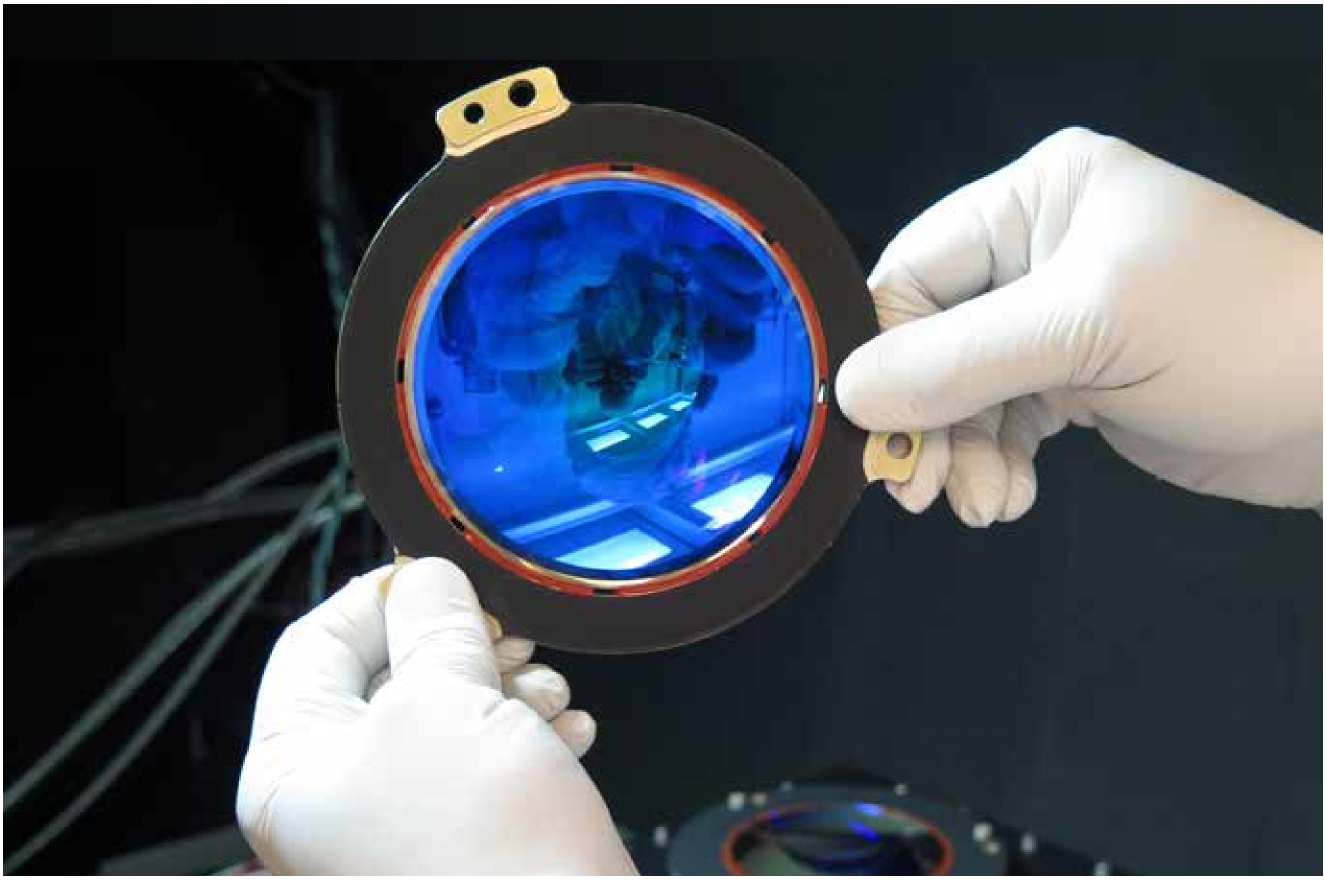
AEROSPACE
★ ★ ★ AMERICA ★ ★ ★

FINDING EARTH'S ANALOG

The discovery could come sooner than you think, with NASA's next telescope PAGE 24

MARCH 2018 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org



AEROSPACE
★ ★ ★ AMERICA ★ ★ ★

MARCH 2018, VOL. 56, NO. 3

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

ASSOCIATE EDITOR
Karen Small
karens@aiaa.org

STAFF REPORTER
Tom Risen
tomr@aiaa.org

EDITOR, AIAA BULLETIN
Christine Williams
christinew@aiaa.org

EDITOR EMERITUS
Jerry Grey

CONTRIBUTING WRITERS
Keith Button, Amanda Miller, Joe Stumpe, Robert van der Linden, Debra Werner, Frank H. Winter

James "Jim" Maser AIAA PRESIDENT
John Langford AIAA PRESIDENT-ELECT
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 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.

AIAA Shaping the Future of Aerospace

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.

PAGES 16, 36

Amanda Miller

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

PAGE 22

Joe Stumpe

A freelance reporter based in Wichita, Kansas, Joe has written for The New York Times, Agence France-Presse and The Huffington Post.

PAGE 8

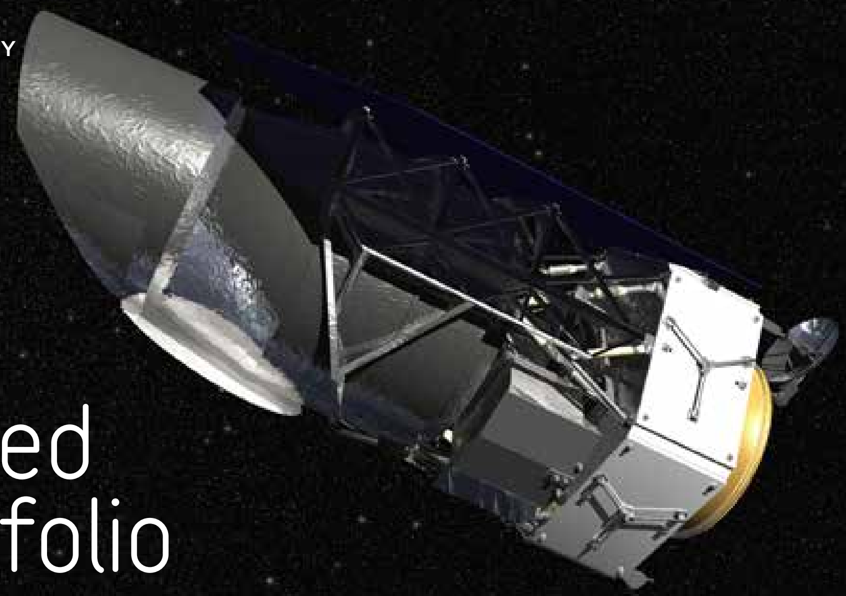
Debra Werner

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

PAGES 9, 30, 64

DEPARTMENTS

In defense of a balanced space portfolio



NASA

▲ The Trump administration's proposed 2019 budget would end funding of the proposed Wide Field Infrared Survey Telescope, or WFIRST, seen here in an artist's rendering.

I came away from our preview of the Transiting Exoplanet Survey Satellite mission (Page 22) feeling that the search for planets beyond our solar system should stand on equal footing with anything NASA does. That does not necessarily equate to equal dollars compared to other endeavors, but it suggests a firm place in a balanced portfolio of NASA space science and exploration.

The Trump administration's NASA budget proposal for 2019 confirms that the competition for dollars is going to be fierce, given the palpable excitement over the possibility of returning astronauts to the moon, reaching Mars in the 2030s and robotically exploring Jupiter's moon Europa. The administration would end funding for development of the Wide Field Infrared Survey Telescope, or WFIRST, whose construction was the "top-priority recommendation" of the U.S. Decadal Survey astronomy and astrophysics committee in 2010. WFIRST would take a broader look at the cosmos than the James Webb Space Telescope and put a spare 2.4-meter spy telescope mirror to work searching for exoplanets and unraveling the mysteries of dark energy and supernovas.

Excitement, of course, is subjective, but I would submit that searching for Earthly worlds is as compelling an endeavor as hunting for fossils on Mars or trying to figure out the origins of the moon. We tell ourselves that human missions to these places will produce more than knowledge, that we'll open up commercial opportunities and put ourselves on a path to becoming a multiplanetary species. It is indeed amazing to realize that we could become extraterrestrials.

That said, we don't know for sure that sustained human exploration in deep space, let alone colonization, will be possible given our human biology, the costs of such missions and our penchant for competing as nations rather than collaborating. If the country that led the way to the moon can't join other nations to clean up Earth's atmosphere, how are we ever going to lead something as complex as an international mission to Mars? As exciting as this vision of exploration is, its feasibility is an open question.

That's why a rich variety of research and development and operational missions is so important. Consider it an insurance policy in case we can't break the surly bonds as entirely as we might like. We would have plenty of good things going on, from sending robots to other worlds to developing technologies for exotic space telescopes capable of viewing planets beyond our solar system.

If the TESS mission goes as planned, it could be instructive about the value of a balanced portfolio. The $200 million mission will come with a multiplier effect. Planet hunters could find seven times more exoplanets in star observations from TESS than they've found so far with the Kepler Space Telescope. TESS also would add value to the innovative but wildly over-budget Webb telescope, which will try to detect atmospheric spectra from planetary targets identified by TESS. ★

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

Climate change

Regarding the article in the January issue on self-censorship at NASA with respect to the global climate change debate ["Self-censorship/discipline at NASA"]. I expected to see some discussion of the political environment of past years, but only found a one-sided presentation.

The author seems to think that there is now an oppressive atmosphere at NASA where certain words are edited out of proposals to provide a better chance of funding due to the outlook of the Trump administration. Really? There were persecutions during the Obama administration against people who had reservations about the doctrine of man-made global climate change (including being labeled as "climate change deniers").

In some instances, governmental entities promoted the idea of criminal charges against the "deniers." Having to self-censor seems rather mild by comparison.

Most sincerely,
Pete Badzey
AIAA associate fellow
Huntington Beach, California

I just read your article "Self-censorship/discipline at NASA" and am surprised that you would buy into the "prevailing wisdom" of human-caused climate change/global warming.

A couple of decades ago, I did my own statistical analysis of global temperatures measured by satellite and balloon-borne radiosondes, obtaining a temperature rise of 0.1 degree Celsius per decade for the satellite data and zero degree for the radiosonde data (for the years 1978-1998).

The record since then has shown a "flat" temperature except for El Nino years. Over half a century ago, President Dwight Eisenhower warned us about the military-industrial complex. Today it's the government agency-research complex" that we must worry about.

Robert C. Whitten
AIAA associate fellow
Cupertino, California
rwhitten@pacbell.net

Management role in Columbia tragedy

I was glad to see the article "Their mission became our mission" by astronaut Tom Jones in the January issue. It was an excellent summary of the loss of [the space shuttle] Columbia, the investigation to find the cause, and the training of new NASA employees regarding lessons learned. I believe the lessons learned from Columbia, as well as the loss of Challenger, should be much broader than just NASA, and should extend to all organizations.

Although the article discussed various technical, communication and management failures for the Columbia tragedy, I want to stress the root cause of the failure: management. To support my contention, it is necessary to briefly recount the accident investigation from my perspective. I was a member of the Sandia National Laboratories team that was asked by NASA to help find the cause of the failure. The Sandia team interacted with NASA management and staff during the investigation from February to August 2003.

From the day of the event, Feb. 1, there was suspicion that it could be due to the impact of foam on the wing leading edge. Insulating foam and ice had been regularly torn from the bipod ramp area on several previous shuttle flights. Even though early studies during the investigation began to support the argument that foam impact could cause serious damage to the wing, NASA management was adamantly and loudly against this cause. The turning point came when the flight data recorder was found on March 19. The flight data clearly showed the rapidly increasing temperatures near reinforced carbon-carbon, or RCC, wing panel 8 on the left wing. Management would still not accept that the cause could have been something that was dismissed as "accepted risk" for years. They needed proof that foam could knock a hole in the RCC leading edge. NASA enlisted Southwest Research Institute to conduct experiments firing foam blocks at the leading edge. After a number of shots did not significantly damage the RCC, management redoubled their belief that foam impact was not the cause. Then, on July 7, essentially on the last planned shot at SwRI, the foam blasted a hole through the RCC. There was no longer a basis to deny the cause. In summary, if the flight data would not have been available and experiments would not have shown that major damage could occur, NASA would still be denying the real cause for the catastrophe.

This recounting of history from the trenches of the investigation is not just directed at NASA management, but management of all organizations. Whether it be Volkswagen management involved in the emissions scandal, the Takata airbag scandal or the Flint, Michigan, water scandal, the root cause is failure of management to be open to and to address issues that are brought to their attention. These types of failures are not technical failures per se, but failures in management to develop an organizational structure and internal culture that allows and promotes bad news to travel upward through management and ending with the organization's leadership.

William Oberkampf
AIAA fellow
Georgetown, Texas
wloconsulting@gmail.com


AIAA CONGRESSIONAL VISITS DAY
WEDNESDAY, 21 MARCH 2018
Raise the Image of Aerospace in Washington
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 always enjoy coming out to the Hill and participating in the event. Every time it's a unique experience and it's great being able to advocate policies important to our profession."
BRAVEN LEUNG, pursuing doctoral studies in Aerospace Engineering at the Georgia Institute of Technology
LEARN MORE
aiaa.org/CVD
AIAA
Shaping the Future of Aerospace

Rule #1 is Show Up

AIAA represents the aerospace industry's workforce, today and tomorrow. We live in a new "golden age" of aerospace, where autonomy, AI, and electric propulsion are about to transform many sectors of our industries. This transformation will further intensify an already fierce competition for talent, as the types of skills most in demand will be sought not only by the aerospace and defense industry, but also other very vibrant parts of the economy, particularly the automotive and technology sectors. This is a huge challenge, and AIAA will be a crucial part of our industry's efforts to meet it.

If you are a young engineer looking to advance in the profession, you already know that a professional society is a way to develop your skills, get to know your colleagues, and figure out who is really making things happen. In our family we have a saying that in the basic rules of success, rule #1 is "show up." But often that is not so easy.

As a young engineer in my first job at one of the large aerospace primes, I remember how difficult it was to get approval to attend an AIAA conference. First, you had to join AIAA. Somebody had to pay for that. Second, somebody had to pay for my time to prepare the paper after it was accepted. Third, somebody had to pay the conference fee. Fourth, the time away from the office to attend the conference had to be approved. Finally, there were the not-insignificant travel costs. It was all too much, and I only attended one or two conferences in my early years out of school. The only good thing about the gauntlet I had to run to attend an AIAA conference was that I got to meet the senior leadership of the company, who had to approve attendance and wanted a report afterward.

I suspect my experience is not unusual. AIAA has strong participation from students, but we see unsettling attrition among the "Young Professionals." Even at the company I now run, it's not all that clear what our policies are regarding participating in a career development event such as an AIAA forum. I also suspect other organizations face the same issue, and that it may get to be a bigger problem as the size of the organization gets bigger. Yet I am 100% convinced that if we are to increase participation in our events, we need to attack this problem as a community. **Making it easier for young professionals to engage in our activities must be a top priority for AIAA.**

I am passionate about ensuring we have a strong voice for student members and young professionals and want to hear about your experiences, thoughts, and ideas. What does your own organization do to promote or hinder participation in professional events? What are the "best practices" that you see as an enabler for success at the forums? How can AIAA evolve to make this easier, and what changes should we press our corporate members for? These are all important decisions that cannot be made in a vacuum and needs the leaders of our future to engage and be inspired.

I want to hear from you personally, so take a minute to reach out to me at jslangford@aiaa.org. Together, we're going to change things for the better. ★

Dr. John Langford
AIAA President-Elect

NASA

NASA tech aims to track tomorrow's supersonic airliners

BY JOE STUMPE | jstumpe@cox.net

▲ **NASA plans to test prototype supersonic ADS-B** equipment on F-18s in May and August.

NASA plans two flight tests this year of an enhanced ADS-B radio-and-GPS device that could help a new generation of supersonic commercial jets meet an FAA mandate that will soon be imposed on aircraft in most controlled airspace.

Starting in 2020, FAA is requiring aircraft to be equipped with Automatic Dependent Surveillance-Broadcast Out radios that broadcast a plane's GPS position and identity. The broadcasts will be received by the air traffic control network and by any planes equipped with ADS-B In as part of a move away from reliance on ground-based radar. Current commercial ADS-B equipment would not be adequate to meet the FAA mandate if installed on supersonic aircraft.

The United States banned faster-than-sound commercial flight over land in 1973, one reason it hasn't been tried anywhere since the Concorde was retired in 2003. But Congress has directed the FAA to study whether that restriction could be eased. Lockheed Martin and Aireon Corp. last year announced plans to build a 12-person business jet capable of flying at Mach 1.4 speed — 1,715 kph — or about 60 percent faster than current models, with operations expected to start in 2025.

"There's a big push right now for supersonic operations, so I think there's going to be a lot more" supersonic aircraft proposed, says Ricardo Arteaga, a NASA research engineer at Armstrong Flight Research Center in Edwards, California.

Currently, ADS-B boxes broadcast a plane's GPS position, altitude, ground speed and identity at the rate of 1 hertz, or once per second. The rate is sufficient to meet the FAA's allowable position uncertainty limit of 304 feet (93 meters). But the magnitude of error balloons for planes at supersonic speeds — up to 679 meters at Mach 2, according to Arteaga.

Engineers at NASA Armstrong designed a prototype ADB-S radio that broadcasts at 10 hertz, or 10 times per second, with a maximum error of 68 meters at Mach 2 speed. The prototype also reduces the latency of current ADS-B boxes — that is, the time it takes to create the transmission. The prototype is a modification of an ADS version first developed for reusable space launch vehicles. Vigilant Aerospace Systems of Oklahoma City is providing software related to tracking of the F-18s by a ground station.

Arteaga said ADS-B equipment on supersonic planes also needs to transmit a more powerful signal — 250 watts instead of the current minimum of 125 watts — to help prevent collisions. That signal could be picked up at least 315 kilometers away.

The prototype supersonic ADS-B addresses these issues and more, including changes that would be needed on a supersonic plane's display panel to accommodate incoming data.

Plans call for tests in May and August with two NASA F-18s. They will fly up to 1.4 Mach speed and 50,000 feet. The prototype passed a flight simulation test at Mach 2 speed, Arteaga said. The FAA will evaluate the results to see if the 10 hertz, 250-watt prototype should be adopted as standards for ADS-B technology on supersonic aircraft.

Enhanced ADS-B technology has a couple of other possible uses. One is the tracking of space vehicles as they re-enter airspace from low Earth orbit. Another is providing precise data for research into reducing shockwaves that are felt on the ground when a plane breaks the sound barrier — the reason the U.S. stopped supersonic flight in the first place. ★

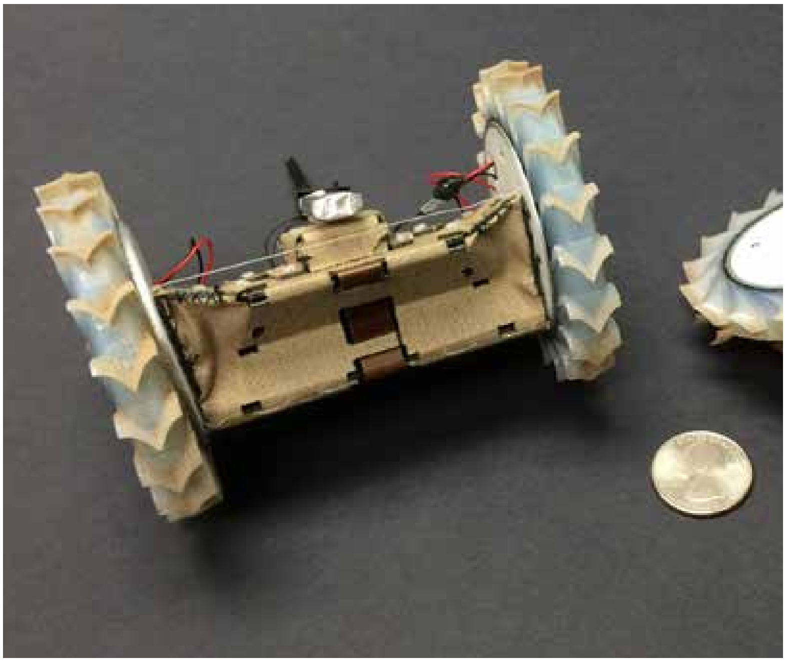
Solving a big problem in tiny robots

BY DEBRA WERNER | dlpwerner@gmail.com

Someday, a dozen palm-sized, origami-inspired robots called PUFFERs, short for Pop-Up Flat Folding Explorer Rovers, could be released from a single, shoebox-size instrument box on a larger planetary rover. Once free from their parent, the PUFFERs would roll in and out of Martian craters or perhaps across Jupiter's icy moon Europa.

It sounds futuristic, but Jaakko Karras, the PUFFER project manager in the Robotics Group of the NASA-funded Jet Propulsion Lab, says he's optimistic that within five years PUFFERs will be chosen for a future Mars mission.

Getting to that level of confidence did not come easily. JPL engineers were testing prototypes in 2015 when they hit a snag. Each rover needed fine wires of copper, called traces **(the shiny patch in the center of the pictured rover)**, to carry sensory data and power through the rover. Designers had embedded the traces in polyimide, a strong polymer that covered the flexible circuit boards which formed the rover's chassis and doubled as its brain. The tests revealed that the copper traces had a habit of cracking when folded and unfolded repeatedly, for instance where the wheels meet the chassis. That was a big problem, because each rover needed to slant its wheels inward to squeeze under obstacles or climb up slippery terrain.



NASA

Electronics on the Pop-Up Flat Folding Explorer Rover are embedded in the chassis made of rigid and flexible printed circuit boards, which are under the fabric. The chassis lies flat for stowage and pops open to drive around. The narrow copper strips in the center of the chassis are the bridges for the copper traces. Teflon wheel hubs house the rover's batteries and motors. The tires with spines for climbing rocky slopes are additively manufactured out of polymers or cast from polyurethanes.

"We had two conflicting challenges, we needed the copper traces to survive enough cycles to be useful and we wanted to keep our hinges fairly thin and narrow like a crease on a sheet of paper," says Karras.

That's when Dale McKeeby, vice president for Pioneer Circuits, a Santa Ana, California, manufacturer of printed circuit boards for aviation and space, met the PUFFER engineering team. He offered to print alternative circuit board mock-ups for PUFFER free, a service Pioneer has performed for JPL missions for decades.

The engineers realized that instead of creating hinges with bendable circuit boards, they could lay stacks of circuit boards end to end and join them with Dupont's Nomex fabric **(the beige burlap-looking material in the image)**. This heat-resistant material is found in space suits and airbags for landing on Mars. This time, the woven material would form the hinges. Next, they embedded the copper traces in narrow polyimide ribbons spanning each hinge like a bridge. This resulted in gentler bending of the copper traces.

Testing shows that these bridges can stand repeated folding and unfolding under mission scenarios, Karras says.

Karras envisions dropping PUFFERs from helicopters onto polar ice sheets on Earth or catapulting them away from rovers on Mars. JPL engineers are writing software to make PUFFERs semiautonomous so they can perform jobs like entering a cave, capturing images and relaying data through a daisy-chain of other PUFFERs to the parent rover. ★

Inflatable lander faces tests

BY TOM RISEN | tomr@aiaa.org

Engineers at NASA's Langley Research Center in Virginia are completing pressure tests on a prototype inflatable spacecraft shield in preparation for a requirements review coming up in April, one of several reviews on the way to a planned atmospheric entry test from low Earth orbit in 2021.

NASA has been working since 2005 on the Hypersonic Inflatable Aerodynamic Decelerator, or HIAD, concept. Tubes of fabric would inflate in space, pulling a heat shield of silicon carbide fabric in front of them to protect a spacecraft from the heat and pressure of hypersonic entry. Shifting away from hard aeroshells could add the option of plowing through a thin atmosphere with larger-diameter spacecraft like those required for a human mission to Mars. Astronauts or rovers also could dare to land at higher elevations on Mars, such as the southern highlands that NASA theorizes were once partially above sea level when the red planet had an ocean.

"This is the technology a lot of people are waiting on," says Neil Cheatwood, the principal investigator for the HIAD at Langley.

Despite the interest in Mars, he says the "most likely near-term candidate for actually using this would be bringing something back from low Earth orbit."

Cheatwood says he's coordinating with United Launch Alliance about the possibility of recovering rocket boosters by protecting them with HIADs.

NASA's Space Technology Mission Directorate in October gave Langley the initial funding to prepare for the 2021 orbital demonstration. Next comes the April systems requirements review by NASA managers independent of the project who will study its initial design.

Engineers launched an earlier version of HIAD in 2012 and released it from the rocket at an altitude of 450 kilometers. It landed in the Atlantic Ocean as planned. The NASA team plans for the aeroshell in the 2021 demonstration to be five times heavier than its predecessor. The engineers will separate that aeroshell from the rocket at a higher altitude than the 2012 flight, testing its ability to withstand the more intense heat and pressure of a faster re-entry speed.

Pressure tests of the latest design were underway in February at Airborne Systems in Santa Ana, California. Engineers pumped compressed water into the doughnutlike tubes while they were submerged in a pool of water to test how much pressure they could withstand.

"We will test it at several times the pressure we intend to operate at," Cheatwood says of the hydro-static tests.

Engineers stress tested the heat shield in August at a supersonic wind tunnel at a Boeing lab in St. Louis. They blasted sections of shield with superheated plasma gas at Mach 4.

"The higher levels we can test these materials at, the less of those materials we need," Cheatwood says. ★

▲ **Models of the Hypersonic Inflatable Aerodynamic Decelerator,** or HIAD, are being tested to determine if they can protect a spacecraft from a fast re-entry.
NASA

▲ **Jan Wörner, the European Space Agency's director general,** sees room for cooperation in space ventures among virtually all nations.
ESA

Q&A

Facilitator in chief

More online aerospace america.aiaa.org

The space-faring countries are going to need to work together if they are to achieve their ambitions for the 21st century. That's the view of German educator and engineer Jan Wörner, who sees the European Space Agency he leads as uniquely positioned to serve as an international facilitator among such competitors as China, Russia and the U.S. Europe wants to enlist collaborators to establish a Moon Village research station; the Trump administration wants to send astronauts to the moon while keeping Mars as the ultimate goal; the White House also would eliminate funding for some Earth science instruments that European scientists had been counting on. Wörner is not naïve to those and other sources of tensions, but he sees a desire to cooperate, too. Scientists in China are eager to share Earth science data, and ESA astronauts are learning Chinese, he notes. Wörner spoke to me by phone from his office at the European Space Agency headquarters in Paris. *— Tom Risen*

JOHANN "JAN" WÖRNER

POSITIONS: Elected director general of the European Space Agency in 2015. Chairman of the executive board of the German Aerospace Center from 2007 to 2015; president of the Technical University of Darmstadt in Germany from 1995 to 2007.

NOTABLE: During his civil engineering studies in 1982, Wörner lived in Japan for a year investigating the earthquake safety of nuclear power plants. As chairman of the executive board of the German Aerospace Center, DLR, he created the national security research department and coordinated with NASA to develop the telescope for the joint NASA-DLR Stratospheric Observatory for Infrared Astronomy, or SOFIA aircraft, a modified Boeing 747SP that studies the cosmos from a vantage point above most atmospheric moisture.

AGE: 63

RESIDENCE: Paris

EDUCATION: Civil engineering degree from the Technical University of Berlin and master's level degree from the Technical University of Darmstadt.

IN HIS WORDS

Moon Village begins

We will have the first missions under the umbrella of Moon Village this year. We have more than 150 signatures on the declaration to be part of the Moon Village. The Moon Village is an open concept. So, what do you provide? Transportation, logistics on the surface, navigation on the surface, would you like to look for energy, harvesting the energy or doing some in-situ resource utilization with 3-D printing and so on. There might be an institution which is interested to do some research on the surface of the moon, but do not have the possibility to go there. We bring them together.

Mining on moon

We need new technologies and we have already, in the International Space Station, developed a lot of things which work in microgravity which we can then also use on the surface of the moon. There may be new challenges. How to make 3-D printing with the moon material in low gravity and so on. There are discussions to [extract] helium-3 from the moon.

Moon base benefits

The far side of the moon is not as investigated as other parts. If you build an observatory and a radio telescope, you can have a better view into space, into the universe, because you are in the shadow of the moon. And the moon can be also a very nice place for planetary defense of the Earth, as an outpost to observe the universe, as an early warning station for asteroids, meteorites coming toward the Earth and, in the far future, also to use the moon as a base for some countermeasures. And the moon can be a test bed to go to Mars. I hope we will not build on Mars or moon for people to stay there forever. But mining in space will be something in the future as tourism will be. That's clear.

Brexit, European Union and ESA

Brexit doesn't affect us because we are an intergovernmental organization, not part of the European Union. We have 22 member states right now. One country, one vote. We have the ESA convention, more or less unchanged since 1975. Every member state of ESA has to go through their parliament to get ratification of this convention. So, it's national law. [The United Kingdom] will leave the European Union probably, but will not leave ESA. I don't like it that U.K. is leaving, but in 2016, Great Britain increased their contribution to ESA dramatically because ESA is a stable point for them.

ESA budget

Our budget right now is something like 5.7 billion euros per year. And in our case, we do not want to have any stable budget year by year. The director general gives a proposal for all the different programs, and then the ministers sign up for all the different proposals. So, it totally depends on how we propose missions. We are fighting always for the money. The advantage is for ESA that we do not have just an annual budget but a multiannual budget based on the different missions.

Commercial Earth observation

The taxpayer paid for these satellites, and therefore the data should be free and open, available, to cover the Earth observation and even more areas in the future. The value of space is today very important, whether it's the value for the return of investments like navigation, cable communication, Earth observation, or whether it's for humankind and geopolitical aspects.

Politics of Earth science

We can tell you that in our case, our member states love Earth observation very much. They would like to do more because, you know, we have what we call geo return rule. If we have member states paying 20 percent of our [Earth observation] program, they are eligible to get also contracts of a value of 20 percent, and therefore, they love it. So, Earth observation is clearly easy to sell. Earth observation is about 30 percent of our overall budget and human space flight is similar to that.

Climate science data business

Climate change is something where we really can give an impact to the society. For man-made disasters as well as natural disasters, and I think that Earth observation is really a good tool to help people worldwide to overcome specific problems. Be it earthquakes, tsunamis, forest fire, flooding, whatever. Also for the future, to look to the source of CO^2 emissions [can] give politicians clear information how to handle it. We are right now changing also the way we are doing Earth observation projects. In the past, we did it financed 100 percent by the public side, be it ESA or the European Union. Right now, we do all the public-private partnership in Earth observation and we are gradually increasing this part, so this is something which I see will come in the future: more private activities.

Sharing climate data with China

I'm arguing in favor of that because if you have, for instance, data concerning CO^2 emission, if this comes just from one country, whatever that country is worldwide, it will not be accepted by the other ones.

If you exchange the data you get two things. First of all, you get higher frequency of information, which is good to see as the sources of CO^2. And secondly, you get trust that you accept the data of the others if you give your data.

Working with China

The most important reason for us to do cooperation is to bridge Earthly crises. And we can do so. We are working with Russia intensively together for launch. In a tiny Soyuz capsule, you have [an] American astronaut, Russian cosmonaut and European astronaut together. Then you have some warm feelings that it's still possible even in times of sanctions and so on to do something together and I think we have to bridge Earthly crises, and therefore we are also cooperating with China. Some of our astronauts are now learning Chinese in order to be prepared if we can have in the future together some human missions.

The far side of the moon is not as investigated as other parts. If you build an observatory and a radio telescope, you can have a better view into space, into the universe, because you are in the shadow of the moon. And the moon can be also a very nice place for planetary defense of the Earth ... as an early warning system.

Mars is a challenge

For our exploration, we have three destinations right now. Lower Earth orbit, the moon and Mars. We will have in 2020 a rover on the surface of Mars, which will drill into the surface, 2 meters deep, let's say 6 feet or something, to look for life. The Russians are providing us a launcher for that mission and United States of America are part of the scientific investigation. We are working together for Mars. Where we have some slightly different opinion maybe, timewise, is when to go to Mars with humans. Mars is really a challenge. With today's technology and the orbits of Mars and the Earth around the sun, a journey will take about two years, plus-minus some months. And this is with respect to health issues, it's really difficult. If you look back to Apollo 13, they had a technical problem. They were back in a few days.

Space debris

Right now, we have 4,500 known satellites in orbit. 4,500. 1,500 are still active, meaning we have already 3,000 satellites which are not active any longer. We can call them space debris, and we have to do something. This is the danger. Space debris is really something. Three years ago one of our satellites was hit by a space debris and part of the solar panel was destroyed, so we know that this is not only a movie like "Gravity." It is a real issue. We are looking to something like space traffic management and also assist with automatic systems in case a satellite is not working any longer so that we have automatic systems to avoid a future increase of space debris.

ESA as facilitator of cooperation

We have regular meetings [with NASA]. None of our scientific missions is purely a European mission. In most of them, we have contributions from the United States of America and we're also part of missions in the U.S., so therefore this is really the difference to the middle of the last century when it was a race in space. Right now, it's cooperation in space, and there's still some race on the Earth. Maybe this is part of the beauty that we can do it more easily and NASA and others can use us also as a, how should I call it, facilitator of cooperation.

Sharing exploration costs

The cost of landing people on the moon is already something. I saw some numbers these days for a trip to Mars which is really so far beyond our limits that I don't dare to discuss about it right now. ESA has no project, no program so far for human transportation, so we are heavily dependent on our friends in the East and West. So, that means that also in the SLS, the new launch system, ESA is part of it. We are happy with that.

Rocket supply and future demand

I don't think that we have a shortage. It's the opposite right now. Worldwide, we have so many launch providers that the competition is very strong. We have through NASA the new SLS system, we have Boeing activities, we have ULA activities, you have Jeff Bezos doing something with Blue Origin, then you have SpaceX with Elon Musk. You have India. So, you have a lot of providers already.

Asteroid strike

Looking into the danger of some asteroid impacting the Earth, you need only a small impact to get it away from impacting the Earth. But this means that

▲ **ESA's Aeolus satellite** is an example of the kind of Earth observation technology that ESA's director general says is popular among the organization's members.

we need detection systems much earlier than we have today. The far side of the moon might be an interesting place for something like that. Today, one can say we would need years and we do not have that time if something comes, and last time, they found out only a few weeks before that there was some asteroid very close to Earth. Worldwide, we do not have the possibility, the means to counteract [an asteroid strike] in a short period of time.

Deep space travel

If you want to make deep space journeys in a quicker time, in a shorter time than in the past, you need disruptive solutions. I don't know whether you saw the movie "Interstellar." I mean, this is the way we should think about it but there's no new concrete idea so far. So, using the curvature of space and time to get faster through the universe, it would be really nice. We need disruptive solutions for transportation in space if we want to go farther. I mean, Mars is already something, as I said, two years' travel forth and back, but if we want to go for other areas, for other places in the universe, we need totally different technology.

Public or private space funding?

It depends very much on the subject. For instance, using Earth observation data and providing some special information for industry, where to build a new factory or whatever. So, they can sell information. They don't need any public support. And there are others which need public support. Launcher sector, for instance, needs institutional launchers and, as you know, SpaceX also contracts with NASA for a long period of transportation to the station. The private investor wants a heavy return of investment. Whether it's tourism or whether it's some other activities, I think that science and exploration will in the future, mainly be paid by public money. But that's not bad. ★


MD
530F


Gwinnett County (Ga.) Police Department

Wringing out the risks

Today's aircraft are, for the most part, so safe that any needed improvements to their designs are hard to find. Engineers must run hours of simulations in hopes of determining when and why things could go wrong, and then finding technical solutions. Keith Button spoke to mathematicians who are exploring an entirely new approach, one that relies on algorithms and probability.

BY KEITH BUTTON | buttonkeith@gmail.com

An MD Helicopters 369FF operated by a local police department crashed in Lawrenceville, Ga., on Sept. 1, 2017, after a strong wind gust. Applied mathematicians are working on modeling such relatively rare occurrences in the hopes of developing means to prevent them.

The chances of failure for complex aerospace systems, such as a helicopter, are so extremely small that it's difficult for designers to understand the unlikely confluence of circumstances that leads to failure. These systems exhibit an "average behavior" of high reliability, which is why "plane crashes happen very infrequently," explains applied mathematician Tuhin Sahai, a Berkeley, California-based associate director of United Technologies Research Center in Connecticut.

The current method for simulating and predicting failure requires running computer models millions of times to try to re-create the moment when the system "will do something crazy," as Sahai puts it. It's not a very efficient method for wringing out the causes of today's exceedingly rare failures.

Sahai and his co-principal investigator, applied mathematician Youssef Marzouk of MIT, think they can pinpoint the causes of failures by conducting hundreds of simulations. "All of that stuff is kind of hidden in the model. We're trying to make the model reveal it to us," says Marzouk.

They have until April 2019 to prove the technique under a DARPA project called SIRE, short for Scalable Inference for Rare Events. They plan to harness the power of probability and algorithms to define the calculations that would be required for establishing the probability of failure in a complex system and the path to it.

If they succeed, the results could point to safety improvements during design and set the stage for a cockpit alert or intervention system that would stave off dangerous aerodynamic stalls. The SIRE team plans to share its step-by-step recipe with the broader aerospace community, so that other researchers would decide how to apply it.

To define the steps, the SIRE team is starting with two specific cases: aerodynamic stalling in a rotorcraft and power outages in an airplane's electrical system. Currently, they are building digital models of aircraft electrical systems, adapting their algorithms to accommodate certain dynamic features of the rotorcraft system and building filtering, or estimating, algorithms that will help sense when a system is transitioning into potential failure.

UTRC research engineers are working with the applied mathematicians to build two computer models of electrical systems. One models an electrical current exceeding a threshold in an inductor coil. The other models electrical load instability.

While the research engineers build these models, the SIRE mathematicians are working on filtering algorithms, rare-event simulations and in-flight rare-event prediction algorithms for them. Transient behavior — factors that change over time — will play a key role in the simulated electrical system failures and in predicting those rare events, says Marzouk, who is director of MIT's Aerospace Computational Design Laboratory.

"It might be that a certain combination of things demanding power — turning on; turning off — conspire to end up overloading some circuit; demanding too much current overall; overloading some power source," Marzouk says. "We want to understand when things might go catastrophically wrong."

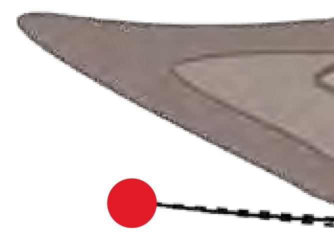
Marzouk and Sahai communicate regularly via video conferencing, phone and email, and occasionally fly to meet each other. They exchange code via email and run the system simulations on both UTRC and MIT server clusters.

Many of the current algorithms for producing rare-event simulations are limited, either because they make a lot of assumptions about the systems they are applied to or because they're applied to only one or two dimensions of those systems, Sahai says. Under SIRE, Marzouk and Sahai are adapting concepts not typically combined with rare-event simulations — such as predicting outcomes in the face of uncertain factors and the study of how dynamic systems like the weather behave over time.

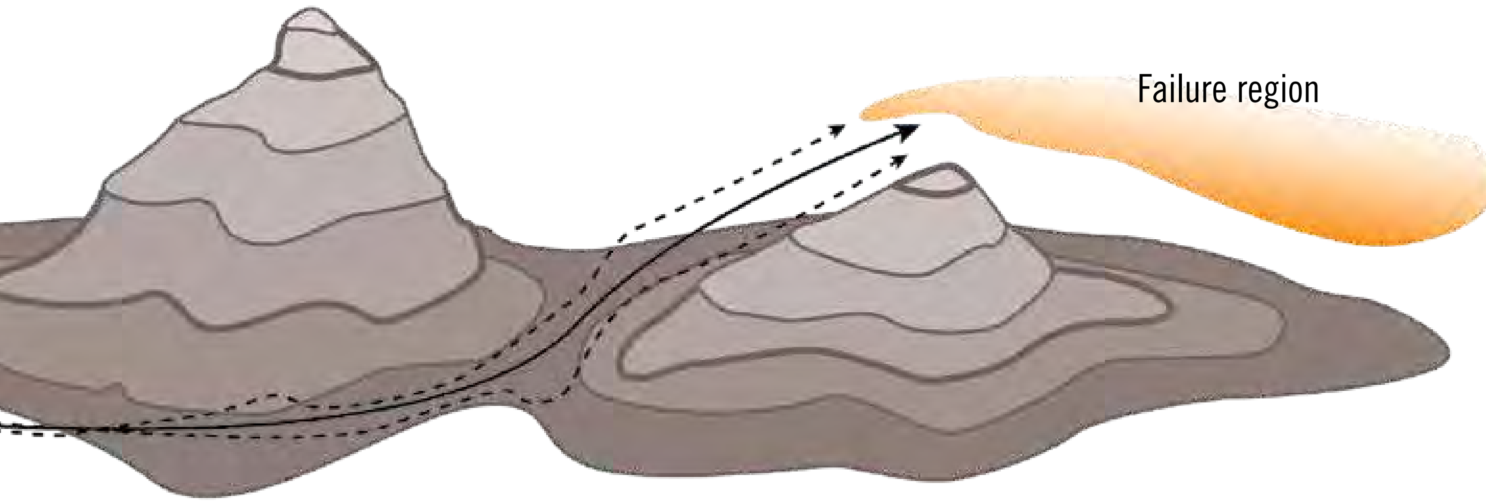
Predicting stalls

Marzouk and Sahai are building a model that will digitally represent a helicopter fuselage, tail, blades, shaft and factors such as blade flapping, blade pitching and blade loading. They will introduce random wind gusts that can force a helicopter into a stall, for example, if the blade angle of attack rises above a certain threshold. That can happen faster than a human pilot can react.

The mathematicians want to find the probability of stalling and the conditions that would lead to that failure point. Simulations like these, and understanding how to create them, would help designers of helicopters and other complex



Predicting catastrophe



This landscape-like representation illustrates the sequences of events that can cause a complex aerospace system, such as an aircraft or its electrical system, to fail as the future unfolds. The red dot represents the system and the valley depicts a constellation of factors, including external disturbances such as wind gusts, that are most likely to lead to failure and that should therefore be avoided in design or operation of a complex aerospace system. The mountains show scenarios in which failure would be unlikely. The solid line represents the path into the future that's most likely to result in failure.

Sources: United Technologies Research Center, Tuhin Sahai, Youssef Marzouk

systems to build them to better withstand or avoid the conditions that lead to failure. The simulations would not only present the probability of failure, but the exact mechanism or path to failure. Knowing that path, an engineer could tweak the design for a helicopter to avoid the rare event that will lead to an aerodynamic stall.

Engineers might design the tail rotor for stability in cruise and hover conditions, and with the thinking that the rotorcraft will need to withstand wind gusts of a certain magnitude, Marzouk says. But sometimes a larger gust occurs, or a sequence of small wind gusts or other factors affecting the system can occur immediately after each other, to cause a stall.

Today, Marzouk says, "you might design [the helicopter] to respond to certain kinds of input, but there might be strange inputs or strange changes to the system, or things you haven't modeled correctly that conspire to give you bad behavior."

Marzouk and Sahai are also estimating the probability of stalling, in real time, for a computer-simulated rotorcraft system as it flies. In the future, a variation of this real-time failure prediction model might be loaded into an onboard computer to help helicopter pilots in midflight assess the risks of flying through bad weather.

"You can constantly update your probability of failure and decide whether you want to continue with the mission or you want to go land somewhere," Sahai says. Or, a failure prediction program could be paired with a digital look-up table to tell the helicopter pilot or the aircraft what to do in specific situations.

Another option could be "some kind of automated system that intervenes faster than the human could," Marzouk adds.

He and Sahai are creating a simplified computer model to predict how the system would behave so the model can spit out its predictions in real time.

The model would be updated with information about the current state of the simulated rotorcraft system — information that sensors would provide if the simulation were a real-world flight.

Building on existing models

One hurdle Marzouk and Sahai had to overcome in working on both rotorcraft scenarios was in modifying filtering algorithms that estimate the current states of complex systems. Filtering algorithms are common in aerospace applications, filtering out noise to produce a clear signal, for example. Marzouk and Sahai adapted these algorithms to track the probability of system failure instead of the overall expected behavior of the system. Instead of focusing the filtering algorithms on the peaks of distribution of possible outcomes — the most common outcomes — the mathematicians focused them on the tails of the distribution, or the rare events.

Conventional filtering algorithms had to be tweaked, because they don't do well at capturing rare transitions, or predicting when the next step will lead to a rare event, Marzouk says. If the data from the system reflects a one-in-a-million phenomenon, the filter will almost always ignore the data.

"Most filtering algorithms are essentially going to say: 'My model says 999,999 times out of a million this is not going to happen, so, look, data, you're noisy; you're an outlier; my prediction is that things are just fine.'" Those are exactly the rare events that Marzouk and Sahai want their algorithms to home in on.

A lot of the filters fail to show the true structure of tail distributions — the low-probability events — because they make approximations based on standard bell-curve probability distributions, Marzouk says. For their real-time stall-estimating algorithms, the mathematicians are building on ideas from large-deviations theory, which characterizes tail distributions, the shapes of those tail distributions and how the probabilities change for events as those events become more and more rare.

Marzouk and Sahai are also building on variational filtering algorithms. These are filtering algorithms that take an optimization approach, so that mathematicians can "push toward probability distributions that are weird, or not what you would have expected," Marzouk says.

"That is exactly what you want to be able to do when the data come in and tell you the system has done something unexpected. You want the algorithm

Instead of focusing the filtering algorithms on the peaks of distribution of possible outcomes — the most common outcomes — the mathematicians focused them on tails of the distribution, or the rare events.

to be able to actually find those distributions that reflect the unexpected thing," he says.

Like a living system

Another problem for the mathematicians is the dynamical nature of the rotorcraft system, meaning that it has inertia and momentum. A dynamical system has its own intrinsic time scale, so it may not react to a change immediately, but it may evolve over time. Marzouk compares it to a living thing, and says it's much more difficult to predict its rare events than those of a static system.

"If you kick it, it won't just immediately deform; it might oscillate back and forth for a while after you kick it, and maybe those oscillations will dampen out after a while because of the intrinsic dynamics of the system," Marzouk says. "Events that have accumulated in the past might conspire to put you in a bad situation currently, even if none of those individually in a static analysis would have looked bad."

For the rotorcraft system, for example, the fact that it may have experienced a series of 10 wind gusts may not make a difference if each gust is analyzed individually, but the direction of the gusts and how long each one lasted may make a difference when the 11th gust comes along, Marzouk says.

The mathematicians need to push the computer-simulated rotorcraft system, computationally speaking, into rare events so they can accurately estimate the probability of failure. But rotorcraft systems are designed to be stable, so even when the system is disturbed, its dynamics tend to push it back into its normal operating range. That's a good feature for a rotorcraft system to have, but it makes it challenging for the mathematicians to push the system into failure, Sahai says.

"You want the system to fail computationally," he says. "If the system doesn't fail, then you don't have a good estimate of the probability of failure."

Another challenge was how to organize and visualize the data. They have defined probability spaces containing 12 to 15 variables, which means these theoretical spaces must have 12 to 15 dimensions. For the rotorcraft model, the dimensions include the rotor blade's angle of attack, its pitch rate, the x-direction velocity and the z-direction velocity. The mathematicians typically visualize the multiple dimensions through lines of figures in a table, or a map plotted with only two or three dimensions at a time, Sahai says. A blob in the probability space represents the failure region, or collective points of failure, and the job of Marzouk and Sahai is to compute the most likely path between the current point of operation and failure.

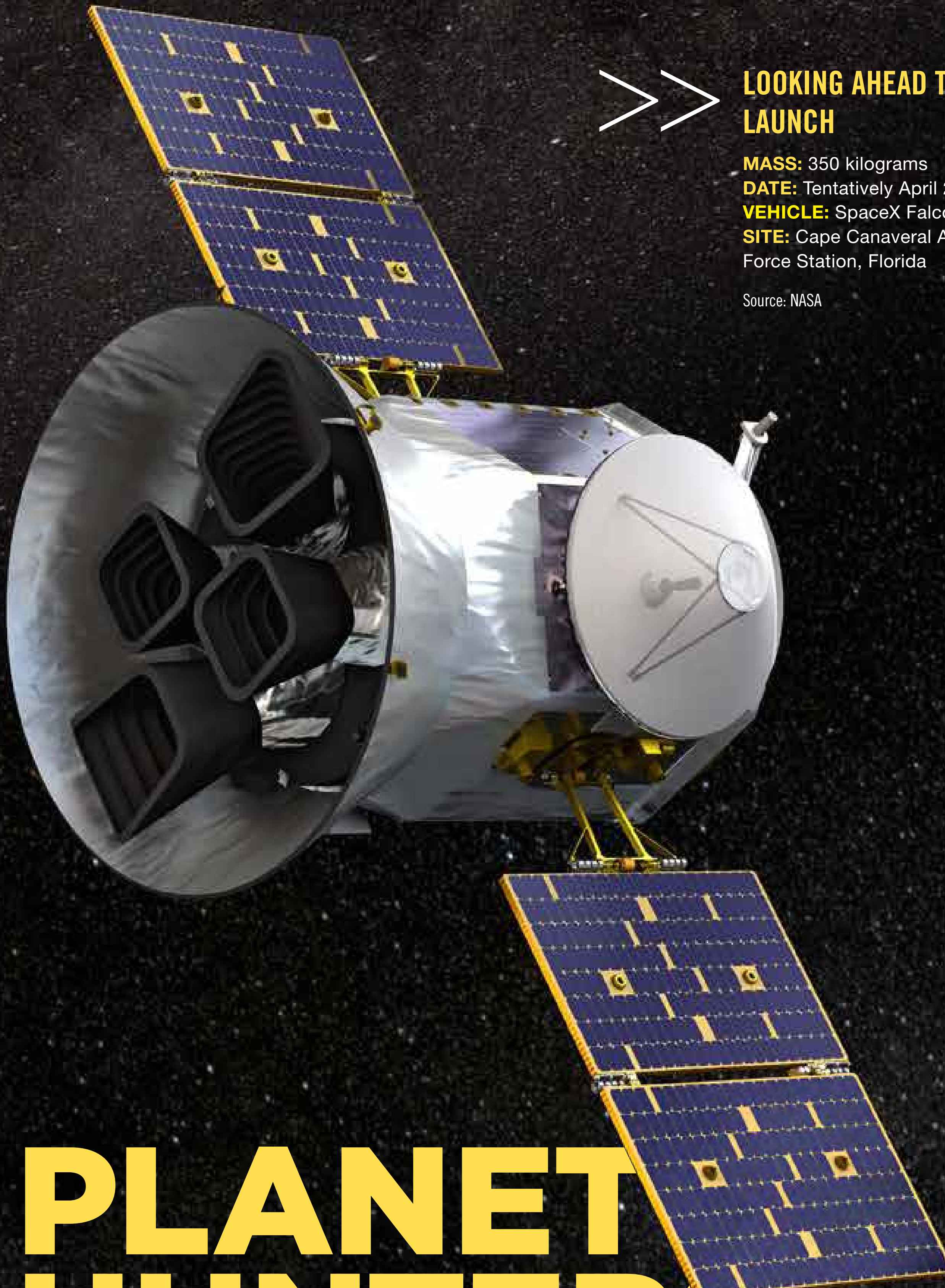
"There's a certain rule in rare-event simulation: The likeliest path to failure is the one you normally take," Sahai says. "That is the path that will dominate all of the other paths."

The complexity of the rare-event distributions within the probability space, which can be "weird and skewed," makes them difficult to reach, Sahai says. One concept that Marzouk and Sahai are adopting to attack this issue is the transport map. The mathematicians simplify the rotorcraft system's distribution to make it easier to fail, then they select a transport map — a mathematical object — that morphs the more normal distribution back to the original, complex distribution. Each system's transport map is unique, but the same mathematical approach to selecting the transport maps can be adopted for different systems. That means the steps the mathematicians build to select the transport map for the rotorcraft system will be the same for the electrical system, and these steps can create transport maps for other complex systems. ★

 BY AMANDA MILLER | agmiller@outlook.com

Most of the intriguing exoplanets detected to date are so far from Earth that observing them directly would require eyesight beyond even what the forthcoming James Webb Space Telescope will muster. Enter TESS, the Transiting Exoplanet Survey Satellite. It aims to find planetary candidates closer to home, so that scientists might zoom in on suspected Earth-like worlds sooner than we think. Amanda Miller spoke to the scientists and designers behind the soon-to-be launched spacecraft.

>> FAST FORWARD FOR



LOOKING AHEAD TO LAUNCH

MASS: 350 kilograms
DATE: Tentatively April 2018
VEHICLE: SpaceX Falcon 9
SITE: Cape Canaveral Air Force Station, Florida

Source: NASA

PLANET HUNTERS

A little more than a decade ago, astrophysicist George Ricker and his colleagues at MIT had a brainstorm. At the time, he was principal investigator for an international satellite that was operating in orbit as planned but whose core mission of monitoring gamma ray bursts had been outpaced by newer technology. He pitched NASA about possibly repurposing the High Energy Transient Explorer and its instruments to look for transiting exoplanets.

NASA said no thanks, but Ricker came away with a sense that "NASA was interested in doing something more ambitious" on the exoplanet front.

So was Ricker. He began conceptual work toward creation of what we now know as TESS, the Transiting Exoplanet Survey Satellite, a $200 million NASA-funded planet-hunting mission that's scheduled to kick off possibly in April with the satellite's launch from Cape Canaveral, Florida.

TESS will record the brightness of individual stars at regular intervals and take periodic snapshots containing hundreds of thousands of stars. These images and data will be downloaded to mission teams at NASA's Ames Research Center in California and MIT who will flag "targets of interest" through what's called transit photometry. When the brightness of a star dips for a period of time, that could mean that a planet is transiting in front of it. These targets and the raw data will be released publicly for other planet hunters who will try to learn more about these planetary candidates or identify altogether new ones.

Planetary scientists are counting on TESS' unique orbit, its focus on relatively nearby stars and its wide-field cameras to speed up the entire planet-hunting business. If TESS can do its job of rapidly assembling a vast numerical trove of likely planetary coordinates, other instruments could then

▼ **Technicians prepare the Transiting Exoplanet Survey Satellite** for transport to Cape Canaveral, Florida, and launch.

zoom in on the most intriguing candidates and perhaps give humanity its first rudimentary look at an Earth-like world — not decades from now but in just a few years.

The news could come in the form of spectra containing chemical signatures of a planet's atmosphere. "When someone gets a transit spectrogram, that'll be a 'holy crap' moment," says astrophysicist Stephen Rinehart, NASA's TESS project scientist at Goddard Space Flight Center in Maryland.

How quickly could all this unfold? TESS' designers expect the spacecraft's first exoplanet discoveries to be validated by mid-2019 on the way to gathering indirect evidence for the existence of 20,000 candidates over the course of the two-year baseline mission. That figure would be a big bump from the current count of some 3,700 confirmed worlds orbiting suns other than our own, which is significant because planet hunting is largely a matter of odds. With that many candidates, NASA estimates that 50 or so might be rocky planets, including a handful in the "Goldilocks" or "habitable" zones around their stars. Those are the terms for orbits that are not so close to the star that any atmosphere or water would be scorched away, but not so far that the planet would be frozen and sterile.

How they did it

If things had played out differently about a decade ago, TESS might not have been a NASA mission. Ricker and MIT at first entered into a partnership with Google, thinking development of the spacecraft might move more quickly that way. Then came the economic recession of 2008-09, which made a corporate funding match seem less secure. Given the interest he sensed from NASA, Ricker reached out to Orbital Sciences Corp., now Orbital ATK, in 2010 to help craft a proposal under NASA's Explorer initiative, which funds space science missions costing up to $200 million.

Robert Lockwood, now the TESS spacecraft manager at Orbital ATK (headquartered on Warp

Orbital ATK

EXPANDED MISSION?

NASA will want to hear pitches for extending operations of the Transiting Exoplanet Survey Satellite beyond its initial two-year mission. Options include revisiting interesting planetary candidates; looking for an Earth analog around a hotter star, like our sun, or something else entirely. TESS principal investigator George Ricker of MIT says TESS could study "stars that are flaring, different types of binary stars — things in the time domain that we've never covered before."

Drive in Dulles, Virginia) was intrigued by the prospect of finding "an Earth analog." He volunteered to help put together the proposal.

As Lockwood and Ricker worked on their Explorer pitch to NASA, they had one overarching goal in mind: Set up scientists to deliver the Holy Grail — images or spectra from a possible Earth-like planet — in something less than the decades that conventional wisdom said the feat would take. NASA selected TESS in 2013, just a month before a mechanical failure ended the primary mission of the Kepler space telescope, the spacecraft that took transit photometry to the masses and engendered so much excitement in exoplanets.

>>

"We are at the beginning of a new era in exoplanet science."

— Stephen Rinehart, NASA's Goddard Space Flight Center

A perhaps obvious choice for TESS' developers was to capitalize on the network of scientists who had sprouted up around Kepler. To stay user friendly, the TESS data will be recorded and presented to the scientific community in the same formats as Kepler's, and stored in the same repository, now called the Barbara A. Mikulski Archive for Space Telescopes, or MAST, and located at the Space Telescope Science Institute in Maryland.

"Because of Kepler, all kinds of scientists have [software] tools" to detect transits, explains NASA's project manager for TESS, Jeff Volosin of Goddard. "If you can find it in Kepler, you can find it in TESS."

Another early decision was to focus in part on what Ricker and other astrophysicists call "naked eye" stars, meaning those that we can see by looking up at the night sky. Exoplanets confirmed around TESS targets would be close enough to Earth for examination by the James Webb Space Telescope, scheduled for launch in 2019. Webb would break down light shining through a planet's atmosphere to try to figure out its contents. Anticipating Webb's launch, TESS' operators will always keep one camera aimed at areas of the sky where Webb will also have continuous viewing.

Before assigning Webb, though, ground telescopes such as those atop Mauna Kea, at Hawaii's W.M. Keck Observatory, would perform reconnaissance on the target of interest to rule out a relationship other than that of planet and sun, such as a binary star system.

TESS will look most closely for signs of transits across 200,000 bright M-dwarf stars, also known as red dwarfs. These are the coolest, longest-lived and most common in the galaxy. TESS will record their brightness every two minutes and take full-frame images every half hour. The plan is to look at cooler stars because planets orbiting in their habitable zones are presumably closer to the star and circling more frequently. That makes TESS more likely to spot them in its initial two-year mission.

The numbers and longevity of M-dwarfs give planet hunters hope that a well-positioned planet might have developed conditions conducive to life. Scientists continue to model what those conditions might actually be like. One planetary system they study closely is called TRAPPIST-1, located 40 light-years away. Transit photometry suggests that it's home to seven rocky, Earth-sized planets. Those planets close to the star could harbor water vapor or even liquid water on their surfaces, while those farther away would be icy.

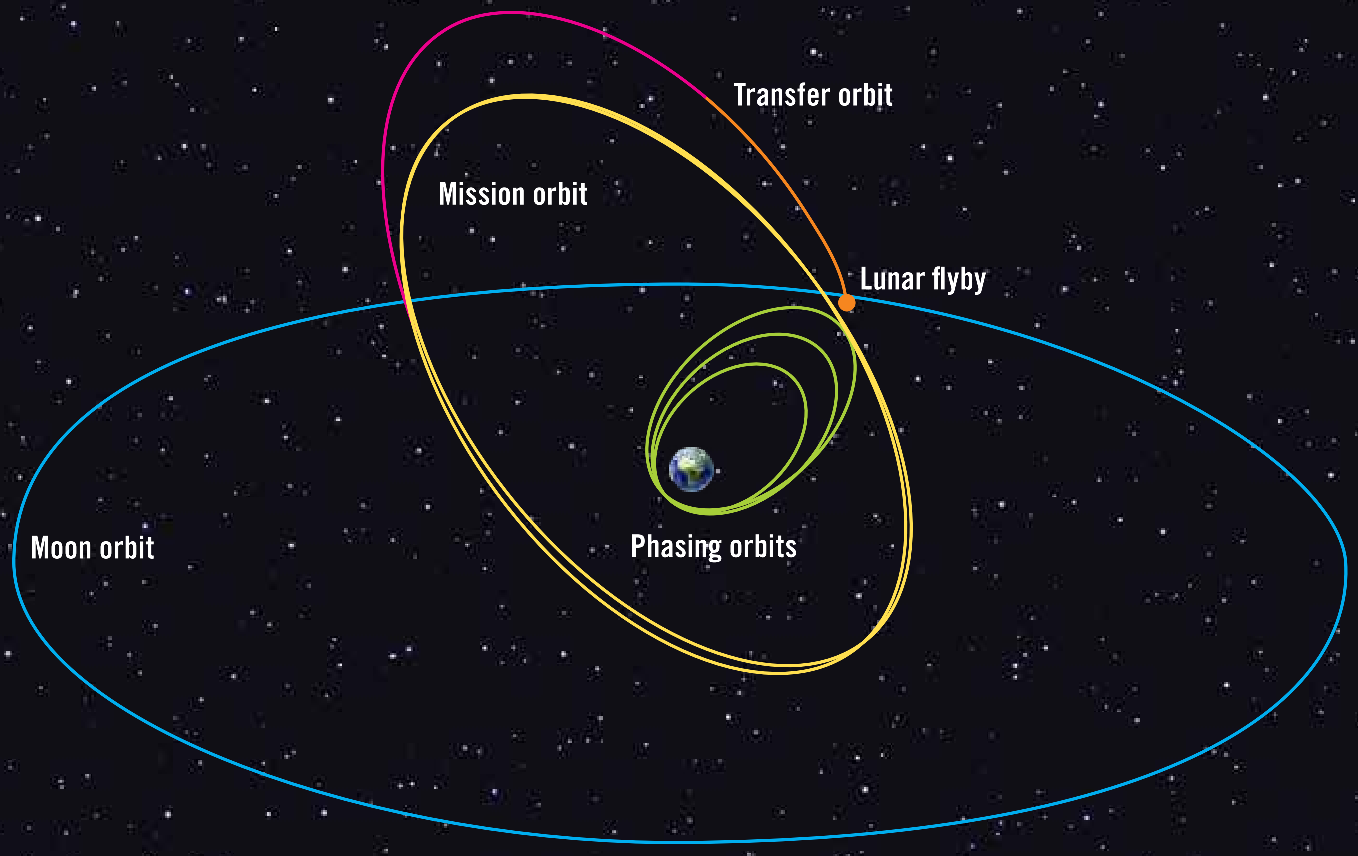
TESS is about "finding the best candidates for characterization and follow-up observation," says Rinehart, the TESS project scientist.

The TESS team decided early on to look at large numbers of relatively nearby stars through an array of wide-field-of-view cameras. Kepler, by contrast, spent its first years looking at one skinny swath of sky continuously to detect fainter stars about 10 times farther out than those TESS will view.

The TESS team has divided up about 85 percent of the sky into two hemispheres, each containing 13 observational sectors. The spacecraft will spend two orbits, or 27 days, surveying each of these sectors, paying particular attention to bright stars from 30 to 300 light years away.

Achieving that means getting Earth out of the field of view. As the team worked to conceive the mission, low Earth orbit was not an attractive option because Earth would eat up too much of the sky. Following Earth around the sun, like Kepler, wasn't practical with the Taurus rocket NASA was considering at the time. There was another option, one that Ricker and Lockwood knew about from a technical paper published in 2001, but that to their

Unprecedented orbit



The Transiting Exoplanet Survey Satellite will soar 376,000 kilometers into space on each orbit (the yellow lines), so that Earth blocks little of the sky when TESS makes its planet hunting observations during each 13.7 day orbit. For gravitational stability, TESS will orbit on a separate plane from the Earth and moon, passing Earth twice for each time the moon orbits Earth. This way, the moon will pull TESS in one direction for one orbit and in the other direction on the next. This orbit should be so stable that TESS won't need to fire its thrusters to stay in its proper orbit. TESS will be the first spacecraft inserted into such a 2:1 lunar resonant orbit. Getting there will require a sequence of events. Once TESS is in space, a solid rocket motor will ignite to begin raising its orbit in phases (the green lines). Once the solid rocket motor is released, hydrazine thrusters will position TESS for its slingshot around the moon and onto a transfer orbit (the red line) that will set up a final thruster firing to put TESS in its mission orbit.

Sources: Staff research, NASA

knowledge no spacecraft had ever used. It's a kind of elliptical orbit called a 2:1 lunar resonant orbit, resonant referring to the stable time ratio: TESS orbits Earth twice for every orbit of the moon around Earth.

"We worked through this a bit and proved that it would work," Ricker says.

By following a path that puts TESS in a specific position relative to the moon and its gravity, the orbit should be so stable that TESS won't need its thrusters to stay on track. In fact, TESS could remain in the same orbit "for decades or longer" without propulsion, NASA says on its TESS website.

Here's how the lunar resonant orbit will be established: Over the span of 60 days after launch, a series of thruster burns and phasing orbits will put TESS in position to swing around the moon and ultimately onto its elliptical path. The final orbit's farthest point from Earth will be 373,000 kilometers, with its closest approach of 108,000 kilometers once every 13.7 days.

Another challenge was getting TESS' voluminous data to the ground as quickly as possible. As it approaches Earth on each orbit, TESS will point its antenna toward NASA's Deep Space Network, or DSN, a network of ground stations around the globe that will await the spacecraft's four-hour data downlink. This happens twice in 16 hours to ensure that all of the data is downloaded before the ops team at Orbital ATK wipes the hard drive clean and TESS sets off on another trip.

TESS also will be the first spacecraft on the Deep Space Network to send information over the 26 GHz "near Earth" Ka-band frequency that NASA is just starting to use. This link will be hundreds of times faster than the older, lower frequency near Earth S-band link. The James Webb Space Telescope will be next to come online with the new link.

An optical engineer at MIT Lincoln Laboratory applies room-temperature vulcanizing silicone to a TESS flight lens. A complication with the RTV caused some concern during testing.
MIT Lincoln Laboratory

Once the DSN receives the information, it gets routed for initial processing to NASA's Ames Research Center in Mountain View, California, while folks at MIT also get a crack at it.

Camera drama

Light enters TESS through the 10-centimeter apertures of its four cameras. Seven glass lenses in each camera then focus it onto charge-coupled device detectors much like those in Kepler and not totally unlike what's in consumer digital cameras. TESS' image-processing computer then isolates the data from certain stars and sets aside periodic full-frame images, getting it all ready for analysis on the ground.

The lenses must focus predictably so that incoming photons from different stars — in a field of view the size of the constellation Orion — don't get too mixed up to reliably distinguish one star from another.

"Once we did our first testing, we noticed the system wasn't focused the way, to our thinking, it was supposed to be," says NASA's Volosin, the TESS project manager at Goddard.

Anticipating that the glass lenses and their aluminum housings would expand and contract at different rates when first getting TESS into space, the instrument designers had glued a rubbery silicone called RTV (room-temperature vulcanizing) between the lenses and housings as a buffer.

"Nobody had used this particular RTV at low temperature, and every rubbery-type product has a glass transition temperature" at which it hardens, Volosin says.

When it came time to test the flight cameras, built by MIT's Lincoln Lab, in the school's thermal vacuum chamber, it turned out the RTV hardened sooner — at a warmer temperature — than its manufacturer had indicated, and it tugged on the lenses. "We're talking microns," Volosin says. The effect took a week to kick in, one reason the problem wasn't caught in the prototype phase.

NASA and the rest of the TESS team have decided just to roll with the inevitable change in TESS' focus that's going to be triggered — once, and only once, they say — when the cameras go below minus 70 Celsius on their way to their final operating temperature. This creates a shift in which areas of the frame are more sharply in focus while others are less focused.

By design, the lenses were never going to bring in totally crisp images, though. "Since we're counting photons, it's built to be an extremely large field of view. We wouldn't have done that if we wanted to make a crisp picture," Volosin explains.

"We decided, 'Well, OK, if [the shift is] going to happen, and it's a one-time thing, let's just get it to happen as quickly as we can,'" Volosin says.

KEPLER'S RECORD

NASA's Kepler space telescope made transit photometry mainstream. After its launch in 2009, it pointed continuously at one section of sky for four years on a mission to figure out the prevalence of terrestrial, or rocky, planets in orbital zones potentially conducive to life. NASA credits the spacecraft with finding 2,341 confirmed exoplanets during those years, 30 of those less than twice Earth's size in habitable zones. Kepler's main mission ended abruptly in 2013 when the second of its four reaction wheels failed and the remaining two could not keep it pointed correctly. Scientists ultimately figured out how to stabilize Kepler by balancing it against the pressure of sunlight. Getting this technique to work limits the telescope's field of view to its own orbital plane as it trails Earth around the sun. The mission now known as K2 is credited with confirming the existence of planets orbiting dead white dwarf stars and for finding the first transiting exoplanet in a dense star cluster.

The new plan is to take TESS down to minus 80 right away and leave it there. In photometry, cooler temperatures equate to less noise or distortion in the image.

After a year of follow-up tests, a panel of outside experts in January deemed the cameras good to go for launch. The first batch of data should become publicly available around midyear.

Fundamentally, "Kepler was a statistical mission," says Rinehart, the TESS scientist at Goddard. He doesn't mean it as a criticism. By looking far away at a single slice of sky, scientists made the astounding calculation that our galaxy likely contains more than 100 billion planets in habitable zones. That realization, in fact, has fueled interest in TESS.

For planet hunters, TESS' legacy could be something approximating instant gratification. ★

DANGER in the air

This Boeing 777 crashed at London's Heathrow Airport in 2008 after flying through air temperatures of minus 74 Celsius.

Marc-Antony Payne

Passenger jets have an amazing ability to fly safely through the subzero air at their cruising altitudes. There are limits, though. If a jet's fuel gets too cold, viscosity or thickness can spell trouble, as can the formation of ice crystals in the fuel. Debra Werner spoke to meteorologists who think they have a way to wave pilots around the most dangerous pockets of cold air.

BY DEBRA WERNER | dlpwerner@gmail.com

“We use this data to say, ‘Hey pilot, I know it’s 75 below where you are right now, but if you make a hard left turn and descend 4,000 feet you’ll be in much warmer air.’”

– **Eric Stevens,** meteorologist at the University of Alaska

When a British Airways jet lost thrust in both engines on the way into Heathrow Airport in 2008 and crash landed short of the runway, the initial examination of the Boeing 777 and its engines yielded no clues about the cause of the accident that miraculously killed no one. The engines did not show evidence of a bird strike, or mechanical failure, and the plane had plenty of fuel.

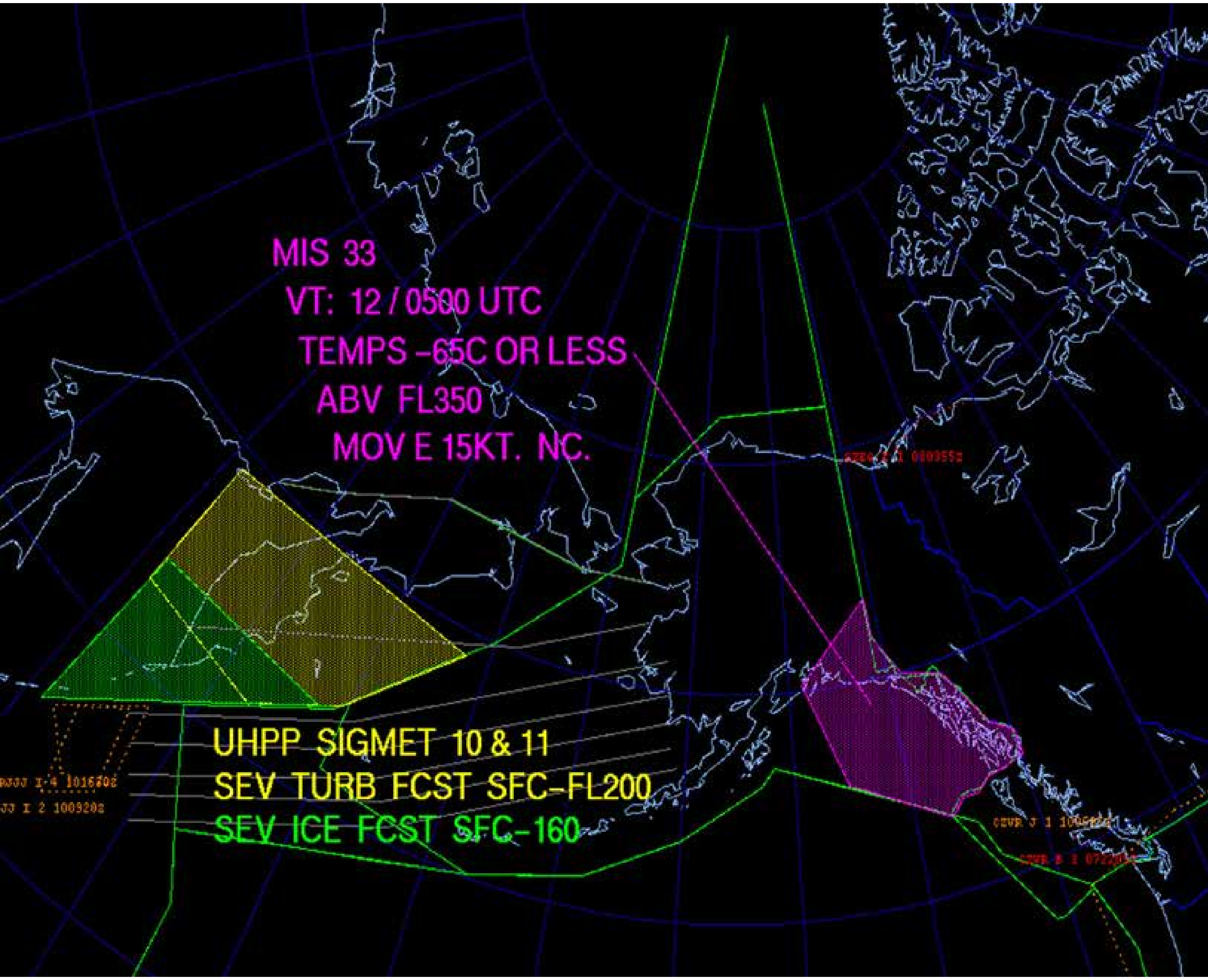
The United Kingdom’s Air Accident Investigation Branch eventually determined that, as the plane flew high over Siberia and Scandinavia in temperatures of minus 74 Celsius, the small amount of water commonly found in jet fuel had in this case coalesced into ice crystals. Those crystals were jarred loose during the descent and restricted the flow of fuel through the plane’s fuel oil heat exchanger, a component consisting of a thousand small tubes surrounded by hot oil that warms the fuel before it reaches the engines.

The aircrew never knew any of that as they cruised through the cold air. Their Engine Indication and Crew Alerting System was tracking the temperature of the fuel, but the alert threshold was based on viscosity, not fear of ice. An alert would have sounded if the temperature sank below 34 Celsius, because at that point the fuel’s viscosity or thickness could increase enough to slow the flow of fuel to the engines. The temperature bottomed out at minus 34 and the alert never sounded. It was only after this crash that safety experts recognized that temperatures of minus 10 Celsius can create ice in fuel and compromise the performance of fuel oil heat exchangers.

What aviation authorities in the U.S. would really like is to equip air traffic controllers nationwide with forecast maps showing expected cells of dangerously cold air at various altitudes and locations. The controllers could then alert crews to change altitude or heading to avoid this cold air aloft.

After the Heathrow crash, meteorologists redoubled efforts to pinpoint these dangerous areas of cold air aloft. The trouble was that in 2008 they had sparse temperature readings from aircraft and weather balloon radiosondes to feed into their global weather forecasting models.

Then, in 2011, a Delta 2 rocket boosted the NASA-NOAA Suomi National Polar-orbiting Partnership satellite into orbit. Among its instruments was a first-of-kind sensor called CrIS, the Cross-track Infrared Sounder. It soaks up heat emitted by the atmosphere to profile temperature and moisture at dozens of altitudes. The satellite also carried the Advanced Technology Microwave Sounder, or ATMS, which detects heat by measur-



National Weather Service

▲ **A Meteorological Impact Statement for aircraft controllers** (purple hatching) shows dangerously cold air of minus 65 Celsius above 35,000 feet and moving east at 15 knots. Controllers can tell pilots to avoid such air.

ing microwave energy emitted from the atmosphere and surface. Moisture droplets in clouds block infrared energy, but microwaves pass right through to show the temperatures below the clouds.

A few years after the launch, researchers from NASA, NOAA and the academic world were looking for problems they might be able to solve with CrIS and ATMS. Meteorologist Eric Stevens of the University of Alaska, who is the liaison between meteorology researchers in Alaska and the National Weather Service, suggested that the sensors might be able to find areas of cold air aloft.

It's perhaps not surprising that this project began in Alaska. That state has the same problem with cold air aloft as Siberia and Scandinavia, plus 6.2 million square kilometers of airspace and only 14 helium balloons, called upper air sounding stations. These take temperature readings every 12 hours by dangling radiosondes from them. "That is just the tip of the spear for us getting the actual temperatures through the atmosphere," says Gail Weaver, an aviation meteorologist at the Anchorage Center Weather Service Unit. Often, aviation meteorologists ask air traffic controllers to solicit air temperature reports from flight crews, but the data is limited to a single altitude.

Alaskan meteorologists are in the midst of an experiment with NASA and NOAA to turn readings from CrIS and ATMS into three-dimensional temperature maps. The maps are shared with air traffic controllers who notify aviators flying through

TEAMING UP

A large team of researchers is supporting NASA and NOAA's effort to pinpoint regions of cold air aloft and develop software and displays to help air traffic controllers steer pilots to warmer skies. The team includes:

- NASA's Short-term Prediction Research and Transition Center at the Marshall Space Flight Center;
- NOAA's National Environmental Satellite, Data and Information Service;
- University of Alaska Fairbanks Geographic Information Network of Alaska;
- University of Wisconsin Cooperative Institute for Meteorological Satellite Studies;
- Colorado State University Cooperative Institute for Research in the Atmosphere; Science Technology Corp. of Hampton, Virginia.

Funding: NOAA Joint Polar Satellite System

Alaska airspace. Pilots can then request flight routes around the cold cells. The experiment has been so successful that NASA research meteorologist Bradley Zavodsky says it could be implemented nationwide in the next couple of years.

"We use this data to say, 'Hey pilot, I know it's 75 below [zero] where you are right now but if you make a hard left turn and descend 4,000 feet you'll be in much warmer air,' " says Stevens.

NASA, NOAA and academic researchers identify the 3-D cells of cold air with the help of an algorithm called the NOAA Unique CrIS/ATMS Processing System. They transfer the information to the Advanced Weather Interactive Processing System, which analyzes and displays data for NOAA and National Weather Service forecasters.

"It gives us a snapshot vertically and horizontally of where that cold air aloft is in our airspace," Weaver says. "We can see what direction it's moving in and if it's intensifying or weakening."

In December 2016, Weaver and other meteorologists in the Anchorage Center Weather Service Unit, housed in the FAA's Air Route Traffic Control Center in Anchorage, started finding cold air cells in those snapshots and creating warnings, known as Meteorological Impact Statements, whenever atmospheric temperatures fell below minus 65 degrees Celsius. Meteorologists share those warnings with air traffic controllers who verbally inform pilots.

From December 2016 to March 2017, meteorologists tested their ability to predict cold air aloft with CrIS and ATMS. They predicted in February that a vast patch of cold air would persist for three days from 35,000 to 40,000 feet and stretch from northern Alaska to the Gulf of Alaska. Their forecast paralleled the actual sounding data captured by radiosondes in the area, giving meteorologists confidence in the technique's accuracy.

In January, Alaskan meteorologists started a second three-month assessment of the cold air aloft data visualization tools. This time, it should be easier for forecasters to share the information with air traffic controllers, because it is displayed by flight levels instead of pressure levels, says Emily Berndt, a NASA research scientist.

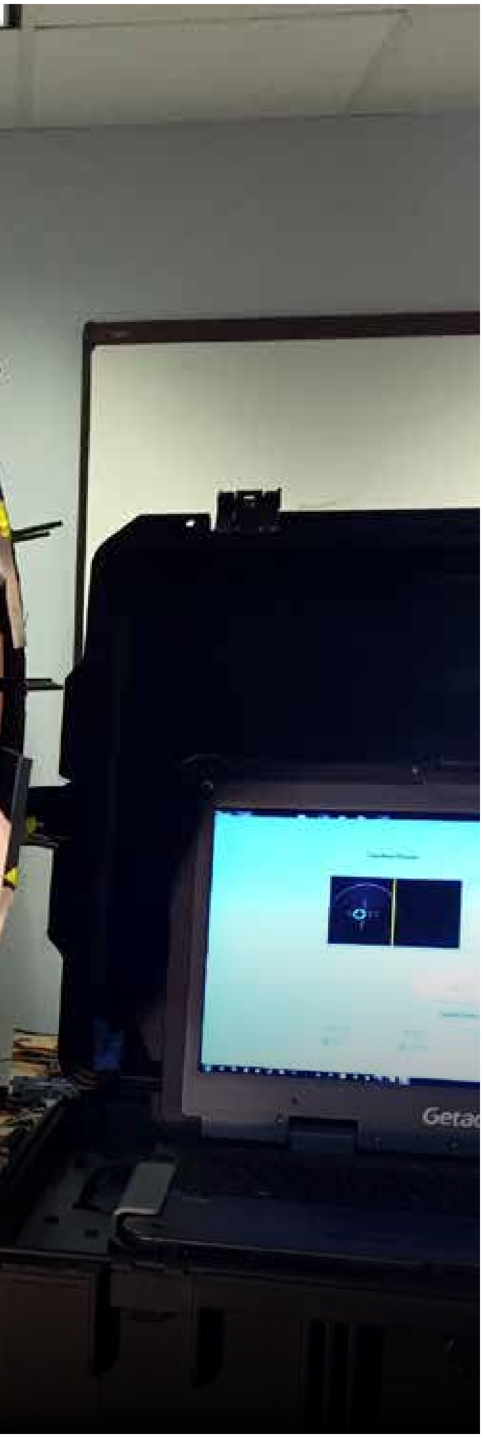
If meteorologists in Alaska determine the cold air aloft data is useful, NASA researchers will prepare during the next couple of years to transfer to the National Weather Service the day-to-day responsibility for creating the cold air aloft visualization tools, and turn their attention to similar problems that could be solved or at least mitigated with satellite data.

For example, the NASA-NOAA team is developing tools to help meteorologists anticipate atmospheric convection. With satellite data, including a second set of CrIS and ATMS sensors launched in November 2017 on NOAA-20, forecasters also might be able to predict dangerous winter weather or wildfires both in the United States and internationally.

"The United States has a very robust network of ground-based sensors, radars and radiosondes, but the rest of the world does not have as many observations," says NASA's Zavodsky. "There are applications for these products around the globe with international partners, the World Meteorological Organization and even operational forecasters in other countries. We haven't pursued that but it's a longer-term vision." ★

Research reboot

An aircraft technician demostrates the Auto-Scan Inlet and Exhaust Damage Registration Sensor, which was developed through a U.S. Air Force Research Lab Critical Small Business Innovative Research contract. The lab's leadership is evaluating which technologies it should pursue.



Intelligent Automation

The U.S. Air Force Research Lab, on orders from Air Force Secretary Heather Wilson, will spend much of this year taking a fresh look at its approach to science and technology. A top goal will be to deliver innovations more quickly. Keith Button spoke to the AFRL executive director.

BY KEITH BUTTON | buttonkeith@gmail.com

Jack Blackhurst, the executive director of the U.S. Air Force Research Laboratory, had a few months earlier settled in his office at the lab's headquarters in Ohio when Heather Wilson, the Trump administration's choice for Air Force secretary, handed down a yearlong assignment. The task: Report back by September 2018 with ideas for the basic and applied technologies AFRL should be pursuing, a plan to speed up delivery of results, and a recommendation for the optimal size and structure of AFRL by 2030.

"I think the secretary is challenging us to think differently, and you don't get this opportunity very often, from a leadership level," Blackhurst says.

He manages the science and technology work at AFRL's facilities, including one at Wright-Patterson Air Force Base in Ohio that's focused mainly on aviation, and another at Kirtland Air Force Base in New Mexico, that's home to the AFRL Space Vehicles Directorate. Blackhurst works closely with Maj. Gen. William Cooley, the AFRL commander, to make efficient use of the $2.5 billion supplied annually by the Air Force, plus $2.3 billion from other government agencies. He is also responsible for engagement and outreach with other laboratories and communities, and he manages the lab's 5,000 civilian workers. The workforce also consists of 4,000 contractors and 1,000 military members.

In the review, AFRL will consider adopting aspects of commercial business models to make it more agile and flexible and better positioned for fast-development of technologies. That focus raises structural issues too: "The question is, when you look at the AFRL in 2030, is it a 6,000-person workforce, or is it 3,000 or 1,000?" Blackhurst asks. "Those are the alternative futures we're going to be looking at this year."

Blackhurst also will examine whether the Air Force is investing enough in science and technology. "We're currently at about 2 percent of the Air Force budget; pharmaceuticals are about 10 percent," Blackhurst says. "The question is, should that 2 percent change; should it increase or not?"

U.S. Air Force

▲ Jack Blackhurst, executive director of the U.S. Air Force Research Laboratory, says the lab has to get new technology to the field faster.

New age

Today, AFRL follows an industrial age acquisition and laboratory business model, Blackhurst says. Now it needs to be restructured for the information age by working more with nontraditional companies instead of just the big defense contractors, he adds.

Typically, AFRL's science and technology work has started with the physics and chemistry of a concept, then bench testing to evaluate its properties and capabilities, and three to five years of demonstrations, plus five to 10 years to develop it into something advanced enough for an acquisition program, Blackhurst says.

"That's probably the old model of how we've done business, because there hasn't been necessarily a demand saying: 'I need it in a year; I need it in two years; I need it in five years,'" he says. "It has evolved at its own pace, per se. And I think the change is, now we're being asked to be more responsive, and looking to new ways of doing business."

Blackhurst wants to embrace process innovations that are starting to be rolled out elsewhere in the Air Force, changes that are modeled on the efficiency of companies that don't rely on government contracts for profits. For example, the Air Force in 2018 will try assigning software coders to its air operations centers to make code changes overnight. That will be a big change from the service's traditional process of ordering up software improvements and embarking on a long testing process before full deployment.

"In the commercial industry, that's how they do business today," Blackhurst says. "If I needed that fixed tomorrow, I'd get 10 or 12 coders together, and I'd have that fixed. I wouldn't wait three years to implement it through a process. And you can see that today in the airline industry and in the computer industry, and they stitch things very quickly as you go through that, and so we're going to try that kind of philosophy out here over the next year."

In with the millennials

Changing workforce demographics will also play a role as AFRL overhauls its processes and research portfolio in the coming years toward an entirely new business model by 2030. The average age of an AFRL employee is about 45, which means an exodus of researchers is coming over the next five to 10 years.

"We have the millennial generation, we have the next generation coming after the millennials," Blackhurst says. "They have a different view of the world, so the question is: How do we need to posture ourselves as a research laboratory to attract, recruit, retain this next generation of scientists and engineers as they come into the workforce?"

AFRL also needs to adapt to a more mobile workforce just as science and technology companies in the private sector must, Blackhurst says. That could mean adjusting to workers who stay for a short time, and those who circle back for another term after an initial departure.

"We know how industry is doing it today, and they're looking at people coming to work for them knowing full well that they're not going to be lifers," he says. "A person comes in the laboratory today and then 30 years later, they retire. That may not be the model of the future, and so from a workforce agility perspective, we need to prepare for that."

The lab will also look at its full-time to part-time employee ratio, whether it should be more evenly split or mostly part time in the future, and whether to adopt a rotation work model like DARPA, where employees may work just four years on a program and then leave.

Fail fast

At the same time AFRL is preparing its report for the secretary of the Air Force, AFRL's commander, Cooley, is asking the lab's managers to feed recommendations into the report on how to push technology from the lab into the field more quickly.

Air Force leaders are pushing AFRL to adopt a "fail fast" motto, Blackhurst says, which means "let's go try an idea, but let's not spend 10 years on that idea. Let's try it for a year, see if it works, and if it doesn't work, let's move on." The idea is to "fail fast initially," and prove whether the technology works quickly, before establishing programs-of-record to develop and acquire operational versions.

In this area, AFRL again is looking at examples it could emulate from the commercial sector. It's looking to companies that include Google and Amazon, and how they develop and adopt technology quickly. "Why are we not doing that?" Blackhurst says. "Why are we not moving faster in terms of getting our record systems out there? Back in the '50s and '60s, we used to produce airplanes every five years. Now it's 10 to 20 years to produce a weapons system."

The Air Force once held a technology advantage of 25 years over other countries, but that has eroded to parity or falling behind, mostly because of the globalization of technology and access to commercial technology, Blackhurst says. AFRL needs to figure out how to keep up in certain technology areas where it won't be spending as much as other countries, such as hypersonics, autonomy, lasers. The answers could lie in off-the-shelf technology.

> "The question is, when you look at the AFRL in 2030, is it a 6,000-person workforce, or is it 3,000 or 1,000? Those are the alternative futures we're going to be looking at this year."
>
> — Jack Blackhurst, executive director of the U.S. Air Force Research Laboratory

"We know our adversaries are investing money in those technologies; probably more money than we're spending today to do that," Blackhurst says. "How do we leap ahead and be smarter in being able to produce the technology, utilizing it as quickly as we can, but knowing full well that the technology may be out on the marketplace? That's a big shift."

In 2017, AFRL experimented with off-the-shelf versions of a possible light attack aircraft. The Air Force hasn't decided whether to purchase the planes, but the flights show the service's willingness to consider aircraft that aren't designed from scratch to the service's specifications.

"We could have systems in the field in the next three to five years; that's probably unheard of in terms of acquiring airplanes that quickly," Blackhurst says. "It's doing business differently than perhaps designing an airplane from ground zero, to actually develop it, test it, and field it, in that perspective."

AFRL is examining promising technology areas to decide whether it should try to become a leader in a particular area, build on the work of others in that area, or simply watch it. In some fields, such as jet engines or space technology or weapons technology, there's no question that the Air Force is a leader, Blackhurst says. But in areas like artificial intelligence, autonomy and quantum technology, the answer isn't so clear cut. "In some cases we're watching, our leadership is questioning that for us, and so we're having to examine that and determine whether we need to shift our investments in that regard. I would say that's a challenge that the leadership has given us."

In some areas, the Air Force could buy services from commercial businesses, such as internet service distributed via thousands of commercial satellites. Instead of the Air Force taking on the task of developing, maintaining and operating the satellites, perhaps it could buy the communications service from one or multiple companies.

"The Air Force is saying: 'How could we use that?'" Blackhurst says. "Those are the trends. Doing things differently, failing fast, experimentation prototyping, analytics, modeling simulation, being able to give leadership data to make decisions versus just sitting around a table and taking their experience and applying it. It's actually using real data to say: 'That doesn't work. That won't work.'"

By testing new prototype models, including models of service delivery, AFRL can discover earlier whether systems work. With space internet, the lab plans to contract with companies as they establish their services over the next five years to run experiments and find out whether they would work for the Air Force, Blackhurst says.

▲ **In its light attack airplane experiment**, the AFRL flew four off-the-shelf aircraft — planes that were not developed specifically for the service. The Air Force plans to continue the experiment in May with the Textron Aviation AT-6 Wolverine, seen here, and the Sierra Nevada/ Embraer A-29 Super Tucano.

Wide net

Wilson, the Air Force secretary, also wants AFRL to expand its research relationships. Currently AFRL works with universities in the Northeast and Southeast, plus Texas, Arizona and California, but few in the Midwest or West, Blackhurst says.

Blackhurst points to the U.S. National Science Foundation as an organization that conducts broad outreach on such issues as climate change and energy. AFRL wants fresh ideas for innovations in science and technology and it has set up listening events through July at universities in Florida, Indiana, Nebraska, Texas, Utah and Washington, and more are planned later. The lab also is asking for online idea submissions "to help us invent the future for 2030 and beyond." AFRL also is collecting ideas through storefront offices, called AFWERX, that the service has set up in downtown Las Vegas and Crystal City, Virginia, across the Potomac River from Washington, D.C. These locations were chosen partly because of the number of technology conventions they host. The Air Force is considering additional AFWERX offices in Boston and Austin, Texas.

"The idea there is to cast a wide net and see what we find out," Blackhurst says. "What are people thinking out there that we ought to be investing in, at the fundamental science level over the next several years?" ★

AIAA/IEEE ELECTRIC AIRCRAFT TECHNOLOGIES SYMPOSIUM

CALL FOR PAPERS

12–13 JULY 2018 | DUKE ENERGY CONVENTION CENTER, CINCINNATI, OH

The aerospace industry has set ambitious goals for the next three generations of commercial transport aircraft to accommodate rapid growth in emerging markets and ensure the future sustainability of air travel. One approach being explored to meet these targets is nontraditional aircraft propulsion using electric, turboelectric, or hybrid-electric powertrains.

Recent workshops by the IEEE and AIAA have identified the need to bring together electrical engineers and aerospace experts as the industry looks to more electric propulsion technologies for future aircraft. For 2018, the AIAA Aircraft Electric Propulsion and Power Working Group, the IEEE Transportation Electrification Community, and the College of Engineering of the University of Illinois at Urbana-Champaign are collaborating to organize a new two-day symposium to address these issues. The event occurs on 12–13 July, following the AIAA Propulsion and Energy Forum.

The symposium will focus on electric aircraft technology across three programmatic tracks: (1) electric-power enabled aircraft configurations and system requirements, (2) enabling technologies for electric aircraft propulsion, and (3) electric aircraft system integration and controls. Abstracts are solicited in specific areas of relevancy including, but not limited to, the following:

TRACK 1

Aircraft Configurations & 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

TRACK 2

Enabling Technologies

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

TRACK 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

All papers will be co-published in both AIAA's electronic library, Aerospace Research Central (ARC), and the IEEE Xplore digital library. In addition, the EATS organizing committee may recommend high-quality papers for journal publication and is exploring the development of an invited special edition publication in a relevant AIAA or IEEE journal, covering the most impactful work presented at EATS.

If you have any questions please visit aiaa.org/EATS or contact the Technical Co-chairs for the symposium:

- Phil Ansell
  ansell1@illinois.edu
- Andy Gibson
  andrew.gibson@esaero.com

For complete symposium details visit:
aiaa.org/EATS

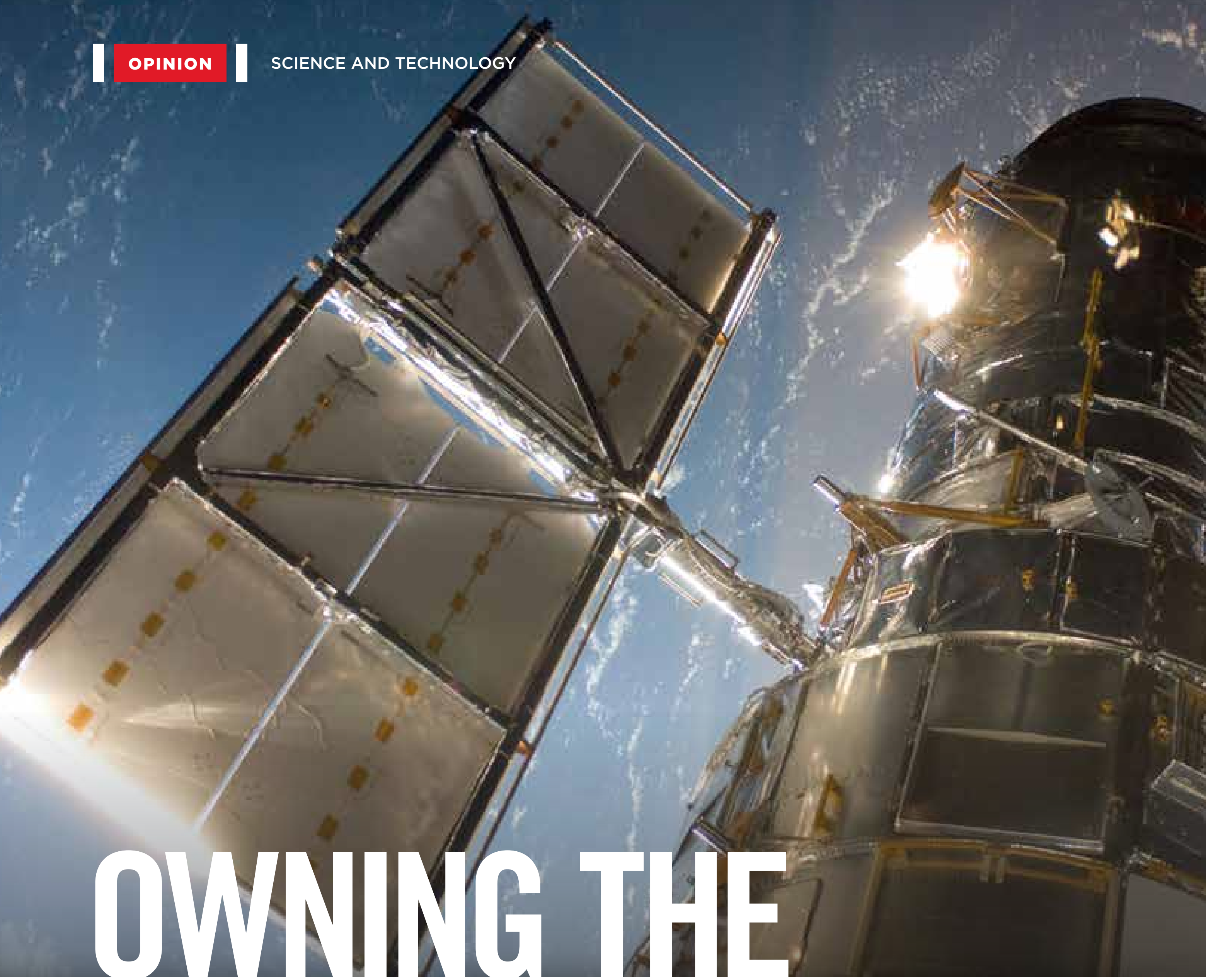
Sponsored by:

AIAA Shaping the Future of Aerospace

IEEE

IEEE TRANSPORTATION ELECTRIFICATION COMMUNITY

ILLINOIS



OWNING THE 21ST CENTURY

For the aerospace industry in the U.S. and abroad, efficient allocation of resources and cross-discipline research will be key to maximizing the sector's potential in the decades ahead. Amir S. Gohardani explains how STS, the study of science, technology and society, can point the way to sounder decisions.

BY AMIR S. GOHARDANI | amir.s.gohardani@springsofdreams.org

NASA

▲ **The Hubble Space Telescope:** Even when results are amazing, as is the case with Hubble, cost overruns are not a sustainable practice.

The history of the aerospace sector shows many cases of technical advances leading to remarkable societal changes, from the advent of jet aircraft to geosynchronous communications satellites to the GPS constellation. In the U.S., researchers target the next breakthroughs like these by advancing concepts along a technology readiness level scale. Doing so requires considerable investment by government agencies, universities, venture capitalists and corporations through their internal research and development funds. Not surprisingly, debates sometimes erupt around which concepts should be pushed up that readiness scale. Complex projects sometimes overrun their budgets, making spending choices even harder.

Those involved in spending decisions would be wise to consider seeking guidance from an emerging branch of study called science, technology and society, or STS. This branch considers how cultural, political and social values affect scientific research and technological innovation and how these, in turn, affect society, politics and culture. Scrutinizing technical advances under the light of STS can help the U.S. or any technically minded nation avoid unnecessary cost buildup while also setting the stage for entirely new technical directions and products. In this approach, the societal impact of a technology should be fully weighed before seeking to advance it up the scale.

The challenge of the 21st century might well be to achieve long-term, positive global impacts without overspending. Consider a case from outside the aerospace sector, the construction of the Montreal Olympic Stadium. Its cost exceeded its original 1973 budget estimate by an astonishing 1,990 percent. In my sector of aerospace, development of the Hubble Space Telescope exceeded its original cost by 525 percent. There is no doubt that Hubble has opened the eyes of humans to the wonders of the universe and inspired future space exploration endeavors. The Montreal stadium hosted the 1976 Olympics that brought enormous international awareness. Some projects righteously earn their global impact over time. In today's environment, however, projects that show such overruns may not be carried to fruition. Budgets are strained, and patience is wearing thin. Even if occasional budget overruns have been accepted in the past, such practice is not sustainable in the long run.

Focusing on STS and societal benefits also points to an interdisciplinary approach to research and development as a strategy for maximizing value. Incongruously, even though each domain of STS is explicitly scrutinized within its own track, often times, many of the shared denominators and emerging subjects stemming from a fusion of disciplines are neglected. The U.S. aerospace industry cannot afford such oversights. The industry has never found itself in a more critical position in terms of budgetary limitations, technical hurdles, an aging aerospace workforce and competition from abroad. The interconnectivity among different disciplines must be considered to an even larger extent than has been the case to date.

Budgetary limitations

For the U.S., recent years have brought budget sequestration, reduced funding and unfunded aerospace programs. Some programs have suffered significant consequences, including workforce reductions. Whether the challenges ahead involve development of the sixth-generation fighter aircraft or identification of the most efficient space propulsion technologies for interplanetary travel, today's budget limitations are forcing managers to minimize product testing and risk mitigation. This is adding complexity to the task of balancing technical feasibility and program execution.

These difficulties are not the complete story, however. The challenges are sparking a wave of innovation, trends and cost optimization that is sweeping through the aerospace sector. The confluence of innovations and technical out-of-the-box solutions has generated secondary waves of efficient program management and program execution practices to meet the constantly increasing demands of the aerospace industry.

Most recently, utilization of commercial off-the-shelf or COTS products has been widely adopted as yet another efficient cost-saving strategy. However, COTS product obsolescence in the aerospace industry, in addition to failures of meeting program requirements as a result of COTS implementation, have proved to carry a tremendous negative impact on meeting program objectives. In an exemplary case, COTS products that inconsistently replace radiation-hardened electronic components for space applications could potentially jeopardize entire space missions if they fall short on technical radiation requirements. Therefore, budgetary limitations initiate new challenges with adjacent areas overlapping the technical domain. For instance, if COTS products implemented in a GEO communication satellite lead to its failure, a new communication channel will be lost. Hence, this exemplifies how technical decisions influence other elements in society.

In the future, if overall global aerospace and defense sector revenues decline, as a result of decreased revenues in the defense subsector, and cuts suffered in global military expenditure, mainly from the United States, in these contexts, program cancellations and delays in major weapons programs will affect the revenues of the top defense contractors. The global revenue trends are further dependent on the strength of main currencies around the world, geopolitical conditions, growth or decline in global gross domestic product, commodity price fluctuations (especially crude oil), demands for passenger travel, access to space, expenditures on global defense budgets, as well as the overall growths and declines in the commercial and defense aerospace subsectors, to name a few examples.

Technical hurdles

Many groundbreaking innovations, such as commercial passenger flight, have developed in societies at a steady, manageable pace. Yet, occasionally, technical advances arrive at a more rapid pace than global communities can embrace. Technical hurdles do not necessarily spring from a lack of willingness to innovate. Rather, they demonstrate a need to expand technical horizons beyond specific technical solutions. This can be done by adopting a multipurpose approach that creates a series of new information channels across disciplines.

During the most recent passages of history pertaining to unmanned aircraft, the first objective was to enable onboard pilotless aircraft. The collective brain children of George Cayley, sometimes known as the father of aviation and famous for the first

▲ **Drones' popularity with the public** led to a market for anti-drone technology.

NASA

The U.S. aerospace industry has never found itself in a more critical position in terms of budgetary limitations, technical hurdles, an aging aerospace workforce and competition from abroad.

successful human glider; Felix Du Temple de La Croix, developer of one of the early powered aircraft of any sort — a powered model plane; Nikola Tesla, inventor and designer of the radio remote control vehicle torpedo; and other prominent individuals, the concepts of unmanned aerial vehicles were transferred from visions to reality. Aerial torpedoes opened the technology door to decoys, drones and ultimately cruise missiles.

Through the launch of unmanned aerial vehicles or drones for the general public, a series of privacy and safety concerns rapidly emerged in remarkable volumes to reignite legislative actions and a new anti-drone market driven by factors such as increased security breach incidences of unidentified drones and increased terrorism and illicit activities. Anti-drone systems are specifically designed to counter unwarranted intrusion of unmanned aerial vehicles. It is estimated the anti-drone market will reach a billion dollars within the next decade and this illustrates how technological solutions can be expanded into new streams of innovation, even if they had been considered during the development phases of the core technology.

Comprehensive reviews of different disciplines and estimations of hypothetical technical impacts on society enable new paths for innovation and a head start to state-of-the-art technologies. The relationships are often cause and effect. Consider, for example, the research underway toward removing debris from orbit. These initiatives were triggered by congestion in space and the realization that anyone's satellites are at risk. Recognizing cause-and-effect scenarios and taking a holistic view of STS can help decision-makers meet the future demands of the aerospace and defense disciplines.

Aging workforce

For aerospace engineers, the U.S. Bureau of Labor Statistics projects an employment growth of 6 percent by 2026 from a 2016 benchmark. This trend alongside an aging workforce calls for further engagement of young individuals in science, technology, engineering and mathematics, or STEM. As aircraft are being redesigned to reduce noise and pollution and to raise fuel efficiency, demand for research and development is likely to be sustained. Nonetheless, growth will be tempered as many of these engineers are employed in manufacturing industries that are projected to grow slowly or even decline. Conversely, as governments refocus their space efforts, new companies are emerging to provide access to space beyond the access afforded by standard space agencies. These visions certainly have led to a new era for U.S. space capabilities. Companies alongside the U.S. are exploring novel low-orbit and beyond-Earth-orbit capabilities for human and robotic space travel. Adopting an all-inclusive STS approach could help lead the U.S. aerospace and defense subsectors into an even brighter future. ★

Amir S. Gohardani, an AIAA associate fellow, is the chair of AIAA's Society and Aerospace Technology Integration and Outreach Committee and the chair of the AIAA Orange County section in California. President of the nonprofit educational organization Springs of Dreams Corp., he has a Ph.D. in aerospace engineering from Cranfield University in the United Kingdom and Master of Science degrees in aeronautical, mechanical and aerospace engineering, and a Bachelor of Science degree in vehicle engineering.

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: megans@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 / Karen Thomas, ext. 7520 • Book Sales / 800.682.AIAA or 703.661.1595, Dept. 415 • Communications / John Blackstein, 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 Blackstein, 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

Notes About the Calendar

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
2018			
8 Mar	DirectTech Webinar— Introduction to Uncertainty Quantification and Industry Challenges	Virtual (aiaa.org/onlinelearning)	
21 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (aiaa.org/CVD)	
26–28 Mar †	53rd 3AF Conference on Applied Aerodynamics	Salon-de-Provence, France (http://3af-aerodynamics2018.com/)	
1 May	2018 Fellows Dinner	Crystal City, VA	
2 May	Aerospace Spotlight Awards Gala	Washington, DC	
3–10 Mar †	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	
6 Apr	DirectTech Webinar—Thermal Modeling and Regenerative Cooling of Liquid Rocket Engines	Virtual (aiaa.org/onlinelearning)	
26 Apr	DirectTech Webinar—Electric Aircraft Design Fundamentals: Enabling Technologies and Analysis Methods for More-, Hybrid-, and All-Electric Aircraft	Virtual (aiaa.org/onlinelearning)	
2–3 May †	Improving Space Operations Workshop	San Antonio, TX (https://isow2018.space.swri.edu)	
8–10 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum) Featuring: – Missile Sciences Conference – National Forum on Weapon System Effectivenss – Strategic and Tactical Missile Systems Conference	Laurel, MD	30 Nov 17
10–11 May	Aerospace Survivability Course	Laurel, MD	
28–30 May †	25th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru)	
28 May–1 Jun	SpaceOps 2018: 15th International Conference on Space Operations	Marseille, France (Contact: www.spaceops2018.org)	6 Jul 17
4–8 Jun†	DATT (Defense & Aerospace Test & Telemetry) Summit	Orlando, FL (www.dattsummit.com)	
23–24 Jun	Design of Electric and Hybrid-Electric Aircraft Course	Atlanta, GA	
23–24 Jun	Missile Aerodynamics Course	Atlanta, GA	
23–24 Jun	Optimal Design in Multidisciplilnary Systems Course	Atlanta, GA	
23–24 Jun	Practical Design Methods for Aircraft and Rotorcraft Flgiht Control for Manned and UAV Applications with Hands-on Training Using CONDUIT® Course	Atlanta, GA	
23–24 Jun	5th AIAA Workshop on Benchmark Problems for Airframe Noise Computations (BANC-V)	Atlanta, GA	
25–29 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – AIAA/CEAS Aeroacoustics Conference – Aerodynamic Measurement Technology and Ground Testing Conference – Applied Aerodynamics Conference – Atmospheric Flight Mechanics Conference – Atmospheric and Space Environments Conference – Aviation Technology, Integration, and Operations Conference – Flight Testing Conference – Flow Control Conference – Fluid Dynamics Conference – Joint Thermophysics and Heat Transfer Conference – Modeling and Simulation Technologies Conference – Multidisciplinary Analysis and Optimization Conference – Plasmadynamics and Lasers Conference	Atlanta, GA	9 Nov 17
25–29 Jun†	15th Spacecraft Charging Technology Conference (SCTC)	Kobe, Japan (Contact: http://www.org.kobe-u.ac.jp/15sctc/index.html)	
3–6 Jul†	ICNPAA-2018 - Mathematical Problems in Engineering, Aerospace and Sciences	Yerevan, Armenia (Contact:: www.icnpaa.com)	

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

AIAA Continuing Education offerings

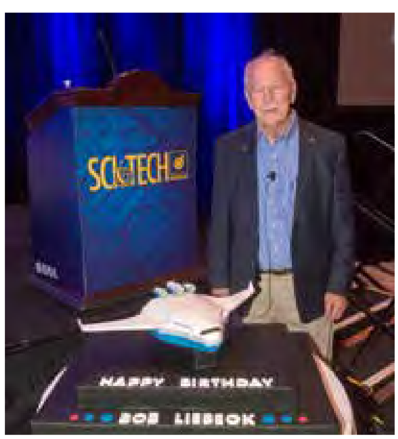
AIAA Symposiums and Workshops

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
7–8 Jul	Emerging Concepts in High Speed Air-Breathing Propulsion Course	Cincinnati, OH	
7–8 Jul	Gas Turbine Aerothermodynamics and Performance Calculations Course	Cincinnati, OH	
7–8 Jul	Liquid Atomization, Spray, and Fuel Injection in Aircraft Gas Turbine Engines Course	Cincinnati, OH	
7–8 Jul	Liquid Rocket Engines: Fundamentals, Green Propellants, and Emerging Technologies Course	Cincinnati, OH	
7–8 Jul	Propulsion of Flapping-wing Micro Air Vehicles (FMAVS) Course	Cincinnati, OH	
7–8 Jul	AIAA Complex Aerospace Systems Exchange (CASE) Workshop	Cincinnati, OH	
7–8 Jul	4th Propulsion Aerodynamics Workshop	Cincinnati, OH	
8 Jul	Enabling Technologies and Analysis Methods for More-, Hybrid-, and All-Electric Aircraft Course	Cincinnati, OH	
9–11 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – Joint Propulsion Conference – International Energy Conversion Engineering Conference	Cincinnati, OH	4 Jan 18
12–13 Jul	AIAA/IEEE Electric Aircraft Technologies Symposium	Cincinnati, OH (aiaa.org/eats)	15 Feb 18
19–23 Aug†	2018 AAS/AIAA Astrodynamics Specialist Conference	Snowbird, UT (www.space-flight.org)	
17–19 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition) Featuring: – Complex Aerospace Systems Exchange – International Space Planes and Hypersonic Systems and Technologies Conference	Orlando, FL	8 Feb 18
1–5 Oct†	69th International Astronautical Congress	Bremen, Germany	
2019			
7–11 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – Adaptive Structures Conference – Aerospace Sciences Meeting – Atmospheric Flight Mechanics Conference – Information Systems — Infotech@Aerospace Conference – Dynamics Specialists Conference – Guidance, Navigation, and Control Conference – Modeling and Simulation Technologies Conference – Non-Deterministic Approaches Conference – Space Flight Mechanics Meeting – Structures, Structural Dynamics, and Materials Conference – Spacecraft Structures Conference – Wind Energy Symposium	San Diego, CA	11 Jun 18
13–17 Jan†	29th AAS/AIAA Space Flight Mechanics Meeting	Ka'anapali, HI	14 Sep 18
3–5 Apr†	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (Contact: www.eurognc19.polimi.it)	
27–29 May†	26th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru/icins2019/en)	

SCITECH FORUM

More than 4,200 attendees – representing 39 countries including all 50 U.S. states, and Washington, DC – gathered for a dynamic and substantive 2018 AIAA SciTech Forum, making it the most attended AIAA forum ever. The top five countries at this year's forum as represented by individual attendees were the United States, Japan, Germany, UK, and Canada, with over 1,270 students also in attendance. The forum featured more than 2,200 presentations covering ground-breaking aerospace technical and scientific research.


Plenary
Forum 360
Lectures
Exposition Hall


HAPPY BIRTHDAY
BOB LIEBECK


ULA
AIRBUS


the HUB
where great minds gather
ULA

AIAA Sydney Section Commemorates 50th Anniversary of WRESAT1

By Gordon Pike and Michael Spencer

SCENARIO: *A rocket launch tower stands erect in the remote central Australian location of Woomera. Red dust is blown by the hot desert wind across the site, coating everything it touches. The rocket engineers at the site make the characteristic "Great Australian Salute" to wave away the black flies droning around their perspiring suntanned faces.*

U.S. MEMBER: *"Hey Aussie! The SPARTA program has now concluded leaving us with one unused Redstone as a spare. If you had it, could you use it?"*

AUSSIE MEMBER: *"Gidday, Mate! You bewdy. Streuth, absolutely, we could."*

This might have been a conversation between the Australian and American scientists and engineers 50 years ago in 1967 to initiate another of the many shared journeys in the history of Australian-U.S. partnered space activities except that this would result in the very first Australian-built satellite being successfully launched into space from an Australia launch site later in that same year.

On 29 November 2017, Australia commemorated the 50th anniversary of WRESAT1 (Weapons Research Establishment Satellite[1]), the first Australian-built satellite launched from an Australian launch site atop a U.S. Redstone rocket. The AIAA Sydney Section helped to commemorate this achievement, and revisit Australia's space history, by hosting Dr. Gordon Pike, AIAA Associate Fellow, to give a lecture on "WRESAT1 – the Program and the People." Dr. Pike is a prominent Australian space engineer who began his career at the Weapons Research Establishment (known today as the Australian Government's Defence Science Technology Group) and had experiences working with the members of the original WRESAT1 project team.

During the late 1960s, the United States, United Kingdom, and Australia formed a research partnership to conduct the SPecial Antimissile Research Tests, Australia (SPARTA) Program[2] at the Woomera Rocket Range to study the atmospheric re-entry phenomena and their effects on re-entering payloads based on a program of ten Redstone rocket launches. When the SPARTA program ended after nine launch events, the United States offered the spare tenth rocket to Australian scientists, on the condition that it had to be used before the U.S.-mandated return date for uplifting and returning all U.S.-owned SPARTA assets from Woomera.

This offer triggered an 11-month critical path project schedule for the Physics Department at the University of Adelaide to conceptualize, design, develop, test and be space-ready with a science mission for WRESAT1. WRE managed the project to mobilize and integrate the WRESAT1 payload to the Redstone rocket at the Woomera launch site. On 29 November 1967, WRESAT1 was launched and Australia had entered the orbital space environment. WRESAT1 successfully completed 642 orbits, and transmitted for 73 of these to tracking and research stations located around the world, before re-entering the Earth's atmosphere on 10 January 1968 over the Atlantic Ocean.[3]

While WRESAT1 was the first Australian satellite to enter the Earth orbital environment, the first satellite built by Australians is credited to the amateur radio team who built Australis - Orbiting Satellite Carrying Amateur Radio-5 (OSCAR-5).[4] Built in 1966 on a shoestring budget by an innovative project team of students and amateur radio enthusiasts studying at the University of Melbourne,[5] it was offered a launch opportunity by the United States on a space launch from Vandenberg Air Force Base Space Launch Complex on 23 January 1970.

The OSCAR-5 university student project team was inspired by the rising popularity of the new science and technology of space communications and promoted in activities led by U.S.-based amateur radio operators. In 1969, the U.S. amateur radio operators established the Radio Amateur Satellite Corporation (today, known as AMSAT). OSCAR-5 was the fifth amateur-built satellite under the AMSAT satellite program, the first one built outside of the United States, and the first to be designed for remote control operations by amateur radio operators on the ground.

It is this spirit of innovation and "daring-do," that inspired Australia's early space engineering pioneers to "have a go," supported by opportunities made available by U.S. counterparts. It is with this proud history that the AIAA Sydney Section, chartered in 1998 as the first AIAA section to be situated outside of the United States, keenly supports its members and engages with the public to promote and advance interests in aeronautics and astronautics. The continuing cooperation provided by the United States helps promote the importance of the enduring partnerships in many aviation- and space-related fields of industry, research, and academia.

The AIAA Sydney Section wanted to publicly commemorate the 50th anniversary of the WRESAT1 mission to highlight the space industry's rightful place in Australian history and bring public recognition to some of the key people involved in the project. Many of the key members of the original WRESAT1 project team are no longer with us, but their family members were invited as special guests and were presented with special commemorative certificates prepared by the AIAA Sydney Section Committee.

Our event speaker, Dr. Pike, is a long-time, prominent figure in Australian space industry, history, and academia. He started his working life at the WRE, alongside members of the original WRESAT1 project team and then built an extensive career as a distinguished Australian scientist and space engineer. He has been directly involved throughout the entire history of Australia's national communications satellite programs, space launch events, and National Broadband Network initiative. The AIAA Sydney Section members, special guests, and public audience were very appreciative of his lecture on the history of the WRESAT1, which entertained the audience with a good balance between technical descriptions of WRESAT1 and his personal experiences in very human encounters with WRESAT1 team members.

Reflecting on Australia's space history also provided an opportunity to review Australia's continuing role in its many diverse partnerships with the United States in space activities. Australia has been an integral part of U.S. deep-space missions dating back to 1957, when NASA started building its first Australian-based spacecraft tracking and communications facilities at Woomera. Today, the NASA Canberra Deep Space Communications Centre at Tidbinbilla continues to operate 24/7 to maintain vital communications for U.S. deep-space missions; cubesat technology has enabled Australian universities to access space missions; U.S. space launch opportunities have enabled Australian access to the orbital environment; cubesat missions have also been inserted into orbit from the International Space Station; and U.S. Air Force space situational awareness sensors sited in Australia enable Australian operators to contribute to the U.S. Space Surveillance Network. There is much to inspire the current and future generations to be involved in aerospace and space, and the AIAA Sydney Section is fortunate to have access to this global space community through AIAA to share these experiences and knowledge with Australian aeronauts, aerospace engineers and, maybe, a future Australian-flagged astronaut.

The opinions expressed are those of the authors and do not reflect the views of Optus, AMSAT, the Royal Australian Air Force, Defence Science Technology Group, or any other organization mentioned in this article.

1

2

1 (L-R) SQNLDR Michael Spencer, Jouke De Baar, Dr. Gordon Pike, SQNLDR Chris Lowe, Arnab Dasgupta (Chair, AIAA Sydney Section), Charles Hoke, Evan Smith, and Matthew Vella at the AIAA Sydney Section public lecture for "50th anniversary: Celebrating the WRESAT1 Program and its People."

2 The Australian WRESAT1 satellite was successfully launched from Woomera in 1967 atop a U.S. Redstone rocket, as one of the earliest examples in a long history of Australia-U.S. space cooperation (DST Group image).

Dr. Gordon Pike retired from Optus in late 2009 following a distinguished 38-year career in the Australian aerospace industry that began at the Weapons Research Establishment. He has had project management responsibilities for seven of the ten Australian communications satellites built and launched since 1985. He was the deputy program manager for the other three. He then became a part-time consultant to National Broadband Network Company for the satellite component of the National Broadband Network. Dr Pike was been recognized with numerous professional awards for his tireless efforts in promoting awareness of the benefits of space in the wider Australian community and for his long service in developing Australia's satellite communications systems. He is an AIAA Associate Fellow.

Squadron Leader Michael Spencer is currently serving at the Royal Australian Air Force Air Power Development Centre in Canberra, analysing potential risks and opportunities posed by technology change drivers and disruptions to future air power. His Air Force career has provided operational experiences and qualifications in long-range maritime patrol, aircrew training, and weaponeering, and management experiences in international relations, project management, air and space concept development, air capability development, and joint force capability integration. He is an Associate Fellow and Section Committee member of the AIAA Sydney Section.

NOTES:

1. DST Group (2017). *WRESAT — Weapons Research Establishment Satellite.* Online at www.dst.defence.gov.au/innovation/wresat-%E2%80%94-weapons-research-establishment-satellite
2. Dougherty, K (2017). *WRESAT – Australia's First Satellite.* Online at
3. DST Group (2017). 5*0th anniversary of Australia's first satellite.* Online at www.dst.defence.gov.au/news/2017/11/08/50th-anniversary-australias-first-satellite
4. Australis OSCAR 5. Online at https://australis-oscar5.weebly.com.
5. Williamson, B (2017). *Stargazing: How Aussie uni students convinced NASA to launch the first amateur radio satellite.* Online at www.abc.net.au/news/2017-04-06/how-uni-students-got-nasa-to-launch-australias-first-satellite/8421480

CONGRATULATIONS AIAA CLASS OF 2018 FELLOWS AND HONORARY FELLOWS!

"AIAA Fellows and Honorary Fellows have dedicated themselves and their careers to the advancement of aeronautics and astronautics. Their hard work, innovative spirit and leadership have made possible scores of noteworthy aerospace achievements—large and small—during the past decades. AIAA congratulates the members of the 2018 Class of Fellows and Honorary Fellows on their selection."

James Maser, AIAA President

2018 HONORARY FELLOWS

H. Norman Abramson
Southwest Research Institute (retired)

Charles Elachi
Jet Propulsion Laboratory
California Institute of Technology

Antony Jameson
Stanford University

2018 FELLOWS

Nancy F. Andersen
Johns Hopkins University Applied Physics Laboratory

Supriya Banerjee
FAMES

Olivier A. Bauchau
University of Maryland

Marty K. Bradley
The Boeing Company

Edward L. Burnett
Lockheed Martin Corporation

Carissa B. Christensen
Bryce Space and Technology, LLC

Jonathan E. Cooper
University of Bristol

James E. Graf
Jet Propulsion Laboratory

Michael A. Hamel
Lockheed Martin Corporation

Vlad J. Hruby
Busek Co. Inc

Parimal H. Kopardekar
NASA Ames Research Center

Eugene Lavretsky
The Boeing Company

Sankaran Mahadevan
Vanderbilt University

Mark D. Maughmer
Pennsylvania State University

Robert E. Meyerson
Blue Origin LLC

Dava J. Newman
Massachusetts Institute of Technology

Robert W. Pitz
Vanderbilt University

Stephen A. Rizzi
NASA Langley Research Center

Hannes G. Ross
IBR Aeronautical Consulting; EADS Military Aircraft (retired)

Robie I. Samanta Roy
Lockheed Martin Corporation

Steven P. Schneider
Purdue University

Steven D. Young
NASA Langley Research Center

All AIAA Fellows and Honorary Fellows, you are cordially invited to join us to celebrate the Class of 2018 at the AIAA Fellows Dinner.

Tuesday, 1 May 2018
Hilton Crystal City, Arlington, Virginia

Reception: 1830 hrs
Dinner: 1930 hrs
Attire: Business
Tickets: $130/each

By Invitation Only

More information and registration: aiaa.org/FellowsDinner2018

AIAA
Shaping the Future of Aerospace

AIAA Diversity Scholars at AIAA SciTech Forum

The AIAA Diversity Working Group is pleased to announce that the inaugural class of AIAA Diversity Scholars attended the 2018 AIAA SciTech Forum. The AIAA Diversity Scholarship aims to directly combat underrepresentation in the industry by providing students from underrepresented groups the opportunity to attend AIAA forums, and receive additional targeted programming that may help them succeed in the aerospace industry.

This program was organized by AIAA volunteer, Therese Jones, and funding was received from Secure World Foundation, Florida Space Grant, Pennsylvania Space Grant and the Texas Space Grant so that 17 students could attend the **AIAA SciTech Forum.** Because of the success of this program, Airbus is sponsoring this scholarship at the **AIAA AVIATION Forum** in June.

The scholarship welcomes applications from students in all disciplines with an interest in aerospace, including but not limited to STEM fields, communications, law, industrial design, journalism, and political science. Applications will open this spring. Students will be selected based on basic demographic information and a short essay describing their interest and experience in aviation.

"With the connections I made at this conference, I was able to land two interviews with companies that I would love to work for. I am exuberant to have the possibility to land a job thanks to this scholarship." — Cody Keenan

"This forum showed me that the professionals currently in the space industry are open to discussing their roles and sharing their knowledge in an open, friendly, and relatable way. It has given me the confidence to better understand my place within this industry and showed me that the people in this industry are warm, welcoming, and willing to share their expertise." — Chelsea Atkins

"Getting to know the other scholars so early on was definitely one of the highlights of the conference for me because I realized I was surrounded by so many like-minded people who share the same passion for space as I do." "I hope to tell the story one day of how this conference and the grant I received started it all for me." — Naia Butler-Craig

New AIAA Student Branches

At the Board of Trustees meeting held in conjunction with AIAA SciTech Forum, five new student branches were approved.

Yale University
Faculty Advisor: Prof. Mitchell Smooke; Student Branch Chair: Clio Byrne-Gudding
Region I, AIAA Connecticut Section

Ohio University
Faculty Advisor: Dr. David Burnette; Student Branch Chair: Quinn Mitchell
Region III, AIAA Dayton/Cincinnati Section

Youngstown State University
Faculty Advisor: Prof. Kevin J. Disotell, Ph.D.; Student Branch Chair: Matthew Lawson
Region III, AIAA Northern Ohio Section

California State University, Fresno
Faculty Advisor: Dr. Deify Law; Student Branch Chair: Bagrad Oganyan
Region VI, AIAA Antelope Valley Section

Portland State University
Faculty Advisor: Mr. Andrew Greenberg; Student Branch Chair: Christopher Rushford
Region VI, AIAA Pacific Northwest Section

Preparing the Next-Generation Diverse Technology Workforce

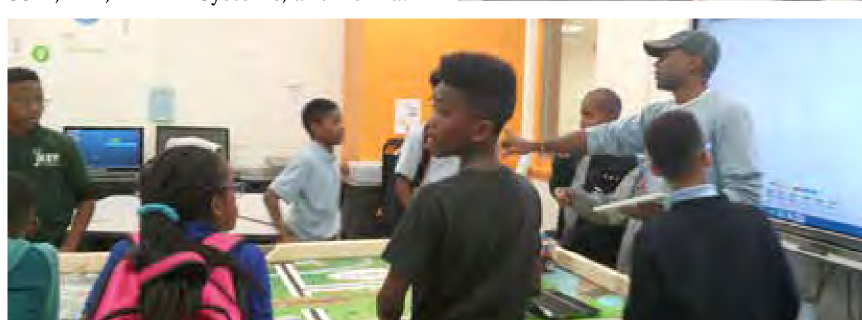
Dr. Supriya Banerjee, FAMES and AIAA K-12 STEM Diversity Working Group Leader

FAMES® is dedicated to mentoring and educating underserved youth in Grades 4-12 in finance, arts, and STEM subjects through after-school and summer programing. The organization's primary educational partnership is with the Boys & Girls Clubs of Greater Washington (BGCGW). As part of the 2017–2018 STEM after-school program, FAMES is engaging BGCGW students in the FIRST LEGO League (FLL) challenge. FAMES volunteers coach and mentor students in coding and robotic design, building team spirit to solve real-world problems and bolstering leadership skills. The program strives to inspire curiosity and introduce students to new career paths.

The students attested: "…I like the Lego League because I feel it will further my education," and "…I want to learn more about Lego robotics and robotics in general." Parents and grandparents are also excited about the students' interest in our program: "My son became very interested in robotics from being part of your program." The BGCGW Branch Director thanked FAMES for coaching and mentoring the students and taking them to the FLL tournament, an experience that helped encourage peer-to-peer learning as well. The students are eager to continue with the FAMES FLL program throughout the rest of the school year.

FAMES is focused on preparing the next-generation workforce by reaching into traditionally under-represented communities to introduce and engage them in STEM fields. Next school year, the program plans to expand by partnering with more youth clubs and schools near military installations to support the children of military families. A very special thanks to the AIAA Foundation for getting FAMES started in FLL. Additionally, FAMES would like to recognize the contributions from the major sponsors: The Boeing Company (sponsor of the AIAA Foundation FIRST LEGO League Grant Program), Leidos, SSAI, ERT, ADNET Systems, and Acima.

FAMES needs both financial and volunteer support from companies and individuals who are interested in nurturing and sustaining the students' interest in STEM. Please consider joining us in our mission to grow the diverse STEM workforce of the future! Contact us at **www.famesusa.org** or **info@famesusa.org.**



Reddy Honored With National Design Award

AIAA Associate Fellow **Dr. G. Satheesh Reddy**, Scientific Adviser to Raksha Mantri and Director General, Missiles and Strategic Systems, has been recognized with the prestigious National Design Award for his significant national contributions toward indigenous design and development of diversified missile systems, guided weapons, avionics technologies and for his sustained efforts leading to the advancement of aerospace technologies and industries in India. Dr. Satheesh spearheads Dr APJ Abdul Kalam Missile Complex, "the missiles hub of India," steering the design and development of wide variety of tactical and strategic missile systems. His contributions have left a lasting imprint on the technology map as well as on the defense preparedness of the country and paved the way for self-sufficiency in missile systems and technologies. Dr. Satheesh has played a major role in indigenous design and development of state-of-the-art weapon systems, formulation of national policies, harnessing the research and innovation in industry, academia, and R&D institutes. He received the award during the Indian Engineering Congress in December.

ASAT 2018 To Be Held In May

By Dr. Amir S. Gohardani, Chair, AIAA Orange County Section

The 15th annual AIAA Southern California Aerospace Systems and Technology (ASAT) Conference and Banquet mark the premier event of the AIAA Orange County Section and will be held on **Saturday, 12 May 2018.** ASAT 2018 brings together Southern California researchers, leaders, students, educators, engineers, and enthusiasts for a program consisting of parallel tracks in both morning and afternoon session. ASAT 2018 accepts unclassified presentation on all aspects of aerospace systems, technology, vehicle design, program management, policy, economics, and education and will be structured the following three categories:

- Aircraft Systems and Technology
- Space Systems and Technology
- Aerospace Public Policy and Education

Students are strongly encouraged to present an outline of their senior thesis or graduate work. The ASAT conferences are carefully planned to provide a forum for exchanging new ideas, review achievements, and enable unique networking opportunities for future aerospace endeavors. These conferences bring together the aerospace sector of Southern California with the hopes of revitalizing the rich history of leadership and innovation in the area. Dino Roman and John Rose are ASAT 2018 Conference Chairs.

For the fourth year, the **Gohardani Presentation Award in Aeronautics and Aerospace** (sponsored by the Springs of Dreams Corporation) will also be presented to two of the most thought-provoking and exceptional all-around presentations delivered during the ASAT conference. The award is presented in a Junior Category and a Senior Category, based on experience and expertise in aeronautics and aerospace.

The deadline for submission of an Intent-to-Present is **30 March 2018.** Notification of acceptance will be sent by **6 April 2018,** and a final copy of the presentation will be due by **4 May 2018.** For additional information, please visit the AIAA Orange County website: **https://info.aiaa.org/Regions/Western/Orange_County** or the event website: **http://events.r20.constantcontact.com/register/event?oeidk=a07ee67lt-0nf97db61d&llr=vitem6fab&showPage=true.**

Spectroscopic Measurements for Next-Generation Space Technologies

By Ben Urioste, AIAA Albuquerque Section Communications Officer

Dr. Christopher Annesley of Air Force Research Laboratory RV gave a presentation at the December AIAA Albuquerque Section meeting. His work involves the study of the fundamental chemical dynamics of thruster plume species. The LaSR (Laser Spectroscopy and Reactivity) Lab studies plume species spectroscopically to better understand chemical transformations that occur in the space environment.

In one project they are studying VUV-induced UV fluorescence of chemical thruster plume species. To date, they have examined water photo-dissociation by 121.6 nm radiation to determine the rovibrational population distribution of OH(A) product. The other major project in the lab is studying ionic liquids that are being adopted as propellants in satellite thrusters. Specially, our research program utilizes gas-phase spectroscopy and mass spectrometry to explore the fundamental optical and structural properties of ionic liquid neutral pairs and ionic clusters. Using infrared spectroscopy, they have made several findings concerning the ion pair [EMIM][TF2N].

They are now expanding the studies to larger, charged clusters and made experimental threshold collision-induced dissociation (CID) measurements of charged clusters, where they have identified dissociation pathways. They have also undertaken a theoretical investigation on the hypergolic reaction of dicyanamide-based IL clusters with nitric acid. The section thanks Dr. Annesley for sharing his exciting work.

Important Announcement:
New Editor-in-Chief Sought for the Library of Flight Book Series

AIAA is seeking an outstanding candidate for this position, to assume the responsibilities of Editor-in-Chief of the Library of Flight series in late spring 2018. The chosen candidate will assume the editorship at an exciting time as AIAA continues to expand its ability to support eBooks and other electronic content, along with publishing a range of titles in traditional print format.

The Library of Flight series encompasses a wide variety of general interest and reference books, including case studies. Appropriate subjects include the history and economics of aerospace as well as design, development, and management of aircraft and space programs. A successful series Editor-in-Chief will have a broad range of interests beyond strictly technical aerospace topics, and some familiarity with book publishing is preferred. The editor works closely with AIAA Headquarters staff to identify new topics and potential authors, maintain high-quality print and electronic content, and promote the series and AIAA's publishing program as a whole. He or she evaluates book proposals and manuscript submissions, recommends outside manuscript reviewers, and works with AIAA staff to ensure that all proposals are processed in a fair and timely manner.

Interested candidates are invited to submit resumes and letters of application for consideration. A selection committee will seek candidates and review all applications received. A final recommendation will be made to the AIAA Board of Trustees for approval. This is an open process, and the final selection will be made only on the basis of the applicants' merits. All candidates will be notified of the final decision. Questions may be referred to Heather Brennan, Director, Publications, **heatherb@aiaa.org.**

Applications are due 1 April 2018. The full series scope and complete application requirements will be available in Aerospace Research Central on the landing page for Library of Flight: arc.aiaa.org/series/4.lof.

Obituaries

Howard Marx

AIAA Associate Fellow Marx Died in January

Howard Marx died the first week of January. An emeritus member of AIAA with over 50 years of membership, he was an Associate Fellow, and was known as the "Grandfather of GPS." He was 95 years old.

Marx attended Tulane University, earning a Bachelor's degree in Mechanical Engineering, because Tulane did not have a program in Aeronautical Engineering. During World War II he served as a Lieutenant on the aircraft carrier, USS Franklin Roosevelt (CV-42). After the war, he completed his Master's degree in Aerospace Engineering at MIT.

In 1963, after working at General Dynamics and LTV in Texas, Marx moved to the Aerospace Corporation to be a part of the space program. There he was tasked with developing a long-range plan for applying space technology to the problem of air navigation. This is when he decided that if there were a system of orbiting satellites transmitting signals continuously to provide position fixes for military aircraft, it would be a great advance in navigation. On 1 December 1964, Marx presented the study results and plans to management, followed by a similar presentation to the U.S. Air Force. GPS was declared operational 21 years later. Marx also worked on the F-5, YA-9, YF-17, and the F/A-18 aircraft programs at Northrop, retiring as a Vice President.

A member of the Institute of the Aeronautical Sciences (IAS) while at MIT, Marx remained committed to the Institute as it transitioned through the merger with the American Rocket Society (ARS) in 1963 and became AIAA. He was dedicated to various sectional, regional, and national positions later into his career and throughout his retirement, serving as the chairman of the AIAA Los Angeles Section, AIAA Region VI director, and on multiple technical committees (TC) including the History TC.

At the 2016 AIAA SciTech Forum, Howard Marx was memorialized as a young professional documented his life in a technical paper presented in the History Track (AIAA 2016-1894).

AIAA Senior Member Jeude Died in January

Edward A. Jeude died on 20 January. He was 90 years old.

Jeude attended a Naval Aviator training program, and Washington University (Saint Louis) where he received a B.S. in Mechanical Engineering. He worked numerous full-time jobs (Kisco Boiler, Anheuser Busch, and Presstite Engineering) while finishing college. His true career passion was aviation, and he joined the exciting era of Cold War jet fighter development, designing the Chance-Vought F-7U Cutlass and F-8U Crusader Navy fighter aircraft before finding his true home at McDonnell Aircraft, starting with the F-4H-1 Phantom program.

In 1963, Jeude transferred to Florida to work on Space Launch Operations for the Mercury and Gemini programs. Returning to Saint Louis in 1970, he enhanced a number of significant features on the F-15 Eagle, the Harrier AV8-B, and the F-18 Hornet (in a full circle moment, his younger grandson maintains F18s as a specialist in the U.S. Marines). Jeude continued to design and had 30 active clients in his private engineering business at the age of 90.

AIAA Senior Member Lineberry Died in January

John T. Lineberry, 71, died on 20 January.

He earned his master's degree from the University of Missouri in Rolla and was awarded an honorary Ph.D. from the University of Tsukuba in Japan. Lineberry worked over 40 years as an aerospace engineering, working at McDonnell Douglas, AEDC, UTSI, ERC, and his own consulting company Lytec, LLC, which he continued to run after his retirement.

He was one of the leading experts in the field of magnetohydrodynamics, authoring over 200 technical papers on the subject. His contributions to the field of aerospace engineering will continue to shape technology and research for decades.

Lineberry received an AIAA Sustained Service Award in 2004 in recognition of 20 years of perpetual service to AIAA in directing national technical committee activities and conferences and fostering national and international membership. He was a member of the Plasmadynamics and Lasers Technical Committee, including as chair in 1999. In 2014, Lineberry received the AIAA Plasmadynamics & Lasers Award in recognition of a distinguished career in plasmadynamics and magnetohydrodynamics, for major contributions to terrestrial and aerospace applications, and fostering scientific and technological advancements through international collaborations and AIAA.

OLD DOMINION UNIVERSITY

The **Department of Mechanical and Aerospace Engineering** at **Old Dominion University** is seeking applicants for a tenure-track Assistant/Associate Professor in the broad area of **Space Systems Engineering**. Any specialty area within this umbrella will be considered, including mission design with single or multiple satellites, payload and instrumentation development, propulsion technology, small satellite systems, planetary exploration, vehicle dynamics, entry systems and thermal analysis, communication and telemetry systems, etc.

An appointment at the rank of Assistant Professor is anticipated although strong candidates can be considered at the Associate Professor level. The successful candidate should possess an earned PhD in Aerospace or Mechanical Engineering, or a closely related field, and will be expected to support undergraduate and graduate teaching, including supervision of student design teams, spacecraft/space payload research, and to oversee an on-campus Space Systems laboratory. They should plan to collaborate with, and support the activities of, the Virginia Commercial Spaceflight Authority, the Virginia Space Grant Consortium, NASA Langley Research Center, NASA's Wallops Flight Facility, the National Institute of Aerospace, and regional industry in the space sector. Development of a strong externally funded research program is essential.

Please submit a letter of application, curriculum vitae, statements of teaching and research interests, unofficial graduate transcripts and contact information for three professional references at **https://jobs.odu.edu/** Review of applications will begin immediately and continue until the position is filled.

Old Dominion University is an equal opportunity, affirmative action institution. Minorities, women, veterans, and individuals with disabilities are encouraged to apply.

1918

March 3 Canada opens airmail service when William Boeing pilots a Boeing seaplane from Vancouver, British Columbia, to Seattle, a distance of 229 kilometers. **Aircraft Year Book**, 1920, p. 250.

March 6 Ambrose and Lawrence Sperry's "Flying Bomb," a forerunner of the guided missile, makes what is claimed to be the first flight of a fully automatic missile in the U.S. and probably the world, at Amityville on Long Island, New York. Also known as the Curtiss-Sperry Flying Bomb because Glenn Curtiss built it on Sperry specifications with Sperry gyrostabilization and a rudimentary automatic pilot, the unmanned plane is catapult-launched and hits a target at 910 meters. Thomas Parke Hughes, **Elmer Sperry: Inventor and Engineer**, pp. 256-274; William Davenport, **Gyro!** pp. 190, 193, 215-218.

During March 1918 U.S. Army aviators fly De Havilland and Martin aircraft to bomb ice floes on the Susquehanna River near Havre de Grace, Maryland, and thereby save the town of Port Deposit, Maryland, from a possible flood because of blockages. These are specially made 22-kilogram bombs dropped from 152 meters. **Aeronautics**, March 18, 1920, p. 243.

1943

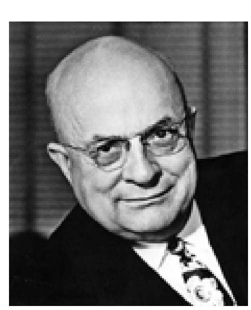
March 1 Berlin experiences its heaviest assault of the war when the British Royal Air Force's Bomber Command makes a concentrated attack for about half an hour. **The Aeroplane**, March 12, 1943, p. 293.

March 1 Rollo Appleyard, the British aircraft navigation pioneer, dies at 76. During World War I, he researched the means of determining altitude by barometric pressure and temperature. He worked out widely used time and distance scales known as the Appleyard Scale. **The Aeroplane**, March 12, 1943, p. 293.

March 5 The fifth prototype of the Gloster Meteor, one of the first British jets, makes its initial flight. It is powered by Halford H-1 turbojet engines. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, pp. 44-45.

March 6 J.D. Parkinson, a pioneer in British commercial aviation, dies. "Parky" joined the Royal Air Force in 1917, and the Holmes Brothers exhibition flyers after the war. In 1929 he flew as an airmail pilot for Canadian Airways, serving on the first Montreal-Vancouver-Montreal flight. He became a test pilot with Curtiss-Reid in Montreal and flew all over Canada and the U.S. **The Aeroplane**, March 19, 1943, p. 319.

March 6 Shipbuilder Henry Kaiser announces that he is acquiring Fleetwings, which goes on to produce parts for the Sea Wolf, Hughes F-11, Boeing B-17 Flying Fortress and Douglas A-20 Havoc aircraft. **Flight**, March 18, 1943, p. 278; "Henry J. Kaiser" file, **NASM**.



1968

March 1 NASA test pilot William Dana flies the X-15 No. 1 rocket-research aircraft up to a 31,852-meter altitude at a speed of 4,664 kmh, or Mach 4.36, from Edwards Air Force Base, California. Among other parts of this mission, Dana tests a newly developed spray foam insulation planned to use on the second stage of the Saturn 5. The new foam is much lighter than insulation previously applied to maintain the low temperatures required for cryogenic propellants, like liquid oxygen and liquid hydrogen. **Marshall Spaceflight Release 68-69**.

March 1 President Lyndon Johnson announces plans for the new Lunar Science Institute to be constructed under a $580,000 grant to the National Academy of Sciences and to be operated by the academy and Rice University in Houston. **New York Times,** March 2, 1968, p. 21.

March 2 The USSR launches the unmanned Zond 4 that, it is later learned, is one of the first Soviet experiments toward manned circumlunar spaceflight. It is launched to test the space-worthiness of a new space capsule design and to gather data about flights in circumterrestrial space. Zond 4 is sent into a 354,000-kilometer apogee orbit. However, upon re-entry its guidance system fails and the spacecraft is automatically blown up at a 5-10 km altitude above Earth. **Washington Post**, March 3, 1968, p. A14.

March 2 The first 24 Dassault Mirage 3S single-seat, single-engine French fighter aircraft of the Swiss Air Force offically become operational when they are handed over in a ceremony at Buochs airfield near Lucerne. The Mirage 3S is the first Western European combat aircraft to exceed Mach 2 in horizontal flight. **Flight International,** March 14, 1968, p. 392.

March 2 President Lyndon Johnson watches the world's largest aircraft, the U.S. Air Force's C-5A Galaxy military transport, roll off its production line at Lockheed's plant in Marietta, Georgia, and calls it "a long leap forward in the effective military might of America." The C-5A makes its first flight on June 30, then soon becomes operational and supports U.S. military operations in all major conflicts including Vietnam as well as in the later space shuttle program besides distributing humanitarian aid and disaster relief. The C-5A is 75 meters long, with a wingspan of 68 meters. **New York Times**, March 3, 1968, p. 1; **Aviation Week**, March 11, 1968, pp. 20-21.

March 3-9 Radio signals, which some scientists speculate might be generated from an extraterrestrial source, are recorded at the Arecibo Ionospheric Observatory in Puerto Rico. Other scientists propose that such signals might originate from normally pulsating neutron stars. **New York Times**, March 10, 1968, p. 1.

March 4-16 NASA's Orbiting Geophysicial Obseravtory, or OGO, 5 satellite, launches from Cape Kennedy, Florida, on an Atlas-Agena D booster and carries out 24 experiments in one of the most comprehensive studies of electric fields in space during a period of maximum solar acitivity. This is a record number of experiments for a scientific satellite. OGO 5's orbit is also very elliptical, with a 149,182 km apogee and 282 km perigee. **New York Time**s, March 5, 1968, p. A7; **Aviation Week**, March 11, 1968, p. 22.

March 5 NASA launches its 90-kg Explorer 37 satellite, to measure solar X-ray and ultraviolet emissions, on a four-stage solid-propellant Scout booster from Wallops Island, Virginia. Although the satellite does not enter its planned circular orbit, it satisfies NASA-Naval Research Lab scientific objectives. **Washington Post**, March 7, 1968, p. D21; **Aviation Week**, March 11, 1968, p. 26.

March 11 French ramjet pioneer René Leduc dies at 69. An engineer with the Louis Breguet aviation company, Leduc began the development of reaction-propelled aircraft from 1930, at first with pulsejet types that required a combustion engine with valves. He soon conceived the idea of a specially shaped nozzle, without moving parts, but using rammed-in air at high speed and fuel injection that combusted with the air and thereby produced a large thrust. It was not until Oct. 21, 1947, that his Leduc 0.10 was carried aloft by a plane to bring it up to operational speed, then released, and it became one of the world's first aircraft to fly powered solely by a ramjet. **Aviation Week**, March 18, 1968, p. 328; Jean Lacroze and Phiippe Ricco, **René Leduc: Pionnier de la Propulsion Réaction**, passim.

March 19 A full functional test of the German third stage of the ELDO booster is carried out at Lampoldhausen, West Germany. **Flight International**, March 24, 1968, p. 427.

March 27 Yuri Gagarin, the first human to journey into outer space in the Vostok 1 spacecraft that completed an Earth orbit on April 27, 1961, is killed along with backup cosmonaut Col. Vladimir Seryogin in the crash of their MiG-15 jet trainer northwest of Moscow. Gagarin has been the commander of the Soviet Cosmonaut Corps of Cosmonauts and officer-in-charge of cosmonaut training. Later, Gagarin's and Seryogin's bodies are cremated and buried in the walls of the Kremlin and nearly 200,000 mourners are present for that occasion in which Premier Alexkey Kosygin and President Nikolay Podgorny are present. **Washington Post**, March 29, 1968, p. 1; **Aviation Week**, April 1, 1968, p. 20; **New York Times**, March 31, 1968, p. 21.

March 27 The British solid-propellant Skylark sounding rocket achieves its first flight from the Estrange site near Kiruna, Sweden, and carries a London Imperial College scientific experiment up to 70 km that investigates the relationship of auroral events. **NASA, Astronautics and Aeronautics**, 1968, p. 70.

March 31 NASA's six-week 1968 Airborne Aurora Expedition concludes and is the most intensive studies ever made of the northern lights that has involved the employment of a high-altitude observatory jet transport aircraft, a Convair 990 carrying 13 experiments and taking some 40,000 auroral photos, besides the use of other aircraft and satellites such as the OGO 4. **NASA, Astronautics and Astronautics**, 1968, p. 72.

1993

March 25 Russia's first solid-propellant launch vehicle, Start 1, is launched. The rocket is based on missile technology developed for the SS-25 mobile intercontinental ballistic missile. It is in essence a modified RT-2PM Topol ICBM fitted with a satellite. Start 1 launches an Israeli EROS B Earth observation satellite into low Earth orbit. Anatoly Zak, "Start Launcher," **Russianspaceweb.com**.

During March 1993
A Lockheed SR-71 Blackbird reconnaissance aircraft assumes a different role when it is fitted with an ultraviolet camera to begin a NASA study of stars and comets. The program, established at the Dryden Research Facility in California, includes six SR-71s turned over to NASA by the Air Force. **NASA, Astronautics and Aeronautics, 1991-1995**, p. 335.

VANESSA REYNA, 32

Mechanical engineer, Raytheon Missile Systems

Vanessa Reyna was in high school in Edcouch, Texas, a town of about 3,400 people in the Rio Grande Valley, when a teacher suggested she try pursing an engineering degree. Reyna now works in Tucson, Arizona, on some of the most timely and critical defense technology the U.S. has. Specifically, she performs finite element analysis and testing of missile defense equipment. Among its products, Raytheon builds surface-to-air Standard Missiles for ship- and land-based Aegis Combat Systems, and Exoatmospheric Kill Vehicles for the Ground-based Midcourse Defense system, the missiles in Alaska and California that would spring from silos and attempt to shoot down North Korean warheads. Reyna's path to this career was anything but typical.

How did you become an engineer?

I wasn't like a lot of the other engineers I talk to. I didn't build stuff when I was young. I didn't try to fix cars. I played Barbies. I was a cheerleader. I was always good at math and science. I could probably credit that to my dad who was a math teacher. In high school, one of my calculus teachers told me I should try engineering when I got to college. I didn't even know what that meant. I went to the University of Texas Pan American in South Texas, which is now called University of Texas Rio Grande Valley. I didn't know what I wanted to do. I was very confused. I had to pick something. I thought, "I'm going to try the dental program and be a dentist." I went over there and they told me I was too late to sign up for the program. So I went across the street to the engineering building and they welcomed me with open arms. As soon as I took my first class, my intro to engineering, I fell in love with engineering. I knew that's what I wanted to continue to do. I did some materials research in school. That got me the opportunity to come here. I did my first internship at Raytheon in the materials lab. I did three internships here. I also did a co-op at another defense industry company. Then I came back to Raytheon full time. I took a vibrations course in school and noticed that Raytheon had a group called structural analysis that was doing finite element analysis and modeling. I said, "Get me into that group next summer and I'll be yours." They did. I enjoyed it so much I wanted to come back the following summer. Then I graduated and came back full time in the structures group.

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

We are always trying to stay ahead of the threat. There are so many threats right now worldwide. We have to make things faster and we have to make things hit targets that are a lot smaller now. That's where we are headed. We always want to keep our troops and country and allies safe. We have to stay ahead of that threat and kind of get into their head. What is their next move going to be? We just have to be faster and stronger than them. We are always trying to protect our war fighters. I know what that's like. My dad was in the Army. Two of my brothers were Marines. I've got two cousins who were Marines. Another cousin was Army. An uncle was a Marine. I feel like we have to do our work with them and their families in mind. I'm happy that I get to work here at Raytheon, preserving the greater good of freedom. ★

By Debra Werner | werner.debra@gmail.com