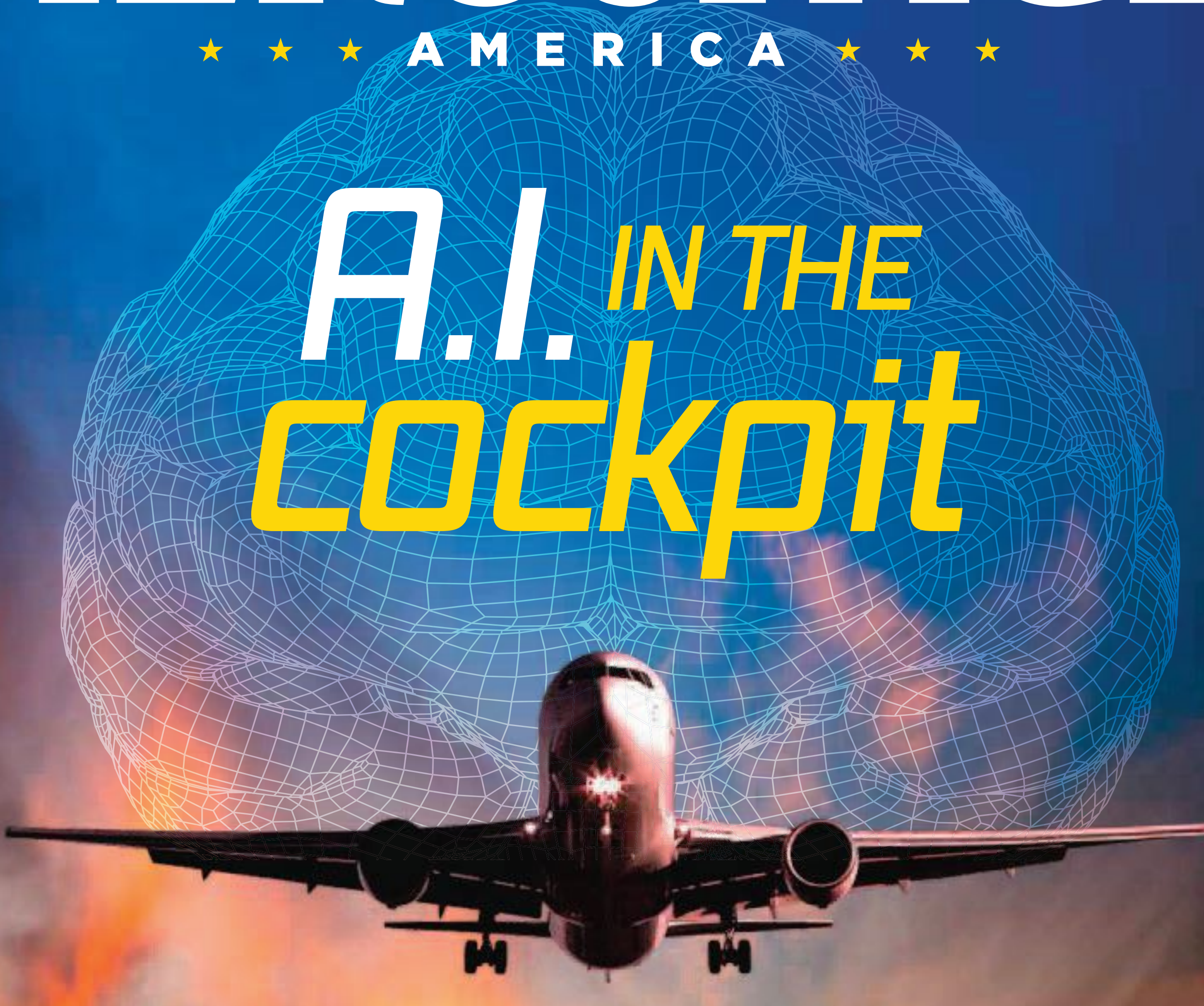
LAUNCH VEHICLES 14
Cutting waste from NASA's SLS

FUTURE TECH 36
Einstein rings and exoplanets

AEROSPACE AT WORK 28
Drones target climate, hurricanes

AEROSPACE
★ ★ ★ AMERICA ★ ★ ★

A.I. IN THE cockpit



Lion Air, Air France and the path to autonomous flight.

PAGE 24

Meet your AIAA
PRESIDENTIAL CANDIDATES
PG 8

AIAA
SHAPING THE FUTURE OF AEROSPACE

JANUARY 2019 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

On the cover
Image credit: iStock


AIAA CONGRESSIONAL VISITS DAY
WEDNESDAY, 20 MARCH 2019
Advocate for Aerospace on Capitol Hill
Every year, AIAA members—engineers, scientists, researchers, students, educators, and technology executives—travel to Washington, DC, for a day of advocacy and awareness with national decision makers. Spend a day meeting with new and established congressional members and their staff.
Your participation, enthusiasm, and passion remind our lawmakers that aerospace is a key component of an economically strong and secure nation. If you are interested in the future of your profession, the advancement of technology, the furthering of scientific research, and the strengthening of our nation's security, this event is for you!
Travel subsidies are available
"I enjoy the fact that CVD connects generations of enthusiastic aerospace professionals. For one day they all bring a single voice to the Hill, informing and compelling Congress to support one of our most vital national interests."
KEVIN SIMMONS, Science Educator, The Weiss School (Florida) Founder, BLUECUBE Aerospace
LEARN MORE
aiaa.org/CVD
AIAA
SHAPING THE FUTURE OF AEROSPACE

AEROSPACE AMERICA

JANUARY 2019, VOL. 57, NO. 1

EDITOR-IN-CHIEF
Ben Iannotta
beni@aiaa.org

ASSOCIATE EDITOR
Karen Small
karens@aiaa.org

EDITOR, AIAA BULLETIN
Christine Williams
christinew@aiaa.org

EDITOR EMERITUS
Jerry Grey

CONTRIBUTING WRITERS
Keith Button, Adam Hadhazy, Tom Jones, Robert van der Linden, Amanda Miller, Debra Werner, Frank H. Winter

John Langford **AIAA PRESIDENT**
Daniel L. Dumbacher **PUBLISHER**
Rodger S. Williams **DEPUTY PUBLISHER**

ADVERTISING
advertising@aiaa.org

ART DIRECTION AND DESIGN
THOR Design Studio | thor.design

MANUFACTURING AND DISTRIBUTION
Association Vision | associationvision.com

LETTERS AND CORRESPONDENCE
Ben Iannotta, beni@aiaa.org

Aerospace America (ISSN 0740-722X) is published monthly except in August by the American Institute of Aeronautics and Astronautics, Inc., at 12700 Sunrise Valley Drive, Suite 200 Reston, VA 20191-5807 [703-264-7500]. Subscription rate is 50% of dues for AIAA members (and is not deductible therefrom). Nonmember subscription price: U.S., $200; foreign, $220. Single copies $20 each. Postmaster: Send address changes and subscription orders to Aerospace America, American Institute of Aeronautics and Astronautics, at 12700 Sunrise Valley Drive, Reston, VA, 20191-5807, Attn: A.I.A.A. Customer Service. Periodical postage paid at Reston, Virginia, and at additional mailing offices.

IN THIS ISSUE

Keith Button

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

PAGE 24

Adam Hadhazy

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

PAGE 30

Tom Jones

Tom flew on four space shuttle missions. On his last flight, STS-98, he led three spacewalks to install the American Destiny Laboratory on the International Space Station. He has a doctorate in planetary sciences.

PAGE 20

Amanda Miller

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

PAGE 12

Debra Werner

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

PAGES 64

DEPARTMENTS

AIAA presidential candidates strike some common themes

▲ **Candidates for AIAA president,** from left, Basil Hassan, George Nield and Wanda Sigur.

The best thing about being a journalist is that it gives me an excuse to engage in heady discussions with fascinating people. Here are some takeaways from my interviews with AIAA candidates (See Page 8 for excerpts and online for extended interviews).

First, let me share an important but unsurprising observation: The three candidates are all longtime AIAA members and high achievers in their day jobs. Basil Hassan of Sandia National Laboratories helps assure the deterrent value of U.S. nuclear weapons; George Nield, after retiring from FAA in 2018, continues to do his part to open up space to commercial enterprises in a consulting role; Wanda Sigur, after contributing to some of the greatest U.S. achievements in space at Lockheed Martin, advises young companies how to achieve their own daring visions.

Each of the candidates, of course, has unique ideas, and you can find them in these interviews. What struck me most were some common signals in their visions for how to better serve prospective AIAA members at a time when consumers have more choices than ever about how to enrich their professional lives and build their career networks.

One theme was that members need more than a venue for sharing technical information, as important as that will always be. Hassan says AIAA needs to "expand to include those whose career paths are going in a different direction." Nield says AIAA "can be a bridge between jobs, or even a bridge between careers." Sigur wants to make 10-year professionals "aware of current opportunities and how to grow their careers."

Each candidate also recognizes the importance of thinking differently about information sharing and professional networking. Hassan notes that "we have something called Google," which means that AIAA must adapt how it delivers information and also "how we accomplish the ability [for members] to network." Nield notes that "work-life is changing. Companies are changing. The whole idea of a professional society needs to change along with some of these new technologies," and he offers some specific proposals for how to become more relevant. Sigur wants to find new ways to empower midcareer professionals to have direct contact with seasoned experts: "Wouldn't it be great if you were able to call the guy? I mean that's what's the difference between people at the top of the organizations and folks that are working in the trenches so to speak: They know the guy."

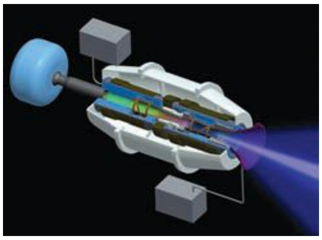
This is just a sample of what you will find in these interviews. I encourage you to dive in before you vote.

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

Next-Generation search and rescue

The article "Next-Generation Search and Rescue" [November 2018] asked: "Why not simply transmit your GPS coordinates to the rescuers?" Cospas-Sarsat does so. The Cospas-Sarsat system has accepted forwarded GPS position data from emergency beacons since 1997. All popular personal locator beacons now sold in the U.S. transmit the user's GPS location. The Doppler processing detailed in the article provides a valuable layer of redundancy for situations where GPS service is questionable.

Richard A. Fowell
AIAA senior member
Los Angeles



Ad Astra Rocket Co.'s image of a Variable Specific Impulse Magnetoplasma Rocket core.

The perilous road to Mars

I see from the latest issue of Aerospace America that VASIMIR, for Variable Specific Impulse Magnetoplasma Rocket, has risen again ["The perilous road to Mars," November 2018]. It's been around forever. Arc jets have flown, Hall thrusters have flown, and ion thrusters have flown. But VASIMIR has never flown, and it's hard to believe it ever will. I think there should be more critical discussion of such issues in the magazine, and not just pie in the sky.

Thomas R. Brogan
AIAA associate fellow
Burlington, Vermont
tcon4@juno.com

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

Weighing risk

Q. A man wants to take his wife for a ride on a hot air balloon for their anniversary. He learns from a safety advocacy group that balloon companies in the U.S. average a fatal accident once every 50 years. One company in his area has never had a fatal accident in its 98-year history. Should the man immediately cross that company from his list because it's obviously due for a fatal accident or should he get out his credit card and make a reservation? What do probability and statistics say about this dilemma, if anything?

FROM THE DECEMBER ISSUE

Q. We asked you why a professor tossed a paper airplane at a student who was attempting to explain lift. We invited Mark Guynn of NASA Langley in Virginia, Anya Jones of the University of Maryland, and David Mayhew, retired from Boeing, to review the responses independently. They were unanimous about the winner:

A. The professor likely reached for the paper as soon as he heard that "it's all about the curved upper surface" because it is, in fact, not all about the curved upper surface! While the slacker had a point that the faster moving particles would cause a corresponding decrease in static pressure over the upper surface of the airfoil (as per Bernoulli's equation), he incorrectly attributed the speeding up of particles solely to the camber of the airfoil. Many shapes, objects, and airfoils can generate lift as long as they can impart a change in the wind velocity flowing around them. Symmetric airfoils at a positive angle of attack can induce flows similar to those around cambered ones, and even spinning cylinders will cause a differential in the relative wind across their surfaces which would then lead to a lift force. It is likely for this reason that the professor began creating an aircraft with 'flat plate' wings: to share a little bit of knowledge on flat plates, angle of attack, and origami!

Daniel Yu
Land O' Lakes, Florida
Danielyu14@gmail.com
Yu is a software engineer at TRU Simulation + Training and a 2018 graduate of the University of Illinois at Urbana-Champaign.

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

Meet your presidential candidates

Basil Hassan

CURRENTLY: Senior manager for the Engineering, Stockpile Analysis and Responsiveness Program at Sandia National Laboratories in New Mexico

NOTABLE: Manages a team that develops engineering techniques to assess and sustain the U.S. nuclear weapons deterrent. Former manager of Sandia's Thermal, Fluid and Aero Sciences Group. Coordinated Sandia's contributions to the investigation of the 2003 Columbia space shuttle accident, including modeling that helped determine that foam from the external tank caused the hole in the wing. Conducted undergraduate and graduate research on hypersonic computational prediction techniques at NASA's Langley Research Center in Virginia. Grew up in Raleigh, North Carolina.

AIAA RECORD: Board member 2008-2017. Assisted with creation of today's forum conference model. Introduced to AIAA by his father, Hassan A. Hassan, as a boy in the 1970s. Now an AIAA fellow.

AGE: 52

RESIDES: Albuquerque, New Mexico

EDUCATION: Bachelor of Science, 1988; Master of Science, 1990; and doctorate in aerospace engineering, 1993, from North Carolina State University

FAVORITE SAYING: "Tomorrow is the first day of the rest of your life."

Why he wants to be president >>

I've reaped a lot of benefits from being a member, both personally as well as professionally, and I want to make sure that the younger professionals who are coming out of school have the opportunity to be able to experience some of the same things I did. If AIAA is going to be a venue to do that, we have to think about evolving ourselves and making sure that those networking opportunities, those information exchange opportunities are not only meeting the needs of the current members but are also going to be meeting the needs of our future members.

Lowering the entry barriers >>

The first thing I'd like to make sure we do is that we provide potential members that value proposition of why AIAA is important both personally and professionally. That comes by making sure we have a lot of engagement opportunities. Not everybody's going to be able to travel, so we need to sort of lower the barrier of entry to allow people to participate, and I think that's just going to be different than the normal model we've done in the past.

Future members >>

We need to engage the younger professionals earlier. When I was a student, being a student member of AIAA was an expectation from the faculty. I've been on five university advisory boards during my career at Sandia, and I'm finding that participating in AIAA is an option now. When I go speak to AIAA student members, I'm constantly telling them that, "Hey, this is a good thing. I wouldn't be here talking to you today if it wasn't for my participation."

Continued on Page 10

George Nield

CURRENTLY: Independent consultant based in Virginia

NOTABLE: Retired from FAA in 2018 as associate administrator for Commercial Space Transportation. Started his own company, Commercial Space Technologies LLC. Worked at FAA for 15 years, before that at Orbital Sciences Corp. for four years, and at NASA Johnson in Houston for 16 years on the space station and shuttle programs. At the U.S. Air Force Academy, taught astronautical engineering and instructed Air Force cadets in gliders. Rated to pilot single and multi-engine aircraft. Grew up in Annandale, Virginia.

AIAA RECORD: Joined AIAA as a Stanford student in 1973. Chairman of the AIAA Houston Section, 1994-95 and 1997-98. Director Technical/Space and Missile Systems Group and member of the AIAA national Board of Directors, 1999-2005. Director-Technical/Space and Missile Systems Group and member of the AIAA national Board of Directors, 1999-2005. Now an AIAA fellow.

AGE: 68

RESIDES: Potomac Falls, Virginia

EDUCATION: Bachelor of Science in engineering science from U.S. Air Force Academy, 1972. Master of Science, 1973, and doctorate, 1981, in aeronautics and astronautics from Stanford University. Master of Business Administration from George Washington University, 2001.

FAVORITE SAYING: "If you don't know where you are going, any road will get you there."

Every two years, AIAA members select a president-elect who will help guide the institute as a member of the Board of Trustees and as president beginning a year later. This year's candidates have strong visions about how to modernize the institute and better serve its members. I interviewed each by phone for this special section and the expanded versions of the interviews online. — *Ben Iannotta, editor-in-chief*

MEMBERS VOTE: Feb. 4 through March 8. See ww.aiaa.org/vote/
THE STAKES: Winner begins a one-year term as president-elect on May 15 followed by two years as president starting in May 2020. Winner also becomes a member of the Board of Trustees.

Wanda Sigur

CURRENTLY: Independent consultant based in Houston

NOTABLE: Former vice president and general manager of Lockheed Martin Space in Denver. Led Lockheed Martin's work on the space shuttle external tank return-to-flight after Hurricane Katrina in 2005 and the company's input to the Columbia accident investigation in 2003. Pioneered career development programs for engineers and leaders. Represented Lockheed Martin Space on the company's Executive Diversity Council. Provided funding for development of the Mars Base Camp proposal for an orbiting station at Mars. Led the team that welded the domes and barrels of the space shuttle's aluminum-lithium external tanks, which made the shuttles light enough to reach the space station. Grew up in New Orleans.

AIAA RECORD: Joined AIAA after being hired by Lockheed Martin. Became secretary and treasurer of her local section. Now an AIAA senior member.

AGE: *"Really?"*

RESIDES: Houston

EDUCATION: Bachelor of Science in materials and mechanical engineering from Rice University in Houston, 1979; Master of Business Administration from Tulane University, 2002.

FAVORITE SAYING: Growing up in Louisiana, my godmother, Angelina Gilbert, used to say, "Nothing beats a trial but a failure," which was a version of an old saying in the South about the value of trying even if you don't succeed.

Why she wants to be president >>

I still remember what AIAA did for me. It established a foundation. It was a chance for me to meet folks that helped my career go forward. I can increase membership, but more importantly I can help make those folks who are opting in to this exciting industry be more capable. It's something that I am doing and will continue to do regardless. It's a passion I have for making folks successful in this industry.

Helping midcareer professionals >>

The numbers of [AIAA] members are dropping, but most significantly they're dropping in the midcareer range. The 10-year professionals are not finding AIAA to be their organization of choice. That can be and needs to be turned around. People are engaged in organizations, but not necessarily engaged in AIAA because it doesn't focus on what helps them move forward. A midcareer professional is looking for perhaps some information on where they are in their career and what else they could be.

Continued on Page 10

Why he wants to be president >>

We're at a pretty unique place in history right now, whether it's the proliferation of drones and flyback boosters, reusable launch vehicles, and the development of flying cars and all-electric aircraft, plants, the lunar settlements, human missions to Mars, point-to-point transportation through space. I see huge potential for us as an organization to try to steer our nation and our society and our industry in the right direction and accomplish some really great things.

Untapped potential >>

We have 1 percent of the number of people that are in aerospace and defense who are members of AIAA, and that is just ridiculous. It should tell you that we're missing a boat somewhere.

Setting goals >>

I really resonated with the book "Good to Great" by Jim Collins. He observes that the really, really good [companies] have "Big Hairy Audacious Goals." There's no reason why we can't do that at the AIAA.

Target of 3 percent membership growth >>

Too easy. We need to at least be talking about doubling [AIAA's membership] in the next few years. Even that is not where we need to be long term, but I don't know how long it's going to take to build some of the relationships with universities, with companies, with the government agencies that can result in, frankly, a trust between AIAA and those organizations that can see this as a win-win.

An AIAA aerospace prize >>

Prizes are something that have been inextricably linked to advances in aerospace right from the start. It makes me wonder: Could AIAA be engaged in coming up with the prize? Either funding some of it ourselves, or getting corporate sponsors, or even talking to some of the wealthy space cadets out in Silicon Valley and see if they'd be interested in working with AIAA.

Teachers in space >>

We've got Virgin Galactic and Blue Origin ready to start their

Continued on Page 10

Basil Hassan *Continued from Page 8*

AIAA as networking opportunity >>

Sometimes it takes one person to make a difference in being involved in an organization like this. When I was a graduate student, I had a mentor at NASA Langley Research Center, David Throckmorton, who encouraged me to join an AIAA technical committee. He told me, "This is one of the best things you can do because it will get you to the conferences. The networking opportunities would really be great." I asked my boss when I first started working in Sandia if it was OK if I got involved, and he said, "Absolutely." A lot of the things I've done during my career, including helping to bring programs and funding to Sandia, wouldn't have happened had I not had that opportunity through AIAA.

Need to adapt >>

If you look at today's aerospace professionals, getting access to information and networking is still very much important, but we do it a lot differently now. We have something called Google, which we can type a question into and probably get 75 percent of the information we need. The needs of aerospace professionals are changing, and how we deliver that information and accomplish that ability to network is changing as well.

Learning to lead >>

I grew up to be a better leader by moving through the different volunteer opportunities that I had within AIAA and that's made me a better leader back here at work. It's a lot harder to convince a set of volunteers to do something than it is to convince someone who works for you, and I've been able to hone my leadership skills through AIAA.

Wanda Sigur *Continued from Page 9*

Wider audience >>

I want it to have a vision of AIAA being inclusive, which means that it's more than just those top folks who get a chance to attend forums, but perhaps using digital media and other tools, we'd be able to reach wider populations and provide ways for them to express their competence and capabilities.

Personal touch >>

We need to recognize that the AIAA that a person experiences is the AIAA that touches them at their job. Wouldn't it be great if you were able to call the guy? I mean that's the difference between people at the top of the organizations and folks that are working in the trenches: They know the guy. They know the person who actually executed the task. I think that having that accessible for folks is a big deal. I'm working with a company now that's working on design trade and we were able to bring in an expert who was able to sort through all that information and was able to cut months off the schedule. Those are the kinds of things that having access to the right information can do. I think AIAA is an organization that can make that happen.

Untapped potential >>

When you called, I was watching footage from the OSIRIS-REx satellite, which today reached the orbit around the asteroid Bennu. That's magical. We had a landing on Mars last week. I had the fortune to meet some folks who were talking about autonomous flight and urban air mobility. There is so much happening in the world today, you would think that there would be a clamor for everyone to become part of the largest professional, technical society in aerospace. I think AIAA is that society, but I don't see the numbers reflected in the numbers of folks who are opting in.

More diverse workforce >>

I see that there is a possibility for a more diverse — in fact, a mandate for more diverse — workforce. AIAA seems to me that type of an organization that could provide a way for those things to happen.

Working with young people >>

Wouldn't it be fantastic if [young people] were able to take advantage of the resources that AIAA has, the expertise that AIAA has, and engagement with fellows and others to provide that safety net of information and data that allows for them to be successful? I think AIAA represents an organization that has all that capability.

George Nield *Continued from Page 9*

regular step orbital flights in the next 12-18 months. Once they get going, maybe you bring back Teacher in Space, but instead of taking one teacher all the way to orbit, you take dozens of teachers ever year on a suborbital flight, or at least make available space-related training, and then they go back to their classrooms. I just get goosebumps thinking about what effect that could have on students today.

Involving educators >>

Let's expand our Educator Associate Program and have it be a goal that we sign up at least one teacher in every school. That could really bring some of that next generation into the tent in terms of this exciting stuff going on. I want to be a part of that.

Adapting to new needs >>

We need to do a better job of showing people how AIAA can be a bridge between jobs, or even a bridge between careers. Secondly, I don't think AIAA has been very successful at retaining its student members once they graduate and become part of the workforce. So we need to convince them why they need to stick around. I'm not sure AIAA has been keeping up with all of the changes in technology. We need to offer more opportunities to learn about, or to develop policies that deal with some hot topics, like drones, and electric aircraft, smallsats, space traffic management, and point-to-point transportation through space.

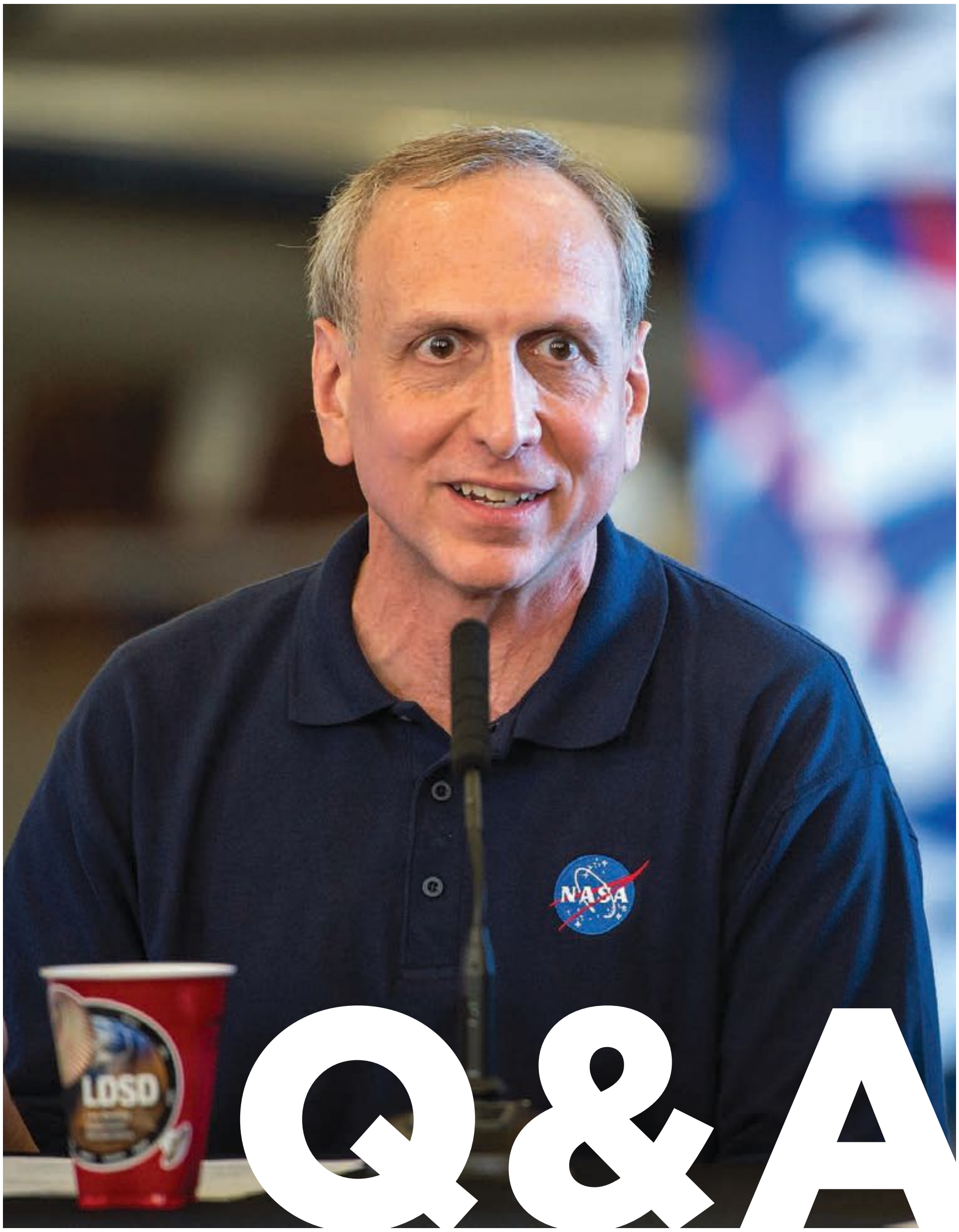
If you combine all these things and try to address those, I think the membership will almost take care of itself.

SURPASSING 5 MILLION FLIGHT HOURS

ga-asi.com

GENERAL ATOMICS AERONAUTICAL

Leading The Situational Awareness Revolution



NASA

NASA's top civil servant

Steve Jurczyk commutes to his headquarters job in Washington, D.C., by train, bypassing an inevitably traffic-choked drive. "No matter how much they widen the roads, the traffic expands to fill them up," according to NASA's top-ranking civil servant, illustrating why humans need to get more day-to-day traffic off the ground and into the third dimension. He had already packed his parka, when we spoke, for a trip to Kazakhstan to attend the December launch of a Soyuz spacecraft carrying a U.S. astronaut after a prior — and quite a dramatic — botched attempt that somehow left no one injured. Somewhat new to the job, Jurczyk may not get many more chances to make the trip. NASA hopes its emerging Commercial Crew Program will end the United States' reliance on Russia to take astronauts to the International Space Station while at the same time opening up commercial lines of transportation to low Earth orbit to stimulate the economy across a range of industries there.

— Amanda Miller

STEVE JURCZYK

POSITIONS: NASA associate administrator, the third-ranking position behind presidential appointees Jim Bridenstine, administrator; and Jim Morhard, deputy administrator, since May 2018; associate administrator, NASA's Space Technology Mission Directorate 2015-May 2018; director, Langley Research Center, Virginia, 2014-2015; deputy director, Langley, 2006-2013; director of research and technology, Langley, 2004-2006; director of engineering, Langley, 2002-2004; design, integration and testing engineer, Langley's Electronic Systems Branch, 1988-2002.

NOTABLE: Among the first at Langley contacted by then-startup SpaceDev (now Sierra Nevada Corp. Space Systems) about plans for the Langley-developed HL-20 lifting-body spaceplane concept that became SNC's Dream Chaser spacecraft. "So I'm partial to that," he says. "I shouldn't say that, but I am." He's a recipient of the federal government's highest leadership honor, the Presidential Rank Award for Distinguished Executive; AIAA associate fellow

RESIDES: Southern Virginia

EDUCATION: Bachelor's and master's degrees in electrical engineering from the University of Virginia in 1984 and 1986.

More online
aerospace america.aiaa.org

IN HIS WORDS

Commercial Crew concept

The original vision was that NASA would purchase seats but that other commercial entities, both domestic and international, would also purchase seats. And then the cost of further developing and operating those vehicles would be spread across a business base that was more than just NASA. That was the original vision. The other vision was industry investment in development of those vehicles. And we did see some of that.

Stimulating a service

Some of the early-on folks could not raise the money they needed to invest, and others were able to, and that allowed NASA to successfully get through the initial phase, which was the COTS [Commercial Orbital Transportation Services] program, through the funded Space Act agreements. And then once it looked like we had viable providers, then we moved to a standard, fixed-price, Federal Acquisition Regulation, FAR-based contracting approach, which is what we're doing now, to buy services.

First customers

I think initially it would probably be other government agencies. I know United Arab Emirates, UAE, has an agreement with Russia, actually, training to fly some of their astronauts on Soyuz. We don't know about ISRO, the Indian space agency, which recently expressed a goal to establish a human spaceflight activity in the early 2020s — we don't know what their plans are yet.

Orbit itself as a destination

Oh yeah, absolutely, [tourist flights will go to orbit and back]. The challenge there will be, there's only a small percent of the population that can afford that kind of flight. And of course, Blue Origin, too, they have this vision — they're not involved in Commercial Crew; right now we do some orbital flights with them through the Fly Opportunities program — but they have a vision of hundreds of thousands of people living and working in space. So that could also provide opportunity for commercial passenger services.

Research and development in space

We definitely would like to see commercial capabilities in low Earth orbit for research and development, to demonstrate and advance technologies and capabilities, and to create both commercial activities in space, like this robotic manufacturing assembly-type capability, [and] also R&D and manufacturing in space, where the final use of the product is on Earth. Some of those things can be done robotically or autonomously, but some of those things are going to require crewed capabilities and missions.

Sensing change

Commercial remote sensing has started to move to a more robust commercial enterprise. But there's a set of things we think we'll see in research, development, manufacturing, tourism, etc., with some enablers like reduction in the cost of access to space — that's a real inhibitor, right, routine access to space — for systems and also eventually people. Applications of technologies like automation and robotics and manufacturing. We're hoping to enable a much more robust set of commercially viable activities. And NASA will be one of the customers. We're going to continue to need R&D and things in low Earth orbit, but it'll be a much more diverse set of customers in low Earth orbit — much more activity, which will provide opportunity for not only the commercial providers for systems but also for launching crew where you need people to actually do the R&D or the manufacturing or for tourism.

> **"We're hoping to enable a much more robust set of commercially viable activities. And NASA will be one of the customers."**

U.S. Commerce Department

We see Commerce taking several roles, and that is developing a regulatory framework and reducing the regulatory burden on companies, so it's easier to enable these new capabilities and services. So that's one thing. The other thing is we want to develop a plan with Commerce and other agencies of how the government should be working with industry most effectively to enable these capabilities — through buying services, through technology development, through collaboration — like we've done on Commercial Cargo and Commercial Crew. We want to take that and extend it to other capabilities. We want to make sure that what we're doing with respect to collaborating with industry and advancing their interests is consistent with the policies that they put into place for supporting a commercial space industry. And so we are actively working with them from the Secretary [Wilbur] Ross level and Administrator [Jim] Bridenstine level on down, making sure that what we're doing is complementary and consistent and we're kind of rowing in the same direction.

Commercial space traffic

We have been clear. We are not a regulatory agency, and we should not be a regulatory agency. We have two other agencies that can do that, and we'll continue to collaborate with them just like we collaborate with the FAA on the air traffic management side, we collaborate with FAA on the space side, and we're beginning to develop that relationship with the Department of Commerce.

FAA's role

The [Trump] administration wants to give the space traffic management to Commerce. The House of Representatives, their legislation says Commerce. The Senate says FAA. There are individual members in Congress who believe FAA should be it, and [the FAA] were already kind of standing that up. In the meantime, we're working with Commerce to try to move out, given the administration's direction. But we already have the relationships if, in the end, everybody decides it's the FAA and not Department of Commerce on the traffic management side, on the commercial side, then we already worked with FAA on Commercial Cargo and Commercial Crew. We already have the relationships. ★

Better booster production

The retirement of the space shuttle fleet in 2011 afforded an opportunity for NASA and industry managers to take a fresh look at production practices. Justin Pancoast of Northrop Grumman explains how engineers expunged inefficiencies from production of the solid rocket boosters for NASA's Space Launch System, the agency's next human-rated launch vehicle.

BY JUSTIN PANCOAST


Northrop Grumman

◀ **Northrop Grumman** technicians apply high-performance ablative insulation materials to the inside of an SLS booster segment.

When you've perfected the manufacturing of a product over decades for a government customer, it isn't easy to make changes. In the aerospace industry in particular, no one wants to introduce risk by modifying processes, even when new materials become available and innovative technologies emerge.

When NASA retired the space shuttle fleet and transitioned work to the heavy lift Space Launch System, or SLS, it opened the door for Orbital ATK, now Northrop Grumman Innovation Systems, to make changes that could simultaneously improve the quality and cost of the large solid rocket boosters the company builds for SLS. Part of my job during that review in 2011 and 2012 was to help come up with changes in my work area, the insulation component work center where SLS boosters are now prepared. During the shuttle program, bare metal rocket motor cases and components began their production journey here following refurbishment after a previous space shuttle flight. Today, metal case surfaces are meticulously cleaned and prepared for exterior painting and internal case bonding operations. Erosion-resistant thermal insulation materials are applied to interior case surfaces to protect metal hardware from the heat generated by burning propellant. Following the autoclave curing of this insulation layer on the case, an adhesive liner is applied to act as glue between the insulation and propellant that will be cast in a different facility after liner application. In addition to insulated cases, this center is also responsible for fabrication of the flex bearing, which is a critical component of the booster that allows the thrust vector control system to move the nozzle for steering control.

Similar efforts took place concurrently in each of the other work centers — case refurbishment, non-destructive inspection, insulation, nozzle, mix-cast and final assembly — as well as in administrative support functions, such as supply chain management, finance and quality.

We followed six steps to make these changes.

Step 1: Involve the customer

When I started working with the other members of the insulation component work center team on this assignment, building a solid rocket booster was an orchestrated process that had developed and evolved over the course of the Space Shuttle Program. Throughout the program the original process had grown little by little to include additional checks and inspections introduced to correct and/or verify problem areas within the process. These additions were in response to non-conformances discovered at later stages of production or during post-flight inspections. There were many "obvious" (or so we thought) areas where we could reduce cycle times — the number of hours required to manufacture each part of the booster — by modifying or eliminating production steps and eliminating wasteful practices in general. However, we were concerned NASA might not be willing to accept those changes, as the existing processes were flight-proven over many years and had evolved with mission success in mind.

During our first several meetings with NASA as the prime contractor for the SLS booster element, the agency made it very clear that it was fully on board with nearly any change we could potentially bring forward, as long as we were able to develop a clear technical rationale for the change, and assurances that it would not diminish final quality or product performance and would offer a positive return on investment. We also had to get all proposed changes approved and implemented through established control procedures overseen by a joint NASA/Orbital ATK leadership team.

Alex Priskos, who was NASA's SLS booster manager at the time, praised our company's concerted effort to eliminate waste and drive down costs while managing risk. In a "thank you" video to employees in 2012, Priskos said NASA had "accepted the reality that we must embrace change rather than avoid it. We are embracing innovation both technically and in our management processes in order to be successful in these constrained budget environments. ... Our shared goal is to deliver a safe, affordable and sustainable launch vehicle."

Step 2: Map the baseline

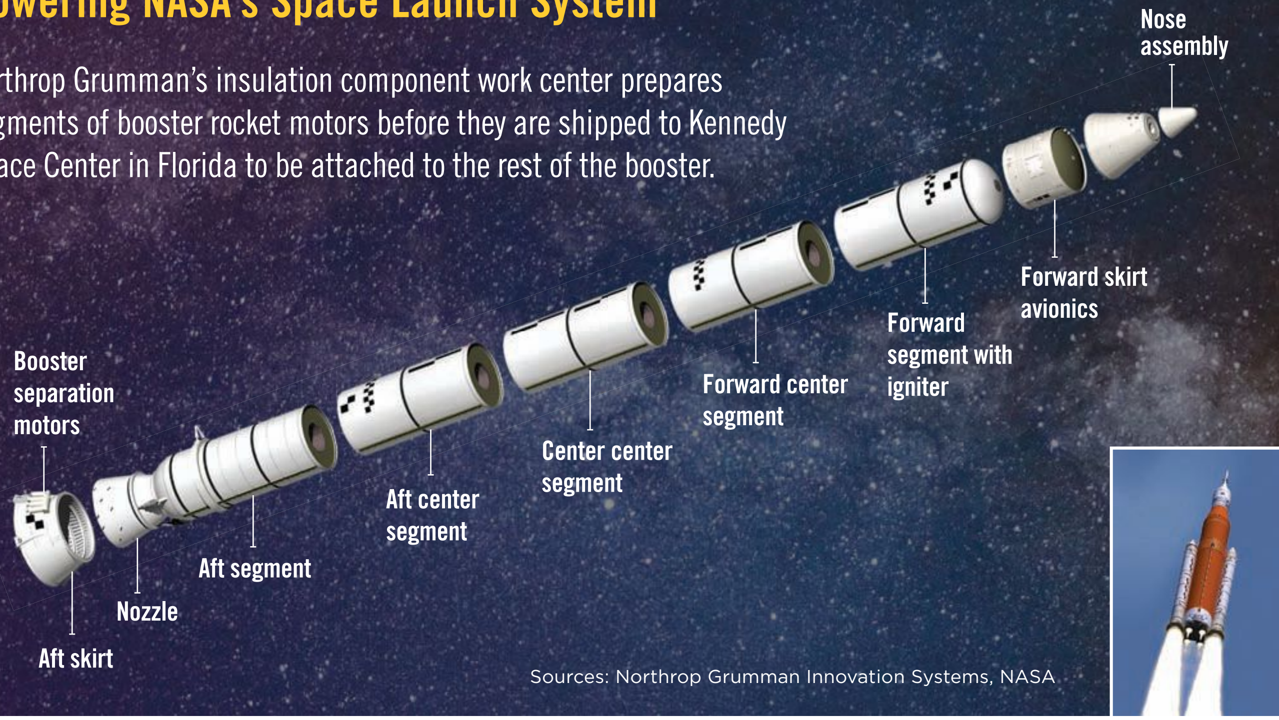
Our next step was to map out the baseline process. We had dedicated conference rooms (designated as war rooms) where we would lay out a process flow diagram and post it on the wall to have a visual reference. Then we used Post-It notes of various colors to identify all of the process steps and laid them out in proper series and parallel flows, so we would see the interconnectedness and have the ability to move the process elements around as we worked through the modifications. In addition to mapping the flow, we estimated cycle times for each part of the process. The frustrating (and informative) part of this effort was that we had to revise the baseline process flow a number of times as we went through the planning documents to verify that we fully understood our baseline process. There ended up being a number of moves and holds in the process that, although we were aware of them, hadn't been included in the original layout of the process. By the time we completed the baseline process layout, we had already identified a couple of moves we could potentially eliminate by combining operations in one station rather than moving a 3.7-meter-diameter steel cylinder weighing anywhere from 9,000 to 14,000 kilograms from station to station, thus reducing cycle time, improving safety, and reducing risk to the product.


Northrop Grumman

▼ **After vertically** stacking two case cylinders together to create an SLS booster center segment, technicians perform a breakover procedure to transport the hardware for horizontal case insulation layup operations. The segments shown are destined for the Exploration Mission-1 vehicle that will send an uncrewed version of the Orion spacecraft around the moon.

Powering NASA's Space Launch System

Northrop Grumman's insulation component work center prepares segments of booster rocket motors before they are shipped to Kennedy Space Center in Florida to be attached to the rest of the booster.



Sources: Northrop Grumman Innovation Systems, NASA

Step 3: Have conversations with the customer about obvious waste

As we started to look at the process in more depth, we came up with more ideas about how to reduce the amount of time required for various steps. Sometimes these ideas were relatively simple. For instance, our baseline insulation process required a 55-minute dry time after cleaning with a specific solvent. Other work centers doing similar critical bonding operations successfully used a 30-minute dry time for the same solvent on a very similar material. By aligning our dry time with that used by other work centers, we could eliminate 25 minutes of process time on every step where that solvent was used. NASA asked for verification that the change would not impact bond integrity. We were able to point to the similarity with other work centers and develop bounding technical rationale for the change. As a result, NASA asked us to implement the change immediately. We found another easy refinement was in the standard practice of performing an alcohol wipe on bonding surfaces just prior to bonding. At first glance, this seems like a prudent precaution. However, the practice had crept over the years to the extent that operators were cleaning some parts multiple times even though they had not undergone any additional processing. We determined the alcohol wipes at these unprocessed stages were redundant and wasteful and could be eliminated.

Other process change recommendations were less straightforward but still relatively simple. As an example, over the years of the shuttle program, someone determined that a station used to apply a coating to the interior of the case segments would be more effective if operators introduced a heating capability to decrease dry times. That resulted in the need to let the coated part cool before operators could perform the next step in the process. We thought it might be possible to deliver ambient air to the station via what are normally heating ducts to "force cool" the part. After some testing we determined that the accelerated cooling did not introduce any changes to the initial coating. After hearing our justification, NASA allowed us to adopt the forced cooling option, saving nearly 24 hours of process time.

Another example was the procedure for touching up Alodine, which is a coating applied for corrosion resistance and surface preparation for bonding. As certain parts moved through the insulation component work center, operators would repair any scratches in the Alodine immediately, which introduced a delay into the process. The baseline process carried nearly 72 hours of process time to perform these touch-up operations while in the insulation component work center. Because the final assembly work center also had the requirement to perform any necessary Alodine repairs prior to final assembly operations, all Alodine operations in the insulation component work center were redundant. When we discussed the elimination of Alodine repairs in the insulation component work center, some team members hesitated to eliminate the repair of a corrosion control feature, but we determined that with the typical ambient conditions in

▲ **A team of technicians** removes the casting mandrel from a center segment after casting and curing the propellant.

Promontory, Utah, where we manufacture the solid rocket boosters, and the length of time involved in moving between facilities in Promontory, the risk was minimal and any necessary remediation was already in place as part of the touch-up procedures in the final assembly work center. NASA approved the elimination of Alodine touch-up in the insulation component work center, saving another 72 hours of process time.

We also scrutinized operations where segments sat idle, looking for additional opportunities to reduce cycle time. One such instance was the amount of time case insulation spent under vacuum prior to the curing process. Review of data on the boosters' new insulation materials and some very basic testing demonstrated a 73-percent reduction in vacuum sit time was possible, effectively shaving one to two days from the overall processing timeline.

Step 4: Challenge norms and debate recommendations

Once we identified and completed the more obvious changes, we made additional efforts to target operations that were potentially more divisive. We examined inspection records from the Space Shuttle Program to determine how often inspectors found defects at various inspection points. After a detailed analysis, we identified several inspection points that had not identified any defects during the duration of the program — that's more than 30 years and 330 boosters built (270 flight boosters and 50 static test motors). We deemed these inspection points unnecessary and recommended their elimination. A healthy debate with NASA representatives ensued, and after analysis of the risks involved, NASA agreed to the elimination of several of them. We did not eliminate all of the inspection points as the debates led to a consensus that a few inspection points were in place to screen for potential failure modes that while obviously unlikely were known and severe enough to warrant the inspection.

Similar to our examination of hardware inspections, we took a deep dive into raw material inspections to identify potentially wasteful practices. We found numerous instances where the material supplier and our own acceptance testing lab performed identical tests, duplicating efforts. In most instances this duplication was not an actual requirement, but a practice developed over time. Stopping this practice significantly improved lead time on the material's availability, and as a bonus, the extra capacity created in the lab enabled the lab employees to streamline their operations. We made similar material enhancements by carefully reviewing shelf-lives and re-test data on well-characterized materials used over the decades. We assigned new shelf lives to materials that re-tested multiple times without failing, as long as data and aging mechanism analyses supported the change. This resulted in not only less frequent raw material orders, but also greater availability of existing material inventories.

Step 5: Predict results

Over the course of the efficiency effort, which lasted several months, the insulation component work center team recommended changes predicted to reduce the time required to process a center segment of the five-segment booster from 54 days to 24 days. We predicted similar savings for forward and aft segments. For the overall booster operation, 31 teams identified 308 changes to eliminate waste in the workflow. Those changes resulted in cutting 447 material moves from

Northrop Grumman technicians inspect the vacuum bag covering the uncured interior insulation of a Space Launch System booster segment prior to autoclave curing. A good vacuum bag seal is critical for holding the uncured insulation in place and for gas removal during the curing process.

Northrop Grumman

the workflow, which translated into a predicted overall cycle time reduction of 46 percent.

Step 6: Implement changes and track actual results

Orbital ATK concluded this waste elimination exercise in 2012, and we continue operating under these improved processes as part of Northrop Grumman. The company has manufactured seven five-segment solid rocket motors: three development test motors, two qualification motors, and the two boosters for the first flight of NASA's Space Launch System. The flight boosters will be delivered to NASA's Kennedy Space Center in just a few months to be integrated into the vehicle that will enable humans to return to deep space for the first time in more than 45 years.

Having completed the 35 segments for these seven boosters using the improved processes, Northrop Grumman has enough data to validate the quality of the boosters and the actual reduction in cycle time. Much of those data are proprietary, but I can share that the results of multiple static tests indicate the changes in no way compromise the quality of the boosters. In addition, the plant as a whole now performs the same work it did during the Space Shuttle Program, but with a workforce that is less than half the size.

NASA's support of Northrop Grumman's concerted waste elimination initiative seemed revolutionary at the time; little did we know the agency was ushering in a new operating model that would become a permanent part of human spaceflight. Thanks to prime contractors willing to make changes to eliminate waste, and program leaders willing to embrace change while managing risk, NASA can confidently and credibly use words like "affordable" and "sustainable" when talking about human missions to deep space. Affordability and sustainability are just the characteristics we need in a human spaceflight program whose purpose is to return humans to the moon and send the first human explorers to Mars. ★

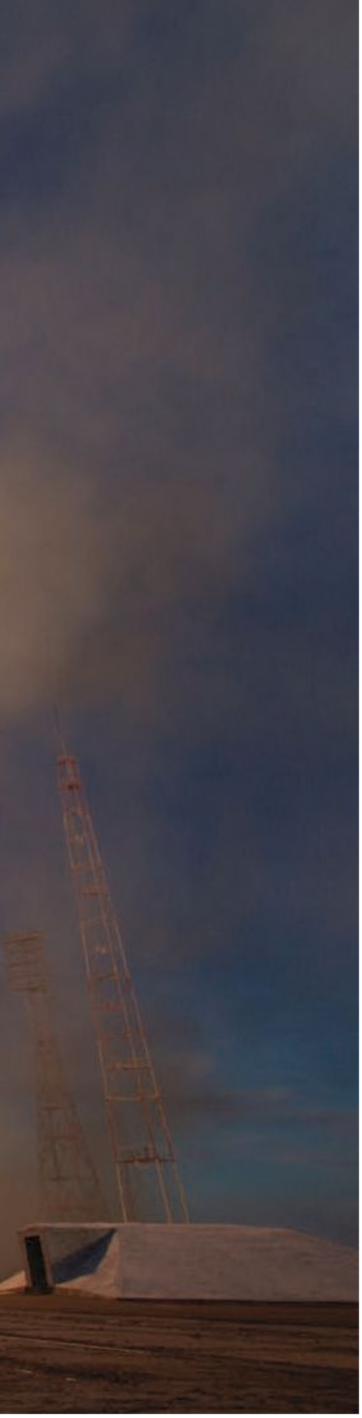
Justin Pancoast

is the engineering manager responsible for Northrop Grumman's Mechanical/Chemical Test Services and Receiving Inspection Labs in Promontory, Utah. Pancoast is an expert in internal rocket motor material system design and in advanced optical metrology measurement and analysis. He has a bachelor's degree in chemical engineering from Arizona State University and a master's degree in chemical engineering with a certification in systems engineering from the University of Utah.

Returning to flight

In spaceflight, failures are inevitable. If a commercial launch vehicle fails while flying NASA astronauts, how would NASA and the service provider return their systems to flight and assure astronaut safety? Veteran astronaut Tom Jones examines how NASA might cope with catastrophe.

BY TOM JONES | Skywalking1@gmail.com | www.AstronautTomJones.com



NASA

NASA TV

When a rocket or spacecraft carrying astronauts suffers a major failure, the shock can convulse a space agency, and indeed an entire nation. Following its three fatal astronaut accidents, NASA grounded its Apollo and shuttle spacecraft for anywhere from 21 months (after Apollo 1) to 32 months (after Challenger). Yet after the Oct. 11, 2018, failure of a Russian Soyuz booster carrying astronauts to the International Space Station, piloted flights resumed less than two months later, on Dec. 3, 2018.

Despite the safe recovery of the crew and rapid return to flight, the Soyuz failure should get us thinking about how NASA might recover from an inflight failure in its commercial crew transport program. Under current legislation, NASA might be grounded until a presidential commission completes an investigation, limiting our access to ISS.

I believe the legislated presidential commission requirement is too restrictive. History and the facts of the Soyuz case show that NASA needs a range of options in investigating accidents, certainly using the talents of the commercial service provider, and/or enlisting government entities like the FAA and the National Transportation Safety Board. NASA's aim — a timely and safe restoration of U.S. orbital access — won't always be well-served by a protracted standdown and commission-led investigation.

Soyuz close call

All appeared normal during the initial ascent from Baikonur of the rocket carrying Russian cosmonaut Alexey Ovchinin and U.S. astronaut Nick Hague on the Soyuz MS-10 mission. Following first-stage burnout 118 seconds after liftoff, at an altitude of 41 kilometers, pyrotechnics fired to drop the four strap-on boosters from the core stage. However, the "D" booster failed to separate cleanly and collided with the core stage, rupturing its propellant tank and sending the rocket out of control.

The abrupt attitude excursions automatically activated the spacecraft emergency escape system, cutting loose the Soyuz descent module from the rocket's third stage and triggering four rocket motors on the aerodynamic payload fairing. The three-second impulse from these solid motors pulled the fairing and the attached orbital and descent modules, with the crew inside, free of the crippled rocket.

Propelled to a peak altitude of 93 km, the descent module finally dropped free of the fairing 160 seconds after launch. The astronauts endured a steep, ballistic descent that saw a peak deceleration of 6.7 Gs. Slowed by its main parachute, the Soyuz descent module landed safely 19 minutes and 41 seconds after launch; recovery crews soon extracted Ovchinin and Hague, who came through in good condition. Roscosmos immediately convened an accident investigation board to find the cause of the abort and recommend corrective action.

Although the Soyuz rocket failed, Roscosmos took solace in the successful, automatic functioning of the emergency escape system. Despite the rapid breakup of the launcher, the system detected the failure and pulled the spacecraft and crew to safety.

Russian recovery

Roscosmos grounded the Soyuz system until the failure's cause could be identified and corrective action implemented. Telemetry and video plainly showed the booster collision with the core stage, but what caused the recontact? Examination of wreckage recovered downrange in Kazakhstan helped reveal that a separation sensor on the errant "D" booster (one of four strap-ons) had failed to trigger the opening of a cover on the booster's reverse-thrust nozzle. The nozzle was to vent high-pressure oxygen from the booster's liquid oxygen tank, pushing the booster away from the core stage. The booster's nose, scraping along the core instead, sliced open the core stage kerosene propellant tank, destroying the rocket.

Investigators traced the sensor failure to physical damage (a slightly bent pin) caused during assembly at Baikonur, a process error like one that destroyed a Soyuz in 1986. Because the October failure was not caused by a design flaw, Roscosmos directed inspections of future Soyuz boosters to verify proper sensor installation. On Nov. 16, the fourth Soyuz to launch since the failure rocketed a Progress cargo freighter to the ISS. That launcher flew in the same configuration as that of the Soyuz crewed mission, launched on Dec. 3.

▲ **A Soyuz rocket** launches the Soyuz MS-11 spacecraft from the Baikonur Cosmodrome in Kazakhstan in December, less than two months after a launch failure.

▶ **A SpaceX Falcon 9** rocket explodes in 2015 after launch from Cape Canaveral Air Force Station, Florida. The subsequent investigations included the company, FAA, NASA and the U.S. Air Force.

In contrast to its adjunct role in past cargo launch failures, NASA would have a much larger part to play in any accident involving a commercial crew.

Past space failures

After 1967's fatal Apollo 1 pad fire, NASA took 21 months to redesign the spacecraft and fly astronauts on Apollo 7. Recovery from the Challenger disaster took 32 months and recovery from Columbia took 30.

Two fatal Russian space accidents, 1967's Soyuz 1 and 1971's Soyuz 11, required 18 and 27 months for crewed flights to resume. By contrast, when the Soyuz T-10a emergency escape system saved a cosmonaut crew from a catastrophic launch pad fire in 1983, the Soviets resumed flights in just seven months. Regaining confidence in a flight system takes less time if the astronauts survive the failure; only the launcher, less complex than the crew's spacecraft, needs the fix.

The two-month recovery time for October's Soyuz MS-10 failure was possible, first, because it was caused by a human processing error and not a design flaw. Second, the escape system saved the crew. Had two astronauts been lost in October, a lengthy, in-depth investigation and spacecraft redesign would have been necessary.

An added incentive to resume operations quickly after October's failure was the need to launch a relief crew to the ISS. The three Expedition 57 astronauts would have had to leave ISS by early January 2019, before their docked Soyuz MS-09 exceeded its orbital shelf life. Although the ISS could fly under ground control for a few weeks, ISS managers were not eager to leave the outpost unpiloted and vulnerable to irreparable systems failures.

Coping with commercial failure

For a launch system failure — U.S. or Russian — the return-to-flight interval depends on the time needed to isolate the failure cause, ground-test the required fix, and prove its efficacy via flight testing. A launcher with an extensive flight history helps: The reliability and flight hardware of the Soyuz booster family, with over 1,700 launches, are very well understood.

NASA's commercial partners will soon be flying the Crew Dragon and Starliner transport systems, whose configurations are new even if their launchers are well-tried. Suppose the SpaceX Crew Dragon's Falcon 9 booster with nearly 65 launches and an approximately 97 percent success rate fails during launch. We can get an idea of how the investigation might proceed by looking back at how NASA and its partner dealt with a previous failure. When the Falcon 9 carrying the uncrewed CRS-7 Dragon cargo capsule to the ISS failed during ascent in 2015, SpaceX set up an accident investigation team and invited the FAA, NASA and Air Force to join. NASA subsequently created its own independent review team to evaluate the events leading to the failure, and ensure corrective actions were implemented. The parties agreed that SpaceX would correct a structural flaw in the mounting of a second stage helium tank. Ten months later, after three successful Falcon 9 missions for other customers, SpaceX successfully launched the CRS-8 Dragon to ISS.

United Launch Alliance's Atlas 5, carrying Boeing's Starliner, has flown 79 times and has never failed to achieve orbit, but no system is perfect. Both Boeing and SpaceX hope that their transports' crew escape systems would protect against a launch failure; both use pusher rockets to blast the crew module clear of a failing booster. The companies plan to flight-test their escape systems in the first half of 2019, well before their first crewed ISS test missions planned for mid to late 2019.

Commission complications

In contrast to its adjunct role in past cargo launch failures, NASA would have a much larger part to play in any accident involving a commercial crew. The agency told me in a statement that "In general, the contractor will lead its investigation with government participation. But there are other options: NASA could conduct its own investigation with support by the contractor; a presidentially appointed Accident Investigation Board; or an FAA/NTSB-led investigation."


NASA

▲ **NASA astronaut** Anne McClain has her Russian Sokol suit pressure-checked before her December flight on a Soyuz spacecraft to the International Space Station with Oleg Kononenko of Roscosmos and David Saint-Jacques of the Canadian Space Agency.

After the Columbia accident, Congress in its NASA Authorization Act of 2005 directed that a presidential commission would investigate "any incident that results in the loss of:

1. a Space Shuttle;

2. the International Space Station or its operational viability;

3. any other United States space vehicle carrying humans that is owned by the Federal Government or that is being used pursuant to a contract with the Federal Government; or

4. a crew member or passenger of any space vehicle described in this subsection."

This language means that if either a Falcon 9 or Atlas 5 fails while carrying astronauts, a presidential commission is called for — even if the crew walks away in perfect health. It could take years before a report is issued, corrective action is implemented, and astronauts are again cleared to fly. Having two transport providers servicing ISS is a wise idea.

Preparing for failure

Why do I believe the presidential commission requirement is too restrictive? After a fatal commercial aviation accident, we don't get a presidential commission, nor does the FAA ground every aircraft of that model while the accident cause is being sought. Many at NASA and the FAA would like Congress to ease this language and allow NASA to emulate the FAA's successful spaceflight incident response model.

NASA should be able to work with its commercial provider and the FAA, identify the cause, make necessary changes, test them, and get back into orbit. This remedial approach works in civil aviation and in the military, and should be applied to the new NASA commercial crew regime.

A healthy tension will always exist between NASA and its commercial partners as the latter strive to meet agency safety standards while conducting profitable launches to ISS and opening an orbital tourism market. For its part, NASA must take a measured pace as it responds to a future commercial launch failure, even as it seeks to restore flight operations and rebuild domestic ISS access.

The right time to fly again is after a thorough, collaborative investigation identifies the failure cause and the fix has been tested rigorously to reinforce crew safety. In the words of famed rocket pioneer Wernher von Braun, "One good test is worth a thousand expert opinions." ★

A.I. IN THE

COCKPIT

Modern airliners do a good job of flying automatically until something unexpected happens. At that point, a pilot takes control and typically resolves the problem with no drama or fanfare. Very rarely, though, a pilot must save the day or die trying. For passenger planes to fly autonomously, software would have to be capable of handling these edge cases. Keith Button looks at the state of artificial intelligence for passenger planes.

BY KEITH BUTTON | buttonkeith@gmail.com

One day on a test range at Fort A.P. Hill in Virginia, two years ago, NASA researchers commanded a model airplane into an unstable flight mode as though it were encountering turbulence. After less than two seconds of porpoising up and down, the plane leveled off without any human intervention.

Autopilots on airliners fly through turbulence every day. What was different about this software was that researchers did not preprogram it with the aerodynamic model of the plane that would normally define how the autopilot should change thrust or the disposition of the plane's flight control surfaces. Instead, researchers designed the software to rapidly figure out how to make the aircraft execute the appropriate pitch, roll and yaw maneuvers.

The software outperformed a human pilot who moments earlier tried but failed to level the plane off by remote control, the test organizers said.

This software, developed under a NASA aeronautics initiative called Learn-to-Fly, is just one example of the kind of research underway in the U.S. toward the vision of fully autonomous aircraft, someday potentially including passenger jets.

Today, airliners do a fine job of flying automatically until something unexpected happens, as was vividly illustrated by the 2009 Air France crash off Brazil and November's Lion Air crash off Jakarta.

What's needed before the flying public will entrust their lives to completely automated aircraft is artificial intelligence software that might utilize Learn-to-Fly code during flight or during software development. This AI software would have to cope with emergencies that by definition play out in three dimensions, with numerous flight control surfaces involved, a range of ambient conditions and data arriving from multiple sensors.

Computer scientists point to in-flight emergencies as examples of edge cases, rare scenarios that can be too complex and uncertain to be resolved by today's combination of automation and human pilots.

Validating performance in these edge cases remains arguably the largest stumbling block toward the goal of assigning complete control of a passenger plane to AI. The software would need to make the right decision in a situation that might never have arisen before, and AI designers and flight regulators would need to be assured that it would make the right decision.

The Air France crash was an edge case in which ice crystals likely accumulated in the pitot tubes on the fuselage of the Airbus 330, creating inconsistent airspeed readings and prompting the autopilot to disengage. Sadly, the crew flew the jet into the surface of the ocean without ever seeming to understand that the plane was in a fatal aerodynamic stall, according to French investigators. All 228 aboard were killed. In Lion Air, software called the Maneuvering Characteristics Augmentation System steered the nose downward some 20 times, a reaction to incorrect angle-of-attack readings that suggested the plane was at risk of stalling, investigators from the Indonesian National Transportation Safety Committee said in preliminary findings. The crew fought the MCAS auto trim software and did not manage to turn it off. All 189 aboard were killed.

"One of the things that automation has a hard time dealing with at this point is uncertain or ill-defined problems," says MIT's John Hansman, chair of the FAA Research Engineering and Development Advisory Committee, referring to today's early attempts at AI.

Planning for unforeseen circumstances

For starters, AI software would need to recognize when sensor readings are incorrect, just as the pilots of Lion Air must have known judging by their fight against the MCAS software. The task would be to keep the aircraft under control despite those incorrect readings, as the crew in the Air France crash was unable to do.

One of those conducting research toward AI for aircraft is Mykel Kochenderfer, an assistant professor of aeronautics and astronautics at Stanford University and co-director of the University's Center for AI Safety. He has confidence in his team's AI software, which is not to say that all challenges have been solved.

"When you have these autonomous systems in the real world, you're basically committing to the program that you write before you experience all the variability in the real world," he says. "If that system is flying your aircraft and there isn't a human operator to take over if it goes wrong, then you have to be really sure that what you programmed is what you want."

Kochenderfer won't speak about the Lion Air and Air France crashes specifically. But he says the AI software that he and his colleagues are designing would make the correct decision even when a sensor fails.

"One of the basic tenants of our research is that the world is inherently uncertain. We're uncertain about how the world will evolve, and we don't place absolute trust in any of our sensors," he says. "What you don't want to have is the system to fail in a very unusual way and say, 'I give up, I'll just transfer control back over to the human.' And then a human won't know how to recover," he adds.

To avoid that scenario, his team is applying an

▼ About a month after this photo was taken, this Lion Air Boeing 737 MAX 8 crashed shortly after takeoff from Jakarta. In the minutes before the October crash, the plane's auto trim software steered the nose downward in a reaction to incorrect angle-of-attack readings, investigators believe.

PK/REN/Ikko Haidar Farozy

approach called dynamic programming, which is different from the Learn-to-Fly approach of modeling on the fly. In dynamic programming, the bulk of the computing work would be done ahead of time. For each scenario, a decision strategy is defined. An automated car, for example, must slow down to 25 kph when approaching a crosswalk. As applied to passenger planes, this decision strategy (slow to 25 kph before crosswalks) would be worked out ahead of time so it could be validated. For each decision strategy, the AI software extracts an optimal decision from a mathematical model of every possible scenario — no matter how unlikely — and every possible outcome of those scenarios. Reflecting billions of outcomes or choices algorithmically would be impossible, so programmers encode approximations in a process called discretizing. This generally limits the potential outcomes to hundreds of millions.

In flight, the software would infer that a sensor failure has occurred, such as a blocked airspeed indicator or an inaccurate angle-of-attack sensor, and then behave appropriately.

A LEARN-TO-FLY ALGORITHM WORKS LIKE A BABY BIRD LEAVING ITS NEST. "EVENTUALLY THEY'VE GOT TO MAKE THAT JUMP, AND THEN THEY LEARN HOW TO CONTROL THEMSELVES; NOT JUST HIT THE GROUND, BUT FLY AROUND AND NAVIGATE THEIR ENVIRONMENT."

— **Eugene Heim**, NASA's Learn-to-Fly initiative

Sensors and the avionics equipment that provide information to pilots or computers will never be perfect, which means there will always be a bit of uncertainty in the data.

"The AI will need to reason about these failure modes and make inferences about the reliability of the different sensor systems," Kochenderfer says.

Kochenderfer and his Stanford colleagues model various situations over time, breaking these sce-

narios down into probabilities to judge what's likely to happen next, so that the software can decide the best action.

For example, if an airspeed indicator shows a speed of 200 knots at one point in time and then 0 knots a second later, the dynamic model would recognize a low probability that the reading is accurate and base its decisions on that probability.

The advantage of defining all the possible outcomes ahead of time is that the programmers can put powerful computer clusters to work on the calculations, lessening the computational burden on AI executing the strategy in the moment. Also, the AI is easier to validate if the decision-making strategy — what to do in a given situation — is pinned down prior to execution, Kochenderfer says.

A possible advantage of this approach would be the ability to show regulators how the software reacts in specific situations. No one as yet wants to turn aircraft or automobiles over to neural nets in which the reasoning logic is impossible to validate.

> "WHAT YOU DON'T WANT TO HAVE IS THE SYSTEM TO FAIL IN A VERY UNUSUAL WAY AND SAY, 'I GIVE UP, I'LL JUST TRANSFER CONTROL BACK OVER TO THE HUMAN.' AND THEN A HUMAN WON'T KNOW HOW TO RECOVER."
>
> — **Mykel Kochenderfer,** Stanford University

To pass muster, AI would need to prove itself virtually foolproof. "What you don't want to have is the system to fail in a very unusual way and say, 'I give up, I'll just transfer control back over to the human.' And then a human won't know how to recover," Kochenderfer says.

Although Kochenderfer was not speaking specifically about the Air France case, the crew in that incident made "inappropriate pilot inputs" after being surprised when the autopilot disengaged, investigators concluded.

Kochenderfer thinks that when AI is deployed aboard aircraft, it will do better in edge cases than humans. People "like to think roughly deterministically: If we do this, then this thing will happen," he says, "but computers can entertain the wide spectrum of different things happening, along with their likelihood."

"I think the strength of AI is in its ability to reason about low-probability events," he adds. "However, you still need to validate that that reasoning is correct," he says.

The AI designers are going to have to make sure that when they define their mathematical universe that it's large enough to include every possible scenario, even those that have never occurred and likely never will. AI doubters say that AI will miss some scenarios and humans should be available to step in.

Adapting on the fly

The Learn-to-Fly researchers view their algorithms as a tool that AI software could employ in novel flight situations, such if a plane were to lose a flight control surface in flight.

Eugene Heim, one of those leading NASA's Learn-to-Fly projects, says he doesn't consider his team's algorithms as AI, in part because they lack a high-level executive or mission-manager function. The algorithms could be building blocks, however, handed off to AI researchers. An AI-controlled flight system could apply the algorithms to control the flight surfaces of an airplane without knowing anything beforehand about the plane's aerodynamics — a valuable capability when a plane suffers extreme damage, for example.

A learn-to-fly algorithm works like a baby bird leaving its nest, learning to control its wings and body in flight for the first time, Heim says. "Eventually they've got to make that jump, and then they learn how to control themselves; not just hit the ground, but fly around and navigate their environment."

The algorithms merge real-time aerodynamic modeling with adaptive controls and real-time guidance, and then model the aerodynamics to steadily improve the control of the vehicle. The algorithms learn by beginning with a guess, which is often wrong, about how to control the plane, but they don't need to know anything about the airplane's design to start with. As they see the vehicle's aerodynamics in flight, they can determine what impact its controls have on the six degrees of freedom for the aircraft: pitch, roll, yaw, up, down, and left and right.

"All of this happens at the same time, so it's not like your normal flight test where you do one factor at a time" and then see what happens, Heim says. "This is happening on all surfaces, all axes, all at the same time. That's really part of the beauty and the uniqueness of this approach."

Modeling the aerodynamics of an airplane — whether for AI, an autopilot function or a human pilot — today requires putting the relevant control surfaces and propulsion components in a wind tunnel, or through a computational fluid dynamics model, and recording what happens under various conditions. An aerodynamic model is then developed to capture the effect on factors such as sideslip and angle of attack. For some new designs, this comprehensive modeling could take years.

Heim was curious about how many years this process would take for a particularly complex aircraft, so he looked at the GL-10, a hybrid diesel-electric tilt-wing aircraft. It has two ailerons, four flaps, two elevators and a rudder, plus eight motors on the wing and two on the tail. His findings were similar to those of other researchers who examined the GL-10. He calculated that assessing it the conventional way would take 45 billion years.

Once installed on an aircraft, the algorithms would do more than save the day in an emergency. The algorithms could run in the background, establishing aerodynamic models over long periods, through the full flight envelope of the aircraft. In the nearer term, these could help tune autopilots, provide a health monitoring function by detecting aerodynamic changes caused by icing, for example, or help update and tweak the control laws for the plane for optimal performance.

Building public acceptance

The learn-to-fly algorithms could also build a stepping stone toward public acceptance of autonomous flight for large passenger planes by modeling the aerodynamics of autonomous single-passenger aircraft, such as electric vertical takeoff and landing vehicles, or eVTOLs. Heim says the learn-to-fly algorithms would help identify aerodynamic models quickly for new urban-air-mobility aircraft because the designs often have redundant control surfaces or propulsion vectors. That complexity makes it extremely difficult to determine their aerodynamic models, and how their control surfaces and propulsion interact, in wind-tunnel testing.

"This is where we can use learn-to-fly techniques where we can change everything at the same time, or vary everything at the same time, and then produce what the aerodynamic model is," Heim says.

Ultimately, the key hurdles for AI flight systems will be certification and approval, not the technology itself, Hansman says. "How do we assure that it's good enough that we can either put passengers on it or have a big airplane flying around that's considered safe?"

"We can automate it tomorrow," he says. "In an airplane like an A320 or a 787, the pilot taxis it out, gets to the end of the runway, and as long as you want the airplane to fly the trajectory you've predefined, you can press a button and the pilot won't touch the control until the airplane rolls out on landing and they put the brakes on and taxi it in."

The question is what happens in a crisis. ★

THE HURRI TO COME

Hurricane Florence as seen through the side cockpit window of a U.S. Air Force WC-130J Hurricane Hunter in September.
U.S. Air Force

CANES

Climate change threatens to breed more extreme hurricanes. Adam Hadhazy describes how the innovations of unmanned aircraft, alongside conventionally crewed Hurricane Hunters, plus small satellites and next-generation big sats, could help forecasters get a better bead on what's to come.

BY ADAM HADHAZY | adamhadhazy@gmail.com

For U.S. forecasters, Hurricane Michael was right out of a nightmare. What started the day as a concerning Category 2 storm in the Gulf of Mexico morphed overnight into a catastrophically powerful, borderline Category 5. Michael's rapid intensification caught forecasters completely off guard. When the hurricane plowed into the Florida Panhandle on Oct. 10, 2018, it did so as the fourth-strongest storm to ever hit the continental United States, devastating the region with maximum sustained winds of 155 mph (249 kph).

Hurricane Michael is emblematic of the challenges ahead for hurricane scientists in the balance of the 21st century. Although forecasters have made tremendous leaps over the last generation in the accuracy of predicting a storm's track, predicting intensity — and thus a hurricane's destructive power — remains frustratingly difficult.

Complicating the picture further is climate change. Warmer ocean waters act as a hurricane's fuel source and will likely lead to stronger storms on average, with more growing into dreaded Cat 4s and 5s, as well as greater rainfall, studies show. The conditions could also make rapid intensification — defined as maximum wind speeds increasing by 35 mph (56 kph) within 24 hours, demonstrated by Michael — alarmingly more common, adding incentive for researchers and forecasters to learn how to identify those storms that will intensify.

Are humans and their carbon dioxide emissions to blame for raising the forecasting stakes so high? "The balance of evidence says we are most definitely impacting tropical cyclones," says James Kossin, an atmospheric research scientist at NOAA's National Centers for Environmental Information. How much and what's to come are open questions.

And so, each hurricane season researchers engage in a high-tech storm-chasing gambit in hopes of acquiring revelatory details about the internal structures of hurricanes. The data could improve intensification models and help researchers gauge the degree to which climate change has put a figurative thumb on the intensification scale.

These new views are coming from high altitudes and also down low. Drones could ply the low-altitude interfaces in hurricanes, where raging sea and turbulent atmosphere meet and spawn conditions too dangerous for even Hurricane Hunter aircraft to venture. Meanwhile, new generations of satellites will provide an ever-keener high-altitude view of tropical cyclones. These spacecraft range from the conventionally bulky and high-powered, to the smaller and more numerous, designed to unprecedently probe storms in essentially real time.

"Rapid intensification is one of the top challenges in hurricane science," says Scott Braun, a research meteorologist at NASA's Goddard Space Flight Center in Maryland. "There is growing evidence that climate change will impact the occurrence and intensity of storms, but one question is whether we are seeing those effects now with storms like Harvey, Maria and Michael, or whether those influences won't emerge until later in this century."

▼ **Raytheon's 1-meter-**long Coyote expendable drone can be launched in a tube from a Hurricane Hunter aircraft. Then its wings unfold and it can fly for up to an hour, collecting weather data and transmitting it to NOAA's National Hurricane Center.
Raytheon

Hurricane history

In assessing the storms of now and of the future, the starting point is, of course, the storms of the past. The U.S. started keeping official hurricane records for Atlantic storms in 1851. Yet compared to modern logs, those of yesteryear are woefully incomplete, limiting the available historical baseline for hurricane comparisons.

"Before satellites, if a storm didn't interact with a ship or an island, there was just no way to know it was there," says Kossin. Accordingly, hurricane counts have spuriously skyrocketed in the Space Age, which scientists factor in when studying trends in frequency.

As for intensity, Chris Landsea, the chief of the Tropical Analysis and Forecast Branch at NOAA's National Hurricane Center, has thought about this. "The raw hurricane record is biased substantially toward an undersampling of numbers and intensities," he says. "It tells you nothing about real climate change."

Taking this into account, hurricane scientists have built up a substantial modern database, with extrapolations to the past. The granular detail available for storms continues to expand with each hurricane season. The following might feel counterintuitive, but to allow apples-to-apples comparisons for longer-term climate change monitoring, researchers must intentionally pare away some of this modern detail.

"We do a very careful recalibration of satellite data," says Kossin, "basically degrading its quality to the spatial and temporal resolution of 1980 data, creating a homogenous dataset." That nearly 40-year record, Kossin says, suggests that hurricanes are on average increasing slightly in strength. It's a troubling trend, especially in light of sea-level rises that will render storm surges in the future more inundating and destructive.

Where nitty-gritty detail from modern instruments is helpful, however, is in understanding hurricane mechanics on ever smaller scales relevant to intensification. Those scales go down to even individual clouds of raindrops and ice particles within a tropical system. "Smaller scales tend to be much more chaotic in nature and therefore much harder to predict," says Braun, compared to the large-scale winds in the environment of the storm. Observations from satellites and the Hurricane Hunter aircraft, along with improved forecasts models, have made these macro-level influences "fairly predictable on time scales of about a week, and sometimes longer," says Braun, leading to the dramatic improvement in storm track forecasts.

The task at hand: to elevate intensity forecasting and long-term trend forecasting to the precision gained for storm tracking.

Measuring hurricane strength

The intensity of a storm is commonly expressed via the Saffir-Simpson Hurricane Wind Scale, organized into Categories 1 through 5, based on maximum wind speeds sustained for a minute.

CATEGORY	MILES PER HOUR
5 — Major	>/= 157 (252 kph)
4 — Major	130-156 (209-251 kph)
3 — Major	111-129 (178-208 kph)
2	96-110 (154-177 kph)
1	74-95 (119-153 kph)

Aerial investigations

For more than seven decades, Hurricane Hunters have flown right into the most powerful storms on planet Earth. This weather reconnaissance could increasingly become the realm of robots, though, rather than brave aircrews.

The Air Force maintains a fleet of 10 Lockheed WC-130s, a modified version of the C-130 Hercules transport plane, that serve as Hurricane Hunters. NOAA's dedicated planes are two Lockheed WP-3D Orion turboprops, nicknamed Kermit The Frog and Miss Piggy. The agency also scrambles a Gulfstream 4-SP, dubbed Gonzo, above storms to monitor air currents.

Though Hurricane Hunters do yeoman's work, researchers hope to augment their abilities with drones. These craft could be deployed en masse, sampling storms with greater granularity at low cost. Drones can also go into the dangerous and difficult-to-access zone under 3,000 feet and even near the ocean's surface. This critical, yet little-explored zone is where air and water intermix, exchanging energy between the ocean and the atmosphere, ultimately revving the storm. Drones "may be able to give us winds near the ocean surface like we've never had before," says Landsea.

Leading the way is the 3-kilogram Coyote, an expendable, electrically powered drone developed by Raytheon. First deployed by NOAA in 2014, Coyotes fall out of sensor tubes on Hurricane Hunters. Their 1.8-meter wings unfurl, and the drones flit about inside hurricanes for upward of an hour. That's far longer than traditional dropsonde sensors which, after being dropped out of the same tubes, can gather only a few minutes' worth of temperature, pressure and humidity data before crashing into the ocean. Hoovering up all this information could build out models of intensification, teasing out variables potentially impacted by climate change.

"Unmanned aircraft certainly have a role to play in helping to define features of the hurricane and near-hurricane environment that may be important in explaining rapid intensification," says Thomas Knutson, a research meteorologist at NOAA's Geophysics Fluid Dynamics Laboratory in Princeton, New Jersey. "Some of these features are related to things which we also expect to change with climate change."

▶ **Eight small satellites,** each roughly the size of a person, comprise NASA's Cyclone Global Navigation Satellite System, or CYGNSS. The satellites receive GPS signals that have bounced off the ocean and passed through a hurricane.

▼ **Residents search for** their belongings in the debris left by Hurricane Michael in November in Mexico Beach, Fla.

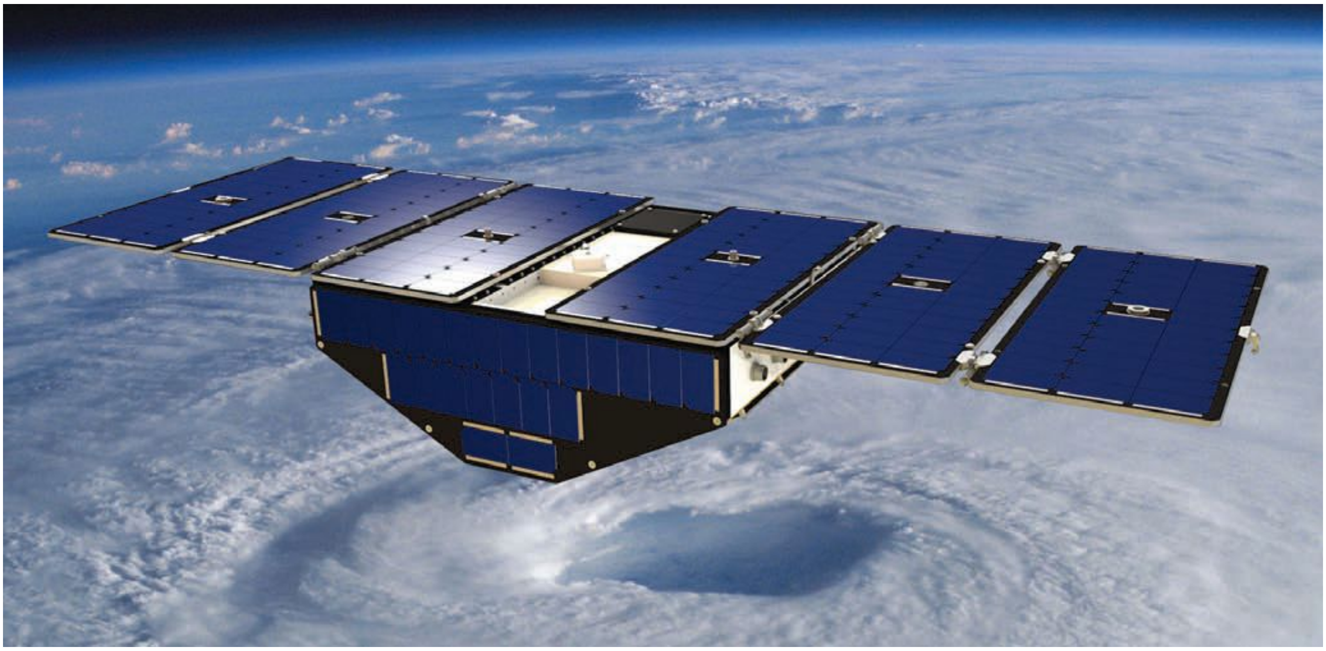
Drones are bit players for now, but could soon become co-stars. "I don't think we're going to be replacing manned aircraft in the next few years," says Landsea. "But perhaps in a generation we would be using fleets of both low-endurance, low-altitude small aircraft as well as high-endurance, high-altitude aircraft."

The view on high

The advent of satellites did more than completely change the game of hurricane forecasting and preparedness. They also transformed public perception by delivering the familiar overhead shots of vast, white vortices scouring across land and sea. NOAA's latest Geostationary Operational Environmental Satellites are now providing insightful new vistas.

Two out of a planned four in the latest GOES series have been launched. The Harris-built Advanced Baseline Imagers, the primary instrument aboard GOES-16 and GOES-17, look down at Earth through 16 spectral bands — two visible, four near-infrared, and 10 infrared, compared to just five for their predecessors. These imagers also provide four times greater spatial resolution and five times faster coverage, meaning the new GOES can snap detailed, successive images of a region of storm activity as little as half a minute apart. "They represent a big leap forward in our ability to observe on the large scale, both in terms of the resolution and the temporal sampling," says Landsea. The upshot is better dynamic modeling of hurricanes' evolution, improving forecasts and feeding into models of storm behavior in conditions potentially altered by climate change.

Another new element of the current generation of GOES sats are the first lightning mapper instruments in geostationary orbit, the GOES Lightning Mappers made by Lockheed Martin. While hurricanes generally produce little lightning, its relative frequency is being explored as an additional means of probing the storms, not unlike a novel test for a



particular substance in the blood serving as a marker of disease severity.

Rise of the smallsats

As in many other aerospace applications, small satellites could prove promisingly disruptive for hurricane studies. The miniaturization of imaging technologies, power systems, navigation and orientation components, along with falling launch costs, is leading to remarkably capable, yet cheap machines for remote sensing in low Earth orbit.

Numerous demonstrations of small satellites are planned or underway. "Smallsats offer a lot of potential," says Braun, "although we are still in the very early stages of evaluating their ability to deliver the data needed to improve understanding of storms and forecasts."

One such smallsat project is NASA's Cyclone Global Navigation Satellite System, or CYGNSS. Launched in December 2016, CYGNSS consists of eight small satellites, each roughly the size of a person. The conventional method for measuring wind speeds is space-based radars, consisting of a transmitter and receiver, called scatterometers. CYGNSS sats, however, only have receivers, cutting down on costs. They measure wave height, an indicator of wind speed, by catching GPS signals that have bounced off the surface of the ocean and passed through the hurricane.

The GPS microwave frequency of 1.575 gigahertz travels well through clouds and rain. This approach lets CYGNSS uniquely look directly into the core of a hurricane, around its eye, where winds are strongest and storms draw much of their power. "All previous methods of measuring ocean surface winds couldn't measure right in the center of the hurricane because the rain is too heavy," says Chris Ruf, principal investigator of CYGNSS and a professor of climate and space science at the University of Michigan.

Because it consists of eight satellites whizzing around the planet instead of one, CYGNSS further benefits forecasters by providing frequent check-ins on hurricanes every several hours — better than the scrutiny that the low-altitude, polar-orbiters can offer, and much closer to the action than geostationary satellites like GOES. CYGNSS "lets us capture a storm's rapid intensification phase, which often lasts maybe 24 to 36 hours," says Ruf. "Standard polar orbiters only come back around [to a particular storm] every two to three days, so you miss it."

Ruf says that initial results with CYGNSS of the highly active 2017 hurricane season suggest ingesting its data into state-of-the-art hurricane modeling does improve accuracy of storm behavior.

CYGNSS is hardly alone in testing the scientific value of smallsats. RainCube, a shoebox-sized cubesat, is testing a compact kind of radar. It was deployed from the International Space Station and in August took images for the first time of a brewing storm over Mexico. Another sat, TEMPEST-D, put a mini-microwave radiometer through its paces in September, peering through clouds to visualize rainfall within Hurricane Florence.

As with CYGNSS, smallsat fleets of RainCubes and TEMPESTs could reveal storms' heretofore well-guarded secrets and in virtually real time. Paired with drones, plus continued advances by crewed aircraft and conventional satellites, researchers have reason to hope that intensification and behavior — all in the light of climate change — will soon be as readily foreseeable as hurricane tracks.

"We're going to go after the storm from all angles," says Ruf. "That's the master plan." ★

TOMORROW'S TECHNOLOGY

Imaging a habitable world

Scientists are detecting exoplanets daily by the slight decrease in light from a host star as a planet transits in front of it. Photos of such a planet could tell us whether or not we are alone in the universe. Ideas for delivering this photographic evidence have ranged from assembling a large telescope in space to dispatching interstellar probes. Louis D. Friedman and Slava G. Turyshev think they have a better solution, one that will require a 900 trillion-kilometer journey and applying a phenomenon discovered by Einstein.

Epiphany can be a hyperbolic word, but while co-leading a Keck Institute for Space Studies study four years ago, Lou had a genuine one.

Lou knew intellectually that there are no targets of interest in terms of searching for life in the universe between where the Voyager 1 spacecraft is now (approximately 145 astronomical units or 21.7 billion kilometers from Earth) and Alpha Centauri, the nearest star to our own, 4.37 light years (276,000 AU) away. Viewing a graphic of mostly empty space made the problem visceral. How could humanity ever hope to reach across such a vast void to learn meaningful details about exoplanets, including whether they harbor life?

We were familiar with the renewed dream of interstellar space flight, because we are members of the advisory committee for the privately funded Breakthrough Starshot Initiative, which seeks to send a robotic interstellar probe through the Alpha Centauri system. As enthusiastic as we are about this long-term interstellar vision, its realization may be centuries away, at least.

Lou's epiphany was to see that we could set an intermediate objective of sending a telescope to a region outside our solar system and photograph an exoplanet from there. Slava briefed the Keck

◀ **This image of Earth** was taken at a resolution of 10 to 15 kilometers, similar to the level of detail that could be provided by a telescope positioned to tap the sun's gravity as a magnifying lens. The photo was taken by NASA's Earth Polychromatic Imaging Camera, or EPIC, on the Deep Space Climate Observatory, or DSCOVR, satellite.
NASA

Just as Einstein predicted, the sun's gravity field bends light rays to provide a natural lens with the power to magnify light from distant objects by a factor of about 100 billion times.

Institute for Space Studies, or KISS, study group about this idea for studying exoplanets not only in the Alpha Centauri system but much farther beyond and much sooner. We will be refining the concept this year and next under a two-year NASA Innovative Advanced Concepts Phase 2 grant of $500,000 awarded last year.

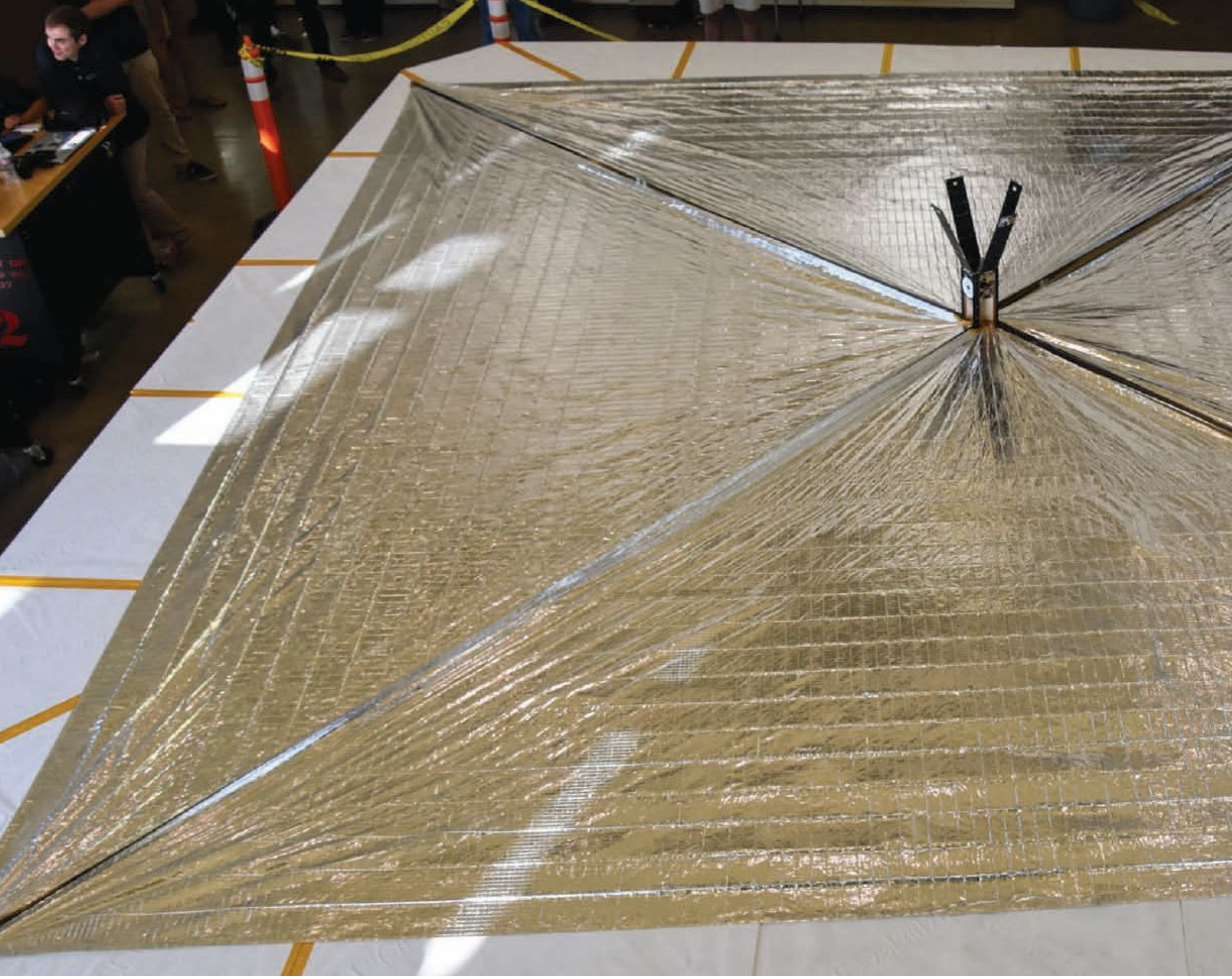
We owe the origins of the idea to Albert Einstein. Just as Einstein predicted, the sun's gravity field bends light rays to provide a natural lens with the power to magnify light from distant objects by a factor of about 100 billion times. To put this phenomenon to work, we would begin by identifying a promising, potentially habitable exoplanet in data from either the Kepler space telescope or TESS, the Transiting Exoplanet Survey Satellite, or those found by other exoplanetary surveys. We would observe them from Earth to confirm the best habitable candidate. Then, we would send a 1- to 2-meter aperture solar-gravitational telescope on a smallsat to the focal area of the solar gravity lens located beyond 547 AU from the sun. Looking back beyond the sun and toward the exoplanet through the solar gravitational telescope would collect light from the exoplanet after it passes by the periphery of the sun's photosphere. With this technique, we would achieve a 10-kilometer resolution, fine enough to see continental lines, topography, weather patterns and most intriguingly, signs of civilization, if one exists.

Are there other practical ideas for telescopes that would do this? No. Imaging an exoplanet from space with a conventional lens would require it to be 90-kilometers in diameter, and once erected in space, this lens would have to point at the target for several million years. Even then, it would only acquire just a single picture element — a dot of light — from an exoplanet 100 light years away. That would be impossible with present technology. Another advantage of gravitational lensing is that it would permit years of detailed remote sensing observations of the putative habitable exoplanet at continental scale, rather than gathering at best a few pixels from a fast interstellar fly-by. Our 1-2 m telescope would travel outside our solar system and with small maneuvers follow a trajectory along the focal line, collecting data for many years.

Amazing gift of nature

How does gravitational lensing work? According to Einstein's General Theory of Relativity, gravity changes the refractive properties of space-time so that light rays no longer move along straight lines. Their paths are bent toward the center of gravity of an object such as the sun. This property of a gravitational field to bend light was confirmed by the famous Eddington experiment conducted during a solar eclipse in 1919. This effect is well understood and is accounted for in tracking of interplanetary and Earth-orbiting spacecraft and used to study the distribution of dark matter in the universe.

As the light from an exoplanet approaches our sun, each part of its wavefront is bent at an angle that is inversely proportional to the distance from that part to the optical axis, an imaginary line connecting the center of the exoplanet to the center of the sun. This angle is rather small, with light rays that just touch the limb of the sun bent by only 1.75 seconds of arc. As a result, after passing by the sun, any two parts of the incident wavefront enveloping



▲ **The Planetary Society's** LightSail 2, seen after a test with its solar array deployed, is an example of a solar sail smallsat spacecraft.

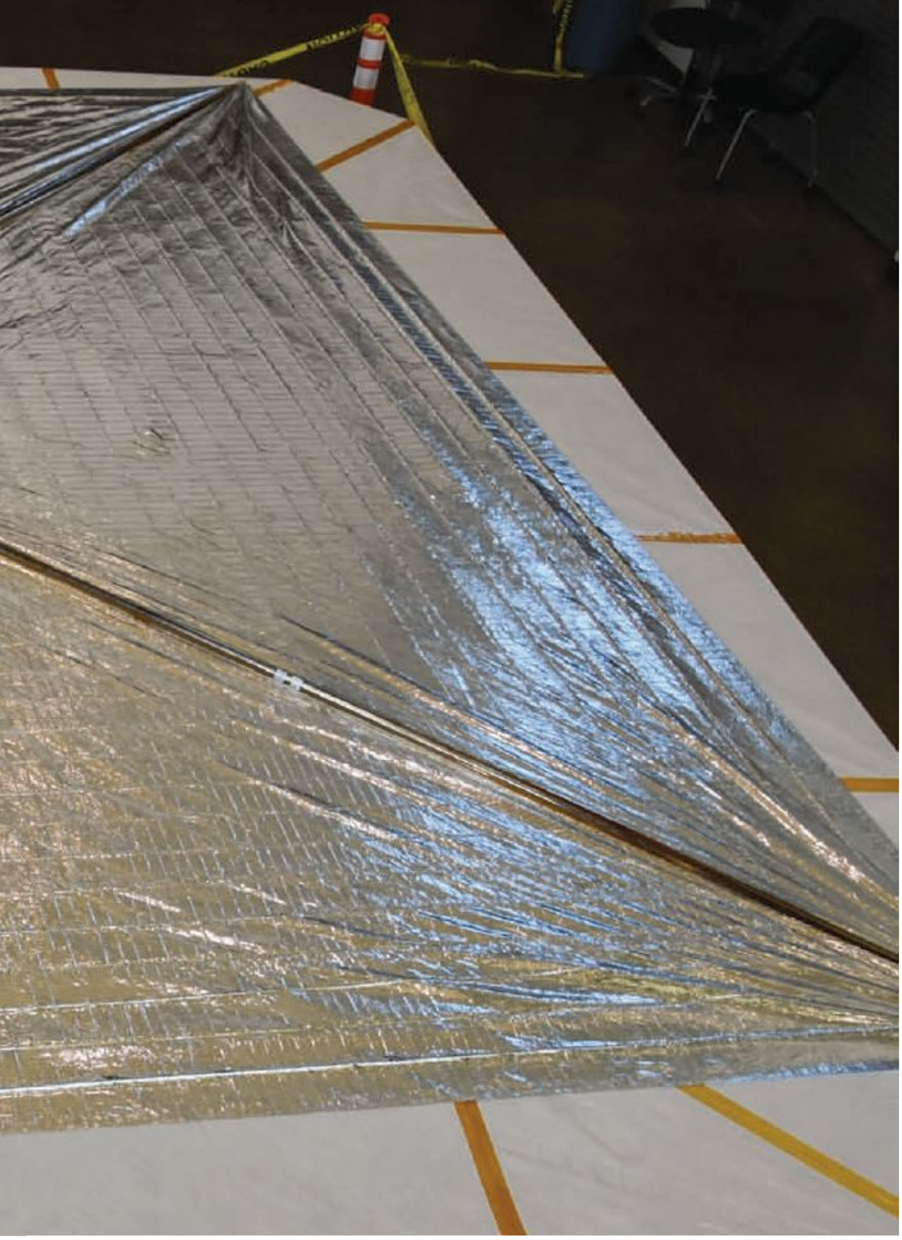
the sun from two opposing sides will move toward each other and will ultimately intersect at the optical axis. The rays that move at a larger distance from the sun will intersect farther along the optical axis, forming a focal line. Given the physical size of the sun, the rays begin to intersect at 547 AU, forming a focal region that extends far beyond 2,500 AU.

The parts of the wavefront with similar separations from the optical axis coherently add, thus amplifying the light intensity to a telescope in this region. As seen by an observer at the focal region and because of the azimuthal symmetry of the lens, the light would form a disk around the sun, called an Einstein ring. The larger the distance between a part of the wavefront and the optical axis or, conversely, the larger the radius of the Einstein ring, the farther from the sun the focusing occurs. This gravitational focusing amplifies the photometric intensity, or brightness, by the 100 billion factor and provides a fine angular resolution of a billionth of an arcsecond, another requirement for sharp resolution. This is how the sun acts as a giant lens — our amazing gift from nature.

Technical hurdles

One challenge of gravitational lensing is that light from an exoplanet would be stretched and squeezed while forming the Einstein ring. This spherical aberration would distort the proportions of the original image while admixing the information from adjacent segments on the planetary surface, but the basic features of the exoplanet would still be recognizable. Thus, this problem is surmountable. We know the physical properties of the lens, and so we can recover the original information contained in the images by applying standard image deconvolution techniques. The images would be mathematically broken down into a large number of constituents and reassembled by applying precision mapping algorithms developed with the knowledge of the optical properties of a particular imaging system.

The entire image of an exoplanet situated at, for example, a distance of 100 light years away from us, would be contained with a cylinder with a diameter of about 1.3 km in the vicinity along the optical axis. Thus, a telescope-carrying spacecraft would have



The Planetary Society

to reach the focal region of the solar lens and then continue to move within this cylinder while taking data to form an image.

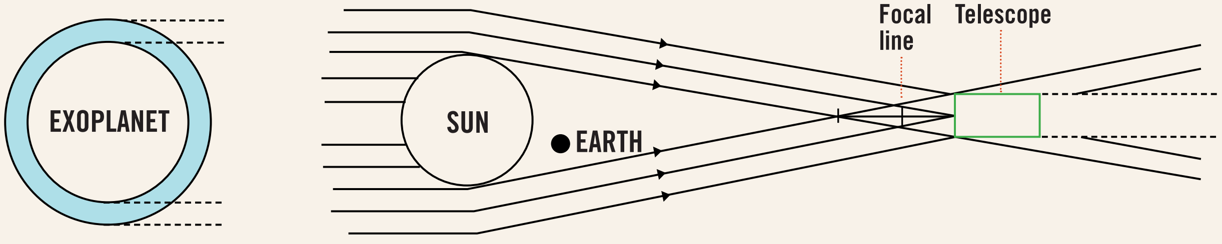
However, before using the solar lens for imaging purposes, we need to block the light emitted by our sun. A classical coronagraph with a contrast ratio of one part in 10 million is sufficient for this purpose. Given the performance of modern coronagraphs, rejecting this level of solar light does not pose a challenge. In fact, we already have a very robust design for an internal telescope coronagraph that meets the requirements with a significant margin.

We also need to consider the effect of the sun's corona, or atmosphere, on the light from an exoplanet that passes through it. The brightness of the corona amounts to noise that will make it challenging to detect the faint optical signals of a distant exoplanet. To overcome this difficulty, we need to move sufficiently far from the sun, so that the Einstein ring will become well-separated from the solar disk and the most turbulent part of the corona. Distances beyond 650 AU are well suited for this purpose. This is the distance we must reach to begin the exoplanet imaging. Solar corona will still be present in the data, albeit to a lesser extent, increasing the signal integration time.

Our analysis suggests that with all the effects taken into account, including scattering of light by the ever-present interstellar dust, we could collect enough light in approximately half a year to form the first-ever direct megapixel-class-resolution image of an exoplanet. As nothing is stationary in the universe — the planet orbits its own star, which also moves with respect to our own sun — the spacecraft must

Solar boost

Sending a telescope outside the Earth's solar system to take advantage of gravitational lensing could give scientists the first close-up view of an exoplanet. The telescope would look toward the sun and collect light from the exoplanet in an Einstein ring (in blue at left) created by the light-bending effect of the sun's gravity. This gravitational lens could achieve a 10-kilometer-resolution image.



Sources: Louis D. Friedman and Slava G. Turyshev

Diagram is not to scale

The smallsat will have months and years to observe the target exoplanet, deconvolute the image, and communicate to Earth — a virtual orbiter of the distant exoplanet.

Louis D. Friedman and Slava G. Turyshev were co-leaders of the Keck Institute for Space Studies 2018 workshop "Technology Requirements to Operate at and Utilize the Solar Gravity Lens for Exoplanet Imaging." Friedman is co-founder and executive director emeritus of The Planetary Society and former mission designer at NASA's Jet Propulsion Laboratory in California. Turyshev is a physicist at JPL. His areas of research include gravitational and fundamental physics, research in astronomy, astrophysics and planetary science. Turyshev is an expert in spacecraft navigation and solar system dynamics. He is a NASA Innovative Advanced Concepts Fellow.

have a propulsion system that would compensate for such a motion. If we were limited to conventional imaging by a giant unitary telescope or by multiple telescopes arrayed for interferometry, the telescope or telescopes would have to stare for millions of years to gather enough light.

Also, to assemble the parts of a unitary image, the spacecraft will have to maneuver small distances to capture all the pixels in the Einstein ring. It also will have to compensate for the orbital motion of the target planet and the barycentric rotation of the sun. As hard as those tasks are, they are thousands (if not millions) of times easier than either interstellar flight or the huge (and enormously expensive) task of building kilometer-sized telescopes in space. Fortunately, all the technologies required for such a mission are already in development and flying with their early stages.

Then there is the question of how to get to the focal region in a timely way. The target region of 650 AU is more than four times farther away than Voyager-1, and it took 41 years to reach this distance of 145 AU. This would mean an unacceptable travel time of 182 years. The brute force option calls for sending a large spacecraft to deep space by nuclear electric or nuclear thermal propulsion. This would cut the travel time to perhaps 25 years, but such designs are likely to be politically and economically untenable for the foreseeable future. By contrast, solar thermal or even chemical propulsion could send our notional small telescope within 2 to 4 solar radii of the sun for a gravity assist that would accelerate it enough to exit the solar system and reach the focal area in about 30 years. This, too, would require a large, complex spacecraft with a huge thermal shield. So, we are examining another approach, one that involves thinking small. A smallsat with a mass of, say, 50 kg, and a solar sail measuring 200 x 200 meters, could achieve exit velocities approaching 25 AU/year, depending on the sail material and how close it can get to the sun. We could be gathering light from an exoplanet 26 years after launch. We currently consider approaching the sun to 0.1 AU (21 solar radii) as a reasonable perihelion goal for the solar sail. The solar sail is especially well-suited to the small spacecraft, since its final speed is determined by the area of the sail divided by spacecraft mass. In addition to providing a much lower cost and hence more realizable spacecraft and mission concept, this approach also provides a replicable one, permitting us to consider launching multiple spacecraft to observe multiple targets or to arranging telescopes in distributed architectures that increase reliability, redundancy and mission design flexibility.

The precise size of the smallsat will be dictated by the required telescope size (e.g. , 1-2 meters) and the radioisotope power system requirements. The power system will supply the energy for electric micro-thrusters to enable maneuvering around the focal line as the spacecraft flies outward beyond 650 AU. It will have months and years to observe the target exoplanet, deconvolute the image, and communicate to Earth — a virtual orbiter of the distant exoplanet. It will also be possible to observe whole planetary systems, several exoplanets, orbiting the same star since their focal lines will be relatively close.

Our fellow mission designers at the Aerospace Corporation in California who have joined us in the study, have devised a "string-of-pearls" distributed architecture. They are investigating successive yearly launches of "pearls" (each being a combination of nanosats) that would fly along the target focal line to gather the required light. This would ease the mission design requirements and render technical readiness earlier than would be possible with a single behemoth spacecraft architecture .

No matter which architecture is ultimately chosen, tapping the solar gravitational lens may be our only means to have a high-resolution image of an alien world (and perhaps its putative life) in the foreseeable future — a very sobering realization, one that motivates getting a spacecraft out there. That we can achieve it relatively soon — far earlier than super large space telescopes could be built or interstellar travel achieved, and even with technologies now currently flying in space, brings us ever closer to the goal of finding our analogs, life on another world. ★

OPINION

THE MOON AS STEPPING STONE TO MARS

Assuring safety to the maximum extent possible for a human mission to Mars depends in large part on proving technologies and procedures through human exploration of the moon. Once those techniques and procedures are proven, there should be no need for a human precursor orbital mission to Mars. Mike Helton, a retired risk management expert who once worked on the Apollo missions, explains.

When Columbus set sail in 1492 to find a new route to India, his command ship, the Santa Maria, was built as an ocean-going vessel with a deep draft of 3 meters to accommodate a crew of 41 and 98 metric tons of cargo. The other two ships, La Niña and La Pinta, were built for Mediterranean sailing with shallow drafts of about 2 meters. This assured Columbus that he would have vessels capable of exploring smaller water ways, inlets and shorelines. Multiple vessels also gave him lifeboats should something go wrong.

Columbus knew he needed to be ready for the unexpected and take advantage of all his opportunities, because he might not get a second chance at the resources for this kind of venture. Likewise, the first voyage to Mars must include the full complement of space exploration elements for a landing on the surface.

At the moment, NASA is considering a "human Mars orbital mission" and exploration of "interim destinations," such as the Martian moons Phobos current plan, which calls for returning astronauts to the moon as a proving ground for a later mission to Mars. Nevertheless, the elements are as follows:

- NASA's Space Launch System rocket, poised for its first flight in mid 2020.
- The SLS-launched Orion capsule with a European-supplied service module.
- A deep space habitat for the crew of a long-duration transfer vehicle.
- A propulsion and power tug for long-duration deep space transits
- An entry and ascent vehicle for landing and launching.
- A surface crew vehicle and systems for surface life support.

For long-duration flights away from low Earth orbit, there are still two major issues of concern centered on crew health: One is exposure to radiation outside of Earth's protective magnetosphere; the other is lack of gravity.

Drive 2: International partnerships

Most countries want to get more involved in space exploration, starting with the moon and someday extending to Mars. Government partnerships bring much needed expertise, capability and resources. NASA should integrate this vital asset into a tightly focused Mars program. Along the way we would learn more about the moon, its history and the resources it can yield.

Drive 3: Commercial partnerships

Also critical will be partnerships between NASA and commercial businesses, beginning with the moon. For NASA, private companies would bring new technologies and improved living conditions for explorers there and ultimately on Mars. Companies would realize several benefits: They could win future contracts from the U.S. government and perhaps other governments. They would have the opportunity to create new lines of business, including for materials mined from the moon and someday Mars, and products manufactured on the moon or in its orbit. A whole new industry of tourism on the moon, and possibly even Mars, could result. There could be hotels on the moon; exploration trips; a rail tram that one day goes all around the moon. Maybe most importantly, each company would earn the stature that comes from being a high-tech, space-exploration-oriented firm.

Drive 4: Lunar stepping stone

The moon, in NASA's latest plan, is no longer in competition with Mars; it is now an aid. The NASA Transition Authorization Act of 2017 specifies that NASA should consider "the applicable enabling aspects of the stepping stone approach to space

Astrobotic Technology

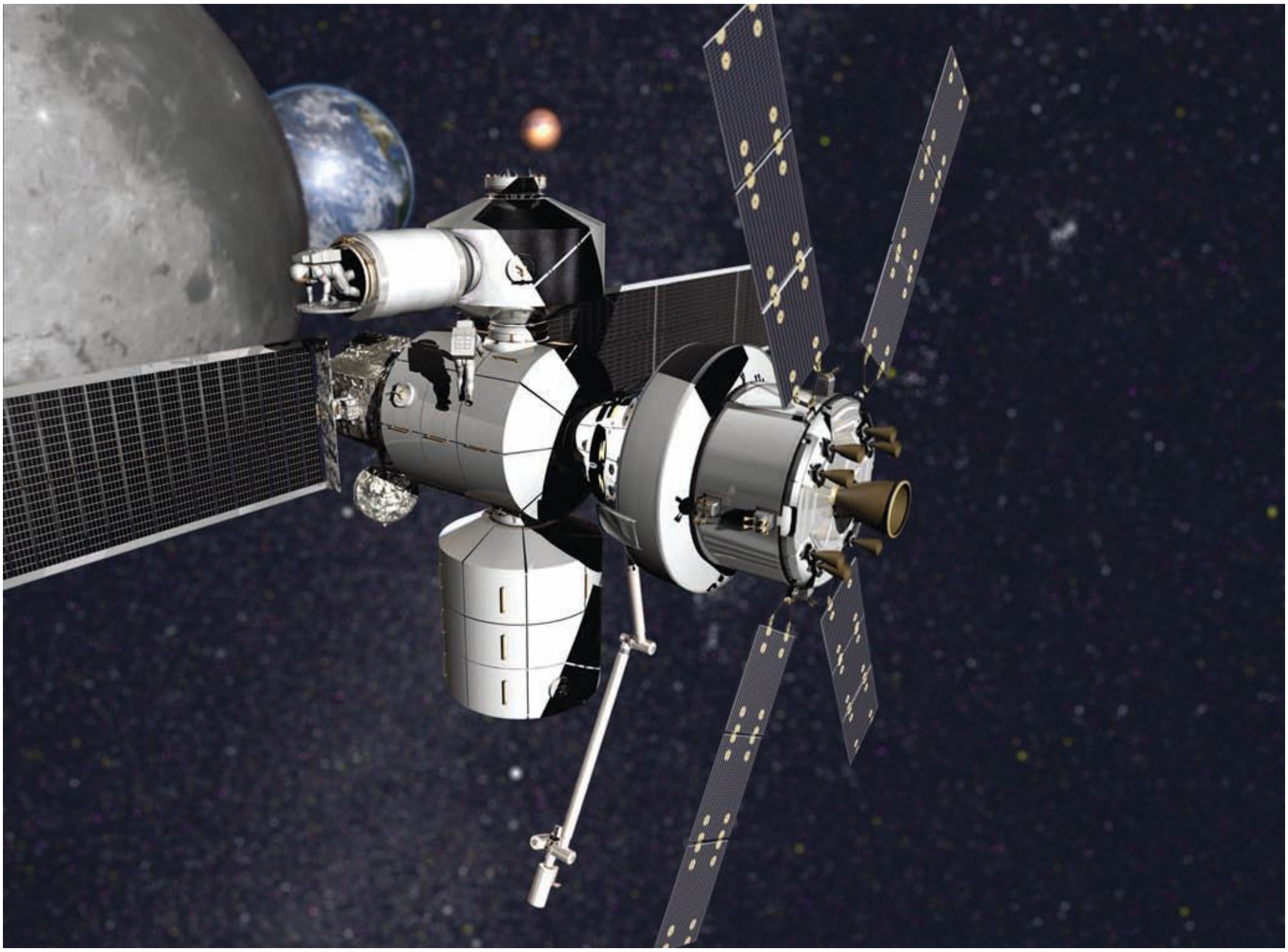
▲ **A commercial lunar lander in an artist's** rendering from one of the nine companies that NASA selected to participate in its Commercial Lunar Payload Services program.

and Deimos, before sending a separate mission to land on the surface, according to the September "National Space Exploration Campaign Report."

This approach should be truncated into a single mission that would reduce overall risk while saving time and resources. NASA could do this by combining lessons from future moon missions with the confluence of five major thrusts, or drives:

Drive 1: Mission elements

Over the years, NASA and human exploration advocates outside the agency have deliberated over whether to concentrate on going back to the moon, on to Mars, or do something with asteroids, or perhaps a little of each. Technology projects were started, so that no matter which way the political whims directed, NASA would be ready to explore. Because of this strategy, the necessary space exploration elements of a human mission to Mars are in various stages of build, design and study. Exactly how these elements would be connected in a physical or thematic sense remains to be fully defined under the


Lockheed Martin

▲ **Conceptual art of a** deep space habitat

exploration." The moon, in this analogy, would not be a stepping stone toward Mars in a geographic sense, but in the strategic sense as a place relatively close to home where we can demonstrate "the proficiency of specific capabilities and technologies," as the act says. In other words, we have the moon to use to get to Mars.

Drive 5: Public support

Currently in every sector of the American society (if not the world), I detect a slow buildup of excitement about robotic and human space exploration, particularly of Mars. Politically, space exploration is one of the few bipartisan subject areas in the U.S. Congress. This is very critical since a full Mars exploration program to be done correctly will need much more funding for continuing operations than is now envisioned, and our citizens must be behind a significant budget for Mars. Reaching Mars can be accomplished with a flat NASA budget, but exploring Mars will need greater considerations. At the same time, NASA needs to manage a full Mars program in a cost-effective way. What is this return on this public investment for the U.S. citizen? Most significantly, it is long-term national pride — an irreplaceable, generational value.

These five forces can produce a synergy to deliver an extensive Mars exploration program. The question is: How to get started with minimum risk to assure continued application of the required drives?

Reducing risk and budget

Risk could be substantially reduced by carrying out the first human mission to Mars with the same hardware, software, systems and procedures established for a lunar base, wherever possible. We are lucky to have the moon as a quasi-Mars test platform. Ideally, missions to the moon and Mars would be designed with identical versions of the space exploration elements listed above. The transfer vehicles could be flown in the same configuration, right down to the amount of fuel that's carried. If there were unused fuel, this could be put in storage in orbit around and moon — perhaps at the planned Lunar Orbiting Platform-Gateway, a proposed space station for lunar explorers. The transfer vehicle would fire retro rockets to enter into lunar orbit and make preparations for a landing. A precursor mission (or set of missions) would have already landed robotic ships on the moon with supplies and the start of some infrastructure needed for about an eight-month stay. One of these ships would be a launch vehicle

Risk could be substantially reduced by carrying out the first human mission to Mars with the same hardware, software, systems and procedures established for a lunar base, wherever possible.

to get the crew back to rendezvous with the orbiter. Another ship on the surface would be dedicated to carrying stored fuel. The infrastructure would include a surface habitat supplied by a partner and ways of making air, food, fuel, water, energy and parts. The moon has no atmosphere and Mars has very little atmosphere, so the entry and landing system should not rely on any atmosphere of the target body. This abides with the NASA space exploration theme of providing a set of vehicles for most of the small solar system bodies to be explored.

Eventually, an international partner would take over that lunar base and continue building and providing much science and exploration. There could be a Japanese base, another one for the European Space Agency and perhaps a third for another partner. Another base could be built by a commercial company or two. These bases would be funded by the corresponding partner from the start. Thus, with no spending of its own on the bases, NASA would nevertheless gain the opportunity to practice the same base establishment operation that will need to be done on Mars. The partners would get a "free" ride to the moon, and NASA would get a continued refinement and improvement of this base establishment process along with needed technology and processes to produce air, food, fuel, water, energy and parts.

This would allow the risk for the first human mission to Mars to be reduced by at least an order of magnitude — perhaps more. The closer the lunar base formation process is to what would be used for Mars, the lower would be the risk. Many of the crew members who help establish the lunar bases could also participate in the first Mars base establishment unless health reasons preclude them.

If this strategy were to begin in the early 2020s, a first landing/base formation mission to Mars could be done in the early 2030s.

This risk-reducing strategy means it is not necessary to follow the Apollo precedent of first sending orbiters with human explorers, as was done in the Apollo 8 and Apollo 10 missions that preceded Apollo 11. The Apollo 8 mission was, in part, a political move, but a proper one, since that was the first time a human was influenced by the gravity of a body other than Earth. We had to build confidence in the celestial mechanics capability and flight hardware. This was further enhanced with the Apollo 10 mission, which included lunar orbit insertion, undocking, orbital maneuvers, rendezvous and re-docking. We achieved those things on Apollo, so we have become celestial travelers and there is no need to duplicate them at Mars just to verify it can be done. Also, since the moon is only two to three days away, it made sense to take it one step at a time; not too much time was needed compared to taking these steps with Mars, which has a one-way travel time between six and nine months, more akin to 10 weeks of Columbus' journey.

Learning to survive

As lunar bases are built up with the international and commercial partners, NASA could conduct extensive environmental control and life support system improvements and address long-term deep space effects on the human body. The most detrimental effects are due to radiation outside the Earth's radiation belts and the lack of gravity. NASA could place the proposed long-duration habitat, which would have the required radiation protection and provisions for artificial gravity in high Earth orbit. A crew could occupy this hab for a year. Although this would not be the exact conditions for the long trip to Mars, it would lend a verification lab to gain confidence that the long-term exposure and trip to Mars can be done with known effects on the human body.

Once a "good" hab is established, it would be wise to have a spare hab in space for use in transfer to and from Mars in an emergency, akin to Columbus' multiple vessels. It's worth noting that weeks after reaching the "New World," his command vessel Santa Maria ran aground on the coast of Haiti and had to be abandoned. Columbus left 39 men behind and sailed back on La Niña. This first voyage started the long series of exploration voyages that opened up the New World. Now it's time for us to "open up" a new planet. ★

Mike Helton is a retired aerospace engineer and a senior risk manager. He worked on the Apollo program for North American Rockwell and on early versions of the space station concept. At NASA's Jet Propulsion Laboratory, he worked on unmanned missions including Mariner 9, Pioneer 10 and 11, and Galileo; and he worked on Earth observing programs including Landsat and Seasat. He has taught classes in risk management.

AIAA/IEEE ELECTRIC AIRCRAFT TECHNOLOGIES SYMPOSIUM
CALL FOR PAPERS

22–24 AUGUST 2019 | INDIANAPOLIS, INDIANA

This two-and-a-half-day symposium will focus on electric aircraft technology across three general areas: electric-power-enabled aircraft configurations and systems requirements, enabling technologies for electric aircraft propulsion, and electric aircraft system integration and controls. Papers are solicited in all relevant areas including, but not limited to:

TOPIC AREA 1

Aircraft Configurations and Systems Requirements

- System feasibility studies
- Electric-enabled innovative aircraft design and propulsion concepts
- Electrical powertrain performance requirements
- Safety, critical failure modes, certification
- Lifecycle energy, operational cost, and emission analysis

TOPIC AREA 2

Enabling Technologies and Components

- Machines and drives integration for optimum performance
- Conventional, cryogenic, and superconducting
- Energy storage devices and systems
- Electric machine and gas turbine integration
- New material solutions or applications
- Novel thermal management solutions

TOPIC AREA 3

System Integration and Controls

- Electric powertrain architectures
- Fault isolation and reconfigurable systems
- Energy management systems
- Integrated electro-thermal systems
- System modeling tools
- Monitoring and diagnostics
- Verification and testing

Sponsored by:

AIAA SHAPING THE FUTURE OF AEROSPACE

IEEE

IEEE TRANSPORTATION ELECTRIFICATION COMMUNITY

Learn More:
propulsionenergy.aiaa.org/EATS

AIAA Bulletin

DIRECTORY

AIAA Headquarters / 12700 Sunrise Valley Drive, Suite 200 / Reston, VA 20191-5807 / aiaa.org

To join AIAA; to submit address changes, member inquiries, or renewals; to request journal fulfillment; or to register for an AIAA conference. Customer Service: 800.639.AIAA (U.S. only. International callers should use 703.264.7500).

All AIAA staff can be reached by email. Use the formula first name last initial@aiaa.org. Example: christinew@aiaa.org.

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

Other Important Numbers: Aerospace America / Karen Small, ext. 7569 • AIAA Bulletin / Christine Williams, ext. 7575 • AIAA Foundation / Merrie Scott, ext. 7530 • Book Sales / 800.682.AIAA or 703.661.1595, Dept. 415 • Communications / John Blacksten, ext. 7532 • Continuing Education / Jason Cole, ext. 7596 • Corporate Members / Tobey Jackson, ext. 7570 • Editorial, Books and Journals / Heather Brennan, ext. 7568 • Exhibits and Sponsorship / Chris Semon, ext. 7510 • Honors and Awards / Patricia Carr, ext. 7523 • Journal Subscriptions, Member / 800.639.AIAA • Journal Subscriptions, Institutional / Online Archive Subscriptions / Michele Dominiak, ext. 7531 • Media Relations / John Blacksten, ext. 7532 • Public Policy / Steve Sidorek, ext. 7541 • Section Activities / Emily Springer, ext. 7533 • Standards, Domestic / Hilary Woehrle, ext. 7546 • Standards, International / Nick Tongson, ext. 7515 • Student Programs / Rachel Dowdy, ext. 7577 • Technical Committees / Karen Berry, ext. 7537

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

Calendar

FEATURED EVENT

7–9 MAY 2019

Laurel, MD

The 2019 forum will use the 2018 National Defense Strategy as a framework to discuss the strategic, programmatic, and technical topics and policy issues pertaining to the aerospace and defense community. This Secret/NoForn event provides a venue for leaders from government, military, industry and academia to explore aerospace technologies and their application to complex national security challenges.

defense.aiaa.org

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2019			
5–6 Jan	2nd AIAA Geometry and Mesh Generation Workshop	San Diego, CA	
5–6 Jan	Aircraft and Rotorcraft System Identification Engineering Methods for Manned and UAV Applications with Hands-on Training Using CIFER® Course	San Diego, CA	
5–6 Jan	Design of Aircraft Structures Course	San Diego, CA	
5–6 Jan	Design of Electrified Propulsion Aircraft Course	San Diego, CA	
5–6 Jan	Diagnostics for Plasmas and Gases Course	San Diego, CA	
5–6 Jan	Fundamentals of Space Systems Course	San Diego, CA	
5–6 Jan	Guidance, Control, and Astrodynamics of Space Vehicles Course	San Diego, CA	
5–6 Jan	Integrating Program Management and Systems Engineering Course	San Diego, CA	
6 Jan	A Unified Approach for Computational Aeroelasticity Course	San Diego, CA	
6 Jan	Additive Manufacturing: Structural and Material Optimization Course	San Diego, CA	
6 Jan	Hypersonics: Test and Evaluation Course	San Diego, CA	
7 Jan	AIAA Associate Fellows Recognition Ceremony and Dinner	San Diego, CA	
7–11 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition)	San Diego, CA	11 Jun 18

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.).

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
13–17 Jan*	29th AAS/AIAA Space Flight Mechanics Meeting	Maui, HI	14 Sep 18
28–31 Jan*	65th Reliability and Maintainability Symposium (RAMS 2019)	Orlando, FL (www.rams.org)	
2–9 Mar*	2019 IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
20 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (aiaa.org/CVD)	
25–27 Mar*	54th 3AF International Conference on Applied Aerodynamics	Paris, France (http://3af-aerodynamics2019.com)	
3–5 Apr*	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (www.eurognc19.polimi.it)	
29 Apr–3 May	2019 IAA Planetary Defense Conference	Washington, DC (pdc.iaaweb.org)	
7–9 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum)	Laurel, MD	20 Nov 18
14 May	AIAA Fellows Dinner	Crystal City, VA	
15 May	AIAA Aerospace Spotlight Awards Gala	Washington, DC	
20–23 May*	25th AIAA/CEAS Aeroacoustics Conference (Aeroacoustics 2019)	Delft, The Netherlands	15 Oct 18
27–29 May*	26th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (elektropribor.spb.ru/icins2019/en)	
10–13 Jun*	18th International Forum on Aeroelasticity and Structural Dynamics	Savannah, GA (http://ifasd2019.utcdayton.com)	
12–14 Jun*	The Sixth International Conference on Tethers in Space (TiS2019)	Madrid Spain (http://eventos.uc3m.es/go/TiS2019)	
17–21 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition)	Dallas, TX	7 Nov 18
11–15 Aug*	2019 AAS/AIAA Astrodynamics Specialist Conference	Portland, ME (space-flight.org)	5 Apr 19
19–22 Aug	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition)	Indianapolis, IN	31 Jan 19
22–24 Aug	AIAA/IEEE Electric Aircraft Technologies Symposium (EATS)	Indianapolis, IN	31 Jan 19
21–25 Oct*	70th International Astronautical Congress	Washington, DC	28 Feb 19
2020			
6–10 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition)	Orlando, FL	

AIAA Continuing Education offerings

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

Researching to Better Support Astronauts in Space

MAKING AN IMPACT

The AIAA Foundation's Neil A. Armstrong Graduate Award 2018 winner **Emily Matula** is preparing for a career to support and study life in space. Closer to home, she's been training to become an EMT after seeing the need for medical assistance with Hurricane Harvey.

"A passion of mine is helping people, especially in crisis situations and I have always had an interest in medicine," said Matula, a Ph.D. candidate at the University of Colorado Boulder, and a NASA Space Technology Research Fellow.

The EMT training has helped her become a better engineer. "In crisis situations, seconds are at stake, and no time to read an instruction manual or remember 30 different steps," she said. "Making sure that an AED (automated external defibrillator) or ventilator is easy to use can be the difference between life and death.

1

"While long duration spaceflight missions are typically slower paced, they still require designs with streamlined usability to accommodate crews of all different disciplines. Exposure to these medical designs will help me to produce simpler aerospace solutions."


3


4

Currently, Matula is taking a break from EMT training to head to Antarctica and collect algae samples to use in extremophile research. Her research supports Environmental Control and Life Support Systems (ECLSS), "making sure that the basic human metabolic needs of clean cabin air, drinking water, food, thermal control, waste remediation, and radiation protection are being met."

She's focused on using bioregenerative technologies—that's where the algae come in—to provide simultaneous cabin air revitalization and thermal control.

"Algae typically grow in a water-based media, and water is currently being used by the International Space Station in its thermal loop to transport metabolic and experiment heat to the ammonia radiators. I hope to make a multi-functional system by using an algae photobioreactor to cool down the cabin, like the ISS thermal system, while also using algae's photosynthesis to sequester respired CO2 and provide breathable oxygen."

Ultimately, Matula would like to become program director of NASA's Human Research Program (HRP).

She's dreamed of becoming a scientist since she was a child in rural Ohio, home of clear starry nights. "I distinctly remember my dad waking me up at 4 in the morning, throwing coats and boots over pajamas, and laying down a large piece of cardboard for everyone to sit on and watch the Geminid meteor shower."

2

1 When interning with Boeing out in Seattle, a few of the interns got to explore the Blue Angels when they came in for Seafair **2** Test subject for the g-profile of the Virgin Galactic Spaceship 2 **3** First flight in a private aircraft, taken up by an undergrad professor to tour Ann Arbor **4** Drilling holes into the core section of the Space Launch System by Boeing

Applications for 2019 AIAA Foundation scholarships are being accepted until 31 January 2019. For more information on establishing a scholarship and making a difference in students' lives, please visit aiaafoundation.org.

2019 AIAA Sustained Service Award Winners Announced

Congratulations to the following AIAA Sustained Service Award winners. Without their passion for aerospace engineering and science as well as their dedicated efforts, AIAA could not fulfill our mission to inspire and advance the future of aerospace.

Marty K. Bradley
Technical Fellow
Boeing Commercial Airplanes – Advanced Concepts

"For sustained, significant service at the national level with emphasis on Technical and Program/Integration Committee leadership, including formation of new committees."

Timothy Dominick
Senior Principal Mechanical Engineer
Northrop Grumman Innovation Systems

"For sustained AIAA leadership at the section, region, and national committee levels attested by service to the Delaware Section and Public Policy Committee."

Mark Melanson
Senior Manager for Integration and Infrastructure
Lockheed Martin Aeronautics (ret.)

"For his recognition of more than 24 years of Institute leadership including key contributions to the evolution of the New Event and Governance Models."

Anthony M. Springer
Director, Integration and Management Office
Aeronautics Research Mission Directorate, NASA

"For decades of sustained service to the Institute in the areas of Membership, Technical Activities and Publications at all levels, from the Section to serving on the Board of Directors."

Randy Truman
Professor
University of New Mexico

"For over 36 years of outstanding, exceedingly active, sustained service to AIAA as a Faculty Adviser, as well as involvement in Section leadership and participation in the Student Activities Committee."

The Sustained Service Award recognizes an AIAA member who has shown continuing dedication to the interests of the Institute by making significant and sustained contributions over a period of time, typically 10 years or more. Please visit the AIAA Honors and Awards webpage (aiaa.org/HonorsAndAwards) for further information about this award. The 2019 Sustained Service Award deadline is **1 July 2019**.

AIAA Region VII-Australia Student Conference Winners Announced

The AIAA Region VII-Australia Student Conference took place 22–23 November 2018, at the University of Adelaide in Adelaide, Australia. The winners were:

1st place – **Lloyd G. Button**, University of Adelaide (The Effect of Corrosion-Inhibiting Compounds on the Mechanics of Fastened Aircraft Joints)

2nd place – **Nahid A. Kermani and Con Doolan**, University of New South Wales (The Effect of Splitter Plate(s) Attached with Square Cylinder in Turbulent Flow)

3rd place – **Reece Otto and Shon Mori**, University of Queensland (Concentrated Solar Power for Space Settlements)

The first-place winner is invited to compete in the AIAA International Student Conference, which will take place at the AIAA SciTech Forum in January.

Register Now for CVD 2019!

Registration is open for any AIAA member who would like to attend the 2019 Congressional Visits Day program, which will take place on 20 March in Washington, DC. AIAA is offering limited subsidies to assist members in their efforts to attend. Details about the event can be found at **aiaa.org/cvd-2019**.

Obituaries

AIAA Associate Fellow Flomenhoft Died in August

Hubert Ivan (Hugh) Flomenhoft, 93, died on 3 August 2018.

Dr. Flomenhoft attended Rensselaer Polytechnic Institute (RPI), where he received a Bachelor's degree in Aeronautical Engineering, and the Massachusetts Institute of Technology (MIT) where he received a Master of Science degree. In 1961, he moved his family to Zurich, Switzerland, where he studied at the Federal Institute of Technology (ETH) and received his Doctorate in Science. He also served in the U.S. Navy during World War II.

Dr. Flomenhoft worked as an aeronautical engineer for his entire career, including managing the missile development for the PATRIOT missile system at the Raytheon Company. He was an Associate Fellow of AIAA and had been a member for over 70 years. After retiring he volunteered as a math tutor for high school students and published a book, The Revolution in Structural Dynamics, donating the proceeds to a special memorial fund at MIT.

AIAA Fellow Hubert Died in October

Dr. Carl H. Hubert died on 19 October, a week before one of the last projects that he worked on for NASA (the Dawn Mission) came to an end. He was 70.

Dr. Hubert received a B.S. from the State University of New York at Stony Brook and an M.S. and a Ph.D. from the Department of Theoretical and Applied Mechanics at Cornell University. Follow graduate school, he joined the technical staff of RCA's Astro-Electronics Division, which ultimately became part of Lockheed Martin. In 1998, he left Lockheed Martin to start an independent consulting practice. Dr. Hubert participated in the design, analysis, and in-orbit operation of more than three dozen space vehicles for commercial, civil, and military programs. He authored 15 papers on spacecraft attitude dynamics and control and was awarded eight patents in the area of space vehicle control.

In May 2006, Dr. Hubert was diagnosed with Primary Lateral Sclerosis, which is a variant of Lou Gehrig's disease. In 2010, he took early retirement. With the help of his partner, Judy DuBois, and family he was able to live at home until 2017, when he moved to Boston.

Over the course of his career, Dr. Hubert consulted with many companies/organizations, including Intelsat, NASA Jet Propulsion Laboratory, Johns Hopkins University Applied Physics Laboratory, NASA Goddard Space Flight Center, and Orbital Sciences, among others. For the Dawn Mission, he worked on the spinning upper state nutation dynamics (analyzed effect of heat pipes and technical lead for subscale drop tests of propellant tanks), extensive involvement in test program to determine the effect of rapid spin up/down on supercritical xenon. His work on the Lunar Reconnaissance Orbiter led NASA to switch the mission to an EELV with a three-axis stabilized upper state. And for the Messenger spacecraft, Dr. Hubert demonstrated that baffles were needed in the propellant tank to prevent nutation instability. His work on a major study for NASA Kennedy Space Center on nutation behavior of spinning space vehicles with onboard liquid propellant helped to identify and collect all available flight/test data and analyze, correlate, and combine it for future space programs. The resulting report is an important reference for NASA and its contractors.

An AIAA Fellow, Dr. Hubert was part of the Guidance, Navigation, and Control Technical Committee. In 1993, he won the AIAA Space Operations and Support Award: "For innovation and tenacity in successfully recovering the ANIK-E satellite from a potential mission-ending anomaly."

AIAA Fellow Eric Rice Died in November

Dr. Eric Rice died on 15 November. He was 74.

Dr. Rice attended college at the University of Wisconsin-Madison where he earned a B.S. in Chemistry (1967). He went on to Ohio State University where he obtained a Ph.D. in Aeronautical & Astronautical Engineering (1972).

During the 1970s and the early 1980s, Dr. Rice worked at Battelle in Columbus, Ohio, as a researcher and manager in the Space Systems and Applications sections. From 1984 to 1988, he was the Director of the Astronautics Technology Center in Madison, WI. In 1988, he founded Orbital Technologies Corporation (ORBITEC) with his business partners, Ron Teeter and Tom Crabb. He served as President, CEO, and Chairman at ORBITEC before he retired in 2014.

At ORBITEC, Dr. Rice led the development of a growing small aerospace business, which was acquired by Sierra Nevada Corporation (SNC) in 2014. Many of ORBITEC's technologies are being integrated into SNC's Dream Chaser Space Vehicle. Dr. Rice was involved in developing: future space mission concepts; advanced space lunar and Mars resources processing systems; advanced lunar transport and colonization system concepts, advanced chemical and electrical space propulsion, cryogenic solid hybrid propulsion, low-cost launch vehicle approaches; Mars colonization approaches; microgravity technologies for Space Station; commercial space vehicles, and future manned bases; advanced SRU based-propulsion for future space missions; bi-propellant liquid vortex and vortex-fed hybrid rocket engines; and advanced propellant systems.

An AIAA Fellow, Dr. Rice was involved with the Space Transportation Technical Committee (TC), the Microgravity and Space Processes TC, the Nuclear and Future Flight Propulsion TC, and the Space Colonization TC. He was also a member of the AIAA Commercial Space Group and the Corporate Member Committee.

AIAA Fellow Byers Died in November

David C. Byers died on 26 November.

Mr. Byers received his Bachelor of Science in Physics from Pennsylvania State University, after which he joined the gridded ion thruster development team at NASA Lewis Research Center (now Glenn) under the leadership of Harold Kaufman and worked on both the SERT I and SERT II missions. He worked as Section Head for gridded ion thruster systems. In 1984, he worked at NASA Headquarters, supporting the Technology Directorate, before returning to Glenn and assuming the role of Branch Chief, Low-Thrust Propulsion Branch (later the On-Board Propulsion Branch), where he led teams developing gridded ion thruster, arcjet, multi-propellant resistojet, pulsed plasma thruster, MPD thruster, and microwave electrothermal systems for the remainder of his NASA career. In addition to his electric propulsion (EP) work, he also led the highly successful development of chemical bipropellant "hot-rocket" technology using Iridium-lined Rhenium combustion chambers as well as early research into green monopropellants.

Mr. Byers' experiences led him to realize in the early 1980s that commercial uses were the key to broad application of EP systems, and he drove the development of arcjet systems for the geosynchronous communications satellite market, which enabled immediate commercial returns with low perceived risk. The immediate commercial success of arcjet systems in 1993 led directly to the widespread commercial use of arcjets, gridded ion thrusters and Hall thrusters on spacecraft. Additionally, his approach to directly addressing the risks perceived by mission planners led to the selection of the NSTAR gridded ion thruster systems for the NASA Deep Space 1 mission, which validated that technology for the recently completed Dawn mission to the asteroids Vesta and Ceres.

For his unique and wide-ranging contributions to spacecraft propulsion Mr. Byers was awarded the AIAA Wyld Propulsion Award (1988), the NASA Outstanding Leadership Medal (1990), was elected a Fellow of AIAA (1998), and was awarded the ERPS Stuhlinger Medal (2007).

After retiring from NASA in 1995, Mr. Byers worked at TRW (now Northrop Grumman) in Redondo Beach, where he led various spacecraft propulsion development and application efforts for five years. Following his retirement from TRW, he continued contributing to the EP community through his multiple consulting contracts, his service to the ERPS, and his continual efforts to advance younger members of the spacecraft propulsion community in their professional careers.

AIAA Student Branches, 2018–2019

AIAA has over 225 student branches around the world. Each branch has a student branch chair elected each year, and a faculty advisor who serves long term to support their branch's activities. Like the professional sections, the student branches invite speakers, take field trips, promote career development, and participate in projects that introduce students to membership with AIAA and their professional futures. The branches, and their officers in particular, organize their activities in addition to their full-time schoolwork, and their advisors clearly care deeply about their students' futures. Please join us in acknowledging the time and effort that all of them take to make their programs successful.

FA = Faculty Advisor; SBC = Student Branch Chair

REGION I

Boston University, FA, Sheryl Grace (New England)

Boston University, SBC, Pien van Westendorp, (New England)

Brown University, FA, TBD (New England)

Brown University, SBC, TBD (New England)

Carnegie Mellon University, FA, TBD (Mid-Atlantic)

Carnegie Mellon University, SBC, TBD (Mid-Atlantic)

Catholic University of America, FA, Diego Turo (National Capital)

Catholic University of America, SBC, Grace Boras (National Capital)

City College-New York, FA, Prathap Ramamurthy (Long Island)

City College-New York, SBC, Alaa Barakat (Long Island)

Clarkson University, FA, Kenneth Visser (Northeastern New York)

Clarkson University, SBC, Dalton Alexander (Northeastern New York)

Columbia University, FA, Robert Stark (Long Island)

Columbia University, SBC, TBD (Long Island)

Cornell University, FA, Dmitry Savransky (Niagara Frontier)

Cornell University, SBC, Akshay Kadhiresan (Niagara Frontier)

Drexel University, FA, Ajmal Yousuff (Greater Philadelphia)

Drexel University, SBC, Jonathan Moore (Greater Philadelphia)

George Washington University, FA, Adam Wickenheiser (National Capital)

George Washington University, SBC, Steven Brunetto (National Capital)

Hofstra University, FA, John Vaccaro (Long Island)

Hofstra University, SBC, TBD (Long Island)

Howard University, FA, Nadir Yilmaz (National Capital)

Howard University, SBC, TBD (National Capital)

Johns Hopkins University, FA, Kerri Phillips (Mid-Atlantic)

Johns Hopkins University, SBC, Jalen Doherty (Mid-Atlantic)

Lehigh University, FA, Terry Hart (Greater Philadelphia)

Lehigh University, SBC, TBD (Greater Philadelphia)

Manhattan College, FA, John Leylegian (Long Island)

Manhattan College, SBC, Alexander Kavalchuk (Long Island)

Massachusetts Institute of Technology, FA, David Darmofal (New England)

Massachusetts Institute of Technology, SBC, Blake Berk (New England)

National Institute of Aerospace, FA, TBD (Hampton Roads)

National Institute of Aerospace, SBC, TBD (Hampton Roads)

New York Institute of Technology, FA, James Scire (Long Island)

New York Institute of Technology, SBC, TBD (Long Island)

Northeastern University, FA, Andrew Gouldstone (New England)

Northeastern University, SBC, Karl Swanson (New England)

Old Dominion University, FA, Colin Britcher (Hampton Roads)

Old Dominion University, SBC, TBD (Hampton Roads)

Pennsylvania State University, FA, Robert Melton, (Central Pennsylvania)

Pennsylvania State University, SBC, Josiah Mooney (Central Pennsylvania)

Polytechnic Institute of Brooklyn (now NYU), FA, TBD (Long Island)

Polytechnic Institute of Brooklyn (now NYU), SBC, TBD (Long Island)

Princeton University, FA, Michael Mueller (Northern New Jersey)

Princeton University, SBC, Michael Whitmore (Northern New Jersey)

Rensselaer Polytechnic Institute, FA, Farhan Gandhi, (Northeastern New York)

Rensselaer Polytechnic Institute, SBC, Richard Healy (Northeastern New York)

Rochester Institute of Technology, FA, Mark Olles (Niagara Frontier)

Rochester Institute of Technology, SBC, Kory Schimmelpfennig (Niagara Frontier)

Rowan University, FA, John Schmalzel (Southern New Jersey)

Rowan University, SBC, Pietro Sparacio (Southern New Jersey)

Rutgers University, FA, Javier Diez (Northern New Jersey)

Rutgers University, SBC, Robert Randolph (Northern New Jersey)

Southern New Hampshire University, FA, David Guo (New England)

Southern New Hampshire University, SBC, Tadd Shiffer (New England)

State University of New York-Buffalo, FA, Paul Schifferle (Niagara Frontier)

State University of New York-Buffalo, SBC, Jessica Evans (Niagara Frontier)

Stevens Institute of Technology, FA, Siva Thangam (Northern New Jersey)

Stevens Institute of Technology, SBC, Aidan Petti (Northern New Jersey)

Stony Brook University, FA, Sotirios Mamalis (Long Island)

Stony Brook University, SBC, Christos Liopyros (Long Island)

Syracuse University, FA, John Dannenhoffer (Northeastern New York)

Syracuse University, SBC, TBD (Northeastern New York)

United States Naval Academy, FA, Josh Dittmar (Mid-Atlantic)

United States Naval Academy, SBC, Charles Oestreich (Mid-Atlantic)

University of Connecticut, FA, Chih-Jen Sung (Connecticut)

University of Connecticut, SBC, Sam Calello (Connecticut)

University of Maine, FA, Alexander Friess (New England)

University of Maine, SBC, Michael Orne (New England)

University of Maryland, FA, Norman Wereley (National Capital)

University of Maryland, SBC, Casey Ohringer (National Capital)

University of Massachusetts - Lowell, FA, Marianna Maiaru (New England)

University of Massachusetts - Lowell, SBC, TBD (New England)

US Military Academy\West Point, FA, Drew Curriston (Long Island)

US Military Academy\West Point, SBC, TBD (Long Island)

Vaughn College of Aeronautics and Technology, FA, Amir Elzawawy (Long Island)

Vaughn College of Aeronautics and Technology, SBC, Chamathke Perera (Long Island)

Villanova University, FA, Sergey Nersesov (Greater Philadelphia)

Villanova University, SBC, TBD (Greater Philadelphia)

Virginia Polytechnic Institute and State Univ, FA, Mayuresh Patil (Hampton Roads)

Virginia Polytechnic Institute and State Univ, SBC, Julie Duetsch (Hampton Roads)

Wentworth Institute of Technology, FA, Haifa El-Sadi (New England)

Wentworth Institute of Technology, SBC, Kylee Julia (New England)

West Virginia University, FA, Wade Huebsch (Mid-Atlantic)

West Virginia University, SBC, Samantha Keyes (Mid-Atlantic)

Worcester Polytechnic Institute, FA, John Blandino (New England)

Worcester Polytechnic Institute, SBC, Isaiah Fleischer (New England)

Yale University, FA, Mitchell Smooke (Connecticut)

Yale University, SBC, Clio Byrne-Gudding (Connecticut)

REGION II

Alabama A&M University, FA, Zhengtao Deng (Greater Huntsville)

Alabama A&M University, SBC, TBD, (Greater Huntsville)

Athens State University, FA, J Wayne McCain (Greater Huntsville)

Athens State University, SBC, Katherine Brewer (Greater Huntsville)

Auburn University, FA, Dudley Nichols (Greater Huntsville)

Auburn University, SBC, Catherine Twesme (Greater Huntsville)

Duke University, FA, Kenneth Hall (Carolina)

Duke University, SBC, Jack Cohen (Carolina)

East Carolina University, FA, Tarek Abdel-Salam (Carolina)

East Carolina University, SBC, TBD (Carolina)

Embry-Riddle Aeronautical University-Daytona Beach, FL, FA, Ebenezer Gnanamanickam (Central Florida)

Embry-Riddle Aeronautical University-Daytona Beach, FL, SBC, Curtis Barton (Central Florida)

Florida A&M University, FA, Chiang Shih (Northwest Florida)

Florida A&M University, SBC, Daniel Bradley (Northwest Florida)

Florida Institute of Technology, FA, David Fleming (Cape Canaveral)

Florida Institute of Technology, SBC, Archit Srivastava (Cape Canaveral)

Florida International University, FA, George Dulikravich (Palm Beach)

Florida International University, SBC, Rami Ghazzara (Palm Beach)

Florida State University, FA, Chiang Shih (Northwest Florida)

Florida State University, SBC, Alexander Sharp (Northwest Florida)

Georgia Institute of Technology, FA, Dimitri Mavris (Atlanta)

Georgia Institute of Technology, SBC, Lorenzo Capasso (Atlanta)

Kennesaw State University, FA, Adeel Khalid (Atlanta)

Kennesaw State University, SBC, Cindy Vo (Atlanta)

Louisiana State University, FA, Keith Gonthier (Greater New Orleans)

Louisiana State University, SBC, Connor Becnel (Greater New Orleans)

Mississippi State University, FA, TBD (Greater Huntsville)

Mississippi State University, SBC, TBD (Greater Huntsville)

North Carolina State University, FA, Jack Edwards (Carolina)

North Carolina State University, SBC, Paul Neil (Carolina)

Polytechnic University of Puerto Rico, FA, Jose Pertierra (No Section Assigned)

Polytechnic University of Puerto Rico, SBC, Gabriel Morales (No Section Assigned)

Tuskegee University, FA, Mohammad Khan (Greater Huntsville)

Tuskegee University, SBC, TBD (Greater Huntsville)

University of Alabama at Birmingham, FA, Roy Koomullil (Greater Huntsville)

University of Alabama at Birmingham, SBC, Jordan Whitson (Greater Huntsville)

University of Alabama-Huntsville, FA, D Brian Landrum (Greater Huntsville)

University of Alabama-Huntsville, SBC, Katelyn McGinnis (Greater Huntsville)

University of Alabama-Tuscaloosa, FA, Weihua Su (Greater Huntsville)

University of Alabama-Tuscaloosa, SBC, Piper Daniels (Greater Huntsville)

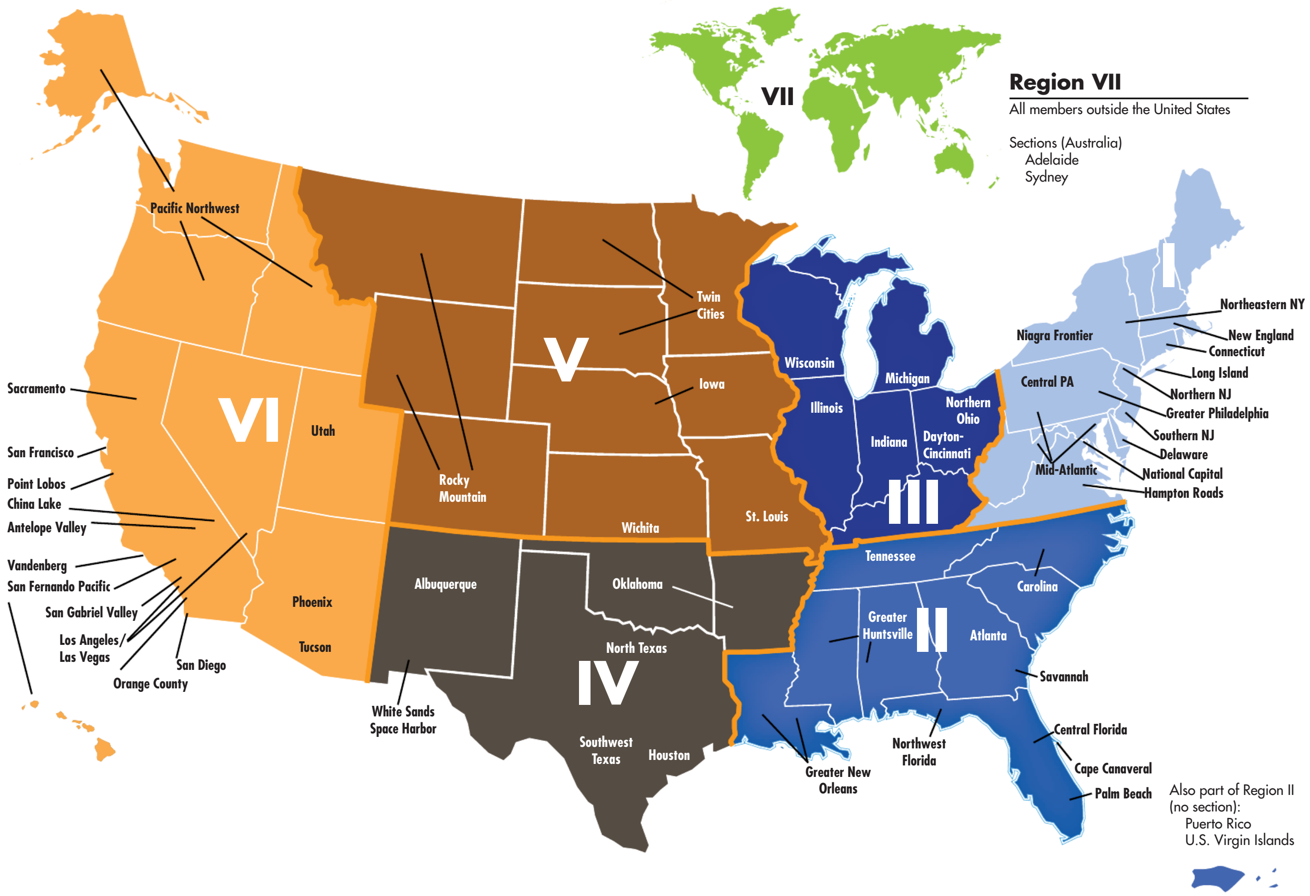
University of Central Florida, FA, Seetha Raghavan (Central Florida)

University of Central Florida, SBC, Luis Gonzalez (Central Florida)

University of Florida, FA, Richard Lind (Central Florida)

University of Florida, SBC, TBD, (Central Florida)

AIAA SECTIONS AND GEOGRAPHICAL REGIONS



University of Memphis, FA, Jeff Marchetta (Tennessee)

University of Memphis, SBC, William Bowen (Tennessee)

University of Miami at Coral Gables, FA, Ryan Karkkainen (Palm Beach)

University of Miami at Coral Gables, SBC, TBD (Palm Beach)

University of Mississippi, FA, Erik Hurlen (Greater Huntsville)

University of Mississippi, SBC, Annie Richardson (Greater Huntsville)

University of Puerto Rico, FA, Guillermo Araya (No Section Assigned)

University of Puerto Rico, SBC, Stephanie Chan Yau (No Section Assigned)

University of South Alabama, FA, Carlos Montalvo (Greater Huntsville)

University of South Alabama, SBC, Joseph Kahl (Greater Huntsville)

University of South Carolina, FA, Michael Van Tooren (Carolina)

University of South Carolina, SBC, Paul Sinkez (Carolina)

University of South Florida, FA, TBD (Central Florida)

University of South Florida, SBC, TBD (Central Florida)

University of Tennessee, FA, James Coder (Tennessee)

University of Tennessee, SBC, Camille Bergin (Tennessee)

University of Tennessee Space Institute, FA, Trevor Moeller (Tennessee)

University of Tennessee Space Institute, SBC, Katherine Stamper (Tennessee)

Vanderbilt University, FA, Amrutur Anilkumar (Tennessee)

Vanderbilt University, SBC, Christopher Romanoski (Tennessee)

REGION III

Air Force Institute of Technology, FA, Marc Polanka (Dayton/Cincinnati)

Air Force Institute of Technology, SBC, Carol Bryant (Dayton/Cincinnati)

Case Western Reserve University, FA, TBD, (Northern Ohio)

Case Western Reserve University, SBC, Ryan Murphy (Northern Ohio)

Cleveland State University, FA, Wei Zhang (Northern Ohio)

Cleveland State University, SBC, Maggie Kolovich (Northern Ohio)

Illinois Institute of Technology, FA, Boris Pervan (Illinois)

Illinois Institute of Technology, SBC, Corey Small (Illinois)

Indiana University-Purdue University Indianapolis (IUPUI), FA, TBD (Indiana)

Indiana University-Purdue University Indianapolis (IUPUI), SBC, William Conover (Indiana)

Kettering University, FA , TBD (Michigan)

Kettering University, DBC, TBD (Michigan)

Lawrence Technological University, FA, Andrew Gerhart (Michigan)

Lawrence Technological University, SBC, Cody Hoeffel (Michigan)

Miami University, FA, Ryan Clark (Dayton/Cincinnati)

Miami University, FA, James Van Kuren (Dayton/Cincinnati)

Miami University, SBC, Jacob Veta (Dayton/Cincinnati)

Michigan State University, FA, Patton Allison (Michigan)

Michigan State University, SBC, Anthony Anason (Michigan)

Milwaukee School of Engineering, FA, William Farrow (Wisconsin)

Milwaukee School of Engineering, SBC, Alex Van Dyck (Wisconsin)

Ohio Northern University, FA, Jed Marquart (Dayton/Cincinnati)

Ohio Northern University, SBC, Olivia Paganelli (Dayton/Cincinnati)

Ohio State University, FA, Ali Jhemi (Dayton/Cincinnati)

Ohio State University, SBC, Eric Kaiser (Dayton/Cincinnati)

Ohio University, FA, David Burnette (Dayton/Cincinnati)

Ohio University, SBC, Caleb Saunders (Dayton/Cincinnati)

Purdue University, FA, Li Qiao (Indiana)

Purdue University, SBC, Astha Tiwari (Indiana)

Rose-Hulman Institute of Technology, FA, Calvin Lui (Indiana)

Rose-Hulman Institute of Technology, SBC, Clayton Richards (Indiana)

Trine University, FA, James Canino (Indiana)

Trine University, SBC, Eric Romanowski (Indiana)

University of Akron, FA, TBD (Northern Ohio)

University of Akron, SBC, TBD (Northern Ohio)

University of Cincinnati, FA, George Black (Dayton/Cincinnati)

University of Cincinnati, SBC, Austin Wessels (Dayton/Cincinnati)

University of Dayton, FA, Sidaard Gunasekaran (Dayton/Cincinnati)

University of Dayton, SBC, Matthew Gazella (Dayton/Cincinnati)

University of Illinois at Urbana-Champaign, FA, Kai James (Illinois)

University of Illinois at Urbana-Champaign, SBC, Brenda Reyn (Illinois)

University of Illinois-Chicago, FA, Kenneth Brezinsky (Illinois)

University of Illinois-Chicago, SBC, TBD (Illinois)

University of Kentucky, FA, Alexandre Martin (Dayton/Cincinnati)

University of Kentucky, SBC, Mingping Zheng (Dayton/Cincinnati)

University of Kentucky-Paducah, FA, Sergiy Markutsya (Dayton/Cincinnati)

University of Kentucky-Paducah, SBC, Samuel Smith (Dayton/Cincinnati)

University of Michigan at Ann Arbor, FA, Ella Atkins (Michigan)

University of Michigan at Ann Arbor, SBC, TBD (Michigan)

University of Notre Dame, FA, Thomas Juliano (Indiana)

University of Notre Dame, SBC, Brian Kennedy (Indiana)

University of Wisconsin at Madison, FA, Matthew Allen (Wisconsin)

University of Wisconsin at Madison, SBC, Brandon Wilson (Wisconsin)

University of Wisconsin at Milwaukee, FA, Ryoichi Amano (Wisconsin)

University of Wisconsin at Milwaukee, SBC, Mandana Sheikhzad Saravani (Wisconsin)

Western Michigan University, FA, Peter Gustafson (Michigan)

Western Michigan University, SBC, Avery Maurer (Michigan)

Wright State Univ, FA, Rory Roberts (Dayton/Cincinnati)

Wright State Univ, SBC, Robert Ashbaugh (Dayton/Cincinnati)

Youngstown State University, FA, Kevin Disotell (Northern Ohio)

Youngstown State University, SBC, Matthew Lawson (Northern Ohio)

REGION IV

New Mexico State University, FA, Andreas Gross (White Sands/Space Harbor)

New Mexico State University, SBC, Tristan Tyson (White Sands/Space Harbor)

Oklahoma State University, SBC, Reid Williams (Oklahoma)

Rice University, FA, Andrew Meade (Houston)

Rice University, SBC, Wil Coben (Houston)

Texas A&M University-College Station, FA, Gregory Chamitoff (Houston)

Texas A&M University-College Station, SBC, Jared Blunt (Houston)

University of Arkansas-Fayetteville, FA, Po-Hao Huang (Oklahoma)

University of Arkansas-Fayetteville, SBC, TBD (Oklahoma)

University of Houston, FA, Edgar Bering (Houston)

University of Houston, SBC, Sharlyn Tijerina (Houston)

University of New Mexico, FA, Svetlana Poroseva (Albuquerque)

University of New Mexico, SBC, Victoria Ramirez (Albuquerque)

University of Oklahoma, FA, Thomas Hays (Oklahoma)

University of Oklahoma, SBC, Trevor Trevino (Oklahoma)

University of Texas at Arlington, FA, Zhen-Xue Han (North Texas)

University of Texas at Arlington, SBC, Ian Raybon (North Texas)

University of Texas at Austin, FA, Brandon Jones (Southwest Texas)

University of Texas at Austin, SBC, Rohan Sikdar (Southwest Texas)

University of Texas at Dallas, FA, Arif Malik (North Texas)

University of Texas at Dallas, SBC, Rohit Gattamaraju (North Texas)

University of Texas at El Paso, FA, Jack Chessa (White Sands/Space Harbor)

University of Texas at El Paso, SBC, Andrew Salas (White Sands/Space Harbor)

REGION V

Colorado School of Mines, FA, Angel Abbud-Madrid (Rocky Mountain)

Colorado School of Mines, SBC, Adam Marcinkowski (Rocky Mountain)

Colorado State University-Fort Collins, FA, Xinfeng Gao (Rocky Mountain)

Colorado State University-Fort Collins, SBC, Brennan O'Connor (Rocky Mountain)

Iowa State University, FA, Anupam Sharma (Iowa)

Iowa State University, SBC, Nicholas Wijaya (Iowa)

Kansas State University, FA, TBD (Wichita)

Kansas State University, FA, TBD (Wichita)

Metropolitan State University of Denver, FA, Jose Lopez (Rocky Mountain)

Metropolitan State University of Denver, SBC, Jonathan Swavely (Rocky Mountain)

Missouri University of Science and Technology, FA, Lian Duan (St. Louis)

Missouri University of Science and Technology, SBC, Austin Foutch (St. Louis)

North Dakota State University, FA, Yildirim Suzen (Twin Cities)

North Dakota State University, SBC, Devyn Gray (Twin Cities)

Saint Louis University, FA, Larry Boyer (St. Louis)

Saint Louis University, SBC, TBD (St. Louis)

United States Air Force Academy, FA, Matthew Satchell (Rocky Mountain)

United States Air Force Academy, SBC, TBD (Rocky Mountain)

University of Colorado-Boulder, FA, Donna Gerren (Rocky Mountain)

University of Colorado-Boulder, SBC, Joseph Beightol (Rocky Mountain)

University of Colorado-Colorado Springs, FA, TBD (Rocky Mountain)

University of Colorado-Colorado Springs, SBC, TBD (Rocky Mountain)

University of Iowa, FA, TBD (Iowa)

University of Iowa, SBC, Joseph Jalowiec (Iowa)

University of Kansas, FA, Ronald Barrett-Gonzalez (Wichita)

University of Kansas, SBC, Nidhin Ninan (Wichita)

University of Minnesota, FA, Yohannes Ketema (Twin Cities)

University of Minnesota, SBC, Tiger Rost (Twin Cities)

University of Missouri at Columbia, FA, Craig Kluever (St. Louis)

University of Missouri at Columbia, SBC, Cale Crawford (St. Louis)

University of North Dakota, FA, TBD (Twin Cities)

University of North Dakota, SBC, TBD (Twin Cities)

University of Wyoming, FA, TBD (Rocky Mountain)

University of Wyoming, SBC, TBD (Rocky Mountain)

Washington University in St Louis, FA, Swami Karunamoorthy (St. Louis)

Washington University in St Louis, SBC, Peter Sharpe (St. Louis)

Wichita State Univ, FA, L Scott Miller (Wichita)

Wichita State Univ, SBC, Sai Tarun Prabhu Bandemegala (Wichita)

REGION VI

Arizona State University, FA, Timothy Takahashi (Phoenix)

Arizona State University, SBC, Omar Alavi (Phoenix)

Boise State University, FA, Sin Ming Loo (Pacific Northwest)

Boise State University, SBC, Carlos Frode (Pacific Northwest)

Brigham Young University-Utah, FA, Andrew Ning (Utah)

Brigham Young University-Utah, SBC, Jon Rice (Utah)

California Institute of Technology, FA, TBD (San Gabriel Valley)

California Institute of Technology, SBC, TBD (San Gabriel Valley)

California Polytechnic State University, San Luis Obispo, FA, Amelia Greig (Vandenberg)

California Polytechnic State University, San Luis Obispo, SBC, Justin Connerly (Vandenberg)

California Polytechnic State University-Pomona, FA, Subodh Bhandari (San Gabriel Valley)

California Polytechnic State University-Pomona, SBC, Nicholas Clement (San Gabriel Valley)

California State University, Fresno, FA, Deify Law (Antelope Valley)

California State University, Fresno, SBC, Jeremiah Folia (Antelope Valley)

California State University, Fullerton, FA, Salvador Mayoral (Orange County)

California State University, Fullerton, SBC, Darove Prado (Orange County)

California State University, Long Beach, FA, Eric Besnard (Los Angeles-Las Vegas)

California State University, Long Beach, SBC, Anthony Tan (Los Angeles-Las Vegas)

California State University-Northridge, FA, Peter Bishay (San Fernando Pacific)

California State University-Northridge, SBC, Jimmy Trejo (San Fernando Pacific)

California State University-Sacramento, FA, Ilhan Tuzcu (Sacramento)

California State University-Sacramento, SBC, TBD (Sacramento)

Embry-Riddle Aeronautical University-Prescott,AZ, FA, David Lanning (Phoenix)

Embry-Riddle Aeronautical University-Prescott,AZ, SBC, Paul Sanders (Phoenix)

Northern Arizona University, FA, Thomas Acker (Phoenix)

Northern Arizona University, SBC, TBD, (Phoenix)

Oregon State University, FA, Roberto Albertani (Pacific Northwest)

Oregon State University, SBC, Amy Caldwell (Pacific Northwest)

Portland State University, FA, Andrew Greenberg (Pacific Northwest)

Portland State University, SBC, Christopher Rushford (Pacific Northwest)

San Diego State University, FA, Allen Plotkin (San Diego)

San Diego State University, SBC, Stephen Nick (San Diego)

San Jose State University, FA, Periklis Papadopoulos (San Francisco)

San Jose State University, SBC, TBD (San Francisco)

Santa Clara University, FA, Christopher Kitts (San Francisco)

Santa Clara University, SBC, Emma Kulick (San Francisco)

Stanford University, FA, Stephen Rock (San Francisco)

Stanford University, SBC, TBD (San Francisco)

University of Alaska Fairbanks, FA, Michael Hatfield (Pacific Northwest)

University of Alaska Fairbanks, SBC, Michael Radotich (Pacific Northwest)

University of Arizona, FA, Jekan Thangavelautham (Tucson)

University of Arizona, SBC, Michael Nathanson (Tucson)

University of California-Berkeley, FA, George Anwar (San Francisco)

University of California-Berkeley, SBC, Andy Mandrell (San Francisco)

University of California-Davis, FA, Ronald Hess (Sacramento)

University of California-Davis, FA, Case Van Dam (Sacramento)

University of California-Davis, SBC, Erina Kitamura (Sacramento)

University of California-Irvine, FA, Haitham Taha (Orange County)

University of California-Irvine, SBC, TBD (Orange County)

University of California-Los Angeles, FA, Jeff Eldredge (Los Angeles-Las Vegas)

University of California-Los Angeles, SBC, David Lu (Los Angeles-Las Vegas)

University of California-Merced, FA, YangQuan Chen (Sacramento)

University of California-Merced, SBC, TBD (Sacramento)

University of California-San Diego, FA, Mark Anderson (San Diego)

University of California-San Diego, SBC, Sean Angelo Delos Santos (San Diego)

University of Nevada, Las Vegas, FA, Darrell Pepper (Los Angeles-Las Vegas)

University of Nevada, Las Vegas, SBC, Luis Cuevas (Los Angeles-Las Vegas)

University of Nevada, Reno, FA, Jeffrey LaCombe (Sacramento)

University of Nevada, Reno, SBC, Barry Jones (Sacramento)

University of Southern California, FA, Geoffrey Spedding (Los Angeles-Las Vegas)

University of Southern California, SBC, Randi Arteaga (Los Angeles-Las Vegas)

University of Utah, FA, Kuan Chen (Utah)

University of Utah, SBC, TBD (Utah)

University of Washington at Seattle, FA, James Hermanson (Pacific Northwest)

University of Washington at Seattle, SBC, TBD (Pacific Northwest)

Utah State University, FA, Stephen Whitmore (Utah)

Utah State University, SBC, Sam Dalrymple (Utah)

Washington State University, FA, TBD (Pacific Northwest)

Washington State University, SBC, TBD (Pacific Northwest)

Weber State University, FA, John Sohl (Utah)

REGION VII

Beihang University, FA, Zhiqiang Wan (International)

Beihang University, SBC, Shi Yan (International)

British University in Egypt, FA, TBD (International)

British University in Egypt, SBC, TBD (International)

Cairo University, SBC, Mohannad Draz (International)

Cairo University, FA, Osama Mohammady (International)

Carleton University, FA, Steve Ulrich (International)

Carleton University, SBC, Carmen Huang (International)

Chulalongkorn University, FA, Joshua Staubs (International)

Chulalongkorn University, SBC, Phrare Teinwan (International)

Concordia University, FA, TBD, (International)

Concordia University, SBC, TBD, (International)

Ecole Polytechnique de Montreal, FA, TBD (International)

Ecole Polytechnique de Montreal, SBC, TBD (International)

Emirates Aviation College, FA, TBD (International)

Emirates Aviation College, SBC, TBD (International)

Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, FA, TBD (International)

Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, SBC, TBD (International)

Hindustan University, FA, TBD (International)

Hindustan University, FA, TBD (International)

Hong Kong University of Science & Technology, FA, Larry Li (International)

Hong Kong University of Science & Technology, FA, Wei Shyy (International)

Indian Institute of Technology-Kanpur, FA, Ajoy Ghosh (International)

Indian Institute of Technology-Kanpur, SBC, TBD (International)

Institute of Space Technology-Pakistan, FA, Shuja Rehman (International)

Institute of Space Technology-Pakistan, FA, Abdul Munem Khan (International)

Institute of Space Technology-Pakistan, SBC, TBD (International)

Istanbul Technical University, FA, TBD (International)

Istanbul Technical University, SBC, TBD (International)

Khalifa University of Science,Technology, and Research, FA, Ashraf Al-khateeb (International)

Khalifa University of Science,Technology, and Research, SBC, Nouf Al Suwaidi (International)

Korea Advanced Institute of Science and Technology, FA, Jiyun Lee (International)

Korea Advanced Institute of Science and Technology, SBC, TBD (International)

McGill University, FA, TBD (International)

McGill University, SBC, TBD (International)

Middle East Technical University, FA, TBD (International)

Middle East Technical University, SBC, TBD (International)

MLR Institute of Technology, FA, TBD (International)

MLR Institute of Technology, SBC, TBD (International)

Monash University, FA, Daniel Edgington-Mitchell (International)

Monash University, SBC, TBD (International)

Moscow Aviation Institute, FA, TBD (International)

Moscow Aviation Institute, SBC, TBD (International)

Nagoya University, FA, TBD (International)

Nagoya University, SBC, TBD (International)

Nanjing University of Aeronautics and Astronautics, FA, TBD (International)

Nanjing University of Aeronautics and Astronautics, SBC, TBD (International)

Northwest Polytechnical University, FA, TBD (International)

Northwest Polytechnical University, SBC, TBD (International)

Queen's University , FA, TBD (International)

Queen's University , SBC, TBD (International)

Royal Melbourne Institute of Technology, FA, Cees Bil (International)

Royal Melbourne Institute of Technology, SBC, TBD (International)

Royal Military College of Canada, FA, Ruben Perez (International)

Royal Military College of Canada, SBC, TBD (International)

Ryerson Polytechnic University, FA, Sayed Hashimi (International)

Ryerson Polytechnic University, SBC, TBD (International)

Sapienza Universitá di Roma, FA, Giuliano Coppotelli (International)

Sapienza Universitá di Roma, SBC, Luca Migani (International)

Technion Institute of Technology, FA, TBD (International)

Technion Institute of Technology, SBC, TBD (International)

United Arab Emirates University, FA, Emad Elnajjar (International)

United Arab Emirates University, SBC, TBD (International)

Universidad Autonoma de Baja California, FA, Juan Antonio Paz (International)

Universidad Autonoma de Baja California, SBC, TBD (International)

Universidad Autonoma de Chihuahua, FA, Eloy Normando Marquez Gonzalez (International)

Universidad Autonoma de Chihuahua, SBC, Kevin Trejo (International)

Universidad de San Buenaventura, FA, Ruben Salazar (International)

Universidad de San Buenaventura, SBC, TBD (International)

Universidad Pontificia Bolivariana, FA, TBD (International)

Universidad Pontificia Bolivariana, FA, TBD (International)

Universitá degli Studi di Napoli Federico II, FA, TBD (International)

Universitá degli Studi di Napoli Federico II, SBC, TBD (International)

Universität Stuttgart, FA, TBD (International)

Universität Stuttgart, SBC, TBD (International)

University of Adelaide, FA, Rey Chin (Adelaide)

University of Adelaide, SBC, Zoe Rich (Adelaide)

University of Palermo, FA, TBD (International)

University of Palermo, SBC, TBD (International)

University of Queensland, FA, TBD (International)

University of Queensland, SBC, TBD (International)

University of Sydney, FA, Gareth Vio (Sydney)

University of Sydney, SBC, Joseph Dowsett (Sydney)

University of Toronto, FA, TBD (International)

University of Toronto, SBC, TBD (International)

Von Karman Inst of Fluid Dynamics, FA, TBD (International)

Von Karman Inst of Fluid Dynamics, FA, TBD (International)

Nominate Your Peers and Colleagues!

NOW ACCEPTING AWARDS AND LECTURESHIPS

PREMIER AWARD

- Daniel Guggenheim Medal

TECHNICAL EXCELLENCE AWARDS

- Aerospace Power Systems Award
- Air Breathing Propulsion Award
- Dr. John C. Ruth Digital Avionics Award
- Energy Systems Award
- Propellants & Combustion Award
- Space Automation and Robotics Award
- Space Operations & Support Award
- Space Processing Award
- Space Systems Award
- von Braun Award for Excellence in Space Program Management
- Wyld Propulsion Award

LECTURESHIPS

- Dryden Lecture in Research
- Durand Lecture for Public Service

Please submit the four-page nomination form and endorsement letters to **awards@aiaa.org** by **1 February 2019**

For more information about the AIAA Honors and Awards Program and a complete listing of all the AIAA awards, please visit **aiaa.org/HonorsAndAwards**.

AIAA
SHAPING THE FUTURE OF AEROSPACE

EMBRY-RIDDLE Aeronautical University. PRESCOTT, ARIZONA

The College of Engineering at Embry-Riddle Aeronautical University in Prescott, Arizona, invites applications for tenure track positions in our Aerospace and Mechanical Engineering Departments at the Assistant or Associate Professor levels, to start in Fall 2019. The Department is interested in candidates in all areas that will enhance our college strengths and growth.

The Department seeks candidates with strong interests in engineering education, a commitment to excellence in teaching and learning, an ability to perform applied research, as well as dedication to service and collegiality. Successful candidates will be expected to teach undergraduate courses and laboratory experiments, to collaborate with students on independent research and to supervise student projects. An earned doctorate in Aerospace or Mechanical Engineering or similar degree along with related experience is highly desired; however, candidates with a Master's Degree and significant industry experience are strongly encouraged to apply.

Qualified candidates who wish to be considered should apply online by visiting careers.erau.edu. Screening of applicants will begin on December 15th, 2017. Queries may be submitted via email to the Search Committee Chair, Dr. Brad Wall, at wallb@erau.edu.

Embry-Riddle Aeronautical University excels as a leader in undergraduate education for engineering, aviation, global security, and related fields. We draw students from around the world who are serious about their future careers. U.S. News & World Report ranks Embry-Riddle Prescott as the #1 undergraduate Aerospace Engineering Program in the nation among schools whose highest degree is a Bachelor's or Master's.

For more information about the college, please visit **http://prescott.erau.edu/college-engineering/index.html**.

prescott.erau.edu

Embry-Riddle Aeronautical University is dedicated to building a culturally diverse faculty and staff. We strongly encourage women, minorities, and members of under-represented groups to apply for this position. Embry-Riddle Aeronautical University is an Equal Opportunity Employer.

CAL POLY Aerospace Engineering

ASSISTANT/ASSOCIATE PROFESSOR IN AEROSPACE ENGINEERING

The Aerospace Engineering Department within the College of Engineering at Cal Poly, San Luis Obispo, CA invites applicants with an earned Ph.D. in Aerospace Engineering, or closely-related field, to apply for a full-time, academic-year tenuretrack faculty position at the Assistant or Associate Professor Rank. The projected start date is September 12, 2019.

The College of Engineering at Cal Poly is committed to building a diverse faculty of teacher-scholars who collaborate to provide a multi-disciplinary and hands-on approach to student learning and applied research. We believe that individuals from diverse backgrounds strengthen our programs and positively impact student success. We encourage qualified applicants from all backgrounds to apply for consideration.

Duties include teaching Aerospace Engineering courses; building a vibrant and innovative research program; and supporting and developing students into engineers ready to thrive in the modern aerospace industry. This position is open to candidates with experience in all areas of aerospace engineering—including aeronautics, astronautics, and advanced technologies. Candidates with research or private industry experience are encouraged to apply.

To apply, visit WWW.CALPOLYJOBS.ORG, complete a required online Cal Poly faculty application, apply to requisition #105136. Interested candidates must attach (1) a cover letter, (2) resume/curriculum vitae, (3) a statement of research, as it relates to undergraduate and graduate student projects, and (4) teaching philosophy. Please be prepared to provide three professional references with names and email addresses when completing the online faculty application. Review of applications will begin February 1, 2019 and will continue until the position is filled. Please submit any materials you are not able to attach online to: Kendra Bubert, Aerospace Engineering Department, Cal Poly, San Luis Obispo, CA 93407 or email kbubert@calpoly.edu.

Cal Poly's commitment to diversity informs our efforts in recruitment, hiring and retention. California Polytechnic State University is an affirmative action/equal opportunity employer. EEO.

1919

Jan. 2 A new altitude record of 30,500 feet is set by Capt. Andrew Lang and Lt. A.W. Blowes of Britain's Royal Air Force in their open cockpit de Havilland D.H.9 light bomber fitted with a new 430-horsepower Napier Lion engine. They are protected from the bitter cold by Sidcot heated flight suits. They return to the ground after the fuel pump freezes, causing the engine to stop. David Baker, **Flight and Flying: A Chronology**, pp. 122.

Jan. 6 Four Army Curtiss JN-4H aircraft complete a special transcontinental pathfinding mission of 6,400 kilometers in 50 flying hours to take photos and make maps to prepare U.S. Air Mail routes. **Aircraft Year Book, 1920**, p. 248.

Jan. 8 Germany's first regularly scheduled airline receives its operating license. The Allegemeine Elektrizitats Gesellschaft, in cooperation with the Zeppelin and the Hamburg-Amerika companies, will use aircraft of its own design, modified from World War I light bombers and flying under the name of Deutsche Luft Reederei. First service with passengers and cargo is scheduled for February between Berlin and Weimar. R.E.G. Davies, **A History of the World's Airlines**, pp. 11-12.

1944

Jan. 1 At the request of the U.S. Army Ordnance Department, the Caltech Guggenheim Aeronautical Lab initiates Project ORDCIT (combining the names Ordnance and California Institute of Technology), which leads to the experimental solid-fuel Private A and Private F missiles for testing aerodynamics and booster separation of large-scale missiles. The project will also lead to the liquid-fuel Corporal missile. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 47.

Jan. 1 A U.S. 13th Air Force bomb squadron flying new SB-24s (radar-equipped aircraft, for night missions) starts to become known as the "Snooper Squadron." K.C. Carter and R. Mueller; compilers, **The U.S. Air Forces in World War II**. p. 243.

Jan. 1 The U.S. Strategic Air Forces in Europe is activated for control of the 8th and 15th Air Forces. Gen. Carl Spaatz assumes command on Jan. 6, taking on administrative responsibility for all U.S. Army air forces in the theater. K.C. Carter and R. Mueller, compilers, **The U.S. Air Forces in World War II**," pp. 243, 246, 254.

Jan. 8 The Lockheed XP-80 makes its first flight, powered by a British Halford turbojet engine. Development took Lockheed designer Clarence L. ("Kelly") Johnson and his team only 143 days. The production version, the P-80, will not become operational until December 1945. It is the first single-seat turbojet-powered fighter/bomber to enter combat with the U.S. Army Air Forces. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p; 47.

Jan. 9 The operational version of the Northrop P-61 Black Widow radar-equipped nightfighter is announced, amid claims that it is the best airplane of its class. The aircraft begins flight in the European and Pacific theaters. **The Aeroplane**, Jan. 14, 1944, p.32.

Jan. 11 First U.S. combat use of forward-firing aircraft rockets is achieved by a Navy Grumman TBF-1C torpedo bomber against a U-boat. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 47.

1969

Jan. 3 Time magazine honors the Apollo 8 astronauts as the Men of the Year for 1968 for their Dec. 21-27, 1968, flight during which the three-man crew of Frank Borman, James Lovell and William Anders became the first humans to leave low Earth orbit, the first to see Earth as a whole planet, the first to reach the moon and orbit it, the first to directly see the far side of the moon, and the first to return safely to Earth from the moon. **Time**, Jan. 3, 1969, p. 3.

Jan. 5 The Soviet Venera 5 is launched from Tyuratam for a soft landing on Venus. As the atmosphere of Venus is approached in mid-May, a 405 kilogram capsule containing scientific instruments is jettisoned from the main spacecraft. During satellite descent toward the surface of Venus, a parachute opens to slow the rate of descent. For 53 minutes on May 16, while the capsule is suspended from the parachute, data from the Venusian atmosphere is radioed back to Earth. Venera then lands and carries a medallion bearing the coat of arms of the USSR. Venera 5's new chemical analysis experiments provide more precise measurements of the planet's atmospheric components. **Aviation Week**, Jan. 13, 1969, p. 19; **Washington Post**, May 17, 1969, p. A3.

Jan. 7 U.S. Patent No. 3,420,471 is granted to John D. Bird and others for "jet shoes" to enable astronauts to move in space by means of nitrogen-powered thrusters in the sole of each shoe. **New York Times**, Jan. 11, 1969, p. 39.

Jan. 10 Just five days after Venera 5 is launched, the Soviet Union launches Venera 6, which is identical but is to gather atmospheric data from a different portion of Venus. Similarly to Venera 5, for 51 minutes on May 17, while Venera 6 is suspended from its parachute, important scientific data on the Venusian atmosphere is returned before it makes a landing. **Aviation Week**, Jan. 20, 1969, p. 29; **Washington Post**, May 18, 1969.

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

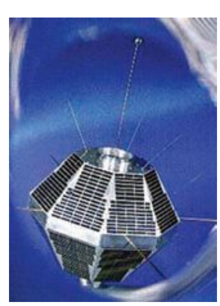
Jan. 13 NASA announces the termination of the joint NASA/Department of Defense XB-70 flight research program. The North American Rockwell XB-70 was originally a supersonic bomber prototype but only two were built and it was decided to use them for research, resulting in a four-year program. A top speed of Mach 3 and peak altitude of 22,555 meters (74,000 feet) were recorded. **Flight International**, Jan. 23, 1969, p. 119; NASA Release 69-10.

Jan. 14-17 Hailed as the Soviet Union's "most ambitious manned space venture so far," the Soyuz 4 spacecraft is launched carrying cosmonaut Vladimir A. Shatalov. The next day the Soviets launch Soyuz 5, manned by cosmonauts Yevgeny Khrunov, Boris Volynov and Alexei Yeliseyev, and the two craft dock on Jan. 15. This is the first time two manned spacecraft dock, although the command module and the service module of the United States' Apollo 9 dock in March. Two of the cosmonauts, Khrunov and Yeliseyev, make space walks in their spacesuits and board Soyuz 4, the first transfer of crew from one space vehicle to another of any nation. On their 35th revolution of Earth, the two cosmonauts exit their spacecraft for the second Soviet spacewalk. Soyuz 4 and 5 separate after four hours and 35 minutes docked together. Soyuz 4 re-enters the atmosphere and lands 100 kilometers southwest of Karaganda on Jan. 17. Volynov remains on Soyuz 5 and returns to Earth on Jan. 18 although he has a difficult re-entry and landing. Among other problems, his parachute cables become partially tangled and the soft-landing rockets fail, resulting in a hard impact that breaks some of his teeth. **Flight International**, Jan. 23, 1969, pp. 148-149.

Jan. 15 A 10-year extension of the patent on the droop nose of the Concorde is granted by a High Court judge. The application is made on behalf of the British aerospace firms Fairey Aviation, Westland Aircraft and British Aircraft Corp., and France's Sud-Aviation. **Flight International**, Jan. 23, 1969, p. 118.

Jan. 22 NASA's OSO 5 orbiting solar observatory is launched by a Delta rocket from Cape Kennedy, Florida, into a circular orbit. It is designed to provide data on solar physics throughout an 11-year solar-activity cycle. The first in the series, OSO 1, was launched on March 7, 1962. OSO 5 weighs 290 kilograms, of which 120 kg are scientific instruments. **Flight International**, Jan. 30, 1969, p. 184.

Jan. 24 British jet aviation pioneer Sir Frank Whittle is the first foreigner to receive the Tony Jannus Award, given annually to those who "contributed greatly to the development of the scheduled airline industry." He accepts the 1969 award from the Tony Jannus Distinguished Aviation Society in Tampa, Florida. Jannus was the pilot of the world's first scheduled commercial airline flight, between St. Petersburg and Tampa, Florida, in 1914. **Flight International**, Jan. 9, 1969, p. 44.



Jan. 29 The Canadian-built ISIS-A, or International Satellite for Ionospheric Studies, is launched by a U.S. Thrust-Augmented Delta from Vandenberg Air Force Base, California. The satellite carries six Canadian and four U.S. experiments to study the topside of the ionosphere during a period of high solar activity. **Aviation Week**, Feb. 3, 1969, p. 25.

During January 1969 The first British Hovercraft Corp.'s SRN4 passenger-car hovercraft ferry starts sea trials. Earlier, only passenger-carrying hovercraft were tried. The SRN4 is capable of carrying 30 vehicles and 254 passengers. The service between Ramsgate, England, and Calais, France, becomes highly popular and operates until the early 1990s. **Aviation Week**, Jan. 20, 1969, p. 52.

1994

Jan. 5 NASA loses contact with the Mars Observer just three days before the spacecraft is scheduled to enter orbit around the planet. Scientists suspect that a ruptured fuel line caused the craft to spin uncontrollably. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 455.

Jan. 8 A Soyuz TU-18 with three cosmonauts onboard lifts off from Kazakhstan to rendezvous with the orbiting Mir space station. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 457.

Jan. 13 Due to a NASA budget cut, Search for Extra-Terrestrial Intelligence, or SETI, program is canceled, but former SETI Director Frank Drake announces the program will continue with private backing and is renamed Project Phoenix. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 463.

Jan. 25 The Clementine space probe is launched by a Titan 2 and captures 1.8 million images of the moon. Clementine's imagery capabilities also test anti-missile technology. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 485, 711.

JOHN DOLAN, 34

Senior systems engineer, Aireon

John Dolan's childhood fascination with technology, and computers in particular, sparked his career in engineering. In college, he gradually homed in on orbital dynamics and control theory, expertise he applies at Aireon, the aircraft tracking joint venture of Iridium Communications and the air navigation authorities of Canada, the United Kingdom, Italy, Denmark and Ireland. Dolan focuses on data analysis and modeling at Aireon, the company flying a constellation of satellite-based ADS-B, for Automatic Dependent Surveillance-Broadcast, receivers on Iridium NEXT communications satellites to offer continuous global updates on air traffic.

How did you become an aerospace engineer?

I attended Virginia Tech, where I earned my bachelor's and master's degrees in aerospace engineering. Initially, my interest was in space vehicle design. Through my course work, I gravitated toward orbital dynamics and control theory. The education in control theory helped me get my start in the air traffic surveillance industry working on multisensor trackers. As I continued to work in the industry, I spent much of my time on data analysis and complex simulations to model and test systems. Everywhere I worked, I was close to ADS-B, the technology at the heart of Aireon. All that experience and the colleagues I met along the way led me to my current position at Aireon. I am one of the primary caretakers of our Aireon Simulator, a high-fidelity complete simulation of every part of the Aireon system; from aircraft, to the satellites and all the way down to the data we transmit to our customers. Before we make any changes or do any work on the real system, we model the impact in our simulator. In addition, I analyze recorded data from the Aireon system to determine performance, troubleshoot any anomalies and explore ways to improve our service.

Imagine the world in 2050. What do you think will be happening in aviation?

To the average passenger, I don't think aviation in 2050 will be much different from what it is today. There may be some interesting ideas starting to take root, such as supersonic/suborbital transports or space tourism. But I think the industry is moving toward efficiency. Aircraft will continue to get larger, engines will become more fuel efficient and aircraft will go farther distances than ever before. I imagine flights that travel halfway around the world in a single leg will become commonplace. This move toward efficiency will eventually challenge how we control, monitor and separate aircraft. I believe that the work we do here at Aireon will help make those flights safer and more efficient because we will be able to track those aircraft, uninterrupted, across the globe. ★

BY DEBRA WERNER | werner.debra@gmail.com