SPACE ECONOMY 18
GPS for deep space

WORKFORCE 42
Smithsonian's Stofan on diversity

Q & A 10
U.S. Rep. DeFazio on the pandemic

AEROSPACE

★ ★ ★ AMERICA ★ ★ ★

SURVIVAL PLAN

Airlines chart a long, slow path back from the pandemic. **PAGE 24**

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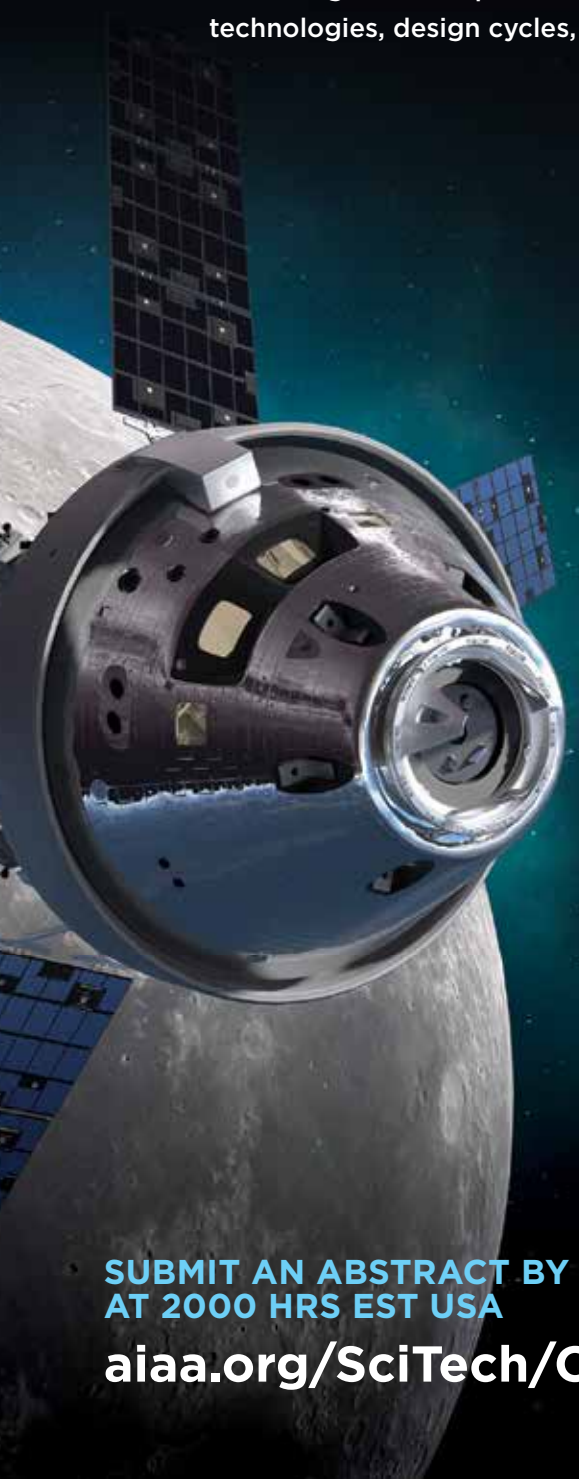

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American Airlines

American Airlines jets are parked at Tulsa International Airport, Okla., and five other locations during the shutdown caused by the coronavirus.

24
Preparing for takeoff

U.S. lawmakers and airlines are taking financial and technical steps to revive airline and manufacturing businesses once the coronavirus is less of a threat.

By Cat Hofacker

18
GPS for lunar missions

Scientists are proving that GPS is a viable tool for spacecraft flying beyond the GPS constellation.

By Adam Hadhazy

32
Taking charge of space debris

While the U.S. Congress and the White House wrestle over space traffic management oversight, commercial satellite operators are stepping in.

By Debra Werner

42
Opinion: Lifting up STEM role models

The National Air and Space Museum is working to uncover the stories of women who have helped move aerospace forward.

By Ellen Stofan

As an analyst and developer, Kevin knows the importance of location. Lately, he's been eyeing some charming real estate 250 miles above Earth.

DEVELOPER

As a real estate developer and business analyst, Kevin Barry has big plans. Kevin is going to ASCEND, where he'll share his vision for establishing the infrastructure that'll make life off Earth commonplace. ASCEND is all about big ideas and bringing together the people with the vision and those with the means and expertise to make it happen. You can read Kevin's story at **ascend.events/barry**.

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IN THIS ISSUE

Adam Hadhazy

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

PAGE 18

Cat Hofacker

Cat joined Aerospace America as staff reporter in 2019 after an internship at USA Today, where she covered the 2018 midterm elections.

PAGES 10, 24

Amanda Miller

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

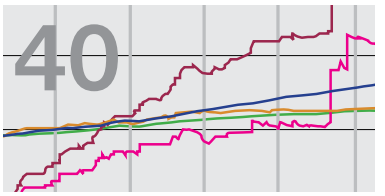
PAGE 14

Debra Werner

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

PAGES 32, 64

DEPARTMENTS



OPINION
Space debris and the coronavirus

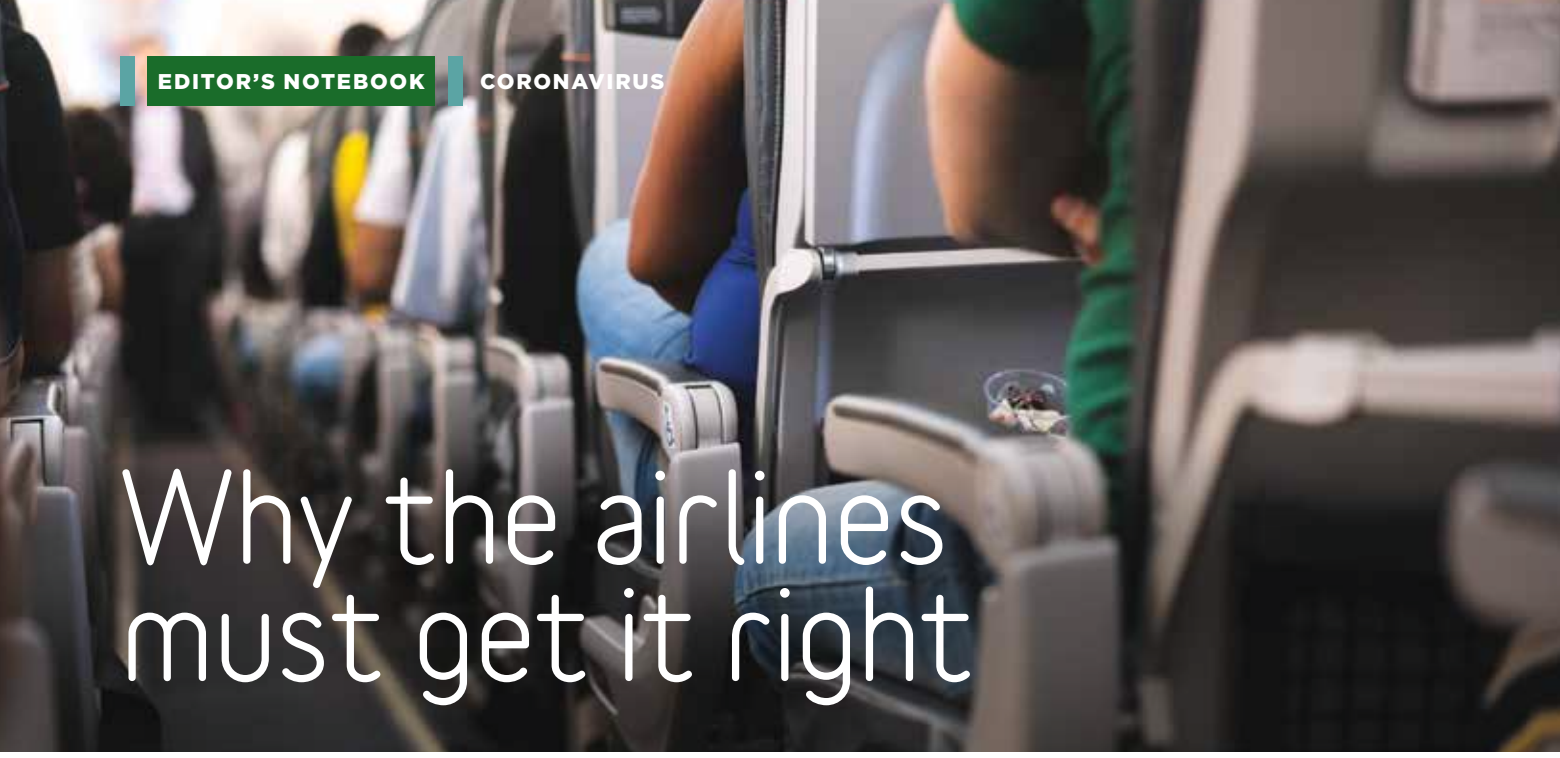
4 Editor's Notebook
5 Letters
7 Flight Path
8 AeroPuzzler
10 Q & A
14 Engineering Notebook
49 AIAA Bulletin
62 Looking Back
64 Trajectories

8
AeroPuzzler
Controlling the descent of a helicopter

10
Q & A
U.S. Rep. Peter DeFazio on the effects of the coronavirus and drone regulations

62
Looking Back
U.S. Coast Guard makes one of the first helicopter rescues

64
Trajectories
From a youth taking apart electronics to a career as a manager at Embraer



Why the airlines must get it right

Supersonic flight, cleaner burning engines, biofuels and electric propulsion: These are among the exciting advances in aviation whose timing and perhaps fruition depend on airlines earning the trust of customers in the coming new reality.

Inside the U.S. industry, we often hear about thought leaders and subject matter experts, but the coronavirus pandemic reminds us that it's the actions of consumers that drive and define progress.

Listening to health experts, it sounds like we're headed for a future in which the current pandemic subsides but the danger from the virus persists. What happens then will be largely determined by our collective behaviors. For air travelers, those new behaviors are likely to extend beyond this pandemic. It no longer seems like a healthy choice to pack oneself onto a crowded plane.

Airlines should be working now to prepare for this new reality, and I mean with more than social distancing measures in boarding lines and hand sanitizer and bottled water on planes, as important as those are.

The first days of the outbreak offer a tough lesson about planning ahead. Airline executives at the March 5 Aviation Summit 2020 in Washington, D.C., like many of us, were slow to grasp the seriousness of the threat. "It's a gut punch right now, but hopefully it will be short-lived," said Gary Kelly, the CEO of Southwest Airlines.

No one could have predicted the future with certainty, but by the date of the summit, CDC officials had publicly warned that this could be bad. Just days later, on March 9, CNN declared the virus to be a pandemic, and two days later the World Health Organization did the same. There was ample cause by early March to prepare for the worst.

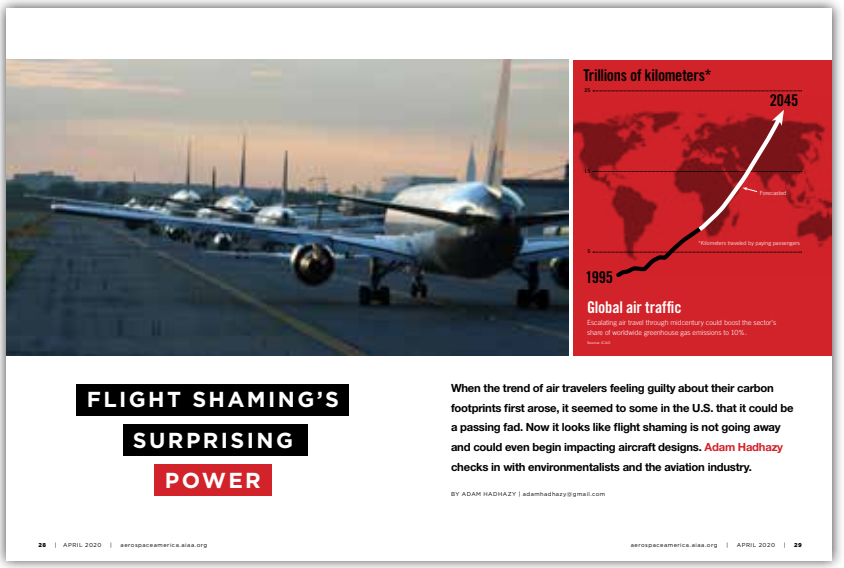
If airlines were slow to react, they now have a chance to get it right. Winning the trust of the public will almost surely require physical changes to passenger cabins. Customers in the cheap seats, for one, are going to need more personal space. We can't have the person next to us dozing off onto our tray tables, mask or no mask. This will be true even after the pandemic.

Aside from the ethics of the situation, health can't be bought by well-heeled travelers. Even with today's special clubs inside airports, we all cross paths at some point. Maybe a snafu made the first-class baggage come out late, or we see each other at a restroom sink or in line at a coffee shop.

The virus is a community problem, and it's going to require a community-minded response from the airlines. The broader aerospace industry is counting on airlines to succeed, and this mindset will help. ★

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

Your reactions to "flight shaming"



The article "Flight shaming's surprising power" [April 2020] is a good summary of the effect reactions to climate change might make on air travel. As more people become aware of the problems being created by climate change, some will change their actions from altruism.

What is missing in the article is an understanding of the real cause of climate change. When we use fossil fuel, we pay the cost of the production and delivery of the product, but we do not pay the "social" cost from the pollution coming out the tailpipe or exhaust stack. The result is a distortion of the true market cost, making the product too cheap, and leading to overuse. We need to fix this problem by using the Fee and Dividend, where a fee is added to extraction of fossil carbon and returning the money to people equally.

James A. Martin
AIAA associate fellow
Huntington Beach, California

Thank for the great article, "Taking stock of flight shaming." This is great progress in a sensible response to the human-induced climate crisis. Writer Adam Hadhazy has been good about that in at least one prior issue of Aerospace America, too.

Shame is never a good thing, but shame is universal, so we develop a healthy shame resilience if we manage to be among the few to develop such skills. Brené Brown of the University of Houston has become famous for her work with such topics, all based on her research in sociology, as I recall. It is a paradox to make progress in response to the climate crisis with the phrase flight shaming. But as Greta Thunberg says, we need cathedral thinking. The solution is simple and complex at the same time, and we do not have all of the answers yet, so we must start the years of work on our cathedral project even if we have no idea yet about the final appearance of the ceiling and the top parts of our cathedral.

Douglas Yazell
AIAA associate fellow
Houston
douglas.yazell@me.com

I was disappointed and annoyed to see that a green advocacy article was included in what I thought was a magazine that credibly featured things aerospace ["Taking stock of flight shaming," April 2020]. Popularizing and legitimizing an emerging and threatening cultural issue doesn't belong here, at least not without balance.

While I suppose in the big picture, we as aerospace engineers need to be aware of the environment that we work in, I was disappointed to see so much of what the author wrote was anecdotal or flat-out non-factual. None of the arguments were countered by Aerospace America with any narrative of substance or force. Your silence serves to validate the main theses of the climate movement, that climate change is human-caused and that the issue is settled science. Many scientists, some of whom are AIAA members, disagree with both tenets.

Richard Docken
AIAA senior member
Beavercreek, Ohio

Rescheduled Event!

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Highlights and Challenges, 2018–2020

As we go to press the world is gripped in a pandemic the likes of which no one alive today has experienced before. COVID-19 turned our modern air transportation network into a disease vector, and the result is much of that system and the industries that support it have been temporarily shut down. While no one has escaped the impact, AIAA is benefiting from a very wise financial policy put in place many years ago and updated in 2009 after the last financial crisis that requires us to maintain operating reserves sufficient for nine months of operations, plus fulfilling our out-year strategic commitments. While this may have at times seemed like an overly conservative policy, today it is proving its value as AIAA has been able to continue operations, including supporting our professional staff, even as most of our events for this spring have been cancelled. We are rapidly pivoting to a "more virtual" reality, including the first major flagship event, AIAA AVIATION Forum, that will be fully virtual.

As I wrap up my term as AIAA President and hand the reins to Basil Hassan, I wanted to reflect on a few highlights and challenges.

Membership. After decades of decline, our membership reached a minimum in FY2018 and has begun to grow again. As our Board of Trustees shifts their focus from a five-year project of reforming the governance structure to a focus on membership growth, we have seen experiments such a e-Membership start to pay off. A renewed focus on our corporate members, led by Executive Director Dan Dumbacher, is key to this effort. We're also converting AIAA AVIATION to an all-virtual format this year to benefit our members working from home during the pandemic. In addition, we have launched the ASCEND event, which includes the best parts of the AIAA SPACE Forum—building the program on a foundation of technical excellence, but taking that experience to the next level, opening the door to more interdisciplinary collaboration and conversation. ASCEND will debut this November in Las Vegas. We need all our membership to support both of these pioneering efforts.

Diversity. Similarly, our focus on increasing the diversity of our membership is showing tangible signs. At our recent AIAA SciTech Forum plenary sessions, three of the five speakers were women and two were people of color. One of my favorite parts of being AIAA President is that I get to host the 20 Twenties, a joint program AIAA runs with Aviation Week Network. This year, for the first time, more than half of the rising stars in aerospace were women. And last year we established the Diversity Scholars Program, in which we provide financial support through a competitive selection process to diverse students who might not otherwise be able to attend. We have now extended this program to all our major events

Education. The key to making our workforce look more like the nation is to extend our recruiting pipeline much deeper into the K–12 education system than ever before. I'm thrilled that the AIAA Foundation now has a full-time director and additional staff, that its endowment has reached record highs, and that new programs are in development. We have begun a serious partnership with the AIA for the The American Rocket Challenge (TARC), and so far over 138 AIAA members have volunteered to help TARC schools.

The Power of the Past, The Promise of the Future. Over the last two years one of the big AIAA projects was marking the 50th anniversary of the Apollo 11 moon landing and hosting the 70th International Astronautical Congress (IAC 2019). Like ASCEND, hosting this event was a heavy lift and a financial gamble for the Institute. Led by Craig Day, the entirety of AIAA rose to the occasion and pulled off an event that no one who attended will ever forget, and which not only broke even but generated a modest financial return for the organizers. Perhaps my favorite memory of the event was the recognition of the Apollo 11 crew with the World Space Award. What really made this special was that the crew was represented by three generations: one from the generation that made the flight, one from the generation that grew up with it, and one from the generation that so far has not seen a human walk on the moon. And changing *that* is all of our jobs! *Per aspera ad astra.*

John S. Langford
AIAA President (2018–2020)

AERO PUZZLER

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

Surviving the fall

Q: You're buckled in a helicopter when the hum of the engine disappears from your headset. You feel yourself lift from your seat slightly, and you realize the aircraft is accelerating toward the ground. The pilot moves his hands and feet quickly, but not frantically, as the aircraft turns toward an open field. Near the ground, G-forces push you into your seat, and then the aircraft settles to the ground. What maneuver did the pilot perform to control the descent, and what explains the G-forces?

Draft a response of no more than 250 words and email it by midnight May 7 to aeropuzzler@aiaa.org for a chance to have it published in the June issue.

FROM THE APRIL ISSUE

PUNISHING PITCHERS: We asked you whether hypothetical baseball executives would be right or wrong to think that higher seams on baseballs would make it harder to hit home runs.

Your answers were reviewed by Barton Smith of Utah State University and author of the blog, Baseball Aerodynamics (see posts 36, 38, and 54).

WINNER: As a member of the NCAA Baseball Research Panel, a technical advisory group, we had virtually the same problem, but in reverse. We had decreased the performance of non-wood college bats to the level of wood bats. But home run production had also greatly decreased. Fans and coaches complained. To remedy the situation, and on the basis of careful aerodynamic research, we lowered the seam height of the college ball to match the seam height of major league baseballs. The result: ball aerodynamic drag decreased, hit distance increased, but the ball exit velocity (hit speed) did not change. Player safety is intact, but the game is more exciting.
So, the answer to the question is that, based on the aerodynamic research that has been done and on the results in college baseball, it is very likely that higher seams will increase the drag of the ball and will decrease home run production in major league baseball. There will be an effect on pitch speed, very slightly increasing the time of flight.

Keith Koenig, AIAA senior member
Starkville, Mississippi; kk2@msstate.edu; Koenig is a professor emeritus of aerospace engineering at Mississippi State University.

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

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Chris Weaver/Air Line Pilots Association

Q&A

Aviation advocate

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U.S. Rep. Peter DeFazio's first year as chair of the House Transportation Committee was marked by the deadly Boeing 737 MAX crashes; his second will be consumed with the coronavirus pandemic and its aftermath. With the air transport industry facing an unprecedented challenge, DeFazio must balance his role as a longtime advocate with the strong oversight he believes FAA and the industry need. He plans to continue the committee's investigation into the certification of the MAX, and he expects FAA to complete the tasks related to safety assigned to it in the last reauthorization act. I spoke with DeFazio by phone from his home in Oregon. — *Cat Hofacker*

PETER DEFAZIO

POSITIONS: Chair of the House Committee on Transportation and Infrastructure overseeing FAA, aviation industry and other transportation sectors, since 2019; member of the House General Aviation Caucus, since its founding in 2009; House member, since 1987, representing the southern half of Oregon's coastal counties, a largely rural area.

NOTABLE: Opened a committee investigation in 2019 into the development and certification of the Boeing 737 MAX after the Lion Air and Ethiopian Airlines crashes that killed 346 people; top Democratic negotiator of the FAA Reauthorization Act of 2018 that directed the agency to regulate recreational drones; co-sponsored the Airline Safety and Pilot Training Improvement Act of 2009 that increased the number of flight hours required for a pilot to fly passenger jets for U.S. airlines from 250 to 1,500.

AGE: 72 (turns 73 this month)

RESIDENCE: Springfield, Oregon

EDUCATION: Bachelor of Arts from Tufts University, 1969; majored in economics and political science; Master of Arts in public administration and gerontology from the University of Oregon, 1977

IN HIS WORDS

Oversight versus advocacy

I think those two things fit together perfectly. When we write laws or FAA or the FTA [Federal Transit Administration] or anybody promulgates rules, it's our duty to see that those rules conform to the law. And then it's our duty to see that those rules are followed by the impacted industries, which are a broad range of industries under our jurisdiction. I think that is something, unfortunately, that Congress has overlooked. When I was first in Congress, every committee had an oversight and investigations subcommittee. Newt Gingrich did away with all that. And I still don't have a dedicated oversight and investigation subcommittee, but I do have now a dedicated oversight and investigation staff — albeit only three of them, but they're very good. I could use more to do more oversight or we could go back to the prior model. We do have a global oversight committee under Rep. Carolyn Maloney [D-N.Y.], but they've got to cover the whole government. The individual committees of Congress, particularly in my case, Transportation and Infrastructure, do need to be more focused on this critical function. It would make for a better government and a safer country.

CARES Act: not a repeat of 9/11 aid

Airlines constitute obviously a very significant portion of our economy, and in terms of aviation, a large part of our export economy. Anything that has a dramatic impact on that industry is going to hit very hard in the country. That's why we fought so hard in the CARES Act to get an aviation package. I was, it was determined not to do it the way it was done after 9/11. They got assistance and then when they burned through the assistance, declared bankruptcy, took away their workers' pensions, busted the unions. In the case of United [Airlines], it was particularly egregious. There was a jerk there named Tilton, Glenn Tilton, and the day before he took away everybody else's pension he got a $4.5 million special account that couldn't be touched in bankruptcy. [Editor's note: United Airlines said the funds were part of Tilton's original contract, meant to compensate for retirement money he gave up when he joined United in September 2002.] So I was on a conference call early on with the CEOs in their conference rooms. We began discussion and negotiations [with other members of Congress], and we came up with a package that I think should be a model for all industries.

Last-minute changes

I actually added a third component of the airline aid; didn't make it, but the third component would ultimately have been a very ambitious plan to begin to reduce carbon pollution. They agreed to a plan that wanted to have them all carbon neutral by 2025 — not ideal, but until we develop and distribute sustainable fuels, that's a good step. In the final package, Mitch McConnell [R-Ky. and the Senate majority leader] made fun of that and made a point of taking it out, and secondly at the last minute, Republican Sen. Pat Toomey from Pennsylvania got inserted a provision to say that they could exercise warrants on those grants. We don't want conditions on that. The loans, we certainly expect that the loans would be rated as to risk. There's a whole host of questions Treasury asked about the loans at the outset. It didn't ask those same questions about the grants at the outset. They have now asked all of the same questions about the grants, which doesn't make sense since they already got that information on the loans. But no, the loans would definitely have a rate of return to the Treasury and I assume they would be risk rated. Whether it would just be an interest or whether there would be other interest in terms of preferred stock or something, that part of the bill was totally discretionary on the part of Secretary [Steven] Mnuchin.

The FAA's to-do list

Obviously getting the MAX back in the air, for the airlines that had them on order or already bought them, is not as much of a pressing need at the moment. The FAA's got a lot of things it's got to get done, and that's one of them. But before that, I'm really hopeful they'll get the rule out on drones much more quickly because we have heard from companies that could be delivering medical supplies to areas by drone and other needs. We're heading into the West Coast fire season. We're going to need comprehensive rules on drones for that. So they've got to get the drone rule done and out as soon as possible. It would also be an ideal time for them to approve previously written rules. The FAA wrote the standards for secondary barriers [to cockpits] through a special committee years ago. They want, because of objections by the airlines, to start another lengthy process. It would be a great time for them just to implement those earlier recommendations and put a few people to work. Putting the secondary barriers on the airplanes has been too long delayed. Then it would be a great time for the FAA to recognize that we were very definitive about the rest duty time [of flight attendants]. The airlines would have plenty of time now to redo their schedules and accommodate the new rest duty time; that would keep the schedulers busy who don't have much to schedule right now.

737 MAX investigation on hold

We issued an interim report, and we felt we had enough with the interim report to move forward with ODA [Organization Designation Authorization] reform, but we have not reached the ultimate conclusions to exactly what went wrong in some places. The FAA has not been particularly forthcoming with a lot of communications that we've asked for. So far as we know, we have everything from Boeing, although every once in a while, they surprise us. And we're still conducting interviews, so it's ongoing. We know enough to legislate, but we do want to come to a more conclusive report in the future.

Reforming aircraft certification

We were working on an ODA reform bill. We had shared it and were in discussions with the Republicans just before all this came down. I've got to say that the CARES package and everything we did, work and in the space of infrastructure, that bill took precedence, but the process does need to be reformed; it failed clearly. The Boeing [Aviation Safety Oversight] office in Seattle was essentially captive of the company at the management level. Even when the technical specialists, seven of them, nonconcurred with a decision — and they were upheld through two appeals — one single manager, apparently without ever contacting the Washington, D.C., office, decided to overrule them. That's totally unacceptable. We did a seven-hour interview with the head of safety [at FAA] and he reported to be

Hobbyists protest outside FAA headquarters in Washington, D.C., over proposed drone rules. Rep. Peter DeFazio says such regulations are an important item on FAA's agenda.
Hillel Steinberg/Flickr

absolutely clueless about anything that went on with the MAX. Never heard anything about it, wasn't in the loop. There needs to be much more accountability throughout the FAA from the local office, regional office, to the head office and we're going to fix that. I think we can fix the mixed system we have and make it work. No, we're not going to get into every detail of every manufacturer with FAA employees.

Remote identification of drones

We've got to be able to arrest and prosecute the jerks who interfere in public safety and violate rules. It's a small percentage of people, mostly hobbyists. And it took me many years to get preclusion removed up on the FAA on requiring remote ID. There is still some fighting back, particularly the toy manufacturers. That's just got to get done, otherwise we can't safely reintegrate. And if just one idiot flies a drone into a helicopter and causes a crash — or potentially, since we have yet to conduct the test — it's assumed that even something as small as a quadcopter could cause uncontained failure of a jet engine. We've got to get the remote ID on that aircraft, all the drones in America, including all the ones that are beneficial. So we need to get that remote ID rule done. They [operators] have got to figure a workaround on the broadcasting requirements, but these things have to be identified just like every plane in the air has to have a transponder.

Returning to service post-coronavirus

There are certain requirements when a plane has been out of service that have to be met. We were dealing with that in terms of all the back planes that had been produced, some of which had been in service, many of which have been in service. And in that case, because of the particular problems with the MAX, FAA Administrator Steve Dickson said the FAA was going to individually certify every plane, a very ambitious and time-consuming undertaking. In this case it doesn't require full recertification, but there are certain procedures that have to be followed and it's critical that we protect the workforce who can do that work.

Future aid

On aviation, the most critical thing is the Airport Improvement Program is going to run out of money in a few months, which means that stalls the NextGen and other investments by the FAA, which would be very unfortunate. It would also mean limiting airport projects or capital expenses. There are terminals and runways and that, so that will be a major component. We did get $10 billion for the airports in the first bill, but they're hemorrhaging way more than that in terms of lost revenues. So support to airports will be critical. I think the bill goes far beyond aviation in terms of infrastructure and investments in infrastructure.

Working remotely

I had a joint conference call with my ranking member, Sam Graves [R-Mo.] and all the members of the committee, both sides of the aisle. We laid out our agenda, made suggestions of things that we would like members to do and proposed that we think that we can do some oversight. We can do some briefings, certainly like with FEMA where we have a strong role, and others. I have had briefings there. So ongoing we're doing briefings, we're looking at moving more into oversight. We are writing bills remotely. We've set a deadline of May 1 for submissions for the Water Resources Development authorization for all the members of the House. So we are moving ahead with legislation. When we'll be at a place to actually physically be together? I don't know.

New norms for Congress?

After 9/11 [then-Rep.] Brian Baird from Washington state said, "We need rules, we need rules for disasters, we need rules on how to reconstitute Congress." Because if everybody in the House is killed, there will be no members of the House because you can't be appointed to the House under the Constitution. So he was proposing both emergency measures and reconstitution-of-government measures. I supported him strongly. We got blown off and now the folly of that is very, very apparent. We had to get 218 people to D.C. because of one jerk who was going to object to a voice vote on the CARES package. And that meant we had to have a quorum present in the chamber to go ahead with a voice vote, and that was not ideal at the time, obviously. I flew across the country, more than 218 of us got there. But the question of how the rules can be changed, that is very much an ongoing intense discussion. ★

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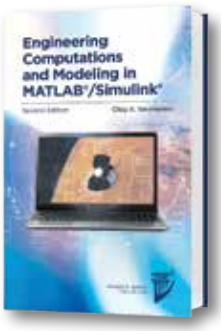

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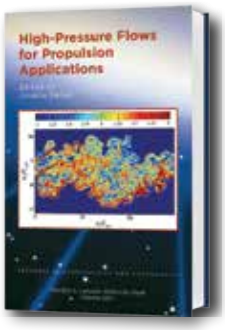

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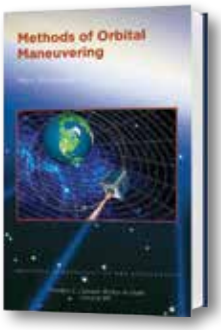

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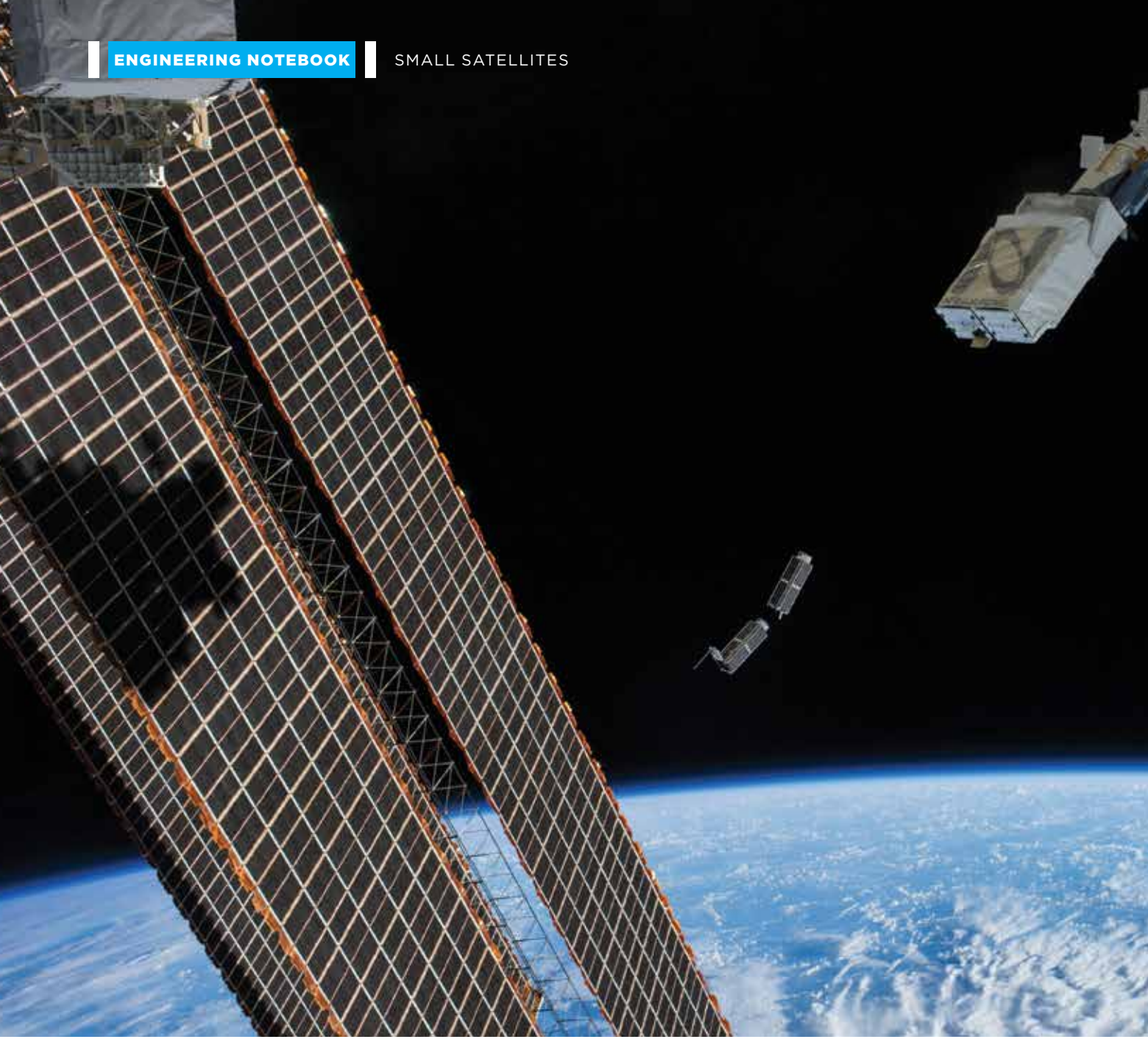


Tracking cubesats

Students love their cubesats, except maybe when they lose contact with one in the first days after launch because the team hasn't yet nailed down its orbital track. Cubesats are often reacquired, but not without frayed nerves and lost experiment time. Amanda Miller spoke to researchers who think they can keep cubesat operators locked onto their satellites from the start.

BY AMANDA MILLER | agmiller@outlook.com

Two cubesats are deployed from the Nanoracks cubesat deployer at the end of one of the International Space Station's robotic arms. To better help track cubesats, a team of researchers at the University of Colorado in Boulder has suggested adding cameras to the Nanoracks deployer.
Nanoracks

The first passes overhead by the Miniature X-ray Solar Spectrometer 2 cubesat were exhilarating to the students who built it. At each anticipated crossing time, a small crowd of students, professors and staff gathered around computers at the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder. Signals raced from LASP's ground station toward the estimated track of MinXSS-2. The signals hit their mark and triggered MinXSS-2 to confirm that it was listening and to send a report about its well-being, including its temperature, position relative to the sun, and the performance of its solar panels, battery and science instrument.

Several ham radio operators in the U.S. and Japan were pulling in the information, too, aiding the students to predict the timing and path of MinXSS-2's orbit.

Then came the letdown. On one pass, no reply came back. That's not unusual, but soon it happened again. Matters turned tense. "You spent five years to build it, and not being able to talk to it is very excruciating," says Scott Palo, CU Boulder professor of aerospace engineering sciences and one of MinXSS-2's investigators.

If an equipment failure on the satellite were to blame, the spacecraft's mission to chronicle the X-ray intensities of solar flares might be over before much useful data was collected.

As it turned out, the culprit was a frustrating side effect of the most affordable way to get a cubesat into orbit. MinXSS-2 was dispensed from its launch vehicle with dozens of other cubesats, which meant that on its initial passes, the signal beam projected from LASP covered all or many of the satellites in this cluster. But as the satellites drifted apart due to atmospheric drag and differences in their masses, the job of estimating when and where to direct the signal became more challenging. At this point, MinXSS-2 was not yet in the catalog of satellite tracks published by the U.S. Air Force by parsing radar detections (a job now done by the U.S. Space Force).

MinXSS-2's operators scrambled during each eight-minute pass to figure out if they were missing the return signal perhaps by incorrectly anticipating the Doppler shift in the cubesat's radio frequency caused by the satellite's motion relative to LASP. "You're sitting there turning a bunch of knobs trying to dial it in," says Palo, making a figurative reference to the process that's actually commanded by software.

Enter Palo's colleagues at the university's Colorado Center for Astrodynamics Research. They have come up with a technique that could someday relieve cubesat operators from the prospect of temporarily losing contact with their satellites during the harrowing first weeks in orbit.

The problem

Our story starts in 2015, when then-doctoral candidate John Gaebler decided to take up the challenge of ending sagas like the one experienced by the MinXSS-2 team. He'd witnessed the advent of clustered deployments in his years as a flight dynamicist at NASA's Goddard Space Flight Center in Maryland, before he began his Ph.D. work.

Even then, "I couldn't envision that they would launch 100 cubesats in five minutes," he says.

Gaebler won a research grant from FAA, which, at the time, had been tasked with figuring out how to regulate space traffic.

His plan was to write software algorithms that would sort radar measurements gathered by the Air

> "Not only does it take [the military] a long time to find the cubesats, once they find them, they don't necessarily know whose is whose."
>
> — **Penny Axelrad**, University of Colorado in Boulder

Force before the service converted them to tracks of known and unknown objects in its Satellite Catalog. This would be done through a filtering process called finite set statistics.

If the approach worked, he could produce reliable tracks, comparable to the military's, within a few days rather than the weeks it can take clustered satellites to show up in the catalog published on websites including CelesTrak.com and Space-Track.org.

By simulating a real deployment, he could create his own sets of simulated radar measurements to test the process, since he did not have that data from the Air Force.

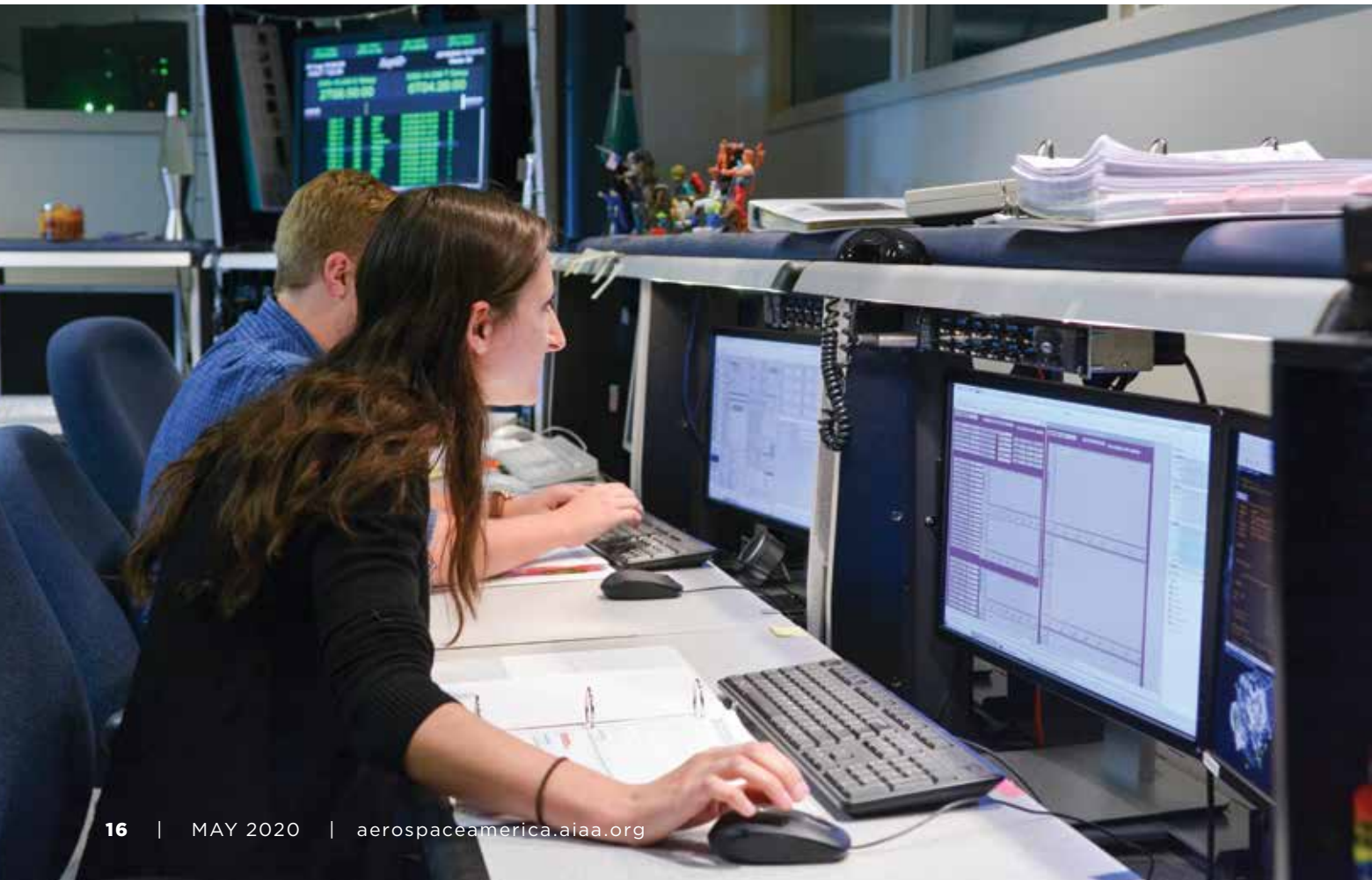
Gaebler's project was no slight against the U.S. military's space trackers. "What's hard about it is cubesats are small. They have a low radar cross-section," as Penny Axelrad, the project's faculty adviser, explained during a public lecture last year.

When first dispensed, cubesats can be separated by as little as 5 meters, and Space Force trackers at first can't sort out which radar measurements, such as the range, azimuth or direction of travel, and elevation, represent one orbit.

"Not only does it take [the military] a long time to find the cubesats, once they find them, they don't necessarily know whose is whose," Axelrad said.

Indeed, the Satellite Catalog lists unidentified satellites with a number. Once operators receive a signal confirming that one of these unidentified satellites is theirs, they report that to the Space Force's 18th Space Control Squadron, which adds the identity to the catalog.

Back when just a cubesat or two reached space by riding along with bigger payloads, estimating the orbits according to the radar findings was "fairly obvious," says Gaebler, who completed his doctorate this year. "What was plenty good enough before now isn't so good."



▼ **Then-graduate** students in the mission operations center at the Laboratory for Atmospheric and Space Physics in Colorado communicate with a satellite.

Glenn Asakawa/University of Colorado in Boulder

Building a simulation

To test his plan for quickly sorting radar measurements into satellite tracks, Gaebler first built a simulation of the 2017 deployment of 104 satellites from an Indian Space and Research Organization Polar Satellite Launch Vehicle rocket.

Plugging the cataloged radar tracks into NASA's open-source General Mission Analysis Tool showed him how the orbits spread apart over time. Next, he picked four of the military's radar sites around the world, and within the GMAT software he generated simulated measurements — range, azimuth and elevation — as though the satellites were being observed from those sites.

The 2017 launch afforded the added benefit that one company, Planet Labs of San Francisco (now simply Planet), owned 88 of the satellites. The company provided Gaebler with the only other information cubesat operators often have to go by upfront: prelaunch predictions of the satellites' positions.

"Now my simulation was that much more realistic," Gaebler says.

Running the algorithms

He went to work on the simulated radar measurements, before any had been matched as belonging to the same satellite.

After next defining the far outside limits of possible tracks for any satellite from the deployment of 104, he wrote algorithms to quickly pair up all the measurements one by one, calculating rough tracks and rejecting any combinations that exceeded his constraints.

To save time, Gaebler combined fewer data points at this stage than if he'd been trying to calculate precise tracks.

Once he'd narrowed down millions of possible measurement combinations into matches that could make realistic tracks, the algorithms set about doing the slower, more complex calculations of figuring precise orbits.

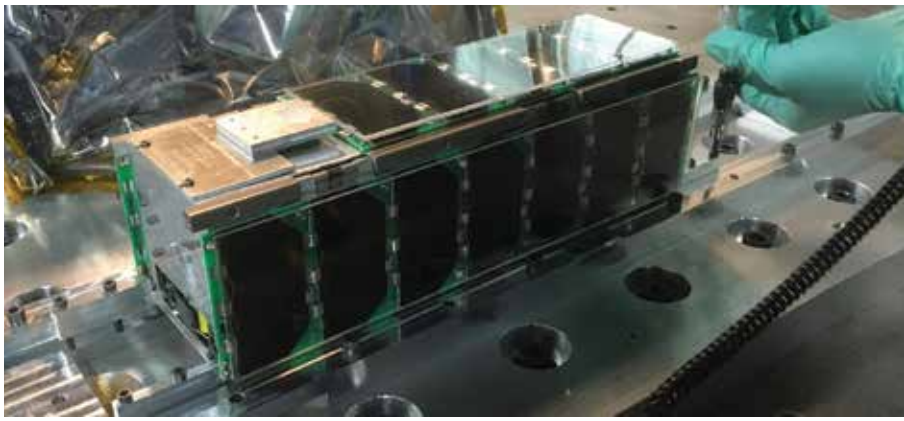
The process proved he could sort out the orbits of the 104 clustered cubesats "within days" with an uncertainty of about 50 meters.

Gaebler is continuing the research as a postdoctoral student, working on a proposal for an Air Force grant to figure out how few measurements he could get away with and still have the method work.

New data

Gaebler thinks radar might not be the only source of helpful information.

As the algorithm work progressed, Gaebler and Axelrad had a brainstorm when they recalled to each other how they had pored over the grainy black-and-white video taken from the launch vehicle as the 104 cubesats were dispensed, hoping for clues about the cubesat tracks.



▲ **Controllers lost track** of the Miniature X-ray Solar Spectrometer 2 cubesat, shown here during vibration testing, and were unsure whether they would be able to reconnect.
University of Colorado in Boulder

One of the issues with cubesats is that they're dispensed by spring from their carriers. "There's a little bit of variability in how much oomph [each cubesat] goes out with," Gaebler explains. Accounting for that variability could make estimating the tracks more precise.

A more sophisticated camera system would be needed, one that measures the velocity of the departing cubesats.

Ten students in a yearlong senior design class mocked up a two-camera setup, thinking something like it might someday be mounted inside one dispensing tube of the Nanoracks cubesat carrier that dispenses up to six cubesats at a time from the International Space Station.

A time-of-flight camera would emit flashes of infrared light to bounce off the cubesats as they departed to calculate each cubesat's velocity during the deployment. Another camera would snap photos of each cubesat as it moved away.

Now a new class of seniors has continued the research. Axelrad says she hopes the camera idea will prove worthy of a grant or other opportunity to do a flight experiment.

"We think these contributions are really going to be valuable for commercial space operations," she says.

As for MinXSS-2, the team reacquired it intermittently and finally nailed down the satellite's track after a month. Not long after, a computer card on the cubesat failed.

The cubesat is now considered a loss, but at the time, the team remained hopeful. The last MinXSS-2 post on the team's Twitter account was from Jan. 14, 2019:

"We think the MinXSS-2 is in a really slow tumble in an unusual software condition. At some point, the battery will trigger a system reset and beacons should begin again. #hamradio operators, please keep on tracking!" ★

COSMIC GPS

The U.S. Global Positioning System has changed how we operate spacecraft in low-Earth orbit. Now GPS is starting to do the equivalent for spacecraft flying beyond the GPS constellation, and someday possibly all the way to the moon, where positioning contributions from other nations could add up to stunning accuracy. Adam Hadhazy tells the story.

BY ADAM HADHAZY | adamhadhazy@gmail.com

Before GPS receivers became standard issue on low-Earth orbit satellites, the spacecraft had limited information on where they were and where they were going. Control stations on the ground needed minutes or even hours to process radar signals bounced off of these LEO satellites to calculate position and velocity and then send that info back up to orbit. The advent of GPS changed the game, making precision navigation and timing information on board the satellites available in real time. The system provides key time-tagging for communications, Earth observations and other satellite services, while keeping those services available nearly 24/7 and slashing fuel use because satellites no longer have to be taken offline for large, station-keeping thruster burns.

For LEO spacecraft whizzing underneath the GPS constellation's altitude of 20,200 kilometers, tuning into GPS was a straightforward affair of turning their receivers upward to collect the readily available rain of GPS signals pouring down toward Earth. Twenty years ago, researchers proved that this signal collection could actually be done above the GPS constellation. The trick was to feed on GPS scraps, as it were, by capturing the weak "spillover" signals from GPS satellites on the far side of Earth that beam right past the planet, missing their terrestrial target. The breakthrough of snagging this spillover led to the adoption of GPS aboard satellites in geostationary orbit, some 36,000 kilometers above the equator, and to demonstrating the capability as far out as halfway to the moon.

Now, for their next feat, researchers want to equip new spacecraft to benefit from GPS all the way at the moon and even down to its cratered surface. If successful, this capability would go a long way toward enhancing operations in what could one day be a very busy lunar environment.

"It's really only been since late 2018, early 2019 where we could show that lunar was feasible," says engineer Frank Bauer, a 30-year NASA veteran and now president of FBauer Aerospace Consulting Services in Maryland.

"What GPS has done for spacecraft in LEO has been phenomenal," says Bauer. Likewise, "GPS could be transformative for lunar missions."

Future endeavors could harness GPS to help build out a durable human presence in cislunar space between Earth and the moon. Envisioned enhancements include boosting autonomous spacecraft operation with real-time navigation and precise timing for formation flying, rendezvous and docking, station keeping, and more.

Extending the reach of GPS

For Bauer and others, getting to this point has been a two-decade personal quest.

Developed in the 1970s and then made available for civilian use in the 1980s, the U.S. Air Force-operated GPS constellation service was first demonstrated out to low-Earth orbit in 1982 by the Landsat-4 Earth-imaging satellite.

Bauer and colleagues at NASA's Goddard Space Flight Center in Maryland realized that it might be possible to install GPS equipment on new satellites destined for duty out past the GPS constellation. These beyond-the-constellation GPS receivers would have to capture those spillover signals that spread from each GPS satellite along multiple radio beam pathways, called lobes. The main lobe of a GPS radio signal beam's width forms a V-shape. While most of the main lobe hits Earth as intended, some of that "V" extends beyond the limb, or curve of the planet, and into empty space. Residual signal coming out of the transmitting antenna forms side lobes that pass well clear of Earth. Normally, engineers disregard side lobes as wasted energy. The side lobes are quite weak — only about 3% of the total signal strength, whereas the main lobe constitutes 97%. But so long as there is line of sight to these side lobes, and better yet a bit of spillover from the main lobe, a sufficiently sensitive receiver aboard a spacecraft on the opposite side of Earth from the GPS-transmitting satellite can detect the signal.

The initial big step for proving out this capability came when Bauer and colleagues piggybacked a GPS receiver on a satellite called OSCAR-40, short for the Orbiting Satellite Carrying Amateur Radio. The satellite was launched in 2000 for the Radio Amateur Satellite Corp., or AMSAT, where Bauer continues to serve as the vice president of human spaceflight programs. OSCAR-40 ultimately reached a maximum altitude of about 60,000 km and detected GPS signals at this rarefied height, marking the first-ever demonstration of GPS in this new regime.

The proof of principle was now in place. Next, creating reliable GPS beyond the constellation required the engineers to deal next with weak signals and situations in which few satellites are available. On Earth, receiving signals from three GPS satellites

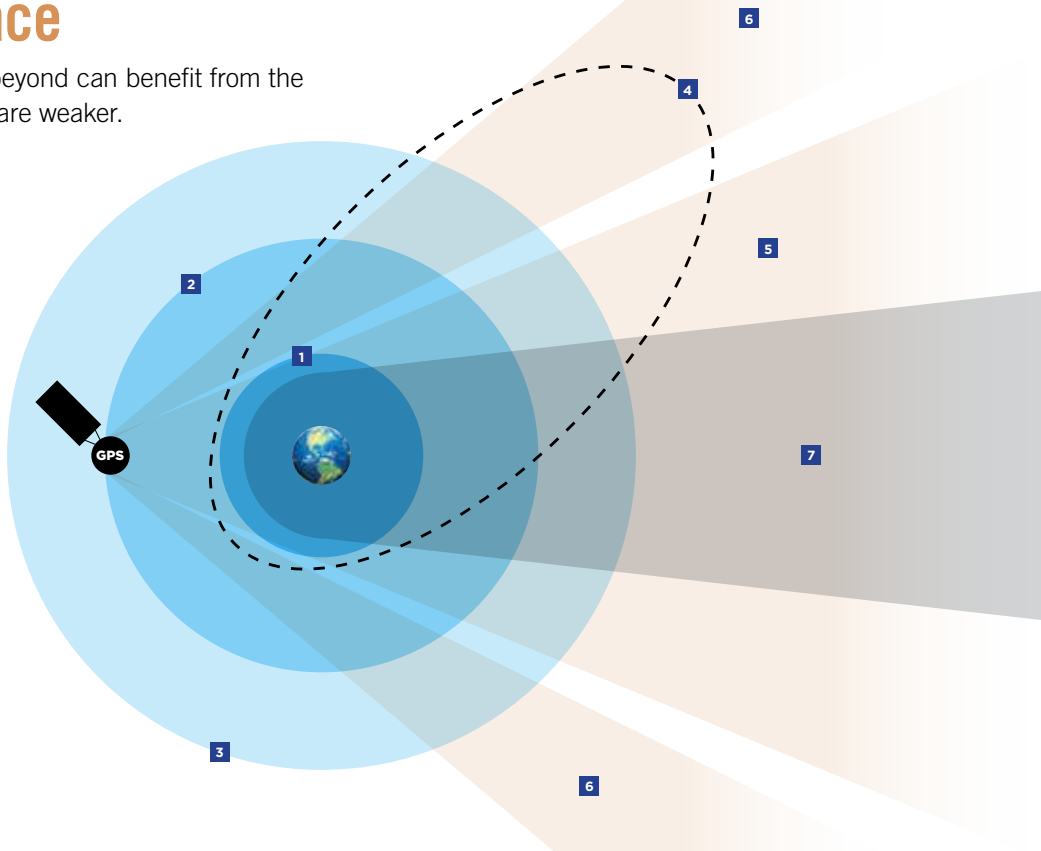
Each of the four identical Magnetospheric Multiscale satellites carries a Navigator GPS Receiver to test GPS signals beyond low-Earth orbit. The satellites are stacked to be inserted in the payload fairing of a United Launch Alliance Atlas V rocket before their launch in 2015.

NASA

GPS for deep space

Spacecraft going to the moon and beyond can benefit from the GPS constellation, although signals are weaker.

Source: NASA



1. Low-Earth orbit
2. Medium-Earth orbit
3. Geosynchronous orbit
4. Highly elliptical orbit: An orbit used for certain science spacecraft, such as the Magnetospheric Multiscale, or MMS, mission.
5. Main lobe coverage: The area covered by the main GPS signal.
6. Side lobe coverage: The coverage area provided by the GPS antenna signals outside the main beam. NASA has shown these weak signals can provide GPS coverage for spacecraft in GEO and beyond.
7. Earth obstruction

Figure not to scale.

produces a rough position, and a fourth delivers accuracy to within meters. Getting out past the GPS constellation, though, satellite availability (through signal line of sight) can be poor because Earth tends to get in the way. So for those times when only a single GPS satellite is in view, the Goddard team developed a software package, dubbed GEONS (GPS-Enhanced On-board Navigation System). GEONS accepts a single GPS signal, combining that information with other onboard sensors, such as the accelerometers and gyroscopes in an inertial navigation system, to arrive at precise time and position solutions.

As for dealing with signal weakness, a terrestrial analog is the all-too-familiar problem of straying too far from a cell tower to maintain a strong connection. "The farther out you go, the poorer reception you have, so you're going to have to augment what the receivers are capable of," says Joel Parker, the positioning navigation and timing policy lead at Goddard, who joined NASA shortly before Bauer's retirement from the agency in 2011 and whom Bauer later mentored for the role. "The real magic of this is to pick up signals that are really weak because of the losses that are inherent to that big of a distance."

A mission selected for development by NASA five years after the OSCAR-40 breakthrough provided the vehicle to test out the GEONS software and the sensitive receivers and at far greater altitudes. The Magnetospheric Multiscale, or MMS, mission called for sending four octagonal satellites into space to measure the transfer of energy between the sun's magnetic field and Earth's for space weather forecasters. The MMS satellites would need to fly in a tight tetrahedral formation to measure the structure of these magnetic fields in three dimensions. GPS or a technology with its capabilities was mission-critical. "You can't do formation flying unless you really know where you are continuously," says Bauer, who had a long-standing interest in formation flying because of the exquisite navigation precision it requires. He and his colleagues quickly became involved in discussions with MMS engineers on the project.

Development work culminated in the Navigator GPS Receiver, which they loaded with the GEONS software and flew on each 3.5-meter-wide MMS satellite when they were launched together in 2015. The receivers proved highly capable, even at apogee on an elliptical orbit extending to 190,000 km, or about halfway to the moon. Today, the MMS spacecraft continue to fly synchronously with just 7.2 km separating them — the closest formation flying for spacecraft ever demonstrated, NASA says. "We've broken world records now with MMS," says Bauer.

Precision through stability

As MMS was going through its early paces in orbit, the GOES-R weather satellite, the first of NOAA's four next-generation Geostationary Operational Environmental Satellites, was launched in November 2016. The satellite (rechristened GOES-16 once aloft) became NOAA's first geosynchronous satellite to be equipped with GPS. The satellite, now in the GOES-East slot for an optimal view of the Atlantic Ocean and Caribbean and Eastern side of the Americas, was built by Lockheed Martin under NASA's management at Goddard.

The GOES program had originally provided funding for the OSCAR-40 experiment, recognizing the potential that GPS could have for precision weather forecasting. Bauer had been involved

here as well, serving as an architect for the control system of the predecessors to the newest satellites.

In February 2019, the similarly equipped GOES-17 was declared operational in the GOES-West slot for a view of the Americas and the Eastern Pacific Ocean. Prior GOES generations had to perform station- keeping maneuvers every few weeks, taking the satellites offline for several hours at a time. Now, both GOES-16 and GOES-17 keep on obtaining multispectral images while performing minuscule thruster burns for station keeping with very minimal downtime.

"GPS navigation helps keep the spacecraft rock steady in terms of where it thinks it is," says Parker.

GOES-16 and 17 keep a constant watch on tropical cyclones and other weather systems as they evolve, ultimately gathering four times the spatial resolution of prior GOES generations. "It's like going from a standard-definition screenshot" with the other satellites "to a full-motion, high-definition movie" with the newest satellites, says Parker.

Bauer says the onboard GPS delivered even better stability than expected. "I would have been happy to get 100-meter performance at GEO," says Bauer, "but what we have is like what you've got on the ground." On Earth's surface, GPS is typically accurate to within 5 meters, indeed matching the low end of one type range error with of the newest satellites.

Surprisingly to those who pioneered the technology, despite the success on GOES-16, GPS utilization remains scant among the several hundred satellites at GEO, says Parker. That said, companies such as Virginia-based General Dynamics (which built GOES-16's receiver) are now offering commercial receivers for this orbital region, having licensed the NASA technology originally developed for Navigator.

James "JJ" Miller, deputy director of policy and strategic communications within the Space Communications and Navigation Program at NASA headquarters, hopes more companies and government program offices choose to adopt GPS beyond the GPS constellation, because better positioning could multiply the number of spacecraft able to safely operate in the increasingly congested GEO — just like how GPS has enabled commercial aircraft to fly closer together.

"If you had every GEO bird in the future equipped with GPS," says Miller, "you could in essence create real estate in the space domain because you could reduce the separation distance between spacecraft."

Realizing lunar GPS

The next step would be to extend GPS where humans haven't trodden in nearly half a century.

In simulations run in 2018, based in large part on MMS and GOES-16 data, Bauer, Parker and colleagues worked out the number of GPS satellites that would be visible in the near-moon environment and what sort of signal strengths could be expected. The upshot: With relatively modest upgrades to existing post-constellation GPS equipment, lunar GPS appears eminently possible.

▲ **GOES-16 is the first** NOAA geostationary satellite equipped for GPS, helping to avoid long periods of for station-keeping maneuvers.

Lockheed Martin

A more powerful receiving antenna will be required, perhaps with about 14 decibels of gain, a measure of the amount of power transmitted in a particular direction compared to an antenna radiating equally in all directions. Another element: including actuators to keep the antenna pointed at Earth to maximize line of sight, because the Earth-orbiting GPS constellation spans less than 10 degrees on the lunar sky. (For comparison, when viewed from Earth's surface, the moon is half a degree in diameter.)

So far, so simple, and based on components already routinely incorporated into spacecraft. "It's not cost-intensive," adds Parker. The one pricey bit of equipment would be including atomic clocks, as are found in GPS satellites, aboard a lunar-bound, GPS-signal-receiving spacecraft. That second clock or clocks would be good for extremely precise timekeeping on the spacecraft's end, which further cuts down on overall error. But the ultraprecise ticks from a single such clock — for instance, if installed on NASA'S proposed lunar Gateway station under NASA's Artemis program — could be disseminated and received by any space vehicles in radio vicinity, Parker says.

Toward these ends is the currently deployed state-of-the-art, deep-space GPS unit, called NavCube, developed by colleagues of Parker's at Goddard. NavCube is a 25-by-20-by-15 centimeter unit that weighs about 5 kilograms and is attached to the exterior of the International Space Station on the P3 truss segment. The device is part of a broader experiment to test out the feasibility of ultra-high-data X-ray communications, which would require precise timing, and is also expanding GPS capabilities in space. Unlike its predecessor, Navigator, flown on MMS, and which only received a single GPS frequency, NavCube receives both L1 and L2 signals, with L2 being a more accurate civil signal now available from 19 of the GPS constellation's satellites.

A demonstration of lunar GPS could come next year, when an uncrewed Orion spacecraft carrying GPS receivers is scheduled to orbit the moon.

Lockheed Martin

(L3 is reserved for transmitting data on detected nuclear explosions, and L4 is not yet in service.) Continuing work on the ground at Goddard is looking into use of L5 signals, which would be twice as powerful and have wider beam width than L1 and L2 signals, and thus would provide increased visibility out at the moon.

Even more help could be on the way. Bauer, Parker, Miller and others are all working through the United Nations International Committee on Global Navigation Satellite Systems to foster interoperability among all six major GNSS, short for Global Navigation Satellite Systems. Besides GPS, the five other constellations are the European Union's Galileo, Russia's GLONASS, China's BeiDou Navigation Satellite System, India's NavIC and Japan's Quasi-Zenith Satellite System. Adding in those constellations would triple the number of available satellites from the U.S. fleet of 27 (plus four on-orbit spares) to circa 100.

If it were possible to collect everyone's GNSS signals, Bauer says accuracy at the moon would be on the order of 1 km — certainly useful. But if atomic-clock precision were incorporated into the lunar-bound spacecraft, or fed to it by the Gateway, for instance, the accuracy could improve to more like 100 meters. That accuracy should be sufficient to enable efficient, autonomous navigation through cislunar space toward the Gateway — the driver, the iron and the chip shot. The short putt or docking would then be handled by conventional means of radar, lidar and cameras. Excursions to the lunar surface could likewise count on GPS for most of the descent. "You probably switch from using GPS almost exclusively to lidar and then visual sensors to make sure you don't hit any boulders or whatever as you come in for landing," says Bauer.

Getting your bearings, at terra and luna

The first full demonstration of lunar GPS could come as soon as mid- to late 2021, when a Space Launch System rocket lifts off from Florida carrying an uncrewed Orion crew capsule on the Artemis-1 mission. Orion will orbit the moon for several days, capping a three-week deep-space jaunt. Orion will keep its GPS receivers on during both the outbound and inbound legs in order to characterize how much useful GPS signal is available.

For researchers who have long wanted precision positioning in deep space, being able to take the existing system with us, so to speak, versus having to construct a new system, would be welcome news. "Ten years ago, people talked about building another GPS constellation around the moon," says Parker, the policy lead at Goddard. "Now we know we can use what already exists."

Still, that build-out possibility has not been abandoned, given the expected limited precision of relying on GPS spillover from Earth, and in light of the advent of small satellites. One NASA concept, dubbed LunaNet, would consist of small sats that would augment terrestrial position and timing, while also routing communications among astronauts, explorers, astrophysicists or prospectors.

The more data brought to bear for position, velocity and time, the better, says Bauer. "Even ancient navigators fused navigation sensor data," he says, "using a compass, chronometer and a sextant or the stars and sun to navigate the oceans."

If the most ambitious plans for lunar activity next decade come to fruition, cislunar space could become just the latest ocean for our species to traverse. "We want to establish a sustainable human presence at the moon," says NASA's Miller. "There's a lot of things we could do there in our lifetimes." ★

ACTION

With taxpayer dollars, their own reserves and some nudging from Congress, airlines in the U.S. are planning an ambitious comeback for when the coronavirus pandemic subsides and travelers begin looking to the skies again. Cat Hofacker explains.

BY CAT HOFACKER | catherineh@aiaa.org


PLANS

Under the Arizona sun, hundreds of aircraft sit in orderly rows, awaiting their return to the sky. Until coronavirus travel restrictions and social distancing guidelines are lifted, the only visitors these planes will see are the mechanics who stop by weekly or monthly to check tire pressures and change out the mylar coverings shielding the aircraft from sun and dust.

As I write this in mid-April, 2,820 passenger aircraft were confined to open lots like this one and empty taxiways at U.S. airports, a figure that amounts to 46% of the planes flown by domestic airlines, according to a count taken by the lobbying group Airlines for America.

In happier times, those aircraft would be part of an industry that directly and indirectly generates nearly 4% of the U.S. gross domestic product. Getting back in the air is not just about getting travelers from here to there; having so much of the fleet grounded has begun reverberating through the supply chain, including among aviation research and development projects.

Thousands of planes are idle, but the leaders of the air transport industry and U.S. lawmakers are anything but. Steps are being taken on the financial, workforce and technical fronts to position airlines for their best shot at surviving the expected long slog back as the coronavirus recedes and travelers begin thinking about flying again.

At this writing, June could mark the downward turn in daily deaths across the U.S., according to the University of Washington model shown at the televised White House briefings. But, from listening to pandemic experts, I know that more cycles could lie ahead and that when you read this in May, the projections could look better or worse because they depend on human behavior.

Once state governors lift their stay-at-home orders or other restrictions, the question becomes how fast consumers will return to the air.

"The flying public isn't just going to go run into a crowded airport and jump on a crowded plane right away," predicts Brian Foley, founder of the aerospace consultancy Brian Foley Associates in New Jersey. "It's going to have to be a relearned behavior where it's OK after being told to hide in your house for weeks on end."

The following account is based on interviews with analysts, a legislator and technical experts, and reviews of video presentations, letters and memos released by airline executives. American Airlines, Delta Air Lines, Emirates, Southwest Airlines and United Airlines — the top carriers in terms of kilometers traveled by paying passengers in 2018 — each declined to make executives available for interviews, telling me that the situation is just too fluid to comment.

Parking passenger planes

The growing volume of planes in storage, and the length of time they may need to be stored, is unprecedented. The good news is that even before the virus, a handful of maintenance, repair and overhaul companies had honed a specialty in storing passenger jets in such a way as to avoid exterior corrosion, sun damage and the caustic effects of fuels. One of them is Ascent Aviation Services, based at Pinal Airpark near Tucson, Arizona. In normal circumstances, Ascent would host perhaps a few dozen aircraft awaiting maintenance or retirement, when valuable parts must be kept ready for stripping. As I write this, there are 240 aircraft on Ascent's 500-acre lot, which is headed toward full capacity of 400 planes probably by mid-June.

"We're adding aircraft every day pretty much," says Scott Butler, chief commercial officer of Ascent.

At Pinal, some planes linger in active parking, where mechanics keep aircraft "a day away from flight readiness" by firing up the engines and rotating the tires regularly, Butler says. Other aircraft sit in short-term or long-term storage, where mechanics disconnect and preserve engines and other major systems so planes can linger for months or, if necessary, for years with little upkeep. Flight manuals supplied by Airbus, Boeing and other manufacturers define the specific steps mechanics must take.

The low humidity in Arizona guards against external corrosion compared to, for instance, Pittsburgh International Airport, where American Airlines has parked some planes. There is a tradeoff, though, for the dryness of Arizona. The accompanying high temperatures would wreak havoc on computers and electronics, so Ascent mechanics stretch sheets of mylar across all windows, sensors, engines and external ports to reflect sunlight and keep out dust. Tires and other rubber parts are likewise covered.

"Anything you would think that's moving or going to move has to be greased, and anything that's sitting, you want to make sure it's protected as well as it can be," Butler explains.

For active parking, mechanics must visit aircraft weekly, rotating tires to prevent flat spots and powering up engines to vaporize any moisture that might have collected. That's unnecessary for short-term and long-term storage, because the engines and fuel lines must be drained and then filled with a non-caustic preservation oil. From there, mechanics visit these planes monthly to check tire pressure, recirculate the oil inside the engines, and open cockpit and cabin doors to circulate air and cool the interior.

Aircraft at Pinal or elsewhere can linger in short-

term storage for up to a year, a comfortable margin given the uncertainty about when coronavirus-related travel restrictions will end. But some planes moved to storage because of the virus will never fly again. American Airlines said in March it would retire its remaining Boeing 767s by mid-May, ahead of the original 2021 end-of-service date, as well as its Boeing 757 fleet in 2021 instead of in 2025.

For those planes and others that will sit idle for longer than a year, mechanics take additional steps to "pickle or preserve the major systems," Butler says. That includes disconnecting electronics and removing batteries. These planes also receive monthly inspections, along with more in-depth checkups about four times a year.

It's a process playing out at numerous locations around the world, and analysts and storage companies are unsure whether there will be enough room. As of mid-April, airlines worldwide had grounded about 17,000 aircraft, which amounts to two-thirds of the global fleet, according to Cirium, the London-based aviation data and news service. Compounding the space crunch are the hundreds of Boeing 737 MAX, grounded since March 2019 after the two deadly crashes that killed 346 people. About 70 MAX jets from the American, United and Southwest fleets are parked at various U.S. airports awaiting recertification by FAA, and Boeing is storing about 400 new planes in Washington and Texas, pending delivery to dozens of airlines.

Betting on bailouts

Storing a plane is vastly cheaper than flying one with a handful of passengers, but the fee of $2,000 to $5,000 per month, depending on the aircraft size, adds up quickly. Plus, airlines in the U.S. continue to fly some routes under the terms of the U.S. coronavirus bailout, which means they must pay for the people and apparatus surrounding that. Those are steep costs to ferry what Airlines for America says is

▼ **Delta Air Lines jets** parked in the desert at Victorville Southern California Logistics Airport as the airline awaits the reopening of U.S. airports to nonessential travel.

Ron Reiring/Flickr

▲ **A handful of** passengers wait for takeoff on a Delta Air Lines flight from Atlanta to Melbourne, Fla.

an average of 10 passengers per flight.

For the airlines, maintaining cash flow has become the highest short-term priority.

"If we don't have cash, we stop operating and nobody has any opportunity to come back and fight another day," Southwest Airlines CEO Gary Kelly told employees in an April Q&A, according to a video.

The Geneva-based International Air Transport Association estimates that the global air transport industry is on track to lose $314 billion in revenue this year, a loss that would equal 55% of the total revenue in 2019. Airlines are reacting by cutting flights, deferring maintenance when safety permits and encouraging employees to take voluntary leaves of absence. But these cost-cutting measures can't go too far, lest airlines undermine the very processes and workforce they'll need once the virus subsides and demand returns.

To help the passenger airlines get ready, the U.S. in March created a $50 billion cash-flow bridge for them (plus $8 billion for cargo carriers), but it is not easy money. Creating this portion of the $2.2 trillion Coronavirus Aid, Relief and Economic Security, or CARES Act, was colored by long memories of airline actions in the aftermath of the Sept. 11, 2001, terrorist attacks.

After the attacks, it took three years for passenger numbers to completely recover, according to the Bureau of Transportation Statistics. In the meantime, United Airlines accepted $774 million in grant money and then declared bankruptcy in December 2002. U.S. Airways accepted $331 million and declared bankruptcy in August 2002. American Airlines did not declare bankruptcy but laid off tens of thousands of workers after receiving $694 million in grant money.

The bankruptcies were "egregious," Rep. Peter DeFazio, D-Ore., who was in Congress at that time, told me in an April interview. "They got assistance, and then when they burned through the assistance, the airlines declared bankruptcy, took away their workers' pensions, busted the unions," he said. "So I said, 'not going to happen that way this time.'"

So for the CARES Act, DeFazio and House Democrats insisted that $25 billion of the airline funds be doled out in grants specifically to pay the salaries and benefits of pilots, flight attendants and other workers. Airlines are also prohibited from laying off

> **"Anything you would think that's moving or going to move has to be greased, and anything that's sitting, you want to make sure it's protected as well as it can be."**
>
> **— Scott Butler,** Ascent Aviation Services, explaining how to prepare an aircraft for storage

SPACE CRUNCH

Airlines around the world were continuing to ground passenger planes in April, and storage companies were fast running out of room. All told, 17,000* planes were grounded due to the pandemic, 2,820* of them belonging to U.S.-based airlines. The previous grounding of the Boeing 737 MAX has exacerbated the crunch. Here's where the world's top five airlines (by kilometers traveled by paying customers) are storing their planes.

*Tally as of April 20; does not include the already-grounded Boeing 737 MAX jets or aircraft awaiting delivery.

Airline	How much of the fleet is grounded?**	Storage sites
American Airlines Source: American Airlines	450 of 950	• Tulsa International Airport, Okla. (includes 16 Boeing 737 MAX jets) • Pittsburgh International Airport • Roswell International Air Center, N.M. (includes 8 Boeing 737 MAX) • Mobile Downtown Airport, Ala. • Piedmont Triad International Airport, N.C. • San Antonio International Airport
Delta Air Lines Source: number of aircraft via Delta Airlines; locations via Planet and ICEYE satellite imagery	600 of 900	• Hartsfield-Jackson Atlanta International Airport • Pinal Airpark, Ariz. • Victorville, Calif. • Pittsburgh International Airport • Birmingham-Shuttleworth International Airport, Ala.
United Airlines Source: United Airlines	Declined to say how many of its 800	• Orlando International Airport, Fla. • Cleveland Hopkins International Airport • Phoenix Goodyear Airport (includes 14 Boeing 737 MAX) • Roswell International Air Center, N.M.
Emirates Source: Emirates	270 of 270 (does not include flights returning residents to United Arab Emirates and visitors to their home countries)	Declined to say where they are stored.
Southwest Airlines Source: Southwest Airlines	Declined to say how many of its 750	• Victorville, Calif. • Paine Field, Wash. • Indianapolis • Southern California Logistics Airport (34 Boeing 737 MAX)

**Counts are approximate

Source: Cirium, Airlines for America

▲ **A member of Hawaii's** National Guard takes the temperature of a passenger leaving Daniel K. Inouye International Airport in Honolulu. Soldiers are helping airport personnel with screening all travelers arriving and departing.

U.S. Army National Guard/ Sgt. John Schoebel

workers until October. The other $25 billion is loans that airlines can spend on storing or maintaining their planes. These U.S. taxpayer dollars must be paid back to the Treasury Department with interest; expressly forbidden are stock buybacks to buoy value, dividends and executive bonuses.

The reactions to such strings have been mixed among airline executives and analysts. In one view, they amount to tough love to ensure that the airlines have the tools to get enough aircraft back in the air.

Analyst Foley says the conditions of the aid are not ideal, "but there is really no other choice" if the airlines are to avoid bankruptcy and be ready to fly once travel demand increases. "We need a national air system and having these airplanes on the ground for any length of time won't serve anyone's interest."

Aviation consultant Mike Boyd of Boyd Group International in Colorado says the government's conditions get to "the need to have the airlines alive and ready to go" once the pandemic passes while also ensuring taxpayer money isn't wasted.

American Airlines CEO Doug Parker greeted customers and employees with a smile hours after President Donald Trump signed the CARES Act: "The question I keep hearing from our team is, 'are we going to be OK?'" he said in a video message. "I'm happy to report the answer to that question is yes."

Delta Air Lines CEO Ed Bastian was less enthusiastic in an April memo issued a week after the bill's passage, writing that Delta's portion of the payroll grants "are not nearly enough" to cover costs.

Nevertheless, Delta and nine other airlines — including American, Southwest and United — agreed on terms with the Treasury Department three weeks after the CARES Act passed. Airlines receiving more than $100 million in payroll assistance must now pay back 30% of the money, no longer purely grants, and offer the U.S. government shares at a reduced price.

As of April, the Treasury Department was still negotiating with airlines on the terms of the $25 billion in loans, but ownership shares are on the table in exchange for those as well.

The $25 billion payroll assistance frees up much-needed cash for other expenses, Foley says. It also helps with a speedy return to service by eliminating the time it would take to retrain and rehire workers. However, the grants run out after Sept. 30, following which nothing would prevent airlines from laying off pilots, flight attendants and technicians if money is still tight.

"I'm not convinced by Sept. 30 we'll be back to where we were as far as previous staffing levels," Foley says.

United is one of the airlines already thinking along those lines. In a memo sent out the day the CARES Act passed, President Scott Kirby and CEO Oscar Muntz wrote that despite the aid, future layoffs are a possibility if travel demand remains "suppressed for months" as expected.

"The flying public isn't just going to go run into a crowded airport and jump on a crowded plane right away. It's going to have to be a relearned behavior where it's OK after being told to hide in your house for weeks on end."

— Brian Foley, Brian Foley Associates

"If the recovery is as slow as we fear, it means our airline and our workforce will have to be smaller than it is today," the memo reads.

JetBlue Airways CEO Robin Hayes, in a letter to employees, voiced another concern after the payroll assistance was finalized: The cash that's buying "some breathing room" today means more debt to contend with tomorrow.

"Thankfully, we entered this crisis with one of the stronger balance sheets in the industry," Hayes wrote, "but we will come out of this with significant debt to pay down."

Adjusting to the new normal

Airlines could be facing two to three years before air travel approaches the record-setting year of 2019, said John Grant, senior analyst at aviation data firm OAG, in an April webinar on the impact of the coronavirus. In 2019, according to the Bureau of Transportation Statistics, 1 billion passengers flew to, from or within the U.S., which was an "all-time high."

As to when airlines will start adding flights back into their schedules, Grant said, "it is unlikely that we are going to see anything like a recovery back to January 2020-type capacity before this time next year at the earliest."

Foley says the next likely development will be decisions by airlines to defer deliveries of new aircraft "just to try to preserve some capital." He expects airlines to slowly bring their existing aircraft out of storage as travel demand increases, but that has its own challenges. The longer an aircraft has been grounded, the longer it takes mechanics at storage facilities like Ascent Aviation Services to restore it to flight readiness.

"If it's coming from a short-term or an active parking, it's not as tedious because you haven't taken as many things offline," Butler of Ascent says, but lingering social distancing guidelines could play a role here as well.

A team of 10 mechanics would usually spend about a week bringing a wide-body aircraft out of storage: removing the mylar coverings, draining the preservation oil and refueling the tanks, reconnecting the electrical systems and so on. This process could stretch on if mechanics have to stay 2 meters apart, especially if the aircraft requires more extensive maintenance to get it ready to fly again.

And once planes do return to flight, what might air travel post-coronavirus look like? Steps taken during the pandemic offer some clues. Through May, Delta Air Lines will leave the middle seat of each row open and have passengers board 10 at a time to prevent crowding. Emirates in the United Arab Emirates tested passengers before they boarded an April flight to Tunisia for the virus via a blood test that shows results within 10 minutes.

Similar measures are likely to continue as travel demand picks back up, predicts analyst Boyd. While he's skeptical that leaving the middle seat open is an effective way of separating passengers, blood tests are something "that can be done very quickly and will have to be done."

But even when demand for air travel does pick up, restoring profits will take priority over propulsion and other technological advancements, predicts Richard Aboulafia, analyst with the Teal Group of Virginia.

He expects the first to go will be engineering and design budgets for "advanced new product development" such as hybrid-electric aircraft and sustainable aviation fuels. "You can safely add three to five years for just about anything that's in the pipeline," he says, more if recovery is slow.

Foley says that also goes for future purchases of in-development aircraft like the Airbus A321XLR, scheduled to debut in 2024 with 30% less fuel burn per seat compared to the Boeing 757. If travel demand does not reach 2019 levels until the mid-2020s, airlines could be relying on their older, less-fuel efficient aircraft for years to come. Manufacturers are adjusting accordingly; Airbus said in April it will cut production of wide-body aircraft by 40%, making only six A350s and two A330s per month.

It's a bleak state of affairs, but OAG's Grant sees a small ray of sunshine. In the April webinar, he pointed to Chinese airlines, which since early March have begun adding back millions of seats on flights within the country to their schedules, according to OAG data.

Foley says a longer view of history also shows reason for optimism. The scale of the impact from the coronavirus pandemic exceeds anything the industry has experienced before, but the airlines have so far survived every tragedy they've encountered.

"People said after 9/11, 'the industry will never be the same; it'll never recover,' and it certainly did," he says. "This industry will recover again." ★

SPACE TRAFFIC IMPASSE

Europe and Japan are leading the way toward cleaning Earth orbit of debris; satellite operators around the world must be ready to dodge debris and each other. It's a chaotic situation that, to some, feels like an abdication of the U.S. government's traditional leadership role in matters of space at a time when it's never been more needed. Debra Werner examines the arguments and a potential solution.

BY DEBRA WERNER | werner.debra@gmail.com

Two satellites abandoned in orbit decades ago by NASA and the U.S. Air Force hurtled toward each other in January at a closing speed of 14.7 kilometers per second or 10 times faster than a bullet from an M16 rifle. A collision could have flung 12,000 satellite fragments into rings of debris along the orbital path of each satellite.

Luckily, the possible conjunction turned out to be just a close call, but those with stakes in space know that the next big collision is coming and that it could be more catastrophic than anything to date. "The question is not if, it's only when," says Darren McKnight, who tracks space debris and spacecraft anomalies as a technical director for Centauri Group, an engineering and technology company based in Chantilly, Virginia.

For the moment, there's not much anyone can do about abandoned satellites or rocket upper stages headed for a dead-on-dead collision except warn nearby satellites to move out of harm's way. In Asia and Europe, companies backed by space agencies are designing orbiting tow trucks to haul old satellites and rockets back into the atmosphere.

Such backing is not happening in the United States, where the Trump administration's plan to put the Commerce Department in charge of space traffic management remains stalled without adequate funding and authority from Congress. Today, no one in the U.S. government has the job of advocating for expenditures on such future activities as clearing debris from crowded orbits.

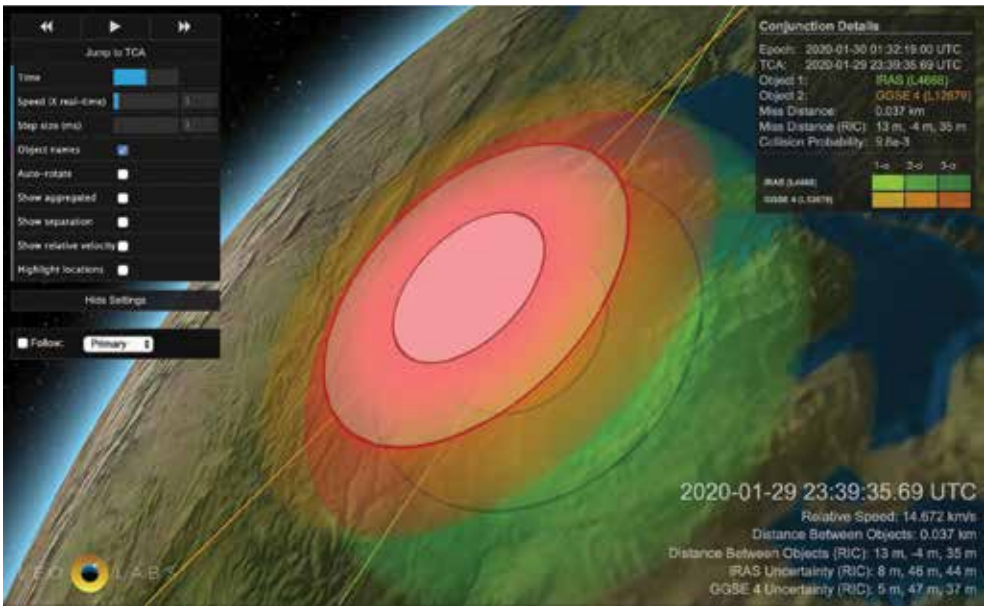
Even worse, in this view, the impasse persists despite the fact that U.S. companies are starting to launch the first satellites in what would be a massive wave of tens of thousands of new satellites destined for low-Earth orbit if today's bold business plans hold together. Those spacecraft would join 2,300 functioning satellites, not to mention 900,000 pieces of debris ranging in size from cornflakes to 8-metric-ton rocket bodies.

Owners and operators of satellites are doing their best to avoid calamity with a combination of collision warnings from the U.S. government and a growing array of privately run radars and services. U.S. leadership on the international stage through creation of a space traffic management agency will be essential, they say, if the United States is to meet its international treaty obligations and manage increasingly congested orbits.

"U.S. space situational awareness and space traffic management services are failing to address

▼ **LeoLabs says its** Kiwi phased-array radars in New Zealand are sensitive to small, previously untracked space debris.

LeoLabs



global needs," says Dan Oltrogge, director of the Center for Space Standards and Innovation at Analytical Graphics Inc., the Pennsylvania company that makes software for tracking satellites and visualizing the orbital environment. "Lack of a cohesive, properly resourced U.S. space traffic management program places the U.S. at risk of losing this vital initiative."

The handoff

Advocates of a space traffic agency have endured years of frustration waiting for Congress and the executive branch to agree. The Trump administration, like the Obama administration before it, has called for the Defense Department to continue identifying and tracking objects in orbit but to assign another agency — an office of the Commerce Department in Trump's plan — the responsibility to warn satellite operators in the U.S. and abroad about potential collisions. The Obama administration tried to hand off the work to FAA's Commercial Space Transportation Office.

Trump's Space Policy Directive 3 in 2018 also instructed the Commerce Department to work with NASA, NOAA and other federal agencies to develop standards and protocols to make it easier to merge radar and telescope observations.

Since the directive was issued, Commerce and Defense Department managers have been preparing for the transition. A Commerce Department liaison official works at the Combined Space Operations Center, or CSpOC, and the U.S. Space Force's 18th Space Control Squadron, co-located at Vandenberg Air Force Base in California, where personnel from the U.S. military services and industry monitor large screens to identify objects in orbit, chart orbital paths and notify satellite operators of conjunctions. The military operation, originally focused on space surveillance and missile warning, took on the job of spotting conjunctions for most active satellites after Russia's defunct Cosmos communications crashed into an Iridium telecommunications satellite in 2009, sending at least a thousand of pieces of debris into orbit.

▲ **This screenshot** shows the LeoLabs' Conjunctions Dashboard predicting that NASA's Infrared Astronomical Satellite (the green line) and the U.S. Air Force's Gravity Gradient Stabilization Experiment satellite (orange line) were at risk of colliding in January. The orange ellipse showed the covariance, or area of uncertainty, where the Air Force satellite might pass, and the green tones showed the covariance of the NASA satellite. The overlap, the pinkish red ellipse, indicated the possibility of a collision that thankfully did not occur.

Leo Labs

The Commerce Department-CSpOC liaison is learning how the military spots conjunctions and notifies commercial and international satellite operators. Commerce Department personnel also are participating "in exercises, simulations and war games" to better understand how CSpOC pulls in data from government and commercial space telescopes and radars, a Commerce Department spokeswoman said by email.

Before the Commerce Department can take over collision warnings, though, it needs congressional authority to collect and share space situational awareness data, information on objects and activities in orbit. Plus, the Commerce Department will need immunity from lawsuits and funding to expand its staff, says George Nield, former FAA associate administrator for commercial space transportation and an AIAA fellow.

So far, Congress has not provided any of that. The Trump administration requested $10 million in 2020 funding, an increase of $6 million, to merge the Commerce Department's Office of Space Commerce with NOAA's Commercial Remote Sensing Office and give the Office of Space Commerce the additional responsibility of managing space traffic.

Congress did not approve the merger or provide additional funding in the Commerce, Justice, Science and Related Agencies Appropriations Act of 2020. Instead, appropriators gave the Office of Space Commerce and the NOAA Commercial

Remote Sensing office the same funding they received in 2019: $1.8 million each. Congress did give the Commerce Department $500,000 to hire the National Academy of Public Administration, a Washington nonprofit group, to perform a six-month study on how the government should organize, fund and regulate civil space traffic management work.

Some in Congress have expressed concern about giving regulatory oversight to the Office of Space Commerce, an organization focused on economic growth without expertise in space operations, safety or regulation. Other lawmakers say they haven't made up their minds which federal agency should take on space traffic management.

The study is scheduled to be completed in September. Meanwhile, the Trump administration asked Congress for $15 million in its 2021 budget request to hire more staff for the Office of Space Commerce and to work with industry to establish an open architecture data repository. The idea is to create a computer network for space traffic management that draws on government, university and commercial observation of objects in orbit and pairs them with algorithms designed to pinpoint the location of satellites, rockets and debris and to figure out their orbital paths and conjunction risks.

"One of the biggest hurdles in making space transparent and predictable is sharing of observational data," says Moriba Jah, University of Texas, Austin, associate professor of aerospace engineering and engineering mechanics. "We don't do that very well," adds Jah, an AIAA fellow who is helping to plan ASCEND, AIAA's space conference.

Advocates want the Commerce Department to combine observations from the U.S. military's space surveillance network with observations of objects in space made by commercially owned sensors.

"Bringing together the operators' data and observations of their own spacecraft with observation from telescopes and radar, that's the holy grail," says Oltrogge of AGI.

"Bringing together the operators' data and observations of their own spacecraft with observation from telescopes and radar, that's the holy grail."

— **Dan Oltrogge**, Analytical Graphics Inc.

Private sector warnings

While the Trump administration and Congress engage in a tug of war over space traffic management oversight, the private sector is increasingly warning satellite operators when and how to maneuver to avoid accidents.

LeoLabs, a Silicon Valley startup, was the first to spot the potential collision of the old satellites in January and to share the news on Twitter. The company operates phased-array radars in Texas, Alaska and New Zealand. Its Kiwi Space Radar built in 2019 on New Zealand's South Island consists of flat transmit-and-receive panels spanning 1,000 square meters, an area twice the size of a basketball court. The radar continuously emits radio wave pulses and listens for the faint echo of waves bouncing off objects.

These radars feed data into a cloud-based network where software automatically detects the location and direction of anything in orbit softball-size or larger once or twice a day. Within the network, algorithms identify satellites and debris at risk of colliding in the next seven days. LeoLabs allots additional radar time to the objects at risk of collision, observing each one as many as six times a day to further pinpoint its location and orbit.

Another commercial firm heavily involved in space traffic safety is Peraton, the government contractor formed in 2017 from the assets of Harris Corp.'s Government Services business in Herndon, Virginia. NOAA, the Space Force and other government agencies track approximately 300 satellites with the help of Peraton's OS/Comet software, a tool that helps satellite operators decide when to move their spacecraft to avoid potential collisions and how to ensure maneuvers don't put one satellite on a collision course with another.

Even during the coronavirus pandemic, Peraton employees are taking social distancing measures while continuing to work alongside personnel from the Defense Department, National Reconnaissance Agency and NASA in mission control centers, says Dean Bellamy, Peraton space strategies senior director and a retired U.S. Air Force colonel.

Before LeoLabs and Peraton got into the business, the world's largest satellite operators formed the Space Data Association, a nonprofit based on the Isle of Man between England and Ireland to share satellite information. SDA was coincidentally formed in 2009, the same year as the Iridium-Cosmos crash. SDA members predict the future positions of their spacecraft and feed the information along with any

planned maneuvers into the group's database operated by AGI. AGI forwards the information to the 18th Space Control Squadron.

"We realized that we had the best information about our own assets," says Mark Dickinson, SDA chairman and operations vice president for Inmarsat, the London-based telecommunications satellite fleet operator. SDA's corporate and government members, including NOAA, NASA and European meteorological satellite operator Eumetsat, control 52% of the working satellites in geostationary orbit and 32% of the working satellites in low- and medium-Earth orbit.

Operators also often track their own satellites in low-Earth orbit with GPS receivers. **[Related story, Page 18.]** Planet, the San Francisco Earth-imaging company, also mounts a low-power ultra-high-frequency radio on the 140 shoebox-size satellites in its fleet. The radios act as transponders, revealing each cubesat's position **[Related story, Page 14.]** and the direction it's pointed, said Robbie Schingler, Planet chief strategy officer, speaking at the Satellite 2020 conference in Washington, D.C., in March.

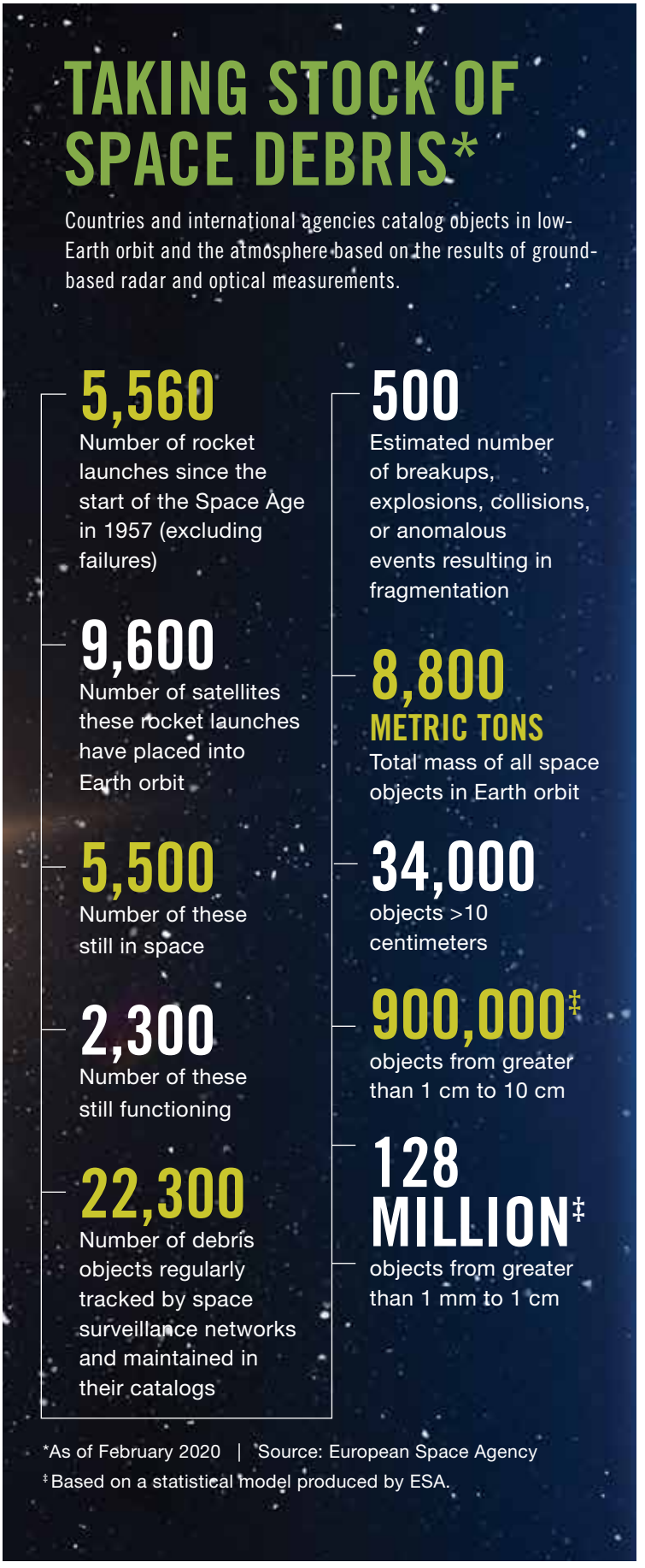
In geostationary orbit, satellite operators often rely on techniques like ranging, or finding the location of an object by measuring the time it takes for light or radio waves to reach it and travel back. For help analyzing conjunctions and planning maneuvers, they also turn to companies like AGI.

AGI software merges satellite operator ranging measurements with observations from commercial radars and telescopes around the world to better predict where spacecraft will be when, their ephemerides. For SDA, analysts track space objects on large screens and analyze collision risks in the firm's Commercial Space Operations Center at AGI's Pennsylvania headquarters. The Space Data Center compares the ephemerides of all SDA member satellites against everything else in the Space Force's public catalog.

While these commercial products and services help the individual satellite operators who pay for them, experts say a more comprehensive space traffic management system is needed.

"As we get thousands more objects in space, we have to focus on improving positional knowledge so we can reduce false alarms," says AGI's Oltrogge, who is also the program manager for the Space Data Center, the Space Data Association's cloud-based computing environment, designed and operated by AGI.

Some want a space traffic management network that expands on the Space Data Association's model of operators sharing what they know about the locations of their own spacecraft. This would require merging data from government and commercial satellite operators with observations from ground-based and satellite telescopes and radars around the world. To determine a single satellite's precise orbit requires multiple sightings, preferably by different radars and telescopes.



▲ **Large screens and** computers dominate the room at the Combined Space Operations Center at Vandenberg Air Force Base, Calif., where military personnel and contractors watch for conjunctions of satellites.

U.S. Air Force video

Even then, a satellite maneuver, change in solar radiation or increase in drag caused by unfolding solar panels can throw off calculations.

"The only way to get good data is to have operators tell me where they are," says Dickinson, the SDA chairman.

Operators often have the best information on their own satellites, but they still don't know the precise location. They narrow it down to an elliptical area called a covariance. The size of the covariance depends on many factors like when and how the object was last detected. News that two satellites are on a collision course really means that the covariances will overlap.

The size of the covariances matter for figuring out the likelihood of a collision. False alarms cause satellite operators to maneuver and burn fuel unnecessarily. "One of the biggest complaints of satellite operators is they don't know how good the data is," says Dan Ceperley, LeoLabs co-founder and CEO.

As for the scope of the traffic challenge, the wild card is whether many thousands of new satellites will indeed be launched.

SpaceX is launching 60 satellites at a time into its Starlink global broadband constellation, which could include as many as 42,000 satellites, according to paperwork filed with the International Telecommunications Union, the United Nations agency in Geneva that assigns satellite communications frequencies and orbital slots.

Competitor OneWeb, meanwhile, sent 72 satellites into its constellation before requesting Chapter 11 bankruptcy court protection in March after its primary backer Japanese conglomerate Softbank declined to invest more money in the London-based startup. And Amazon has filed paperwork to operate as many as 3,236 satellites in a constellation called Kuiper.

Flood of conjunction warnings

More satellites in orbit means more potential collisions with other satellites and debris. Today, a typical satellite owner and operator might receive a couple of conjunction warning messages every few days. "In the future, that's going to increase by at least a factor of 10," says Andrew Abraham, an engineering manager at the Center for Orbital and Reentry Debris Studies at the Aerospace Corp., a federally funded research company in Los Angeles.

The Aerospace Corp. hopes to reduce the frequency of conjunction warnings by helping satellite operators and regulators better pinpoint the location of spacecraft. The Aerospace Corp. plans to flight test a prototype transponder next year, one roughly the size of a deck of cards. The device would broadcast the identify of its host satellite and precise orbital

location. The goal is to create a digital license plate so the satellite isn't simply "a blob on a radar screen," says Abraham.

The start of daily operations in March of the Space Fence, a radar with a basketball-court-size receiver array and a tennis-court-size transmitter array on Kwajalein Atoll, one of the Marshall Islands, has added to concerns that the floodgates of conjunction warnings are about to open. Built by Lockheed Martin and operated by the Space Force, the Space Fence's S-band radar could detect 10 times as many objects in low-Earth orbit as the other radars and telescopes around the world that make up the U.S. military's Space Surveillance Network.

Government and industry managers also take different views of transparency in terms of information sharing. Because national security, not transparency, is the Space Force's main objective, it doesn't reveal the size of satellite covariances or specific observations that prompt conjunction alerts. Without that information, satellite operators have trouble determining whether they need to maneuver and if so, how far.

By contrast, the private sector embraces transparency. When AGI warns operators of potential collisions, it points to extensive data behind its conclusions, including observations of commercial radars and telescopes to supplement the Space Force catalog of expected orbits for satellites and baseball-sized debris or larger.

Similarly, LeoLabs offers customers access to a computer dashboard with multiple daily updates. For the near miss in January, LeoLabs' dashboard displayed about a one in 100 chance of collision. The dashboard also revealed how radar updates in the days leading up to the close approach highlighted the risk of a collision.

No space agency or company as yet knows how to avert a dead-on-dead collision of large satellites or debris, but startups Astroscale of Tokyo and ClearSpace of Switzerland are building satellites and robotic arms that with adequate lead time might do so. With funding from the European Space Agency, ClearSpace leads a consortium of European companies preparing to catch and drag into the atmosphere a 100-kilogram Vespa rocket payload adapter. Astroscale, meanwhile, has funding from JAXA, the Japan Aerospace Exploration Agency, to inspect a discarded Japanese rocket upper stage as a precursor to a future debris-removal mission.

"Where is the United States government in this? Nowhere because that's nobody's job," says Nield, the former FAA official. "Nobody is responsible for looking at that. That's why you need a lead agency." ★

In his words: Don Kessler on orbital debris and pandemics

BY DON KESSLER

The math underlying the predictions in a pandemic and what is known as the Kessler Syndrome can be expressed with similar equations. In each situation, the prediction depends on the frequency that some "Object" encounters a "Victim." In a pandemic, the Object is a virus and the Victim is a person. In Earth orbit, the Object is a large piece of debris and the Victim is a structure or another large item of debris. The frequency with which an Object hits a Victim is proportional to their speed relative to each another. If that were the only factor, then we would see a slow, linear increase in Victims with time.

However, in each case, an Object that hits a Victim creates more Objects, each creating even more Victims, i.e., a cascading. This results in an exponential increase in Victims with time — with much greater speed in a pandemic than in orbit, of course — and will continue until there are no longer any operational satellites in orbit or vulnerable people in a pandemic.

That's the simple answer — the math is the same. The uncertainty in the equations is "Frequency." In a pandemic, how quickly the virus transfers itself from an Object is determined by biology and by human behavior.

Thirty years ago, NASA formulated mitigation guidelines for orbital debris that have been adopted internationally. Other countries made the guidelines mandatory, but NASA's implementation has lagged. As a result, these measures have failed to adequately slow the growth in the debris population. The same results can be expected if the virus mitigations are not followed. ★

Don Kessler established NASA's Orbital Debris Program Office in 1979 and continued researching the topic until his retirement in 1996. His calculations showing that cascading collisions could someday render entire orbits useless became known as the Kessler Syndrome. He now lives in North Carolina.

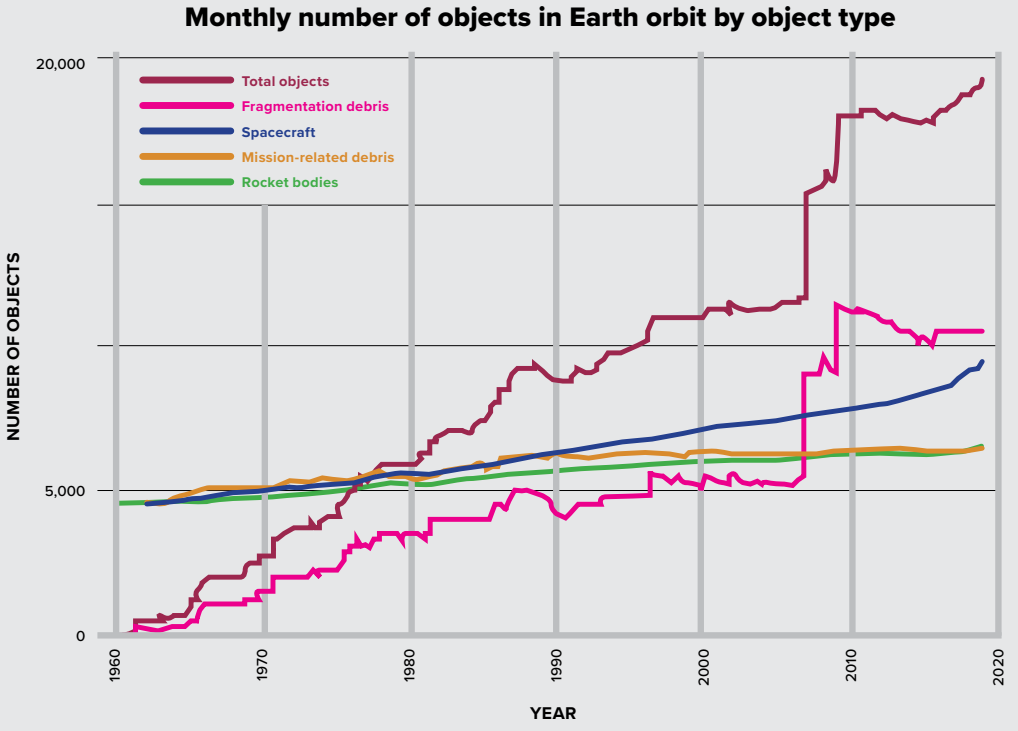
▼ A chart from NASA's Orbital Debris Program Office resembles the COVID-19 graphs that health officials refer to when explaining the virus's spread.

NASA

Familiar trajectory

The increases in orbital debris tallied by NASA on this chart corresponds with predictions of the Kessler Syndrome. The 2007 spike comes from an anti-satellite weapon test in which China destroyed one of its own satellites, a nonfunctioning weather satellite; the 2009 spike resulted from the collision of an operational Iridium satellite and a nonoperational Russian satellite.

CREDIT: NASA



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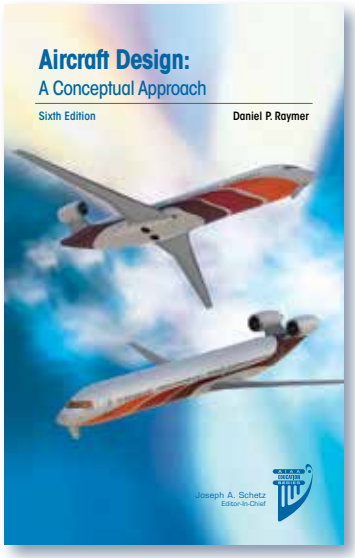

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SHAPING THE FUTURE OF AEROSPACE

OPINION

How history can inspire diversity

The National Air and Space Museum's location in Washington, D.C., is getting more than a physical update. The museum plans to place new emphasis on the people who defied racial and gender biases to break new ground in the aerospace field. It is a matter of justice, and much more. Director Ellen Stofan explains.

BY ELLEN STOFAN

▲ **Children play at an** interactive wall in the National Air and Space Museum in Washington, D.C., in a photo taken before the coronavirus pandemic.

Jim Preston/National Air and Space Museum

This column was adapted from a talk Ellen Stofan gave at AIAA's SciTech Forum in January.

As I see girls and young women exploring our museum and interacting with our content, I can't help but think about my first work experience at the National Air and Space Museum. I had just finished my freshman year in college, and I was interning for the museum's Center for Earth and Planetary Studies. While I found an incredible mentor there who really helped me in my career, I didn't see anyone who looked like me. Here were real scientists doing important work understanding the solar system, but none of them could be a role model for the challenges I encountered so often as the only woman in the room. When I became director, I was forced to consider that it's also what young girls might feel when they walk through the museum. Are we providing them with the role models, the resources, the encouragement to make their mark in STEM fields?

We started talking about this a lot at the museum, and it's such an important conversation to have because the kind of achievements we commemorate take the combined efforts of whole sectors of society. A workforce of hundreds of thousands put a person on the moon in less than 10 years. That same energy and talent built industries that, over aviation's first hundred years, shrank the world, creating the global community that greeted the new century. From defense and commercial aviation to communication satellites and deep-space probes, the opportunities have never been greater nor the stakes higher than for the next generation of aerospace innovators.

The future of aerospace relies on top talent, and increasingly that means recruiting the best minds from science, technology, engineering and math programs across the country. To hiring managers, that competitive talent pool can sometimes seem vanishingly shallow, but nothing can be further from the truth. Women make up 49% of the world population, account for 47% of the U.S. workforce but only fill 29% of STEM jobs. Black and Hispanic workers are underrepresented in the STEM workforce as well.

There's an obvious disconnect and a clear opportunity for companies and organizations that are interested in successful innovation. From the "internet of things" to climate change, the opportunities and challenges of the 21st century will outmatch any workforce that underutilizes key sections of our population.

Research shows that diverse teams are stronger, more creative and more agile at solving problems and taking the steps that lead to the next giant leap. But sometime between childhood and the first or second job, whole segments of society are apt to drop away from math and technology subjects or fields. Whether it's stereotyping, inflexible learning environments or unconscious or conscious discouragement from peers, professors or even parents, this attrition within the pipeline remains an enduring problem that threatens not just individual careers but whole industries. When a little girl climbs into the cockpit at our Innovations in Flight family day and spends the rest of the afternoon talking excitingly to her parents about how she wants to be a pilot, I want to encourage her to know that her dream is achievable. There are pilots out there who look like her, and there's a place for her in aerospace.

Familiar stories

As we work to ensure that we are a museum that provides that kind of support and encouragement for people of all backgrounds, the first step is to think about the stories we're already telling. When you think about the Air and Space Museum, you will probably think of the Wright brothers, Apollo 11 and Chuck Yeager, and this is with good reason. These legends of aviation and space transformed our world and have earned prominent positions in our exhibitions.

They embody what our museum is all about and what it's for: ideas that defy expectations, preconceptions and our imaginations. They understood that you don't change the world by sticking to the status quo, accepting limitations as facts or allowing yourself to believe those who utter the word "impossible." You change the world by conceiving an idea, believing in its possibility and making it happen despite the challenges. After all, before the 20th century the idea that humans could fly seemed impossible. In fact, people would say, "You may as well try to fly," when they wanted to underscore that something just couldn't be done. The Wright brothers proved that wrong and defied common understanding of what was possible. A little over 116 years ago on the coast of North Carolina, the Wright Flyer took off and our world was forever changed. Then just 66 years later Neil Armstrong and Buzz Aldrin set foot on the surface of the moon as Mike Collins circled above them in the command module. Only 66 years separated the dunes of Kitty Hawk from the Sea of Tranquility. That rate of innovation seems all but impossible except for the fact that it happened. And it is thanks to the ongoing innovation in aerospace that occurred between that day in 1903 and that night in 1969.

No figure of that era looms quite as large as Chuck Yeager, a pilot who truly had the right stuff. Yeager flew the Bell X-1 Glamorous Glennis to over Mach 1 in October 1947 to become the first person to break the sound barrier. The X-1 hangs in our Boeing Milestones of Flight Hall. It represents the vital flight data that ushered in an era of supersonic flight.

▲▲ **Astronomer Phoebe** Waterman Haas ascends the Mount Wilson 46-meter Solar Tower in California around 1910.
National Air and Space Musuem

▲ **Bessie Coleman** moved to Paris in 1920 to learn how to fly because U.S. flight schools would not accept African Americans or women.
National Air and Space Museum

Stories like these — a unique dilemma, unconventional solutions and unprecedented success — are seen over and over in the chronicles of aviation and space history. And there is a reason we tell them: They are and always will be a vital part of the story. But if we stop there, if we only tell these stories, we limit our ability to affect real change in the lives of those who walk through our doors and, indeed, we contribute to the workforce pipeline problem.

"You can't be what you can't see"

Marian Wright Edelman, founder of the Children's Defense Fund, has said: "You can't be what you can't see." That's why at the National Air and Space Museum we're working to tell the stories of all people who have helped move aerospace forward, including women who defy. We want to elevate the stories you may already know and uncover new stories of women who broke and are breaking barriers for their rightful place in aerospace.

Women like Phoebe Waterman Haas, whose name is on our public observatory at the museum. Phoebe was one of the first American women to earn a doctorate in astronomy, in 1913. When she was a child she witnessed a partial solar eclipse and fell in love with astronomy. She earned an undergraduate degree and a master's degree in astronomy and then went to work in a solar observatory. But despite her two degrees,

the work she was given was disappointing to her. Instead of supporting the work of male astronomers, she wanted to work on an independent project and test her own theories.

When she started work on her doctorate at the University of California, Berkeley, she found the support she was looking for: Colleagues who believed in her as much as she believed in herself and she was able to do the same work as the men. To me she embodies the idea of a woman who defies. She was determined to do the same work as the men. She discovered her passion, found her place and pursued her dreams.

So did Bessie Coleman. In a time before women were supposed to fly, before Amelia Earhart flew solo across the Atlantic, Bessie was flying through multiple glass ceilings. She dreamed of being a pilot, but it was the 1920s and she was an African American woman. The Tuskegee Airmen wouldn't take to the skies for another 20 years. American flight schools didn't admit African Americans or women, and that was two strikes against her. She didn't let that stop her. In 1920, at the age of 28, she left her job and moved from Chicago to Paris to learn how to fly. As the result of her tenacity she became the first African American woman to earn a pilot's license. When she returned to the United States, she took up barnstorming, performing stunts at aviation shows. And even as she worked to make a name for herself,

▲ **Before social** distancing, visitors listen to a volunteer read "Nobody Owns the Sky: The Story of 'Brave Bessie,'" a biography of aviator Bessie Coleman by Reeve Lindbergh, at the Steven F. Udvar-Hazy Center outside Washington, D.C.

Jim Preston/National Air and Space Museum

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she defiantly stood up for what she believed in. In an era of intense racial prejudice and Jim Crow laws, Bessie Coleman would perform at an aviation show only if the crowd wasn't segregated.

Bessie is one of my heroes for these reasons and more. She didn't let other people hold her back. She charged forward and seized opportunities, even those that weren't readily available to her.

A discussion of groundbreaking women in aerospace isn't complete without mentioning astronaut Eileen Collins. Growing up watching gliders in upstate New York, she dreamed of flying, and at the age of 18, she worked multiple jobs to get a pilot's license. She went on to get a bachelor's degree and then joined the U.S. Air Force, graduating from undergraduate pilot training. But early on in her training she met some women who set her a different course. The first class of astronauts that included women visited her base and that's when she knew she was going to be an astronaut and she was going to fly in the space shuttle. In 1990 she was selected to the astronaut program,

NASA astronaut Eileen Collins works out on the bicycle ergometer on the space shuttle Discovery. She was the commander on the 2005 flight.
NASA

Shaesta Waiz in 2017 became the youngest woman to circumnavigate the globe solo in a single-engine aircraft.
National Air and Space Musuem

and five years later she became the first woman to pilot the space shuttle, specifically Discovery's 1995 close approach to Russia's Mir space station. In 1999 she made history again as the first woman to command the space shuttle, when Columbia and its crew deployed the Chandra X-ray Observatory. When she was asked about being the first and, at that time, only female space shuttle commander, her response was, "Hopefully not for long." She was already pulling for Pam Melroy to command a mission, and Pam finally did, in 2007. As we look to the future of aerospace, we see women still pushing the envelope of what is possible.

In 2018, the National Air and Space Museum trophy was awarded to such a woman, Afghan American pilot Shaesta Waiz, who in 2017 became the youngest woman to circumnavigate the globe solo in a single-engine aircraft. When she decided to fly around the world, she knew that she wanted to do it for something much bigger than herself. Shaesta was a young child when her family emigrated to the United States. She developed a passion for aviation and founded the Women's Ambassador Program at Embry-Riddle Aeronautical University to mentor and support young women pursuing education in aviation and engineering. And then she founded an organization called Dreams Soar with the mission of inspiring young people around the world in aviation fields. Her solo flight turned out to be the perfect opportunity for her to spread that mission. Over the course of her five-month, around-the-world flight, she visited 22 countries, meeting young people growing up in socioeconomically underprivileged environments and in regions unsupportive of women.

What makes these innovators so inspiring isn't just what they achieved as women. It's about how they pushed the envelope of what's possible, not just as women, but as humans. At the museum, we've taken steps to find these types of stories and share them in the programming, lectures, online content and more. But now we need to take it a step further.

Despite the coronavirus pandemic, we're in the middle of a massive renovation of the National Air and Space Museum location in Washington, D.C., transforming all of our galleries to tell new stories and share new artifacts alongside the iconic artifacts that you expect to see. We will bring our exhibitions into the 21st century and reflect on where we are heading 50 years after we landed on the moon for the first time, and over 100 years since the first airplane flight. The new National Air and Space Museum will use the past and present to show our visitors that no matter their race, gender or nationality, they have the ability to transform our world. ★

Ellen Stofan, a planetary geologist, became the John and Adrienne Mars Director of the National Air and Space Museum in 2018. She is the former NASA chief scientist and has a doctorate from Brown University. Stofan is also a member of the Guiding Coalition for AIAA's inaugural ASCEND space event in November.

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Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2020			
5–7 May	CANCELLED: AIAA DEFENSE Forum	Laurel, MD	8 Oct 19
8 May	CANCELLED: Trusted Autonomous Systems Course	Laurel, MD	
16 May*	POSTPONED TO MAY 2021: The American Rocketry Challenge	The Plains, Virginia	
19 May	POSTPONED TO 16 JULY: 2020 AIAA Fellows Dinner	Crystal City, VA	
20 May	POSTPONED TO 17 JULY: 2020 AIAA Aerospace Spotlight Awards Gala	Washington, DC	
25–27 May*	27th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (elektropribor.spb.ru/en)	
15–19 Jun	AIAA AVIATION Forum	VIRTUAL EVENT	7 Nov 19
16–20 Jun*	CANCELLED: Spaceport America Cup	Las Cruces, NM	
23–26 Jun*	POSTPONED TO JUNE 2021: ICNPAA 2020	Prague, Czech Republic (icnpaa.com)	
29 Jun–1 Jul*	POSTPONED FROM MARCH: 55th 3AF Conference on Applied Aerodynamics	Poitiers, France (http://3af-aerodynamics2020.com)	
TBD Jul	Design of Electrified Propulsion Aircraft	Online (aiaa.org/events-learning/online-education)	
9–10 Jul	OpenFOAM® Foundation Course	Online (aiaa.org/events-learning/online-education)	
16 Jul	2020 AIAA Fellows Dinner	Crystal City, VA	
17 Jul	2020 AIAA Aerospace Spotlight Awards Gala	Washington, DC	
20–23 Jul	Practical Design Methods for Aircraft and Rotorcraft Flight Control for Manned and UAV Applications with Hands-on Training using CONDUIT® Course	Online (aiaa.org/events-learning/online-education)	
9–13 Aug*	2020 AAS/AIAA Astrodynamics Specialist Conference	South Lake Tahoe, CA	10 Apr 2020
15–22 Aug*	POSTPONED TO 28 JAN–4 FEB 2021: 43rd Scientific Assembly of the Committee on Space Research and Associated Events	Sydney, Australia (cospar2020.org)	14 Feb 20
22–23 Aug	5th AIAA Propulsion Aerodynamics Workshop (PAW05)	New Orleans, LA	
22–23 Aug	Design and Operations of Composite Overwrapped Pressure Vesselss (COPV) Course	New Orleans, LA	
22–23 Aug	Fundamentals of Python Programming with NumPy for Aerospace Engineers Course	New Orleans, LA	
22–23 Aug	Liquid Rocket Engines: Emerging Technologies in Liquid Propulsion Course	New Orleans, LA	
22–23 Aug	Missile Propulsion Course	New Orleans, LA	
24–26 Aug	AIAA Propulsion and Energy Forum	New Orleans, LA	11 Feb 20

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.).

14–18 Sep*	32nd Congress of the International Council of the Aeronautical Sciences	Shanghai, China (icas.org)	15 Jul 19
24 Sep–12 Nov	Design and Operation of Composite Overwrapped Pressure Vessels Online Short Course	Online (aiaa.org/events-learning/online-education)	
26–27 Sep*	CEAS-ASC Workshop 2019 on "Advanced Materials for Aeroacoustics"	Rome, Italy	
11–15 Oct*	39th Digital Avionics Systems Conference (DASC)	San Antonio, TX (https://2020.dasconline.org/)	
12–16 Oct*	POSTPONED: 71st International Astronautical Congress	Dubai, UAE (iac2020.org)	
29 Oct–1 Nov*	37th International Communications Satellite Systems Conference (ICSSC 2020)	Okinawa, Japan (kaconf.org)	15 May 19
16–18 Nov	ASCEND Powered by AIAA	Las Vegas, NV (ascend.events)	31 Mar 20
2021			
9–10 Jan	1st AIAA CFD Transition Modeling Prediction Workshop	Nashville, TN	
9–10 Jan	2nd AIAA Workshop for Multifidelity Modeling in Support of Design & Uncertainty Quantification	Nashville, TN	
9–10 Jan	1st AIAA High Fidelity CFD Workshop	Nashville, TN	
9–10 Jan	1st AIAA Stability and Control Prediction Workshop	Nashville, TN	
11–15 Jan	AIAA SciTech Forum	Nashville, TN	8 Jun 20
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)	
20–22 Apr	AIAA DEFENSE Forum	Laurel, MD	
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)	
5–11 Jun	AIAA AVIATION Forum	Washington, DC	
22–25 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
9–11 Aug	AIAA Propulsion and Energy Forum	Denver, CO	
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/Co-SponsorshipOpportunities.*

AIAA Calls Upon U.S. Policymakers to Protect Mission-Critical Aerospace and Defense Workforce and Supply Chain

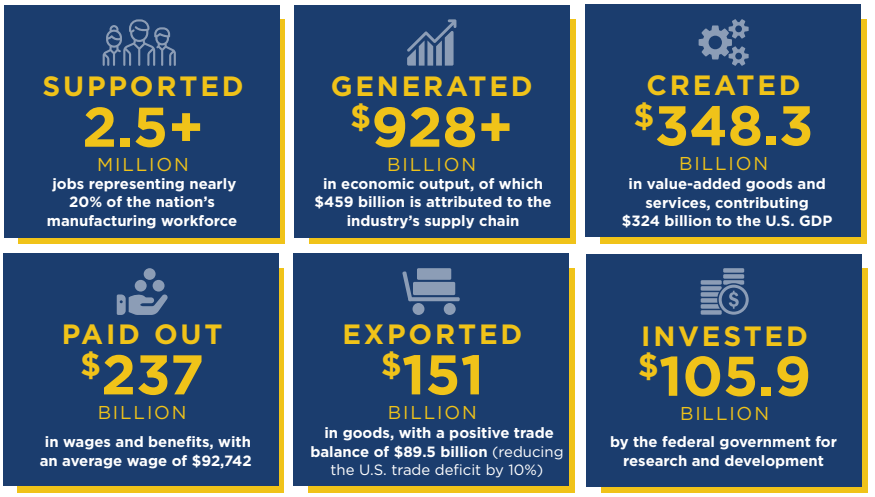
On 20 March AIAA released the following statement asking for U.S. policymakers to assist the mission of the aerospace and defense workforce and supply chain.

The coronavirus pandemic is stalling the global economy, impairing businesses, and changing how we go about our daily lives. Its impact is multiplying, and the effects reach far beyond this year's balance sheets.

Here in the United States, the aerospace and defense industry supports more than 2.5 million jobs and 17,000 suppliers from large manufacturers to small businesses that form the backbone of the supply chain. It represents more than $928 billion in economic output for the United States and more than $237 billion in wages. The industry has improved our quality of life by transforming transportation, medicine, defense, and security, among other things.

In times such as these, the aerospace and defense sector is essential to protect our national security and provide much needed logistics capability to bring critical supplies to areas of need. Its highly skilled workforce has made significant advances in areas such as autonomy, cybersecurity, air mobility, and space exploration. The aerospace and defense workforce is an essential driver of innovation for the U.S. economy, our national security, and expanding the utilization of space for future generations. We need the industry to survive the crisis and build our future.

The aerospace and defense industry is vital to the prominent position of the United States in global competitiveness, innovation, and technical leadership. The coronavirus pandemic presents a new challenge and our global leadership in this sector will falter if the industry is not protected during this time of crisis. The aerospace and defense contribution to the economy on the other side of the COVID-19 crisis will be crucial for restarting and building the economic engine to its pre-crisis momentum.



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

The industry is experiencing an economic downturn that's worse than 9/11. Airlines are laying off thousands of workers and cutting flights. Maintenance, repair, and overhaul workers are also feeling the impacts. We're in the initial stages of the COVID-19 crisis and can expect to see more jobs affected as the world responds to the pandemic.

We call on federal government officials and lawmakers to be mindful of and support the aerospace and defense industry during this challenging time.

AIAA and the Coronavirus Pandemic

The coronavirus pandemic has changed the way we all do business. AIAA is on the job and ready to help. Find event updates, AIAA coronavirus-related information, and working from home resources for professionals, university students, and K-12 students on our expanded Coronavirus Updates page (**aiaa.org/coronavirus**).

On 12 March, the 2020 winners of Aviation Week Network's **"Tomorrow's Technology Leaders: The 20 Twenties"** were recognized at a lunch in Washington, DC. The awards recognize students earning STEM degrees who are nominated by their universities on the basis of their academic performance, civic contribution, and research or design project. In addition, the program brings together technology hiring managers, students, and faculty around the world to recognize what's needed for business and academic success. Winners receive a membership to AIAA.

LEFT: New premises for Neumann Space in Adelaide, South Australia.

2020 Sperry Award Winner Moving Technology Forward As Fast As He Can

By Michele McDonald, AIAA Communications Manager

A fascination with asteroids drew Lawrence Sperry Award winner **Patrick "Paddy" Neumann** first to aerospace and then to developing a miniature electric spacecraft propulsion system.

"As a child in a part of the world with such a beautiful view of the stars and planets, it's not surprising that I was drawn towards aerospace, but that was not the only factor," Neumann said. "After being fascinated by dinosaurs, as many children are, I was then drawn to understand more about asteroids, because the asteroid impact theory was becoming more accepted and filtering into children's books on ancient life."

Born in Subiaco, part of Perth, Western Australia, Neumann spent most of his childhood in Lesmurdie, which is in the Darling Range just to the east of Perth, as well as some of his childhood in Southern Cross and in a couple of remote communities on the Nullarbor Plain.

He recalls avidly watching Voyager 2's flyby of Neptune on *Quantum*, the science and technology TV show produced by the Australian Broadcasting Corporation. Neumann's childhood fascination with space grew and "after this, I began reading everything I could find on space exploration, as well as more general topics on science and technology, while consuming a lot of fiction and focusing my school studies on science and maths."

As a high school student in 2001, Neumann attended a highly regarded summer camp at the University of Sydney called the International Science School. He enjoyed the camp so much, and since the University of Sydney has good programs in both aerospace engineering and physics, he applied to study there and also won a scholarship.

During his undergraduate work, he was drawn to plasma physics and began studying the pulsed cathodic arc as it could apply to spacecraft propulsion. He founded Neumann Space after earning his doctorate in order to further develop and commercialize the technology and works as the company's chief scientist. Neumann also has partnered with Australia's Defence Science and Technology Group to develop domestic capability in test apparatus for spacecraft propulsion systems.

His hard work has resulted in him winning the 2020 Sperry Award "for continued development of miniature electric spacecraft propulsion systems and ceaseless advocacy for the development of Australian space capabilities."

Established in 1936, the Lawrence Sperry Award recognizes a notable contribution made by a young person, age 35 or under, to the advancement of aeronautics or astronautics. The award honors Lawrence B. Sperry, pioneer aviator and inventor, who died in 1923 in a forced landing while attempting a flight across the English Channel. Past recipients include fellow Australian Michael West, Karen Berger, Sally Ride, Eugene Kranz, and Katya M. Casper.

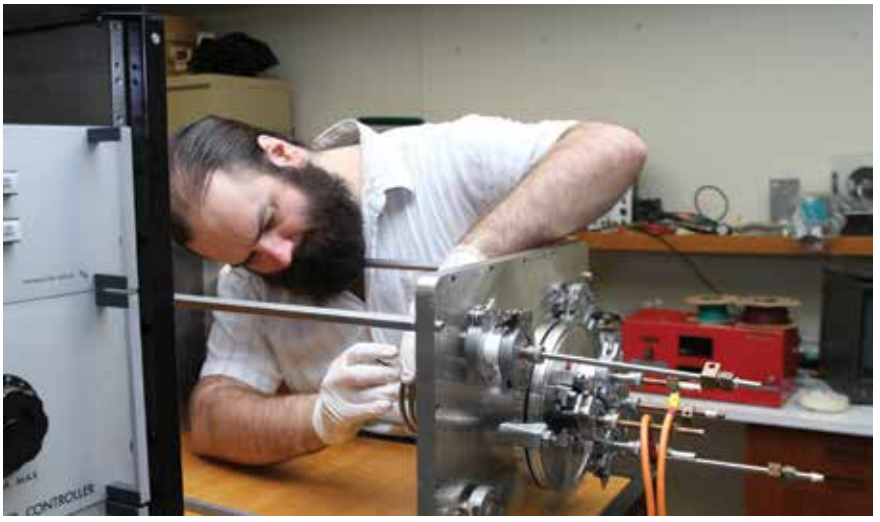
Miniature Electric Spacecraft Propulsion System

In his work at Neumann Space, Neumann is developing a pulsed cathodic arc plasma source, similar to those used in thin film deposition, into a propulsion system that could be used to give small spacecraft a broader range of capabilities. He explained that "pulsed arcs work using the same physics as an electrical welding arc, in that the arc discharge erodes material from the cathode (the negative part of the circuit, which is the welding rod), ionising and energising it, while accelerating the ions in the plasma away from the cathode surface."

Neumann described how pulsed cathodic arc applies to spacecraft

propulsion: "While welding and coating systems direct the plasma towards either the work piece or the substrate to be coated, we let the plasma escape from the system, which means that the plasma is the exhaust of our thruster, and momentum conservation pushes the spacecraft along. This system has a number of benefits compared to other technologies, since like other electric propulsion systems it has a high specific impulse (fuel mass efficiency) compared to chemical propulsion systems; uses a dense, solid, robust and chemically inert propellant; does not require an exhaust charge neutralisation system and operates at much lower voltages than other electric propulsion systems, increasing ease of integration and operation."

LEFT: Neumann at the University of Sydney, where he did his Ph.D., holding a triple cathode-anode array used for growing thin film coatings.



ABOVE: Working on hardware at the University of Sydney lab.

"His technical work is novel and important, since developments in propulsion technologies will enable greater mission flexibility and capability for spacecraft operators," noted Pamela Melroy, an AIAA Associate Fellow and former astronaut, in her Sperry nomination support letter for Neumann. "The efficiency gains from electric propulsion are being realized today, but novel thruster technologies face a long qualification pathway.

"Patrick is moving his technology forward as fast as he can, with initial demonstrators on cubesats planned in 2021 to show that pulsed arc thrusters can deliver on the promises of terrestrial lab tests," Melroy continued. "The benefits of arc thrusters for CubeSat applications as an alternative to Hall and ion thrusters include operational benefits such as higher specific impulse and lower operating voltages, inert propellants, propellant density and exhaust neutrality. These benefits combine to make his work relevant and important for the future of space. It's clear to me that his technical contributions will continue into the future and bring great credit to AIAA and the industry."

The Value of His AIAA Membership

Neumann is described as a ceaseless advocate of Australia's growing space sector, serving as chair of the AIAA Adelaide Section and also as a member of the AIAA Electric Propulsion Technical Committee. He has published his work in several international peer-reviewed journals and conference proceedings.

"Patrick is a talented and inspiring public speaker and regularly works with the AIAA and other professional and interest groups to promote aerospace and science in Australia," wrote 2018 Sperry Award winner Michael West in his support letter for Neumann's nomination. "He has given numerous public talks, invited lectures and guest presentations throughout Australia and overseas."

Neumann said while he originally joined the AIAA University of Sydney Student Branch to get the book discount, belonging to AIAA has helped his work. "Being an AIAA member has helped my career by allowing me to read more widely in the technical details of my field, including in test hardware and instrumentation."

Neumann's Advice to Future Aerospace Engineering Students

"I would recommend that they pay close attention in mathematics classes and learn to code as early as they can. Solid foundations in these disciplines will help a student to excel in any modern engineering discipline but will also give you the time to learn more of the parts of your chosen discipline that are more art than science.

"It is this latter one that is the most important; there are many specialties within aerospace engineering, and aspiring students must have the chance to investigate them all, so that they can find which one excites their passion and can anchor their professional life. For me, this was a combination of structures and propulsion, with electric spacecraft propulsion being my chosen field, but for others this may be aerothermal design, aeroacoustics, human factors engineering or fluid mechanics."

MAKING AN IMPACT

Education Achievement Awards

Each year, AIAA presents its Educator Achievement Awards, which honor three outstanding K–12 educators for their contributions to the continued study of science, technology, engineering, and mathematics within the classroom and beyond. Each of these teachers has had a significant impact on creating the next generation of aerospace professionals who will shape our community's future. Since 1997, the award has honored more than 65 educators from the United States.

The nominees must be a K–12 educator who supports AIAA in its efforts to bring real-world STEM experiences to students, and they must be AIAA Educator Associates. AIAA looks for enthusiastic educators who promote active learning and encourage students to think imaginatively, critically, and independently.

The honorees each received $5,000 for themselves and $5,000 for their respective schools to continue their efforts in STEM education. They also receive a trip to Washington, DC, to be honored at the AIAA Aerospace Spotlight Awards Gala.

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

Three K–12 Educators Win AIAA Educator Achievement Awards

Three K–12 educators from across the United States have won the 2020 AIAA Educator Achievement Awards, honoring their efforts to promote STEM education. This year's honorees are:

Elizabeth L. Bero, Gifted Specialist at Horizon Elementary School in Madison, Alabama, for "instilling a sense of wonder in students through curiosity-based learning and for her four-decade-long service to the community as an educator."

Bero's sixth grade space science class making rockets with the help of the Huntsville Area Rocketry Association.

A lab on DNA extraction with Bero's sixth grade forensics class.

Bero's third grade class experimenting with the best Lego legs needed to support a lunar lander.

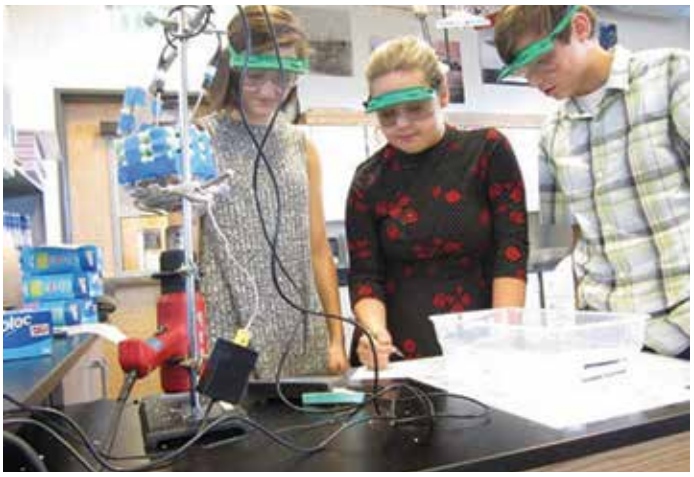
Demonstration of vacuum of space in Leavitt's physics class.

Beth Meade Leavitt, Teacher of Physics and Astronomy and Director of FIRST Robotics Team 283 at Wade Hampton High School in Greenville, South Carolina, for "believing that with the right tools and mentors all students can become STEM literate with the confidence they can solve any problem encountered."

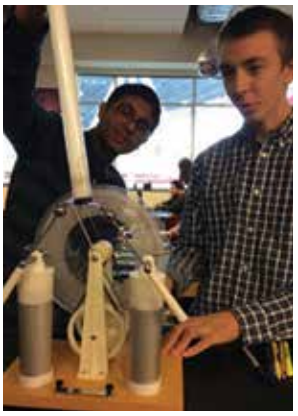
Students in Leavitt's summer rocketry camp.

Member of her robotics team demonstrating their robot at Military Officer Association meeting.

Scott McComb, Science Instructor, AIAA Advisor, Green Energy Team Advisor, and Science Olympiad Coach at Raisbeck Aviation High School in Seattle, Washington, for "implementing an outstanding program of aerospace education and creating a supportive classroom community of learners."



Students test the effectiveness of the second iteration of their heat shield to protect a chocolate bunny from the heat of re-entry.



TOP: Students prepare to fly their tethered-electric cargo aircraft.

LEFT: Students exploring electric field and dielectric properties of air.

Rescheduled Event!

CONGRATULATIONS, AIAA CLASS OF 2020 FELLOWS AND HONORARY FELLOWS

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

John Langford, AIAA President

2020 AIAA HONORARY FELLOWS

Robert D. Briskman
Telecommunications Engineering Consultants

Wes Bush
Northrop Grumman Corporation (retired)

Jason L. Speyer
University of California, Los Angeles

2020 AIAA FELLOWS

Holger Babinsky
University of Cambridge

John S. Baras
University of Maryland

Rodney D. W. Bowersox
Texas A&M University

Russell R. Boyce
University of New South Wales

Salvatore "Tory" Bruno
United Launch Alliance

Mark Campbell
Cornell University

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

Walter Engelund
NASA Headquarters

Hermann F. Fasel
University of Arizona

Hector Fenech
Eutelsat SA

Farhan Gandhi
Rensselaer Polytechnic Institute

Michael Gazarik
Ball Aerospace

Stanley Gustafson
Lockheed Martin Space

Steven J. Isakowitz
The Aerospace Corporation

Christopher T. Jones
Northrop Grumman Corporation (retired)

David Klaus
University of Colorado Boulder

Christophe Laux Ecole
CentraleSupélec, CNRS
University Paris Saclay

Joaquim R.R.A. Martins
University of Michigan

Beverley J. McKeon
California Institute of Technology

Daniel Mooney
Boeing Global Services

Scott A. Morton
U.S. Department of Defense

Nelson Pedreiro
Lockheed Martin Space

Christopher Pestak
Universities Space Research Association

Amy Pritchett
Pennsylvania State University

Dhanireddy R. Reddy
NASA Glenn Research Center

Donald O. Rockwell
Lehigh University

Suzanne Weaver Smith
University of Kentucky

Edgar G. Waggoner
NASA Headquarters

Michael M. Watkins
NASA Jet Propulsion Laboratory

AIAA FELLOWS AND HONORARY FELLOWS

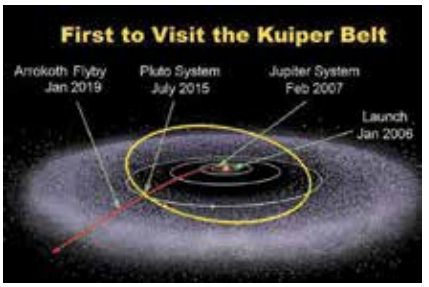
You are cordially invited to join us at the Class of 2020 Induction Ceremony at the annual AIAA Fellows Dinner.

NEW DATE
Thursday, 16 July 2020
Hilton Crystal City, Arlington, Virginia

Reception: 1830 hrs
Dinner: 1930 hrs

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

AIAA
SHAPING THE FUTURE OF AEROSPACE



Screen captures courtesy of Alice Bowman

Northern Ohio Section Livestreams Distinguished Lecture

By Joe Connolly, Vice Chair, Northern Ohio Section

On 25 March, the AIAA Northern Ohio Section (NOS) for the first time livestreamed their Distinguished Lecture series via the Zoom web conferencing platform and 37 section members attended. Alice Bowman, who serves as the Space Mission Operations Group supervisor and the NASA New Horizons Mission Operations Manager (MOM) from the Johns Hopkins Applied Physics Laboratory, gave the lecture on "Mission to Pluto and the Kuiper Belt." Ms. Bowman supervises approximately 50 staff members who operate deep space and Earth-orbiting spacecraft, including NASA's TIMED, STEREO, New Horizons, and Parker Solar Probe. As the New Horizons MOM, Ms. Bowman leads the team that controls the spacecraft that made a historic flyby of the Pluto system in July 2015.

The lecture covered the voyage of NASA's historic mission to Pluto and the Kuiper Belt, which culminated with the first flight past the distant dwarf planet on 14 July 2015 and the first encounter with a Kuiper Belt object (KBO) on 1 January 2019. She spoke about the New Horizons spacecraft's continuing journey through the eyes of the mission operations team and described some of the technical, scientific, and personal challenges of piloting the spacecraft across the solar system on its voyage to the farthest reaches of the planetary frontier.

With the success of their first virtual Distinguished Lecture, AIAA NOS is planning more such events in the future.

Todd Barber (wearing blue shirt, near center) with some of the student branch members, including FIT Student Branch President Archit Srivastava (left of Barber) and Vice President Sean Dungan (right of Barber).

FIT Dinner Meeting Hosted JPL Propulsion Engineer

The AIAA Florida Institute of Technology (FIT) Student Branch welcomed Todd Barber, Senior Propulsion Engineer at NASA Jet Propulsion Laboratory, as speaker at their annual dinner meeting on 27 February. Mr. Barber gave a lively, informative, and humorous presentation about his experiences as a propulsion engineer with the Curiosity mission, as well as a brief look ahead to the Mars 2020 mission. The meeting created an opportunity for students to get inside information on one of JPL's signature missions and to learn from his successes and mistakes (watch out for open mikes when working the console).

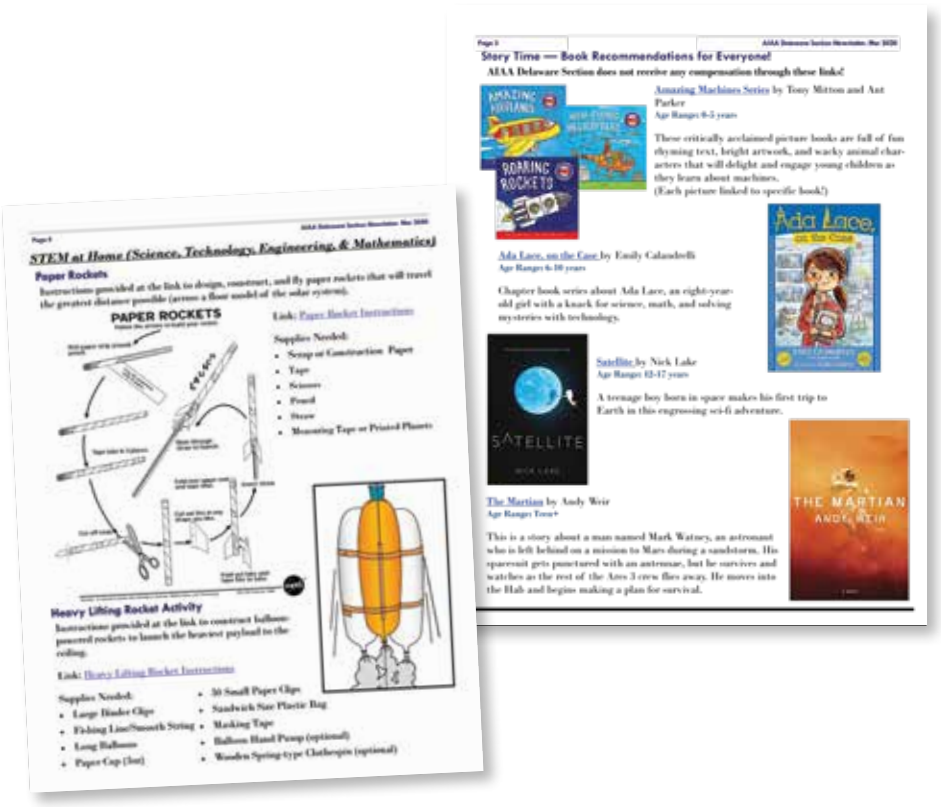
FROM LEFT TO RIGHT: Michael Oates, Dan Nice, and Daniel Klopp

"First State, First Step" Hosted at University of Delaware

As E-week was winding down in February, the viewing of "First State, First Step" was the one last hoorah for the week for the AIAA Delaware Section. With approximately 30 people in attendance, 302 Stories founder Michael Oates was able to illustrate the impact such a small state had on the space race and helping to put the first humans on the moon.

The video (www.302stories.com/first-state-first-step-delaware-to) 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 stirred up an effervescence of energy as we look to the moon and beyond once again.

After the video, Oates provided further insight into the stories that were told. Also present at the event were several folks currently working at ILC, including Daniel Klopp, who supported an impromptu Q&A session.



AIAA Delaware Section Adapts to the Coronavirus Pandemic

The AIAA Delaware Section, like so many of our other sections, is adjusting to the new normal. They included resources in their most recent newsletter to help members who are spending time at home find activities, experiments, good reads, and even a design-your-own rocket simulator. To the left are a couple of the resources they put together.

AIAA is interested to see what all our sections are doing during the coronavirus pandemic.

Sections Promote AIAA at GoFly Event

By Ken Lui, AIAA LA-LV Events/Program Chair

This year AIAA was one of the sponsors of the GoFly event, held 27–29 February at NASA Ames Research Center's Moffett Federal Airfield, and the AIAA Los Angeles–Las Vegas Section exhibited alongside other sponsors such as Boeing, Hiller Aviation Museum, and the California Aeronautical University. The AIAA San Francisco Section was also able to exhibit on 29 February side by side the LA-LV Section table.

The exhibit was very well received, and we saw several of our members and former event speakers, as well as having the opportunity to educate prospective members about the benefits of AIAA membership. We found that people were inspired by what AIAA and AIAA members had been doing and the AIAA events and programs offered. Several STEM demos were performed, such as the electric paper plane launcher, magnetic levitation gyroscope, rocket launcher, and a green energy robot. The AIAA promotional items, along with the ASCEND event promotional bottles and fliers, were very popular and got lots of attention from the visitors.

AIAA Executive Director Dan Dumbacher gave a talk during the "Meet the Executive Directors" panel on 28 February. Other speakers discussed the technologies and business of personal aviation or their teams/designs in this festival/competition, before they went on to actually demonstrate their aircraft or flying devices. While the GoFly competition took place, people also enjoyed viewing and playing with several models, such as B-1B Lancer, F-35, International Space Station, Space Shuttle, SR-71, F/A-18 Hornet and Super Hornet, B-52/X-15, WhiteKnightTwo/SpaceShipTwo, Mars Rover, and rockets, and there were some breathtaking airshows.

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1 Amazing acrobatic airshows took place alongside the GoFly competition.
2 The AIAA LA-LV exhibit table.
3 Children and adults playing with the displays and viewing demos, as they got to know more about AIAA.
4 Visitors were curious about AIAA LA-LV's little robot demo.
5 GoFly sign at the entrance of the event site.

PHOTOS COURTESY OF KEN LUI

1920

May 7 The first airmail in China is inaugurated between Peking and Tientsin by a Handley-Page which carries 15 passengers besides mail. Among the passengers is the British ambassador to China. By December, a Peking-Shanghai airmail service is started, a distance of 1,100 kilometers. **Flight**, May 13, 1920, p. 535 and July 1, 1920, p. 691.

May 31 Italian pilots Arturo Ferranin and Guido Masiero complete a 106-day trip from Rome to Tokyo in two Ansaldo SVA-9 trainers. Eleven planes started the journey. **U.S. Air Service, Volume 2**, p. 36.

1945

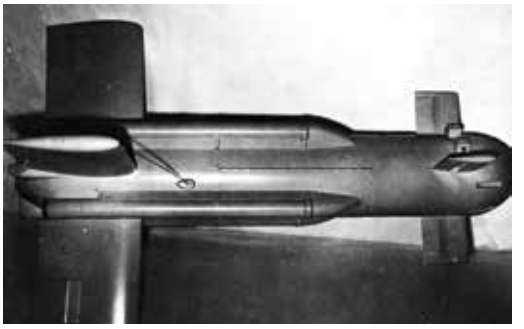
May 2 U.S. Coast Guard Lt. August Kleisch, flying a Sikorsky HNS-1 helicopter, makes one of the first helicopter rescues when he picks up 11 Canadian airmen marooned in northern Labrador. **United States Naval Aviation, 1910-1980**, p. 142.

May 3 To ensure that German military forces comply with the surrender terms, American fighter aircraft fly reconnaissance missions over northern Italy and southwest Austria, while medium bombers drop leaflets over areas where German forces might be unaware of the surrender. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 644.

May 7 The British Royal Air Force's Coastal Command sinks the U320, the last German submarine of World War II, west of Bergen, Norway. M.J.H. Taylor, **The Aerospace Chronology,** p. 154.

Imperial War Museums

May 7 The war in Western Europe ends at midnight following Germany's unconditional surrender. M.J.H. Taylor, **The Aerospace Chronology**, p. 154.



May 10 An emergency program to counteract the Japanese Baka suicide bombs begins when the Naval Aircraft Modification Unit starts to develop the radio-controlled Little Joe missile, which will have a standard Aerojet JATO solid-fuel rocket with 4,500 newtons (1,000 pounds) of thrust. **United States Naval Aviation 1910-1980**, p. 142.

May 17 Aerojet Engineering receives the contract to develop the Aerobee sounding rocket. This liquid-fuel vehicle will be launched first in 1947. It will go through a dozen model types and be in operation for almost 40 years, collecting data from high altitudes for upper atmospheric and astronomical studies. F.H. Winter, **Rockets into Space**, pp. 63-64.

May 17 The Douglas XB-43 light jet bomber makes its first flight, but it never reaches production. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 54.

May 26 The British Royal Air Force flies an Avro Lancaster Aires over both the true and magnetic north poles for navigational tests. The plane's instruments include an inclinometer to measure the angle of dip when approaching the magnetic pole. **The Aeroplane**, June 1, 1945, p. 618.

During May 1945
The Graf Zeppelin, Germany's only aircraft carrier, is captured incomplete and damaged in the port of Stettin. **The Aeroplane**, May 25, 1945, p. 611.

1970

May 1 Henry Berliner Sr., an early helicopter pioneer, dies in Washington, D.C. He was an aerial photographer with the Army Air Service in World War I. In 1922, Berliner bought a surplus Nieuport 23 fighter fuselage, fitted it with a Bentley 220-horsepower engine on the front and connected it by geared shafts to two horizontal rotors. A third horizontal rotor at the rear provided pitch control. This craft (a version is shown above) was demonstrated at College Park, Maryland, to the U.S. Navy's Bureau of Aeronautics in June 1922 and is thought to be one of the world's first helicopters. In 1926, Berliner founded the Berliner Aircraft Co., which developed fixed-wing aircraft. **Aviation Week**, May 11, 1970, p. 27.

May 1 The city of Chicago welcomes Apollo 13 astronauts James Lovell and John Swigert in a huge ticker-tape parade. Fred Haise can't attend because of health problems. **Houston Post**, May 2, 1970.

May 1 Samuel Hoffman of North American Rockwell Corp.'s Rocketdyne Division retires after 20 years, including 10 as Rocketdyne's president. He received the American Rocket Society's Robert H. Goddard Memorial Award in 1959 for outstanding work in the design and construction of liquid-propellant rocket engines, including the H-1, J-2 and F-1 used in Project Apollo. NASA, **Aeronautics and Astronautics, 1970**, p. 164.

George Lowe, left, then acting administrator of NASA, and Wernher von Braun in 1971.

May 2 NASA Deputy Administrator George Low sums up the phenomenal growth of computer capabilities in the space program at an event for academic scientists. "In Project Mercury," he says, "ground-based computers were only required to determine quickly and accurately booster cut-off conditions. In Apollo, however, computers are used throughout the mission in real time, to calculate the trajectory to the moon and back, to compare separate solutions for the lunar descent, to record and analyze thousands of bits of telemetered spacecraft information," and so on. Since the Mercury days, he says, computers' speed has increased sevenfold. NASA, **Aeronautics and Astronautics, 1970**, pp. 164-165.

May 4 Frank Borman, the Apollo 8 mission commander, is to join Eastern Airlines as a vice president. He is to be responsible for helping Eastern implement aerospace techniques and equipment as they become available to the airline industry. **Aviation Week**, May 4, 1970, p. 30.

May 5 NASA ends its experiments with a propeller-driven Ling-Temco-Vought XC-142 vertical or short takeoff and landing aircraft at Langley Research Center in Virginia. Pilots for NASA fly the aircraft, which was on loan to the agency from the U.S. Air Force, to the Air Force Museum at Dayton, Ohio. The four-engine tilt-wing XC-142 evolved from wind-tunnel models tested at Langley and other NASA centers starting in 1956. NASA, **Aeronautics and Astronautics, 1970**, p. 166.

May 6 Apollo 11 astronauts Neil Armstrong, Buzz Aldrin and Michael Collins receive the Robert J. Collier Trophy for "their high courage and stunning success in accomplishing man's highest adventure in recorded history — the first moon landing." NASA, **Aeronautics and Astronautics, 1970**, p. 166.

May 17 The Space Electric Rocket Test spacecraft known as Sert II, launched on Feb. 3, reaches its halfway point of a six-month endurance test in space with the ion engine operating for more than 2,000 hours, NASA announces. During its run, however, controllers had to turn off the electric bombardment for several hours on March 7 to avoid damage during a solar eclipse when Sert II intersected the eclipse path on two orbits with a sharp loss in electric power from solar cells. NASA, **Aeronautics and Astronautics, 1970**, p. 173.

May 29 India completes a series of five tests of its multistage solid-propellant Rohini sounding rocket at the Thumba Equatorial Rocket Launching Station. At the same time, India announces it has completed a feasibility study of the design and development of a space launch vehicle that could launch a 30-kilogram satellite into orbit by 1973. NASA, **Aeronautics and Astronautics, 1970**, p. 185.

1995

May 15 Boeing makes it first delivery of a 777 passenger jet when United Airlines receives a 777. The airliner completes its first commercial flight on June 7, after the 777 design earns its 180-ETOPS rating, short for Extended Range Twin-engine Operational Performance Standards. This certification permits 777s to fly for three hours from an en-route airport, and is typically awarded two years after a twin-engine jet begins commercial service. **New York Times**, May 31, p. 1.

May 20 Russia launches the research module Spektr aboard a Proton rocket. Carrying 800 kilograms of U.S. biomedical research equipment and atmospheric instruments, Spektr will dock with the Russian space station Mir on June 1. **Aviation Week**, May 29, p. 24.

LUCAS SOUSA DE OLIVEIRA, 29

New programs manager at Embraer Commercial Aviation

Lucas Sousa de Oliveira was 6 when he began disassembling cassette players and radio-controlled cars at his home in Natal, Brazil. Instead of scolding, his parents encouraged him. De Oliveira spent a year in the U.S. during college and graduated in 2013 with a bachelor's degree in electrical engineering from the University of Brasília. After college, he went directly to Embraer in São Paulo to work on the E-Jets E2 program, a family of medium-range airliners that consume less fuel, produce fewer emissions and cost less to operate than Embraer's original E-Jet series.

Landing a job ▶ In school, I was eager to find out how mathematics and physics could be used to hack nature and make our lives better. I was lucky to have teachers and friends who nurtured this curiosity. I studied electronics engineering at the University of Brasília, where I took part in research, internships and exchange programs. Through the Science Without Borders exchange program, I spent a year at Catholic University of America in Washington, D.C., studying electrical engineering and computer science. A Catholic University professor helped me get an internship at NASA's Goddard Space Flight Center in Maryland. I saw highly complex flying systems at NASA. That was the tipping point that made me want to work in aviation. I sought a company where I could perform great engineering. I found Embraer.

From training to program management ▶ I received my undergraduate degree in 2013 and went straight to Embraer, not as a full-time employee but as part of an 18-month engineering training program. As soon as I started the training program, I began work on a master's degree in aeronautical engineering, aerospace systems and mechatronics at the Aeronautics Institute of Technology in São José dos Campos. I completed the degree in 2017. After the training program, I started as a program manager in commercial aviation at Embraer working on E2. I was on E2 from 2015 to 2018. The E2 program showed we can set the bar high and jump higher. The results were far beyond what we expected. Now, I work on new programs. At Embraer, we are pushing the limits of developing mature aircraft on short schedules, on tight budgets, with very challenging specifications. It's great. It feels like constant evolution.

Aviation in 2050 ▶ I expect aviation to become a lot more personal, to seamlessly integrate with other means of transportation. You won't feel like you are traveling in an airplane or a boat or a car. Everything will become a part of an integrated system. Of course, we also have a lot of ground

breaking technologies coming along like vertical takeoff and landing, electric propulsion, alternative aircraft configurations and autonomous aircraft that will make flying a lot cheaper, a lot greener and a lot more comfortable. But I believe the turning point will be when all these things come together to make the traveling experience unique, to exceed the customer's expectations. There are companies around the world already trying disruptive business models with some going as far as not charging fares and still making a profit. ★

BY DEBRA WERNER | werner.debra@gmail.com

AIAA Engage

THE AEROSPACE INDUSTRY—NOW ONLINE

Now more than ever, communities and personal connections are of the utmost importance. **AIAA Engage** is your community and the virtual place to connect with the global aerospace community. As an AIAA member you can start or join wide-ranging discussions with people as passionate about aerospace as you are. At the same time, you will grow your personal network and make a friend or two. Join our 30,000-strong community and tap into shared resources and well-regarded aerospace advice that are just a click away.

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To access Engage, use your AIAA log-in credentials.

AVIATION FORUM

15–19 JUNE 2020 | **VIRTUAL EVENT**

A FULLY VIRTUAL EXPERIENCE

For the first time the AIAA AVIATION Forum will be held as a virtual event in an online-only format, 15–19 June 2020. While the venue has changed, the forum will continue to be instrumental in connecting aviation business with cutting-edge research and development. This new format creates exciting opportunities, opening up the critical technical exchange to a broader and more diverse audience than ever before.

WHAT TO EXPECT

The quality plenaries, Forum 360s, and technical sessions you've come to expect from AIAA will be part of the virtual event. Hear from industry leaders including*:

James Bridenstine, Administrator, NASA

Walt Odisho, Vice President, Manufacturing, Safety and Quality, Boeing Commercial Airplanes

Robert Pearce, Associate Administrator, Aeronautics Research Mission Directorate, NASA

Jenette Ramos, Senior Vice President, Manufacturing, Supply Chain & Operations, The Boeing Company

Tom Vice, Chairman, President, and Chief Executive Officer, Aerion Corporation

Grazia Vittadini, Chief Technology Officer, Airbus

**Speakers subject to change*

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AIAA

SHAPING THE FUTURE OF AEROSPACE