CLIMATE CHANGE 30
NASA's self-censorship

PERSONAL AIRCRAFT 38
A whole new way to commute

Q & A 10
Former ICAO chief Graham

AEROSPACE

★ ★ ★ AMERICA ★ ★ ★

Storm warning

How NOAA's newest weather satellites could nail the tracks of stronger hurricanes PAGE 22

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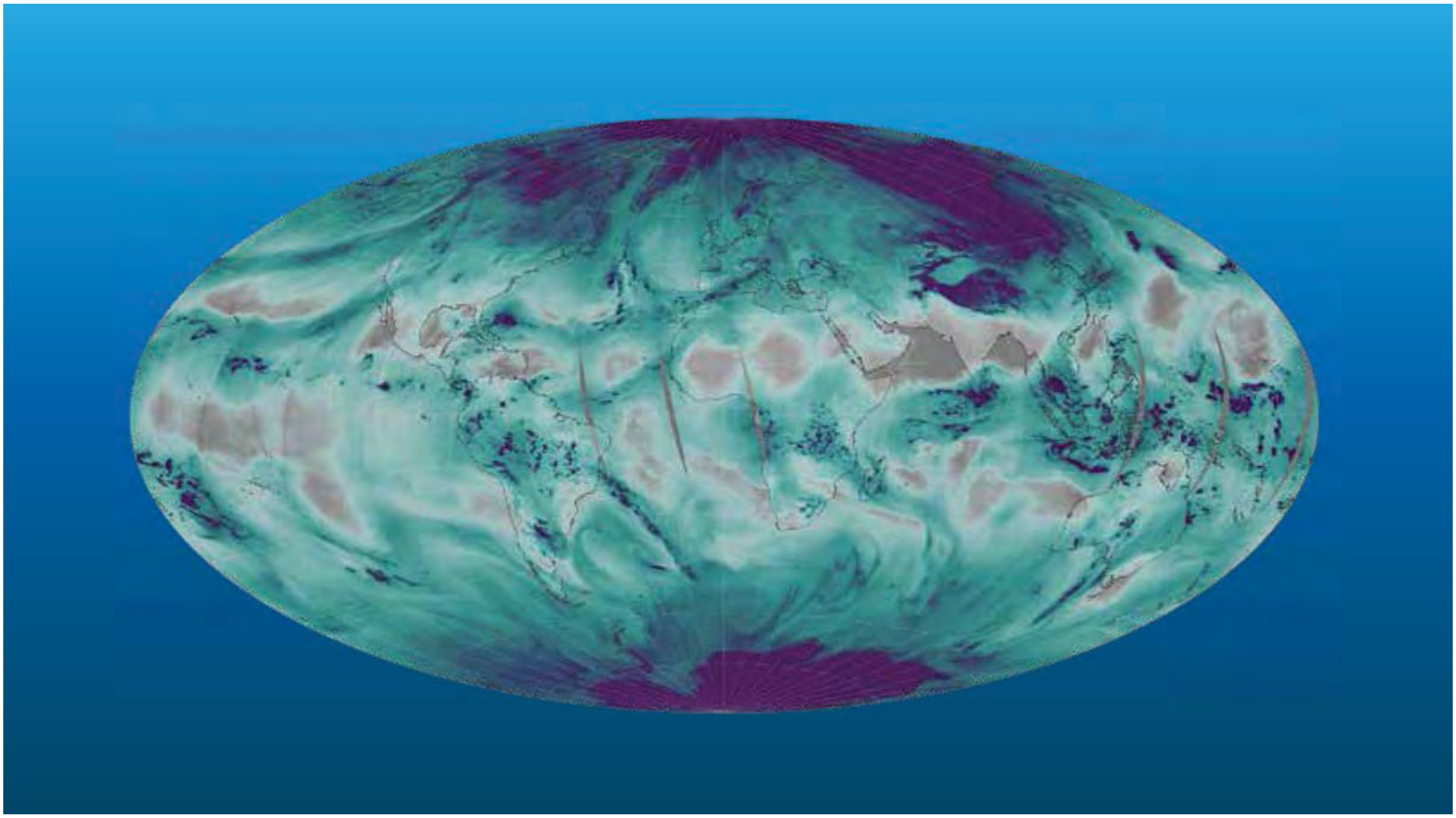
AIAA
Shaping the Future of Aerospace



22
Weather watch

Data collected by instruments on NOAA's newest satellite, NOAA-20, could empower forecasters to extend hurricane track predictions to seven days.

By Debra Werner

30
Navigating the politics of climate research

Some scientists working with NASA say they take special care to avoid words that might draw scrutiny.

By Keith Button

38
What will it take to make sky taxis a reality?

As urban air mobility entrepreneurs multiply, NASA plans for supporting the technology.

By Tom Risen

On the cover: An image of Hurricane Irma in the Caribbean on Sept. 8, based on data from the Suomi National Polar-orbiting Partnership satellite.

Image credit: Colorado State University, Cooperative Institute for Research in the Atmosphere

AEROSPACE
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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.

PAGE 30

Tom Jones

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

PAGE 16

Tom Risen

As our staff reporter, Tom covers breaking news and writes features. He has reported for U.S. News & World Report, Slate and Atlantic Media.

PAGE 38

Debra Werner

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

PAGE 22

DEPARTMENTS

8 **TRENDING**
The U.S. Marine Corps is preparing to experiment with a kit of sensors and software that could turn a conventional helicopter into an autonomous one.

4 Editor's Notebook

7 From the Corner Office

47 AIAA Bulletin

59 Career Opportunities

62 Looking Back

10 **Q & A**
Former ICAO official Nancy Graham on enforcing standards, new technology

12 **Case Study**
Powerful X-rays show defects as they develop during additive manufacturing

16 **Astronaut's View**
Lessons drawn from Columbia accident and reinforcing culture of flight safety

42 **Opinion**
Advice on innovation for maintenance, repair and overhaul companies

The human factor in science and technology

NASA

▲ At Kennedy Space Center's Visitor Complex in Florida, two fallen shuttle crews are honored in the "Forever Remembered" exhibit. Aerospace workers and visitors can view personal mementos of the Challenger and Columbia astronauts, and see evidence of the costs of inattention to flight safety.

Articles in this issue cover entirely unrelated technical topics, but they are bound together in the sense that each captures the human stakes of the topic in tangible, real-world terms.

Those stakes shine through most poignantly in "Their mission became our mission" (Page 16), a recounting by former shuttle astronaut Tom Jones of the Columbia space shuttle disaster and aftermath 15 years ago. This piece is a must-read for anyone who plans to send people into space, whether for the government or in private business.

As important as safety is for space travel, that issue will affect only a relatively small number of people, and that's likely to be true for the foreseeable future. Not so for hurricane forecasting, the topic of our cover story, "Storm warning" (Page 22). Each hurricane season, millions of residents and emergency authorities in coastal communities rely on NOAA's publicly released prediction cones to decide whether and when to evacuate. If all goes as planned, new satellite instruments are about to make those cones even more accurate and longer range. The timing is fortunate, based on the growing realization that hurricanes are in fact becoming stronger, just as scientists warned about a decade ago that they would.

The article "Self-censorship at NASA" (Page 30), brings home just how frightened some researchers and scientists are of the Trump administration, given the president's criticism of the conventional scientific view of climate change. The article portrays a fascinating turning of the tables about political correctness in the U.S., where references to climate change, global warming and fossil fuel reduction are suddenly out of bureaucratic favor. The piece explores whether these fears of the Trump administration are valid, and it delves into the possible unforeseen consequences of what might seem like an innocent trend of self-censorship.

Those of us with nightmarish commutes might want to read "Sky taxis: How to make them a reality" (Page 38). Will these concepts hit the market before most of us retire? I don't know, but I do know that the pioneers of this new market are doing their best to save time by building on work by those in the consumer drone industry, at FAA and NASA. ★

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

CORRECTION

An article in the November issue, "HyperSizing the largest aircraft," misstated the total weight that the Stratolaunch is designed to carry. The rocket and payloads could weigh a combined 250,000 kilograms. We do not have a figure for the payloads alone. Also, the rocket would not be reusable.

Stratolaunch is building its aircraft in a hangar at the company's Mojave, Calif., site.

Stratolaunch Systems

Farewell, Not Goodbye

On 4 January 2018, Dan Dumbacher joins AIAA as the new executive director. I am very excited to hand over the reins of leadership of the Institute to him; he will serve the membership well and bring a fresh perspective that will allow the Institute to continue to evolve and better serve our members. Over the next several months Dan and I will be working together to ensure a smooth transition to his tenure. Consequently, even though Dan comes on board at the beginning of the year, my last day with the Institute won't be until 30 March 2018—but this is my farewell Corner Office.

As I come to the end of my tenure I am very optimistic about the trajectory of the Institute and the prospects for the future. Because our members had the courage and resolve to embrace landmark governance change, because of the infrastructure upgrades we are embarking on, and because of the (always impressive) energy of our members, I really see things happening! Even though we are in the first year of the governance transition, the flexibility that we now have is paying off. Several new member communities have either formed or are being formed around subjects as diverse as hybrid electric aircraft, certification by simulation analysis, CFD for the 2030s, and complex system sustainment. The rollout of AIAA Engage—our community collaboration platform from Higher Logic—will help our members connect with each other more fully and more frequently. It will also provide a place for our student members to "find" our committees and local sections so they can connect while still in school, facilitating their transition to professional members.

In addition to being the executive director of the Institute, I also have had the privilege of concurrently serving as president of the AIAA Foundation. Working with staff, the Foundation's chair, and Board of Trustees we have made it a priority to reimagine and reignite it—and we have definitely moved the needle. I am proud of how far the Foundation has come both financially and programmatically. With your support and contributions, the Foundation is well positioned to engage and positively impact our future workforce. Let's keep up the momentum!

The past five years have been busy, challenging, productive, wonderful, and most of all just very special. I have enjoyed myself immensely; especially the opportunities to get out in the community, visit so many sections, meet so many of you, and learn about all of the amazing and interesting things that our community does on a day-to-day basis. The dedication and time that our members invest in AIAA has always impressed me. As you know the aerospace industry is composed of people passionate about what they do. AIAA members are the "passionate of the passionate" and truly are the standard bearers that move our industry forward. So, thank you all, so much, for contributing the most valuable asset you have—your time—to the Institute.

I would also like to thank everyone, both staff and members, for your support over the past five years—your willingness to accept change, and more importantly your trust in the vision and the future for the Institute that we are pursuing. I am truly honored to have had the opportunity to serve such a great community. Although I am leaving AIAA's paid staff, I will gladly continue to play an active role in the organization as a volunteer member, so I'll still be seeing many of you out and about in the community and at AIAA events! I look forward to being a resource for Dan and for you, as we continue our forward journey. ★

Sandra H. Magnus, AIAA Executive Director

U.S. Navy

Marines consider future of helo autonomy kit

BY HENRY CANADAY | htcanaday@aol.com

The wars in Afghanistan and Iraq gave U.S. military planners a visceral sense of the dangers of resupplying Marines, special operators and others in remote combat outposts. If roads existed, they were laced with improved explosive devices, and helicopters were subject to ground fire.

The U.S. Office of Naval Research in 2011 began conceiving of a possible solution: A kit of sensors and software that could be attached to a conventional helicopter to turn it into an autonomous one. The aircraft could then be loaded with supplies and commanded into a combat zone without putting an aircrew at risk.

ONR last month conducted the last in a series of demonstration flights in Virginia with the Autonomous Aerial Cargo/Utility System, military officials say. A Marine with just 15 minutes of training controlled a UH-1 Huey via a tablet computer without incident, though a safety pilot was aboard just in case. The test was conducted at Marine Corps Base Quantico in Virginia.

Next, the Marines will experiment with AACUS in upcoming exercises and decide whether to deploy the technology after more development.

AACUS Program Manager Dennis Baker expects the Marines to "balance their investment in further development of the system against other emergent priorities. It is too soon to know if they will ultimately put the system into the acquisition system."

He ticks off the now-proven AACUS capabilities: independent control of aircraft; development and execution of flight plans; sensing terrain and determining safe landing sites; avoiding no-fly zones; landing in confined spaces; and sensing and avoiding obstacles. The technology also could serve as a "pilot aid" when GPS and communications are unavailable.

Current unmanned aircraft require an operator with lots of training to manually control the aircraft.

At least one Marine general sounds optimistic about the odds that the service will adopt the AACUS technology: "It's up to us to determine how to use it," says Lt. Gen. Robert Walsh, commanding general of the Marine Corps Combat Development Command. Walsh says that young Marines have grown up in a technologically savvy society, a big advantage when it comes to autonomous control systems. "We've got to keep pushing and moving this technology forward." ★

U.S. Navy

▲▲ **A UH-1 Huey equipped with an Autonomous Aerial Cargo/Utility System** kit makes an approach for landing during final testing at Marine Corps Base Quantico, Va.

▲ **The sensor of the Autonomous Aerial Cargo/Utility System** is mounted on the front of the helicopter.

New instruments to plot solar radiation

BY AMANDA MILLER | agmiller@outlook.com

The latest instruments to gauge the energy Earth receives from the sun are onboard the International Space Station and expected to begin generating data by April. Scientists say data from the mission could be more important than any other in understanding not only the sun's effects on Earth's climate but people's influence on it as well.

Scientists have been taking measurements of the sun's energy from space continuously since 1978, but that record has been in jeopardy in recent years.

The instruments currently gauging total radiant energy from the sun, plus how the energy is distributed across the electromagnetic spectrum, are 10 years past their projected lifespan. Replacements bound for space in 2011 were lost when NASA's Glory satellite failed to reach orbit.

Staff at the University of Colorado's Laboratory for Atmospheric and Space Physics in Boulder have been putting NASA's existing satellite to sleep each night and manually waking it up each morning — with every orbit — to help preserve its failing battery.

"The value of this record is enhanced by its being continuous," says lead mission scientist Peter Pilewskie, who spoke with Aerospace America prior to the launch of the Total and Spectral Solar Irradiance Sensor, or TSIS-1, which consists of two instruments. "If there's a break, we lose accuracy in the measurements."

The unbroken, nearly 40-year record of total solar irradiance has revealed solar activity occurring in 11-year cycles, with energy output about 0.1 percent greater during a "solar maximum" than in the minimum phase. If that number seems small, consider that the sun is the planet's primary energy source. That 0.1 percent "still represents a lot of energy," Pilewskie says.

The higher energy output during a solar maximum is understood to correlate with temperatures 0.1 degree Celsius warmer. Pilewskie predicts that future data will chart wider swings in solar activity but doesn't think a corresponding temperature spike would absolve humans from having a hand in Earth's warming trend, which has occurred during a less active period for the sun overall.

NASA

▲ **Technicians at the Kennedy Space Center's Space Station Processing Facility** prepared the Total and Spectral Solar Irradiance Sensor-1 instrument in September to be launched to the International Space Station.

The total solar irradiance record started as part of the Earth Radiation Budget experiment in 1978, continuing under the Active Cavity Radiometer Irradiance Monitor program. The new hardware includes upgraded versions of the monitors collecting data aboard NASA's Solar Radiation and Climate Experiment satellite.

TSIS-1's Total Irradiance Monitor, or TIM, intended to extend the 40-year record, is slightly more accurate than its predecessor.

The TIM gathers solar radiation on a little black cone pointed at the sun. Solar energy heats up the sensor. Using electrical power, the instrument heats an identical cone facing away from the sun, determining its solar measurement based on the energy required to do so.

Continuing a 14-year spectral record, the new Spectral Irradiance Monitor, or SIM, works similarly but breaks up the light using a prism and measures wavelengths individually, Pilewskie says. The breakdown is useful in climatology because energy of different wavelengths behaves differently in different parts of the atmosphere.

NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the TSIS-1 project. Under a $90 million contract, the CU-Boulder lab has built and will operate TSIS-1 and distribute its data to the scientific community.

Launched from Kennedy Space Center atop a SpaceX Falcon 9 rocket Dec. 15, TSIS-1 traveled in a reused Dragon cargo capsule to the space station. The flight was SpaceX's first to reuse both a Dragon capsule and first-stage booster rocket.

Pilewskie anticipates that astronauts operating the ISS' robotic arm will install the TSIS-1 solar instruments on an ExPRESS Logistics Carrier platform after Dec. 25, with the first data returned by early April. ★

Courtesy of Nancy Graham

Advocating for better air navigation

Nancy Graham has direct experience with the limits of airliner flight tracking and data technology within the airline industry. The disappearance of Malaysia Airlines flight MH370 and the shootdown of MH17 over Ukraine happened during her eight-year term as director of the International Civil Aviation Organization's Air Navigation Bureau. Now in the private sector, she continues to advocate for improved flight tracking and for proposals to stream black box data from the cockpit. As a consultant, Graham is working with clients involved in opening up the stratosphere to aircraft that would act as cellular relays and internet hubs. She spoke with me on the phone from her home office.

— Tom Risen

NANCY GRAHAM

POSITIONS: President of her consulting firm Graham Aerospace International; Director of the Air Navigation Bureau at the U.N.s International Civil Aviation Organization from 2007 to 2015

NOTABLE: Maintained torpedoes as a civilian mechanic after joining the Naval Undersea Warfare Engineering Center in 1979. Joined the FAA in 1991 where she was responsible for building automation into operations of oceanic air traffic. At ICAO, she negotiated return of flight recordings from the Malaysia Airlines Flight MH17 wreckage after the plane was shot down over Ukraine in 2014.

AGE: 59

RESIDENCE: San Antonio, Texas

EDUCATION: Master of Science from University of Maryland. Bachelor of Arts in Technology Management from National Louis University in Illinois.

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Industry partnership with ICAO
Where there's some more progress needed is in collaboration with the industry, and that is a function mostly of the way the organization was structured. It is, today, funded exclusively by the [international] states themselves, and the U.S. hasn't been all that friendly toward U.N. agencies of late. If you think about how aviation has evolved, it was never set up as a public/private partnership. Today, the relationship of the industry is on an "observer" basis. They can come to the same meetings, but they don't get to play. Can they speak? Yes, but in a very structured, formal way. The organization has to find a way to both finance itself, for the future, and to open the doors to industry.

Enforcement teeth
ICAO audits the [member] states themselves, both in safety and security, on how well they're complying with the standards. So, compliance of standards doesn't necessarily equal safety. That program has been strengthened, both from the safety side, and on the security side. In years past, those were not transparent results. There's much more transparency not only to the public, but to the aviation community as a whole. States have begun to take action against states that have very, very poor audit records.

Google Loon hurricane relief
They've been flying for about three years now, and their objective is to have these floating cell towers in the sky. Facebook has a program very similar called Aquila. It's the big airplane that's sort of geostationary as well. There's a project that Airbus has and there are others. The point of all of them is to put infrastructure in the sky that supports the internet [in] places that don't have it. In the spring, for example, Loon was testing over Peru and they had a horrible, horrible [storm] there. Loon began to provide services on a test basis because they were there testing anyways, to Peru. They now have a number of balloons over Puerto Rico and have been providing service in Puerto Rico.

Opening the stratosphere
There's a tremendous amount of money that's headed into the upper airspace from an industry point of view and regulators just now need to catch up. We don't necessarily need to manage it in the same way as we manage regulated airspace, because everything up there can be equipped to be relatively, nearly autonomous and that's a very controversial discussion right now. There's lots to learn from the small-drone arena that we can apply to upper airspace. In the small-drone world, there are a number of companies that are trialing right now how to have remotely piloted drones essentially work in and around each other. If you think about it, upper airspace is a much easier testing ground, it's much less dense traffic.

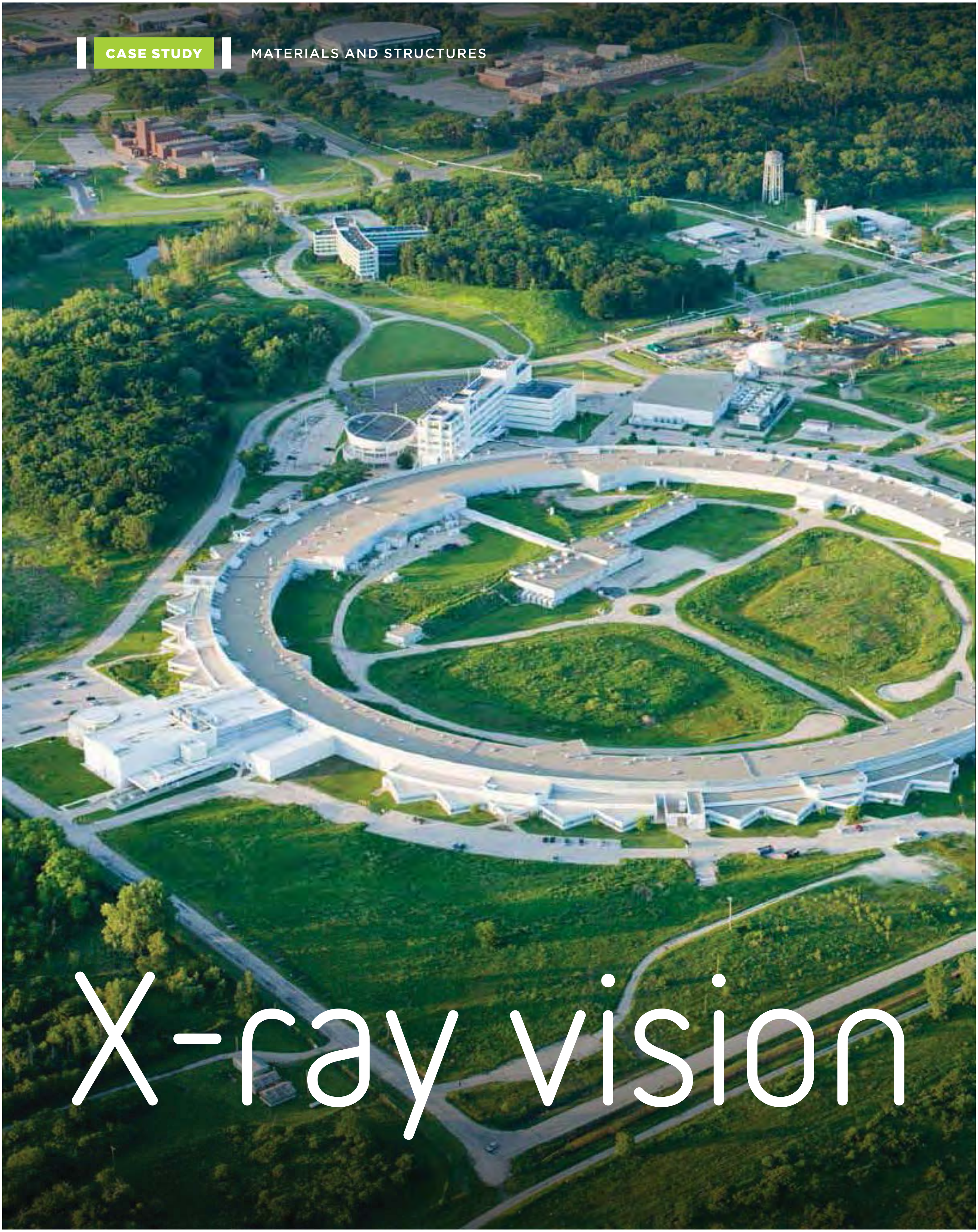
Fresh interest in supersonic planes
There was no push for ICAO to do anything in the supersonic arena [during my term that ended in 2015]. That's how quickly this system changed. Now, in one way I could tell you that that's a bit how detached ICAO might be in a sense, but I also think there just recently has been, like in the last three or four years, an infusion of cash in that arena from private sources. That's the difference. If you look back to the beautiful Concorde, that was predominantly sponsored by the states.

There's a tremendous amount of money that's headed into the upper airspace and regulators just need to catch up. There's lots to learn from the small-drone arena. If you think about it, upper airspace is a much easier testing ground, it's much less dense traffic.

Switching from black boxes to streaming flight surveillance
There's no reason why we shouldn't have that now. The technology is available. The challenge is when do you do that? When do you retrofit? When do you make those transitions? And this upcoming year, in 2018, there's something called the Air Navigation Conference. It provides the opportunity to rethink, for those transition points, in something called the aviation system block upgrades. Tracking is a compliance requirement now [for ICAO]. How you do it is up to the airlines, or the service providers themselves, as long as they can meet that standard.

2020 deadline for Automatic Dependent Surveillance-Broadcast
Some parts of the aviation industry, they're struggling, as is always the case when there's any requirement that's put in place. But there was certainly years of notice for this. It's not a surprise to anybody, and it's for the greater good for those operating. The FAA, I think, stands by their rule, and has absolutely no change in mind. It is what we need to have in the system to make it safe. It's the cost of doing business.

FAA corporatization, not privatization
I don't use the word privatization, because it has lots of implications, and I don't think it's what the FAA has in mind, or even what Congress has in mind. I would use the word corporation, which is still wholly owned by the government, but operates more like a business. I do think that it's important for the FAA to corporatize. They get a lot of "help" from down the street, and that's not helpful. They need to operate like a business without political interference. ★



X-ray vision

Additive manufacturing, also called 3-D printing, can't revolutionize aviation until engineers can print parts with repeatable quality and specifications, and consistent mechanical properties. One hurdle has been a near inability to see how irregularities form within particular metals. Researchers at Argonne National Laboratory outside Chicago are addressing that challenge by watching 3-D manufacturing with powerful X-rays. Argonne's Aaron Greco and Tao Sun tell the story.

BY AARON GRECO AND TAO SUN

A challenging problem in aerospace engineering is: How can we build metal parts with improved functionalities and performance without increasing their weight? Additive manufacturing or AM for short, is one potential solution. AM or 3-D printing refers to a suite of techniques for building three-dimensional objects by adding materials layer by layer based on a digital design. AM structures can be topologically optimized to reduce the weight of parts in planes, thereby saving fuel and decreasing CO^2 emissions. AM also largely eliminates tooling constraints, and gives engineers the freedom to design and build parts with complex geometries and improved performance. Other advantages of AM include short time to market, a short supply chain, and on-site manufacturing of spares.

As promising as AM is, there are still many fundamental problems we need to solve before these techniques can reach their full potential of revolutionizing the way we build parts for aircraft. A key challenge is that only a few metals are currently considered suitable for use in AM after years-long efforts on process optimization. For others, we do not understand yet how to reliably produce parts without cracks, porosities, and other microstructure defects. At Argonne National Laboratory outside Chicago, we (a team with backgrounds in physics, materials science, computer science and engineering) began tackling this problem in 2016 by additively manufacturing metal parts in the path of a high powered X-ray to observe how various defects form.

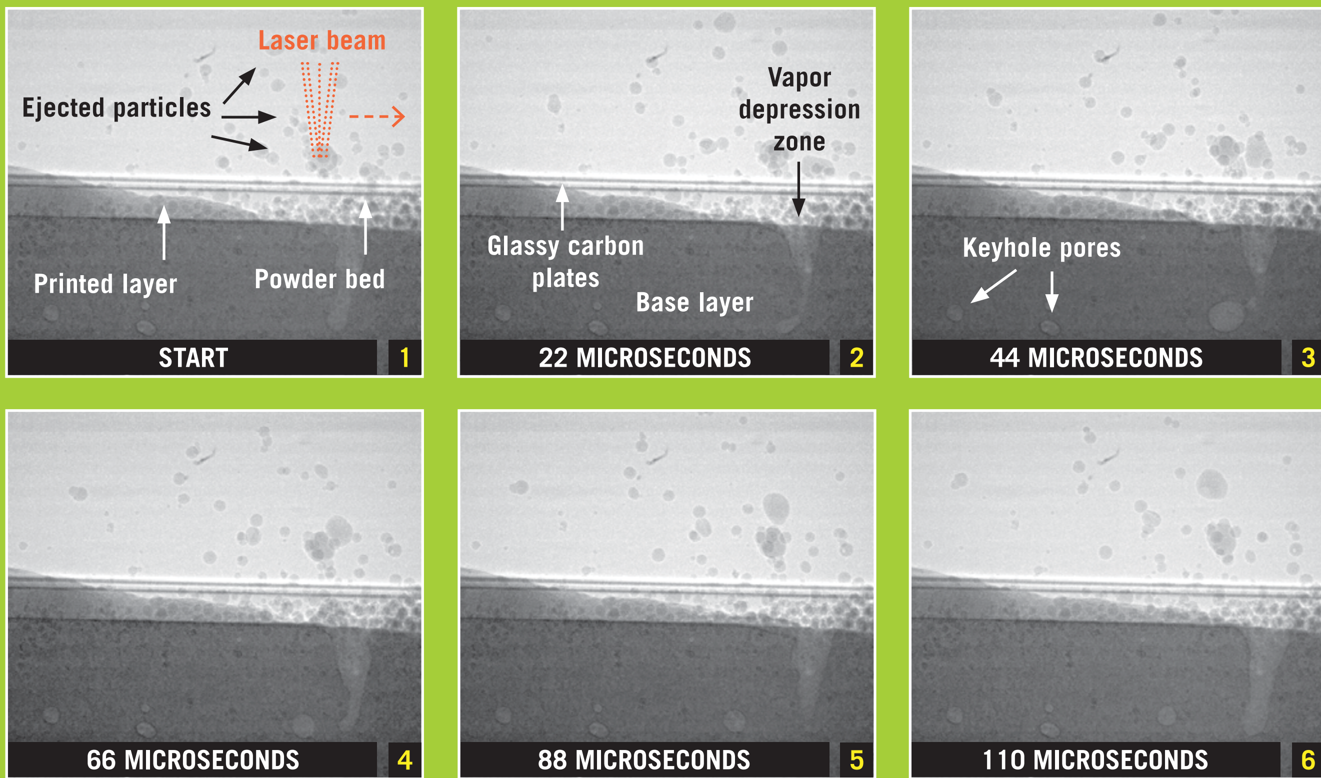
To understand why AM metal parts are susceptible to defects, it's helpful to consider the process. An electron or laser beam melts a feedstock, most typically in the form of a powder. In laser powder bed fusion, a thin bed of metal powder is mechanically spread on top of the previously fused layer. The laser melts the powder and the previously printed layer. Several problems can occur before the material cools and fuses. The extremely high and non-uniform thermal gradient inside the sample leads to a high surface tension difference, making conditions favorable for Marangoni flow, in which a gradient or difference in surface tension causes liquid material to move. In the case of laser fusion, liquid flows from the center of the laser-heated zone (lower surface tension) to the surrounding regions (higher surface tension), and so does the heat. As a result, the melt depth increases, and the powders in the close vicinity are pulled into the melt pool, and high-speed surface liquid metal may break away from the melt pool and spatter off. Meanwhile, the heat also vaporizes some of the metal, creating a small cavity, called a vapor depression zone. The vapor carries away some amount of powders and molten metal from the powder bed. The speed of the ejected powder can reach tens of meters per second. Once the laser leaves the area, the temperature decreases and the sample solidifies rapidly, sometimes accompanied by phase transformation (i.e., change in the atomistic structures of metals) and/or precipitation of a secondary phase (i.e., a certain part of the material contains different crystal structure with the surrounding matrix).

The entire melting and solidification process typically lasts only a few milliseconds in powder bed AM, so capturing these transient phenomena with high spatial and temporal resolution has been very challenging. Scientists have achieved some success in the past by illuminating the process with visible light and taking high-speed images. Powder flow, ejection, and melt pool dynamics near the sample surface can all be observed using this technique. However, almost all metals are opaque, so we cannot use visible light imaging to watch what happens below the surface and inside the sample during printing, and this is where most of the microstructure evolution occurs.

Argonne is the home of the Advanced Photon Source, or APS. The APS is a synchrotron facility,


Argonne National Laboratory

The Advanced Photon Source at Argonne National Laboratory in Argonne, Ill., is one of four such facilities in the world.



Argonne National Laboratory, Tao Sun

FIRST-TIME LOOK

Researchers at Argonne National Laboratory bombarded titanium alloy with high-speed X-rays to view how defects form during additive manufacturing. These images, selected from 340 in a series over 7.5 thousandths of a second, show the laser bed powder bed fusion process of a titanium alloy with a 360-watt laser. There is a slim and deep vapor depression zone, generated by the high-power laser. Particles of raw powders and molten metal are ejected away from the powder bed near the laser beam. When the laser moves away, the sample local temperature decreases, and the unstable collapse of the vapor depression zone causes the formation of pores, called keyhole pores. These pores weaken metal parts and can make them prone to fatigue and corrosion.

Source: Staff research, Tao Sun

which provides ultra-bright, high-energy storage ring-generated X-ray beams for research in almost all scientific disciplines. In the storage ring, electrons with energy of 7 billion electron volts are traveling at greater than 99.999999 percent of the speed of light. When these moving electrons change direction, they emit energy at X-ray wavelength. Scientists have known about the unique ability of X-rays to penetrate solid matter ever since Wilhelm Röntgen first discovered X-rays more than 100 years ago. The APS X-rays are about a billion times brighter than those generated by a machine in a hospital's radiology department. For synchrotron facilities, the larger the circumference of the storage ring, the higher the energy of electrons can reach, and the more flux the high-energy X-rays can contain. The APS is one of four high-energy synchrotron facilities in the world. The others are in Japan, France, and Germany.

In fiscal 2016, Argonne provided internal research and development funds to support our project to study metal AM with X-ray imaging. These development funds are intended for high-technical risk, yet potentially high-payoff research and development projects like ours. Frankly, even though we knew how to build the laser AM apparatus and conduct the X-ray experiment, we had very limited ideas about the kinds of phenomena we would be able to see. Therefore, at the beginning of this project, we only hoped to get some images showing the dynamics of powder melting while we heated it with a short-pulse laser. We started the project by building our own laser AM system. With the initial funding, we purchased a high-power laser that was delivered in May 2016, followed in July by a custom-built sample chamber that would be placed in the X-ray beamline. We then faced a challenge — we didn't have enough funding left to buy the laser optics. In the end, IPG Photonics Corp., from which we purchased our laser source, was kind enough to lend us a laser head, so our project could proceed.

In August 2016, we performed the first high-speed X-ray imaging experiment at the beamline of the APS. We had six days of beam time in August, the last month of the final APS cycle for the fiscal year. The pressure was pretty high at that point. If we couldn't get results from our experiment, we would end our first-year project almost empty handed, because the APS shuts down every September. We wouldn't have a chance to try again until it reopened one and a half months later, at the start of fiscal 2017. We spent two and a half days assembling the laser system, integrating it into the beamline, and certifying it with Argonne laser safety officials. On the afternoon of Aug. 20, right after lunch, we opened the X-ray shutter and performed our first high-speed imaging experiment on laser heating process. We chose a titanium alloy plate to start with. The result didn't disappoint us at all. We could clearly see the melt pool developing inside the sample as the laser heated it. After a few adjustments of the laser beam size, we began to observe additional phenomena, including the dynamics of vapor depression zones, Marangoni flows of molten materials, and rapid solidification. On Aug. 21, we started to collect high-quality X-ray images of the powder bed samples. On Aug. 22, we got greedier. We set up a diffraction detector and conducted simultaneous imaging and diffraction to probe the phase transformation process in titanium alloy. By the end of our beam time, we had collected nearly 90 gigabytes of data from 150 samples. We summarized these data and published them in Scientific Reports.

In fiscal 2017, we received extra funding from Argonne and bought a laser scanner that functions just like those in commercial powder bed fusion machines. We began to collaborate with a team led by Anthony Rollett, a professor at Carnegie Mellon University, and one led by Lianyi Chen, a professor at Missouri University of Science and Technology. Together, we designed and conducted X-ray experiments to investigate fundamental problems in laser powder bed fusion associated with porosity and crack generation, melt pool flow, solidification and powder ejection. Our collaborative team is currently drafting several papers summarizing our observations and the understanding we gained on these topics.

Along with the experiments, we have been developing multiple image analysis approaches to extract as much microstructure information from our X-ray data as possible. With the quantitative data about the dynamic material microstructure evolution during AM processes, we can help build highly accurate numerical models to optimize the manufacturing of parts with different geometries and dimensions.

Metal AM has developed rapidly in recent years, thanks to substantial investments in the technology from both public and private groups worldwide. Gaining precise control of microstructures and the properties of additively manufactured products remains challenging, which is why at this writing the pool of materials for AM remains very small. We believe our research delivers new information about the physics underpinning metal AM process, facilitates the development of new alloys for AM, and accelerates the application of AM in the aerospace industry and many other fields. ★

Aaron Greco

is a principal materials scientist at the U.S. Department of Energy's Argonne National Laboratory outside Chicago. He is co-leader of an effort to study microstructure formation and growth during additive manufacturing of metal components. Greco has worked at Argonne since 2010 and has a doctoral degree in mechanical engineering from Northwestern University and a bachelor's degree in mechanical engineering from Iowa State University.

Tao Sun

is a physicist at the U.S. Department of Energy's Argonne National Laboratory. Sun conducts his research at the Advanced Photon Source, one of only four third-generation, hard X-ray synchrotron radiation light sources in the world. He is co-leader of an effort to study microstructure formation and growth during additive manufacturing of metal components. Sun has worked at Argonne since 2010. He holds a doctoral degree in materials science and engineering from Northwestern University, a master's degree in materials science and engineering from Tsinghau University (China), and a bachelor's degree in materials science and engineering from Tsinghau University.


Their mission became our mission

Fifteen years ago Feb. 1, space shuttle Columbia broke up during re-entry, killing its crew of seven and scattering wreckage across east Texas and Louisiana. Veteran astronaut Tom Jones, who flew on Columbia in 1996, describes how NASA is using the recovered wreckage and lessons drawn from the accident to reinforce a culture of flight safety.

By Tom Jones | Skywalking1@gmail.com
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NASA

NASA

▲ **Reconstruction of Columbia** debris in a hangar at Kennedy Space Center. The process paid special attention to recovered fragments of the heat shield tiles and left wing reinforced carbon-carbon panels at the site of the foam impact.

▶ **The STS-107 mission astronauts** leave crew quarters at Kennedy Space Center on launch day. Rear, from left to right: Ilan Ramon, Michael Anderson, David Brown. Front, from left: Kalpana Chawla, William McCool, Laurel Clark and Rick Husband.

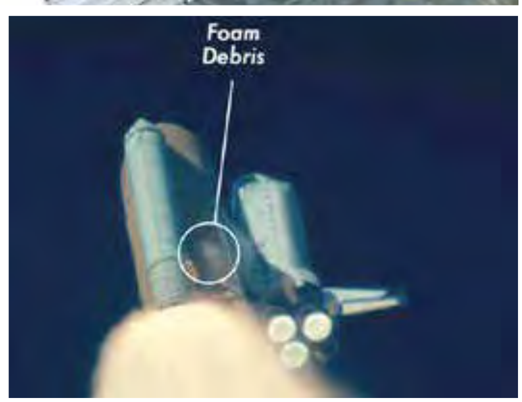
On Saturday morning, Feb. 1, 2003, I watched on television as shuttle orbiter Columbia, once my spacecraft, headed home from its 28th space mission. Minutes later, with contact lost with the STS-107 mission crew, I knelt in a prayer for those astronauts — my friends. None of us can forget those brilliant streaks etched across the skies of Texas, proof that ship and crew were gone.

Columbia's story didn't end with its searing breakup 60 kilometers (200,000 feet) over Texas. The orbiter's physical remains and lessons from this terrible, preventable accident are teaching a new generation of spacecraft operators and managers how to prevent a future spaceflight tragedy.

Bringing Columbia home

A new book, "Bringing Columbia Home: The Final Mission of a Lost Space Shuttle and Her Crew," tells how thousands of Americans strove to recover Columbia and its crew, while NASA studied physical and electronic evidence to determine the cause of the accident. The authors are Michael Leinbach, who was STS-107 launch director at Kennedy Space Center in Florida and led the Columbia Reconstruction Team, and space historian Jonathan Ward. Together, they capture the unceasing, three-month effort that mirrored the dedication of STS-107's astronauts, and serves today as an example of the perseverance and focus needed to ensure safety in a new generation of spacecraft.

What happened that February morning still commands sobering attention. Columbia was struck during its Jan. 16 launch by a chunk of insulating



NASA

◀ This prelaunch image of Columbia shows the bipod ramp, an aerodynamic fairing for the struts connecting the orbiter to its external tank. During ascent, foam insulation from the ramp separated and struck the leading edge of the left wing.

foam ripped from its external fuel tank 81 seconds after liftoff. The foam was seen on video slamming into the leading edge of the orbiter's left wing. Ascent imagery analysis during the 16-day mission did not reveal any explicit impact damage, and the astronauts themselves could not see the possible impact site from the crew cabin. Nor was the robot arm and its inspection camera installed on this flight. Some flight controllers expressed worry over the re-entry consequences if the thermal protection system had been compromised. These concerns did not reach the mission management team, and a spacewalk inspection (which would have revealed the damage) was never ordered. Mission Control relayed word to the crew that the potential impact damage had been assessed to be insignificant.

Cleared for re-entry, Columbia's crew was unconcerned as their ship streaked into the upper atmosphere at 25 times the speed of sound. But the leading edge of the left wing had indeed been breached, and hot re-entry plasma blazed into the wing and melted its internal aluminum structure. At Mach 18 or 19,000 kph the left wing failed, causing loss of control and disintegration of the orbiter. Debris rained down over a 400-by-30-kilometer swath from Dallas to the Louisiana border.

As heartbreaking video of the breakup splashed across TV screens at the launch control center, NASA Administrator Sean O'Keefe leaned over a desk and asked softly, "I wonder how many people on the ground we just hurt."

Finding Columbia

Within hours of the disaster, NASA had a rapid response team headed for the impact zone. At the newly established command center in Lufkin, Texas, David King, Marshall Space Flight Center's deputy director, took charge of the effort with superb support from the Federal Emergency Management Agency, the Environmental Protection Agency, the FBI and local agencies. His interagency team set immediate priorities:

1. Protect the public.
2. Find and recover Columbia's crew members.
3. Recover the orbiter debris crucial to identifying the cause of the accident.

The air, land and water search eventually grew to involve 25,000 Americans, the largest ground search in U.S. history. The local populace pitched in, determined to help "their" space program in any way possible. Volunteers set up a round-the-clock cafeteria for searchers in the Hemphill, Texas, VFW hall. Astronauts deployed to the area to aid the search for the crew, thank workers and maintain morale.

Search for the crew

Locating the crew was extremely important to the STS-107 families, their astronaut colleagues and NASA's close-knit personnel. The Flight Crew Operations Directorate at Johnson Space Center worked closely with the FBI, Texas law enforcement and the National Guard to mount the search. By calculating the post-breakup trajectory of the orbiter's crew cabin, confirmed by the impact sites of cabin wreckage, search teams pinpointed a second-day search box stretching from Nacogdoches southeast to Hemphill.

As searchers located crew cabin components, astronaut equipment and eventually human remains, the search narrowed to a strip of land south of Hemphill and west of the Toledo Bend reservoir. The painstaking effort found the astronauts, one by one, most within a 2-by-8-kilometer corridor. FBI field agents with forensic experience guarded and documented each recovery site until a NASA team, including an astronaut, could escort their colleagues with honor into the care of their families. Six crew members were located within a week; the last STS-107 astronaut was found 10 days after the accident.

Debris search

As the crew search intensified, so did the wider hunt for every piece of debris that could help unravel the accident's cause. Over a hundred federal, state, local and volunteer organizations participated. Aircrews searched 1.6 million acres along the breakup path, but aerial surveys proved ineffective at locating the thousands of small fragments of Columbia spread across the countryside, much under heavy tree cover.

After two weeks of searching for wreckage with a force of NASA, National Guard, local police and volunteer personnel, King employed U.S. Forest Service wildland firefighters, self-sufficient teams trained to scour rugged terrain in line-abreast fashion. Some 2,000 to 3,000 searchers were in the field at any one time, canvassing every acre of the search grid at arm's length. Augmented by the Texas Forest Service, the teams put in 1.5 million manhours and walked 680,750 acres of rural Texas and Louisiana.

They found Columbia everywhere, in thousands of pieces. Main engine forgings had buried themselves several meters deep in the muddy terrain, while spherical fuel and nitrogen tanks, paper checklists, and even cloth mission patches had decelerated and drifted to earth remarkably intact. Fragments reported by the public (via 12,000 phone calls) or found by searchers were geo-located with GPS, logged, bagged and shipped to Barksdale Air Force Base in Louisiana, and eventually Kennedy Space Center.

When the search concluded by April 30, teams had recovered about 84,000 fragments totaling 38,500 kilograms and comprising 38 percent of the orbiter. One tile fragment was found in far west Texas, near the New Mexico border.

Miraculously, all this debris, including pyrotechnics and toxic rocket propellants, resulted in no inju-

NASA

▲ This boot sole from one of two extravehicular activity spacesuits aboard Columbia was found in Sabine County shortly after the accident.

ries to those on the ground. However, on March 27, 2003, a low-flying search helicopter lost power and plummeted into the forest, killing U.S. Forest Service contractor pilot Jules "Buzz" Mier Jr. and Charles Krenek of the Texas Forest Service.

Data team

Meanwhile, the National Transportation Safety Board had recommended that a NASA-led data team work in parallel with the debris searchers to independently determine the cause of Columbia's loss. This group analyzed orbiter telemetry and ascent and breakup imagery to unravel the accident event sequence.

The data team's work received a huge boost when searchers in Texas recovered Columbia's Orbiter Experiments recorder, a magnetic tape "black box" that logged temperature and load measurements from sensors throughout the orbiter. The suitcase-sized box was found nearly intact on spongy ground just a few hundred meters uprange of a lake. Its tapes preserved crucial data from the orbiter's final moments after the telemetry downlink was lost.

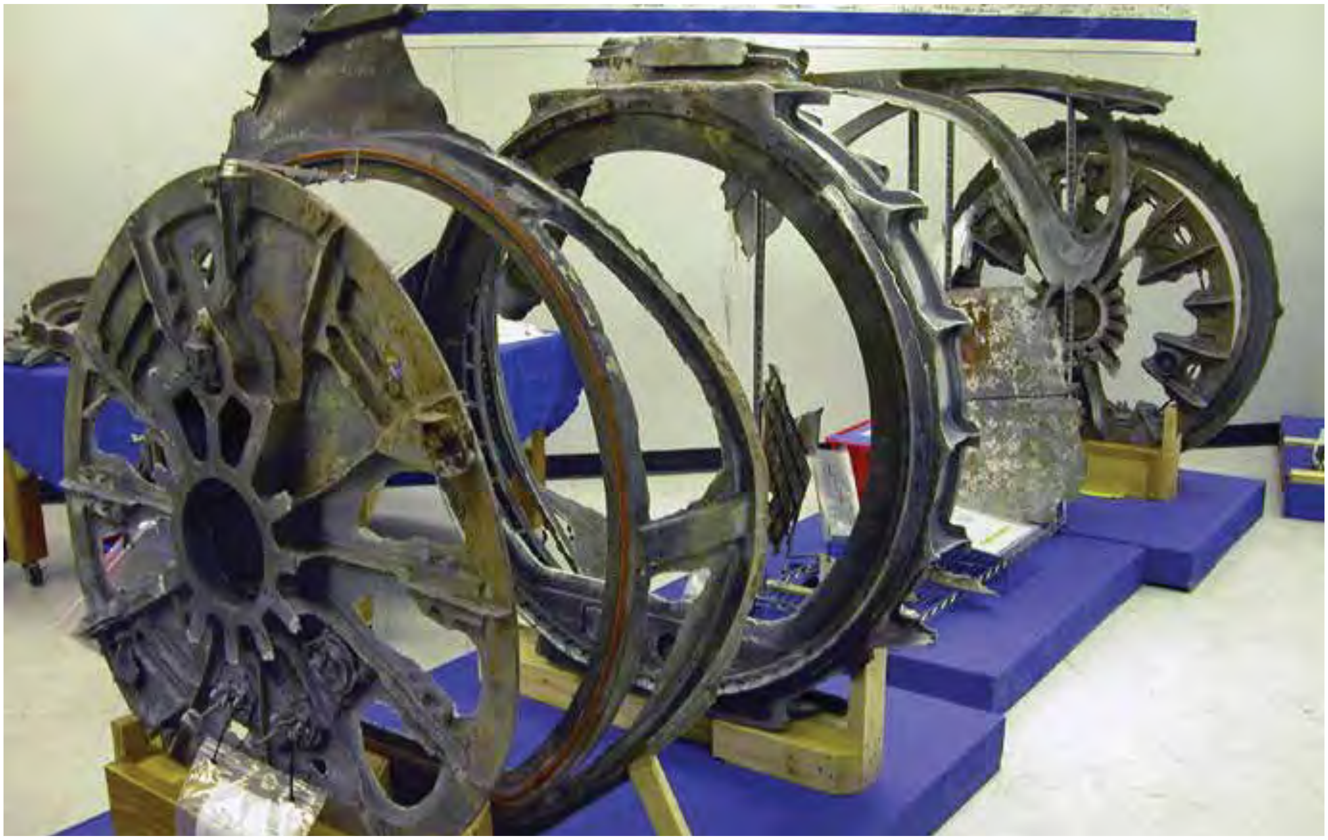
Reconstruction

Debris was collected at Barksdale, where Leinbach was deployed for 12 days to lead the initial debris identification and sorting. The debris was then shipped to Kennedy Space Center and laid out on a hangar floor for Leinbach's Columbia Reconstruction Team. Investigators paid special attention to the belly heat shield, the lower wing surfaces, and especially the foam impact site on the left wing's leading edge. Only tiny shards of those reinforced carbon-carbon panels were recovered, pointing to a breach in that critical surface. By analyzing cooled droplets of molten metal coating other pieces of recovered wing structure, NASA learned how the hot plasma had penetrated and destroyed Columbia's left wing. Thanks to this forensic reconstruction, the Columbia Accident Investigation Board by April had most of the physical evidence it needed to understand the accident sequence.

The board's August 2003 report found that after repeated instances of tank foam loss, NASA had not understood the risk of catastrophic heat shield damage, and continued to fly. Damage from foam loss was normalized as an "accepted risk." Further, during the mission itself there were lapses in leadership and communication that made it difficult for engineers to raise concerns or understand decisions. Managers failed to understand that critical damage might be present, and failed to investigate the actual presence or extent of damage to Columbia.

Their mission became our mission

Unlike Challenger's remains (buried in an isolated missile silo on Cape Canaveral — another story), Columbia's wreckage is today stored on the 16th floor of NASA's Vehicle Assembly Building at Kennedy. Mike Ciannilli, an engineer who worked 58 shuttle launches, 21 as the NASA test director, is today the "Apol-



NASA

▲ These sections of the pressurized tunnel from the crew cabin to the Spacehab module are preserved with other Columbia debris in NASA's Vehicle Assembly Building at Kennedy Space Center.

lo-Challenger-Columbia lessons learned program manager," in charge of acquainting NASA and industry with the experiences of three space tragedies. If we just lock Columbia's remains away, he says, "we're not effectively sharing the lessons from the past that will make our future more successful."

At Kennedy, new employees learn about spaceflight's seriousness with a visit to the Columbia Research and Preservation Area. Ciannilli infuses these visits with hard engineering, but emphasizes the physical presence of the astronauts amid Columbia's debris. Here is an airlock hatch they operated; there, avionics boxes from the crew cabin. "Their mission became our mission," he says.

Since 2016, thousands of NASA personnel have seen the spacecraft's artifacts and heard the importance of effective communication, of getting critical information to sometimes-unreceptive bosses, and of avoiding the "normalization of deviance" that makes an organization comfortable with accepting potentially fatal risks.

Sharing the Columbia story

Ciannilli wants to get those lessons not only to NASA's workforce, but to the new generation of commercial spacecraft engineers and operators. "It's critical to pass on that torch — what we all lived through with Columbia — so that no one repeats those mistakes." The lessons learned program has created a 90-minute HD video presentation aimed at aerospace industry audiences, and a 30-minute version suitable for smaller staff meetings, focused on how to prevent a Columbia-like tragedy. The artifacts reinforce the message that anything less than excellence in spaceflight opens the possibility of another Challenger or Columbia catastrophe.

Outreach also continues through NASA's Debris Loan Program to exploit the research potential of Columbia artifacts. About 450 kilograms of components are out on loan to industry and academia. For example, the University of Texas at El Paso is using recovered debris to refine re-entry dynamics models and so improve future spacecraft designs. The loan program has so far generated three doctoral dissertations.

As Leinbach speaks to NASA and new space groups, he relates the emptiness he felt at the shuttle landing runway, waiting for Columbia to appear, asking himself what he might have done to save the returning crew. Operators and managers, he says, "will make thousands of decisions that affect safety and human life. Listen to your people; listen to what the hardware is telling you. More than in any other technical endeavor, in spaceflight you have to be perfect."

In the coming year, we may see piloted commercial spacecraft launch to the International Space Station, and NASA move closer to its goal of returning astronauts to deep space. Co-authors Leinbach and Ward, writing of the recovery of a lost shuttle and crew, urge us to find the lessons born from tragedy, and act to prevent another on our watch. ★

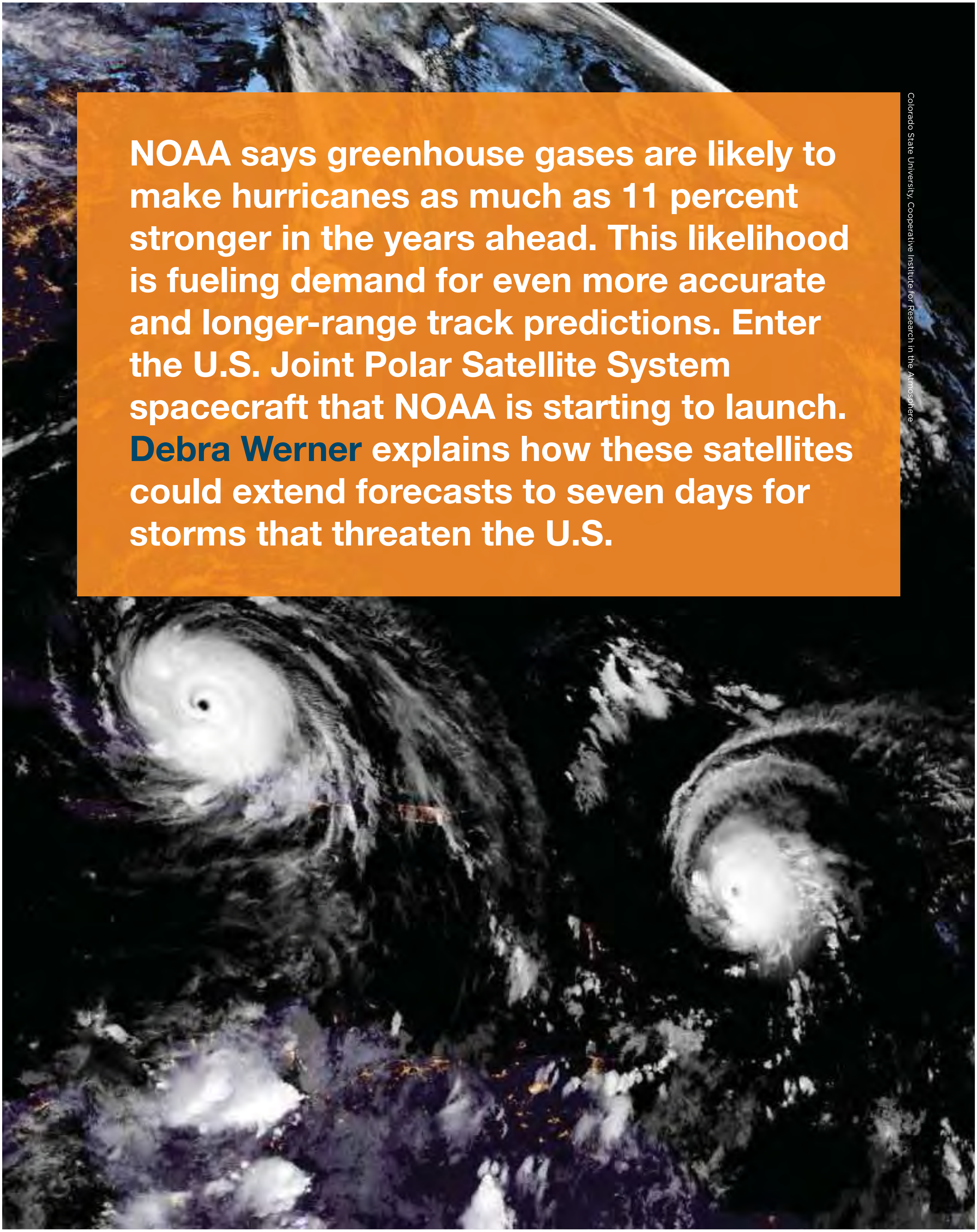
COVER STORY

BY DEBRA WERNER | werner.debra@gmail.com

Storm warning

The Visible Infrared Imaging Radiometer Suite, or VIIRS, on the Suomi National Polar-orbiting Partnership satellite collected the data for this mosaic of three hurricanes, from left, Katia, Irma and Jose, in the Caribbean on Sept. 8. The image is a composite, combining data on city lights and cloud imagery.

NOAA says greenhouse gases are likely to make hurricanes as much as 11 percent stronger in the years ahead. This likelihood is fueling demand for even more accurate and longer-range track predictions. Enter the U.S. Joint Polar Satellite System spacecraft that NOAA is starting to launch. Debra Werner explains how these satellites could extend forecasts to seven days for storms that threaten the U.S.



Colorado State University, Cooperative Institute for Research in the Atmosphere

Last September, with Hurricane Irma three days from Florida, residents of Cudjoe Key and vicinity probably breathed a cautious sigh of relief and turned their thoughts and prayers to Miami. The latest cone of uncertainty shifted the path of the storm's center away from nearby Key West and eastward by about 140 kilometers toward Miami. If the forecast held, given the anatomy of hurricanes, the winds and surge of ocean water would be less severe in the Florida Keys on the west side of the storm.

This shift in the storm track turned out to be nothing more than a few hours of false hope for the Keys. The National Hurricane Center in Miami moved the track back to the west, and Irma made landfall at Cudjoe Key at 9:10 a.m. on Sept. 10, just 32 kilometers east of the original forecast and 70 minutes later.

Knowing that residents make evacuation decisions at least partly based on these shifting forecast cones, U.S. meteorologists are determined to make their storm track and intensity predictions even more accurate. They're about to get help in the form of a 2,295-kilogram weather satellite packed with innovations that have been years in coming.

NOAA-20 arrived in orbit in November and is undergoing commissioning before it's put to work forecasting hurricanes and other weather phenomena. It is the first of four satellites in the $11.3 billion next-generation Joint Polar Satellite System that will gradually take over duties from today's NOAA Polar Operational Environmental Satellites. Forecasters are confident about the performance of NOAA-20's instruments, because nearly identical versions have been flying since 2011 on the Suomi National Polar-orbiting Partnership satellite, an experimental spacecraft named for U.S. weather satellite pioneer Verner E. Suomi who died in 1995.

The National Hurricane Center averages its track errors annually in miles, and there has been a decreasing average error since 1970, notwithstanding the wobble in the Irma track. "We are hoping that [NOAA-20] helps to continue this downward trend," says Mark DeMaria, head of the center's Technology and Science Branch. NOAA-20 was not in orbit for the 2017 season, but even without it, "preliminary data show that this was our best year ever," he adds.

The polar orbiters' global coverage is critical "because a storm brewing off the coast of Japan can unleash moisture plumes headed for North America."

—Mitch Goldberg, NOAA's chief scientist for the Joint Polar Satellite System

High value orbiters

Creating accurate hurricane forecasts is a bit like assembling a complex puzzle. Forecasters run data through various models, such as the National Weather Service's Global Forecast System model and the European Center for Medium-range Weather Forecasting model. They then apply their experience and knowledge to narrow these "spaghetti" tracks into a predictive cone consisting of the possible paths of the storm center.

NOAA's polar orbiters chip in by circling the globe from pole to pole 14 times a day, gathering observations of critical factors such as temperature and humidity. These readings are fed into the models together with data from hurricane hunter aircraft, balloons, ocean buoys and NOAA's geostationary weather satellites.

The two classes of weather satellites operated by NOAA, the polar orbiters and geostationary satellites, each have distinct strengths. By flying 40 times closer to the atmosphere, polar orbiters provide higher fidelity data, including about specific weather features in their fields of view. Plus, their successive orbits add up to global coverage. That's critical "because a storm brewing off the coast of Japan can unleash moisture plumes headed for North America," says Mitch Goldberg, NOAA's chief scientist for the Joint Polar Satellite System.

One thing the polar orbiters can't do is provide an almost unblinking eye over the Americas, which is the role of NOAA's geostationary satellites. The newest one, Geostationary Operational Environmental Satellite-16, or GOES-16, was called into action in September to take snapshots every 30 seconds of Hurricane Maria, after the weather radar in San Juan was knocked out. By stringing together these shots from the satellite's Advanced Baseline Imager, meteorologists watched almost continuously as the structure of Maria's storm center evolved. In December, after months of on-orbit check out, GOES-16 was designated as NOAA's GOES-East satellite to keep watch over the East Coast, Atlantic Ocean and Caribbean Sea. A companion satellite, GOES-West, watches the Pacific Coast and Ocean.

While the GOES satellites can pause their north to south scanning and stare, it is the polar orbiters that account for 85 percent of the data that's fed into the prediction models. Forecasters expect major improvements in that data from NOAA-20, enough so that in the 2018 hurricane season, they will begin experimenting with six- and seven-day hurricane forecasts with a goal of someday publishing cones

Once orbital testing is finished, NOAA-20 (known as Joint Polar Satellite System-1 during its NASA-managed fabrication) will gather weather readings in tandem with the Suomi National Polar orbiting Partnership satellite, which carries a set of nearly identical instruments. This will improve the odds of catching the eye wall of a hurricane in the fields of view of NOAA's best instruments.

1 Advanced Technology Microwave Sounder (85 kilograms) Can measure temperature and moisture at various altitudes through clouds and darkness due to properties of microwaves. Not as precise as other sensors. *Built by Northrop Grumman.*

2 Cross-track Infrared Sounder (175 kilograms) Hyperspectral sensor capturing temperature and moisture readings at numerous altitudes where there are no clouds. Measures temperature of cloud tops. *Built by Harris Corp.*

3 Visible Infrared Imaging Suite (280 kilograms) Collects visible and infrared imagery of the atmosphere, land and oceans. *Built by Raytheon.*

4 Ozone Mapping and Profiler Suite, or OMPS (56 kilograms) The version on NOAA-20 views ozone in the nadir direction below the satellite. The Suomi NPP version also looks off to the horizon or limb. Views are combined to depict vertical structure. *Built by Ball Aerospace.*

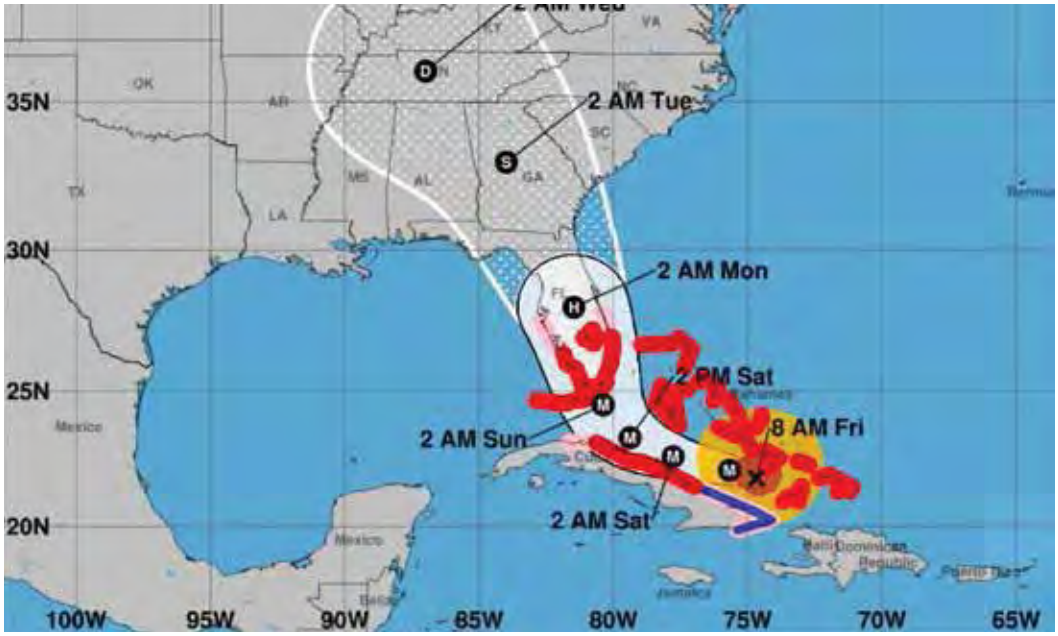
5 Clouds and the Earth's Radiant Energy System (54 kilograms) Monitors solar energy reflected by Earth and Earth's emitted thermal energy. *Built by Northrop Grumman.*

Staff research, NASA

of uncertainty looking that far ahead, compared to today's cones that look three to five days ahead. The National Hurricane Center will not release those experimental forecasts to the public until they evaluate them for accuracy, says DeMaria.

Sophisticated instruments

To fully appreciate NOAA-20's contribution to weather forecasting, it helps to delve into the technology, which has been in development since the 1990s. To predict the path of a hurricane, forecasters must map upper atmospheric wind patterns, looking for areas of low barometric pressure that guide storms along specific tracks. To find these upper level lows, forecasters need to identify changes in temperature from one area to the next high in the atmosphere. Predicting intensity is even more challenging. Forecasters need extensive observations of wind, temperature and moisture in and around the storm center to tell whether warm



NOAA

The National Hurricane Center plotted this cone of uncertainty for Hurricane Irma on Sept. 8. The part of the cone that is shaded white is the one- to three-day forecast. The red indicates areas where hurricane warnings were in effect one to three days before the storm would make landfall. The hurricane center is going to experiment with six- to seven-day forecasts, though not for public release.

How NOAA avoided a gap in weather coverage

For years, U.S. government auditors warned that the United States faced a possible gap in weather satellite coverage due to a failed government effort to merge defense and civil satellite programs, funding shortfalls and delays by NASA's partners in developing the instruments for the next generation constellation of polar orbiting satellites. Until that constellation was ready, NOAA relied on its small fleet of Polar Operational Environmental Satellites with decades-old technology.

The fears of a gap subsided greatly with the launch in November of Joint Polar Satellite System-1, a spacecraft also developed under NASA's management and renamed NOAA-20 in orbit. NOAA-20 must still undergo a commissioning process before feeding data into numerical weather prediction models, but forecasters have renewed confidence that a gap will be averted.

It was a decision by NOAA in 2012 (this is when the decision was made but it became operational in 2014) that bought much-needed time for forecasters and developers of JPSS-1. In orbit since 2011 was the Suomi National Polar-orbiting Partnership satellite that carried the same lineup of weather instruments as JPSS-1. This spacecraft sprang from a complicated plan formulated in the 1990s to demonstrate first-of-a-kind weather and climate instruments in space before committing to buying them for an entire new constellation. In fact, the two Ps at one time stood for "Preparatory Project." Suomi was meant to operate for only five years, but NOAA decided to declare it an operational weather satellite because key instruments on two of the agency's three other polar orbiters had failed. To avoid a data gap, NOAA also began relying more on partners. In 2010, NOAA and the U.S. Defense Department agreed to split up weather monitoring duties with the Defense Meteorological Satellite Program operating satellites that crossed the equator early in the morning while NOAA and the European Organization for the Exploitation of Meteorological Satellites shared responsibility for polar orbiters crossing the equator in the afternoon.

What's surprising is not that Suomi NPP was pressed into an operational role, but how well it has worked. Interagency managers once cautioned that Suomi's instruments "may not continue to operate throughout the planned 5-year mission," according to a 2011 audit by NASA's Office of the Inspector General.

Meteorologists say Suomi NPP is helping them forecast weather more accurately than ever, including the track and intensity of severe storms. Those forecasts will get even better when NOAA-20 and Suomi NPP begin working in tandem, says Mitch Goldberg, NOAA's JPSS chief program scientist. "Numerical weather prediction models have a thirst for accurate data."

By Debra Werner

moist air in its path will fuel it or whether pockets of cool dry air will weaken it.

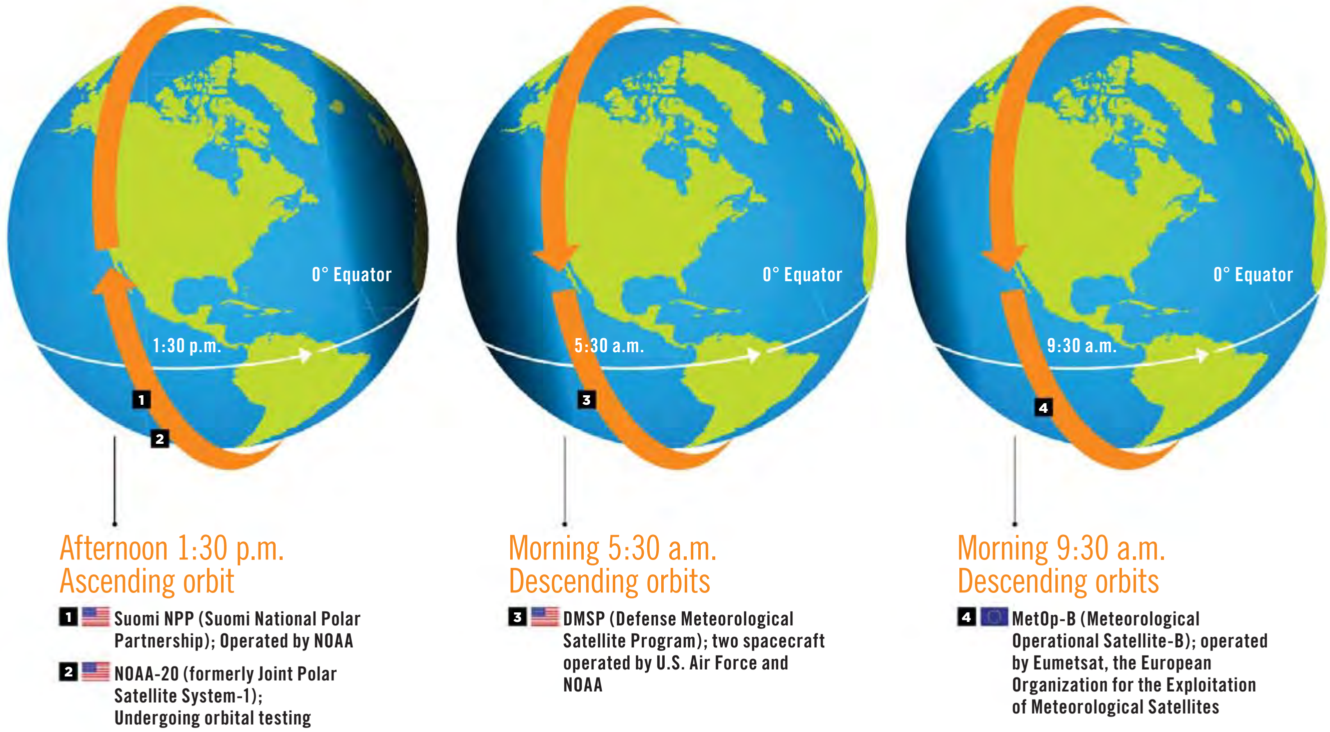
For the track measurements, forecasters will especially rely on temperature readings by two NOAA-20 instruments: the Advanced Technology Microwave Sounder, or ATMS, and CrIS, short for Cross-track Infrared Sounder.

ATMS observes microwave radiation emitted by Earth's surface and atmosphere with rotating reflectors that collect energy in 22 spectral bands ranging from 23 gigahertz to 183 GHz. The two rotating reflectors direct energy onto fixed reflectors on the opposite ends of the instrument where the energy is focused through a grid and into small antennas called feedhorns. Inside the feedhorns, the energy is amplified and filtered into discrete channels before it is steered to detectors. ATMS recalibrates itself once after each ground scan by staring into deep space and at an internal calibration target. Because clouds do not completely block microwaves, forecasters can measure atmospheric temperature, the critical factor for finding the upper level lows, and also moisture even when it is cloudy, in addition to gauging precipitation rates, snow and ice cover.

The infrared readings from CrIS complement the microwave data from ATMS. Clouds largely block infrared energy from below, but everywhere else CrIS measures temperature and also the atmospheric water content that can strengthen storms. CrIS does this in a multistep, intricate process that nevertheless

▼ **The Ozone** Mapping and Profiler Suite, or OMPS, instrument is aboard NOAA-20. After the satellite is commissioned, OMPS will track the Earth's ozone and help produce ultraviolet index forecasts.

Ball Aerospace & Technology



Team coverage

Polar orbiters cross the equator at the same local time but at different locations on each orbit. Assigning morning and afternoon crossings assures fresh readings will be available for forecasting models that are run at intervals. Because of the declining functioning of NOAA's other polar orbiters, U.S. forecasters today receive the bulk of their polar satellite readings from three sources: NOAA, the U.S. Air Force and Eumetsat, Europe's weather satellite organization. NOAA-20 will contribute to this coverage as soon as orbital testing is completed.

Source: Staff research, NOAA

happens in seconds for each collection. Arriving radiation is converted to an interference pattern through an optical process first conceived in the 1880s by German-born American physicist Albert Michelson. Next, a telescope focuses this Michelson interference pattern into an aft optics system that directs it to cooled photo-voltaic detectors. These separate the energy into three spectral bands and create an interferogram that is divided into 2,200 spectral bands from shortwave through longwave infrared through a process invented by the French mathematician and physicist Joseph Fourier. Like ATMS, CrIS recalibrates itself after each scan with an internal calibration target and view of deep space. By filtering out certain spectral bands and combining others, forecasters can focus on specific layers of the atmosphere.

ATMS will take over for the Advanced Microwave Sounding Unit and the Microwave Humidity Sounder on NOAA's other polar orbiters. ATMS has three more spectral channels and a wider ground swath. CrIS observes light in 2,200 spectral bands compared with 19 spectral bands on its predecessors, the High-Resolution Infrared Radiation Sounders.

Once NOAA-20 is fully commissioned, its readings will join those from Suomi NPP, which orbits 50 minutes ahead of NOAA-20. Having two satellites staggered like this will improve the odds of capturing a close-up look at a specific weather feature. The ATMS coverage swath is 2,500 kilometers across: "The information we get depends on where [ATMS] hits the storm, whether it is on the eye or on the side of the eye," DeMaria says. "But if we have two passes 50 minutes apart, we have a pretty good chance of getting a solid view of the eye."

Temperature and wind speed aren't the whole story. Forecasters also need to see how storms are evolving. That's where the geostationary satellites and a third NOAA-20 and SNPP instrument come in: the first-of-its-kind Visible Infrared Imaging Radiometer Suite, or VIIRS (pronounced VEERZ). The tops of clouds are cold, so they stand out in VIIRS imagery. Even before a hurricane forms a tight eye, forecasters can examine VIIRS imagery and find the center of circulation. VIIRS has a day-night band sensitive enough to reveal storm clouds in scant moonlight.

"Hurricanes like Irma are pretty easy to track even at night with infrared imagery," DeMaria says.

VIIRS does this by rotating a telescope to capture light from Earth in 22 spectral bands. Other optics then direct this light into VIIRS' aft optics assembly and through a beam-splitter. This sends visible and infrared wavelengths to four focal planes cooled to cryogenic temperatures to ensure sensitivity.

The version of VIIRS on Suomi NPP featured prominently in forecasting the track and intensity of the disturbance that would grow into Hurricane Harvey and inundate Houston with flooding rains. On Aug. 17, "potential tropical cyclone 9" brought heavy rain and wind gusts to the Lesser Antilles islands in the Caribbean Sea. Two days later, it all but petered out in the eastern Caribbean Sea. The question was what would happen next.

"We couldn't see the low-level circulation and tell how organized it was at night without visible imagery. The day-night band gives us the ability, provided we have some moonlight," DeMaria says.

Forecasters correctly predicted the remaining circulation would perk up. On Aug. 23, the storm became a tropical depression in the Gulf of Mexico and strengthened into Hurricane Harvey on Aug. 24.

With VIIRS flying on NOAA-20 in addition to Suomi NPP, forecasters will have a second source of imagery. Just as important as the extra data is McMurdo Station in Antarctica, where NASA and NOAA began operating a new network of satellite antennas in August. Suomi NPP downloads its data in X-band only once each orbit, specifically to a ground station in Svalbard, Norway. NOAA-20 downloads stored data via Ka-band twice each orbit to Svalbard and McMurdo. Suomi NPP can't do that because McMurdo does not have an X-band receiver.

Downloading twice cuts in half the time forecasters must wait for observations. Suomi NPP sends 95 percent of its data to forecasters within 100 minutes. NOAA-20 aims to share 90 percent of its data within 40 minutes.

That adds up to far more frequent updates on storms like Irma, Harvey and Maria.

What difference could the addition of NOAA-20 have made to the Irma track? DeMaria says it's "difficult to determine which sources of error" contribute to the history of an individual forecast, such as the temporary eastward shift of Irma's track. Typically, the main sources of error are insufficient observations "to adequately map the wind, temperature and moisture field around and in the storm," and also "errors in the way the computer models handle certain physical processes such as the turbulence in the boundary layer, energy exchanges with the ocean, and the way the models treat the clouds that form." If all goes as planned, NOAA-20 will address the observations part of the error equation.

"That is a big deal for us," DeMaria says. ★

Commissioning NOAA-20

NOAA meteorologists aim to start feeding data from NOAA-20's three weather instruments into numerical weather prediction models sometime in the "spring." They can't offer a more specific timeline because they don't know how long it will take to calibrate these sensors and validate their datasets by comparing them with readings from other ground, airborne and space-based sensors.

NOAA is turning on the instruments according to a planned sequence that was scheduled to run through early January.

Once all the instruments are turned on, the NOAA-20 science team expects to spend about three months calibrating and validating them, a process they expect to run smoothly because NOAA-20 carries sensors that are nearly identical to the ones on a pathfinder satellite called the Suomi National Polar-orbiting Partnership. Validating Suomi NPP sensors took two to three times as long as expected for NOAA-20, says Arron Layns, who leads NOAA's JPSS algorithm management.

SELF-CENSOR

~~SHIP~~ discipline AT NASA

When the Trump administration arrived in Washington, D.C., a year ago, one might have expected climate change skeptics in the new administration to revel in ordering a cleansing of climate terminology across agencies, given their view that much of the science is politically motivated junk. That hasn't happened, at least not at NASA. Instead, something else has happened. Some researchers began censoring themselves. Keith Button tells the story.

BY KEITH BUTTON | buttonkeith@gmail.com

▲ During a series of NASA test flights, this DC-8 compared JP-8 jet fuel to a 50-50 blend with a renewable alternative fuel. Some scientists working for NASA say they've started changing the language but not the goals of their research to avoid triggering criticism.

After the election of Donald Trump, a consortium of universities headed by Ohio State had second thoughts about the wording of a grant application to NASA. Instead of referring to a goal of reducing carbon emissions from aircraft, the consortium adjusted the wording to say the research would explore "electrical propulsion challenges and opportunities." The fear was that referring to carbon emissions would hurt chances of winning the grant, given the political climate after Trump's election, says Meyer Benzakein, Ohio State aerospace professor. The goal and substance of the five-year project — to reduce carbon emissions by shifting to electrical propulsion — remained unchanged, and in April 2017 the consortium won the $10 million grant.

Consider also the planning document produced annually by the NASA Aeronautics Research Mission Directorate. The 2016 version of this "Strategic Implementation Plan" listed the "transition to low-carbon propulsion" as a top goal. The version published in 2017 reworded that to "transition to alternative propulsion and energy." Yet the target of reducing net emissions by 50 percent by 2050 remained the same.

This cleansing of politically fraught terminology in documentation and sometimes the spoken word has become a pattern among NASA researchers and affiliates, based on my review of documents and interviews with a dozen researchers in private industry, universities and NASA.

It is a cat-and-mouse game that has some in the field questioning whether fear of the Trump administration is pushing scientists over the line between their responsibility to accurately convey the rationale for their work and their desire to keep funding going.

"Squandering an opportunity"

Maxwell Boykoff, director of the Center for Science and Technology Policy Research at the University of Colorado-Boulder, worries about this trend. "If you're deliberately avoiding talking about the implications as they relate to climate change, you are squandering an opportunity, and you are self-censoring, and you are avoiding rather than confronting, some of the very motivations that are behind one's work," he says. "When it comes to sharing your research findings, and to talking about how it relates to other issues, I do think there's a certain responsibility to name it what it is."

Reached by email, climatologist and geophysi-

NASA/SSAI

cist Michael Mann of Penn State says, "the idea that scientists now have to alter their science (or at least how they characterize it) in deference to the politically motivated ideologues that now run the current administration is truly disturbing." He pointed to the case of post-Russian Revolution agronomist Trofim Lysenko, whose story is often cited by climate change activists. Lysenko's incorrect conclusions about how plants acquire and pass on traits are partly blamed for causing scientific purges and starvation in the Soviet Union. Mann said the U.S. is "perilously close" to that kind of situation.

So far, though, the scope of the trend at NASA appears to be limited mainly to bureaucratic interactions within government, mostly in documents and sometimes in conversation. The trend has not spread to the agency's public face, for example. Pages on NASA's website continue to display extensive evidence of climate change, including rising carbon dioxide levels, rising global temperatures, shrinking Arctic sea and land sheet ice, and rising sea levels, along with links to NASA's related climate science missions.

Why are climate researchers and technologists so worried then? President Trump's disdain sounds personal to them, and it appears to run deep. The

NASA NOMINEE SHIFTS TONE ON CLIMATE QUESTION

President Donald Trump's choice for NASA administrator, Rep. Jim Bridenstine, R-Okla., told senators during his November confirmation hearing that "human activity is absolutely a contributor" to the warming climate, but he added that "there are other contributing factors that may have more of an impact."

His message was similar to that of a 2013 speech on the floor of the House of Representatives, but this time his tenor was entirely different. In 2013, Bridenstine colorfully bucked scientific consensus:

"Global temperatures stopped rising 10 years ago. Global temperature changes, when they exist, correlate with sun output and ocean cycles. During the medieval warm period from 800 to 1300 A.D. — long before cars, power plants, or the Industrial Revolution — temperatures were warmer than today. During the Little Ice Age from 1300 to 1900 A.D., temperatures were cooler."

Scientific consensus rebuffs Bridenstine on most of those points. Since 1970, Earth's average temperature has been rising at a rate of about 0.17 degrees Celsius per decade, according to the NOAA website. The close of 2009 marked the second warmest year on record and ended the warmest decade, according to the NASA website. As for the role of the sun, if there is one, it's much less significant than that of human activities. Scientists continue to research the question of global temperature during the medieval period compared to today, but the period from 1901 through 2016 was "the warmest in the history of modern civilization," according to the latest U.S. "Climate Change Special Report."

Bridenstine did not get into any of that during his confirmation hearing. Instead, he said "we have to keep the debate dispassionate and driven by science."

topic was a hot one on his Twitter feed even before he announced his candidacy for president in June 2015. A year earlier, Trump tweeted: "This very expensive GLOBAL WARMING [expletive] has got to stop. Our planet is freezing, record low temps, and our GW scientists are stuck in ice." As a candidate, Trump promised to "cancel" the Paris climate accord. The U.S. president can't unilaterally end an international agreement signed by 197 countries and the European Union, but Trump made good on his promise in a sense by announcing in June that the U.S. would withdraw from the accord.

No mass exodus

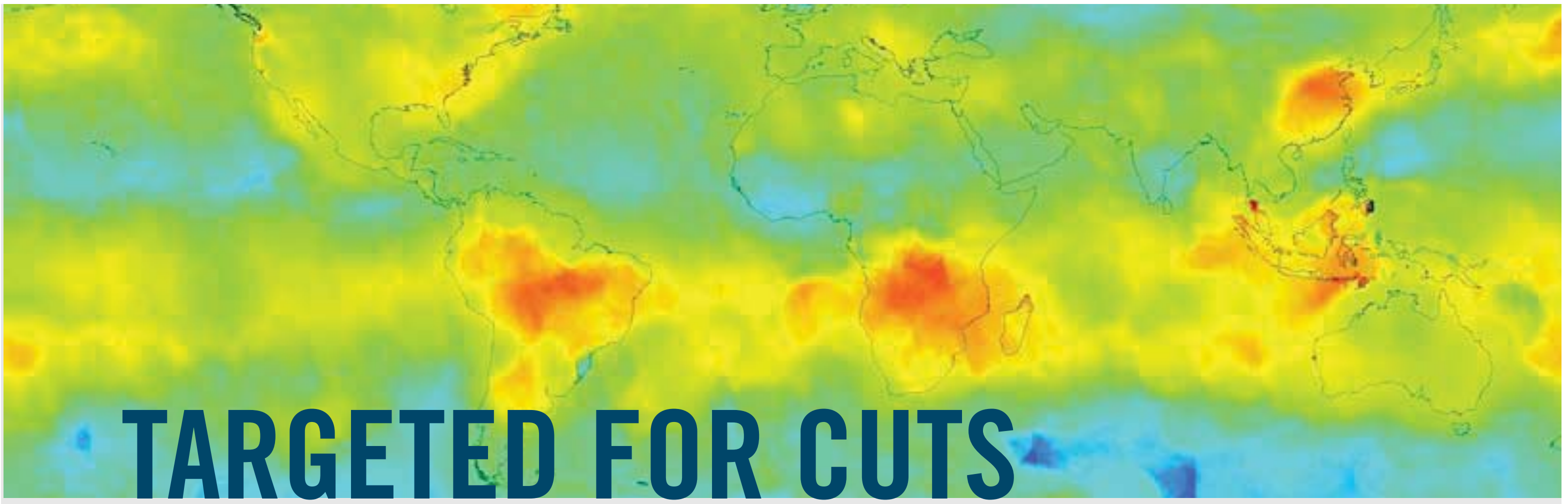
Researchers in NASA's Earth Science Division were discouraged and disheartened by the election of Trump. His views about the climate are at odds with international scientific consensus that warming of the climate since the 1950s is unequivocal and that human activity is extremely likely to be the dominant cause of that warming.

One scientist in the division who asked not to be identified says that after the election, many peers began making plans to retire or resign. So far, though, there has not been a mass exodus from the division. The administration seemed to become distracted

Melt ponds like this one photographed by an instrument on NASA's ER-2 plane will be among the science targets for NASA's ICESat-2, the Ice, Cloud and Land Elevation Satellite-2, which is scheduled for launch in 2018. A photon-counting laser altimeter will bounce laser pulses off Earth's surface to measure the height of ice.


NASA

TARGETED FOR CUTS



NASA/JPL-Caltech

▲ **NASA's Orbiting Carbon Observatory-2,** or OCO-2, collected the data for this map showing global atmospheric carbon dioxide concentrations, which are highest above northern Australia, southern Africa and eastern Brazil. The Orbiting Carbon Observatory-3 is planned to be OCO-2's successor, but funding to continue the program is not included in the Trump administration's 2018 budget request.

Congress has yet to fully weigh in on the Trump administration's proposal to cut NASA funding in 2018 for five satellites or instruments related to climate science.

Climate Absolute Radiance and Refractivity Observatory Pathfinder (CLARREO PF)

This spectrometer would be attached to a pallet on the truss of the International Space Station to measure reflected sunlight over many wavelengths. As a pathfinder, it would demonstrate measurement technologies needed for a possible free-flying satellite or satellites that would gather long-term observations to test and improve climate predictions.

Management: NASA's Langley Research Center, Virginia

Deep Space Climate Observatory (DSCOVR)

The budget proposal would block data from two NASA instruments on this NOAA solar-wind satellite positioned 1.5 kilometers from Earth:

- NASA would no longer post daily images of Earth online from EPIC, the Earth Polychromatic Imaging Camera, an instrument first proposed by Al Gore when he was vice president. Funds for acquisition and processing of the images would be cut.

  Management: NASA's Goddard Space Flight Center, Maryland

- Ends funds for NASA analysis of data from NISTAR, the National Institute of Standards and Technology Advanced Radiometer. NISTAR measures Earth's emitted radiation and reflected sunlight, improving climate science modeling and studies of global temperatures.

  Managment: NASA's Goddard Space Flight Center

Orbiting Carbon Observatory-3 (OCO-3)

This near-infrared spectrometer would be attached to a shelf on the International Space Station called the Japanese Equipment Module Exposed Facility. From this perch, it would measure the distribution of carbon dioxide in the atmosphere. OCO-3 is undergoing final prelaunch tests after being assembled from spare parts left over from construction of its free-flying predecessor, OCO-2.

Management: NASA-funded Jet Propulsion Laboratory, California

Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)

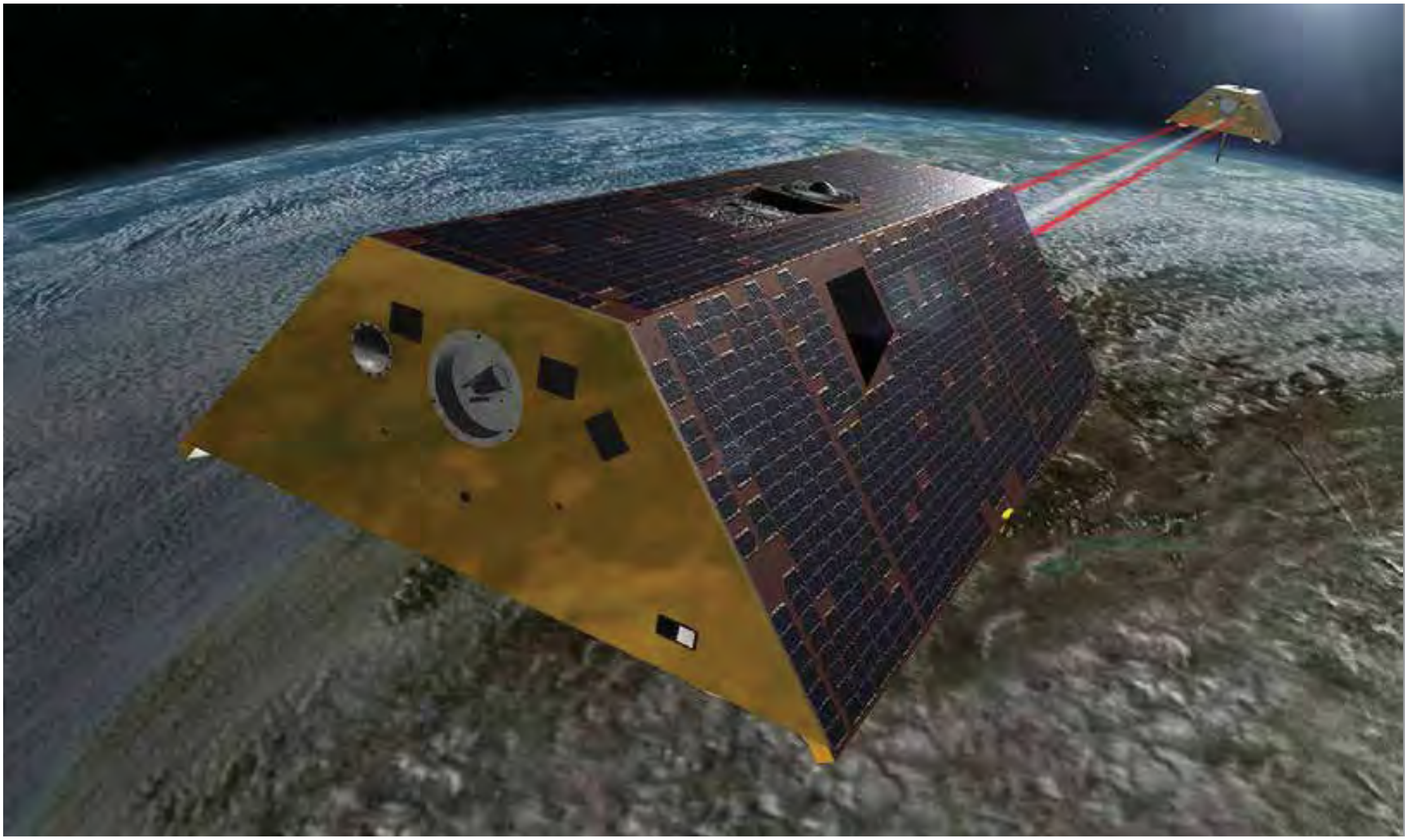
This free-flying satellite would carry a hyperspectral Ocean Color Instrument to chronicle the changing distribution of varieties of phytoplankton, which are vital food sources for ocean fish that can also proliferate into harmful algal blooms. PACE also would gather atmospheric readings related to air quality and the land-ocean carbon cycle, with a goal of better defining the ocean-atmosphere relationship.

Managmement: NASA's Goddard Space Flight Research Center, Maryland

Radiation Budget Instrument (RBI)

A scanning radiometer instrument that would ride on NOAA's Joint Polar Satellite System-2 weather satellite to measure the effects of clouds on Earth's energy balance, factors that impact weather and climate. RBI would continue measurements dating back about 30 years, including those from the CERES (Clouds and the Earth's Radiant Energy Systems) instruments on NASA and NOAA satellites.

Management: NASA's Langley Research Center, Virginia



NASA/JPL-Caltech

▲ **Engineers and** technicians check the fit of ICESat-2's telescope to its sling, before moving it into place on the instrument's optical bench.

▲ **NASA's Gravity Recovery and Climate Experiment Follow-On** would consist of two satellites flown in tandem to document the changing mass of features including ice sheets, glaciers and aquifers. Just as in the first GRACE mission, the tandem will pass radio waves between each other to measure the distance between the pair, which varies with variations in the pull of gravity. GRACE FO also would test a laser ranging system developed in collaboration with the German Aerospace Center, DLR, for even more accurate measurements.

by other issues, including health care and tax legislation. The Earth Science staff started to believe that the White House might not accept an idea that worried them the most: Cutting the $1.9 billion division from NASA and leaving Earth studies entirely to NOAA, and then not funding NOAA to continue the work that NASA was doing.

The fear sprang from an op-ed in Space News written a few weeks before the election by Trump policy advisers Robert Walker, a former congressman from Pennsylvania who once chaired the House Science Committee, and economist Peter Navarro, a former University of California-Irvine professor. They said NASA should focus on "deep space activities rather than Earth-centric work that is better handled by other agencies."

Today, the Earth Science Division remains in place, and the Trump administration's nominee as NASA administrator, Rep. Jim Bridenstine, R-Okla., has shown no appetite for dismantling it. Just the opposite, in fact. In written answers to lawmakers after his Nov. 1 confirmation hearing, Bridenstine said that if he is confirmed, "the world class experts in NASA's Earth Sciences Division will continue contributing to important reports" such as the latest "Climate Change Special Report" from the U.S.

Global Change Research Program. That report says "human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century."

Given the tone of Trump's tweets about climate science, Bridenstine also was pressed during his confirmation hearing about possible reprisals against NASA researchers. "Without question, I will not punish them," he said.

When I asked NASA's media office about the future of the Earth Science Division, I received a prepared statement: "NASA remains committed to studying our home planet and the universe, but we are reshaping our focus within the resources available to us."

As for those resources, the budget ax has fallen, but not as deeply as some researchers feared. The administration's proposal for 2018 would cut five of the division's 18 space projects. Gone would be the Orbiting Carbon Observatory-3, for instance, an instrument that would be attached to the exterior of the International Space Station. In dollars, the division's budget would be trimmed to $1.75 billion compared to the 2017 budget of $1.93 billion.

When I asked a White House spokesman about the administration's policy on climate change research, he referred me to an August 2017 memo by Michael Kratsios, the U.S. deputy chief technology officer, and Mick Mulvaney, the director of the Office of Management and Budget. The memo does not mention climate research. The closest would be a reference to "American Energy Dominance" as a priority.

Semantic cleansing

So, with some climate projects pegged for cancellation and the administration's overall policy at best uncertain, some researchers are defending the semantic cleansing. Their goal is not so much to sneak under the White House radar as to avoid any wording that could make a project harder to sell or protect in Congress, which they consider their last line of defense.

Changing some words assures "that some 22-year-old intern can't go searching through and pull out everything that says 'climate.' That's kind of the level of what people are doing now. That's what they're preventing against: Some Congressman waving your project around, calling it the stupidest thing that's ever been funded," said one researcher who works with NASA and asked not to be named.

The trend is not limited to the Earth Science Division. Technology in the Aeronautics Research Mission Directorate that was once billed as reducing carbon dioxide as a greenhouse gas is now emphasized as increasing efficiency and American economic competitiveness. When NASA's legislative liaisons meet with members of Congress, they avoid mention of climate change and place greater emphasis on analyses showing the economic benefits for U.S. business interests.

The goal of relabeling is to blend in. "If it says 'frequency of weather distribution' instead of 'climate' in the abstract, it doesn't bother me that much," says the climate researcher who works with NASA.

And if that strategy doesn't work, NASA over the decades has distributed research and funding for its projects across congressional districts. For example, NASA's proposed ICESat-2 satellite, still planned for launch in 2018 to measure sea ice and Earth's vegetation, had its ground system built in Dulles, Virginia, its spacecraft built in Gilbert, Arizona, and its space launch provider based in Decatur, Alabama. Cutting funding across the board for the Earth Science Division would draw the ire of congressional members, NASA researchers believe.

"NASA has been very good about that; they make sure that the very expensive satellites aren't just built in one state," one climate scientist says.

Is the strategy succeeding at protecting projects? The results are mixed. The Trump administration has brought "an unprecedented set of changes," Boykoff says. Past presidential administrations have recognized "a common set of goals of environmental stewardship, of commitment to science, of commitment to discovery. This new administration has really forced a reprioritization. A number of these science and environmental themes were not partisan as much as they are today." ★

NASA

SKY TAXIS

HOW TO MAKE THEM REALITY

▲ **NASA hired** consultants to study how the agency could enhance its support for the urban air mobility industry and how these aircraft might fit into society.

It sounds futuristic: You wake up late, open your phone and request an aircraft that will pick you up at a nearby landing site and take you to your job downtown. The aircraft notably lacks a human at the controls. Is this scenario possible? Tom Risen spoke to the pioneers who aim to make it so.

BY TOM RISEN | TOMR@AIAA.ORG

Piloting a modified Mooney M-20K plane at 275 kph has made it easy for Jon Rimanelli to travel to other cities, sometimes three times a week, to meet with clients for Nextronix, the electronics manufacturing firm he owns in the Detroit area. Seeing commuters stuck in the gridlock below gave Rimanelli a business idea. He contacted NASA to learn what he could about research toward personal air mobility services.

That was in 2010. Within a year, Rimanelli and a small team of experts were pitching local investors with their plan to put Detroit's automobile-focused industrial base to work mass producing small aircraft that would fan out to landing sites near neighborhoods and ferry commuters to work.

How did things go? "There was zero interest," Rimanelli recalls.

What a difference six years make. Inspired by consumer drones and Uber's 2016 announcement that it aims to transport passengers in self-piloting aircraft, a cast of competing startups and established players are in discussion with NASA and the FAA about how to shepherd this proposed new class of aircraft into service. Hurdles abound, from social acceptance to safety certifications.

If things go as designers hope, commuters of the future will be whisked safely and affordably over highways and railways, likely in propeller-driven, electric-powered aircraft steered by autonomous software.

Unlike the situation with drones, designers are not starting largely from scratch. "The interest in drones has certainly made people realize this is possible," says Rimanelli, who last year founded AirSpaceX, a 10-person air mobility company near Detroit.

Aurora Flight Sciences

▲ **Aurora is developing its electric vertical takeoff** and landing aircraft in a partnership with Uber. Here the unmanned subscale version makes its first test flight, in April.

Spinning off from drones

Rimanelli's conceptual vehicle, a tilt-wing propeller aircraft called MOBi, must vie against at least 12 other designs in the nascent market, according to a list of new vertical flight concepts assembled by the American Helicopter Society. One is Vahana, a tandem tilt-wing full-scale demonstrator made by Airbus' Silicon Valley arm, A^3 [pronounced "A cubed"]. The company plans to fly the aircraft at its site in Pendleton, Oregon, in 2018. Then there is the eight-propeller aircraft conceived by Uber's partner, Aurora Flight Sciences, now a Boeing subsidiary. Aurora flew a subscale version of the craft, which has not yet been named, in April at an airfield in California.

These and other designs capitalize on electric power, propeller technologies and software pioneered for consumer drones. Each would achieve the transition between vertical and horizontal flight by different methods, but all are eVTOLs, short for electric vertical takeoff and landing aircraft. Just as with many drones, multiple propellers would be driven with electricity from batteries.

It is early days for those pioneering this new breed of craft. While NASA has become more involved with drone makers in recent years, this time the agency wants to be proactive. In October, NASA hired the consulting firms Booz Allen Hamilton and Crown Consulting to complete a one-year study that will suggest how the agency could enhance its support for this new industry and how these aircraft might fit into society. The results of the study will be coordinated among different parts of NASA, says John Cavolowsky, the director of NASA's Transformative Aeronautics Concepts Program.

NASA already sponsors some research specifically on the topic, and work in related areas, such as drone air traffic management and rotorcraft noise testing, will also benefit the personal transportation industry, says Cavolowsky.

Social acceptance

Judging by interviews with Cavolowsky and others, the biggest questions facing the industry revolve around the interface of the technology with the prospective human customers. "We think we are getting much better at planning legal and regulatory approaches to urban air mobility," Cavolowsky says. "Social acceptance is really very different," he adds. "Just because there is a technology that can help doesn't necessarily mean there is a market there to accept it."

Would a passenger or passengers climb aboard an aircraft with no human at the controls? "Going to a fully automated passenger service for the uninitiated public is a pretty steep ask" in the short term, says John Hansman, a professor of aeronautics and astronautics at the Massachusetts Institute of Technology. Hansman predicts that during the span of years it will take the FAA to approve these aircraft, consumers will gradually adjust to the idea of self-flying taxis, because they will see publicity about the results of safety tests.

Hansman's team at MIT is doing research for NASA on operational barriers for urban air mobility, including how to update air traffic control so fleets of air taxis can safely fly over the same city at once.

"If a regulator were to approve autonomous passenger aircraft you could probably find someone who would be willing to fly in it," he predicts. "At some point it will become socially acceptable because people will get used to automated cars

▼ **The Vahana** test aircraft in Airbus' A^3 facility in Santa Clara, Calif.

Airbus

and automated military aircraft."

Giving consumers time to adjust appears to be a key factor, according to a survey published in July by New York-based market research firm YouGov. Two-thirds of Americans surveyed had not heard of unmanned eVTOLs, which the survey called "passenger drones," and only 5 percent said they would feel safe flying in one. Two-thirds of respondents said they would expect FAA safety certification and precautions including parachutes, but 62 percent also said they would consider buying these unmanned passenger drones in the future.

The technologists I interviewed view autonomy as essential for making maximum use of the limited space aboard their proposed craft, which are typically about the size of a small helicopter. That said, the FAA told me that for the "urban transport market" it has received one application from a company for a type certificate, the document declaring a design's airworthiness, and that application was for a "piloted VTOL airplane." The FAA declined to name the company under its longstanding policy, but said the company has since shifted its focus to an unmanned aircraft.

As prominently as autonomy features in planning, it sometimes comes with caveats. Aurora, on its website, says its aircraft will fly initially with a safety pilot, but is designed for "fully autonomous operations." A^3, on its website, says it plans to employ "full automation and sense and avoid technology" so that many "air taxis" can be managed in the sky at one time.

Another challenge for social acceptance could be privacy, once fleets of eVTOLs are flying routinely overhead in cities and suburban areas, says NASA's Cavolowsky.

These social acceptance considerations partly drive the aircraft designs. Not much can be done if passengers demand a human at the controls, but the noise of combustion engines and a helicopter rotor can be avoided by relying on electric power and multiple, small propellers.

This "distributed electric propulsion is a game changer," says Diana Siegel, program manager of Aurora's personal transportation eVTOL, which might someday be flown by the Uber Air service.

In addition to creating a quieter aircraft, "it means our design freedom is much larger."

Those designs must be matched to the needs of the market, though. For military applications, noise might be less of a concern and payload capacity a greater one. Siegel points to Aurora's XV-24 Lightning Strike aircraft funded by DARPA and the U.S. Air Force. It takes off with ducted fans embedded in its tilt wing and canard. These ducted fans are hybrid electric, meaning their electric motors are powered by generators, which are in turn powered by a gas-turbine engine. The company built and flight-tested an unmanned, subscale, lithium battery-powered version in March at Webster Outlying Field in Maryland.

Siegel says an electrical design with multiple small propellers is better suited for air taxis than the ducted fans that are more powerful but heavy.

"IF A REGULATOR WERE TO APPROVE AUTONOMOUS PASSENGER AIRCRAFT YOU COULD PROBABLY FIND SOMEONE WHO WOULD BE WILLING TO FLY IN IT."

—John Hansman, professor of aeronautics and astronautics at the Massachusetts Institute of Technology

Fresh optimism

The advent of distributed electric propulsion, which for some applications could replace mechanical drive shafts, hydraulics and fuel lines, is welcomed by one prominent member of the rotorcraft industry.

"The history of aviation is littered with failed vertical takeoff craft," says Mike Hirschberg, whose engineering background in vertical flight propulsion includes working in the U.S. Defense Department's Joint Strike Fighter (F-35) Program Office and on several DARPA programs. "Many past designs for vertical takeoff craft failed because they relied on propellers turned by mechanically complex transmissions," he says.

What avenues will these companies take to win FAA certification for their innovations? Hirschberg says there are two possible pathways. One would be Part 23 of the FAA's Federal Aviation Regulations for small planes, which was revised in 2016 to create a less prescriptive and, it was hoped, less expensive process for certifying newly designed planes. Another would be Part 27, the regulations for small helicopters.

When he considers the regulatory and technology groundwork laid so far, Rimanelli ventures a bold prediction. Picture a chart showing demand: "Once we prove these aircraft to be safe and reliable, we will see hockey stick-rapid growth," he says. ★

Modernizing MRO

Companies specializing in maintenance, repair and overhaul of commercial planes are beginning to face competition from the companies that built the planes. How can MRO specialty providers compete? Industry executive Tom Hennessey says it all starts by embracing the concept of the digital thread.

By Tom Hennessey

Lufthansa

The number of commercial airliners in the world is expected to grow annually for the next 20 years. The maintenance, repair and overhaul market is projected to grow, too, specifically at an annual rate of 5.2 percent between 2022 and 2027. The global fleet will be refreshed over the next 10 years, with half of the 20,000 new planes delivered replacing in-service aircraft; the passenger fleet will net more than 10,000 new planes by 2027. Due to regional differences in air travel, fleets in China and India will continue to age as aircraft are kept in service to meet outsized demand in Asia. In fact, aviation MRO in Asia has boomed in recent years, and the region is under constant pressure to keep up with infrastructure needs. The story is different in developing areas like Africa and the Middle East, where fleets are newer overall. The "2017-2027 Fleet & MRO Forecast" by the Oliver Wyman firm details these technology, travel, and fleet trends and their impacts on the MRO market.

With outsourced maintenance representing more than 60 percent of direct maintenance costs, competition among upstart and established MRO players has intensified. To keep up with global capacity demand and stay competitive, all MROs will have to make leaps forward in efficiency.

Fleet age, travel demand, outsourcing trends and global economic pressures will shape the MRO market, with regional differences and new aircraft technologies disrupting business as usual. Traditionally, MRO businesses have not needed to invest heavily in R&D and corporate strategy. To rise to the challenge of more dynamic, globalized markets, MROs must quickly develop internal abilities to recognize, assess and prepare for change. Incorporating analytic and automation technologies is key to modernizing MRO operations and harnessing the power of enterprise-wide digital integration.

For MRO companies to come up to speed with smart manufacturing and the digital transformation of the value chain, they will have to make significant capital investments. Given time and resource constraints, they must choose wisely. Extending the concept of the digital thread throughout MRO operations will help shape investment and forge powerful links with aircraft manufacturers, airlines and the supply chain.

A digital thread links all model data, product structure data, metadata, effectual data, process definition data, including supporting equipment and tools, into a contiguous definition of all value-added decisions. Choices must be made about the definition of a product, its configuration, manufacturing and repair processes, logistics, and operational support. This thread provides a single reference point for design, engineering, manufacturing and service to ensure that those in charge of these areas act in concert.

Challenges to reaching altitude

Many years without disruption means many established MRO firms do not have a strong innovation foundation. Efficiency will require embracing automation technologies, analytics and 3-D modeling. That will mean bringing in new leaders in some cases and jumpstarting R&D, workforce training and infrastructure investment. That's a tall order, and will demand a new level of executive focus.

The most compelling force in MRO innovation

◀ **Aviation maintenance,** repair and overhaul companies can expect their market to grow in the next 10 years, but they must incorporate analytic and automation technologies to keep up, the author says.

KLM

▲ **A Boeing 777** undergoes a major overhaul at KLM's hangar at Amsterdam Airport Schiphol in the Netherlands.

is the new generation of aircraft, defined as those built after 2000. New manufacturing methods and materials (including carbon fiber composites, highly engineered titanium, and aluminum alloys) obviously require MRO retooling. On top of that, they change everything from recommended maintenance schedules to aircraft longevity. As more new aircraft come online over the next 10 years, these changes will continue to impact the MRO industry, perhaps in ways not yet identified. Advanced systems on new planes include sophisticated avionics and thousands of sensors designed to feed aircraft health monitoring systems, which promise to transform predictive maintenance and incident prevention. This specialized internet of things, or IoT, for aircraft produces endless amounts of operational data.

MROs must gear up to fully leverage and integrate these data streams along with others from design to engineering to production. This is the essence of the digital thread. Aircraft manufacturers are already adopting the digital thread concept, which means MROs face new competition from them. By applying the digital thread, manufacturers are beginning to "servitize" various components of their planes. Simply put, manufacturers are capturing MRO business for themselves. Building up data management and analysis capabilities and closely integrating them with inspection, maintenance, and repair systems will help fend off these incursions. On the flip side, establishing alliances with manufacturers could prove to be a fruitful new business model for many MRO outfits; mature capabilities in advanced analytics and machine learning technology will be a precondition.

New-era MRO

The digital thread is in essence a communication framework that enables connected data flow throughout the asset lifecycle and across traditionally segmented functions (design, engineering, production, maintenance). This all-encompassing framework ensures an integrated, authoritative, up-to-the-minute view of the aircraft's data that can be accessed at any point along the way. A related concept, the digital twin, refers to a digital model of a specific airplane identified by tail number. This twin includes specifications and descriptions of its geometry, materials, components and behavior. More importantly, it includes the as-built and operational data unique to that specific physical asset.

Incorporating analytic and automation technologies is key to modernizing MRO operations and harnessing the power of enterprise-wide digital integration.

The digital twin includes engineering changes made during production and deviations from original design, as well as inspection, operation and MRO data. Building the integrated infrastructure and capability to leverage these comprehensive digital records will be a game changer for MRO.

In the years ahead, the interaction between human expertise and machine learning or artificial intelligence has the potential to vastly improve the functionality, safety and sustainability of the global fleet. Progressing toward this AI vision depends in large part on an enterprise's ability to collate, store, manage and analyze data collected by sensors in industrial equipment, aircraft, and operational and business management systems. The predictive and prescriptive analytics enabled by comprehensive and nuanced use of digital thread data and models could radically improve MRO planning and reduce aircraft downtime. Today, most maintenance activities are planned based on a combination of elapsed time and asset usage frequency, which leads to both over- and under-servicing of assets.

Sophisticated integration of data and systems is fundamental to the successful implementation of several core technologies that are already changing the way MRO work is performed: unmanned air vehicles for autonomous, intelligent inspections; additive manufacturing of spare parts on demand; and augmented reality and natural language interfaces for advanced guidance of inspections and repairs. It's not difficult to imagine how these innovations, used in concert and underpinned by the digital thread framework, could result in step changes in productivity, accuracy and efficiency. They will certainly prove to be a key differentiator in the increasingly competitive MRO landscape, with wide ranging repercussions for the entire value chain. A continuous, data-driven feedback loop from design through MRO will help optimize every stage of aviation manufacturing.

Flight plan

MROs cannot afford to taxi around the runway. The scope, growth and dynamism of the market indicate that the time for acceleration is imminent. Each innovation (not to mention any related integration projects) will require assessment, experimentation, iterative implementation and skill development. There is no better time than the present to head down that runway, and many leading MRO hangars are well on their way.

The first step is to create and rejuvenate internal organizations devoted to R&D, infrastructure assessment and strategic planning. Executives have to lead with a clear focus on digital transformation and a road map for all the change it engenders, including cultural and organizational change. The retraining and hiring required to cultivate an appropriately skilled workforce will be disruptive. Widespread technical skills shortages, especially in data science and cybersecurity, will be an ongoing challenge. First movers, as always, will have an advantage.

The next step is to focus on completing connectivity across the enterprise. Building up foundational data management and analytics capabilities is essential. Identifying and eliminating outdated functional silos and barriers between departments will unleash the collaborative power necessary to undertake enterprise-wide digital initiatives and pinpoint disconnects that will require extra attention. Implementing manufacturing management software platforms that drive integrated processes and enable the digital thread is a key preparatory step for bringing MRO operations into the smart manufacturing fold.

The change of pace over the next 10 years will be relentless, and the 10 years after that hold challenges we can't yet imagine. From global economic disruptions to the surge of travel demand in developing nations, there will be plenty of turbulence. Intelligent application of the powerful innovations converging to drive the transformation of complex manufacturing will boost MRO's flight into higher levels of global competition, fleet sustainability and enterprise resilience. ★

Tom Hennessey
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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!
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BRAVEN LEUNG, pursuing doctoral studies in Aerospace Engineering at the Georgia Institute of Technology
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AIAA
Shaping the Future of Aerospace

AIAA Bulletin

DIRECTORY

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

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

Calendar

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			
6–7 Jan	5th International Workshop on High-Order CFD Methods	Kissimmee, FL	
6–7 Jan	Future CFD Technologies Workshop: Bridging Mathematics and Computer Science for Advanced Aerospace Simulation Tools	Kissimmee, FL	
6–7 Jan	Aircraft and Rotorcraft System Identification Engineering Methods for Manned and UAV Applications with Hands-On Training Using CIFER® Course	Kissimmee, FL	
6–7 Jan	Large Eddy Simulation of Turbulent Combustion: Theory, Modeling and Practice Course	Kissimmee, FL	
6–7 Jan	Introduction to Software Engineering Course	Kissimmee, FL	
6–7 Jan	Stochastic Mechanics of Materials and Structures Course	Kissimmee, FL	
6–7 Jan	Missile Guidance Course	Kissimmee, FL	
7 Jan	Aeroelastic Wind Tunnel Testing and Aeroelasticity Considerations for Non-Aeroelastic Tests Course	Kissimmee, FL	
7 Jan	Space Standards and Architectures Workshop	Kissimmee, FL	
8 Jan	2018 Associate Fellows Recognition Ceremony and Dinner	Kissimmee, FL	
8–12 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – AIAA/AHS Adaptive Structures Conference – AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – AIAA Non-Deterministic Approaches Conference – AAS/AIAA Space Flight Mechanics Meeting – AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – AIAA Spacecraft Structures Conference – Wind Energy Symposium	Kissimmee, FL	12 Jun 17
22–25 Jan †	64th Annual Reliability & Maintainability Symposium (RAMS)	Reno, NV (Contact: www.rams.org)	
1 Feb	DirectTech Webinar—Introduction to Computational Aerodynamics	Virtual (aiaa.org/onlinelearning)	
22 Feb	DirectTech Webinar—UAV Conceptual Design & Testing Using Computer Simulations	Virtual (aiaa.org/onlinelearning)	
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)	
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)	
8–10 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum) Featuring: – AIAA Missile Sciences Conference – AIAA National Forum on Weapon System Effectivenss – AIAA Strategic and Tactical Missile Systems Conference	Laurel, MD	30 Nov 17
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

†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
4–8 Jun†	DATT (Defense & Aerospace Test & Telemetry) Summit	Orlando, FL (www.dattsummit.com)	
25–29 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – AIAA/CEAS Aeroacoustics Conference – AIAA Aerodynamic Measurement Technology and Ground Testing Conference – AIAA Applied Aerodynamics Conference – AIAA Atmospheric Flight Mechanics Conference – AIAA Atmospheric and Space Environments Conference – AIAA Aviation Technology, Integration, and Operations Conference – AIAA Flight Testing Conference – AIAA Flow Control Conference – AIAA Fluid Dynamics Conference – AIAA/ASME Joint Thermophysics and Heat Transfer Conference – AIAA Modeling and Simulation Technologies Conference – AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference – AIAA 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)	
9–11 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – AIAA/SAE/ASEE Joint Propulsion Conference – International Energy Conversion Engineering Conference	Cincinnati, OH	4 Jan 18
12–13 Jul	AIAA/IEEE Electric Aircraft Technologies Symposium	Cincinnati, OH	
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: – AIAA Complex Aerospace Systems Exchange – AIAA 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: – AIAA/AHS Adaptive Structures Conference – AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Dynamics Specialists Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – AIAA Non-Deterministic Approaches Conference – AAS/AIAA Space Flight Mechanics Meeting – AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – AIAA Spacecraft Structures Conference – Wind Energy Symposium	San Diego, CA	
3–5 Apr†	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (Contact: www.eurognc19.polimi.it)	

Around The Institute:
Local Public Policy Activities

AIAA's Public Policy Committee recently reestablished the August is for Aerospace program where we encourage local sections to more actively speak with their elected officials about the Institute's key issues during district work periods, while also engaging those lawmakers in their outreach activities. While Congressional Visits Day (CVD) and August is for Aerospace are two examples of concentrated and coordinated outreach activities, we call on our members and sections to be advocates for aerospace at every opportunity throughout the year. Several sections have taken part in this year's August is for Aerospace program, having held meetings and events that have helped raise awareness about important issues impacting the aerospace community and have helped reinforce AIAA as a reliable resource on these matters. Following are some examples of these efforts.

Twin Cities Section

The AIAA Twin Cities Section hosted a public policy happy hour in July to discuss various policy issues that impact the A&D industry. Participants were encouraged to become more active in public outreach, serving as ambassadors of AIAA and the aerospace and defense community as a whole, while also doing more to engage lawmakers at the federal, state, and local levels in the future. The section intends to make the happy hour a recurring activity.

Utah Section

In late August, the AIAA Utah Section hosted a joint event with the International Council on Systems Engineering's Wasatch Chapter where local civic, academic, industry, and government leaders discussed the importance of recruiting and retaining a skilled aerospace workforce. Guests of honor included Utah State Senator Ann Millner, Weber State University President Charles A. Wight, and Hill Air Force Base Director of Engineering and Technical Management Jay Fiebig. A group of 25 engaged in topics such as how universities could structure their programs to best prepare graduates, how to attract out-of-state talent at the mid-career level, and which specialties were most in demand for the local area. Students and young professionals in attendance mingled with senior leadership to relay their perspectives on how to support future STEM workforce needs.

Savannah Section

Also in August, the AIAA Savannah Section launched an ongoing policy-themed activity titled "Talking Policies." This activity engages the aerospace public policy arena by educating the local aerospace community and other stakeholders on AIAA's annual key issues. Several accomplishments of "Talking Policies" have included:

- A meeting with Congressman Buddy Carter (R-GA).
- Two lunch and learns to a local audience. The first was an overview of the AIAA key issues and the second was an overview of the Next Generation Air Transportation System.
- Conversations with local subject-matter experts involved with aircraft noise and emission control and those that have witnessed certification requirement rewrites, such as Part 23.
- Studying current legislative and policy events published in the AIAA Daily Launch. The intent at some point is to start a local small group that can discuss the events.

1

Greater Huntsville Section

Congressman Mo Brooks (R-AL) spoke with approximately 40 members of the AIAA Greater Huntsville Section during a luncheon on 30 October. The congressman opened with comments on Alabama's leading role in aerospace, specifically highlighting the higher education and job opportunities provided across the state.

Rep. Brooks continued his remarks with great emphasis on the nation's debt. During a moderated Q&A session led by Greater Huntsville Public Policy Director Chris Crumbly, the congressman provided additional commentary on a range of topics, including education, Earth science, the National Space Council, and nuclear propulsion. When asked about the National Space Council and its renewed efforts under the Trump administration, Rep. Brooks said we need a "better marketing effort by everyone involved to sell to the public why space exploration and national advancement is so important." He suggested that this same effort should be applied directly to legislators to convince them to support NASA's budget.

Referring back to the need for a more integrated marketing effort when asked about nuclear propulsion, Rep. Brooks specifically citing the need to educate the public on the role of NASA's Space Launch System once it is operational. He added that our nation needs to branch out and engage other countries, citing a recent visit to India as an example, so the U.S. can share the cost of exploration with like-minded nations.

Tucson Section

On 16 November, the AIAA Tucson Section hosted an event to discuss the most important policy issues facing Southern Arizona's aerospace industry. Though most look toward agriculture and mining as the primary contributors to the Arizona economy, the aerospace and defense sector is responsible for over 52,000 jobs and $3.5 billion in total exports. Over the past several years, the Tucson and Phoenix sections have successfully carried this message to Congress during CVD, but until recently, little effort has been made to engage state representatives. This event was the first of what will be an annual effort to engage with local lawmakers.

Attending the event were members of the Tucson Section and the International Council on Systems Engineering (INCOSE), engineering and public policy students, as well as representatives from Paragon Space Development Corporation, Rincon Research, Physics Materials and Applied Mathematics, Raytheon, and the University of Arizona's Steward Observatory and Lunar and Planetary Laboratory. During the presentation and following discussion, speakers addressed the Institute's key issues and how they pertain to the Southern Arizona aerospace industry. Participants also discussed why AIAA should take the lead in aerospace advocacy, and how critical it is that passionate members join the conversation.

Through this process, it was made clear that there is still significant work to be done delivering this message to state and county officials. Even though the discussion topics and key issue papers were shared with many members of the Arizona House of Representatives, few were prepared to engage in a discussion regarding how they filter down to the local level. For this reason, there will be continued engagement with the local lawmakers to help grow their understanding of the aerospace industry's influence and importance to the state.

2

1 Representative Mo Brooks (R-AL) with AIAA Greater Huntsville Section Officers. 2 Utah Section event attendees.

AIAA's Directed Energy Systems Integration Committee

By Mark Neice & Daniel Miller, AIAA Directed Energy Systems Integration Committee

The Directed Energy Systems Integration Committee provides a cross-organizational U.S. national forum to discuss, exchange, and generate technical issues to promote integration of a High Energy Laser (HEL) on air platforms. The committee, chaired by Daniel Miller (Lockheed Martin) and DJ Wittich (Air Force Research Laboratory), in collaboration with the Directed Energy Professional Society (DEPS), held a series of technical interchange meetings in 2017 focused on HEL capability and transition. Focus area teams have been established in the areas of systems engineering; components; modeling and simulation; and test and evaluation. The teams will coordinate their individual studies around a generic UAV platform in order to identify the top technical challenges associated with HEL/aircraft integration. The committee drafted the HEL platform system requirements, began forming design concepts, and identified baseline components to meet the design requirements. Additional tasks are to determine what modeling tools are already available, any capability gaps in said models, and how those models can be used to establish test parameters for the as-designed system. The three-year objective of the committee is to establish the necessary steps to define the system parameters, go through the project design process, and document those efforts for a team to demonstrate a laser capability from an airborne platform.

The committee highlights two major developments in 2017 relevant to maturing directed energy for airborne platforms.

1. The U.S. Air Force awarded a $26 million contract to develop a high-powered laser source as part of the Air Force Research Laboratory's podded electric laser concept for fifth- and sixth-generation fighter jets under the Self-Protect High Energy Laser Demonstrator (SHiELD) program. This represents a milestone in developing a fiber high energy laser source tailored to a rugged fighter environment.

2. The U.S. Air Force Strategic Development, Planning, and Experimentation office launched a demonstration using directed energy technology to counter unmanned aircraft systems following the signing of the Air Force Directed Energy Weapon Flight Plan in May 2017. This testing event demonstrates the utility of DE technology to address relevant threats to the warfighter.

For more information on this committee, contact Daniel Miller, Chair, daniel.n.miller@lmco.com.

Courtesy of AFRL

Reuben H. Fleet Scholarships Awarded by the San Diego Section

AIAA San Diego Section awarded the Reuben H. Fleet Scholarships at the AIAA San Diego Honors and Awards Banquet on 4 May 2017. Since 1983, 190 students have received the scholarship, which is made possible by the Reuben H. Fleet Foundation at The San Diego Foundation.

The 2017 Reuben H. Fleet Scholarship recipients (left to right): Alex Fleet (grandson of Reuben H. Fleet), Yoon Kim Jae (La Jolla High School), Paulina Diaz-Montiel (San Diego State University [SDSU]), Benjamin Martins (University of California, San Diego), Bashar Qashat (SDSU), Michael Stromecki (SDSU), Greg Marien (Scholarship Coordinator), Enrico Santarpia (SDSU; not pictured).

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AIAA Region VII-Australia Student Conference

The AIAA Region VII-Australia Student Conference took place 23–24 November 2017, at RMIT University in Melbourne, Australia. The winners were:

1st place: Rhiannon Kirby – Monash University (Tomographic Background-Oriented Schlieren for Three-dimensional Density Field Reconstruction in Asymmetric Shock-containing Jets)

2nd place: Joshua Grant – University of South Wales (An Acoustic Travelling Wave System for High-Cycle Fatigue Analysis)

3rd place: Jake Dell-O'Sullivan – University of New South Wales (UAV Emergency Forced Landing, Utilising Stored Geographic Data Towards a 3-Phase Approach)

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

AIAA Student Branches, 2017–2018

AIAA has over 215 Student Branches around the world. Each branch has a Student Branch chair elected each year, and a faculty advisor who serves long term to support their branch's activities. Like the professional Sections, the Student Branches invite speakers, take field trips, promote career development, and participate in projects that introduce students to membership with AIAA and their professional futures. The branches, and their officers in particular, organize their activities in addition to their full-time schoolwork, and their advisors clearly care deeply about their students' futures. Please join us in acknowledging the time and effort that all of them take to make their programs successful.

FA = Faculty Advisor; SBC = Student Branch Chair

REGION I

Boston University, FA, Sheryl Grace (New England Section)

Boston University, SBC, Benjamin Bax Michalakakis (New England Section)

Brown University, FA, TBD (New England Section)

Brown University, SBC, TBD (New England Section)

Carnegie Mellon University, FA, Satbir Singh (Mid-Atlantic Section)

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

Catholic University of America, FA, TBD (National Capital Section)

Catholic University of America, SBC, TBD (National Capital Section)

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

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

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

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

Columbia University, FA, Bob Stark (Long Island Section),

Columbia University, SBC, Benjamin Barton (Long Island Section)

Cornell University, FA, Dmitry Savransky (Niagara Frontier Section)

Cornell University, SBC, Akshay Kadhiresan (Niagara Frontier Section)

Cornell University, SBC, Connor Dempsey (Niagara Frontier Section)

Dartmouth College, FA, Simon Shepherd (New England Section)

Dartmouth College, SBC, TBD (New England Section)

Drexel University, FA, Ajmal Yousuff (Greater Philadelphia Section)

Drexel University, SBC, TBD (Greater Philadelphia Section)

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

George Washington University, SBC, Ellise Damschroder (National Capital Section)

Hofstra University, FA, John Vaccaro (Long Island Section)

Hofstra University, SBC, TBD (Long Island Section)

Howard University, FA, Nadir Yilmaz (National Capital Section)

Howard University, SBC, TBD (National Capital Section)

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

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

Lehigh University, FA, Terry Hart (Greater Philadelphia Section)

Lehigh University, SBC, TBD (Greater Philadelphia Section)

Manhattan College, FA, John Leylegian (Long Island Section)

Manhattan College, SBC, Alexander Kavalchuk (Long Island Section)

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

Massachusetts Institute of Technology, SBC, Martina Stadler (New England Section)

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

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

New Jersey Institute of Technology, FA, Edward Dreizin (Northern New Jersey Section)

New Jersey Institute of Technology, SBC, TBD (Northern New Jersey Section)

New York Institute of Technology, FA, ZhiYun Lu (Long Island Section)

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

Northeastern University, FA, Andrew Gouldstone (New England Section)

Northeastern University, SBC, Harry Brodsky (New England Section)

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

Old Dominion University, SBC, TBD (Hampton Roads Section)

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

Pennsylvania State University, SBC, Veerandra Chakkaravarthy (Central Pennsylvania Section)

Polytechnic Inst. of Brooklyn, FA, TBD (Long Island Section)

Polytechnic Inst. of Brooklyn, SBC, TBD (Long Island Section)

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

Princeton University, SBC, Josh Freeman (Northern New Jersey Section)

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

Rensselaer Polytechnic Institute, SBC, Michael McKay (Northeastern New York Section)

Rochester Institute of Technology, FA, Agamemnon Crassidis and Mark Olles (Niagara Frontier Section)

Rochester Institute of Technology, SBC, Cayla Denning (Niagara Frontier Section)

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

Rowan University, SBC, Tyler Harlow (Southern New Jersey Section)

Rutgers University, FA, Francisco Diez (Northern New Jersey Section),

Rutgers University, SBC, Ravi Bauer (Northern New Jersey Section)

Southern New Hampshire University, FA, Xinyun Guo (New England Section),

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

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

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

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

Stevens Institute of Technology, FA, Arun Aruljothi (Northern New Jersey Section)

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

Stony Brook University, SBC, Matthew Lee (Long Island Section)

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

Syracuse University, SBC, Jessica Szela (Northeastern New York Section),

United States Military Academy, FA Drew Curriston (Long Island Section)

United States Military Academy, SBC, TBD (Long Island Section)

United States Naval Academy, FA, Scott Drayton (Mid-Atlantic Section)

United States Naval Academy, SBC, James Madigan (Mid-Atlantic Section)

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

University of Connecticut, SBC, Ryan Hyatt (Connecticut Section)

University of Delaware, FA, TBD (Delaware Section)

University of Delaware, SBC, TBD (Delaware Section)

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

University of Maine, SBC, John Seekins (New England Section)

University of Maryland, FA, Christine Hartzell (National Capital Section)

University of Maryland, SBC, Christopher Bernard (National Capital Section)

University of Massachusetts - Lowell, FA, David Willis (New England Section)

University of Massachusetts - Lowell, SBC, Samuel Johnson (New England Section)

University of Pittsburgh, FA, Peyman Givi (Mid-Atlantic Section)

University of Pittsburgh, SBC, Paul Gatto, Mid-Atlantic Section)

University of Vermont, FA, Darren Hitt (New England Section)

University of Vermont, SBC, Duncan Hacker (New England Section)

University of Virginia, FA, Christopher Goyne (National Capital Section)

University of Virginia, SBC, Gabriel Norris (National Capital Section)

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

Vaughn College of Aeronautics and Technology, SBC, Utsav Shah (Long Island Section)

Villanova University, FA, Sergey Nersesov (Greater Philadelphia Section),

Villanova University, SBC, John Coppa (Greater Philadelphia Section)

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

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

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

Wentworth Institute of Technology, SBC, Bryan Genest (New England Section)

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

West Virginia University, SBC, Hunter Dalton (Mid-Atlantic Section)

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

Worcester Polytechnic Institute, SBC, Matias Campos (New England Section)

REGION II

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

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

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

Athens State University, SBC, TBD (Greater Huntsville Section)

Auburn University, FA, Dudley Nichols (Greater Huntsville Section)

Auburn University, SBC, Rehman Qureshi (Greater Huntsville Section)

Duke University, FA, Kenneth Hall (Carolina Section)

Duke University, SBC, Joshua Furth (Carolina Section)

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

East Carolina University, SBC, Jameson Morris (Carolina Section)

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

Embry-Riddle Aeronautical University-Daytona Beach, SBC, Nathan Crane (Central Florida Section)

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

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

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

Florida Institute of Technology, SBC, Francisco Bayon (Cape Canaveral Section)

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

Florida International University, SBC, Christopher Lara (Palm Beach Section)

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

Florida State University, SBC, Daniel Bradley (Northwest Florida Section)

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

Georgia Institute of Technology, SBC, Dawn Andrews (Atlanta Section)

Kennesaw State University, FA, Adeel Khalid (Atlanta Section)

Kennesaw State University, SBC, Kamyar Karimian (Atlanta Section)

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

Louisiana State University, SBC, Jake Roblez (Greater New Orleans Section)

Mississippi State University, FA, Gregory Olsen (Greater Huntsville Section)

Mississippi State University, SBC, Rebecca Oppenheim (Greater Huntsville Section)

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

North Carolina State University, SBC, Alex Chen (Carolina Section)

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

Polytechnic University of Puerto Rico, SBC, Karelia Silvestrini (No Section Assigned)

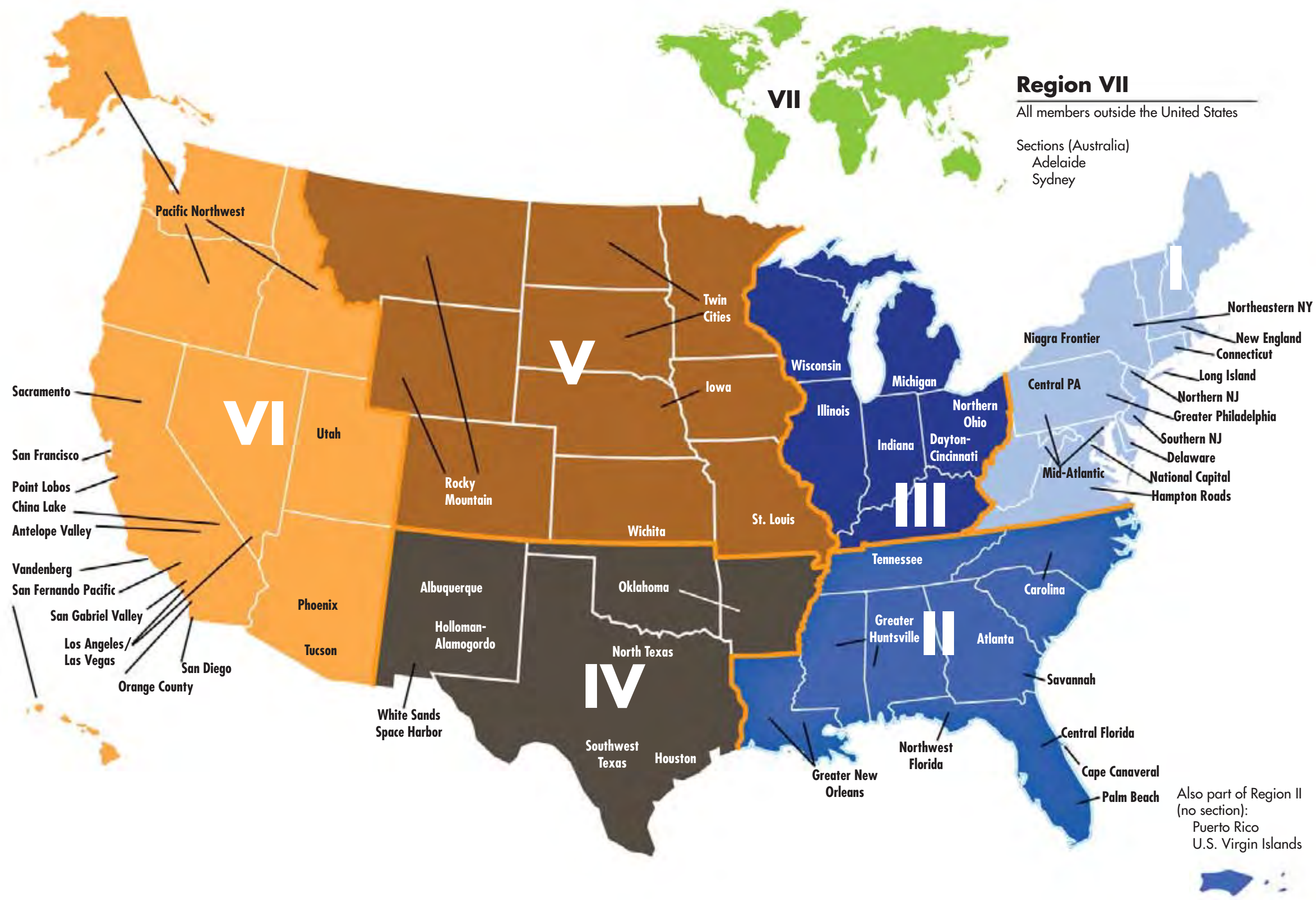
Tuskegee University, FA, Mohammad Khan (Greater Huntsville Section)

Tuskegee University, SBC, TBD (Greater Huntsville Section)

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

University of Alabama-Huntsville, SBC, Ashley Scharfenberg (Greater Huntsville Section)

AIAA SECTIONS AND GEOGRAPHICAL REGIONS



University of Alabama-Tuscaloosa, FA, James Hubner (Greater Huntsville Section)

University of Alabama-Tuscaloosa, SBC, William Sumner (Greater Huntsville Section)

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

University of Central Florida, SBC, Rayon Harris (Central Florida Section)

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

University of Florida, SBC, Tanya Martin (Central Florida Section)

University of Memphis, FA, Jeff Marchetta (Tennessee Section)

University of Memphis, SBC, Ken Mitchell (Tennessee Section)

University of Miami, FA, Ryan Karkkainen (Palm Beach Section)

University of Miami, SBC, TBD (Palm Beach Section)

University of Mississippi, FA, Nathan Murray (Greater Huntsville Section)

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

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

University of Puerto Rico, SBC, Karina Lopez (No Section Assigned)

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

University of South Alabama, SBC, Matthew Posey (Greater Huntsville Section)

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

University of South Carolina, SBC, Rachael Rudd (Carolina Section)

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

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

University of Tennessee, FA, Hans Desmidt (Tennessee Section)

University of Tennessee, SBC, TBD (Tennessee Section)

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

University of Tennessee Space Institute, SBC, TBD (Tennessee Section)

Vanderbilt University, FA, Amrutur Anilkumar (Tennessee Section)

Vanderbilt University, SBC, Christopher Romanoski (Tennessee Section)

REGION III

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

Air Force Institute of Technology, SBC, Brian Bohan (Dayton/Cincinnati Section)

Case Western Reserve University, FA, Joseph Prahl (Northern Ohio Section)

Case Western Reserve University, SBC, TBD (Northern Ohio Section)

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

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

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

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

Indiana University-Purdue University Indianapolis (IUPUI), FA, Mohamed Nalim (Indiana Section)

Indiana University-Purdue University Indianapolis (IUPUI), SBC, Williams Conover (Indiana Section)

Kettering University, FA, TBD (Michigan Section)

Kettering University, SBC, TBD (Michigan Section)

Lawrence Technical University, FA, Andrew Gerhart (Michigan Section)

Lawrence Technical University, SBC, Cody Hoeffel (Michigan Section)

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

Miami University, SBC, Michael Gunderman (Dayton/Cincinnati Section)

Michigan State University, FA, Dahsin Liu (Michigan Section)

Michigan State University, SBC, John Conklin (Michigan Section)

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

Milwaukee School of Engineering, SBC, Michael Hinaus (Wisconsin Section)

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

Ohio Northern University, SBC, Logan Glauner (Dayton/Cincinnati Section)

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

Ohio State University, SBC, Jacob Cantin (Dayton/Cincinnati Section)

Purdue University, FA, Li Qiao (Indiana Section)

Purdue University, SBC, Yipu Zhang (Indiana Section)

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

Rose-Hulman Institute of Technology, SBC, Thomas Ryan (Indiana Section)

Trine University, FA, James Canino (Indiana Section)

Trine University, SBC, Nicholas Maher (Indiana Section)

University of Akron, FA, TBD (Northern Ohio Section)

University of Akron, SBC, TBD (Northern Ohio Section)

University of Cincinnati, FA, Tom Black

University of Cincinnati, SBC, Jordan Lealos

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

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

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

University of Illinois at Urbana-Champaign, SBC, Joseph Billhartz (Illinois Section)

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

University of Illinois-Chicago, SBC, Matheus Scotti Alves Tonin Simoni (Illinois Section)

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

University of Kentucky, SBC, Harrison Wight (Dayton/Cincinnati Section)

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

University of Kentucky-Paducah, SBC, Justin King (Dayton/Cincinnati Section)

University of Michigan, FA, Ella Atkins (Michigan Section)

University of Michigan, SBC, Rebecca Hill (Michigan Section)

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

University of Notre Dame, SBC, Robert Braddock (Indiana Section)

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

University of Wisconsin at Madison, SBC, David Zeugner (Wisconsin Section)

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

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

Western Michigan University, FA, Peter Gustafson (Michigan Section)

Western Michigan University, SBC, Heather Irish (Michigan Section)

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

Wright State Univ, SBC, TBD (Dayton/Cincinnati Section)

REGION IV

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

New Mexico State University, SBC, Phoenix Carter (White Sands Space Harbor Section)

Oklahoma State University, FA, Andrew Arena, (Oklahoma Section)

Oklahoma State University, SBC, Nicholas Foster (Oklahoma Section)

Rice University, FA, Andrew Meade (Houston Section)

Rice University, SBC, Roberto Rosas (Houston Section)

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

Texas A&M University-College Station, SBC, Cody Shelton (Houston Section)

Texas Christian University, FA, Walton Williamson (North Texas Section)

Texas Christian University, SBC, TBD (North Texas Section)

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

University of Arkansas-Fayetteville, SBC, Austin Briscoe (Oklahoma Section)

University of Houston, FA, Edgar Bering (Houston Section)

University of Houston, SBC, Michael Greer (Houston Section)

University of New Mexico, FA, Randy Truman (Albuquerque Section)

University of New Mexico, SBC, Blade Allen (Albuquerque Section)

University of Oklahoma, FA, Thomas Hays (Oklahoma Section)

University of Oklahoma, SBC, Chris Hughes (Oklahoma Section)

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

University of Texas at Arlington, SBC, Alejandro Contreras (North Texas Section)

University of Texas at Austin, FA, Todd Humphreys (Southwest Texas Section)

University of Texas at Austin, SBC, Han All Cha (Southwest Texas Section)

University of Texas at Dallas, FA, James Hilkert (North Texas Section)

University of Texas at Dallas, SBC, Craig Hartnell (North Texas Section)

University of Texas at El Paso, FA, Evgeny Shafirovich (White Sands Space Harbor, Section)

University of Texas at El Paso, SBC, Roman Herrera (White Sands Space Harbor Section)

REGION V

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

Colorado School of Mines, SBC, Robert Frazier (Rocky Mountain Section)

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

Colorado State University-Fort Collins, SBC, Jared Ham (Rocky Mountain Section)

Iowa State University, FA, Anupam Sharma (Iowa Section)

Iowa State University, SBC, Michael Mohr (Iowa Section)

Kansas State University, FA, TBD (Wichita Section)

Kansas State University, SBC, TBD (Wichita Section)

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

Metropolitan State University of Denver, SBC, Shawn Sloan (Rocky Mountain Section)

Missouri University of Science and Technology, FA, Joshua Rovey (St. Louis Section)

Missouri University of Science and Technology, SBC, Andrew Kueny (St. Louis Section)

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

North Dakota State University, SBC, Bradley Hoffmann (Twin Cities Section)

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

Saint Louis University, SBC, Lindsay Jasper (St. Louis Section)

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

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

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

University of Colorado Boulder, SBC, Lauren Darling (Rocky Mountain Section)

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

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

University of Iowa, FA, Albert Ratner (Iowa Section)

University of Iowa, SBC, Thomas Niemeyer (Iowa Section)

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

University of Kansas, SBC, Anna Gardner (Wichita Section)

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

University of Minnesota, SBC, Briana Preimesberger (Twin Cities Section)

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

University of Missouri, SBC, James Gentles (St. Louis Section)

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

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

University of Wyoming, FA, TBD (Rocky Mountain Section)

University of Wyoming , SBC, TBD (Rocky Mountain Section)

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

Washington University in St Louis, SBC, Noah Rowe (St. Louis Section)

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

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

REGION VI

Arizona State University, FA, Timothy Takahashi (Phoenix Section)

Arizona State University, SBC, Philip Thomas (Phoenix Section)

Arizona State University Polytechnic Campus, FA, John Rajadas (Phoenix Section)

Arizona State University Polytechnic Campus, SBC, TBD (Phoenix Section)

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

Boise State University, SBC, Zachary Weyn (Pacific Northwest Section)

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

Brigham Young University-Utah, SBC, Isaac Becker (Utah Section)

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

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

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

California Polytechnic State University, San Luis Obispo, SBC, Alexander Lisso (Vandenberg Section)

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

California Polytechnic State University-Pomona, SBC, Patrick Watkins (San Gabriel Valley Section)

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

California State University, Fullerton, SBC, Rubi Raymundo (Orange County Section)

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

California State University, Long Beach, SBC, Serena Quach (Los Angeles-Las Vegas Section)

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

California State University-Northridge, SBC, Edwin Pacheco (San Fernando Pacific, Section)

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

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

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

Embry-Riddle Aeronautical University-Prescott, AZ, SBC, Brian Study (Phoenix Section)

Northern Arizona University, FA, Thomas Acker (Phoenix Section)

Northern Arizona University, SBC, TBD (Phoenix Section)

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

Oregon State University, SBC, Karen Kuhlman (Pacific Northwest Section)

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

San Diego State University, SBC, Claire Quento (San Diego Section)

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

San Jose State University, SBC, Trung Nguyen (San Francisco Section)

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

Santa Clara University, SBC, Leslie Yang (San Francisco Section)

Stanford University, FA, Stephen Rock (San Francisco Section)

Stanford University, SBC, Brian Munguia (San Francisco Section)

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

University of Alaska Fairbanks, SBC, Dawson Lewandoski (Pacific Northwest Section)

University of Arizona, FA, Jekan Thangavelautham (Tucson Section)

University of Arizona, SBC, Ayden Jimenez-Smith (Tucson Section)

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

University of California-Berkeley, SBC, TBD (San Francisco Section)

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

University of California-Davis, SBC, Andy Trang (Sacramento Section),

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

University of California-Irvine, FA, TBD (Orange County Section)

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

University of California-Los Angeles, SBC, Amanpreet Kaur (Los Angeles-Las Vegas Section)

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

University of California-Merced, SBC, Moataz Dahabra (Sacramento Section)

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

University of California-San Diego, SBC, Kalpa Semasinghe (San Diego Section)

University of Idaho, FA, TBD (Pacific Northwest Section)

University of Idaho, SBC, TBD (Pacific Northwest Section)

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

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

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

University of Nevada, Reno, SBC, Justin Patridge (Sacramento Section)

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

University of Southern California, SBC, Alan Simonini (Los Angeles-Las Vegas Section)

University of Utah, FA, Kuan Chen (Utah Section)

University of Utah, SBC, Axel Kerksiek (Utah Section)

University of Washington, FA, James Hermanson (Pacific Northwest Section)

University of Washington, SBC, Riley Harris (Pacific Northwest Section)

Utah State University, FA, Stephen Whitmore (Utah Section)

Utah State University, SBC, Jack Kiefer (Utah Section)

Washington State University, FA, Jacob Leachman (Pacific Northwest Section)

Washington State University, SBC, TBD (Pacific Northwest Section)

Weber State University, FA, John Sohl (Utah Section)

Weber State University, SBC, TBD (Utah Section)

REGION VII

Beihang University, FA, Zhiqiang Wan (International)

Beihang University, SBC, Jing Pu (International)

British University in Egypt, FA, Talat Refai (International)

British University in Egypt, SBC, TBD (International)

Cairo University, FA, Osama Mohammady (International)

Cairo University, SBC, Mohannad Draz (International)

Carleton University, FA, Stephen Ulrich (International)

Carleton University, SBC, TBD (International)

Chulalongkorn University, FA, Asi Bunyajitradulya (International)

Chulalongkorn University, SBC, TBD (International)

Concordia University, FA, Hoi Dick Ng (International)

Concordia University, SBC, TBD (International)

Ecole Polytechnique de Montréal, FA, TBD (International)

Ecole Polytechnique de Montréal, SBC, TBD (International)

Emirates Aviation College, FA, Ahmed Obaide (International)

Emirates Aviation College, SBC, TBD (International)

Ghulam Ishaq Khan Institute of Science & Technology-Pakistan, FA, Khalid Rahman (International)

Ghulam Ishaq Khan Institute of Science & Technology-Pakistan, SBC, TBD (International)

Hindustan University, FA, TBD (International)

Hindustan University, SBC, TBD (International)

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

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

Hong Kong University of Science & Technology, SBC, TBD (International)

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

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

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

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

Istanbul Technical University, FA, TBD (International)

Istanbul Technical University, SBC, TBD (International)

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

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

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

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

McGill University, FA, TBD (International),

McGill University, SBC, TBD (International)

Middle East Technical University, FA, TBD (International)

Middle East Technical University, SBC, TBD (International)

MLR Institute of Technology, FA, TBD (International)

MLR Institute of Technology, SBC, TBD (International)

Monash University, FA, TBD (International)

Monash University, SBC, TBD (International)

Moscow Aviation Institute, FA, TBD (International)

Moscow Aviation Institute, SBC, TBD (International)

Nagoya University, FA, TBD (International)

Nagoya University, SBC, TBD (International)

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

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

Northwestern Polytechnic University, FA, Zhichun Yang (International)

Northwestern Polytechnic University, SBC, Peng Xia (International)

Queen's University Belfast, FA, TBD (International)

Queen's University Belfast, SBC, TBD (International),

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

Royal Melbourne Institute of Technology, SBC, Thang Nguyen (International)

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

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

Ryerson Polytechnic University, FA, Seyed Hashemi (International)

Ryerson Polytechnic University, SBC, TBD (International)

Technion—Israel Institute of Technology, FA, TBD (International)

Technion—Israel Institute of Technology, SBC, TBD (International)

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

United Arab Emirates University, SBC, TBD (International)

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

Universidad Autonoma de Baja California, SBC, Christian Sanchez (International)

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

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

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

Universidad de San Buenaventura, SBC, TBD (International)

Universidad Pontificia Bolivariana, FA, TBD (International)

Universidad Pontificia Bolivariana, SBC, TBD (International)

Università degli Studi di Roma "La Sapienza", FA, Giuliano Coppotelli (International)

Università degli Studi di Roma "La Sapienza", SBC, Luca Migani (International)

University of Adelaide, FA, Rey Chin (Adelaide Section)

University of Adelaide, SBC, Marcus Andreucci (Adelaide Section)

University of Naples Federico II, FA, Francesco Marulo (Adelaide Section)

University of Naples Federico II, SBC, TBD (Adelaide Section)

University of Palermo, FA, TBD (Adelaide Section)

University of Palermo, SBC, TBD (Adelaide Section)

University of Queensland, FA, TBD (International)

University of Queensland, SBC, TBD (International)

University of Stuttgart, FA, TBD (International)

University of Stuttgart, FA, TBD (International)

University of Sydney, FA, Gareth Vio (Sydney Section)

University of Sydney, SBC, Mathew Gardiner (Sydney Section)

University of Toronto, FA, TBD (International)

University of Toronto, SBC, TBD (International)

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

Von Karman Institute of Fluid Dynamics, SBC, TBD (International)

Obituaries

AIAA Senior Member Lee Died in September

Albert (Al) Chong Lee, 92, died on 7 September.

Lee's early academic success led to his acceptance to a dual-degree program at Reed College in Portland, OR, and the Massachusetts Institute of Technology. In 1953, he graduated with degrees in physics and electrical engineering and began a long career as an electrical engineer.

After starting with GE in Pittsfield, MA, his interests led him across the country to Los Angeles in 1961, where he began working for the U.S. space program. After becoming an expert in solar cell arrays, he moved to Houston, TX, to support the Apollo program.

After his time with the space program, he began designing electrical transformers with GE, first in Louisana and then in North Carolina in 1973.

Lee worked for GE until retiring in 1992. He was especially proud of the patents he developed at GE related to transformers and amorphous metals. eu tortor cursus interdum.

AIAA Senior Member Isbell Died in October

William M. Isbell, Ph.D., died on 8 October 2017.

Dr. Isbell, a 45-year member of AIAA, received his B.S. in Engineering/Physics from University of California, Berkeley in 1958, and his Ph.D. from Tohoku University, Sendai, Japan. His career encompassed over 60 years experience in weapon systems and weapon lethality. He was a Captain in the U.S. Air Force. He was internationally recognized as a specialist in applications of shock wave technologies and a participant in the development of missiles and space exploration during the 1960s and the Strategic Defense Initiative (Star Wars) during the 1980s. He was considered an expert in the weapon system lethality field, NMD damage and kill assessment, supporting numerous special studies.

He joined Stanford Research Institute's Poulter Laboratories, as a Research Physicist in 1960. Later he was head, Applied Physics Division of Material and Structures Laboratory, General Motors Corporation Technical Center, Santa Barbara. In 1971 he became a senior scientist at Lawrence Livermore National Laboratory, followed in 1976 by joining General Research Corporation as principal scientist, Kinetic Weapon Operations. In 1998, Dr. Isbell joined Xontech Inc. and provided input to NMD Lethality Plans, and consulting services for numerous organizations supporting the developing National Missile Defense System programs. He directed hypervelocity impact testing, developed shock wave instrumentation, and performed underground nuclear phenomenology tests.

Dr. Isbell was owner/president of ATA Associates, designing and building optical instruments. He was a member of the Army Science Board, Washington, DC, and a Senior Research Fellow, Advanced Technologies Center, University of Texas at Austin. Dr. Isbell contributed to a number of Oversight Panels for SDIO/BMDO, DOD, NASA, and DOE National Laboratories. He authored over 150 publications in fields of system assessment, damage assessment, weapons effectiveness, impact lethality, underground nuclear testing, and shock wave physics, non-lethal weapons, anti-terrorism and high tech solutions, just to name a few. He authored a book entitled *Shock Waves* and a book entitled, *Measurements of the Dynamic Response of Materials to Impact Loading*.

Dr Isbell was a member of the AIAA Weapon System Effectiveness Technical Committee, a regular contributor to AIAA classified conferences, and member of the AIAA Vandenberg Section. He was founding President and Inaugural Fellow, Electric Launcher Association; Founding Board of Directors, Hypervelocity Impact Society; and Fellow, Aeroballistics Range Association. He also held membership with ARA Association, HVIS, National Defense Institute, American Physical Society, and SPIE.

AIAA Fellow McCormick Died in October

Barnes (Barney) W. McCormick Jr., Boeing Professor Emeritus and former department head of aerospace engineering at Penn State University, died on 29 October. He was 91 years old.

McCormick earned his bachelor's, master's, and Ph.D. degrees in aeronautical engineering from Penn State. He then joined the Penn State Department of Aeronautical Engineering as an associate professor of engineering research. To gain experience, he joined the Piasecki Helicopter Corporation as chief of aerodynamics. In 1957, he became department head at the University of Wichita, before returning to Penn State in 1959 as professor of aeronautical engineering and as a member of the Ordnance Research Lab. In 1969 he was appointed head of aerospace engineering and held the positions for 16 years until he became Boeing Professor of Aerospace Engineering.

In 1990, he officially retired from Penn State, although he continued to teach on a regular basis for the next 22 years. He participated in close to 60 litigations involving aircraft accidents, offering expert testimony in the first accident ruled to be caused by wake turbulence.

McCormick's research areas included low-speed aerodynamics, flight mechanics, aerodynamics of vertical flight, propeller design, hydrodynamics, noise and the behavior of vortex systems, including their interaction with aircraft and lifting surfaces.

His professional service was extensive. McCormick was the editor-in-chief of the *Journal of the American Helicopter Society* (1970–1972) and associate editor of the AIAA *Journal of Aircraft* (1978–1982). He also served on the Congressional Advisory Committee for Aeronautics (1984–1987), and was past chairman of AHS's Educational Committee and AIAA vice president of Education (1987–1988). McCormick authored and coauthored several books, including *Aerodynamics of V/STOL Flight; Aerodynamics, Aeronautics, and Flight Mechanics; Aerospace Engineering Education During the First Century of Flight* and *Aircraft Accident Reconstruction and Litigation*.

McCormick's work earned him numerous honors and awards including the J. Leland Atwood Award (1976), the AHS International Alexander A. Nikolsky Lectureship (2004); the AIAA F.E. Newbold V/STOL Award (2002); and the Aerospace Division/AIAA Educational Achievement Award (1976) from ASEE. He was an Honorary Fellow of AHS.

AUBURN UNIVERSITY
SAMUEL GINN
COLLEGE OF ENGINEERING
Aerospace Engineering

Multiple Tenure Track Faculty Positions

The Department of Aerospace Engineering at Auburn University invites applications for multiple tenure-track and tenured faculty positions at the Assistant, Associate and Full Professor level. Areas of immediate interest include flight dynamics & control; orbital mechanics and space sciences; remote sensing; guidance, navigation and control; aerospace design and manufacturing; aerospace systems; unmanned aerial systems; and experimental fluid dynamics. Candidates with strong backgrounds in other areas relevant to aerospace engineering are also welcome to apply and will be fully considered as part of the current search.

Senior level candidates with a strong interest in providing mentorship and leadership to a young, enthusiastic and rapidly growing department are particularly encouraged to apply. Senior level candidates are also eligible for a Walt and Virginia Woltosz Professorship. All candidates will be expected to fully contribute to the department's mission through the development of a strong, nationally recognized, funded research program, teaching at both the undergraduate and graduate level, and professional service. Successful candidates will have a demonstrated track record of scholarship, a creative vision for research, an active interest in engineering education and strong communication skills. Candidates must have an earned doctorate in aerospace engineering, mechanical engineering or a closely related field.

Candidates can login and submit a cover letter, CV, research vision, teaching philosophy, and three references at: https://aufacultypositions.peopleadmin.com/postings/2454. Cover letters may be addressed to: Dr. Brian Thurow, Search Committee Chair, 211 Davis Hall, Auburn University, AL 36849. To ensure full consideration, candidates are encouraged to apply before December 1, 2017 although applications will be accepted until the positions are filled. The successful candidate must meet eligibility requirements to work in the U.S. at the time the appointment begins and continue working legally for the proposed term of employment. Additional information about the department may be found at: http://www.eng.auburn.edu/aero/

Auburn University is one of the nation's premier public land-grant institutions. In 2018, it was ranked 46th among public universities by U.S. News and World Report. Auburn maintains high levels of research activity and high standards for teaching excellence, offering Bachelor's, Master's, Educational Specialist, and Doctor's degrees in agriculture and engineering, the professions, and the arts and sciences. Its 2017 enrollment of 29,776 students includes 23,964 undergraduates and 5,812 graduate and professional students. Organized into twelve academic colleges and schools, Auburn's 1,450 faculty members offer more than 200 educational programs. The University is nationally recognized for its commitment to academic excellence, its positive work environment, its student engagement, and its beautiful campus.

Auburn residents enjoy a thriving community, recognized as one of the "best small towns in America," with moderate climate and easy access to major cities or to beach and mountain recreational facilities. Situated along the rapidly developing I-85 corridor between Atlanta, Georgia, and Montgomery, Alabama, the combined Auburn-Opelika-Columbus statistical area has a population of over 500,000, with excellent public school systems and regional medical centers.

In support of our strategic plan, Auburn University will maintain its strong commitment to diversity with standards to help ensure faculty, staff, and student diversity through recruitment and retention efforts.

Auburn University is an EEO/Vet/Disability Employer

CAL POLY

SAN LUIS OBISPO

AEROSPACE ENGINEERING (SPACE SYSTEMS): ASSISTANT OR ASSOCIATE PROFESSOR

Cal Poly is committed to recruiting individuals who are dedicated to furthering inclusive excellence in our campus community. We seek to enhance our diverse University population, welcoming people from all backgrounds, to sustain an environment in which all can thrive, create, work and learn.

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

The Aerospace Engineering Department, within the College of Engineering at Cal Poly, San Luis Obispo, CA invites applications for a full-time, academic year, tenure-track faculty position at the Assistant or Associate Professor rank. Rank and salary is commensurate with qualifications and experience. The projected start date is September 13, 2018. Duties include teaching Aerospace Engineering courses, including the Spacecraft Design sequence; building a research program in a Space Systems advanced technology area; and supporting Cal Poly's CubeSat development activities.

This position is open to candidates with experience in all areas of Space Systems. Candidates with a professional or academic background in small satellite systems engineering are encouraged to apply.

Professional Qualifications: The department seeks candidates who have an interdisciplinary mindset and who work well in a highly collaborative environment. Candidates must demonstrate a commitment to diversity and inclusivity; have a strong commitment to teaching excellence and laboratory-based instruction; and exhibit potential for professional recognition via research and publication. Demonstrated ability in written and oral use of the English language is required.

Academic Preparation: An earned doctorate (Ph.D.) in Aerospace Engineering or a related field from an accredited institution or international equivalent is required for appointment. Candidates nearing completion of the doctorate (ABD) will be considered, but must provide proof that the doctorate was completed prior to the start of appointment.

To apply, visit WWW.CALPOLYJOBS.ORG, complete a required online Cal Poly faculty application, apply to requisition #104675. Interested candidates must attach (1) a cover letter, (2) resume/curriculum vitae, (3) a statement of research, as it relates to undergraduate and graduate student projects, and (4) teaching philosophy. Please be prepared to provide three professional references with names and email addresses when completing the online faculty application. The selected candidate will be required to provide three letters of recommendation and official transcripts. Applicants are encouraged to submit materials by January 2, 2018 for full consideration, however, the position will remain open until filled.

For questions, please contact: Kendra Bubert, Aerospace Engineering Department, Cal Poly, San Luis Obispo, CA 93407 or email kbubert@calpoly.edu.

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

Academic Preparation: An earned doctorate (Ph.D.) in Aerospace Engineering or a closely related field from an accredited institution or international equivalent is required for appointment.

Candidates nearing completion of the doctorate (ABD) will be considered, but must provide proof that the doctorate was completed prior to the start of appointment.

Professional Qualifications: The department seeks candidates who have an interdisciplinary mindset and who work well in a highly collaborative environment. Candidates must demonstrate a commitment to diversity and inclusivity; have a strong commitment to teaching excellence and laboratory-based instruction; and exhibit potential for professional recognition via research and publication. Demonstrated ability in written and oral use of the English language is required.

1918

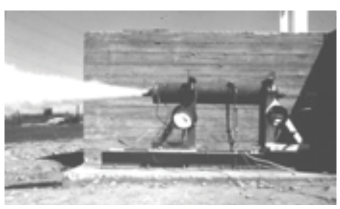
Jan. 14 Robert Goddard writes a paper titled "Outline of Certain Notes on High Altitude Research." It is later referred to as Goddard's "Ultimate Migration" paper. Unpublished until 1972, the paper contains Goddard's speculation on the need for space flight to continue life on other worlds if the sun cools and Earth is no longer fit for human habitation. The spacecraft will use "intra-atomic energy." If atomic energy is not possible, a hydrogen-oxygen rocket "aided by solar energy," can be used. The pilot will be in hibernation for "perhaps 10,000 years" for a passage to the nearest stars. R.H. Goddard, "The Ultimate Migration," **Journal of the British Interplanetary Society — Astronautics History**, December 1983, pp. 553-554.

Jan. 19 The U.S. School of Aviation Medicine at Hazelhurst Field, on Long Island, New York, is activated. The first experiment conducted is with a low-pressure tank to simulate altitudes up to 30,000 feet. The school is under the command of Col. William Wilmer, Signal Corps. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 7.

1943

Jan. 2 An experimental U.S. Navy rocket motor, using nitric acid and aniline as propellants, explodes during tests at Annapolis, Maryland. The motor is being developed as a jet-assisted takeoff unit for seaplanes. Robert Goddard, who works with the motor, disavows responsibility for the accident since he had warned the Navy about the hazards of using hypergolic propellants, which ignite spontaneously upon contact. E.C. Goddard and G.E. Pendray, eds., **The Papers of Robert H. Goddard, Vol. 3**, p. 1,488.

Jan. 5 The U.S. Army Air Forces' Northwest African Air Forces are activated under the command of Maj. Gen. Carl Spaatz, who becomes chief air adviser to Gen. Dwight Eisenhower, commander-in-chief of the Allied forces. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 77.



◀ Static test of a 2,000 newtons thrust solid-propellant rocket motor at an RRI facility.

Jan. 6 The educational organization Rocket Research Institute, or RRI, is founded by George James and five associates and becomes the nucleus of the nonprofit corporation known as the Southern California Rocket Society. As the group evolves, it becomes the Glendale Rocket Society (1943-1946), then the Reaction Research Society, or RRS, (1946-1949). In 1949, the founding members rename the organization the Rocket Research Institute to emphasize the objectives of education and research. Those wishing to retain the earlier RRS designation did so. Thus, both the RRI and the RRS share a common six-year heritage. In 1968, the RRI becomes a member of the International Astronautical Federation. The institute's educational concepts of inspiring and motivating young people through a combination of experimental hands-on activities and textbook learning becomes a precursor to some of today's science, technology engineering, art and mathematics, or STEAM, programs. George James and Charles Piper, **"The Rocket Research Institute, 1943-1993…"**; Philippe Jung, ed., **History of Rocketry and Astronautics, AAS History Series, Vol. 22**, pp. 343, 348.

Jan. 9 The Lockheed L-049 Constellation makes its first flight, from Burbank to Muroc Dry Lake, California. The U.S. Army Air Forces adopts the airplane as the C-69 and it becomes a pressurized cabin transport. Its range is 4,800 kilometers at 400 kph and it can carry 10 tons of freight. **Flight**, Feb. 25, 1943, pp. 198-201.

Jan. 14-23 A wartime meeting is held at Casablanca, Morocco, between British Prime Minister Winston Churchill, U.S. President Franklin Roosevelt and their chiefs of staff. They agree to increase round-the-clock bombing of targets in Germany and to hold off on a cross-channel invasion until 1944. Ronald Schaffer, **Wings of Judgment: American Bombing in World War II**, p. 38.

Jan. 15 Robert Goddard signs a contract with the U.S. Navy's Bureau of Aeronautics to develop liquid-fuel jet-assisted takeoff rockets. E.C. Goddard and G.E. Pendray, eds., **The Papers of Robert H. Goddard, Vol. 2,** pp. 1,490-1,491.

Jan. 27 U.S. Army Air Forces makes its first bombing raid on Germany when 53 heavy bombers of the 8th Air Force strike the naval base, U-boat construction works, a power plant and docks at Wilhelmshaven. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 88.

Jan. 28 Hugh Dryden, chief of the Mechanics and Sound Division of the National Bureau of Standards, is elected president of the Institute of the Aeronautical Sciences. He has been editor of the institute's journal since September 1941 and is highly acclaimed for his interpretation of wind tunnel experiments. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 44; **Aero Digest**, January 1943, p. 38.

1968

Jan. 7 Surveyor 7 is launched by an Atlas-Centaur booster and is the last of the Surveyor series of unmanned spacecraft designed to soft-land on the moon. The main mission of the Surveyors is to obtain detailed post-landing TV pictures of the lunar surface and to determine the nature of the chemical elements in the landing area. The pictures and data are needed to plan the best landing sites for the coming missions of Project Apollo. On Jan. 9, the Surveyor becomes the fifth U.S. spacecraft to land on the moon when it touches down in highlands around the crater Tycho and begins transmitting the first of 21,274 TV pictures of the lunar surface. **New York Times**, Jan. 8, 1968 p. 14; **New York Times**, Jan. 12, 1968, p. 4.

Jan. 11 Explorer 36, also designated Geodetic Earth Orbiting Satellite 2, or GEOS 2, is launched by a Thrust-Augmented Delta rocket from Vandenberg Air Force Base, California, and is to contribute to a more precise model of Earth's gravitational field and add to knowledge of Earth's size and shape. **New York Times**, Jan. 11, 1968, p. 30; **Flight International**, Feb. 1, 1968, p. 169.

Jan. 12 Hayne Constant, chief scientist of the Royal Air Force since 1964 as well as head of the Research Department of Power Jets from 1944 to 1946, who thus played a key role in the development of gas turbines in Great Britain, dies at age 63. Constant had been awarded the Gold Medal of the Royal Aeronautical Society for his outstanding contribution to gas turbine development. **Flight International**, Jan. 18, 1968, p. 75.

Jan. 17 Canadian Pacific Air Lines, or CPAL, takes delivery of its first Douglas DC-8-63 airliner, and the first of the type to be delivered in the Western Hemisphere. The plane is to enter the fleet Jan. 31 on CPAL's Vancouver-Tokyo-Hong Kong route. **Flight International**, Jan. 25, 1968, p. 116.

Jan. 20 The USSR launches the 200th satellite in its Cosmos series. This is later identified as the first of the operational Tselina-O type photo reconnaissance Soviet satellites in this series; it was launched from the Plesetsk Cosmodrome. **Flight International**, Feb. 1, 1968, p. 167; Jeffrey Richelson, **A Century of Spies — Intelligence in the Twentieth Century**.

Jan. 22 NASA launches Apollo 5, the first unmanned lunar module test flight, on a Saturn 1B rocket from the Kennedy Space Center in Florida. The mission is to verify the operation of the lunar module and its two primary propulsion systems, its descent and ascent engines, in a space environment, and its ability to separate the ascent and descent stages. The Saturn's second stage is placed in a 163-by-222-kilometer orbit. The nose cone is jettisoned and, after a coast of almost 45 minutes, the lunar module separates from its adapter and the tests are conducted. Atmospheric drag soon causes the orbits of the two stages to decay and they re-enter the atmosphere and burn up. Ivan Ertel, et al., **The Apollo Spacecraft — A Chronology, Vol. 4**, p. 196; **Flight International**, Feb. 1, 1968, p. 167.

Jan. 28 A Convair 990 jet named Galileo completes a weeklong series of missions as an airborne laboratory that conducted flights above Alaska and Canada as part of NASA's 1968 Airborne Auroral Expedition in which scientists aboard the aircraft obtain hundreds of unique photos and data of auroras. This program, described as "the most comprehensive study made on the aurorae," also includes intensive observations made from the ground, besides sounding rockets and a satellite. **Flight International**, Jan. 25, 1968, pp. 135-136; **NASA Press Release 68-18**.

Jan. 28 The Pakistan Space and Upper Atmosphere Research Commission completes the installation and testing of Pakistan's first satellite tracking station at Dacca, East Pakistan. The station is capable of receiving cloud-cover photos via U.S. Nimbus and Environmental Science Services Administration satellites that will enable meteorologists to forecast cyclones, which frequently strike Pakistan. **New York Times**, Jan. 29, 1968.

Jan. 31 The National Press Club in Washington, D.C., marks the 10th anniversary of the first U.S. satellite, Explorer 1, which was launched on this date in 1958. Since then, the U.S. has placed about 500 vehicles into Earth orbit while the USSR has launched about 250. **New York Times**, Feb. 1, 1968, p. 15.

1993

Jan. 13 The launch of the space shuttle Endeavour, STS-54, includes Physics of Toys experiments to demonstrate basic physics principles in microgravity to elementary school students. **NASA, Astronautics and Aeronautics, 1991-1995**, pp. 299, 699.

DAVID COOTE, 33

Senior Systems Engineer at BAE Systems

As the son of a British Royal Air Force officer, David Coote moved often. Each new home was surrounded by airplanes and Coote often attended air shows like the one at Farnborough outside London. Instead of flying planes, Coote wanted to understand the technology. While earning a software engineering degree in 2006, he began an internship in Rochester, England, at BAE Systems, the British aerospace company with more than 83,000 employees worldwide. Still at BAE Systems, Coote works on active control side sticks, which give pilots tactile feedback from fly-by-wire systems. Gulfstream Aerospace is adopting active side sticks for the twin-engine G500 and G600 business jets.

How did you become an engineer?

There's the usual stories that all engineers have: the love of trying to take things apart, put them back together and understand how they work. In school, I gravitated to math, science and computing, which then led me to doing a software engineering degree at the University of Portsmouth in England. That degree program included a one-year internship in industry. I applied to BAE Systems and managed to secure a place. At the end of that internship, BAE Systems offered me a bursary through my final year to pay for my tuition fees and also a job for the Graduate Development Framework [a two-year training program] once I had completed my degree. It was a perfect joining of my engineering skillset and aviation interest. I've been working in active inceptors for a number of years, initially in the front end of the business to do with bids, technical proposals and demonstration. That evolved into joining the main development program for the active control side stick. I've been involved in the program for about four years. I am involved in the design, integration and certification of the product as well as supporting the product at customer facilities, including in the United States and South America.

What do you think will be happening in aviation in 2050?

The pace of development around autonomous and remotely or optionally piloted vehicles is very exciting. I think there will always be a position for pilots aboard the aircraft, so it will be very interesting to see how we end up with a harmonious mix of those different platforms. I think we'll see technology development that will reduce cockpit management and reduce pilot workloads, allowing pilots a lot more capacity to focus on their actual mission and achieving it safely rather than cockpit maintenance. It's exciting to be part of the active control side stick development at the moment, because it is playing a key part in improving cockpit situational awareness and crew coordination and has a lot of benefits that I think we will see it performing well into the future. ★

By Debra Werner | werner.debra@gmail.com

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