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AEROSPACE

★ ★ ★ AMERICA ★ ★ ★

SOFT TARGETS

Worried about cybersecurity and aviation? Don't look up: The biggest problem may be on the ground. PAGE 28

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By Tom Risen

AEROSPACE
★ ★ ★ AMERICA ★ ★ ★

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AIAA
Shaping the Future of Aerospace

IN THIS ISSUE

Henry Canaday

A former energy economist, Henry has written for Air Transport World, Aviation Week and other aviation publications for more than two decades.

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Adam Hadhazy

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

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Joshua Hatch

Josh is an editor at The Chronicle of Higher Education and was a 2018 Knight Science Fellow at MIT.

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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.

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Debra Werner

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

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What Apollo 11 says about our future

The run-up to the Apollo 11 50th anniversary has begun, and that has me thinking about the passage of time and the power of culture to shape our future.

Looked at one way, humanity needed just eight years to reach the moon, measured from President John F. Kennedy's speech to Congress in 1961 [See Page 10]. But looked at another way, humanity needed 200,000 years, taking as a starting point the evolution of a brain about the size of ours.

What explains the sudden surge of science and engineering breakthroughs capped by the moon landing?

In a word: culture. Societies from Asia to Europe and North America grew to value science, technology and facts. In the U.S., we married our love of learning with a determination to protect and spread freedom and market economics. We welcomed immigrants including a former Nazi rocket scientist named Wernher von Braun. As imperfect as we were, someone at NASA's Langley Research Center in Virginia had the moxie to let a group of African-American women perform their trajectory math.

This was how we met JFK's challenge and how we went on to win the Cold War against the Soviet Union.

The Apollo 11 anniversary will be fun, and I feel blessed to be here to enjoy it. Hopefully the anniversary also will lead to self-reflection in the U.S. about whether we still have the right stuff to do the things we want to do, or that we might need to do. We're living on what is essentially a giant but delicate spacecraft, and we're going to have to do our part to treat it better. We want to out-compete China and Russia; get back to the moon and onto Mars; find out if we are alone in the universe; fly supersonically, and bop around like the Jetsons.

We want to do those things soon, and in some cases, we might have no choice. Can we still work fast? I'm not sure. NASA and the industry achieved the moon landing in fewer years than it took to build and launch the unmanned Parker Solar Probe that's now headed toward the sun [Page 42]. That's not to blame the Parker managers. Something similar could be said of just about any government-led space or aviation program. As Jeff Babione of Lockheed Martin Skunk Works notes in this month's Q and A [Page 16], today's government acquisition processes are not what they were when Clarence "Kelly" Johnson founded Skunk Works. I'm not sure the private sector is immune either.

If we want to do these amazing things, we'll need faster acquisition; we'll need the best minds; we'll need international coalitions and alliances. It's the culture we choose that will determine the way ahead. The question is whether we will choose wisely. ★

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


COVER STORY

Even before Russian President Vladimir Putin's saber rattling this year about high-speed weapons, the U.S. was laying plans to sharpen its focus on hypersonic weapons, motivated mainly by China's ambitious research and weapons tests. The Trump Pentagon wants to put this new focus in place in the 2019 budget. Keith Button examines what could be the next great weapons race.

BY KEITH BUTTON | buttonkeith@gmail.com

HYPERSONIC WEAPONS RACE

20 | JUNE 2018 | aerospaceamerica.aiaa.org

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The June article "Hypersonic weapons race" overstated the velocity of hypersonic missiles relative to the fastest bullets in the world. Hypersonic weapons are only marginally faster than those bullets.

How Do We Prepare for Ever-Increasing Levels of System Complexity?

In 2012, I was asked to participate in the inaugural AIAA Complex Aerospace Systems Exchange, or CASE. That year CASE was held in conjunction with the AIAA Space Conference in Pasadena. I recall sitting on the beach on Monterey Bay wondering what I could possibly say that would get attendees thinking about system complexity and how, as aerospace engineers, to better design, develop, and test and evaluate increasingly complex space and aeronautical systems.

I remember seeing these freakishly long blackish tubes with a bulb on one end that had washed up on the beach. Never having been to Monterey before, I had no idea what they were. Visiting the Monterey Bay Aquarium the following day, I learned how kelp plants were the foundation upon which the entire Monterey Bay ecosystem is based. It dawned on me that I was amidst one of the most complex and dynamic systems on the planet. Think about it for a moment — on any given day, the bay is a stable system, albeit a complex one. Nature has a self-correcting way of dealing with emergent behavior associated with a complex system that would otherwise upheave, and possibly destroy, more fragile systems, certainly one less robust than Monterey Bay. As a result my message became that we, engineers, need to be inspired by bio-mimicry not only in singular design aspects, but in complex systems as well. Complex systems need to be as robust as possible, and designers and developers of those systems need to be adaptable to changing conditions, to external variables, and to the evolution of the system itself.

The inaugural CASE made a big splash, attracting several hundred participants who spent two days discussing aerospace system complexity. One topic covered at the 2012 event was a case study of the Air France 447 accident where a highly automated twin-aisle aircraft defied attempts, incorrect as it turns out, by the crew to avert disaster. At the second CASE in 2013, we flipped the script and focused on what is still a stunning aerospace success story — the successful entry, descent, and landing (EDL) of the Mars Science Laboratory (MSL) Curiosity rover. You'll recall that MSL was successfully placed on the surface via the untried sky-crane system. Adam Steltzner, the engineer in charge of the MSL EDL, attributed the success of that mission to a dedicated team that was "personally respectful, but intellectually disrespectful." It struck me that both Air France 447 and MSL show the importance of human–machine interaction and teaming in complex systems, regardless of the phase of the engineering project — design and development, test and evaluation, or operations. Both studies are also great examples of how CASE embraces the lessons inherent in success and failure.

Since those early exchanges, we have expanded our programming and have held CASE sessions at many AIAA forums. The CASE community has evolved to include both practitioners and theorists. We have a core of energized professionals from industry, government, and academia who organize events that attract those who research and develop approaches to the engineering of complex systems. We have also hosted workshops and panels on developing engineers and the engineering workforce to deal with complexity. The work of the CASE organizers will be vital to the future given the rapid state of technology convergence in aerospace.

However, we have not fully engaged our core target audience. We initially sought to attract aerospace chief engineers, program managers, and systems engineers who face important system development challenges. These are your colleagues and co-workers who probably don't see AIAA as the organization that offers them practical tools that relate directly to their job responsibilities. Wilson Felder, in preparing for one of the early exchanges, correctly noted that designers, developers, testers, and program managers must be prepared to react with flexibility to changing requirements, opportunities for design modification, and insertion of new technology into previously designed systems. By concentrating on topics such as minimizing cost and schedule overruns, strategies for integration, test, and verification early in product life cycles, strategies for program management and integrated planning tools, we believe we are presenting and discussing the most relevant and pressing challenges that engineering organizations face as they deal with ever-increasing levels of system complexity.

As exemplified by Monterey Bay, with its spectacular biodiversity, remaining dynamically connected and balanced for the benefit of all inhabitants, the engineer of today must be prepared to think through the dynamic connectivity in engineered complex systems. Many of us know the hardware store jingle "Ace is the Place." To borrow that jingle, CASE is the place — to increase your knowledge and hone your skills necessary to succeed in an era of ever-increasing system complexity. Please invite a colleague who you feel would benefit from an exchange of best practices associated with complex aerospace systems to the next CASE program. You, your colleague, your organization, and AIAA will all benefit. ★

Thomas B. Irvine
Managing Director, Content Development

AERO PUZZLER

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

Time machine

When it is launched in 2021, the James Webb Space Telescope will look back in time at the early universe by collecting light that has been shifted to infrared wavelengths by the expanding universe. In 250 words or fewer, explain why the following statements are true or false: Webb could very well detect energy and particles that eventually coalesced into the sun, Earth and its 7.6 billion human inhabitants. Scientists could get a glimpse of the stuff that became us.

Email your response to:
aeropuzzler@aiaa.org

ABOUT THE AEROPUZZLER

Your task is to boil down a complex concept into a maximum of 250 words that anyone could understand (without equations or drawings). Email your response to aeropuzzler@aiaa.org by midnight Sept. 7 for a chance to have it published in the next issue. Include your city or town and a phone number (we won't publish it). For an early start, remember that each AeroPuzzler is published online on the first of the month at aerospaceamerica.aiaa.org.

FROM THE JULY/AUGUST ISSUE

GIANT FRUIT FLY

We asked whether a fruit fly as big as a Cessna could fly. An ideal answer would have discussed the concept of the Reynolds number (the ratio of inertial forces to viscous forces in the flow that increases with scale and impacts flow behavior) and also the square-cubed law (as the surface area increases, volume and mass increase at a faster rate). But given our 250-word limit, here is this month's winner:

The short answer is "no," and the simplest explanation is something called the "square-cube law." A fact of life in our three-dimensional world, when the size of an object increases, the volume and mass increase faster than the surface area. A fruit fly is properly sized for wing area and body mass at a typical length of about a millimeter. A 1975-model Cessna 172 is an inch under 27 feet long [8.2 meters]. A quick weight estimate for a 27-foot-long fruit fly, using the proportions shown in the picture and water density as an approximation for the fly's biomass, yields a weight in the 100,000 pound [45,000 kilograms] range, compared to the Cessna's 2,300 pound [1,000 kg] gross weight.

David Mayhew
AIAA senior member
Stratford, Oklahoma

UK fighter concept emphasizes stealth, next generation sensors

BY TOM RISEN | tomr@aiaa.org

Britain wants to build a twin-engine stealth fighter jet that the Defense Ministry says would enable the United Kingdom to stay competitive in air-to-air combat technology and maintain its domestic fighter industry.

Defense Secretary Gavin Williamson unveiled a full-scale model of the Tempest at the Farnborough Airshow in July as a commitment that the U.K. would remain "a world leader in the combat air sector."

The U.K. contractors chosen to design the plane must first present a business case for the fighter to the ministry by the end of the year to begin the approval process for funding. The ministry has promised to draw 2 billion pounds ($2.6 billion) for the Tempest over several years from the ongoing Future Combat Air System Technology Initiative enacted in 2015 that ends in 2025 to develop a successor to the twin-engine Eurofighter Typhoon.

Team Tempest shared limited details about the design in progress beyond the concept they showcased. With their near-diamond shape, the Tempest wings resemble those of the YF-23 stealth fighter demonstrator built in 1990 for the U.S. Air Force by Northrop and McDonnell Douglas, notes Adam Routh, an aerospace researcher at the Center for a New American Security in Washington, D.C. The YF-23 was flown in 1990 but lost the competition for the Air Force contract to what became the Lockheed Martin F-22 Raptor.

The F-22 engines include thrust vectoring to maneuver the plane around enemy aircraft at close range, which the YF-23 lacked. Thrust vectoring engines were not presented as part of the Tempest concept, possibly because "next generation stealth and guided missiles may undermine the benefits of maneuverability by allowing planes to attack from a significant distance," Routh says.

Retired U.S. Air Force Maj. Gen. Mark Barrett, who commanded the first operational wing of F-22 fighters, says improved electronics, including sensors and data fusion to monitor the battlespace, are the best chance for Tempest to "take a generational leap." Lockheed Martin's F-35, for instance, improved on the F-22 by adding a radar-absorbent coating that is more durable against heat conducted during supersonic flight, Barrett says. Concealing engines to minimize heat signature and avoid infrared detection, and supercruise flight at Mach speeds without an afterburner are other "pretty darn good" stealth strategies the Tempest could include, he says.

▲ **The Tempest** concept on display at the Farnborough Airshow.

Rolls-Royce

Team Tempest consists of the Royal Air Force's Rapid Capabilities Office, and U.K.-based contractors Rolls-Royce and BAE Systems, along with Leonardo and MBDA Missile Systems, which have British branches under the same Italy-based parent company.

Rolls-Royce aims to advance "the building blocks of the gas turbine," for Tempest by "going to higher temperatures, advanced materials, ceramics, composite materials," according to a company video clip of Conrad Banks, chief engineer for Rolls-Royce's Defense Future Programs.

Britain hopes to have a fleet of Tempests in service by 2035 if funding is approved and is expanded after 2025. The RAF's air combat fleet will include the Eurofighter Typhoon planes until at least 2040, according to a national air strategy also unveiled at Farnborough by Williamson, who called Typhoons "multirole combat aircraft." ★

APOLLO 11 | 50TH ANNIVERSARY GUIDE

Cities, agencies and museums across the U.S. and in some cases abroad are planning an array of activities to celebrate the 50th anniversary of the Apollo 11 lunar landing on July 20, 1969. Below is what we've learned so far. Stay on top of developments online at aerospaceamerica.aiaa.org. If you have an event to add to the online list, contact Debra Werner at werner.debra@gmail.com.

SEPTEMBER (DATE TO BE DECIDED)

Bookstores

The 2005 biography "First Man: The Life of Neil Armstrong" is scheduled to be re-released with a cover tied to the forthcoming movie of the same name. (see Oct. 12)

http://www.simonandschuster.com/books/First-Man/James-R-Hansen/9781501153068

OCT. 12, 2018

In movie theaters

"First Man: The Life of Neil Armstrong," based on a 2005 biography, will be released to U.S. theaters, with Ryan Gosling starring as Armstrong.

https://www.firstman.com/

NOVEMBER

Australia

The non-fiction book "Honeysuckle Creek: The story of Tom Reid, a little dish and Neil Armstrong's First Step" scheduled for release; tells how the director of a tracking station in Australia and his colleagues overcame technical challenges and storms to relay Armstrong's "one giant leap for mankind" transmission.

ONGOING THROUGH JULY 2019

Flagstaff, Ariz., where Buzz Aldrin, Neil Armstrong and Michael Collins trained for moon walks.

Lunar Legacy lectures on the scientific and cultural impacts of the moon landing. Second Wednesday of each month.

- Coconino Community College, Lone Tree Campus
- Free
- https://www.flagstaffarizona.org/lunarlegacy/

FEB. 14 - AUG. 23, 2019

Huntsville, Ala.

Apollo: When We Went to the Moon exhibit

- U.S. Space and Rocket Center
- Adults (13 and up) - $25; children (5 to 12) - $17; Children 4 and under, free
- https://www.rocketcenter.com/admission

DATES TO-BE-DETERMINED

Houston

Visitors get to imagine they are witnessing the history-making events from the Mission Operations Control Room, Visitor Viewing Area, Simulation Control Room and Summary Display Projection Room, which have been restored to their 1969 appearance, complete with vintage furniture.

- Space Center Houston at NASA's Johnson Space Center
- $29.95 adults, $24.95 children
- https://spacecenter.org/support/restore-mission-control/

JULY 13-20, 2019

Denver

ApolloPalooza, activities and events featuring astronauts and historians.

- Wings Over the Rockies Air & Space Museum
- To be decided
- https://wingsmuseum.org/wp-content/uploads/2018/05/Apollopalooza-one-pager-low-res.pdf

JULY 16, 2019

Cape Canaveral, Fla.

Apollo Celebration Gala alongside a Saturn 5 rocket

- Kennedy Space Center
- To be decided
- http://apollocelebrationgala.com/2019-event/

"I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon."

— President John F. Kennedy in 1961 before a joint session of Congress

JULY 16, 2019

Huntsville, Ala.

Participants will attempt to break Guinness World Record by launching 5,000 model rockets at 9:32 a.m. Eastern time to commemorate the launch of the Saturn 5 on this day and time 50 years ago

- U.S. Space & Rocket Center
- To be decided
- https://www.rocketcenter.com/admission

JULY 19, 2019

Huntsville, Ala.

A parade from the U.S. Space and Rocket Center museum to Courthouse Square, featuring the Lunar Rover replica from NASA's Marshall Space Flight Center. A street party with dancing after the parade.

- Parade route in downtown Huntsville and including Courthouse Square. Exact route TBD.
- To be decided
- https://www.rocketcenter.com/admission

JULY 19, 2019

Online

NASA TV to show anniversary celebrations at NASA facilities across the country.

JULY 19-21, 2019

Wapakoneta, Ohio

Birthplace of Apollo astronaut Neil Armstrong (60 miles north of Dayton) plans exhibits, science demonstrations, races and live entertainment.

- Neil Armstrong Air & Space Museum
- Free
- https://armstrongmuseum.org/summer-moon-festival-14

JULY 20, 2019

Huntsville, Ala.

Rocketfest Moon Landing Concert

- U.S. Space & Rocket Center
- To be decided
- https://www.rocketcenter.com/admission

"We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard."

— President John F. Kennedy at Rice University in 1962

JULY 20 (TENTATIVE), 2019

Wright-Patterson Air Force Base, Ohio

Newton in Space, a family day offering participants a chance to build and launch model rockets.

- National Museum of the Air Force
- Free
- https://www.nationalmuseum.af.mil/

JULY 20

Tucson, Ariz.

Summer Science Saturday features Apollo 11 lectures, displays and family activities.

- University of Arizona Lunar and Planetary Laboratory
- Free

JULY 24, 2019

Houston

Johnson Space Center Gala

- Johnson Space Center
- To be decided

ALSO HAPPENING...

Smithsonian National Air and Space Museum invites all interested to share their Apollo 11 moon landing stories at airandspace.si.edu.

Australia plans to release a commemorative coin and postage stamp to honor those who worked at tracking stations that relayed communications between astronauts and mission control and the Parkes radio telescope, which received signals from the Apollo 11 spacecraft and relayed them to Houston for international television broadcast.

Forum Highlights

Disrupting aircraft design and production

AIAA

Pradeep Fernandes, managing director of disruptive horizons at Boeing HorizonX

Companies must rely on new tools for design and development to meet shifting consumer demand with new types of aircraft, including electric vertical takeoff and landing, or eVTOL, vehicles, a group of executives and academics said during the "New Paradigms in Aviation" panel.

Maturing technologies, including autonomy and increased battery density, give companies opportunity to create "a new layer of transportation" not possible a few years ago, said Pradeep Fernandes, managing director of Disruptive Horizons at Boeing HorizonX, an arm of Boeing he said exists to "beat our own game."

The challenge for the aircraft industry, Fernandes said, is to pursue better fuel efficiency, and lower maintenance and crew operating costs for a new layer of transportation.

"If you cannot do that, you need a new unique capability that today's system cannot provide," he said.

Fernandes cited Boeing's ecoDemonstrator program — which test flies new technologies, including plant-based biofuel, every year on a commercial airliner — and referred to the eVTOL vehicle being test flown by Aurora Flight Sciences, the Virginia-based company acquired by Boeing last year. Aurora Flight Sciences CEO John Langford is the president of AIAA.

Additive manufacturing is an increasingly mainstream production method that promises lower costs and easier creation of aircraft parts in complex shapes, but "it has to be done with significant care," said Jack O'Banion, vice president of strategy and customer requirements with Advanced Development Programs at Lockheed Martin, also known as Lockheed Martin Skunk Works.

The challenge for additive manufacturing of aircraft parts is certifying them for safety with regulators, O'Banion said, calling certification "a whole science in itself."

"It has opened avenues of design that weren't there before," O'Banion said of additive manufacturing. "We are able to create new propulsion systems and other things that would have been impossible to machine a part to do."

— Tom Risen | tomr@aiaa.org

FAA rules change as demands of general aviation change

AIAA

Anna Dietrich, co-founder of Terrafugia

General aviation is transforming from a world of uniform, small aircraft to one of a mix of air vehicles, both manned and unmanned, and technology and infrastructure must adjust to accommodate new types of vehicles into the national airspace, a panel of experts said during the "Entering a New Era of General Aviation (Part 23)" session.

Wes Ryan, unmanned systems certification lead at the FAA, said safety in general aviation has improved over the past several years.

"We were flat in our fatal accidents for general aviation aircraft for a very long time, and over the last several years, we've seen a marked, measurable decline in fatal accidents in general aviation aircraft," Ryan said. "We believe that is from the technology initiatives and also coming from some of the training aspects that we've done and collective efforts for safety. But we'd like to give credit to a lot of the new technology and the new ideas that industry has brought to us like moving map displays, GPS, envelope protection autopilots, all of those kinds of things."

David Sizoo, an FAA test pilot, said there is still room for improvement with small airplanes.

"In general aviation in the United States alone, there is a fatal accident once every two or three days. We can do much better than that," Sizoo said, adding that he believes that fly-by-wire technology needs to become more affordable for general aviation pilots.

Anna Dietrich, co-founder of Terrafugia, said recent changes in the FAA regulatory schema for general aviation will help accelerate the transformation of the space.

Dietrich said before the Part 23 rewrite, it was meant for fixed-wing aircraft and that Part 27 was for rotor-wing.

"They were kind of self-replicating," she said. "You followed a very prescriptive set of rules, and you got a very predictable set of aircraft out the other end."

Dietrich said that during the Part 23 rewrite, the prescriptive language was removed.

"We took that all out," she said, adding, "Part 23 is a good solution for eVTOL and on-demand aircraft."

— Hannah Thoreson | hannaht@aiaa.org

AVIATION FORUM

- **2,896** Attendees
- **41** Countries represented
- **700** Students

Michael Swanson, left, chief engineer of advanced development programs at Lockheed Martin, and Bob Morgan, director of research and development at Scaled Composites

Global partnerships fuel F-35 program

The F-35 has required international partnerships and extraordinary collaboration between private industry and government, said industry experts during the "Reflection on the Partnerships Within the F-35 Enterprise" session.

"I can honestly tell you that in the over 30 years that I've been in the business ... certainly the F-35 program is unlike any other program I have worked on," said Frank Carus, vice president and F-35 program manager at Northrop Grumman.

Thomas Johnson, director of F135 weapon system integration for military engines at Pratt & Whitney, said that working together was a critical ingredient for program success and that the concept applies to companies, organizations and people.

"The trick in a big program like this is getting all three functioning," he said.

Eric Branyan, vice president of F-35 supply chain management at Lockheed Martin, said some international cooperation resulted in improvements on overall time, cost and quality.

"The partnerships are not just there to build the program," Branyan said. "The partnerships are there, really, to make the airplane a better part because of the sum of all those pieces together."

John Mazur, director of foreign military sales for the Pentagon's F-35 Joint Program Office, said the F-35 program is evolving and will keep accelerating.

"This program is nothing today like it was 20 years ago or 15 years ago," Mazur said. "The landscape for the international part is constantly evolving, and so every day, we have a new set of problems that comes scooting across our desks that we have to reach out and try to find some workable solution."

Panel moderator Graham Warwick, technology managing editor for Aviation Week and Space Technology, said that prior aeronautical programs also experienced setbacks.

"They all had tremendous problems either in development or in early service introduction," he said. "No program of that scale ever goes smoothly, and the F-35 is no exception."

— Lawrence Garrett | lawrenceg@aiaa.org

"If we don't get it right, right now, I don't think we are going to be able to do this again in 30 years."
— David Richardson, director for air vehicle design and technology at Lockheed Martin Skunk Works, on certifying commercial supersonic aircraft to fly over land.

"I would bet it's hundreds of billions of dollars going into this industry over the next few years."
— Davis Hackenberg, strategy adviser for urban air mobility at NASA's Aeronautics Research Mission Directorate.

"I am on my ninth startup, and five of them have worked."
— Bruce Holmes, vice president of digital aviation at SmartSky Networks

How to speed to prototype

Moving quickly from aerospace design to prototype can be daunting, but a few principles may help: Keep it simple; fail early and often; use existing technology; and perhaps most essential, have a great team.

A panel of aerospace experts outlined these factors for a successful and fast prototype launch during the "Rapid Spiral Development from Ground to Flight" session.

Scott Drennan, director of innovation at Bell, said there's a lot to learn from getting your hands on hardware because it feeds back into the design. "

I'm a big believer in the build," he said.

Bob Morgan, director of research and development at Scaled Composites, said doing the work in-house helps speed the path to prototype; he advised not to design something you can't build yourself.

Companies should keep it simple and resist design changes late in the process because they add cost and time, Morgan said. Look at what really needs to be done and then add from there; the simplest answer can be surprising.

For example, Morgan said, an aircraft with a pilot can be faster to prototype than an unmanned system, depending on the size of the aircraft.

"Sometimes it's easier to stick a guy into it," he said.

Another tenet: "Fail early and fail often," Morgan said. Fixing problems early saves time and money.

In addition, reuse what you know, said Michael Swanson, chief engineer of advanced development programs at Lockheed Martin. Costs can be reduced by a factor of four by simply using existing parts and technology. Skunk Works tries to bite off only one miracle per aircraft program, Swanson joked.

Panelists agreed that during this rapid process, both the team and the customer must have a high tolerance for risk and failure.

"It's not for the faint of heart," Swanson said.

— Michele McDonald | michelem@aiaa.org

Forum Highlights

Glenn director: Space exploration needs propulsion advances

Propulsion technologies are paramount to achieving the next era of space exploration, Janet Kavandi, director of NASA's Glenn Research Center, said during her "Propulsion and Energy: Enabling NASA Missions Today and Tomorrow" keynote.

Glenn is focused on a number of areas in thrust technology, including high-altitude and long-duration aircraft designs, passenger-carrying commercial aircraft — such as NASA's X-59 QueSST concept — and hybrid-electric commercial aircraft. Kavandi said she hopes "to see a commercial-size 150-passenger type of aircraft with hybrid-electric designs" within the next couple of decades.

Glenn is working on the X-57, an experimental, all-electrified aircraft system. Kavandi said the program's goal is to make the technology suitable for larger aircraft and that the biggest challenge is determining best packaging for the batteries.

"We're working on packaging those batteries to make them safer so that eventually we can find the best packaging for the high-density energy storage systems that we will need for the larger aircraft," Kavandi said.

Compact core technologies also must be advanced to make engines lighter and more efficient, Kavandi said.

"We're working on ways to develop the smallest core capable and the different materials that are required," she said. "3D printing will allow us to make smaller and smaller cores for future engines."

Two other major areas of focus for Glenn are the Hall thruster and ion propulsion designs, Kavandi said, adding that in searching for the right solution, NASA is trying a new concept.

"We're trying to go out and solicit what the state of the art is in industry on the commercial side and see how much of that we can take back and use at NASA without imposing so many specifications," she explained. "We want to start out with small-scale commercial landers, non-human-rated type landers, and eventually we'll get up to a human-rated lander."

The challenge is how to power these things in such an environment as the moon's, where there are 14 days of sunlight and 14 days of darkness, Kavandi noted.

"So, you need a system that can power through that whole time, so nuclear-generated power is probably the best way to go," she said.

The technology, radioisotope power systems, has already been in use for several years on such spacecraft as deep space probes, Kavandi said. But, she added, some of the biggest challenges of enabling RPS is getting the plutonium.

"It is a great power source, and it's very necessary to power a lot of these systems, but it's challenging to use, challenging to make and expensive to make," she said.

— Lawrence Garrett | lawrenceg@aiaa.org

Lessons learned from developing the F-35B's F135 engine and LiftSystem


AIAA

Carl McMurry, director of F-35 vehicle sciences and systems at Lockheed Martin

Lockheed Martin's F-35 program has benefited from a complex testing and integration process that involves several of the largest defense contractors working together, a panel of engineers said.

The F-35 development program ended in July 2016, but panelists in the "F135 LiftSystem Development: How Complex Systems Integration Works in Real Life" session discussed what they learned while developing the F-35B's F135 engine and LiftSystem.

"The testing included over 17,000 ground test hours on 14 engines, over 13,000 flight test hours on 18 aircraft," said Glenn Bartkowski, the F135 STOVL chief engineer at Pratt & Whitney. "You have to go test at the extremes of the flight envelope. Some of the testing we did was corrosion testing where the engine was exposed to salt for over 3,000 hours, rain testing where it ingested over 2,500 gallons of water, including rainfall rates of up to 23 inches per hour, as well as a sand test where the propulsion system ingested over 100 pounds of sand successfully. ... In addition, we also obviously did the ballistic testing and fuel ingestion testing that was required to meet the survivability requirements."

Carl McMurry, director of F-35 vehicle sciences and systems at Lockheed Martin, shared a few lessons he learned from the development phase.

"You don't start and say 'I want to develop all these new technologies and integrate them on the airplane,'" he said. "You start well ahead."

McMurry said that some new technologies were tested first on the F-16 since it is a well-studied aircraft. He also advised not to wait to solve problems.

"The worst thing you can do is sit on a problem for a while and then it becomes bigger, because we've got 305 airplanes out there," he said. "We're trying to get problems solved as fast as we can."

— Hannah Thoreson | hannaht@aiaa.org

- **1,407** Attendees
- **29** Countries represented
- **375** Students

PROPULSION ENERGY FORUM

AIAA

Mary G. Adams, co-founder and program manager of the Greater Cincinnati STEM Collaborative

Aerospace is hiring for now and the future

The aerospace industry is dealing with the problem of needing to reach out to elementary students to build a workforce pipeline while hiring people right now, panelists said during the "Workforce Challenges and Policy Initiatives to Support the Propulsion and Energy Industry" session.

Steven Justice, panel moderator and executive director of the Centers of Innovation at the Georgia Department of Economic Development, said aerospace jobs are available but tough to fill.

Panelists said strategies to address the issue of hiring for now and the future include K-12 STEM education, mentoring, attracting military veterans, and communicating excitement and purpose about the work.

Engaging elementary students in STEM is vital for the future but doesn't help with today, said Gary Mercer, vice president and general manager of the Engineering Division at GE Aviation.

"I can't wait 11 years," he said.

Mercer had a message for universities: Students who are struggling need support, not flunking out and leaving the field.

This is especially true of students who are from lower-income areas and didn't have access to STEM activities in K-12, Justice said. Bringing broadband access to rural areas is akin to the electrification of America in the last century and just as essential in bridging the STEM gap, he said.

Community colleges can be game changers because they're a better economic value than four-year universities for many technology fields, said Mary G. Adams, co-founder and program manager of the Greater Cincinnati STEM Collaborative.

"You're paying less to earn more," Adams said. "The community colleges are really part of the solution."

— Michele McDonald | michelem@aiaa.org

"Avoid those people who say they are using best practices, because by definition, a best practice is an old practice."

– Christopher Clay, program manager of DARPA's Tactical Technology Office

"Today, almost every new rocket engine has additive manufacturing."

– Nicholas Case, lead for liquid engine system analysis at NASA's Marshall Space Flight Center

"The worst thing you can do is sit on a problem for a while and then it becomes bigger."

– Carl McMurry, director of F-35 Vehicle Sciences and Systems at Lockheed Martin

Future of hypersonics

AIAA

Douglas Blake, director of the Aerospace Systems Directorate at the U.S. Air Force Research Laboratory

The U.S. aerospace sector can encourage research to benefit the emerging and competitive field of military and even commercial hypersonic flight, a panel of executives and government officials said during the "Future of Hypersonics Research and Development" session.

Hypersonic weapons and military aircraft have been around for 60 years, but advancing the science requires new ways of thinking, said Christopher Clay, program manager of DARPA's Tactical Technology Office. Clay encouraged the audience to find the disrupters in their organizations.

"Avoid those people who say they are using best practices, because by definition, a best practice is an old practice," he said.

The lion's share of hypersonic research the U.S. Air Force is doing is directed at air-breathing and boost glide expendable vehicles, including missiles, which are "becoming close to operationalized," said Douglas Blake, director of the Aerospace Systems Directorate at the U.S. Air Force Research Laboratory.

That research into expendable vehicles must be successful to maintain interest in hypersonic research and to develop techniques that will lead to more far-term technologies, Blake said.

During the AIAA Aviation Forum in June in Atlanta, Boeing unveiled a concept for a commercial airliner that would travel at Mach 5. Kevin Bowcutt, chief scientist of hypersonics at Boeing, is leading that effort.

"The foundation under which we are working is not as strong as it could be," Bowcutt said of U.S. hypersonics research. "Hypersonic funding has been very cyclic."

Bowcutt said people have left the field of hypersonic research because of inconsistent government funding.

— Tom Risen | tomr@aiaa.org

AIAA

Lockheed Martin Skunk Works chief Jeff Babione speaks at AIAA's 2018 Aviation Forum.

Q&A

Out of the fish bowl

When he was managing Lockheed Martin's F-35 program, Jeff Babione liked to say that it was like working in a fish bowl. Congress and reporters were digging into the over-budget and delayed program, and one of Babione's jobs was to vigorously make the case that the program was getting on track. Babione now finds himself in the opposite of a fish bowl, having moved over in June to head the company's secretive Advanced Development Programs business in California, better known as Skunk Works. Work is underway there on the SR-72 spy plane, hypersonic weapons, a NASA X-plane and other technologies that only those with the right clearances know about. I spoke to Babione at the AIAA Aviation Forum in June about perceptions of the F-35 program and whether the fabled Skunk Works culture can survive with so many billions of new dollars flowing into the business unit.

— Ben Iannotta

JEFF A. BABIONE

POSITIONS: Since June 2018, general manager, Lockheed Martin Advanced Development Projects, also known as Skunk Works. 2016-18, Lockheed Martin executive vice president and general manager in charge of the F-35 program; 2013-15, vice president and deputy general manager for F-35; 2012-13, vice president and general manager for the F-15/F-22 Integrated Fighter Group; 2010-12, vice president in charge of the F-22 program; 2006-10, chief engineer for the F-22.

NOTABLE: The shift to Skunk Works puts Babione at the helm of a research and development culture, after 25 years spent largely in development and production of fighter aircraft. A structural engineer by training, Babione joined Lockheed Martin in 1993. As the F-35 deputy, Babione led the implementation of the "Redesign for Growth" strategy in which manufacturing processes were restructured to accommodate expanded production. As general manager, he shepherded the F-35 program to completion of system design and development testing and to declarations of initial operational capability by the U.S. Air Force, Marine Corps and Israeli Air Force.

EDUCATION: Master of Business Administration from the University of Tennessee in Knoxville, 2008; Master of Science in aerospace engineering, University of Washington, 1991; Bachelor of Science in aerospace and ocean engineering, Virginia Tech.

FAVORITE SAYING: "No one of us is as smart as all of us."

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IN HIS WORDS

Misperceptions about the F-35

I would say it this way: It has had a strong headwind from a political standpoint. I don't disagree that the [F-35 program] should get a lot of focus. But with this 24-hour news cycle, the ability for anyone to write an article about anything, we don't often get the context. One of the [audience members at AIAA's Aviation Forum raised a news account saying] that [the F-35] is not as good as the F-16. That's a sound bite that came out about five years ago, but it was reported again just about a year ago. The test was designed to find the limits of [the F-35]. Go talk to the guys that fly the F-35 now. They would never hop in an F-16. It's a target in their world. They're like, "This airplane is so much better," because it's not about any one bit, it's the overall weapon system, the aircraft.

Stealth as a necessity for fifth generation fighter aircraft

If you're in Afghanistan, there are no surface-to-air threats. But if you're [facing a better-equipped adversary] and the troops are in contact, there won't be any airplanes overhead that aren't stealth airplanes [like the F-35] because they'll be shot out of the sky by the surface-to-air missiles. You quickly get to a place where there aren't any fourth gens. None. So, if you're in an uncontested environment, sure, an A-10 can go in there. But if you're in a contested environment, the A-10 wouldn't get within hundreds of miles of there without being destroyed.

More quality, less cost

That happens because we've continued to change the way we build the airplane, improve the quality of the airplane. During the manufacturing process, we occasionally don't perform a step correctly, and we have to do what's called rework. And that takes time that normally would go in to having the airplane flow through the line faster. We're looking at every time we don't do it quite right and finding a way to prevent it from happening again. What I'm referencing is in-process quality. How many times did I have to redo something or change, correct something in the build? By the end of the day, the airplane meets all requirements because the U.S. government has the accountability to sign off on the airplanes.

Achieving an $80 million F-35

Reducing the in-process errors; challenging the supply chain to invent new technologies that actually give you the same or better capability for a lower cost — that's how we're going to get to an $80 million airplane [from $94.3 million for an A model F-35]. I'm incredibly confident. I've seen what we need to do to get there. It's not easy, but it's not as hard as it was to develop the airplane. There are levers, and [production] numbers is the most important. Why is it more cost-effective to buy at Costco? You're getting a discount because of the quantities of the things that you're buying. About 80 percent of that cost reduction is getting up to a number of airplanes to reduce the cost.

"Go talk to the guys that fly the F-35 now. They would never hop in an F-16. It's a target in their world. They're like, "This airplane is so much better.'"

Staying "Skunk-like"

We are working in an acquisition system that's completely different than when [Skunk Works founder Clarence "Kelly" Johnson] started. And so it becomes more difficult to remain Skunk-like. That doesn't mean that we aren't doing it. That's why I think our customer continues to come to the Skunk Works. We can do things quickly and quietly faster than others and more affordably. We do need to be cautious not to get too big, because that culture is unscalable to a lot of things. You see us take things to a certain point like an X-plane, and then we give it to the broader company to go execute, because you don't want to compromise what we have in these small teams and that's what we continue to do.

Managing new Skunk Works contracts

Certainly that is a challenge but one I think that we're up to. The good news is, even though ADP [aka Skunk Works] is only around, say, 3,000 people, I have access to the broader 20-plus-thousand people at Aeronautics as well as the close to a hundred thousand across the corporation. So it's very common to be in one of my programs. I will have people from Marietta [Georgia] or Fort Worth [Texas], where our largest footprint is. I might have somebody from Missiles and Fire Control out of either Orlando [Florida] or the Texas location, or I might have somebody from Space systems working collaboratively on these things.

Finding enough of the right workers

We're aggressively hiring here [at AIAA's Aviation Forum], and so you will see our talent people here leading that. We have our engineering hiring manager here looking to find new hires, both college and experienced. We're hiring a significant number of men and women to staff the existing contracts as well as prepare ourselves for new contracts.

Supersonic X-plane

That's a really exciting program to finally see NASA back into the X-plane business. It gives our engineers a chance to do an X-plane that they haven't done in a long time. You can come to Lockheed Martin tomorrow right out of college, go work for ADP and work on an X-plane. How many times can you say it? It's a unique opportunity. ★

Making 3D-printed parts for Boeing 787s

Companies face an array of crucial technical decisions as they pioneer additive manufacturing techniques for parts on commercial aircraft that must carry hundreds of passengers safely to their destinations. Henry Canaday chronicles one company's journey to get its parts onto Boeing 787s.

By HENRY CANADAY | htcanaday@aol.com


Boeing

▲ **A Boeing 787** on the assembly line in Everett, Wash.

Two kinds of additively manufactured parts on today's Boeing 787s offer a study in contrasts between techniques for additive manufacturing, also called 3D printing, and the kinds of companies that do this work.

Consider first the fuel nozzles in the GEnx engines that power more than half of 787s. They were made in Auburn, Alabama, by the additive manufacturing unit of the century-old, $120 billion-a year industrial giant GE through a process centered on fusing metal powder with lasers. Next, consider the 33-centimeter-long titanium fittings that anchor the floor of the aft kitchen galley to the 787 airframe and bear structural stresses. These were made in Oslo, Norway, and Plattsburgh, New York, by the Norwegian company Norsk Titanium, an 11-year-old firm of about 140 employees. Norsk applied an entirely different technique tailored for larger structures.

For Norsk, several early decisions determined its path to production.

In theory, Norsk could have started by making parts for business sectors other than aerospace, since those sectors are less regulated. From its startup in 2007, though, Norsk elected to make aerospace parts. "We wanted to take on the hard one first," explains Chief Technology Officer Carl Johnson, a mechanical engineer who joined Norsk in 2016 from Northrop Grumman. If Norsk could meet the standards of this most demanding sector, it could offer its additive manufacturing to any market, something it has begun doing.

Some firms sell specialized machines for additive manufacturing, but Norsk decided early on "to make parts, not sell machines," Johnson says. In fact, in its early days, Norsk had about as many metallurgists as machine designers. The metallurgists were essential for Norsk to meet the rigorous requirements, including strength and uniformity, of the aerospace sector.

Norsk decided to focus on titanium partly because of the metal's increasing importance in aviation and partly because it is very expensive at nearly $7 per gram. One big advantage of additive manufacturing is that it cuts the buy-to-fly ratio, that is, the volume of material that must be purchased relative to the volume in the finished part. When parts are machined, excess material must be scrapped or expensively recycled. Additive manufacturing leaves much less leftover material to be recycled. By working with titanium, Norsk would be saving plenty of a high-value metal compared to machining.

Norsk elected to build large titanium structural parts, hence the galley fittings. The question was which basic additive technique the company should adapt to meet its needs. Most aerospace firms have concentrated on powder bed fusion, also known as direct metal laser sintering. In this technique, lasers or electron beams melt and fuse powdered metals. This is how GE printed its fuel nozzles.

But powder bed is really suited for small, intricate parts, such as GE's nozzles, says Norsk Chief Commercial Officer Chet Fuller, who joined the company in 2015. It is a slow process in which a few dozen grams of metal are laid down per hour. Norsk would be producing parts weighing 2 kilograms or more. "Powder takes too long for that," says Fuller. Norsk wanted a technique to produce parts on an industrial scale of kilograms per hour.

To do that, Norsk developed its own version of direct metal deposition, a technique in which

“We went from very large machines to smaller ones, we even looked at robotic arms. What we eventually came up with was a machine that reduced variability and enhances control.” — Norsk Chief Technology Officer Carl Johnson

metal powders or wires in the case of Norsk are deposited into shape via a plasma, with dimensions and material integrity managed by a control system. Norsk calls its patented technique Rapid Plasma Deposition, or RPD, and it built its own machines to do it.

As with all additive techniques, the process starts with a computer assisted design drawing of the part to be printed. This data is entered into a control system programmed to generate deposition coordinates for the part. These coordinates are fed into the production machine, the latest of which is Norsk's Merke 4.

Norsk's titanium wire starts out at room temperature and is fed into inert argon gas atmosphere in the Merke 4's build chamber. An electrode in a torch forms a plasma arc that is forced through a nozzle and exits at high speed and a very high temperature. This arc in turn raises the wire's temperature by thousands of degrees, momentarily

▲ **Norsk Titanium technicians** watch a process the company has patented called Rapid Plasma Deposition, in which the company produces 3D-printed parts quickly on an industrial scale.
Norsk Titanium

melting it into a liquid that is laid down according to the computer drawing. Once laid and separated from the arc, the liquid cools and solidifies in milliseconds. Then the process repeats to lay down the next layer. When the part is fully formed into its basic shape, it is machined into its final shape.

Norsk chose a wire feedstock rather than titanium powder because wire has a higher deposition rate and is thus faster to lay down than powder. And metal powders, which must be atomized from bar stock, can be extremely expensive. Very expensive powder could reduce or eliminate the advantage in buy-to-fly ratio. Titanium wire costs more per kilogram than bar stock, but "not dramatically so," Fuller notes.

The engineers looked at various standard diameters of titanium wire that are produced in large and therefore affordable volumes. They found the most efficient diameter was 1.6 millimeters. Suppliers of this standard titanium wire must only meet Norsk's specifications for the wire's twist and cleanliness.

Direct metal deposition processes usually must operate in a vacuum. Norsk chose plasma with positive pressure and no vacuum because it makes loading and unloading parts more efficient. There was no need to create vacuum conditions for each new part, which takes time and slows production.

Norsk has adjusted the design of its Merke machines through four generations.

"We went from very large machines to smaller ones, we even looked at robotic arms," Johnson says. "What we eventually came up with was a machine that reduced variability and enhances control."

Norsk had its first machine, the relatively simple Merke 1, up and running in 2008. By 2010, the second-generation Merke 2 was in operation. This machine applied dual-torches to produce the plasma arcs and to make test parts for qualification and delivery to customers. This was the prototype that cleared the way for development of the RPD process.

By 2012, Norsk had moved on to the Merke 3. Like Merke 2, its six-axis robots manipulated the torch head and substrate, the surface on which printing is done. Norsk improved the processing monitoring system and made proprietary upgrades for manufacturing larger and more complex parts. This is the version that made sample titanium materials for FAA material testing.

The current machine, Merke 4, was ready by 2015. In this version, computerized numerical controls rather than robots manipulate the torch head and substrate. Norsk designed Merke 4 for serial production with further upgrades in its monitoring and closed-loop control systems. Merke 4 can build parts up to 900 millimeters by 600 mm by 300 mm, depositing titanium rapidly at five to 10 kg per hour, the company says.

Norsk says its monitoring and control systems are highly proprietary and crucial to its success. The Merke 4 now monitors 600 parameters per second as a part is printed. The sampling rate for each parameter is chosen according to how often tests have shown the parameter can change. Parameters for electricity, both voltage and current, are sampled at very high rates. Sampling covers the current between the work piece and the plasma and the current between the wire and the gas that is melting the wire. Sensors sample other parameters at different rates, according to how often they might change.

Monitoring of some parameters feeds back to the production machine, controlling its operation. That is the closed-loop part of monitoring. Other parameters are just monitored to prove that a part has been produced under required conditions.

A major goal of control and monitoring is to ensure that the microstructure of each part is homogeneous and meets specifications.

"We are unique in the way we control our process and the way we document our process," Johnson stresses. "We are meticulous in our record-keeping and very consistent in our quality."

For installation in aircraft, regulators must certify the additive process itself, the materials produced by the process and the specific parts produced. The first two certifications are the toughest, and took years to achieve. Once that was done, it took about 10 months to certify the 787 fittings in 2017.

Norsk produced and tested roughly two tons of materials and parts to obtain certification of its 787 parts. That meant 2,000 individual specimens at a cost of $700,000, in addition to the cost of manufacturing the test material itself. "Testing wasn't difficult, just time-consuming and expensive," Johnson says.

Apart from satisfying customers and regulators, meticulous monitoring also provides a big economic advantage. Unlike some additive processes, which are certified machine by machine because each machine may differ slightly in its operation, all three Merke 4s in Norway and now nine in upstate New York have been certified by FAA. Norsk can thus achieve its aim of producing parts at industrial scale.

For about a year now, Norsk has been producing four parts, and three part numbers, for 10 Boeing 787s per month. The near-net shape parts produced by Norsk are machined to final parts by a supply-chain partner.

This machining generates some scrap titanium, but not nearly as much as cutting parts from blocks. Fuller estimates that a typical 2 kg structural titanium part on an aircraft would have to be cut from a 30 kg block, generating 28 kg of scrap. The same part, printed by Norsk and machined to final shape, would require only 6 kg of titanium wire.

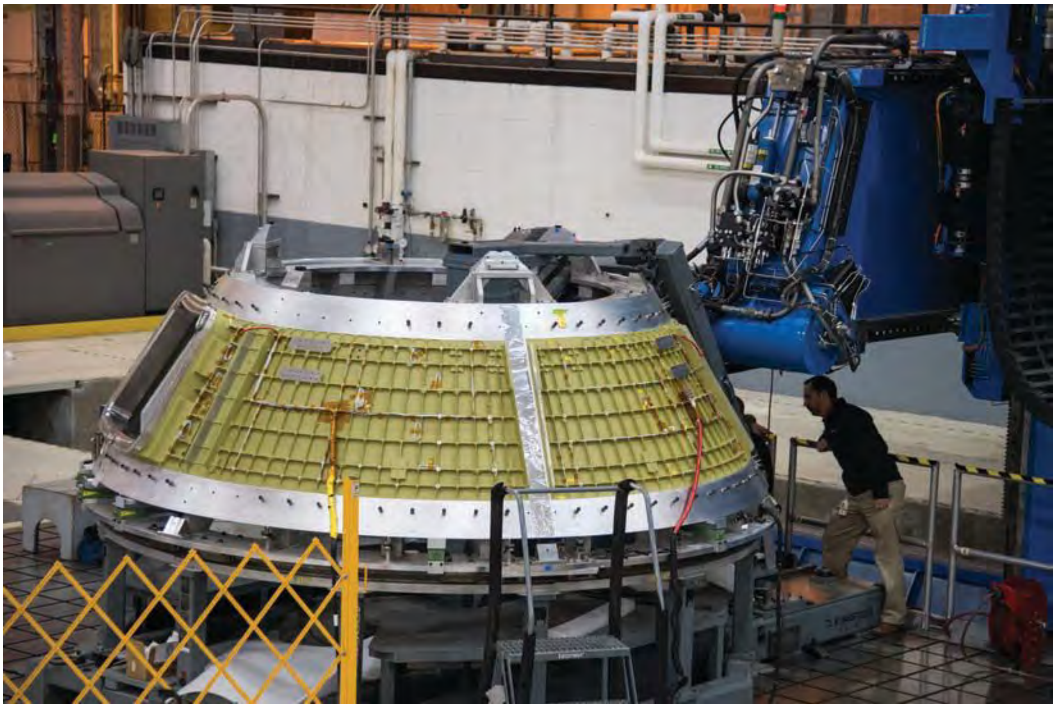
That's money in the bank for Boeing and Norsk. ★

Moon ship rising

▲ **Technicians move the Orion crew module** for Exploration Mission-1 toward the thermal chamber in the Neil Armstrong Operations and Checkout Building high bay at NASA's Kennedy Space Center in Florida.
NASA

NASA's Orion spacecraft is intended to fly astronauts into lunar orbit on regular visits to a planned deep-space platform called the gateway. Orion's second test flight, Exploration Mission 1, will likely launch aboard a NASA Space Launch System booster in early 2020. Veteran astronaut Tom Jones recently visited the Orion assembly line at Kennedy Space Center to assess the craft's progress and path into translunar space.

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



NASA

▶ Lockheed Martin engineers at NASA's Michoud Assembly Facility in New Orleans weld the cone section for the Orion spacecraft that will carry humans beyond the moon on Exploration Mission-2. The EM-2 crew module was scheduled for delivery at Kennedy Space Center in Florida in late August.

I've seen my share of space hardware, and flew into orbit aboard some of it, but inspecting a spacecraft bound for the moon is something special. In mid-May, I received a close-up tour of Orion, a four-person ship capable of extended flight to and around the moon. The spacecraft is undergoing final assembly in Florida at the Kennedy Space Center Armstrong Operations and Checkout Building. Managers from NASA and Lockheed Martin, the spacecraft's builder, walked me around the assembly floor to give me a sense of how this moon ship is coming together, and what challenges remain before Orion's launch.

Orion is sized to support a crew independently on a 21-day lunar mission. The spacecraft can also dock at the planned Lunar Orbital Platform-Gateway for up to a year, drawing power and consumables from that outpost. An early version of Orion completed two unmanned orbits around Earth in 2014 and splashed down off California in Exploration Flight Test 1. The next Orion will undertake an uncrewed lunar voyage in early 2020 called Exploration Mission-1. EM-1 will be a critical checkout of Orion's guidance, propulsion, communications and thermal control systems in advance of the first crewed Orion mission, EM-2 in 2022.

Mark Kirasich, NASA's Orion program manager, tells me his team is finishing "the paper-intensive parts of the program — where you're changing requirements and you're moving designs on the PowerPoint charts — and we are really starting into production mode."

His Orion team is simultaneously pursuing five major campaigns to make EM-1 a reality. The first is to finish assembly and testing of the EM-1 spacecraft. The second is to complete the welding of the EM-2 crew module (scheduled to happen in July) and ship it from the Michoud Assembly Facility in Louisiana to Kennedy (scheduled for August). The third task is to continue to procure and machine the thick aluminum sheets for the hull of the EM-3 crew module, marking the shift from developmental spacecraft to series production. The fourth is to fly the high-altitude Ascent Abort 2 test at Kennedy in April 2019. The fifth task is to prove Orion's readiness for flight with the full-scale avionics and structural qualification versions in Denver and the propulsion system at NASA's White Sands, New Mexico, facility. "There is more hardware and software in manufacturing, integration and test than we've ever had before," Kirasich says.

Preparing for deep space

Kirasich describes EM-1 as "where we are trying to demonstrate and validate all critical systems to take people to low Earth orbit, to the moon and back again, and then re-enter the Earth's atmosphere on a high-energy lunar return."

The uncrewed Orion will be injected on a lunar trajectory by the Space Launch System's Interim Cryogenic Propulsion Stage (ICPS, based on the Delta Cryogenic Second Stage flown on the Delta 3 and 4 boosters). Orion will perform a close lunar flyby and then, with a burn of its orbital maneuvering system engine, swing into a distant retrograde orbit around the moon. Orion will stay in this stable lunar orbit, roughly 70,000 kilometers above the moon, and farther from Earth than any human-rated spacecraft has ever traveled — until its extended deep-space systems checkout is complete.

To achieve the requirement of a daylight launch and Earth landing, Orion will remain in the distant retrograde orbit for either one or two 14-day revolutions, then perform an Earth-return maneuver to splash down in the Pacific. Adding the round-trip transit time to the moon, EM-1 will last between 26 and 42 days.

Some assembly (still) required

What I saw nearing completion at Kennedy were two major components of Orion's crew module: the pressure vessel (or cabin) and the heat shield. I also saw the U.S.-built crew module adapter: the structural, power and fluids bridge between the crew module and the European Space Agency service module. Together, the launch abort system and the crew and service modules comprise the complete Orion spacecraft, to be stacked atop a Space Launch System booster on its inaugural launch.

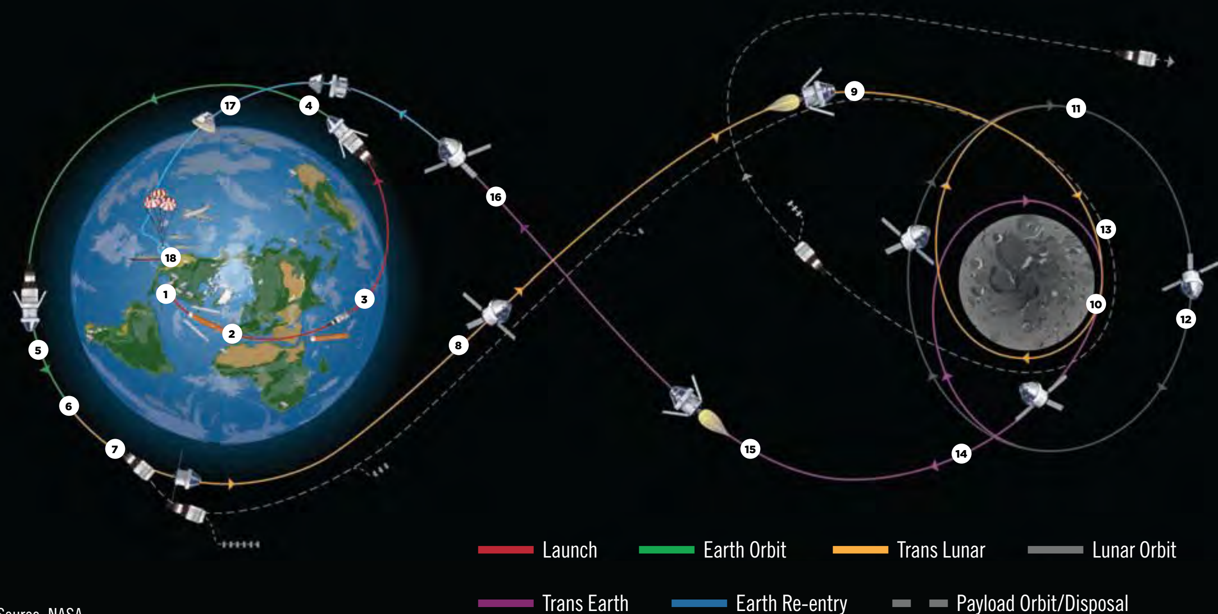
The ESA service module is not yet at Kennedy. The service module, based partly on ESA's Automated Transfer Vehicle cargo spacecraft, is being assembled by Airbus in Bremen, Germany. ESA is furnishing the service modules for the EM-1 and -2 flights, and Kirasich says discussions have started on procuring the modules for EM-3 and -4. The EM-1 service module was scheduled to be flown to Kennedy in early September.

Scott Wilson, who manages production of Orion for NASA at Kennedy, says the service module is "a whole new piece of hardware that we didn't have

One Plum Brook test will vent the cabin interior to vacuum to see whether spacecraft systems can withstand a cabin leak and keep the suited astronaut crew alive during a three-day return to Earth.

▼ **An engineer at the Armstrong Operations** and Checkout Building, housing the Orion assembly line, completes the instrumentation of the crew module's ablative heat shield for Expedition Mission 1. NASA

Around the moon and back



Source: NASA

Exploration Mission-1, the first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, is scheduled for 2020 from Cape Canaveral, Florida.

1. Launch: SLS and Orion lift off
2. Solid rocket boosters separate
3. Core stage separation; launch abort system jettisoned
4. Enter Earth orbit
5. Earth orbit: Systems check and solar panel adjustments
6. 20-minute translunar injection burn
7. Interim cryogenic propulsion stage separation
8. Outbound transit: several attitude maneuvers and optical navigation checkout
9. Outbound trajectory correction: adjusts trajectory for lunar insertion into distant retrograde orbit
10. Outbound powered flyby of the moon: results in insertion into distant retrograde orbit; 100 kilometers from the moon
11. Orbit insertion: enter distant retrograde orbit for 6-10 days
12. Distant retrograde orbit: burn maneuver and solar panel adjustment; 60,000 kilometers from the moon
13. Return power flyby: RPF burn prep and return coast to Earth initiated
14. Return trajectory correction burn prep; travel time 6-10 days
15. Return trajectory burn: precision trajectory burn aiming for Earth's atmosphere
16. Final return trajectory correction: precision targeting for Earth entry
17. Enter Earth's atmosphere
18. Splashdown in Pacific Ocean off the coast of Baja, California

with EFT-1 [Orion's first test flight in 2014]. … This period of working together with [the Europeans] has been a learning curve that I think we got through pretty well."

At Kennedy, engineers will bolt the crew module adapter to the top of the service module, weld fluid fittings, and mate electrical harnesses. After power-on functional tests and an initial run through the thermal/vacuum chamber, the service module will be mated with the crew module in early 2019.

The EM-1 spacecraft will then be flown to Ohio for high-stakes environmental qualification tests in the massive Plum Brook Station thermal/vacuum and acoustic chambers. During 60 days at vacuum, Orion will be baked and frozen to test its thermal control systems. Chilling the 30-meter-diameter, 37-meter-tall chamber to deep space conditions will consume eight tank trucks of liquid nitrogen daily.

One Plum Brook test will vent the cabin interior to vacuum to see whether spacecraft systems can withstand a cabin leak and keep the suited astronaut crew alive during a three-day return to Earth. To enable vacuum operation, Orion's avionics and life support systems are conduction-cooled via water-chilled cold plates. (The space shuttle cabin systems were cooled by forced air circulation and cold plates.)

Plum Brook was chosen because "it's a one-stop shop" for environmental testing," says Wilson. The


European Space Agency/NASA

facility will test Orion's ability to withstand launch and abort vibration and sound levels, just as intended during the Constellation return-to-the-moon program canceled in 2010. "In Constellation, we invested in upgrading the chamber and put in a very large shaker table that is capable of shaking the Altair lunar lander," he says. "For Orion, our biggest acoustic input is from the launch abort system. It's about 172 decibels, which is really unheard of. It's about eight times more powerful than anything in the world in terms of size and acoustic volume." The Plum Brook acoustic generators will subject Orion's structures and cabin insulation to the intense sounds and vibrations characteristic of the launch abort motor firing just a few meters above the crew module.

Once Orion returns to Kennedy, Lockheed Martin will make necessary modifications, complete final qualification tests, and turn the spacecraft over to Kennedy ground operations by October 2019. After handover comes fueling and integration with the launch abort system, followed by stacking atop the SLS rocket for launch.

▲ **In 2016, the European** Space Agency's service module structural test article underwent testing at Kennedy Space Center. Visible are the large main engine nozzle below and the smaller, red, auxiliary thrusters surrounding it.

First crewed mission

EM-2's pressure vessel, the airtight aluminum shell housing the crew, was scheduled to arrive at Kennedy by September. Technicians will then outfit this pressurized core with structural ribs, electrical harnesses, propellant tanks, and fluid lines to fashion the crew module.

If EM-1 goes well, NASA hopes to fly the EM-2 version of Orion with astronauts aboard in 2022. The moon is also EM-2's destination, but the flight plan will be conservative. Because EM-1 will have flown without a full life support system, the EM-2 mission will first test that vital system in Earth's vicinity.

After an SLS launch, Orion's crew will test their systems for two revolutions in low Earth orbit. With all well, the ICPS will reignite to place Orion in a very high, 24-hour Earth orbit with a 71,500-km apogee and 230-km perigee. Once separated from the upper stage, Orion will perform another day or two of life support and propulsion checkouts before committing to the moon. Given a "Go" by Mission Control, Orion's service module main engine (a refurbished shuttle orbital maneuvering system engine) will propel the spacecraft onto a free-return lunar flyby trajectory.

On EM-2, the crew will not drop into lunar orbit, but take only an extended swing around the lunar far side. This free-return path protects against a propulsion failure, although the service module's auxiliary thrusters are designed to back up the main engine. Notably, the flyby will take Orion some 8,890 kilometers beyond the moon, farther from Earth than any humans have ever traveled.

To prevent the service module's re-entry debris from striking land, Orion will aim for a landing in the Pacific Ocean off California. Mission duration from launch to splashdown will total 10-14 days.

Orion and the gateway

Starting with EM-3, Orion production will be paced at one per year, with crews delivering and installing successive components of the Lunar Orbital Platform-Gateway in a "near-rectilinear halo orbit" about the moon. If you could see a spacecraft in this orbit from the vantage point of Earth, it would appear to circle the moon's poles in a plane perpendicular to the Earth-moon line. For the gateway, the halo offers orbit stability, low fuel requirements for orbit maintenance, and excellent communications and visibility to both Earth and moon. The design orbit has a seven-day period, with a 71,000-km apolune over the lunar south pole and a 3,350-km perilune that offers good remote sensing and later, an advantageous departure point for the lunar surface. One drawback: Orion can abort to Earth from this halo orbit only once a week; in case of a serious emergency, the gateway will serve as a safe haven.


NASA

▲ **In January 2018, Kennedy Space** Center's NASA recovery team spent a week aboard the USS Anchorage off the coast of San Diego, where they and the U.S. Navy practiced recovering a crew module mockup ahead of 2020's planned Exploration Mission-1.

The first gateway component, a power and propulsion element, will be launched commercially into this halo orbit by a Delta 4 or Falcon Heavy. Orion's EM-3 mission will bring along the second element, a habitation module, and dock with the power and propulsion element, inaugurating the gateway.

EM-3 and subsequent Orion missions will launch on SLS boosters equipped with exploration upper stages, more powerful than the interim cryogenic propulsion stage on EM-1 and -2. The added thrust will deliver the velocity change needed to carry 10-metric-ton gateway elements like the habitat module (crew quarters), airlock, partner modules and cargo containers. Docking missions require Orion to withstand larger structural loads, and to maneuver precisely, so EM-3 and later spacecraft will need software upgrades and physical reorientation of the aft thrusters.

Challenges — and excitement — ahead

Kirasich says that one difficult challenge for EM-1 is to qualify remaining parts before they are installed on Orion. Late qualification failures mean that corresponding parts on the spacecraft must be pulled and modified back at the manufacturer, a time-consuming process just completed for inertial measurement units and some phased array communication antennas. Kirasich is seeing steady progress, but the qualification process is still only 60 percent complete.

One problem overcome was the qualification of the beachball-shaped airbags that tip the conical crew module upright, onto its broad heat shield, after splashdown. On EFT-1, three out of five didn't fully deploy. To retire the risk of leaving the crew dangling from their seat straps, more than a dozen design, manufacturing and installation changes were made to ensure proper airbag function.

NASA's Wilson is aware of the significance of the approaching EM-1 flight. "As a little kid I watched the Apollo launches, and I was so excited about that stuff. Now, being in the same building [where Apollo was tested] and building things that go beyond where Apollo could go — being part of that is amazing. The closer we get to launch, the more excited I get."

Building and flying these moon ships now seems to be a national commitment, at long last. The Orion I saw coming together represents U.S. leadership in space — at the moon, the asteroids and Mars — for a generation. Details of our path may change, but Orion demonstrates to me our determination to chart new frontiers in space — and soon. ★

SOFT targ

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Cybersecurity attacks on airlines and their partners are neither a matter of if nor when. They are already happening with serious consequences. Joshua Hatch spoke to independent security experts and aviation executives about the greatest threats ahead.

BY JOSHUA HATCH | hatchjt@gmail.com

In 2015, an attack on LOT Polish Airlines' ground network left 1,400 passengers stranded. Last year, a breach of Delta Air Lines may have compromised as many as several hundred thousand passenger credit cards. At least several aviation companies were targeted by the Russian government as part of its broad intrusion into American infrastructure in early 2017. And in November 2017, a researcher with the Department of Homeland Security said he managed to penetrate the computer network inside a Boeing 757 the year before, though Boeing dismissed the claim.

One thing is certain: Cyberattacks reveal a troubling contradiction for the aviation industry. While the benefits of increased connectivity among aircraft and support systems are straightforward — more information delivered more quickly and more reliably — the cost of all that connectivity may be just as significant with increased vulnerability and a greater chance that a flaw in one part of the commercial airline network could have major consequences throughout it.

The most worrisome question is whether someone could maliciously hack into a plane's flight control systems. That's also the least likely scenario, according to Jessica Ferguson, director of security architecture at Alaska Airlines. One reason is the amount of testing and certification required for every piece of equipment that goes on an aircraft, including networking devices.

"For everything that's put into a plane, it has to be certified by the FAA," Ferguson says, adding that European Aviation Safety Agency certification is often also necessary. Furthermore, equipment "has to be certified not only at the product level, but then our implementation of it," she says.

Alaska Airlines' new Boeing 737s, which come with Linux servers that monitor the aircraft's hardware and software, provide an example. "For us to even uncollar the circuit breakers that turned them on," Ferguson says of the small computers, "we had to file a whole aircraft network security program with the FAA on how we're going to monitor these things." That required testing, documentation and even demonstrations for regulators.

Given the risk of cyberattack, and the regulatory hurdles, what makes it worth adding networked devices to airplanes? Turning planes into, as Ferguson puts it, "flying IoT [internet of things] devices" can improve maintenance efficiency and safety.

"There are economic benefits to the airlines," explains Boeing's John Craig, who is responsible for aircraft information and security, "and a real simple one is predictive maintenance. If you know what is going on in the airplane, you can predict whether a certain part is going to fail."

For example, by constantly monitoring and logging how quickly a valve opens or closes, "you can predict pretty close when that [valve] is going to fail and can schedule getting it replaced." That helps increase safety and reduce unexpected maintenance that can delay flights.

Spotting vulnerabilities

Still, some security researchers fret that clever attackers could exploit flaws in a maintenance computer, in-flight Wi-Fi network or passenger

▼ **Security experts worry** that attackers could exploit flaws in passenger entertainment networks and Wi-Fi onboard airliners.

“If you think that you are secure, that’s a very uncomfortable feeling for us.”

— Jeff Troy, executive director at the Aviation Information Sharing and Analysis Center, referring to aviation companies

entertainment system to gain access to the plane’s flight controls, or communications or navigation systems. This is what Chris Roberts, a security expert, claimed to have done midflight in 2015, and similar to what the Department of Homeland Security says it was able to do in 2016 to a parked 757 it owned.

“We got the airplane on Sept. 19, 2016. Two days later, I was successful in accomplishing a remote, non-cooperative, penetration,” said Robert Hickey in an interview with Defense Daily. At the time, Hickey was an aviation program manager within the Cyber Security Division of the DHS Science and Technology Directorate.

David McKelvey

"[Which] means I didn't have anybody touching the airplane, I didn't have an insider threat. I stood off using typical stuff that could get through security and we were able to establish a presence on the systems of the aircraft."

Hickey did not respond to my voicemail request for an interview.

According to the article, Hickey said the details of the hack are classified, but said his team "accessed the aircraft's systems through radio frequency communications, adding that, based on the RF configuration of most aircraft, 'you can come to grips pretty quickly where we went' on the aircraft."

Don't cancel your reservation on a 757 just yet. "Everybody seems to lay claims that they can break into our systems and there are a few notable ones that just keep coming back," Boeing's Craig says. "To date, we have not had one claim [proved] to be true. And we investigate all of them." Of the DHS claim, Craig notes that those findings are classified, but adds, "We participated in that test and we were not concerned with what they found."

Why such confidence? For one, the various computers and networks — flight control, passenger Wi-Fi, entertainment — are completely segregated through hardware and software. And there

"We basically build a moat around aircraft control."

— Peter Lemme, aviation communications consultant

Dave Shephard

▲ **Pilots are an airliner's** best defense when technology goes awry, whether accidently or through bad actors, say company and government officials.

Wikipedia

▶ **The Aircraft Communications** Addressing and Reporting System, or ACARS, sends information between planes and ground stations.

are nonpublic security protocols in place, including limiting when computers are able to send and receive certain kinds of data. As a result, "there is no open communication at the networking level between systems," says Peter Lemme, an aviation communications consultant. "We basically build a moat around aircraft control."

Being able to monitor and alter the communications in and out of an aircraft is another concern. Since the 1970s, airlines have relied on the Aircraft Communications Addressing and Reporting System, or ACARS, for data communications with their aircraft. Coded, but unencrypted, text messages are sent over radio frequencies and by satellite. These messages, including engine performance data and updates to flight plans or gate assignments, can be printed out on telex machines or displayed on screens.

A wide variety of information is transmitted over ACARS. For example, a flight crew will let ground stations know the plane's location or estimated time of arrival, or request a gate number upon arrival. Likewise, ground stations use it to send messages to aircraft, such as altered flight plans, information about gate assignments, or weather updates.

Still, the system is 40 years old and wasn't designed with cyberattackers in mind. Lemme says ACARS was built for resiliency rather than security, meaning it works to ensure communications get through, rather than also verifying that the communications come from authorized entities.

As a result, it is theoretically possible to send bogus messages to aircraft through ACARS, according to security researchers. But, such messages would likely have little effect. They would be more like sending spam than taking control of a plane or stealing information, since flight crews have to accept the information and decide to act on it. And any nonstandard message would raise red flags.

Even so, for Lemme, transitioning away from the current technology "can't happen soon enough." A possible replacement could be ACARS over IP, or Internet Protocol. Instead of messages being sent via open radio signals, the messages would be sent as encrypted data packets through a virtual private network.

Pilots, the ultimate safeguards

Airline executives are quick to point out the ultimate safeguard: pilots. "No matter how much technology we have on those planes," says Nathaniel Callens, Alaska Airlines' chief information security officer, "pilots still have ultimate control of the aircraft."

Nevertheless, aviation companies actively work to find and patch digital vulnerabilities. "We actually have a secure lab where we can go in and do penetration testing," Craig says, "and we do that on every change to the network on the airplane."

Such testing can involve multiple companies, according to Jeff Troy, executive director at the Aviation Information Sharing and Analysis Center, an industry group that shares security information with its 45 member companies, including Boeing and Alaska Airlines. Exercises known as "red team testing" create scenarios in which one group of experts tries to break into a system and another tries to defend against it.

"The idea is to stress the system," Craig says, with the goal of discovering ways to make it stronger. Furthermore, companies pay close attention to hacking claims by others.

While the safety of an airliner has never been put at risk by a cyberattack, according to Troy, that doesn't mean there aren't other significant cybersecurity threats to the aviation industry, and he cautions against a false sense of security.

"If you think that you are secure," Troy says, referring to companies in the aviation industry, "that's a very uncomfortable feeling for us."

Marc Goodman, the chair for policy, law and ethics at Silicon Valley's Singularity University and author of "Future Crimes: Inside the Digital Underground and the Battle for Our Connected World," encourages that kind of worry. "The only people who are speaking truth about this subject say things like, 'We're being pounded every day. We have our finger in the dam and the wall's about to burst.'"

Even if the planes themselves are well-protected, that is of little solace to Goodman, who says there are plenty of other paths for attackers to wreak havoc through, including GPS, airport security, public Wi-Fi, ground networks, including ticketing and reservations, and even other broad infrastructure like power plants.

One example is the 2015 attack on LOT Polish Airlines. This was a distributed denial-of-service attack in which the computer network was overwhelmed with meaningless traffic, preventing the airline's computers from being able to talk to each other. As a result, the airline was unable to let planes take off for about five hours.

That kind of cyberattack is little different from those inflicted on other industries. Credit card

▼ **Flight tracking software** could be a soft spot.

"No matter how much technology we have on those planes, pilots still have ultimate control of the aircraft."

— Nathaniel Callens, Alaska Airlines' chief information security officer


Wikipedia

companies and retail outlets regularly fend off intrusions into their systems from criminals or others looking for customer information. This was the case with last year's Delta customer breach, in which the credit card information for hundreds of thousands of customers was exposed.

A weak link

Aviation makes for an especially tempting target for attackers. Some are motivated by corporate espionage; others are after customer data such as credit card information, business email addresses or rewards points; some might be disgruntled employees; and still others "have always looked at the aviation industry as a way to highlight their political or social messages," Troy says.

Furthermore, the vast number of companies and systems that have to work together creates opportunities for attacks. "If somebody wanted to attack Delta Air Lines, and they could not get into their computer network, they could go after Hartsfield airport in Atlanta, which is their hub," Troy says. Or vice versa.

In fact, that problem is one that most troubles Ferguson, the Alaska Airlines security executive. She says "common-use systems" at small airports — for example, airport-operated ticketing computers running antiquated and insecure operating systems like Windows XP — interact with all of the airlines' systems, but are out of their control. "We are at the mercy of not only the airport or port authority, but other airlines. And it's a complex problem."

To that end, it's critical for the industry to collaborate. "One of the biggest benefits I've seen is a company that just had an attack on their network will share that information with the other companies," Troy says. "That is probably the most valuable information you can get — to actually know how someone else in your industry was impacted by an attack."

Helping competitors fend off cyberattacks is for the entire industry, according to Ferguson. "I don't win if Delta gets breached," she says. "It's not a competitive industry in that sense." In fact, a competitor suffering from a cyberattack just brings headaches for everyone, she says. "If Delta gets breached, what does that bring? It brings a lot of regulators."

Some cybersecurity concerns aren't about malicious actions, but about technological creep. "I worry a little bit that we've become too tied to technology," Lemme says. In the past, he says, small things that might be easily resolved by a pilot — like ensuring the proper navigation charts are in effect — might instead require the involvement of IT staff and addressing some systemic problem.

Data in public domain

Lemme is also worried about the quantity of aviation data being publicly shared. For example, the vast amount of information about aircraft in the sky, including the tracking of private planes, could be revealing more than people realize.

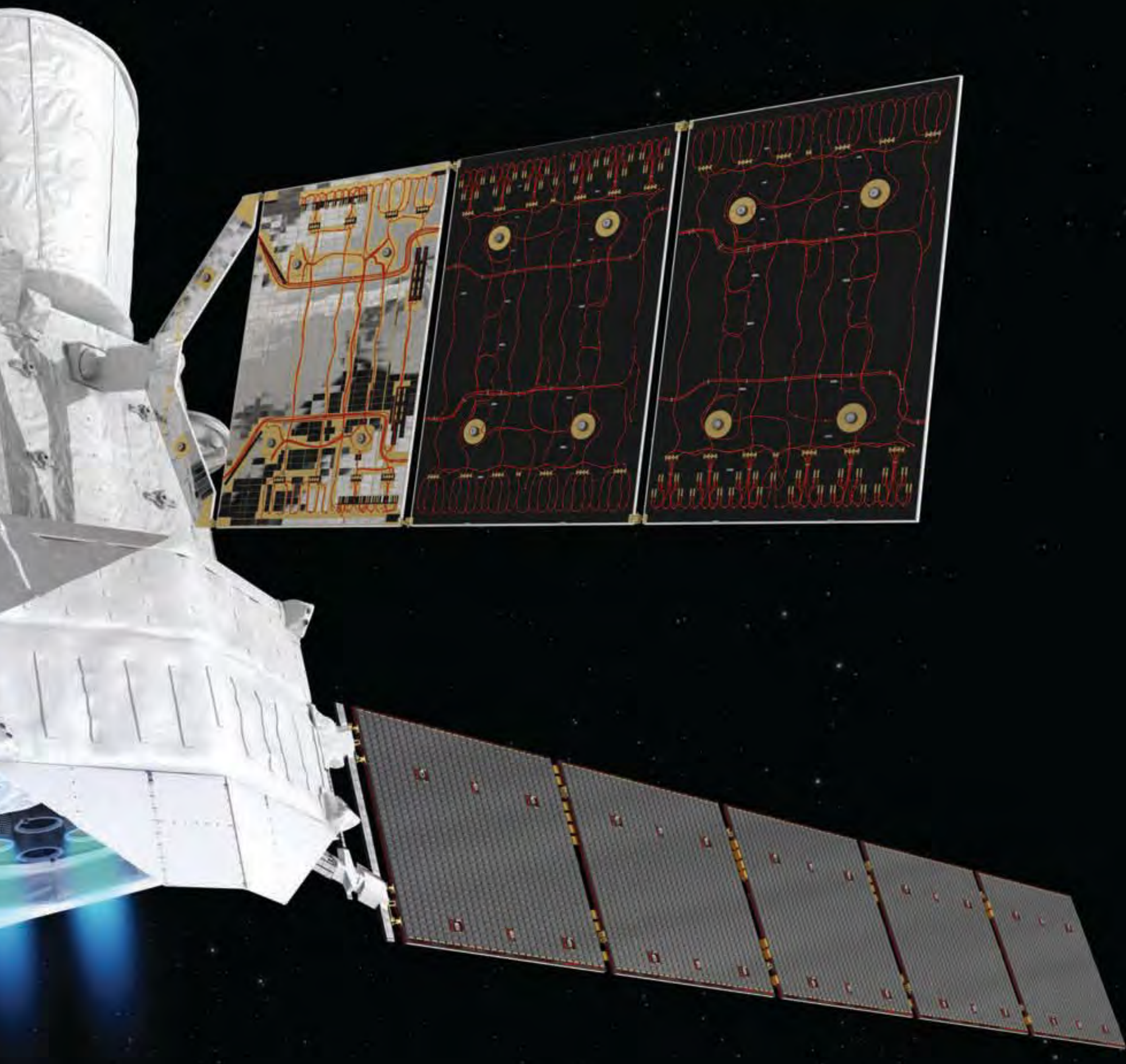
"Over the last 15-20 years, there's been a movement to provide aircraft tracking information to the public," Lemme says, referring to live data providing the names and locations of aircraft in flight, which powers websites like flightaware.com. That information can be valuable, especially with regard to private aircraft or corporate jets. "The movements of corporate executives can illuminate or reveal corporate strategy." Lemme advocates obscuring the identities of more aircraft and instead assigning them temporary random names. "Air traffic control really doesn't care who you are. They just need to have a unique identity for every flight."

Because cybersecurity covers a broad array of concerns — from flight safety to protecting customer data to ensuring smooth operations — there's no one solution to protecting the industry, especially not a technical one. Instead, Troy says what matters is a mindset for vigilance that constantly challenges the status quo.

"We spend a tremendous amount of time, energy and effort on the technological piece," Goodman says, "and almost entirely neglect the human factors."

That's because the biggest cybersecurity hole isn't technology, but people — their understanding of systems, their ability to foresee problems and to avoid making mistakes. "We can never say with 100 percent confidence that somebody didn't screw something up and leave the door open," Lemme says. ★

DESTINATION: MERCURY



The BepiColombo mission to Mercury, getting underway in October, could answer vexing questions about the innermost planet's core and its Earth-like magnetic field. As interesting as Mercury is in its own right, Adam Hadhazy reports that the answers could shed light on planetary matters far beyond our solar system.

BY ADAM HADHAZY | adamhadhazy@gmail.com

Mercury has long languished as the least-studied world in the inner solar system. To date, only two spacecraft — Mariner 10 in 1974 and MESSENGER in 2011 — have visited the remote, tiny, sun-scorched world. Helping to remedy that situation will be BepiColombo, a pair of probes scheduled for launch next month aboard an Ariane 5.

The mission is named after the late Italian physicist Giuseppe "Bepi" Colombo, who in the 1970s cracked how to glide a spacecraft into orbit around Mercury with planetary fly-bys. His namesake mission will initially consist of a four-part composite vessel — two orbiters, a cruise stage and a sunshield. The conjoined spacecraft will loop around Earth, Venus and finally Mercury multiple times to shave off velocity, lest it plummet right into the Sun. Finally, in late 2025, the two orbiters will separate and be captured into polar orbits by Mercury's gravity.

The probes — engineered to survive at least a year in the planet's punishing environs — will then delve into Mercury's ample scientific mysteries. In the process, the orbiters should fuel debates about how planets form and whether mechanisms might exist that would permit radiation-bathed exoplanets to support life, even if scientists are sure that Mercury itself has none.

Among the most pressing of Mercury's mysteries is the precise size and composition of its relatively gargantuan core. Earth's solid iron core fills less than 20 percent of our world's volume. In Mercury's case, however, coarse measurements from previous missions have ballparked its core as possibly taking up as much as a whopping 60 percent of planetary real estate, throwing a monkey wrench into theories of how planets form and evolve.

A second, related science objective will be to nail down the source of Mercury's magnetic field. The other terrestrial planets, Venus and Mars, lack such a field; furthermore, Mercury's field is surprisingly Earth-like, albeit weaker. Beyond its pure geophysics, the magnetic field interests astrobiologists because such fields are deemed critical for shielding planets' surface biospheres (including Earth's) from damaging solar radiation. Getting a better grip on Mercury should thus deliver key insights into the potential habitability of the multitude of exoplanets discovered in similarly tight orbits about their host stars.

"Mercury plays a special role in the solar system," says Johannes Benkhoff, the BepiColombo project scientist for the European Space Agency, or ESA, which spearheads the mission along with the Japan Aerospace Exploration Agency, known as JAXA. The planet closest to the sun, Benkhoff says, is a unique, yet so-far-underused laboratory.

Taking the heat

To be clear, Mercury is in no way a contender for harboring life in any form, owing to its lack of an atmosphere and searing temperatures. For the BepiColombo mission, those temperatures pose the

MISSION TO MERCURY

The BepiColombo mission will send two orbiters and a transfer module to Mercury as part of a single spacecraft. The gravity of Earth, Venus and Mercury, and solar-electric power will propel the spacecraft.

Source: European Space Agency

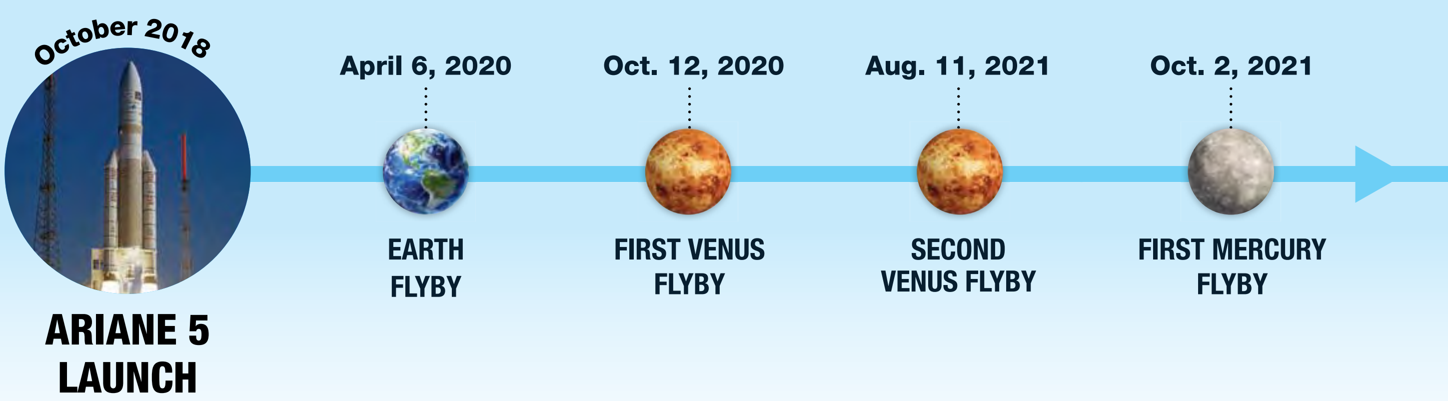
European Space Agency

▲ **The three modules of** the BepiColombo mission to Mercury are, at center, the Mercury Magnetospheric Orbiter, with its white high-gain antenna at the top, tilted upward; at right is the Mercury Planetary Orbiter — without its protective insulation blankets; and the Mercury Transfer Module, background left.

toughest challenge to securing high-quality science returns. "Thermal design has been the biggest hurdle," says Masaki Fujimoto, the JAXA BepiColombo project scientist.

Depending on where Mercury is in its orbit, the planet is blasted by more than 10 times the solar irradiation we receive at Earth. This results in a maximum temperature on Mercury's surface of about 450 degrees Celsius (850 degrees Fahrenheit). As Ulrich Reininghaus, the ESA BepiColombo project manager, points out, that "is the temperature achieved in the best wood-fired Neapolitan pizza ovens."

Dealing with these pizzeria-esque temperatures required innovations for the MPO, short for Mercury Planetary Orbiter — the bigger of the two BepiColombo orbiters, weighing in at 1,150 kilograms. For starters, to avoid temperature buildup and heat damage, MPO's solar arrays will continuously swivel, keeping the sun at a low angle while still catching enough rays for power generation. As for spacecraft insulation, engineers at Airbus — the prime contractor on BepiColombo — realized that conven-

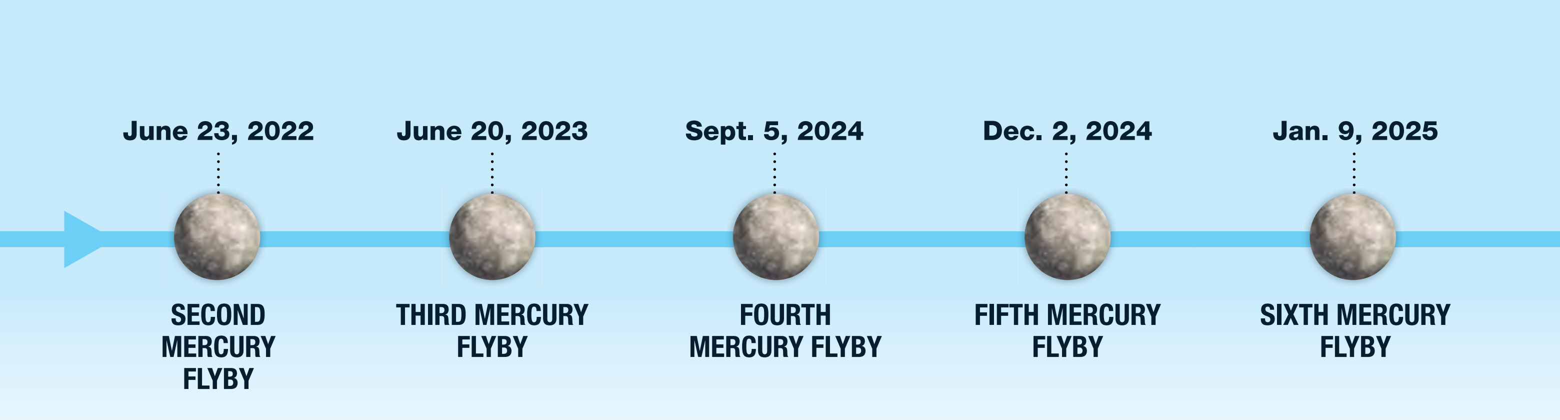


European Space Agency

tional polymers would not suffice for that role. They accordingly developed a new, 50-layer blanket of ceramic fabrics and aluminum sheets. Those blankets wrap around all MPO surfaces, except for a 3.7-meter-wide radiator that always faces away from the sun. Reininghaus explains that all internal heat dissipation, as well as external heat that will inevitably leak through the insulation, is conveyed to this radiator by heat pipes for subsequent shedding into space. In addition, titanium louvers on the radiator's surface will reflect away the intense heat coming up from Mercury.

Overall, this temperature-moderating architecture will allow MPO to descend to low Mercurian altitudes — below 500 kilometers during the closest passes — where it will scrutinize the whole planet at closer range than Mariner 10 and MESSENGER, enabling the characterization of Mercury's crater-pockmarked

▲ **The Magnetospheric Orbiter Sunshield** and Interface Structure that will protect the Mercury Magnetospheric Orbiter en route to the planet is in the foreground; the Mercury Transfer Module that will carry the two orbiters to Mercury is in the background.



> **Mercury's maximum surface temperature of about 450 degrees Celsius (850 degrees Fahrenheit) "is the temperature achieved in the best wood-fired Neapolitan pizza ovens."**
>
> — **Ulrich Reininghaus,** ESA BepiColombo project manager

surface in unprecedented detail with its two cameras and six spectrometers.

Looking within

Counterintuitively, gathering all this surface data will be crucial for seeing what is deep inside Mercury. Monitoring features on Mercury will reveal how the planet wobbles in its orbit around the sun. That, along with precision radio tracking of MPO's orbits to map Mercury's gravitational field, will determine the distribution of mass throughout the planet's crust, mantle and core. With this data in hand, scientists can better answer if Mercury's big core was there from birth, so to speak, and is therefore a natural, though poorly explained outcome of planet formation. Alternately, the data could support the popular theory that a cataclysmic collision with another body early in the solar system's history blew away most of Mercury's original crust and mantle.

The MPO data will also speak to how much of Mercury's internal mass is in solid or liquid form. This distinction matters for identifying the mechanism behind Mercury's magnetic field. Earth's magnetic field is generated by a liquid outer core in which the motion of electrically conducting molten iron creates the equivalent of a planet-scale bar magnet. Mercury's innards could be something else entirely. Measurements from MESSENGER of Mercury's northern hemisphere found that the magnetic field is strongly asymmetrical, unlike Earth's. BepiColombo will fill in missing southern hemisphere data, offering the fullest portrait to date of the enigmatic field. "Is there a different way of situating an electromagnet inside a rocky planet?" asks JAXA's Fujimoto. "There is a reasonable expectation that it is different."

JAXA's BepiColombo orbiter, the smaller, 275-kg Mercury Magnetospheric Orbiter or MMO, will assist by measuring field shape and strength at distances of up to nearly 12,000 kilometers from Mercury, complementing MPO's closer-in measurements. To survive the Mercurian inferno, MMO relies on different strategies than its partner, MPO. For heat distribution, MMO spins, rotisserie-style, at 15 revolutions per minute. Its octagonal body has a polished mirrored surface to reflect excess sunlight that is not needed by MMO's rows of solar cells for conversion to electricity.

Life elsewhere

The lessons learned about Mercury by BepiColombo will shed light on how all planets form and especially how they evolve under the withering glare of an encroaching star. One particular application will be to exoplanets around M stars, also called red dwarfs, which make up four of every five stars in the universe. Though dimmer than the sun, M stars flare more, unleashing bursts of radiation. These flares could sterilize any temperate worlds in orbits sufficiently close enough for life-enabling water to remain liquid on their surfaces. "The space environment of habitable planets around M stars is far more harsh than what we study in detail at Earth," says Fujimoto.

Protective magnetic fields, akin to Mercury's though stronger in magnitude, could just be what gives life a chance. ★

Dec. 5, 2025

SPACECRAFT REACHES POLAR ORBIT AROUND MERCURY AND ORBITERS SEPARATE

March 14, 2026

MERCURY PLANETARY ORBITER REACHES SCIENCE ORBIT

May 1, 2027

END OF BASELINE MISSION

May 1, 2028

END OF PLANNED EXTENDED MISSION

TAKING ON THE SUN

NASA's Parker Solar Probe, now on its way toward the sun, must survive the searing temperatures in the solar corona to unlock the processes driving the solar wind and coronal mass ejections that can harm satellites and electronics on Earth. Tom Risen spoke to the scientists and engineers behind Parker's thermal protection strategy.

BY TOM RISEN | @tomr@aiaa.org

When engineers got to work on NASA's Parker Solar Probe a decade ago, they needed to create a heat shield that would be lightweight, reflective and durable enough for the spacecraft to become the first to fly into the sun's outermost atmosphere, called the corona, and address the mystery of why this region is hotter than the one closer to the surface.

Parker, built by the Johns Hopkins University Applied Physics Laboratory in Maryland, is on a trajectory toward the sun, following its launch in August from Cape Canaveral, Florida. The spacecraft will complete 24 solar orbits, each gradually tightening with the aid of Venus' gravity, until Parker approaches within 6.4 million kilometers of the surface in June 2025, exposing its heat shield to temperatures of 1,377 Celsius.

The gravity of Venus and the sun will accelerate Parker to incredible speeds as the probe flies on increasingly tighter orbits. In fact, if all goes as planned, the spacecraft will become "the fastest human made object" in history when it flies at about 700,000 kilometers per hour, or "fast enough to get from Philadelphia to Washington in one second," said Nicola Fox, NASA's Parker Solar Probe mission scientist, during a pre-launch briefing with reporters.

NASA first discussed the idea of sending a probe near the sun when the agency was founded in 1958. "Every couple of decades since then, NASA sat down and said, 'OK, can we do this?'" says Adam Szabo, NASA's mission scientist for the Parker Solar Probe.

The answer was always "not yet," until 2008 when NASA chose APL to build Parker. Engineers saw that NASA's patience paid off as they drew on a range of technological advancements to build the spacecraft. Instruments on Parker will gather data about magnetic fields and particles from the shadow of a 2.43-meter-diameter, 11.4-centimeter-thick heat shield that will protect the instruments from the searing sunlight. Autonomous navigation software will ensure hydrazine thrusters keep the shield pointed at the sun to maintain a tolerable operating temperature of 30 degrees Celsius.

The autonomous navigation on the spacecraft is "absolutely critical," Szabo says, because NASA won't always be able to maintain contact with Parker to keep the shield focused. "The light pressure is so intense that communications would be a problem," he says. The shield consists of a carbon foam core sandwiched between two panels of a composite derived from the same kind of reinforced carbon-carbon that protected the leading edges of the space shuttle wings. The shield sits atop a truss made of titanium, a metal that can endure the 315-degree Celsius heat it is expected to face.

Testing the heat shield for durability was "very difficult," says Betsy Congdon, the lead engineer at APL for the thermal protection system. "The difficulty is testing for those high temperatures in vacuum, so we tested at a variety of facilities all over the [U.S.]," including at NASA Goddard Space Flight Center's thermal vacuum chamber in Maryland.

Designers simulated the temperature fluctuations the probe will face on each orbit, as it flies toward the sun and then away from it. In fact, Parker will fly by Venus seven times through 2024, a series of gravity assists whose momentum will send the probe deeper and deeper into the sun's atmosphere.

The shield's carbon foam supplied by secondary contractor Ultramet of California is a stronger version of a foam the company has sold as a bone replacement material, though it is 97 percent air.

The shield panels, built by secondary contractor Carbon-Carbon Advanced Technologies of Texas, are made from a "thinner, next generation version" of the shuttle's reinforced carbon-carbon, Congdon says. To reflect as much light from the sun as possible, researchers at Johns Hopkins' main campus created the recipe for a ceramic-based white coating that was sprayed evenly across the outer shield panel by aerospace materials contractor Plasma Processes of Alabama.

Designers also had to find a way to protect the probe's electricity-generating solar arrays during the hottest part of each orbit. As Parker approaches the sun, the arrays will be folded to a shallow angle to reduce exposure to sunlight, "otherwise they could melt," Szabo says. They will extend again as Parker heads away from the sun.

◀▲ Employees of the Johns Hopkins University Applied Physics Laboratory work at Astrotech Space Operations in Titusville, Fla., on the thermal protection system for the Parker Solar Probe.

NASA

Pipes beneath the solar arrays will also pump water back and forth from a radiator within the titanium truss to shed heat into space.

"Space is dark, so you can keep the water cool if you keep it out of the sunshine," Szabo says.

Scientists hope to learn about the acceleration and origin of solar wind, charged particles that course through our solar system after emanating from the corona, and how to better predict more intense blasts of magnetic energy from the sun that could disrupt electronics on satellites. The probe's namesake, heliophysicist Eugene Parker, 89, a professor emeritus at the University of Chicago, predicted the existence of the solar wind in 1958.

The equations Parker published in his 1958 paper predicting the supersonic flight of solar winds "taught us about the threats that come from this plasma," said NASA's Thomas Zurbuchen, the associate administrator in charge of the Science Mission Directorate, during the pre-launch briefing. The spacecraft will gather data about the solar wind by extending a metal solar probe cup just beyond the diameter of the heat shield to determine the velocity, density and temperature of the ionized gas. Pieces of sapphire will create an electric field to make what's called a Faraday cup that will ensure only charged particles can enter the cup.

Also, five electric antennas and three magnetometers will measure fluctuations in the intensity of magnetic fields and detect the shock waves that blow through the corona and are associated with coronal mass ejections, bursts of plasma and magnetic energy that can reach Earth in 18 hours. Four of the antennas will be exposed beyond the heat shield. These are built from niobium alloy, which can endure extreme heat. A mass spectrometer will also weigh ions within the solar wind, and a white light telescope will make 3D images of the wind as it passes.

Lessons learned from designing and constructing the heat shield "can change the way we look at a lot of our re-entry problems, and we can develop and use heat shielding in new ways potentially on missions like interstellar probes as well," Congdon says. ★

OPINION

RX FOR THE WORKFORCE

Veteran aerospace engineers in the U.S. are retiring, and employment data shows that the workforce is contracting. The U.S. remains the global leader in aerospace goods and services, and yet the numbers are concerning. Aerospace expert Amir S. Gohardani researched the workforce problem, and offers some advice for how corporations and policymakers should address it.

Last year, the U.S. aerospace industry led the world in exports of aerospace goods and services to the tune of $143 billion, a figure that amounted to 34 percent of such exports around the world, according to the Commerce Department.

Despite its enormous impact and still stellar performance, the U.S. aerospace workforce now finds itself at a crossroads. The workforce has two options: Either continue with incremental advances or adopt a bolder approach involving radical changes.

When the puzzle box of aerospace workforce challenges is opened, I see four categories of issues: an aging workforce, global competition, new industry practices and leadership. These challenges, which also can be seen as opportunities, arise from a compilation of factors.

An aging workforce

The pending retirement of a significant portion of this workforce is notable, as this group inevitably must be replaced by less-experienced professionals. Leaders in government and industry must decide how to bridge this gap between profoundly experienced aerospace workers and less experienced ones, and embed those decisions into their strategic plans.

Global competition

On balance, the now-global competition among aerospace companies is a positive development, because it boosts creation of state-of-the-art solutions and advances the industry as a whole. However, today's fiercer competition means that U.S. companies must adapt if they are to retain their competitive edge. Elements beyond technology such as brand, work culture, customer experience, program management and program execution play a role in the ability to capture as much market share as possible. But there is a role for U.S. government agencies too.

Those agencies should continue to strive to facilitate unprecedented technical solutions with the objective of leading the global aerospace sector. In many ways, this would be a continuation of previous success stories. DARPA, for example, paved the path to the modern internet and helped inspire miniaturization of GPS devices. These were instances of research objectives leading indirectly to societal benefits. Still, more often than not, research programs under the government umbrella need continuous optimization in terms of program initiation, planning, execution, monitoring and control, and program closure.

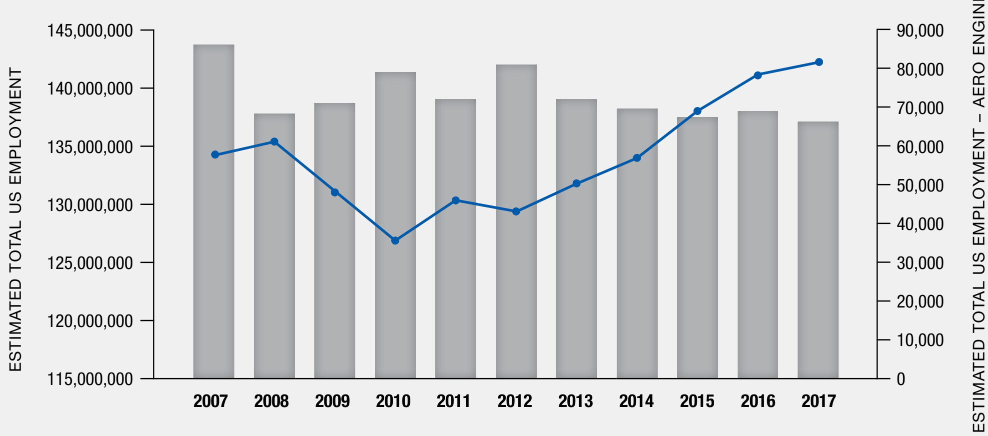
A more complete overview of limitations and opportunities surfaces by recognizing the shared mechanisms of competition and its protocols. The U.S. aerospace industry is bound by ITAR (the International Traffic in Arms Regulations) and the Export Administration Regulations. They restrict the export of most defense-related technologies in the name of protecting U.S. national security. ITAR, in particular, limits the dissemination of knowledge about those technologies to "U.S. persons." This means the U.S. cannot rely on recruiting a nondomestic workforce to work with ITAR-related technologies. A highly skilled aerospace workforce must be maintained domestically, but that is challenging because of today's aging workforce.

Corporations and government agencies should adapt to this reality by undertaking a transitional phase in which senior personnel share their knowledge with less-experienced and typically younger workers in order to safeguard gems of knowledge and preserve the workforce's culture. Also, whenever possible, nonproprietary knowledge should be shared across the aerospace sector to fuse lessons learned with newly available tools of the digital age.

New industry practices

Building on domestic aerospace traditions will be essential. Those in charge of creating new industry practices and standards should always review precedents in different categories, such as functionality, safety, quality control and assurance. I've heard it argued that new technologies and industry practices diminish the importance of looking for precedent from those who developed aerospace systems in earlier days, for example, through wind tunnel testing and flight testing. I disagree. Computational

Aerospace employment Growth in U.S. employment overall (blue line) has outpaced that of the aerospace engineering sector.



Source: U.S. Labor Department

fluid dynamics and additive manufacturing techniques have led to new waves of progress within the aerospace industry, but one cannot solely rely on such tools. Indeed, new industry practices can substantially benefit from the experiences of human beings. A compilation of these findings could then be translated into machine learning approaches. Generally, exclusion of human beings entirely to rely on machines and advances in robotics and artificial intelligence is not the best option. Despite mind-blowing advances in the aerospace sector, human presence in developing aerospace technologies is essential, since humans will be affected by these advances to a smaller or larger extent.

Leadership

A robust and efficient leadership scheme is another key ingredient for preparing the U.S. aerospace workforce for the challenges ahead.

The results were illuminating when my colleagues at the Springs of Dreams Corp., a nonprofit educational organization I co-founded, analyzed employment statistics from the U.S. Labor Department. Aerospace engineering employment has decreased as a percentage of the total U.S. workforce, despite an overall increase in the hourly and mean annual wage of the aerospace engineering workforce.

This trend should be alarming to the aerospace sector. The decreasing size of the U.S. aerospace workforce means that the pool of potential aerospace engineering leaders will be limited. Moreover, the U.S. population continues to increase, and yet individuals are turning away from the aerospace sector despite an increase in salaries. It might be argued that engineers educated in other majors, such as electrical engineering and mechanical engineering, work in the aerospace sector and that, therefore, this decrease is acceptable. This argument misses the point that aerospace engineering as a major should be exhilarating enough to attract students who will one day join the profession.

There are many qualities that could prove to be beneficial to a leader of the future aerospace workforce. By adopting a polymathic approach to engineering, a future leader can value a diverse set of skills and new ways of thinking. Challenging the status quo, such a leader would be able to inject early innovation practices and utilize the diversity of U.S. aerospace workers to advance the industry and the workforce. More than often, an existing chasm between academia and industry is due to a lack of communication regarding the multidisciplinary fusion of technology, business development and management. The U.S. aerospace workforce is in dire need of prominent leaders.

In my January interview with Clayton Daniel Mote Jr., president of the National Academy of Engineering, he explained the role of a leader like this:

"Without a vision, you cannot be much of a leader. You essentially become a manager. Managers essentially run the store. They make the trains run on time. Leaders tell you where the train is going to go. And, how far and so on. So, the leader's job is really the vision piece. Most of the time. Unless the organization does not want a leader. It just wants a manager. That is another leadership question. So, the organization that only wants a manager is happy with a manager."

In order to reach unexplored frontiers in our galaxy and advance science, technology and society, the U.S. aerospace workforce needs visionaries who through an insightful understanding of leadership and the culture of an organization can tailor their leadership style to the cultural needs of the workforce.

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

AIAA Bulletin

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

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

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

Calendar

7–11 JANUARY 2019

San Diego, CA

Innovation in aerospace starts at the AIAA SciTech Forum! The forum covers the science, technologies, and policies that are shaping the future of aerospace. The largest event for aerospace research, development, and technology in the world brings together 11 individual technical disciplines and includes over 4,000 attendees from nearly 1,000 corporate, academic, and government institutions in 42 countries.

scitech.aiaa.org

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2018			
6–7 Sep*	22nd Workshop of the CEAS-ASC: Future Aircraft Design and Noise Impact	Amsterdam, The Netherlands (nlr.org/events)	
15–16 Sep	Integrating Program Management and Systems Engineering Course	Orlando, FL	
16 Sep	Hypersonic Air Breathing Propulsion: A Technical Primer Course	Orlando, FL	
16 Sep	Space Standards and Architectures Course	Orlando, FL	
17–19 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum)	Orlando, FL	8 Feb 18
27 Sep	DirectTech Webinar—Testing Large Ultra-Lightweight Spacecraft	Virtual (aiaa.org/onlinelearning)	
1–5 Oct*	69th International Astronautical Congress	Bremen, Germany	
2 Oct	National Aerospace & Defense Workforce Summit	Washington, DC	
10–11 Oct*	International Symposium for Personal and Commercial Spaceflight	Las Cruces, NM	
12 Oct–14 Dec	Online Short Course: Hypersonic Air Breathing Propulsion		
25 Oct	DirectTech Webinar—Mechanics of Structure Genome: A New Unified Approach to Modeling Composite Structures	Virtual (aiaa.org/onlinelearning)	
5–8 Nov*	ITC 2018	Glendale, AZ (www.telemetry.org)	
13–15 Nov*	2018 CODER Workshop	College Park, MD (www.coder.umd.edu/coder2018)	

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.).

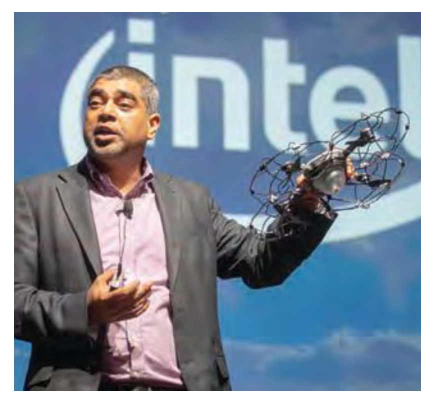
DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2019			
5–6 Jan	2nd AIAA Geometry and Mesh Generation Workshop	San Diego, CA	
5–6 Jan	Aircraft and Rotorcraft System Identification Engineering Methods for Manned and UAV Applications with Hands-on Training Using CIFER® Course	San Diego, CA	
5–6 Jan	Diagnostics for Plasmas and Gases Course	San Diego, CA	
5–6 Jan	Guidance, Control, and Astrodynamics of Space Vehicles Course	San Diego, CA	
7 Jan	AIAA Associate Fellows Awards Ceremony and Dinner	San Diego, CA	
7–11 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition)	San Diego, CA	11 Jun 18
13–17 Jan*	29th AAS/AIAA Space Flight Mechanics Meeting	Maui, HI	14 Sep 18
28–31 Jan*	65th Reliability and Maintainability Symposium (RAMS 2019)	Orlando, FL (www.rams.org)	
2–9 Mar*	2019 IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
25–27 Mar*	54th 3AF International Conference on Applied Aerodynamics: Aerodynamis at Off-Design Conditions	Paris, France (http://3af-aerodynamics2019.com)	
3–5 Apr*	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (www.eurognc19.polimi.it)	
7–9 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum)	Laurel, MD	
14 May	AIAA Fellows Dinner	Crystal City, VA	
15 May	AIAA Aerospace Spotlight Awards Gala	Washington, DC	
20–23 May*	25th AIAA/CEAS Aeroacoustics Conference (Aeroacoustics 2019)	Delft, The Netherlands	1 Oct 18
27–29 May*	26th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (www.elektropribor.spb.ru/icins2019/en)	
10–13 Jun*	18th International Forum on Aeroelasticity and Structural Dynamics	Savannah, GA (http://ifasd2019.utcdayton.com)	
12–14 Jun*	The Sixth International Conference on Tethers in Space (TiS2019)	Madrid Spain (http://eventos.uc3m.es/go/TiS2019)	
17–21 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition)	Dallas, TX	7 Nov 18
19–22 Aug	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition)	Indianapolis, IN	
21–25 Oct*	70th International Astronautical Congress	Washington, DC	

● AIAA Continuing Education offerings

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

AVIATION FORUM

A record 2,896 attendees representing a broad range of the aviation community – from across the U.S. and 40 other countries – gathered in Atlanta, 25–29 June, for the AIAA AVIATION Forum to date. The forum included 700 students and 1,500 technical presentations.

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Nominations for AIAA Board of Trustees – Members-at-Large are Now Being Accepted

The 2018–2019 AIAA Executive Nominating Committee (ENC), chaired by the AIAA Immediate Past President James Maser, will compile a list of potential nominees for the Board of Trustees – Members-at-Large. This list will include nominees who will be selected to go to the next step of competency review and interview held by the ENC. The ENC will select specific candidates for the Institute's Board of Trustees – Members-at-Large by early March 2019. The Board of Trustees – Members-at-Large will be voted on by the Council of Directors at the May 2019 meeting and announced soon thereafter.

The specific list of essential competencies being sought for this election of Board of Trustees – Members-at-Large are:

Vision: Persons who have the ability to understand present states, clearly define what they should be in the future, and identify steps to achieve those ends.

Business Acumen: Persons who have the knowledge and understanding of the financial, accounting, marketing, and operational functions of an organization as well as the ability to make good judgments and quick decisions.

Domestic and International Aerospace Knowledge and Experience: Board membership reflects: a) the breadth of the various major sectors of aerospace industry, both domestic and international; b) all levels of technology and systems development from basic research through all technology readiness levels to product development and deployment; and c) from different disciplines within the aerospace industry.

Leadership/Strategy/Execution: Persons who have the ability to create a shared vision, obtain participation and buy-in, and achieve successful results.

AIAA Leadership and Participation: Board membership reflects experience in successful participation in a wide variety of leadership positions within AIAA.

AIAA members may nominate members qualified for the open position by submitting a nomination no later than 1600 hrs ET, 26 October 2018. Please submit nominations directly to Christopher Horton, AIAA Governance Secretary, chrish@aiaa.org.

AIAA Holds Congressional Educational Briefing on Hypersonics

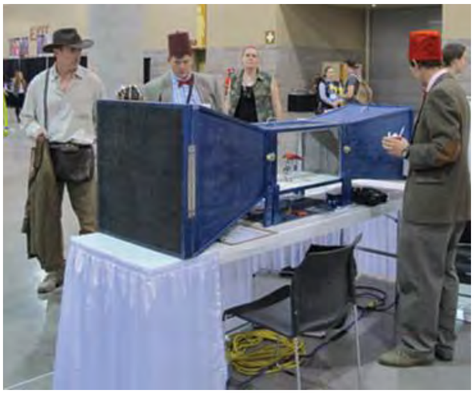
On 17 July, AIAA sponsored a "Hypersonics 101" briefing on Capitol Hill. The session educated congressional staff about the extent to which our nation is ready to defend against hypersonic threats and the imperative for a significant increase in technology investments, infrastructure and test capability investments, and talent development through universities, national and service labs, and industry. No specific programs or priorities were promoted. A background paper (aiaa.org/InformationPapers) was developed for the briefing and distributed to the attendees. Senator Joe Donnelly (D-IN), Rep. Mo Brooks (R-AL), Rep. Steve Knight (R-CA), and Rep. Jim Langevin (D-RI) served as the honorary co-hosts. The speakers were:

- **Kevin Bowcutt,** Senior Technical Fellow and Chief Scientist of Hypersonics, The Boeing Company
- **Iain Boyd,** James E. Knott Professor of Aerospace Engineering, University of Michigan
- **Mark Lewis,** Director, Science and Technology Policy Institute, Institute for Defense Analyses
- **Dan Marren,** Site Director, Air Force Arnold Engineering Development Center

Linking Society with Technology through the Arts

By Dr. Amir S. Gohardani, Chair, SAT IOC

The Society and Aerospace Technology Integration and Outreach Committee (SAT IOC) has discussed the role many aerospace technologies play in everyday lives and planned endeavors to actively reach out to the public, including through the arts. Michelle Rouch, an active SAT IOC member, spearheads many of this committee's art activities.




The wind tunnel was available through the AIAA Tucson Section booth at the Phoenix Comic Fest.

The Art of Space exhibition launched at the Space Tech Expo (22–24 May) in Pasadena, CA, and was followed by the National Space Society's International Space Development Conference (ISDC) (24–27 May) in Los Angeles, CA. Michelle Rouch and two other AIAA members, artists Aldo Spadoni and Mark Pestana, were participating exhibition artists. Jeff Bezos, Blue Origin's founder, stopped by to see a Rouch piece titled "Space-Cation," inspired by Blue Origin's April 2018 advertisement for a space vacation. The artwork depicts "Astro Jeff" surfing on his Blue Origin rocket in outer space, and Bezos commented: "This is awesome."

Also, in late May, Rouch led the AIAA Tucson Section volunteers at the Phoenix Comic Fest. The section's booth showcased a wind tunnel featuring a Superman model to illustrate aerodynamic forces and an art station for kids to draw their own rockets. The 7'-tall banner of "Space-Cation" drew much interest and AIAA handouts were shared with participants. Actor Michael Rooker, best known as the blue-skinned alien Yondu in the "Guardians of the Galaxy," visited the wind tunnel and was interested in how it worked.

SAT IOC will continue highlighting societal aspects of aerospace technology in society and invites those interested to attend the committee tracks during the 2018 AIAA SPACE Forum in Orlando, FL.

AIAA Diversity Scholars Attend AIAA AVIATION Forum

In late June, 16 AIAA Diversity Scholars attended the 2018 AIAA AVIATION Forum in Atlanta, GA. The students attended plenary sessions, Forum 360 panels, and technical sessions, as well as the Rising Leaders in Aerospace events and special sessions geared specifically for the scholars.

The AIAA Diversity Scholarship provides students from underrepresented groups with the opportunity to attend AIAA forums and receive additional targeted programming that may help them succeed in the aerospace industry. The AIAA Diversity Scholars Program at AIAA AVIATION Forum was sponsored by Airbus.

Diversity Scholarships will be offered for select AIAA forums throughout the year. The program welcomes applications from students in all disciplines with an interest in aerospace, including but not limited to STEM fields, communications, law, industrial design, journalism, and political science. Please visit aiaa.org/Diversity-and-Inclusion for more information.

"Attending AVIATION this summer was one of the most rewarding experiences AIAA has ever given me. I left that forum with new friends and relationships, professional connections, and most importantly, direction and control over my future career."

— Luis Cuevas

“This opportunity really made me feel a part of the aerospace community in so many different ways. I look forward to continuing my relationship with AIAA in the future as a student branch section chair, presenting my work at future conferences, and continuing to advocate for diversity and inclusion in the aerospace field.”

— Katherine Stamper

“Coming from a diverse background and being a first-generation graduate student myself, I deeply appreciated hearing how other professionals from diverse backgrounds managed to navigate the aerospace field, overcome adversities, balance work and family, and have successful careers in aerospace.”

— Gustavo E. C. Fujiwara

ASAT 2018 – A Regional Conference in Southern California

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

The AIAA Orange County (OC) Section hosted the 15th annual AIAA Southern California Aerospace Systems and Technology (ASAT) Conference and Banquet on 12 May in Southern California. With more than a decade-long heritage, this conference brought together Southern California engineers, educators, researchers, students, leaders, and enthusiasts for the 15th year in a row.

The one-day program consisted of 35 presentations in a number of parallel tracks both in morning and afternoon sessions. Each session was initiated by a prominent keynote speaker. F-22 Chief Test Pilot Steve Rainey gave a talk called “F-22 Raptor Flight Test Briefing,” and Dr. Anita Sengupta, senior vice president of Systems Engineering, Virgin Hyperloop One spoke about Virgin Hyperloop One.

The banquet immediately following the conference included an overview of section activities for the year and presentation of the AIAA Orange County Section awards for the 2018 Student of the Year, Amir Rezaei (University of California, Irvine): the 2018 Young Professional of the Year, Dr. Haithem Taha (University of California, Irvine); and the 2018 Engineer of the Year, James R. French. The banquet speaker Chief Richard Fields IV gave a talk on the “LAFD Unmanned Aircraft Systems (UAS) Unit.”

During ASAT 2018, there were unclassified presentations on all aspects of aerospace systems, technology, vehicle design, program management, policy, economics and education in three major categories:

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

For the fourth year, the Gohardani Presentation Award in Aeronautics and Astronautics also was presented. The 2018 recipient was Bob Barboza, Barboza Space Center, for his inspirational work to support high school students participating in the Occupy Mars Learning Adventures Fellowship Program. Sponsored by the Springs of Dreams Corporation, a non-profit organization, this prestigious award includes a monetary prize and a certificate.

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1 ASAT keynote speaker Steve Rainey with ASAT General Co-Chair John Rose.

2 ASAT General Co-Chair John Rose with ASAT keynote speaker Dr. Anita Sengupta.

3 ASAT General Co-Chair John Rose with banquet speaker Chief Richard Fields IV.

4 (From left to right) Amir Rezaei, 2018 AIAA Orange County Student of the Year; James R. French, 2018 AIAA Orange County Engineer of the Year; and Dr. Haithem Taha, 2018 AIAA Orange County Young Professional of the Year.

5 (From left to right) Dr. Omid Gohardani, AIAA OC’s Communications Co-Director with Bob Barboza, recipient of the 2018 Gohardani Presentation Award in Aeronautics and Astronautics, and Dr. Amir S. Gohardani, AIAA OC’s Section Chair.

AIAA Journals Announcement

To leverage advances in publishing technology, AIAA has been transitioning our technical journals away from the traditional print format over the past few years. This process will be complete in January 2019, when *Journal of Aircraft* (*JA*), *Journal of Guidance, Control, and Dynamics* (*JGCD*), *Journal of Spacecraft and Rockets* (*JSR*), *Journal of Propulsion and Power* (*JPP*), and *Journal of Thermodynamics and Heat Transfer* (*JTHT*) move to an online-only format. The final 2018 issue for each of these journals will be the last issue distributed in print.

Print customers transitioning to the online format will be able to maximize the user experience with research tools and access to the most up-to-date versions of articles in Aerospace Research Central. All of AIAA’s technical journals will continue to publish high-quality, original research papers spanning the spectrum of aerospace science and technology and reporting on the most critical aerospace advances.

Reuben H. Fleet Scholarships Awarded

On 10 May, the AIAA San Diego Section awarded the Reuben H. Fleet Scholarships at the AIAA San Diego Honors and Awards Banquet. Since 1983, 193 students have received the scholarship, which is made possible by the Reuben H. Fleet Foundation at The San Diego Foundation.

Above: 2018 Reuben H. Fleet Scholarship recipients (left to right): Alex Fleet (grandson of Reuben H. Fleet), Bryan Martin (University of California, San Diego), Paulina Diaz-Montiel (San Diego State University), Thomas Bogott, II (University of California, San Diego), and Greg Marien (Scholarship Coordinator).

Helen L. Reed Wins 2018 Yvonne C. Brill Lectureship in Aerospace Engineering

AIAA Fellow Dr. Helen L. Reed, Regents Professor at Texas A&M University in College Station, Texas, will present her lecture, **"Student Design-Build-Fly Micro- and Nano-Satellites,"** on Tuesday, October 2, 2018, 10:30am-12:00pm at the National Academy of Engineering Headquarters, 2101 Constitution Avenue, NW, Washington D.C. 20418

THE LECTURE IS FREE AND OPEN TO THE PUBLIC

AIAA, with the participation and support of the National Academy of Engineering (NAE), created the Yvonne C. Brill Lectureship in Aerospace Engineering to honor the memory of the late, pioneering rocket scientist, AIAA Honorary Fellow and NAE Member, Yvonne C. Brill. Brill was best known for developing a revolutionary propulsion system that remains the industry standard for geostationary satellite station-keeping. She was a trailblazer at a time when women were not encouraged to enter the science and technology fields.

The Lecture emphasizes research or engineering issues for space travel and exploration, aerospace education of students and the public, and other aerospace issues such as ensuring a diverse and robust engineering community.

AIAA Shaping the Future of Aerospace

REGISTER TODAY

For further information about the Yvonne Brill Lecture in Aerospace Engineering, contact **awards@aiaa.org**

NATIONAL ACADEMY OF ENGINEERING

The Importance of Astronauts — AIAA Space Systems Technical Committee Essay Contest

The AIAA Space Systems Technical Committee's (SSTC) annual middle school essay contest continues to improve its commitment to directly inspire students and local sections. Each year, additional local sections start parallel contests to feed into selection of national winners awarded by the SSTC.

The 2018 essay topic was "In 2017, NASA selected 12 new astronaut candidates. Describe the role of astronauts and their impact on NASA, their impact on the future of the United States, and their impact on international partnerships." Seventh and eighth grade students were asked to participate. This year, seven sections submitted official entries to the contest, including Cape Canaveral, Greater Huntsville, Greater New Orleans, Hampton Roads, Long Island, Rocky Mountain, and the "At-Large section". For each grade, there were first-, second-, and third-place winners, which included $100, $50, and $25 awards for the students, respectively. The first-place winners were also awarded $500 for their classroom toward STEM materials or activities. The six students also receive a one-year membership with AIAA.

The first-place winner for 8th grade was Rachel Pizzolato (and teacher Cathy Boucvalt) from Metairie, LA. The second-place winner for 8th grade was Taylor Honeycutt from Road Harvest, AL. The third-place winner for 8th grade is Maizy Guertin from Satellite Beach, FL.

The first-place winner for 7th grade is Angelina Pilataxy (and teacher Leslie Maynard) from Levittown, NY. The second-place winner for 7th grade is Benjamin Proctor from Carrollton, VA. The third-place winner for 7th grade is Kara King from Melbourne, FL.

All 2018 winning essays can be found on the *Aerospace America* website (aerospaceamerica.aiaa.org/bulletin/september-2018-aiaa-bulletin).

The topic for 2019 is "President Donald Trump announced the idea of a Space Force. What are some advantages and/or disadvantages of having a Space Force and an organizational restructuring with the Department of Defense?" If you, your school, or section is interested in participating in the 2019 contest, contact Anthony Shao (ant.shao@gmail.com) or your local section for more details.

Rachel Pizzolato

Angelina Pilataxy

Apply Now to Join AIAA Technical, Integration, and Outreach Committees for 2019/2020

AIAA members are invited to apply for membership in the 85 distinct AIAA committees that span the breadth of the aerospace community. Sixteen Integration Committees (ICs) are focused on the cross-discipline integration of programmatic and societal outreach of the Institute, and 69 Technical Committees (TCs) focus on specific technical disciplines. Committees seek a balance of member representation from the fields of industry, research, and academia, and geography and career levels.

Nominate yourself or another AIAA member to be considered for the 2019/2020 committee year. The nomination portal is found on the AIAA website (**aiaa.org**) under My AIAA/Nominations and Voting/Technical Committee Online Nomination. Nominations are due by **1 November 2018**, and the new roster will be announced in spring 2019.

If you are currently a committee member, you will be automatically considered for the 2019/2020 year. Descriptions of committees' scope can be found at **aiaa.org/committees**.

Obituaries

AIAA Fellow Venkayya Died in May

Dr. Vipperla B. Venkayya, age 87, died 24 May 2018.

After graduating from the Indian Institute of Technology Kharagpur, Dr. Venkayya moved to the United States in 1957 to pursue Master's degrees at the University of Missouri, Rolla. He completed his Master's degrees in electrical and civil engineering and then worked for the highway department in Harrisburg, PA. He was accepted to the University of Illinois in 1960, and completed his Ph.D. in civil engineering in two years and two months.

He accepted a job at the State University of New York in Buffalo and the university sponsored his green card in 1964. As a student advisor, Dr. Venkayya was introduced to Wright-Patterson Air Force Base where many of his students went to work or intern. In 1967, Dr. Venkayya started a long and rewarding career with the U.S. Air Force at Wright-Patterson Air Force Base. He retired in 2001 as the Director and Leader of the Multidisciplinary Technology Center, Air Vehicles Directorate, Air Force Research Laboratory.

Dr. Venkayya was recognized nationally and internationally for his leadership and expertise in the development of structural design, analysis and optimization techniques and pioneered many advancements in design methods for efficient, lightweight, reliable flight vehicle structures. He developed many structural design/analysis methods used by the Department of Defense, NASA, industry, and academia. A Wright Laboratory Fellow, he was the recipient of many other accolades during his career including the 2000 Multidisciplinary Design Optimization Award, NASA Douglas Michel NASTRAN Award for lifetime achievements; ASCE Aerospace Structures and Materials Award; AF Flight Dynamics Laboratory Director's Award for NASP Integration Team; a two-time recipient of the General Foulouis Award; and the Air Force Outstanding Civilian Career Service Award. Dr. Venkayya developed ASTROS (Automated Structural Optimization System), a premier preliminary design and optimization software program. His accomplishments provided faster, less costly and reduced-weight aircraft preliminary designs. He transformed a culture by convincing designers to adopt techniques different from past experience that led to changes in the way structural systems are designed by substituting analysis for more costly physical testing. In 1997, he became an AIAA Fellow.

AIAA Fellow Eustis Died in May

Robert "Bob" Eustis died on 24 May. He was 98 years old.

Eustis graduated from the University of Minnesota in 1942, receiving a bachelor's degree in mechanical engineering with high distinction. He taught Navy and regular students at the university as an instructor until he enlisted in the U.S. Air Force in 1944 and was assigned to the Aircraft Engine Research Lab of NACA (later NASA), where he headed the Fundamental Turbine Research Section. After discharge in 1947, he entered MIT as an instructor (later assistant professor) and a doctoral student in mechanical engineering. Eustis joined a Philadelphia-based start-up in 1951 as chief engineer, and while there finished his ScD dissertation in 1953. Moving to California Eustis became head of the Heat and Mechanics section at Stanford Research Institute, later SRI International.

In 1954, Eustis was asked to teach a course in thermodynamics in the mechanical engineering department at Stanford University, and the next year joined the faculty as an Assistant Professor. Thus began a 35-year career that ended in 1990 when he reached the then mandatory retirement age of 70. During these years Eustis combined teaching, mentoring, and research with professorial duties such as several terms in the Academic Senate and seven years as a Senior Associate Dean of the School of Engineering.

One of his major efforts was to introduce more science into the mechanical engineering curriculum so that graduate students would be better able to adapt during their careers as engineering evolved. With Professors E. Charles Kruger and Morton Mitchner, Bob founded the High Temperature Gasdynamics Laboratory in 1961, and was its director until 1980. To date the laboratory has graduated 300 Ph.D. students.
Eustis was the Clarence and Patricia Woodard Professor of Mechanical Engineering at Standford and received the Tau Beta Pi award for distinguished undergraduate teaching. He was also a recipient of the Centennial Certificate of the American Society for Engineering Education; a Fellow of the American Association for the Advancement of Science; received the Emerson Electric Technology Award; and received a medal of achievement from the Academy of Sciences of the Soviet Union for his work in magneto hydrodynamics. After retirement, he started a company that designed and manufactured wooden chairs for libraries and clubs, and patented a joint design that allowed the company to guarantee that the joints would not break. After 10 years, Eustis and his wife gave the company to Stanford to endow the Robert and Katherine Eustis Graduate Fellowship Fund.

AIAA Associate Fellow Schafrik Died in July

Robert "Bob" E. Schafrik Sr., 72, passed away on 10 July.

He was a retired Air Force lieutenant colonel who held senior positions at the National Research Council's National Materials Advisory Board and Board on Manufacturing and Engineering Design before joining GE Aviation in 1997, where he rose to general manager of the Materials and Process Engineering Department. Most recently Schafrik was the new Presidential Distinguished Professor of Industrial, Systems and Manufacturing Engineering at the University of Texas at Arlington.

Mr. Schafrik was involved with the AIAA Management Technical Committee (2008–2017) and recently with the AIAA Management Integration and Outreach Committee.

University of Nevada, Reno

Help Develop a New Aerospace Engineering Program at the University of Nevada, Reno

The University of Nevada, Reno Mechanical Engineering Department is creating new undergraduate and graduate Aerospace Engineering programs. This is justified by its proximity to, and support from, aerospace industry in Nevada and Northern California; the need for university aerospace engineering programs in its geographic region; and the Nevada Governor's Office designation of Defense and Aerospace as key industries. The Department is now accepting applications for the following openings.

- Founding Aerospace Program Director and Victor LaMar Lockhart Professorship. See **http://bit.ly/2McPHFT**.
- Full/Associate Professor with expertise in Aerospace Engineering, including aerospace systems/controls, unmanned aerial vehicles, aerospace propulsion, or aerospace thermal/fluids sciences. See **http://bit.ly/2O6I3NA**.
- Full/Associate Professor with expertise in Computational Fluid Dynamics, in either Mechanical or Aerospace Engineering. See **http://bit.ly/2n4Q8af**.

Review of applications will begin on September 3 and interviews are expected to begin in October 2018. The positions are available July 1, 2019. Salary, benefits, as well as research and program startup packages will be highly competitive.

Reno is on the eastern slope of the Sierra Nevada Mountains, 45 minutes from Lake Tahoe and its magnificent recreational opportunities, and 4 hours from San Francisco.

Contact: Dr. Eric Wang, Mechanical Engineering
University of Nevada, Reno
(775) 784-6094, elwang@unr.edu

UND AEROSPACE
UNIVERSITY OF NORTH DAKOTA

The Department of Space Studies at the University of North Dakota seeks a Research Assistant Professor in the area of Space Life Sciences. Appointment will be at the research assistant professor level, non-tenure-track. A Ph.D., or M.D. is required (ABD considered) and professional experience in space life science is highly desirable. Ongoing contact with the space community and teaching experience is preferred. Approximately 70% of effort will involve research with the expectation that the successful applicant will establish a productive program of funded research in the space life sciences, which may include, among others, human adaptation to long-duration space flight, space medicine or psychology, or closed-loop environmental control systems. An established history of funded research and publication is desired. Approximately 20% of the faculty member's effort will involve teaching and advising graduate and undergraduate students on campus and through distance-learning technologies. An additional 10% effort is expected providing service to the space community and the University. Active membership in one or more of the following professional organizations is desirable; AIAA, AsMA, or HFES.

More information about the Department of Space Studies, a detailed job announcement and link to apply are found at **www.space.edu**.

SAN DIEGO STATE UNIVERSITY
Aerospace Engineering
College of Engineering

The Department of Aerospace Engineering invites applications for a tenure-track faculty position at the Assistant or Associate Professor rank. A preference will be given to applicants in Aerospace Propulsion. The areas of interest include but are not limited to: emerging areas of space propulsion such as ion, nuclear and green propulsion, as well as traditional (high-speed) airbreathing and rocket propulsion. Exceptional candidates in other areas of aerospace engineering including structures and navigation, guidance and control may also be considered. The faculty member will be expected to develop a vigorous, externally funded research program in his/her area of expertise, while teaching undergraduate and graduate courses in Aerospace Engineering. Applicants must have an earned PhD in Aerospace Engineering or a closely related field. Recent graduates as well as those with industrial or university experience are welcome to apply.

The department offers the BS and MS degrees in Aerospace Engineering and participates in Joint Doctoral programs with the University of California, San Diego, and Claremont Graduate University. The department has nationally and internationally recognized research programs in aerodynamics, fluid mechanics, structures, and guidance and control. The College of Engineering is the fastest growing of SDSU's seven Colleges. A newly built state-of-the-art Engineering and Interdisciplinary Sciences Complex has significantly expanded and enhanced facilities in the College with over 95,000 square feet of new space added for research and teaching needs. The city of San Diego enjoys a renowned mild climate year-round and is a family-friendly urban environment. The metropolitan area is the hub of several leading industries, including major defense contractors and aerospace companies. San Diego and Southern California offer exceptional opportunities for research partnerships with extensive aerospace industry. For additional information about the department and the university, please visit **http://aerospace.sdsu.edu** and **http://www.sdsu.edu**.

Additional information and application procedures are available at **https://apply.interfolio.com/52765**. Inquires should be directed to Prof. Gustaaf Jacobs, Search Committee Chair, **gjacobs@sdsu.edu**.

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1918

Sept. 12 U.S. Gen. John J. Pershing orders the 1st Army to attack the Saint-Mihiel salient. A force of 1,480 Allied and U.S. aircraft commanded by Col. Billy Mitchell support the attack. David Baker, **Flight and Flying: A Chronology**, p. 117.

Sept. 20 U.S. Navy Lt. David S. Ingalls becomes the first and only U.S. Navy ace when he destroys a German Rumpler while he is flying for the United Kingdom's Royal Air Force. David Baker, **Flight and Flying: A Chronology**, p. 118.

Sept. 25 Capt. Edward Rickenbacker assumes command of the famous 94th Aero Squadron after returning from sick leave. In the next six weeks, he adds another 20 German aircraft to his tally of six, thus becoming America's leading ace of the war with 26 victories. David Baker, **Flight and Flying: A Chronology**, p. 118.

Sept. 29 The Scottish-built R.29 becomes the first and only known airship to sink a submarine, the German U. 115. The R.29 bombs the sub and seriously damages it, then directs two torpedo-boat destroyers to the spot. They deploy depth charges and finish the job. **Aeronautics**, Dec. 23, 1920, p. 449.

1943

Sept. 9 Two German Fritz X-1 radio-controlled bombs sink the 46,200-ton Italian battleship Roma in the Straits of Bonifacio just after the Italian fleet surrenders to the Allies. The Germans did not want the ship to fall into British hands. One Fritz X penetrates the ship's magazine causing a massive explosion. It is the first time that a "capital" ship, a term referring to a navy's most important vessels, is sunk by a radio-controlled bomb. **Flight**, Sept. 16, 1943, p. 303.

Sept. 13 Richard DuPont, special assistant to U.S. Army Air Forces Gen. Henry "Hap" Arnold and one of the nation's leading gliding experts, is killed in a glider crash at March Field, California. DuPont, the soaring champion of America in 1934, was a pioneer in pickup mail and freight service in conventional airplanes. He headed All American Aviation, which began mail operations for the Post Office Department in May 1939. Before his death, DuPont had been working directly with the Army Air Forces glider program. **U.S. Air Services**, October 1943, p. 30.

Sept. 15-16 Britain makes the first operational use of its 12,000-pound bomb when a Royal Air Force Avro Lancaster drops one over the Dortmund-Ems canal in Germany. A.J. Jackson, **Avro Aircraft Since 1908**, p.360.

Sept. 20 The de Havilland D.H. 100 prototype turbojet-powered Vampire single-seat fighter makes its first flight at Hatfield, Hertfordshire, England. A.J. Jackson, **De Havilland Aircraft Since 1909**, p. 423.

During September 1943
Germany's DFS 228 rocket-powered high-altitude reconnaissance aircraft prototype makes its first flight. It is in glider form (unpropelled) and is released from a Do 217K carrier aircraft to test its aerodynamics. J.R. Smith and Antony Kay, **German Aircraft of the Second World War**, p. 99.

1968

Sept. 4 Wernher von Braun, director of NASA's Marshall Space Flight Center in Huntsville, Alabama, dons a full-pressure spacesuit and enters the Center's Neutral Buoyancy Simulator tank. The tank is designed for simulated weightless activities in space. Von Braun finds the suit to be "very good" but recommends additional hand holds and tether points. Leo J. Jones, **A Chronology of the George C. Marshall Space Flight Center**, February 1971, p. 95-96.

Sept. 7 Max Conrad claims a world flight distance record of 7,995 kilometers in a closed-circuit route, landing his twin-engine Piper Aztec at Lambert Field in St. Louis after flying a 999 km triangular route among St. Louis; Des Moines, Iowa; and Kansas City, Missouri, eight times in 37 hours, 50 minutes. Conrad is also acclaimed for holding the world's record for a straight-line distance flight in a light aircraft, set June 2-4, 1959, in flying 12,373 km. **Washington Post**, Sept. 9, 1968, p. C5.

Sept. 10 South African-born astronomer Gerrit L. Verschuur, with the aid of the National Radio Astronomy Observatory at Charlottesville, Virginia, measures for the first time the strength of the Milky Way's magnetic field. The feat greatly helps explain theories of star formations, radio wave propagations and cosmic ray accelerations. **Washington Post**, Sept. 10, 1968, p. A10.

Sept. 15 The USSR launches its Zond 5 unmanned spacecraft, planned as a precursor to a manned lunar spacecraft, which becomes the second ship to circle the moon and the first to return safely to Earth. Although unmanned, it carries two Russian tortoises, mealworms, wine flies, plants, seeds and bacteria, which are said to be the first Earth life forms to reach the vicinity of the moon. **New York Times**, Sept. 17, 1968, p. 1.

Sept. 18 NASA launches Intelsat-3 F-1, intended to be the first of four Intelsat global communications satellites, although it fails to reach orbit due to a pitching of its Long-Tank Delta booster that had to be exploded by a ground-based safety officer. **Washington Star**, Sept. 19, 1968, p. A21.

Sept. 24 The first emergency ejection from a German air force F-104G Starfighter, equipped with a Martin-Baker GQ7A ejection seat, is made at Ramstein Air Force Base, West Germany. The pilot ejects when his jet overshoots the runway on landing. Delivery of the British-made Martin-Baker seats to the German air force began late in 1967. **Flight International**, Oct. 3, 1968, p. 516.

Sept. 26 The Ling-Temco-Vaught A7D Corsair 2 aircraft makes its first flight, by Robert E. Rostine, the company's experimental test pilot. In this flight, the Corsair is flown to Mach 0.94 and 6,096 meters. The LTV Corsair 2 is capable of subsonic flight and is powered by an Allison TF41- A-1 turbofan engine, which is a license-built Rolls-Royce Spey engine. The LTV A7D Corsair 2, a modified version of the U.S. Navy's Corsair 2, is to be assigned to the Air Force and enters the fleet in 1970 and flies extensively in the Vietnam War. **Flight International**, Oct. 3, 1968, p. 316.

Sept. 26 An Air Force Titan 3C rocket launches four satellites into separate Earth orbits. The spacecraft are a Lincoln Experimental Satellite, two Envi-ronmental Research Satellites and an Orbiting Vehicle Research Satellite. The satellites' mission includes investigating radiation; the Lincoln Experi-mental Satellite is to test satellite communications with aircraft. **NASA, Astronautics and Aeronautics,** 1968, pp. 228-229.

Sept. 30 The first Boeing 747, and first wide-bodied jet airliner produced, is rolled out from Boeing's plant at Everett, Washington, for its initial public showing. The aircraft, which is also referred to by its nickname of "Jumbo Jet," subsequently enters commercial operations in 1970 and holds the passenger capacity record for some 37 years. **Flight International**, Oct. 3, 1968, p. 516 and Oct. 10, 1968, p. 554.

Sept. 30 Charles Clement Walker, one of the great British pioneers of aircraft design, dies at age 91. Walker was one of the five founder-members of the de Havilland Aircraft Co. in 1920. He influenced the design of every de Havilland aircraft for the next 50 years, from the D.H. 1 to the D.H. 121, including the famous D.H. 29 cantilever high-wing monoplane that was considered ahead of its time and D.H. 98 Mosquito of World War II. Born in 1877, Walker began his career as an engineer and studying aerodynamics before starting work in 1914 for Geoffrey de Havilland at the Aircraft Manufacturing Works in the London suburb of Hendon. In addition, he was a member of the Advisory Committee of the Royal Aeronautical Society to the Minister of Aircraft Production. **Flight International**, Oct. 3, 1968, p. 516; **Aeronautical Journal of the Royal Aeronautical Society,** April 1969, p. 37.

1993

Sept. 2 U.S. Vice President Al Gore and Russian Prime Minister Viktor Chernomyrdin agree to pursue the construction of an international space station. **NASA, Astronautics and Aeronautics, 1991-1995**, p. 421.

Sept. 12 The Advanced Communications Technology Satellite launches as the main payload onboard the space shuttle Discovery. The high-speed, all-digital satellite operates for six years as a testbed for researchers. **NASA, Astronautics and Aeronautics, 1991-1995**, pp. 423-424.

Sept. 27 Retired U.S. Air Force Lt. Gen. Jimmy Doolittle dies at age 96. One of the most accomplished aviators in history, Doolittle set a cross-continent speed record in 1922, won the Schneider Cup in 1925, and the Thompson Trophy in 1932 while flying the dangerous Gee Bee R-1. He earned a doctorate from MIT and joined Shell Oil, where he helped develop 100 octane jet fuel. He rejoined the military for World War II, received the Medal of Honor for his bomber raid against Tokyo in April 1942, and commanded the 8th Air Force, among his many achievements. **NASA, Astronautics and Aeronautics, 1991-1995**, p. 426.

HALDAN GATES, 31

Flight group lead, Tamarack Aerospace Group

Aerospace engineer Hal Gates was working at a part-time job unrelated to aerospace back in 2010, when an acquaintance introduced him to the founder of Tamarack Aerospace, a 30-person engineering and aircraft modification company in Idaho. Tamarack ended up hiring Gates, who now oversees flight testing of the company's Atlas Active Winglets, an after-market product for business and general aviation airplanes. Small flaps inboard of the winglets protect the wing from excessive stress during wind gusts or high-G maneuvers by rising and temporarily turning off the aerodynamic effects of the winglets. This increases wing-bending stresses even as they improve fuel-efficiency. The FAA, European Aviation Safety Agency, Transport Canada and Brazil's National Civil Aviation Agency have approved the technology for all Cessna Citation C525, C525A and C525B business jets.

How did you become an aerospace engineer?

My family is peppered with engineers of various disciplines, and there are a few naval aviators as well. I've always loved puzzles and technical challenges, and airplanes have always captivated my interest. When it came time to choose a career, aerospace engineering seemed like the natural choice. I have a Bachelor of Science in aerospace engineering from Georgia Tech. I earned my pilot's license and [Instrument Flight Rules] rating, which has helped me considerably in my various roles here at Tamarack. I actually got this job through networking. I had a part-time job in a coffee shop in 2010, and one of my regular customers introduced me to his cousin, Nicholas Guida, Tamarack founder and chief technology officer. I had taken some elective courses that had given me experience programming in C++. I was given a test assignment based on a project that the company was working on and we went from there. When I first started at Tamarack, I was building structural analysis tools. After that, I was involved in the system development and environmental qualification testing. We're a fairly small company, so we all do a bit of engineering cross-training. Now, most of my responsibilities revolve around flight testing, writing test plans and reports, installing instrumentation and collecting data onboard.

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

A lot of our airspace system is still designed for use without automation — instrument approaches that take you out of your way if you're approaching the airport from a particular direction because of cockpit workload considerations, for instance, or arrival and departure procedures that divert you out of your way for traffic separation in congested airspace. As the aircraft themselves take over more responsibility — and more importantly, are communicating directly with each other for separation and sequencing — it will allow more efficient flying, which will ultimately expand access to aviation and allow more flexibility. I think that in 2050, we'll have better air cargo, better aerial emergency services, and more convenient air travel directly between more cities. I think it'll be based on the logical expansion of cockpit automation. I have some mixed feelings about it as a pilot, but as an engineer I'm excited to see where it takes us. ★

By DEBRA WERNER | werner.debra@gmail.com