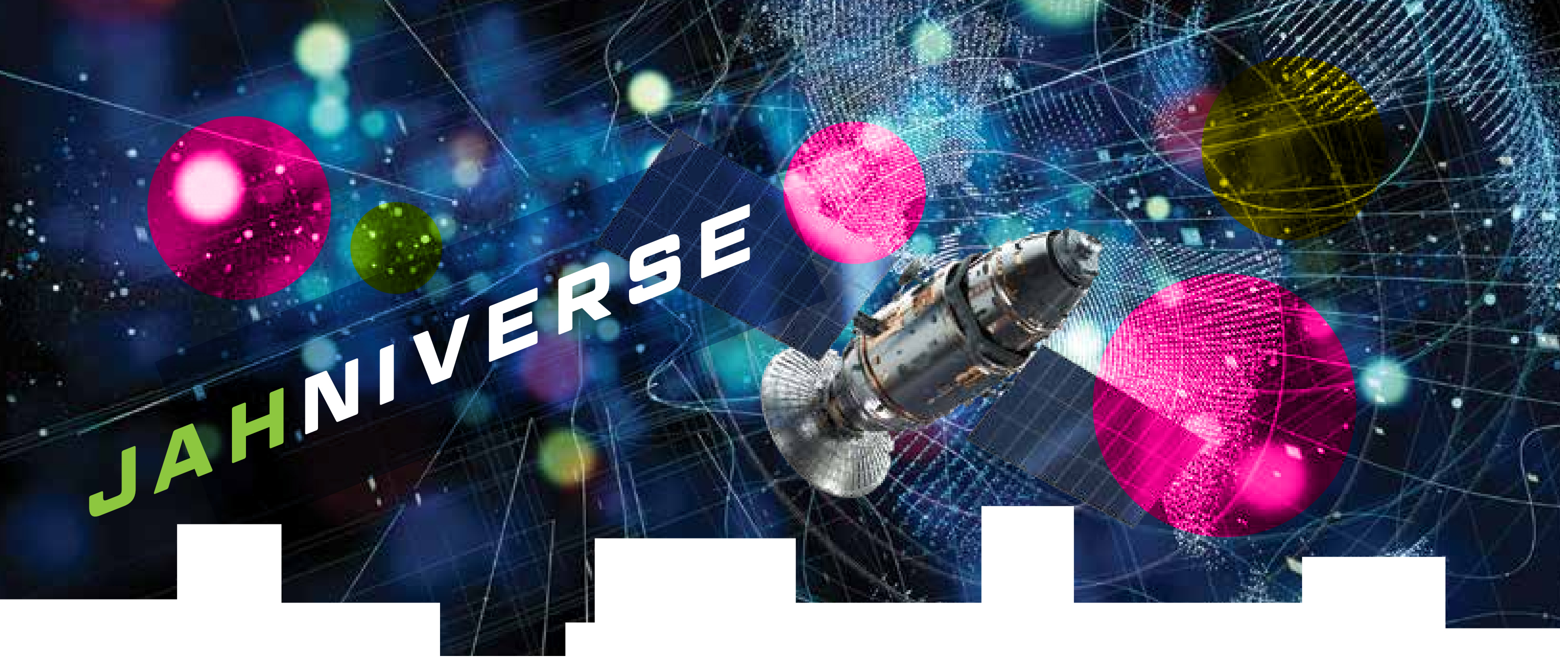
CONTINUED FROM PAGE 64

licenses from the FCC to launch hundreds to thousands, even tens of thousands, of anthropogenic space objects over the next few years. In the absence of a global ecologically sustainable strategy for managing the traffic in near-Earth orbit, we could exceed the orbital environment carrying capacity, resulting in an unacceptable risk of collisions that could make future use of this space impossible.

The Space Domain Digital Twin would have to model all of the elements that influence our inference of the space environment, space objects and information sources comprising the domain, their relationships and interactions, to include accommodating our ignorance and error sources. If we desire the right decision intelligence for licensing space actors to launch and communicate through space, the analyses performed must account for what we know but also what we know we don't know, along with their meaningful uncertainties.

I suggest that satellite operators and regulators perform Monte Carlo analyses incorporating, at a minimum, uncertainties in the size, shape and material properties of the anthropogenic space objects, how accurately and precisely the location and predicted errors might be for the objects other than those of the license requesters. The analyses must also consider how each operator actually commands and controls its own satellites, when to maneuver to avoid a collision, and how frequently to adjust orbits. This owner/operator behavior must be reflected in the Space Domain Digital Twin in order for the regulatory framework to meet the spirit of the regulations, which is to make space safe, secure and sustainable.

The U.S. has some of the world's leading large-scale computing platforms and skilled space research and operations skill set. Let's create this Space Domain Digital Twin and put our best to use it for our own good. ★



Why we need a Space Domain Digital Twin

BY MORIBA JAH

I weep and laugh when I look at the orbital debris analyses that companies typically provide to regulators at the U.S. Federal Communications Commission to win communications licenses for their satellites.

Unfortunately, FCC's proposed amendments to this process, released in August with comments due by Oct. 9, won't stop my tears or chuckles.

Here's my suggestion for a better path: In addition to the FCC review of the analyses, the U.S. government should fund an independent entity, perhaps an academic-led consortium, to subject each license requester's analysis to open and transparent rigor, peer-review and scrutiny, while protecting confidential and proprietary information.

Right now, prospective operators typically perform analyses based on a single model and incomplete data, not properly addressing uncertainty, and some only assessing their own satellites. The results are worse than unrealistic in that they occult the actual risk to the long-term ability of the space environment to carry space traffic and support operations. They of course conclude that they are compliant with, for example, the requirement to demonstrate a no more than 1 in 1,000 chance of creating orbital debris, as stated in the U.S. Orbital Debris Mitigation Standard Practices.

Vetting by an independent entity would underwrite the licensing requirements with a rigorous, comprehensive and independently verifiable process.

Vetting by an independent entity would underwrite the licensing requirements with a rigorous, comprehensive and independently verifiable process. In short, those seeking licenses would be challenged to "TEST LIKE YOU FLY!" on a virtual replica of the orbital environment that we could call the Space Domain Digital Twin. As an example, this digital twin would need to be populated with NOAA's space weather data, the trajectories of other satellites, digital models of them and the criteria that operators apply when deciding whether to maneuver their spacecraft.

The FCC must be bold in this way, given the stakes. An increasing number of companies are requesting

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


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