NAVIGATION 16
Quantum physics could get us to Mars

OPINION 30
Why the U.S. will go back to the moon

AEROPUZZLER 8
Take the Frisbee challenge

AEROSPACE AMERICA

ORDEAL OR IDEAL?

Why the aviation industry stands by the promise of geared turbofans, despite rollout woes. PAGE 22

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

AIAA
SHAPING THE FUTURE OF AEROSPACE

22

Flying with geared turbofan engines

Pratt & Whitney is the first manufacturer to produce them on such a scale, and industry is watching how the company is handling the problems that have cropped up.

By Keith Button

16

Timing it just right

Quantum navigation holds the promise of radically reducing the time it takes engineers and scientists to communicate with spacecraft in deep space.

By Amanda Miller

30

Returning to the moon

A space historian looks at what got the United States there the first time and the future of government-sponsored spaceflight.

By John M. Logsdon

38

Protecting commercial aircraft

A cybersecurity strategist examines what it will take to expand the aviation safety culture to the cyber realm.

By James Vasatka

On the cover: Geared turbofan engine in test cell
Image credit: Pratt & Whitney

AEROSPACE
AMERICA

OCTOBER 2018, VOL. 56, NO. 9

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

ASSOCIATE EDITOR
Karen Small
karens@aiaa.org

STAFF REPORTER
Tom Risen
tomr@aiaa.org

EDITOR, AIAA BULLETIN
Christine Williams
christinew@aiaa.org

EDITOR EMERITUS
Jerry Grey

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

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

ADVERTISING
Katie Taplett, 202-904-0782
katietaplett@yahoo.com
advertising@aiaa.org

ART DIRECTION AND DESIGN
THOR Design Studio | thor.design

MANUFACTURING AND DISTRIBUTION
Association Vision | associationvision.com

LETTERS AND CORRESPONDENCE
Ben Iannotta, beni@aiaa.org

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

IN THIS ISSUE

Keith Button

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

PAGE 22

Amanda Miller

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

PAGE 16

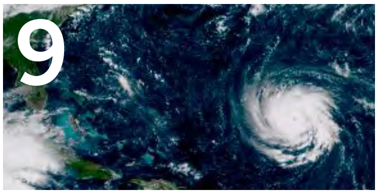
Debra Werner

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

PAGES 64

DEPARTMENTS

AEROPUZZLER
Get a Frisbee and tackle the next challenge.



TRENDING
Satellite imagery of Hurricane Florence

4 Editor's Notebook

7 Flight Path

43 AIAA Bulletin

58 Career Opportunities

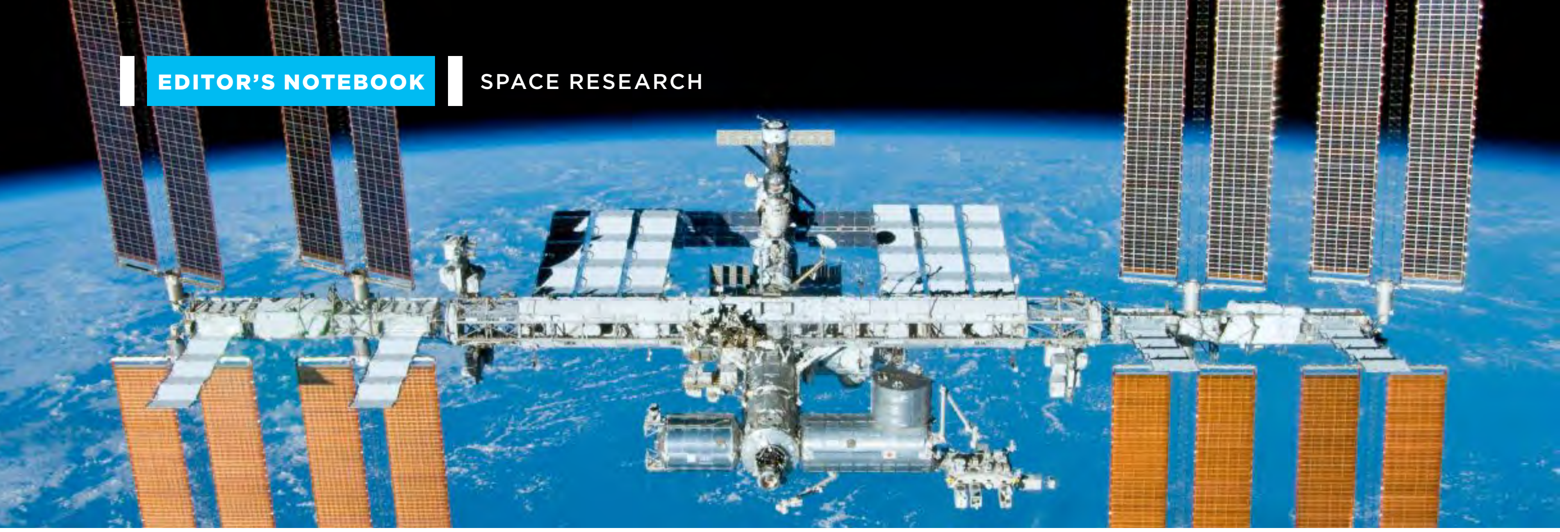
62 Looking Back

10
Q & A
Hiroshi Yamakawa, president of the Japan Aerospace Exploration Agency

12
Case Study
Making aerostats available to those with smaller budgets

62
Looking Back
Historic events in aerospace, including Apollo 7's mission in 1968

64
Trajectories
SSL's technical director for the robotic servicing of geosynchronous satellites



NASA

Quantum physics and the International Space Station

President Ronald Reagan, in his 1984 State of the Union Address, promised that a space station would bring "quantum leaps" in a host of research areas. He meant quantum as in significant, not as in the applied physics experiment due to unfold shortly in the International Space Station's Cold Atom Laboratory [See "Quantum Promises," Page 16].

Reagan's speech illustrates how hard it is to predict the return on investments from space research, or to foresee the research that creative human beings will conceive. Our markets here on Earth aren't yet teeming with products that "could be only manufactured in space," as Reagan predicted. Who could have guessed in 1984 that the station would be a venue for quantum physics research that could point to a whole new way of performing deep space navigation?

The future of ISS after 2024 will probably be just as hard to predict, even if NASA and its international partners succeed at transitioning this $80 billion conglomeration of modules and living space to the control of a private entity of some kind.

One open question is just how much autonomy that private entity would be granted to apply market principles to the future of ISS.

Congress and NASA have constrained the conversation in at least one important way. The "NASA Transition Authorization Act of 2017" envisions NASA becoming "one of many customers of a low-Earth orbit non-governmental human space flight enterprise." That sounds like a call for an independent enterprise, except that the station would remain a "human space flight enterprise." A similar constraint is reflected in NASA's congressionally mandated "International Space Station Transition Report," released in March. NASA lays down eight "core principles" for the transition, four of which call directly or by inference for expanding or continuing human space flight.

This language sounds a lot like offering to privatize a factory so long as the new owner agrees to keep all the workers. We need to remember that we're living in an age of robotics and artificial intelligence. Today's roles for astronauts on ISS might not apply to tomorrow, depending on how one answers the following philosophical question: Should the astronauts on ISS after 2024 be seen as space explorers or space workers? If they are workers, then business judgment must kick in or the business will be short-lived. A business leader would not care that "astronauts have continuously lived aboard the ISS for over 17 years," as the NASA transition report gushes. He or she would need to see the business case for continued human occupation and by how many astronauts. Successful businesses do not keep workers on production lines, in coal mines or on space stations for the sake of tradition.

And then there's the mix of research to consider. Will that be decided by how many dollars customers are willing to pay? By the likelihood of a return on investment? Or must the mix cater to the government's definition of what "ultimately benefits people on Earth," to use the NASA report's language?

These are big questions without easy answers. It's possible that initiatives like the quantum research in the Cold Atom Lab could be squeezed out by those with deeper pockets and better odds of a return on investment. That's a bad thing if one's goal is to open up deep space with findings from this lab. But it could be a good thing if, for example, Parkinson's disease lies in your future and the entity with the deeper pockets finds a treatment because of its research on ISS.

Hard choices like this could lie ahead if the market for space research turns as red hot as many hope. ★

▲ Business decisions may play a part in future research onboard the International Space Station.

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

1


2


3


Three of the photos on the Looking Back pages in the September issue were placed next to the wrong dates. Here are the correct placements:

1 Sept. 15-16, 1943 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.

2 Sept. 20, 1943 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.

3 Sept. 26, 1968 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.

Come Join our Community! Or Better Yet, Create Your Own!

Over the past year, AIAA has been transitioning to its new governance model. This improved way of operating was developed by AIAA volunteers and staff with the goals of creating a Board that was strategically focused, giving members the voice they deserve through the Council of Directors, and perhaps most importantly providing the members with new opportunities for engagement. One of these new engagement opportunities is a concept called Communities of Interest. So, what is a Community of Interest (CoI)? We're glad you asked!

Simply stated, a CoI is a way for AIAA members to interact on a topic of mutual interest relevant in some way to the aerospace community using our online community platform, AIAA Engage. A CoI is meant to be an informal means of sharing ideas and information on just about any topic that individuals involved with the aerospace community can dream up—think of it as a chatroom specific to your interest. A CoI can focus on a very technical topic, but there is no reason that the focus must be purely technical. Often our hobbies and our professional areas of expertise are intertwined. Perhaps there is a community for "airshow addicts" or folks who enjoy "amateur space photography." Many members may also try to fit a little fun time into their travels when attending an AIAA forum, so perhaps a CoI could be created to help organize an outing to a local brewery, a hiking excursion, or a visit to an aviation museum, bringing together folks who might not otherwise get a chance to meet.

The CoI concept is essentially another opportunity for our members to interact with others who have similar interests, expand their knowledge base, enhance their networks, and sometimes just have fun. It is a way to build a member-driven and member-created community around whatever it is you and your colleagues want to focus on. They can connect folks from across the country and around the world. But they can also be more geographically focused, such as creating a CoI on stargazing in the Tucson area or a CoI for UAS pilots in northern Ohio. The possibilities are endless.

You might be asking yourself, can't I just join a Technical Committee (TC), an Integration and Outreach Committee (IOC), or connect with folks in my local section? Sure, that's a great way to get involved with your aerospace colleagues. The CoI concept is complementary in that it allows for a new group to be set up quickly and easily, and it does not have the organizational and product delivery demands of a TC, IOC, or section. TCs, IOCs, and sections are service oriented and exist in large part to develop the products and programs that the AIAA members use (standards, short courses, forum content, etc.). CoIs are not expected to develop any formal deliverables. However, CoI activities and discussions can result in great ideas that could develop into formal products or programs that could be adopted by a member committee, section, or one of the Board committees that oversee product development (such as Standards or Public Policy).

We encourage you to start a discussion thread on the Open Forum of AIAA Engage to see if there are people who share your interest. If so, AIAA staff can create a separate online discussion board space for you to have your focused conversations. The discussion board allows for the members of your community to share ideas and files, ask questions, and set up informal face-to-face gatherings at an AIAA forum, a local section, or a nearby industry site; basically it is your avenue to connect.

To date, four Communities of Interest have been established:

- **Certification/Qualification by Analysis**—An international team focused on developing high-level guidelines for predictive processes/simulations as a means of compliance for aircraft regulatory certification to safely improve efficiency.
- **Complex System Sustainment**—A focused community to develop and share sustainment best practices.
- **Integrating the Aerosciences Toolkit Community**—A clearinghouse and catalog of workforce development initiatives and discussion board to identify significant gaps not being addressed.
- **Workshop for Integrated Propeller Prediction at the 2019 AVIATION Forum**—This workshop will take place 16 June 2019 at the AIAA AVIATION Forum in Dallas, TX. The objective is to validate the aerodynamic efficiency benefits of wing tip mounted propellers and the ability of CFD to accurately predict them using powered low speed wind tunnel test data on a generic configuration representative of the X-57.

These CoI are focused on specific technical topics, but there is plenty of latitude on the types of topics that can be covered.

So, do you have a topic that really intrigues you? Do you think that there are other AIAA members who have the same passion about a certain aerospace problem as you? Maybe it is time that you all found each other and started talking about that topic. Start a thread on the Open Forum of AIAA Engage to see who else shares your passion, and maybe you will be forming your very own Community of Interest!

AIAA members can connect at Engage.aiaa.org. Log in using your AIAA.org credentials. ★

Allen Arrington, Speaker, AIAA Council of Directors, and Nancy Andersen, Chief, Integration and Outreach Division

AERO PUZZLER

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

Frisbee fact or folly

Q Imagine that a right-handed person throws a Frisbee in the Northern Hemisphere. This person travels to the equivalent latitude and longitude in the Southern Hemisphere and throws the Frisbee exactly the same way. Assume that the wind speed is zero and that the atmospheric conditions are identical. Will the flight of the Frisbee differ? If so, how and why?

Email your response to:
aeropuzzler@aiaa.org

ABOUT THE AEROPUZZLER

Your task is to boil down a complex topic into a maximum of 250 words that anyone could understand (without equations or drawings). Email your response for a chance to have it published in the next issue.

FROM THE SEPTEMBER ISSUE

TIME MACHINE

Q: We asked you whether the James Webb Space Telescope, which will look back in time in infrared wavelengths, could detect energy and particles that eventually coalesced into the sun, Earth and its 7.6 billion human inhabitants.

We asked Nobel laureate John Mather, who leads the Webb telescope science team, to help us review your responses. Here is the winner:

A: Whenever we use a telescope, in a literal sense we "look back in time." Since the light we see travels at a finite speed, we see things as they were when the light was emitted, not as they are "now." So, if the light that the Webb telescope gathers has travelled for billions of years, we see things as they were billions of years ago.

Nevertheless, the Webb telescope cannot "detect energy and particles that eventually coalesced into the sun, Earth, and its inhabitants." The Webb telescope looks into the past — but not into our past, but the past moments of places far distant. Although the light originated billions of years before the Earth was formed, it is just arriving at Earth now, and since nothing travels faster than light, we are looking at parts of the universe that have not arrived at, or affected, the Earth.

Since the universe is relatively uniform, though, we know that what we see of distant places must also tell us about our own distant past. When we observe the earliest galaxies, and the formation of the very first stars that coalesced out of the chaos of the Big Bang, we see what our own past was like. When we observe the infrared light from planetesimals accreting from disks of dust surrounding newly formed stars, we see what must have happened as planets formed around our own sun. So, in a real sense, yes: in a distant mirror, we indeed see our own origins.

– Geoffrey A. Landis, AIAA associate fellow, Cleveland

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

The story in Florence's eye

BY BEN IANNOTTA | beni@aiaa.org

The closeup videos of Hurricane Florence's swirling eye that mesmerized online and TV audiences last month came from a satellite camera of an entirely new design that was still in its checkout phase last hurricane season.

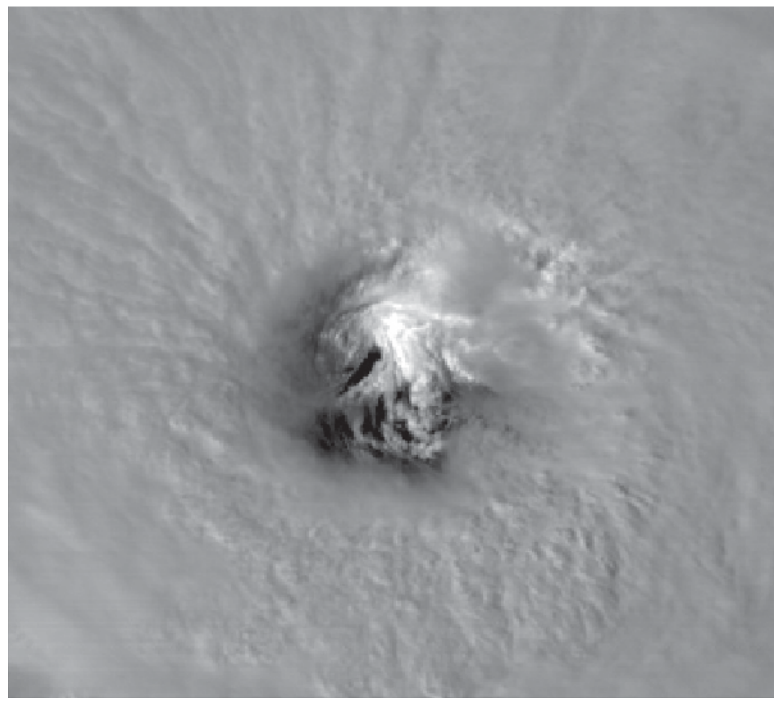
The Advanced Baseline Imager, built by Harris Corp., is the primary camera on NOAA's GOES-16 weather satellite, which is positioned in the GOES-East slot 36,000 kilometers over the equator. From this position, ABI can see the Atlantic Ocean all the way to the coast of Africa and a bit beyond.

ABI scans across Earth by rotating two mirrors, one to control the north-south line of sight and the other to control the east-west line of sight. The concept is a bit like the sideview mirrors of your car, which let you adjust the view from side to side and up and down, explains Paul Griffith, chief engineer in Harris' Environmental Solutions unit in Fort Wayne, Indiana, where the ABI cameras are built. "ABI does this with two sets of mirrors," he says in an email forwarded by a spokeswoman.

The camera delivers a full disc image of the Western Hemisphere every 15 minutes and can also scan two smaller sectors when commanded by the National Weather Service. Forecasters can examine two separate storms at one-minute intervals, or in rare cases the two sectors can be "stacked" at one geographic location to produce images of a single storm every 30 seconds, explains NOAA research meteorologist Dan Lindsey. He is the senior scientific adviser in the NASA office that manages development of NOAA's newest Geostationary Operational Environmental Satellites, the GOES-R series. Some of the most intriguing Florence videos were produced by this 30-second method. The resulting images are "close to snapshots," Lindsey explains. "It's sort of like time-lapse photography from space," he says.

The process of creating a video begins once the scans are downloaded from the satellite and disseminated. Lindsey or anyone with a data feed can apply software to set parameters, such as how much to zoom in.

The videos are smooth because ABI captures imagery five times faster than its predecessors, the GOES Imagers. Were it not for this high temporal resolution, the videos would appear choppy. ABI also provides four-times finer spatial resolution, which is why swirling low-level clouds, called mesovortices, were so clear in the eye of Florence in some videos.



NOAA

▲The eye of Hurricane Florence on Sept. 11, three days before the storm made landfall at Wrightsville Beach, N.C.

Specifically, the images are built from pixels (picture elements) about 500 meters on a side, depending on the storm's latitude, which determines the distance from the camera.

As enthralled as the public was by the motion of the clouds around and within Florence's well-organized eye, hurricane forecasters tend to tune in much earlier in a storm's development. They need to locate the center of circulation to initialize the various forecast models, and that can be tricky when a storm is weak. "With the one-minute updates," Lindsey says, "it's a lot easier to sort of track the low-level clouds and infer where the center is located." ★

JAXA

JAXA's scholar-manager

This month's scheduled launch of the two BepiColombo orbiters to Mercury will be personally significant for Hiroshi Yamakawa, president of JAXA, the Japan Aerospace Exploration Agency. During the planning phase of the mission in the early 2000s, he was the project manager at JAXA for the country's contribution to this joint mission with the European Space Agency. After a stint in academia and advising the prime minister's Cabinet, Yamakawa returned to JAXA in April in time for the launch of BepiColombo and receipt of the first images from Hayabusa-2, a probe now orbiting the asteroid Ryugu in preparation for landing on it. In the aviation realm, Yamakawa arrives as JAXA is planning additional research into quiet supersonic aircraft and continuing work on a laser technology for detecting turbulence ahead of passenger planes, among other endeavors. Yamakawa is the fourth president of JAXA, which was formed in 2003 from the merger of three space and aviation organizations. He is the first president to come from academia rather than the business world. Yamakawa spoke with me by phone from JAXA headquarters in Tokyo.

— Tom Risen

HIROSHI YAMAKAWA

POSITIONS: President of JAXA since April; member of the Committee on National Space Policy in the Cabinet Office, 2012-2018; secretary general, space development strategy in the Cabinet Secretariat, 2010-2012; professor at Kyoto University Graduate School of Engineering, 2006-2018; JAXA project manager for the BepiColombo mission to Mercury, 2005 to 2006; associate professor at JAXA, 2003-2006; associate professor at Japan's Institute of Space and Astronautical Science, 1993-2003.

NOTABLE: Researched methods for tracking and deflecting asteroids, at Kyoto University's Research Institute for Sustainable Humanosphere. Helped design the JAXA side of the BepiColombo mission ahead of the first meeting with the counterpart European engineering team in 2006.

AGE: 53

RESIDES: Tokyo

EDUCATION: Master's degree in engineering in 1990, doctorate in engineering in 1993, both from University of Tokyo.

More online aerospace america. aiaa.org

IN HIS WORDS

BepiColombo's mission
There're lots and lots of mysteries about Mercury because of its size, the existence of magnetosphere, the existence of the very thin atmosphere. Planetary scientists cannot explain everything at the same time. I think it's because of the lack of information. Observing Mercury provides the information and some clues to the formation of planets, including Earth.

Mercury's secrets
It is easy for us to presume its core has already cooled and solidified. Mysteries still remain as to how Mercury was formed and why this is the smallest planet in our solar system that seems to hold a molten core. JAXA will try to better understand those mysteries through geological research and observations of its magnetic field to be obtained by the Mercury Magnetospheric Orbiter and the European Mercury Planetary Orbiter spacecraft.

Defending against asteroids
To tackle hazardous asteroids approaching the Earth, the first step is observation to determine the orbit precisely. That enables us to estimate the collision probability and the time frame. The next step is to change the asteroid orbit well beforehand. If we discover asteroids which may hit Earth, for example, in 20 years, we would have to launch a spacecraft to impact the asteroid 10 years before it hits Earth.

Sampling an asteroid
We believe the asteroid Ryugu contains water and organic matter. The Hayabusa-2 mission to collect the underground material from 4.6 billion years ago in that crater thus explores the origins of sea water and of life on Earth. Remote observation of Ryugu will first be done to make a map of the asteroid including the gravity and geological distribution.

After Hayabusa-2
I think a logical step forward is to orbit and explore a different type of asteroid at a different place. Like those asteroids between Mars and Jupiter, for example. The technologies which enable us to create an artificial crater on the asteroid can be utilized for missions and, of course, private companies can utilize it for their own business.

Supersonic speed limits
In the D-SEND [Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom] project, which is already finished, JAXA ran the world's first low-boom supersonic technology test flight [dropping the supersonic glider from a stratospheric balloon]. As a result, I would say the noise level of a small supersonic passenger plane — equivalent to thunder sounds — has been brought down to a door knock. That was a tremendous reduction of noise and this is, dare I say, significant enough to activate international standardization of low-boom supersonic standards in the United Nations International Civil Aviation Organization.

Designing a supersonic passenger jet
JAXA will expand the D-SEND low-boom technology to include the aircraft and engine for a supersonic passenger plane. That kind of project is maybe the next step, but is not yet funded, so it's still at the research level. There are lots of JAXA researchers engaged in supersonic technologies.

Spotting turbulence
Flight tests of the JAXA Turbulence Detection System were conducted on the Boeing ecoDemonstrator this year. Data analysis is still underway. JAXA and Mitsubishi Electric Corp., the manufacturer, seek to [make an operational version for passenger aircraft]. A standardization process is vital.

Partners to the moon
We're discussing lunar exploration with the international community. China is a member of that working group, not only Europe and the United States. Right now, we are discussing what JAXA can contribute to the [NASA Lunar Orbital Platform-Gateway]. JAXA has its own lunar exploration study framework and our high-precision lunar landing mission called [Smart Lander for Investigating the Moon]. Our next step is the observation of the lunar pole region resources.

View on climate change
I think global warming is a common challenge for everybody. I'm talking about humankind. The impact that global warming poses — the sea level rise is just one aspect of it — is far more serious than what Japan, or any other single country can deal with. In order to contribute to the Paris Agreement, Japan has set goals to reduce greenhouse gases.

Satellites and greenhouse gases
Japan spearheaded satellite-based greenhouse gases monitoring in 2009, when the [Greenhouse Gases Observing Satellite, or GOSAT] observation satellite was launched. Satellite observations are very effective to monitor greenhouse gases because they can provide extensive data. I will be pleased if Japanese satellite observation technology contributes to the world as well as the Paris Agreement.

Outreach with China on Earth science data
There's no direct collaboration now. We're collaborating with every country in the world that is interested and especially talking about greenhouse gases. Environment data from satellites is an asset that belongs to the global science community. Our data is shared through the international framework Group on Earth Observations and the other framework is Committee on Earth Observation Satellites. ★

The power of aerostats

They don't look like impressive flying machines, but aerostats have the advantage of persistence. They can be equipped with radios and antennas to act as communications nodes and with cameras for surveillance. The U.S. military has made widespread use of expensive versions in Afghanistan and Iraq, and larger systems are now operating on the U.S. southern border. Retired U.S. Air Force Col. Charlie Lambert explains how the company he founded, SkySentry LLC, combined existing components to produce an aerostat system for agencies with thinner wallets.

BY CHARLIE LAMBERT

SkySentry

▲ **A TEA (TEE-uh),** short for Tactically Expedient Aerostat, on a mooring trailer.

Picture smoke signals from a bluff high above a remote prairie. That's just one way humans have tried to communicate over remote, rugged terrain for millennia. Humans intuitively understand that they can see and communicate farther from a higher place. Hence the primitive smoke signals from high on a bluff.

When I retired from the U.S. Air Force in 2003, I formed SkySentry near Colorado Springs to help advance the High Altitude Airship project that I worked on during my last decade in service. The North American Aerospace Defense Command wanted to see if airships could expand the radar picture for missile defense. My staff and I embarked on a lengthy effort to explain the potential benefits of a High Altitude Airship to the military. Eventually, we collected over $100 million dollars to build and fly one in a technology demonstration. As development continued, we realized that payload development was every bit as challenging as the vehicle itself, so we acquired large aerostats as a means of field-testing payloads. Those payloads were supposed to be mature enough for deployment on airships, but they were, in fact, rarely ready. Communications nodes required different antenna configurations; radars needed widely separated magnetic sensing; cameras need stabilization and steering. We helped the various engineers resolve these issues by mounting payloads on aerostats in different orientations; varying the power system inputs and whatever else was required.

This experience showed us that aerostats could be tremendously useful in their own right as surveillance and communications platforms. Each can be unreeled to a desired altitude on a synthetic tether about the diameter of a school pencil. When necessary, the tether can house fiber optic strands to download data from the payloads without risk of interference and copper wires to deliver power to the payloads. An aerostat provides persistence and never inconveniently passes over the horizon like a satellite does. Plus, its flight can be controlled more readily than that of an airship. Indeed, when measured on a cost-per-hour basis, there is no cheaper alternative for elevating payloads to improve their ranges. As an example, an aerostat at 500 feet above ground will give a radio nearly 50-kilometer line-of-sight range to the horizon; that exceeds the range of most radio payloads commonly used by field operators.

For five years, SkySentry led a major Army contract task order to specify, order, purchase and operate aerostats for the Army Space and Missile Defense Command. Simultaneously, SkySentry expanded its lines of business to include design and integration of complete aerostat systems for other customers.

SkySentry is a lead system integrator. Our innovation is to find the best off-the-shelf equipment and assemble it into affordable communications, sensor and surveillance platforms.

The right stuff

The heart of such a system is the aerostat, and SkySentry's quest to find a more affordable, properly performing aerostat was lengthy and thorough. Our first few aerostats were not the right solution for agencies with budgets smaller than the U.S. military's. They were traditionally shaped models, looking like Goodyear blimps at about 25 meters long. These were flown by the U.S. military during operations in Afghanistan and Iraq, but these aerostats cost a lot to buy and operate. We postulated that we needed smaller aerostats and alternative designs for these potential new customers.

The laws of physics readily tell us the most efficient shape for maximum lift is a simple spherical balloon, so we focused first on that shape and found several models. However, when exposed to winds, spheres tend to spin and flop around. That behavior isn't conducive to effective payload operations. We assessed manufacturers of small aerostats worldwide, each with different accoutrements aimed at stabilizing their aerostats in strong and turbulent winds. While the designs were often similar, we found a large disparity in the quality, weight and durability of aerostat fabrics and fabrication techniques.

After a detailed trade study, we settled on the patented Helikite design fabricated by Allsopp Helikites in the United Kingdom. These balloons are spherical at the front, which is the most efficient lifting shape in no-wind conditions, and each has a kite-shaped tail and keel for stability in the wind. They have been through extensive U.S. government assessments with good results. They vary in size from a tiny 2-cubic-meter version to one that is about 8 meters in diameter with a volume of 250 cubic meters. The customer buys the size needed to lift the payload and tether. In no wind, the helium volume lifts the balloon, with a rule-of-thumb planning factor of 1 pound of net lift per each cubic meter of helium volume. As wind velocity increases, the underlying kite increases the lift by four times or more over the no-wind lift. The keel below the aerostat acts like a boat rudder, providing considerable stability in the wind flow.

We field tested a common alternative design in which a sail rides behind the balloon to try to keep it from spinning in the wind. In high winds, we found the sail pulled the aerostat down toward the ground, once even bouncing it off the surface. Vendors offering this design try to mitigate the pull-down tendency by specifying a great amount of excess helium lift above desired payload weight. Ultimately, SkySentry adopted the Helikite aerostat and synthesized it with winches, tethers, power supplies and mooring components to provide stable, persistent elevated functionality, while reducing aerostat volume from about 800 cubic meters to 100 cubic meters.

After choosing the Helikite as the basic building component of this SkySentry line of business, SkySentry shifted focus toward design of a rugged, compact, turnkey system. Design is more complex than one might perceive by looking at a complete system. For example, winches must have a minimum core diameter to prevent bending and breaking copper wires and fiber optic strands in the tether. The winch must have a minimum pull strength to launch and retrieve an aerostat and should run at a speed of about 30 meters per minute or more, so launch and recovery don't seem to take forever. Tethers offer similar challenges. Electricity running up copper wires in a tether meets resistance. Large wires lower the resistance from the copper, but the larger the wires, the more weight the aerostat has to lift. So a detailed trade analysis is done for each customer to accurately calculate the smallest wire size needed to power the payload, resulting in the smallest, most cost-effective aerostat size.

There was also the question of how to deliver the aerostat systems to customers. Many of our staff are former U.S. military service members who have experience delivering equipment to sites around the world via C-130s. We decided that the total aerostat system had to be packable into standard shipping containers for sea or airlift to a customer's operational area or for home storage. The complete aerostat system had to require no more than two people to set up, launch and recover.

In early 2011, we announced the result of this research, a system called TEA (TEE-uh), short for Tactically Expedient Aerostat. Each TEA is highly customizable, with trailer, winch, mooring platform, and other supporting components sized to the customer's needs. The design process typically starts with defining the size and weight of the payload. Then a trade study on the power supply assesses whether continuous power up the tether is required, or whether the aerostat can be brought down periodically for changing out the payload batteries without unacceptable impact on the mission. As the lifted weight increases, the aerostat grows in size, which dictates the breaking strength and weight of the tether, in turn influencing the size and performance of the winch and mooring trailer. Should a customer not want to tow a trailer to the flight location, the aerostat and components can be carried in a truck and the TEA can be flown from a ground mooring base.

The versatility of TEAs is limited only by one's imagination. Their small size makes them hard to detect, so they can be deployed in unexpected areas to keep adversaries off balance. For example, a TEA on a trailer can be placed at a location in just an hour, so border intruders may well encounter a team with aerostat-based communications networks and surveillance where none existed just moments before. Further, if a large surveillance asset malfunctions, these small systems can be deployed quickly as gap fillers. For security operations at large sporting events, the TEAs can carry advertising logos, disguising that they are actually enabling a wide area surveillance and communications sphere. We've even mounted them on boats.

Payloads

No one really buys an aerostat just to be able to say, "Look, I own an aerostat!" A customer buys an aerostat to lift a payload. While gyro-stabilized cameras are popular for some relatively limited-range surveillance, we have generally found our aerostats to be most impactful when they carry wide area network communications for operations in austere environments. During the early days of our search for wide area network payloads, we flew and tested radio nodes weighing hundreds of pounds, with huge power draws and awkward antennas for broadcasting radio transmissions. The goal was to establish wide area networks for operators on the ground. But these large payloads were typically priced at more than a quarter million dollars and required huge aerostats to lift. Within the last few years, manufacturers have made quantum-leap improvements to these nodes. They are now smaller and less power hungry with longer ranges.

Each node creates a coverage area that can be visualized as a hemisphere extending below the aerostat and creating a 15-kilometer-radius coverage footprint on the ground. We call this coverage area a Tacti-Sphere. Anyone equipped with a properly programmed smartphone can verbally communicate with everyone else in a wide area network, by talking, texting, or push-to-talk chatting. Each participant in a Tacti-Sphere network can be a sensor out to the far edges of the network, using his or her phone to pass photos and videos to other participants or team headquarters. Greatly enhancing mutual support and situational awareness, each participant's location can be shown to all other participants. By linking the aerostat node to either a network SATCOM or a commercial cellphone tower, all participants can reach back to the internet or commercial communications. In addition, we recognized that customers might want to preserve legacy investment in their land mobile radios, so if an agency wants to use LMRs instead of smartphones, we can accommodate that as well.

Learning about payloads was an arduous effort for us, given the dozens of types, makes and models. We found unexpected idiosyncrasies when integrating with an aerostat, usually boiling down to antenna performance. Two general categories

▲ **An inflatable aerostat mooring** base, winch and pulley.

Charlie Lambert, a retired Air Force colonel, became one of the service's leading experts on lighter-than-air technologies during his 30-year career. Lambert retired in 2003 and founded the company SkySentry. He has a Bachelor of Science degree in civil engineering and a Master of Science in operations management from the University of Arkansas.

of networks have proved most useful. The most popular is a 4G LTE network. An ultralight 4G LTE node is lifted on the aerostat, with the smallest node capable of simultaneous transmissions by about 32 operators. Using a 30:1 planning ratio for the number of registered users to simultaneous transmissions, this smallest node can serve a population of about 1,000 registered users with all the functionality listed above. Disaster response may require more registered users, dictating that a larger node and larger aerostat be employed. 4G LTE networks have been proven in rugged territory over areas as large as 300 square miles. Even larger areas can be covered by linking two 4G LTE nodes together with high bandwidth radio links, with each node surrounded by its own registration of smartphones. Importantly, these 4G networks require pre-deployment spectrum coordination, which is usually not too difficult.

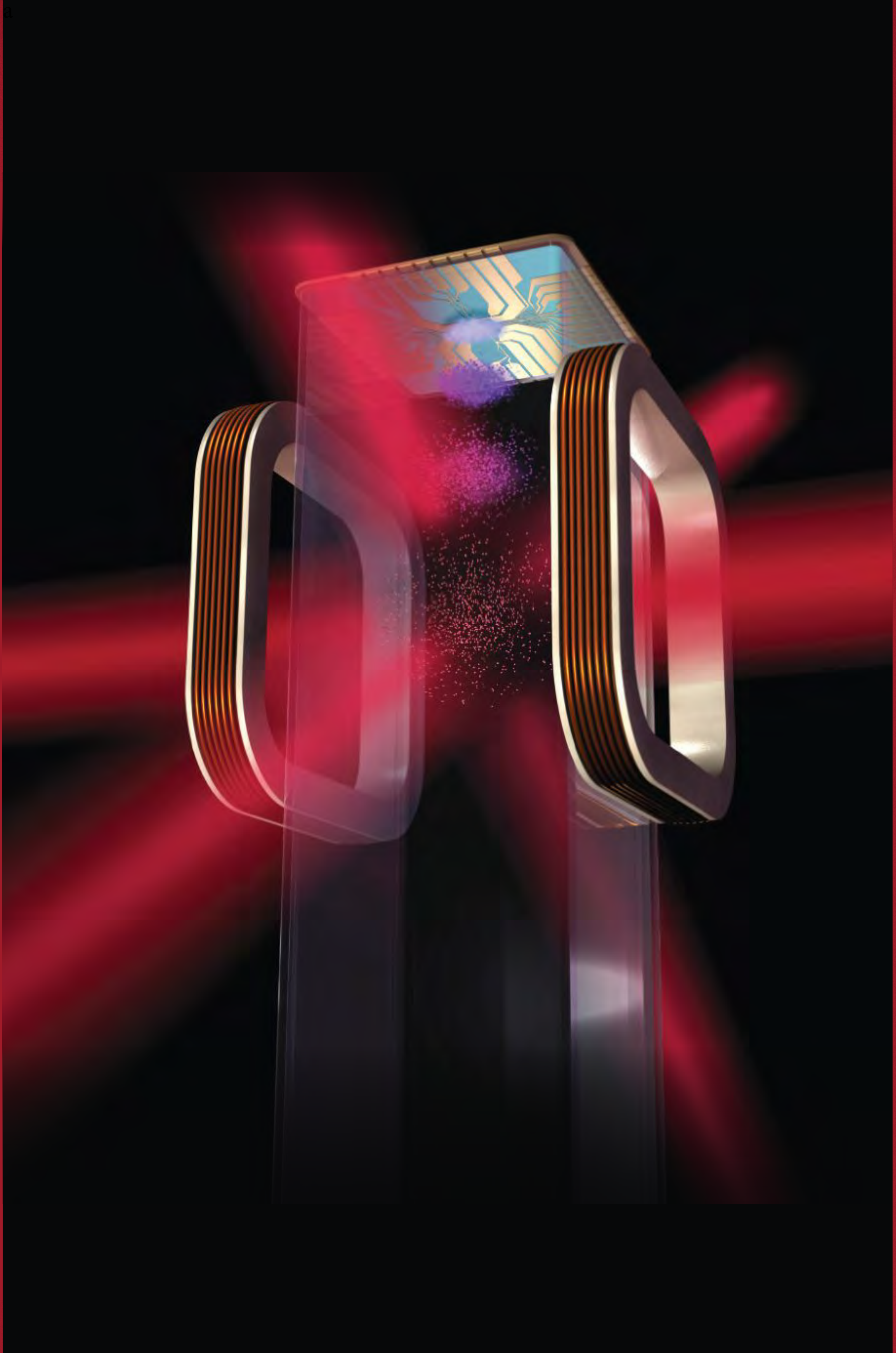
The second category involves mobile ad hoc networks, using peer-to-peer nodes in self-forming, self-healing architectures. These are most useful in smaller areas, with deep ravines or significant surface obstructions. These mesh networks are often a bit less expensive than the 4G LTE. In both technological categories, all the functions of the Tacti-Sphere are fully operative.

For decades, we've observed that wide area austere communications were regarded as a "holy grail" among remote operators. LMRs are blocked by terrain. Cellphones allow communications only when the phone is relatively near and in line-of-sight of a tower. As a most pointed example, shortly after 19 firefighters died in a forest fire near Yarnell, Arizona, we were contacted to assess how firefighters in the middle of the wilderness could stay in touch over ridges. The need for long-haul communications in remote environments prevails for numerous operations as varied as forest firefighting, military actions, search and rescue, security and border patrol, and even disaster response to devastated urban locations. Tacti-Spheres can help resolve this shortfall. ★

QUANTUM PROMISES

Precise navigation will be a necessity for safe human exploration of Mars and other celestial bodies in deep space. A pair of experiments about to get underway could change the way this navigation is done, and for the better. Amanda Miller explains.

BY AMANDA MILLER | agmiller@outlook.com



An artist's concept of a magnetic field, also known as an ion trap, and an atom chip in NASA's Cold Atom Laboratory aboard the International Space Station.
NASA

Making coffee and whatnot, future humans traversing the solar system move around inside their tiny tin can — I mean spaceship — throwing off the trajectory little by little. But this drift is no biggie. By this time, space navigators back on Earth no longer have to spend hours discovering a slight shift in trajectory by sending radio waves to the spacecraft from NASA's Deep Space Network antennas on three continents, waiting for return signals, and calculating the distance to the spacecraft and its position.

Instead, sensors onboard our notional spaceship-of-the-future harness the quantum properties of atoms to detect the drift, needing only a reference signal from Earth plus an onboard atomic clock to do it. The spaceship's flight computer automatically corrects the course in real time.

> "WE CAN MEASURE THE RANGE DOWN TO A METER 140 MILLION KILOMETERS AWAY. FOR MOST ROBOTIC MISSIONS, THAT'S GOOD ENOUGH, BUT WE'LL WANT A MORE REAL-TIME SOLUTION AVAILABLE TO ASTRONAUTS GOING TO MARS."
>
> — TODD ELY, JPL SPACE NAVIGATOR AND AEROSPACE ENGINEER

A quantum-driven navigation revolution like this could reduce the risks of deadly mistakes, such as a failed atmospheric entry or a misdirected thruster firing, during a human mission to Mars in the 2030s. Physicists from NASA and several universities are working with industry researchers to perfect the necessary science and technology.

Specifically, an experimental Deep Space Atomic Clock, built in California at the NASA-funded Jet Propulsion Laboratory, is scheduled for launch in November as an instrument aboard a scientific satellite. Not to be outdone, university physicists are planning to run navigation-related quantum experiments inside an ice-chest-sized container aboard the International Space Station. This Cold Atom Laboratory, which the physicists will command remotely from JPL, remains in its calibration phase after astronauts set it up in May.

These projects were inspired in part by a 2011 report from the U.S. National Academy of Sciences, "Recapturing a Future for Space Exploration, Life and Physical Sciences Research for a New Era." This decadal survey of spending priorities listed unlocking the potential of "quantum gases" — atoms that are so cold that their quantum properties become apparent — along with precision measurements, such as those made by atomic clocks, as two of four top recommended priorities for physical science in space.

I talked to some of the scientists and engineers helping to ensure that the first Earthlings exploring Mars or elsewhere beyond the moon won't end up adrift.

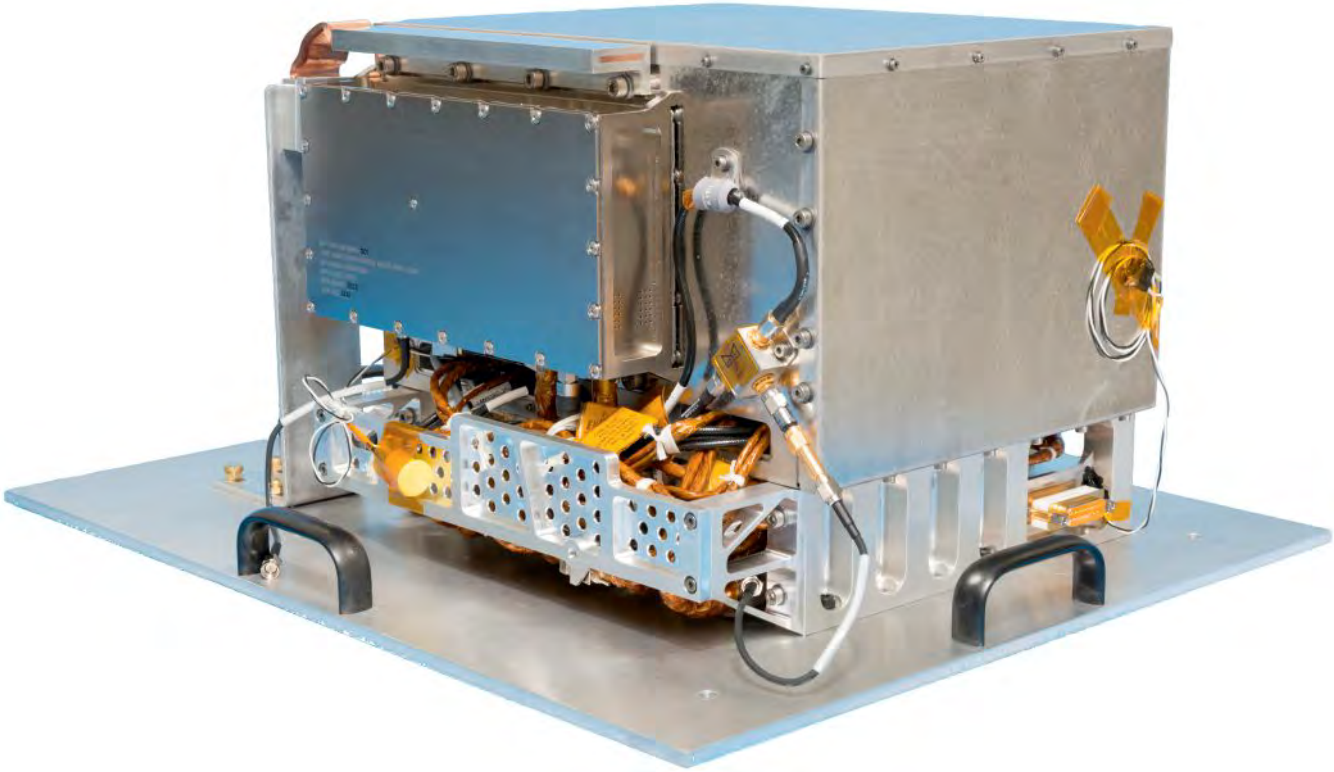
Timing is everything

For a space mission to succeed, engine burns and other maneuvers must be timed precisely, and that's not just true for missions with astronauts playing ping-pong and perturbing things.

Consider NASA's $800 million InSight lander now on its way to Mars for a planned arrival in November to begin a geology mission.

InSight, just as any spacecraft, experiences unpredictable small forces that can add up to trouble over millions of kilometers, forces such as inconsistencies in its thruster firings or pressure from the sun so slight that it's undetectable to today's inertial navigation systems, such as those in aircraft and the atmospheric landing systems of spacecraft.

Today, NASA tracks deep space spacecraft from the Deep Space Network stations in California, Spain and Australia — whichever station's antennas have a direct line of sight to the spacecraft as Earth rotates. An atomic clock at each DSN station times how long the return signal takes to arrive, and navigators then calculate the spacecraft's trajectory based partly on those transit times. They also factor in the frequen-



cy of the signal's Doppler shift plus information from a third method, delta differential one-way ranging. In this technique, two antennas at a time receive signals from the spacecraft while also referencing radio waves from the same star-like quasar.

The process soaks up more of the DSN time than NASA would like. Each station must communicate with just one spacecraft at a time and, depending on where Earth and Mars are in their orbits around the sun, a signal can take 21 minutes to reach Earth from Mars or vice versa. Factor in computing and mission planning, and the whole process of plotting a spacecraft's trajectory can take hours.

InSight, for instance, has been speeding along toward Mars in a relative tracking slumber, with NASA checking up on it one to three times a week throughout the "cruise" phase of the six-month trip. The spacecraft was poised to enter its 60-day approach subphase, which will require intensive tracking by one DSN ground station after another. Trajectory correction maneuvers were scheduled for four dates in October and November.

JPL space navigator Todd Ely, an aerospace engineer, wants to innovate himself out of a job by making the process faster for unmanned probes and safer for future astronauts.

"We can measure the range down to a meter 140 million kilometers away," Ely says. "For most robotic missions, that's good enough, but we'll want a more real-time solution available to astronauts going to Mars."

Enter the Deep Space Atomic Clock, for which Ely is the principal investigator. If all goes as planned, this uber-precise prototype clock will demonstrate a positioning accuracy as good as that of NASA's ground-based clocks but needing only a one-way radio signal sent from Earth — or elsewhere — to do it. With a clock so precise that it needs only the one-way transit time, a spacecraft's computers and/or pilots could manage the rest.

About the size of a four-slice toaster, the clock is one of several instruments on the Orbital Test Bed satellite built by General Atomics Electromagnetic Systems of California and scheduled for launch on SpaceX's next Falcon Heavy flight under an Air Force-administered rideshare program. Ely thinks engineers can get an operational version of the clock down to the size of a two-slice toaster for real missions.

He thinks the one-way method could even justify a space-based extension of the Deep Space Network, sending out signals from a satellite orbiting Mars, for example.

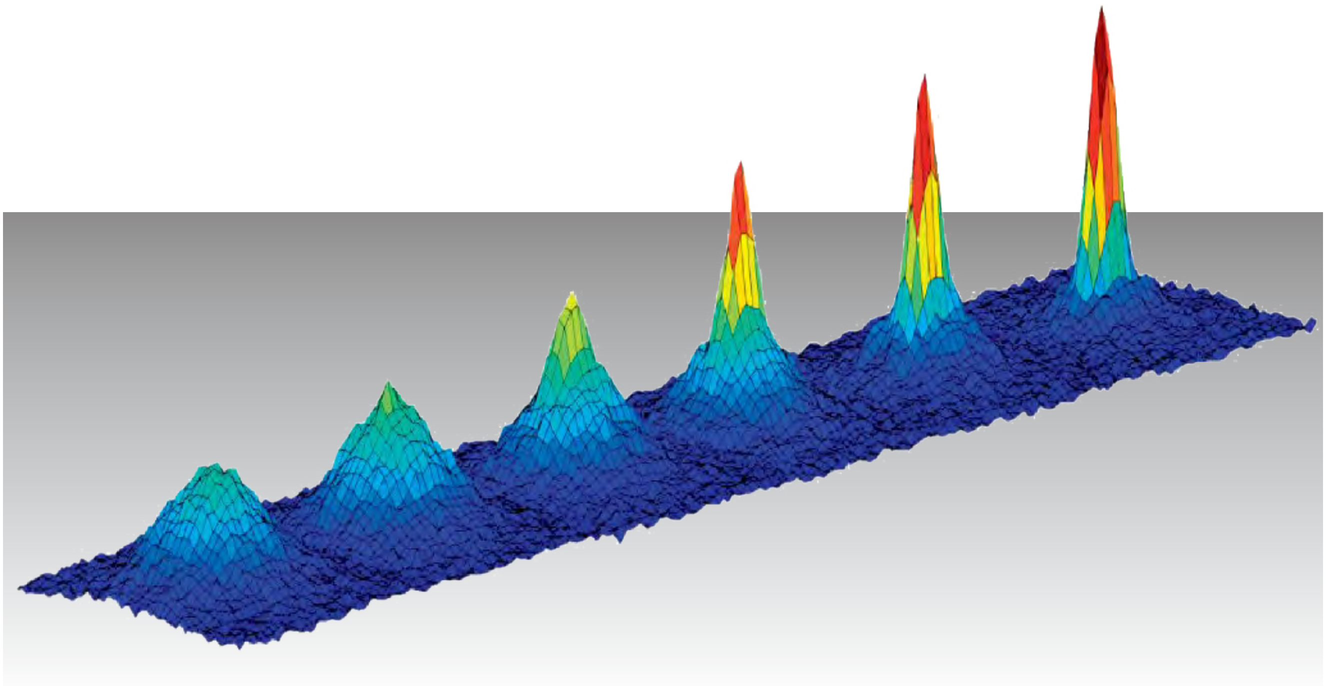
Ely's ideal navigation system for Mars-bound astronauts would pair the onboard clock with onboard navigation cameras, the sky-referencing cameras already guiding autonomous navigation in some spacecraft.

The astronauts will "want a navigation solution that relies on multiple data sources," Ely says. "If you have a failure in any one system, you can detect that."

The deep space clock works similarly to those at the DSN sites, but is engineered to endure space

▲ The **Deep Space Atomic Clock** will ride on the Orbital Test Bed spacecraft.

NASA



▲ This graph shows the changing density of a cloud of atoms as it is cooled to lower temperatures, from left to right, approaching absolute zero. The sharp peak indicates the formation of a Bose-Einstein condensate — a fifth state of matter.

travel and deliver more precision, says Robert Tjoelker, a NASA physicist working on the program.

Just as in a conventional wristwatch, the time-keeping process begins with an oscillating quartz crystal. But that's where the similarities end. Electromagnetic fields trap mercury ions in a titanium vacuum tube. Microwaves emitted by the crystal cause some of the electrons in the mercury ions to transition between quantum energy levels.

If the quartz crystal is vibrating at the correct frequency, this interrogation causes electrons to transition to a more excited level. If the frequency varies, however, fewer electrons make the transition. The clock must correct itself.

Designers chose mercury partly because it has a higher transition frequency than the cesium, hydrogen or rubidium in other atomic clocks. This means the quartz can oscillate faster, providing more gradations in time.

If the Deep Space Atomic Clock performs as planned, it will speed up or slow down only 0.3 billionths of a second a day. That would be a 50-fold improvement over the atomic clocks in today's GPS satellites, according to NASA.

The new degree of accuracy would permit a one-way radio link, whereas today's method using less precise clocks needs the additional data from a two-way trip.

"A one-way link navigation architecture would significantly alleviate the tracking burden on ground-based assets such as the NASA" Deep Space Network, researchers wrote in their July 2016 academic paper "Mercury Ion Clock for a NASA Technology Demonstration Mission" in the journal titled IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control.

Big chill

Meanwhile, other scientists are wondering whether ultracold quantum gases can lead to entirely new and better ways of steering spacecraft. That's where the Cold Atom Lab comes in aboard the International Space Station. Inside it, rubidium and potassium atoms will be cooled to within a near-unimaginable fraction of one Kelvin, which is just a hair above absolute zero. At this temperature, the familiar states of matter (solids, liquids, gases and plasmas) no longer apply. The atoms become what's called a Bose-Einstein condensate in which the atoms act in unison and are sometimes even described as indistinguishable from each other or forming a single quantum entity.

Researchers think that by imaging this condensate and tracking its movement relative to the ISS, they might point the way to development of incredibly sensitive inertial navigation devices such as accelerometers for motion and gyroscopes for rotation, making them suitable for deep space travel.

An advantage of microgravity is that the condensate holds together for several seconds, instead of just a fraction of a second, as would be the case on the ground. That's long enough for physicists at JPL to observe and work with the condensate in the station's Cold Atom Lab.

Here's how the cooling will work:

Magnetic fields first trap a cloud of a billion atoms. These atoms are so sensitive to certain wavelengths of light that turning on the lab's six lasers brings them to nearly "a screeching halt," with a force equivalent to 1,000 Gs, says applied physicist Dana Anderson of the University of Colorado. He is founder of ColdQuanta, the Boulder company that built the cooling technology within the Cold Atom Lab. At this point, the temperature has plummeted in less than a millisecond to within a thousandth of one Kelvin of absolute zero.

Then things get really cold.

The lasers turn off, and magnetism holds the atoms in place. Radio frequencies, working in conjunction with this trap, then slough away the hottest of these atoms until so little energy is left that the 40,000 or so remaining atoms are close to a millionth of one Kelvin of absolute zero. These 40,000 take on the odd quantum properties of the Bose-Einstein condensate. The atoms in this condensate act in unison — not unlike the behavior of photons in a laser beam.

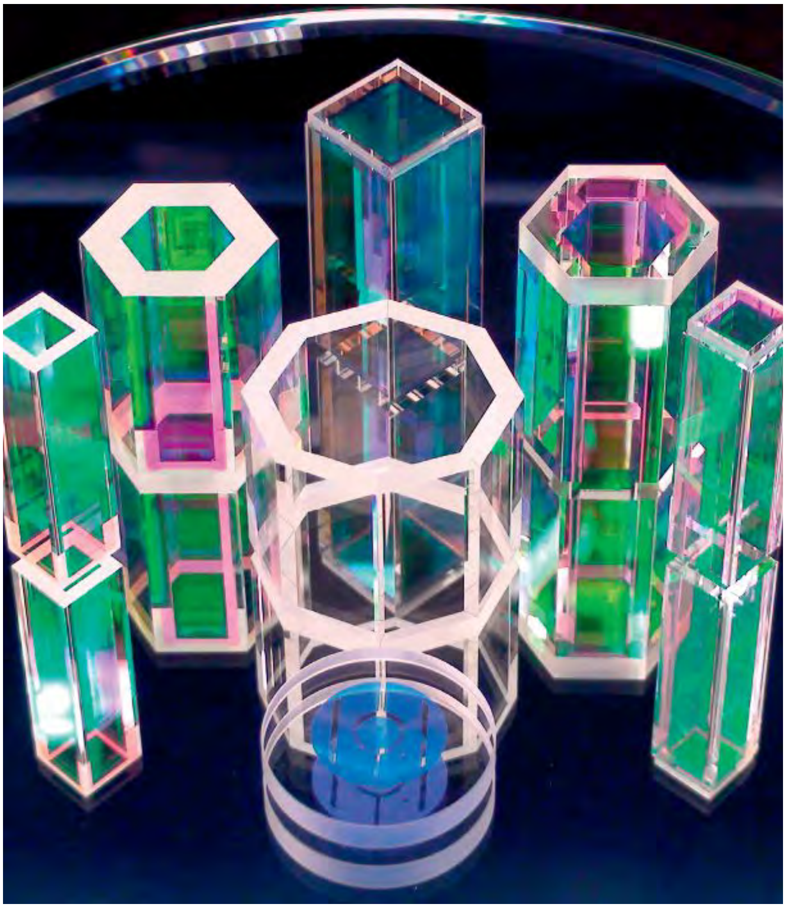
But that might not be as cold as things will get. A team of researchers from the University of Virginia want to see if they can compress and then expand this condensate to chill it to trillionths of one Kelvin. That would be the all-time record for coldness.

The Virginia team also will try to measure the position of the condensate relative to the space station. Here's how JPL explains the process on its website: "Any residual gravity or acceleration of the ISS will cause the cold atoms to 'fall' relative to the station." Observing this relative motion by camera or "more sensitive techniques such as atom interferometry" could be used to measure acceleration — the word for the forces acting on a spacecraft — to better predict the trajectory.

In further research, scientists think they might be able to take advantage of the fact that when atoms transform into a Bose-Einstein condensate, their simultaneous motion appears wavelike. The lab's first upgrade, in fact, will seek to take advantage of this phenomenon with the addition of an atom interferometer instrument that will split up beams of atoms by laser and then recombine the beams.

"Each atom separates and recombines, and it shifts the phase of the atom slightly" along the matter wave, says Jason Williams, principal investigator working on the instrument.

Illustrated visually, the atom would appear in a different spot along the line of the wave than if it had never split. Measuring the difference in phases has potential applications for detecting spacecraft rotation and acceleration.



ColdQuanta

▲ At the heart of NASA's Cold Atom Laboratory, physicists control atoms in a vacuum inside a glass cell like one of these, made by the Colorado-based ColdQuanta.

Making history

Flash forward to our notional crew members decades from now, hurtling across the void, perhaps tending to their food crops without fear that they could unwittingly throw off their ship's trajectory.

If they are students of history, they might know that their peace of mind can be traced to 2018, when the first Deep Space Atomic Clock went to space and scientists pioneered the physics of quantum inertial sensing with the Cold Atom Lab.

Back to the present, work continues toward this future at ColdQuanta's factory in Boulder, Colorado. Engineers and technicians design and put together the electromagnetic atom traps and glass vacuum cells that facilitate much of today's quantum research. The company sells a machine for making Bose-Einstein condensates and fills orders for custom equipment. Anderson, ColdQuanta's founder, notes that one researcher with work slated for the Cold Atom Lab is physicist Eric Cornell who, with two other scientists, won the 2001 Nobel Prize in Physics for making a Bose-Einstein condensate in their lab six years earlier.

As Anderson puts it:

"The science has gone into the technology and come back full circle, enabling the same scientists to do new experiments in space." ★

HIGH G

Geared turbofan engines power Airbus A320neos, Airbus A220s and Embraer E190-E2s.
Pratt & Whitney

EAR

Early troubles with Pratt & Whitney's geared turbofan jet engines have not slowed the aviation industry's growing enthusiasm for this fuel-saving technology. Keith Button set out to find out why.

BY KEITH BUTTON | buttonkeith@gmail.com

At plants in Canada, Germany and the United States, Pratt & Whitney continues to build the first geared turbofans large enough to propel twin-engine single-aisle airliners. So far, the engines are powering at least 220 passenger jets for 26 airlines, and Pratt & Whitney's peers plan to follow suit with their own geared engines in coming years.

The industry is watching how Pratt & Whitney has handled the mammoth engineering task, tracking whether the new engine's operational issues are hiccups or a sign of larger problems, and learning from Pratt & Whitney's hardships and successes with its Pure Power PW1000G series or GTFs, short for geared turbofans.

Geared engines have flown for decades — the British Aerospace 146-passenger plane with four Lycoming ALF 502 geared turbofans started flying in 1982, for example. But Pratt & Whitney is the first engine maker to build them at this scale — capable of generating 15,000 to 33,000 pounds of thrust, compared with up to 7,500 pounds for the Lycoming ALF 502 engines, which are the second-most powerful geared turbofans.

Geared engines' appeal

What is the attraction of geared engines? In a conventional turbofan, the low-pressure turbine and compressor blades are linked to the engine's front fan by the same shaft, or spool, which means they must turn at the same revolutions per minute. Turning the compressor and turbine blades too fast would risk damage to the front fan. Geared turbofan designers solve that problem by placing a gearbox between the front fan and the shaft leading to the engine core, where the low-pressure turbine and compressor blades are. Now, the front fan can spin at its optimal slower speed, and designers can put longer blades on it to push a larger volume of air. Meanwhile, the low-pressure compressor and turbine blades can spin faster to boost fuel efficiency.

To illustrate the difference, the front fan on one version of Pratt & Whitney's engines measures 206 centimeters in diameter compared to 173 centimeters for the largest version of the CFM56, the best-selling airliner turbofan.

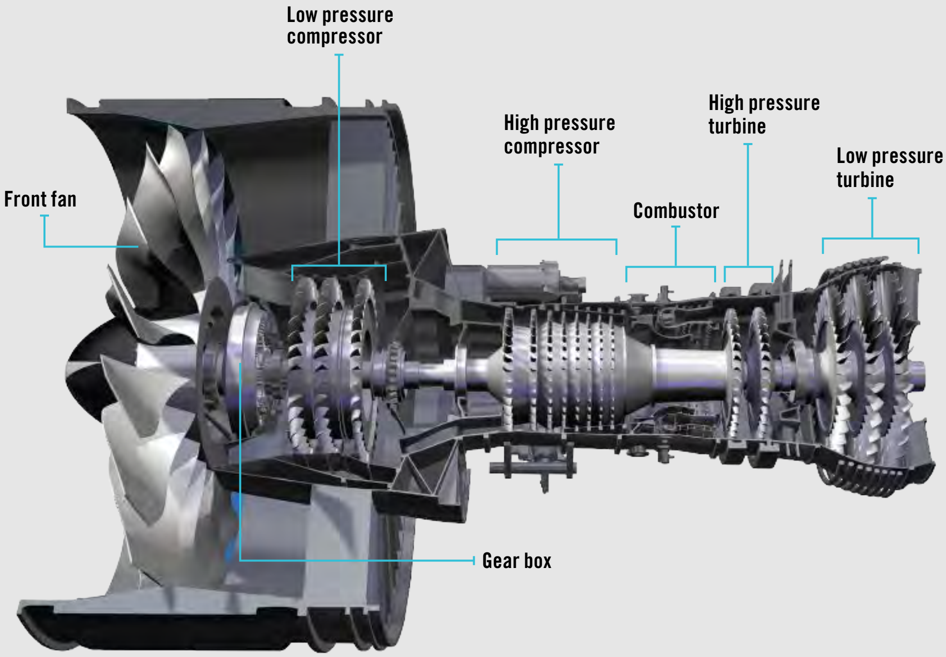
Pratt & Whitney's rollout of its GTFs has been less than smooth, though. Most recently, the company and the FAA have been investigating the cause of excessive in-flight engine vibration that some A320neo pilots have reported. As of Sept. 10, the cause was unknown, the FAA and Pratt & Whitney say. Less than 2 percent of the A320neo GTFs have been affected, says John Thomas, company spokesman.

When the engine was first added to new airplanes in 2016, Pratt & Whitney had to advise airlines to cool the engines for longer periods before engine startup to ensure that compressor blades didn't rub against the walls of the engine. The problem, also known as

▼ **A geared turbofan engine** is mounted on an Embraer E190-E2.

Pratt & Whitney geared turbofan

A geared turbofan engine has a gearbox between the front fan and the shaft to the engine core, so that the speed of the front fan can be decoupled from the speed of the core. This way, the engine can safely drive a larger fan and push a larger volume of air, while the low-pressure compressor and turbine blades spin faster, boosting fuel efficiency.



Source: Pratt & Whitney

Pratt & Whitney

"rotor bow," has affected other types of new engines, but it prompted Qatar Airways to cancel its order of 50 new planes. Akbar Al Baker, the CEO of Qatar Group, told reporters the engines had "huge issues" and "a lot of problems." Pratt & Whitney says the problem was solved with minor hardware and software fixes. Also in 2016 and 2017, Pratt & Whitney had to redesign and replace a carbon seal in the compressor section of the engines because oil chips — contaminants in lubricating oil — were showing up with the old seal in place. In 2017, Pratt & Whitney had to upgrade combustor liners in the engine, modify software and redesign the combustion chamber because parts of the old combustor liners were running too hot. Also in 2017, the company paid compensation to India airline IndiGo for GTF problems that grounded nine new A320neos, and the airline later reported that it replaced as many as 69 of the engines.

This year, the knife-edge seal on the aft hub of the high-pressure compressor in some versions of the GTF cracked, causing aborted takeoffs or in-flight engine shutdowns for four A320neos in February, Thomas says. The same month, the European Aviation Safety Agency and the FAA banned extended-range flights for some Airbus A320neo airplanes because of the knife-edge seal problems. In March, India's Directorate-General of Civil Aviation ordered 11 A320neos grounded because the seal design had caused in-flight engine shutdowns and aborted takeoffs. Pratt & Whitney revised the seal design and began building new engines with the revised seals in February, but Airbus missed its promised deliveries for 50 new A320neos because of the problem. In June, the FAA ordered airlines to replace the front hub of the high-pressure compressor in about 190 engines because corrosion could damage the part and cause engine shutdown. Also in June, the FAA ordered visual inspections for possible damage to the fan hub on 14 of the engines because they may not have been installed properly.

Despite all that, the industry so far is standing by the geared-engine concept.

An engine expert who evaluates the performance of airplanes and engines for buyers of new jetliners says that while Pratt & Whitney's GTF has had more problems than the company would have liked, earlier generations of now-reliable engines had even more issues.

The GE90 is one example. This nongeared engine, which powers widebody Boeing 777s, was hailed by Emirates airline's chief executive in 2015 as an integral part of the airline's growth. But in early models, bearings wore too quickly in the engine's transfer gearbox, which transfers power from the engine to accessories on the plane. In 1998, three years after introducing the new engine to its 777 fleet, British Airways rejected the GE90 in favor of Rolls-Royce engines.

The GE90 "was an absolute pig, when introduced," with "huge problems," says the engine expert, who asked not to be identified discussing clients. For any new engine, he says, "the normal state is that the engine has issues, and then some lucky guys who've done their homework have fewer issues. … It will normally take several years of in-service experience before engines weed out their initial problems."

▼ PW1100G-JM engines are assembled at Pratt & Whitney's Middletown Engine Center in Connecticut, below, and in Canada and Germany.

For potential jetliner buyers, the main appeal of the GTFs is their improved fuel efficiency. “They love the fuel consumption, and they hate the problems,” the engine expert says. Pratt & Whitney consistently boasts that the engines reduce fuel burn by 16 percent compared to similarly sized engines, along with reducing nitrogen oxide emissions 50 percent and producing 75 percent less noise. Per flight hour, that translates to about 380 liters of fuel saved and 1 metric ton of carbon emissions avoided.

The GTFs are extremely efficient for passenger jets that fly many short hauls of one to two hours or up to 800 kilometers. For three- to four-hour, 1,600-kilometer flights, the engines provide less of an advantage. That’s because their principal fuel efficiency advantages come during the climb, when the engine is generating near-maximum thrust before shifting to the cruise portion of the flight. The advantage tapers off on long flights, because geared engines have larger diameters and create more drag, and the gearboxes add weight.

In February, Greg Hayes, CEO of Pratt & Whitney’s parent company United Technologies, characterized the GTF’s problems as “teething issues” and told industry analysts that the knife-edge seal issue was a “short-term snafu.” He also said that most of the teething issues would be cleared up by the time the engine passed 1 million hours of accumulated flight time — a milestone the GTF cleared in August.

Pratt & Whitney’s consistent response to the early engine problems has been “to identify, mitigate and resolve” them “while minimizing impact to our customers’ operations,” Thomas says.

Sales of the GTF are brisk, in spite of the roll-out issues. As of September, the GTF was powering a mix of Airbus A320neos, Airbus A220s and Embraer E190-E2s, all twin-engine, narrow-body, single-aisle airliners. About 2,000 GTF orders were placed in the previous 12 months by 80 customers, including airlines and airplane leasing companies, Thomas says. In July, the GTF for the two-engine A220 had earned FAA certification for single-engine flying within 180 minutes of airports. The engine builder is also caught up on its GTF deliveries to Airbus and is on track to meet its 2018 delivery commitments, the spokesman says.

Squeezing out efficiencies

Despite the early difficulties with the geared turbofan engines, manufacturers of large passenger jets have geared designs in the works, says Ron van Manen, a Dutch aerospace expert and program manager for the European Union’s Clean Sky 2 engine research and development initiative based in Brussels.

As designers revamp their turbofan designs to squeeze out greater and greater efficiencies, they run up against a limit that they can’t overcome without either moving to geared designs or entirely rethinking airframe designs, van Manen says. Uncoupling the front fan and the engine core’s turbine and compressor blades creates greater bypass ratios — the ratio of the volume of air pushed around the exterior of the core to the volume of air sucked

Pratt & Whitney

"There seems to be a certain level of consensus among the large-engine integrators that the next big step in bypass ratio is going to involve a gear."

— Ron van Manen of the European Union's Clean Sky 2 program

through the core. The higher the bypass ratio, the more fuel efficient the engine is, because the fan generates thrust more efficiently than the core.

The GTF produces a bypass ratio of up to 12:1, compared to up to 6:1 for the CFM56, the engine it replaces. A new-engine competitor to the GTF, the nongeared LEAP engine, produces a bypass ratio of up to 11:1. LEAP is built by CFM International, the 50-50 partnership of Safran and GE that also produces the CFM56.

"There seems to be a certain level of consensus among the large-engine integrators that the next big step in bypass ratio is going to involve a gear," van Manen says. "While that presents some challenges, it does seem to be on everyone's road map now rather than being one guy's leap of faith."

Rolls-Royce is testing components of its planned UltraFan geared engine, including a 66-megawatt gearbox — almost three times the size of the largest GTF gearbox — that it plans to offer to airplane builders in 2025 with a bypass ratio of 15:1. Safran is designing its Ultra High Propulsive Efficiency engine with a gearbox, which it plans to ground test starting in 2021.

Powerful gearboxes

Rolls-Royce fired up an engine core at full power for the UltraFan for the first time in July in Derby, United Kingdom, and is testing what it calls the world's most powerful gearbox in Dahlewitz, Germany, outside Berlin. Rolls-Royce says UltraFan will run 25 percent more efficiently than its nongeared Trent engine, which powers long-range widebody passenger jets like the Boeing 777 and 787 and the Airbus A330, A340, A350 and A380. One of Rolls-Royce's targets for the new engine is Boeing's planned New Midsize Airplane, also known as the NMA or 797, which Boeing is tentatively targeting to begin service in 2025. Pratt & Whitney reported that its gearbox, which ranges from 12 to 24 megawatts in size for current GTFs, could be scaled up for "significantly higher megawatts" for future airplanes.

For geared turbofans, the upper limit of efficiency will probably be bypass ratios of 15:1 or 16:1, says Jean-François Brouckaert, a Clean Sky 2 project officer. Beyond that point, the fan diameter creates too much drag and the size of the gear box makes the engine too heavy. After geared turbofans, the next leap in efficiency for aircraft propulsion would come from open-rotor turbine engines and distributed propulsion concepts.

"There's a high level of consensus that this gearbox driving a bigger fan at a slower speed is kind of the only solution that makes sense, and then after that, there are going to be competing steps, but they're going to look very different," van Manen says.

What are the challenges of designing and building a geared turbofan? "Everything," Brouckaert says. "A lot of things are changing in the engine because of the evolution of the gearbox."

At the front of Pratt & Whitney's GTF engine, the longer fan blades were redesigned to control how much they untwist or bend as they push a greater volume of air with a slower spin rate. Normally engines of that size require titanium fans, but designers of the GTF created hybrid blades that are unique to the engine: hollow blades, to reduce weight, made of an aluminum alloy with leading edges of titanium.

Because the gearbox sits between the front fan and the shaft that spins the compressor and turbine blades, its added weight presents a challenge for designers. The weight changes where the bearings are placed to support the spinning shafts of the engine and how the front-heavy engine is balanced and mounted under the airplane wing.

"Integration is not only about finding the space to put the gearbox, with the relevant compactness and so on, but it has also a huge impact on the engine dynamics because you are adding an amount of weight on the shaft line," Brouckaert says.

Another challenge is the heat created by the gear friction. The input shaft spins the center gear, or "sun" gear, which turns five "planetary" gears arranged around it, and those gears turn the outer geared ring that spins the fan. Even with the engine operating at 99 percent efficiency, a 24-megawatt gearbox like that of the largest GTF generates 240 kilowatts of heat, or the equivalent of as many as 24 home heating furnaces, and the heat must be dissipated with lubrication oil circulating through air-cooled heat exchangers, Brouckaert says.

The GTF fan spins at about one-third the speed of the shaft that spins the low-pressure compressor and low-pressure turbine blades in the engine, or 3,200 revolutions per minute versus 9,000 RPM. In a conventional turbofan engine, the pressure of the

▲ Airbus produces A321s, part of its A320 group, with Pratt & Whitney's PW1000G high-bypass geared turbofan engines. Hawaiian Airlines took delivery of its first U.S.-produced A321 in June.

Airbus

air that flows into the core is stepped up by the spinning blades of the low-, intermediate- and high-pressure compressor stages. The air then combusts and pushes through the high-, intermediate- and low-pressure stages of the turbine, spinning the blades that rotate shafts turning the fan and compressor sections. In the GTF, the low-pressure compressor and low-pressure turbine blades are spinning faster than those in the core of a nongeared engine, which boosts the engine's overall fuel efficiency. Engineers designed the GTF core to generate the same power as conventional turbofans, but with fewer rows of compressor and turbine blades.

Separate from adding the gearbox, GTF designers improved the engine core's efficiency by designing it to run about 5 percent hotter than the previous-generation turbofans. The hotter an engine's core is through its turbine, the more power it can generate. With the larger fan, GTF engineers designed a thinner cowling, or exterior covering of the engine, to minimize the distance it hangs below the wing, which cancels some of the noise reduction benefits of the slower-spinning fan. The cowling is also shorter to improve aerodynamics, reduce weight and improve the fit under the wing.

While the source of the latest engine vibration issues is unknown, so far, Pratt & Whitney's other GTF roll-out problems have come from the engine core. For example, the knife-edge seal problem is in the compressor section.

"The area where the GTF made the big advance, the gearbox for that size of engine, hasn't given them problems," the airline and aircraft engine adviser says. "They spent a lot of energy on making sure it didn't. They took that step, did their homework on that piece of tech, and didn't give them any problems."

Thomas, the Pratt & Whitney spokesman, confirms that there have been no issues with the gearbox — what the company labels the "fan drive gear system." He says the company is pleased that the "fundamental architecture of this new engine" — the gearbox — "has performed extremely well."

Pratt & Whitney probably would have welcomed more time to test the engine to better weed out the initial problems, but the company was on a tight schedule to build engines in time for the Airbus A320 rollout, the adviser says. And now the GTF's initial issues will be worked out in the field.

But the positive for Pratt & Whitney — the performance of its gearbox — could be a lesson for Rolls-Royce and Safran when they introduce their engines, the adviser says: If you invest $10 billion and 20 years of development, you too can launch a geared turbofan without problems with the gearbox.

"If you want to do a geared turbofan, you'd better do your homework on the gearbox." ★


ONCE WE WENT

Neil Armstrong, left, and Buzz Aldrin erect the American flag on the moon during the Apollo 11 mission. The picture was taken by a camera mounted on the lunar module.

NASA

TO THE MOON

The circumstances that led the U.S. to undertake the Apollo 11 lunar mission 50 years ago next July, and the five landings that followed, were unique, and they won't be repeated. Even so, space historian John M. Logsdon sees reason to anticipate that U.S. astronauts will in the next decade return to the moon.

It seems incredible, almost a half century later. In the 12-month period between December 1968 and November 1969, NASA five times launched the massive Saturn 5 booster. Four of those launches took an Apollo spacecraft and its three-man crew a quarter million miles to the moon, and on two missions the spacecraft's lunar module transported two astronauts to and from the lunar surface. In the coming months, we will properly be celebrating these remarkable achievements.

Many have been hoping in the decades since Apollo that something similar could happen again. Hoping for another "Kennedy moment" is in my view a false hope. The reasons we went to the moon in the 1960s were unique; so was the national commitment of the resources to make Project Apollo possible.

Even so, am I alone in noticing that the United States in 2018 is well along on its way back to the moon? This time around, we are following a "go as you pay" approach, and we have been spending multiple billions of dollars each year for most of the past decade preparing for resuming human exploration. In my judgment, sometime in the 2020s the momentum built up over the past 15 years or so is likely to be translated into missions to destinations beyond low Earth orbit, and particularly to the lunar surface.

NASA

▲ **Dr. Robert R. Gilruth,** left, director of the Manned Spacecraft Center (now Johnson Space Center), presents President John Kennedy with a model of the Apollo spacecraft in 1962.

Why we went

To understand why an exploration program with the urgency of Apollo will not happen again, it is essential to understand why it happened in the first place. It was, of course, President John Kennedy who decided to send Americans to the moon. Reacting to the Soviet Union being the first to orbit a human, Kennedy on April 20, 1961, asked Vice President Lyndon Johnson to conduct an urgent review to identify a "space program which promises dramatic results in which we could win." Cold War competition between the two superpowers, not space exploration, was the overriding stimulus.

Johnson's review identified a lunar landing as the best way to meet Kennedy's requirements. Achieving that goal would require both the U.S. and the Soviet Union developing a powerful new launch vehicle and, thus, in a technological sense, the race to the moon became a rocket-building contest in which the United States had famed German expatriate Wernher von Braun and his Saturn 5 booster on its side.

In a memorandum dated May 8, 1961, that formed the charter for Apollo, NASA Administrator James Webb and Secretary of Defense Robert McNamara argued that "dramatic achievements in space symbolize the technological power and organizing capacity of a nation" and that the prestige from such achievements was "part of the battle along the fluid front of the Cold War." Kennedy accepted that perspective, in November 1962 telling advisers that "the Soviet Union has made this a test of the system" and therefore "everything we do ought really to be tied to getting on the moon ahead of the Soviets." Kennedy backed up his words by marshaling human and financial resources as though he were mobilizing for war. Apollo was formally assigned the highest national priority; NASA's budget went up by 89 percent in 1962 and another 101 percent the following year. After Kennedy's assassination, Apollo became a monument to a fallen young president. Even after

Apollo was an overwhelming success in achieving the leadership goal set out by President John Kennedy, but it turned out to be a dead end in terms of a sustainable program of human exploration.

The Saturn 5 rocket carrying the Apollo 11 crew lifts off from Kennedy Space Center on July 16, 1969.

NASA

astronauts Roger Chaffee, Gus Grissom and Ed White II died in the Apollo 1 fire, there was little thought of giving up the race to be first. Apollo 8, then Apollo 11, took us to the finish line.

Why we stopped

Kennedy's 1961 commitment and the measures taken to achieve it created enough momentum to carry Apollo through to his "before this decade is out" goal, but that momentum quickly dissipated. By December 1969, even after the successes of Apollo 11 and Apollo 12, President Richard Nixon was asking why the United States needed to continue sending astronauts to the moon. There was no good answer to his question; the Cold War rationale underpinning the race to the lunar surface had been rendered moot by winning that race, and there were no other compelling arguments for continuing an ambitious program of human exploration. Suggestions that missions to the moon be followed soon by journeys to Mars were quickly dismissed by the White House. The Nixon administration decided to shut down the Saturn 5 production line, and NASA chose to cancel two of the remaining six lunar landing missions and apply freed-up funds and engineering talent toward developing the space shuttle fleet, which would be limited to low Earth orbit. As the last lunar landing mission, Apollo 17, left the moon in December 1972, Nixon stated that "this may be the last time in this century that men will walk on the moon." By his decisions, he had made that statement a self-fulfilling prophecy.

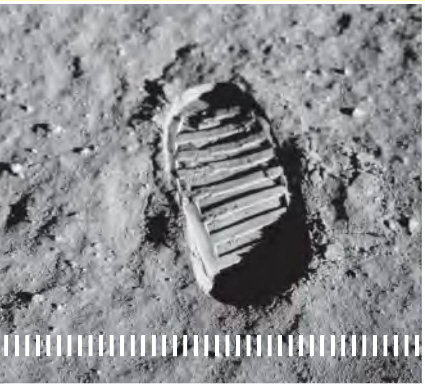
Nixon was very sensitive to public opinion, and he judged that the American public was not interested in continuing an Apollo-paced space program. He told NASA Administrator Tom Paine in January 1970 that "the polls and the people to whom he talked indicated to him that the mood of the people was for cuts in space." Apollo was an overwhelming success in achieving the leadership goal set out by Kennedy, but it turned out to be a dead end in terms of a sustainable program of human exploration.

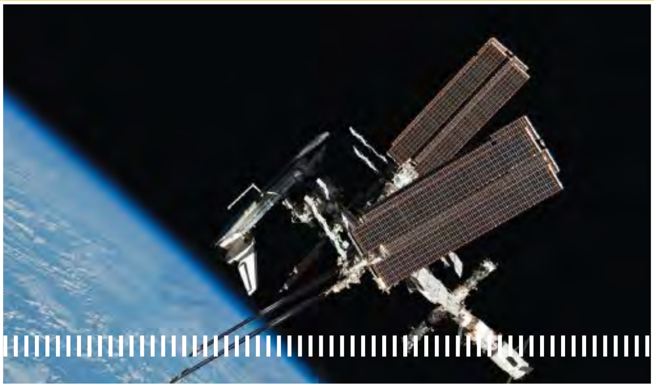
▼ **U.S. President Richard Nixon** greets the Apollo 11 astronauts aboard the aircraft carrier USS Hornet on July 24, 1969, shortly after their capsule had splashed down in the Pacific Ocean.
NASA

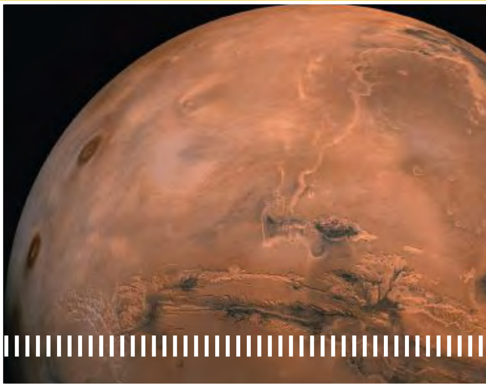
The vision persists

Even so, the belief has persisted, at least among space advocates, that the primary rationale for sending humans into space is, as Apollo 11 astronaut Michael Collins has frequently written, about "leaving" — going somewhere away from Earth. After being in the background for more than a decade, that objective found eloquent expression in the 1986 report of the presidentially appointed National Commission on Space, which proposed as the U.S. space program's 50-year goal "Human Settlements beyond Earth Orbit, from the Highlands of the Moon to the Plains of Mars." That proposal was incorporated into the final space policy of the Reagan administration, issued in early 1988, which set as the long-range goal expanding "human presence and activity beyond Earth orbit into the solar system." This aspiration soon found concrete expression when President George H.W. Bush, on the 20th anniversary of the lunar landing, called for a Space Exploration Initiative that would return humans to the moon, "this time to stay," and then send them on initial voyages to the Red Planet.

Bush's proposal was premature. In the aftermath of the Challenger accident and with the space station program struggling to gain traction, neither the Congress nor NASA was ready to take on an ambitious exploratory effort. The Bush initiative was essentially stillborn. But the idea that the primary justification for government-sponsored human spaceflight was to someday travel beyond Earth orbit lived on, even as shuttle flights and space station assembly dominated U.S. spaceflight activity for the next 20 years. In the aftermath of the 2003 Columbia accident, the Columbia Accident Investigation Board said all members agreed "that America's future space efforts must include human presence in Earth orbit, and eventually beyond." The board's conclusion had a major influence on President George W. Bush's January 2004 announcement of his Vision for Space Exploration. Bush's







This time around we will not be racing a strategic adversary in a zero-sum competition; instead, **NASA should lead a global coalition of governments and the private sector in taking the next steps on the lunar surface.**

proposal, echoing both Reagan's 1988 policy and his father's 1989 initiative, included plans to "extend a human presence across our solar system" and to "return to the moon by 2020, as the launching point for missions beyond."

This 2004 proposal, which also included shuttle retirement, marked a turning point. Since then, no one has argued, as was the case before the Columbia accident, that the long-term focus of the government's spaceflight program should be centered on full exploitation of low Earth orbit. Rather, the debate has assumed that the focus should be on human exploration beyond Earth orbit. These discussions have centered on which destination should take priority, which exploration hardware to develop, what schedule would be feasible, and, of course, the level of funding that is likely to be available. In fits and starts, and ever so gradually, we have been implementing the vision laid out in 2004.

Unlike the situation in the aftermath of Apollo, there are both geopolitical and technical reasons to believe that a U.S.-led mission to the moon will be the outcome. Spacefaring countries around the globe are focusing on Earth's nearest neighbor as a desirable destination. That interest provides an opportunity for U.S. leadership. At least for the initial exploratory missions, it will be the U.S. government in the first position in the effort. This time around we will not be racing a strategic adversary in a zero-sum competition; instead, NASA should lead a global coalition of governments and the private sector in taking the next steps on the lunar surface.

Earth's satellite is basically unexplored territory. The six Apollo landing missions were demonstrations of national prowess more than well-equipped scientific investigations. There is an impressive list of things we do not know about the moon, especially whether it can be a source of economically valuable resources; that itself is reason to go back before setting out for the much more challenging goal of human exploration of Mars. As engineering professor Clive Neal of Notre Dame is fond of saying, there is a "new moon" to discover.

Which future?

In my view, there are only two alternatives for the future of government-sponsored spaceflight. One choice is to continue on the current course — slowly preparing for deep space missions by U.S. government astronauts, with the result, barring a catastrophic accident, being the eventual launch of such missions, first to lunar orbit and then the moon's surface. The other is to end that sponsorship after disengaging from the International Space Station. It is hard for me to think that any U.S. president would fire NASA's astronauts, taking NASA out of the human spaceflight business; such a step would be inconsistent with this country remaining the leading spacefaring nation.

Preparing for resuming space exploration has been incorporated in the policy of the last three administrations. Congress in 2010 wrote into law the statement that "the long term goal of the human space flight and exploration efforts of NASA shall be to expand permanent human presence beyond low-Earth orbit." Billions of dollars have already


NASA

◀ **Apollo 11 astronauts** Neil Armstrong, Michael Collins and Buzz Aldrin ride in a parade down Broadway and Park Avenue in New York on Aug. 13, 1969, as the country celebrated the moon landing weeks earlier.

John M. Logsdon is professor emeritus at George Washington University and has written books on the space policies of U.S. Presidents Kennedy, Nixon and Reagan. He founded GW's Space Policy Institute in 1987 and directed it until 2008. Logsdon was a member of the Columbia Accident Investigation Board. He has a doctorate in political science from New York University and a Bachelor of Science in physics from Xavier University. He is editor of "The Penguin Book of Outer Space Exploration."

been spent on developing hardware to achieve that goal. There is no indication that the Trump administration or the current Congress have any intention of reversing the overall course that the United States has been following, even as the White House has refocused that course on first returning to the moon. It would take a political decision to stop this flow of events; the decisions to pursue it have already been made and reiterated by three presidents and seven Congresses. The United States will resume human exploration, not as the result of a clarion call by an inspirational leader, but as a result of the normal flow of year-after-year government decisions.

Alternatively, a future president could make a "Nixon-like" decision that "the polls and the people to whom he talked indicated to him that the mood of the people was for cuts in space." I find such a choice hard to imagine, but it is certainly not inconceivable. The perceptive 2014 National Research Council report "Pathways to Exploration" commented that, given political and fiscal realities, "there is at least as great a chance that [government] human spaceflight budgets will be below the recent flat line trend as they will be markedly above it." A June 2018 poll that prioritized future missions for NASA gave lowest priority out of nine possibilities to sending astronauts to the moon, with only 13 percent of the respondents ranking a lunar return as the top priority.

I am guardedly optimistic that this country will continue to pursue option one, and that a return to the moon will be an early milestone along the way. There will be continuing arguments over whether NASA's current plans are the best way to proceed, and private sector alternatives will compete with those plans for political attention. My bet is on NASA as the leader of the first round of exploratory missions, given its head start and reservoir of experience. It is most likely that it will be a government astronaut who will take the next "small step."

I was at Kennedy Space Center in Florida on July 16, 1969, as Armstrong, Aldrin and Collins set out for the moon. I hope to be there again when the next lunar journey begins. ★

OPINION

DON'T WAIT FOR DISASTER

Just because hackers have not brought down a commercial aircraft or paralyzed global air travel does not mean it can't happen. Cybersecurity strategist James Vasatka offers a blueprint for commercial aviation cybersecurity.

Much has been said about the state of commercial aviation cybersecurity. Some of it is true. The important questions are which parts are true and which steps airlines, manufacturers and air traffic service providers must take to assure the continued integrity of the aviation system and the trust of the traveling public.

Do commercial aviation cybersecurity standards set a high enough bar? The following thought should give us pause: "The only truly secure system is one that is powered off, cast in a block of concrete and sealed in a lead-lined room with armed guards — and even then I have my doubts," computer scientist Eugene H. Spafford of Purdue University was quoted as saying.

As psychologist Daniel Kahneman has pointed out, humans have a tendency toward what he calls System 1 or automatic decision-making rather than System 2, effortful decision-making. This tendency

▲ The risks to commercial aviation have expanded to the cyber realm.

results in biases, blind spots or lack of imagination. We are inclined to overestimate our capabilities, focus internally, underestimate risk of external threats, underestimate the need to coordinate across organizations, and ignore external innovation.

We can see System 1 decision-making at work before the 1941 Pearl Harbor attack; the Apollo 1 launchpad fire in 1967; the Cuyahoga River fire of 1969; the explosion of the shuttle Challenger in 1986 and the disintegration of Columbia in 2003; and the Sept. 11 terrorist attacks in 2001.

Cyberattacks on critical infrastructure, including the aviation system, will continue to increase, unless we shift to effortful decision-making. Without that, we will not understand the risks we face or prioritize investments appropriately, and we risk outcomes ranging from excessive regulations by well-intentioned legislators to catastrophic loss of life.

The risk expands

Today's cyber risks are not to suggest that society hasn't benefitted greatly from the communications revolution that began in 1969 when researchers working for the Pentagon's Advanced Research Projects Agency (later renamed DARPA) sent the first messages over the ARPANET, the military precursor to today's internet. Those benefits are undeniable, but the desire to realize the economic benefits afforded by these advances is creating a dependence on an unreliable communications technology.

For example, we know from the 2010 Stuxnet attack on Iran's nuclear centrifuges that even obscure, proprietary networks with no connection to the internet can be vulnerable. Even when a site like this is not connected to the internet, the software that runs it was developed in a facility that was connected to the internet, making the software a threat surface. The Stuxnet malware targeted the supervisory control and data acquisition software at an Iranian nuclear facility. This incident proved that software can be deployed as a weapon to destroy physical infrastructure, in this case Iran's centrifuges. The risk to commercial aviation has now expanded from the traditional areas of physical safety and security to the evolving threats in the cyber realm. The only barrier remaining for commercial airplanes is the community's rigorous safety standards.

Some of the key considerations for understanding the current state of affairs include: the internet is not secure; economics are driving increased automation and connectivity; the use of IP-connected systems continues to expand; threats continue to evolve rapidly; adversaries have an asymmetric advantage given that they must succeed once whereas defenders must thwart attackers every time; the increasingly complex and dynamic environment requires improved security; cyber criminals can implement new technology in days or months, whereas the commercial aviation industry typically needs years or decades.

Getting the focus right

I don't believe the risk today centers on the airplane, notwithstanding the claim by a manager from the Department of Homeland Security that during a test, agency experts managed to exploit radio communications to hack into the cockpit of a Boeing 757 at an airport. While the details of the test remain classified, those radio frequency communications would be either voice or for the Aircraft Communications Addressing and Reporting System. I don't believe you can use voice or ACARS to hack into a flight-critical system.

That is not to say that ACARS might not pose other kinds of risks. Widespread disruption of the ACARS system would have a significant impact on the departure of airplanes, the plans of the traveling public and airline costs. ACARS is a two-way messaging system that was designed in the 1970s to improve data integrity and reduce crew and air traffic controller workloads. Flight plans or weather updates from an airline's operations center, for instance, are routed to a central computer and then on to one of two service providers that then transmit via VHF radio ground stations around the world to the airplane. Messages from the airplane, such as automated event reports about the health of equipment, flow through the system in the opposite direction. Anyone armed with a computer, a radio transmitter and easily available know-how can send and receive ACARS messages.

It is important to understand the safety assessment developed for ACARS by a standards committee of the RTCA, an association founded in 1935 as the Radio Technical Commission for Aeronautics. The assessment assumes that the information can be corrupted. Operational mitigations are included in the implementation to ensure that the information received is appropriate for use. The committee exercised System 2 decision-making in the assessment by identifying mitigations for the possibility of corrupted data, but at that time, the internet did not yet exist. Even though I do not believe ACARS could be used to take control of a plane, it may be necessary now to review the safety assessment in the context of the evolving threats.

A second set of mitigations is provided for in many countries by criminal codes for unauthorized interference with aviation. There are many cases in which individuals were fined or imprisoned for unauthorized communications with airplanes.

Establishing consequences

There are a couple of interesting points to glean from the ACARS example.

In the cyber realm, there are no consequences for bad behavior by nation-states involved in attacks on aviation.

The first is that the data may be corrupt and operational mitigations are in place to assure safety of flight. Unauthorized communication can impact the efficiency of airplane and air traffic operations. The second is that the threat surface extends beyond radio communication with the airplane. Any component of the ACARS ground system connected to the internet creates a threat surface.

The third is that unauthorized access to the ACARS network, either ground or air system, may be legal in some countries, and international conventions requiring nations to support law enforcement investigation are not in place for cyberattacks. I find it interesting that if you place a bomb on an airplane you are a criminal in the 192 member states of the International Civil Aviation Organization, ICAO, whereas if you attack an aircraft with electronic digits, you are a cyber warrior or hacktivist in some nations. Today, if a country does not follow the international instruments governing behavior for flight safety, such as not providing safety oversight of airlines, and physical security such as not screening passengers and baggage for bombs, the airlines based in those countries will be denied access to two large aviation markets: the U.S. and Europe.

In the cyber realm, however, there are no consequences for bad behavior by nation-states involved in attacks on aviation. If there are no consequences, there are no rules. If there are no rules, there will be chaos.

This contradiction is not simple to solve since state-sponsored espionage, intelligence and military preparedness are all intertwined.

Where the safety of the traveling public is concerned, including in the cyber realm, nations should follow the underlying principles of the ICAO convention. Countries participating in international aviation have an obligation to prevent attacks on commercial aviation and to respond to law enforcement investigations in a reasonable time. Commercial aviation should be off limits to unauthorized interference. It will take at least 10 years to negotiate such an international instrument for cybersecurity. That is, it will take 10 years after we get started.

The fourth issue is the need to develop a common language and approach. As noted earlier, mitigations are included to address corrupted data over open communications channels. Government agencies, on the other hand, would see open communications as a vulnerability, and it then becomes a classified discussion with no path back into the open and transparent commercial arena.

The last point is that aviation safety, security and efficiency are a shared responsibility — a partnership of government agencies, airlines, airports and manufacturers providing layers of security.

The decision-making culture is an important aspect to meeting these responsibilities and there are, unfortunately, a mix of cultures in the cybersecurity arena.

Decoding the cultures

Today's safety culture evolved separately from the cybersecurity culture, and therefore takes a data-driven, working-together approach driven by a desire to reduce accident rates. Open, transparent collaboration for risk management, modeling and decision support created a shared vision, strategy, goals, standards and implementation models that drive safety improvements and international norms of behavior.

By contrast, the security culture, which today remains separate from the IT security culture, takes a law enforcement/intelligence approach driven by legal and policy considerations. This culture has proved successful in strengthening the system's resilience against physical attacks by terrorists through prevention, response/mitigation and recovery. To protect methods and sources, the distribution of sensitive threat information is restricted to a need-to-know basis. This culture often focuses on components of the aviation system and does not always understand the impact on stakeholders or leverage their knowledge and capabilities.

The security culture also is in dire need of resilience to cyberattacks. The black hat culture of nation-state and criminal hackers adds complexity to the decision-making approach. Black hats have no rules and strong imaginations and are not restricted by the biases and norms of aerospace engineers. One person's criminal is another person's cyber warrior.

The IT security culture is tasked with the untenable position of being on the losing side of asymmetric warfare. IT security professionals survive by exuding confidence even before they understand the scope of the problem, recovering the system to an acceptable state, and repeating the first two steps.

As they strengthen their system, adversaries move on to the next weakest link.

In the U.S., an unauthorized access to a computer system is a crime. Criminal investigations are time and resource intensive. They seldom result in a conviction due to their often-international nature. Therefore, corporations and IT security professionals have little motivation to report these crimes.

White hat hackers in government, industry and research firms have the best jobs in the world. They get to break things for fun. They also tend to over-sensationalize safety implications of their research. Since the aviation community must divert critical resources in reaction to their misrepresentations, they are not considered a responsible party by the aviation community. This creates an unfortunate situation where the community has not figured out how to effectively deploy this creative and imaginative force.

In the United States, back in 1997, the President's Commission on Critical Infrastructure Protection, known as the Marsh commission, recognized the cyber risks to telecommunications, information technology, commercial aviation, GPS and other parts of the infrastructure. The commission urged the government to work with private industry within an existing framework of government policy and regulation. The commission recommendations called for a concept of shared cyber threats, an integrated approach to protection, cultural changes and government to lead by example.

Less than two decades later came the 2014 data breach of the Office of Personnel Management, announced by the agency in 2015. Stolen were background checks, Social Security numbers and other information for millions of current, former and prospective federal employees and contractors. The OPM breach highlights the challenges for just one stakeholder, the U.S. government, to adopt best practices, actively manage risk, and improve security planning in its own information systems.

A possible template

For those in the aviation cybersecurity community, the good news is that there is a model to draw from. In 1997, the FAA and the industry formed the Commercial Aviation Safety Team with a goal of achieving an 80 percent reduction in the fatality rate for commercial aviation by 2007. Today, CAST's various analysis teams provide a collaborative model that the airlines, manufacturers and aviation regulators could extend to implement the cyber recommendations of the Marsh commission. The principles underlying this holistic system's approach include: 1) understanding the needs and risks of the stakeholders, 2) bringing the knowledge base of the stakeholders together for a common understanding of issues, 3) aligning stakeholder positions through data-driven, risk-informed analysis, 4) aligning the strategies and plans of the key stakeholders, and 5) balancing risk reduction with operational and economic impacts.

Leveraging these principles in the context of the needs and cultures of the cybersecurity communities would accelerate development of common risk management, modeling and decision support methods.

Much progress has been made in addressing elements of the comprehensive framework developed and presented by the Commercial Aviation Cybersecurity Panel at the 2013 AIAA Aviation Forum. Work remains to build a common vision, integrated strategy and plan for assessing and prioritizing cybersecurity risk to strengthen the security posture.

So far, the aviation community has built a rigorous governance, risk and compliance model for physical safety and security. Next, a governance, risk and compliance model is needed for cybersecurity. This model will be difficult to develop due to the complexity of the technical issues, the cultural disparities, and the geo-political considerations. The questions that need to be answered include:

- What are the crown jewels that need to be protected?
- Do we understand the risks?
- Are the rigorous safety standards robust enough?
- How do we shift the decision-making environment to prevent a failure of imagination?
- How do we bridge the cultural gaps?
- Is the community ready to take a holistic approach?

Strengthening commercial aviation's cybersecurity posture and improving its resilience if disruption occurs will require the following:

1. A road map, strategy and plan for addressing the evolving threats;

2. A national research and development plan for securing critical commercial aviation connectivity; and

3. An international convention treating cyberattacks on commercial aviation as unlawful interference.

The list of events at the beginning of this piece shows a wide range of consequences for failures of imagination. The 1969 Cuyahoga River fire is the likely scenario that aviation and the high-tech industry face in the near term.

The Cuyahoga River caught fire at least 13 times between 1868 to June 22, 1969. It took the 1969 fire to catch the attention of Time magazine and the environmental movement. The resulting political pressure was one of the catalysts for establishing the Environmental Protection Agency in 1970.

How many fires will aviation face before the nation rallies to create a vision and build a plan? ★

James Vasatka
is the principal advisor and president of Avante Technology Advisors, which focuses on commercial aviation security. Before forming Avante, his work as the director of Aviation Security for Boeing Commercial Airplanes included the International Civil Aviation Organization Industry High Level Cyber Security working group, the Aviation Information Sharing and Analysis Center board of directors, the Aerospace Industries Association Cybersecurity ad hoc working group and the Transportation Security Administration's Risk Management working group.

AIAA Bulletin

DIRECTORY

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

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

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

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

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

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

Calendar

FEATURED EVENT

7–11 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			
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	aiaa.org/onlinelearning	
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)	
8 Nov	DirectTech Webinar—Step-by-Step Process for Designing Weightless Space Habitats	Virtual (aiaa.org/onlinelearning)	
13–15 Nov*	2018 CODER Workshop	College Park, MD (www.coder.umd.edu/coder2018)	
2019			
5–6 Jan	2nd AIAA Geometry and Mesh Generation Workshop	San Diego, CA	
5–6 Jan	Aircraft and Rotorcraft System Identification Engineering Methods for Manned and UAV Applications with Hands-on Training Using CIFER® Course	San Diego, CA	
5–6 Jan	Design of Aircraft Structures Course	San Diego, CA	

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
5–6 Jan	Diagnostics for Plasmas and Gases Course	San Diego, CA	
5–6 Jan	Fundamentals of Space Systems Course	San Diego, CA	
5–6 Jan	Guidance, Control, and Astrodynamics of Space Vehicles Course	San Diego, CA	
5–6 Jan	Integrating Program Management and Systems Engineering Course	San Diego, CA	
6 Jan	A Unified Approach for Computational Aeroelasticity Course	San Diego, CA	
6 Jan	Additive Manufacturing: Structural and Material Optimization Course	San Diego, CA	
6 Jan	Hypersonics: Test and Evaluation Course	San Diego, CA	
7 Jan	AIAA Associate Fellows 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	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 (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.*

PROPULSION ENERGY FORUM

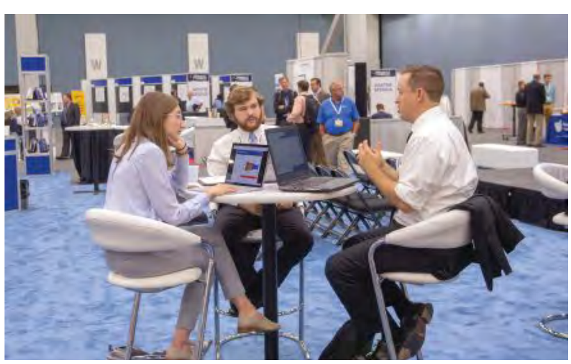
More than 1,400 attendees, including 373 student attendees, representing a broad range of the propulsion and energy community – from across the U.S. and 29 other countries – convened in Cincinnati, 9–11 July, for a focused and successful AIAA Propulsion and Energy Forum.


AIAA
Shaping the Future of Aerospace
www.aiaa.org


AIAA Dayton/Cincinnati Section


NEXT ST


NASA
PROPULSION
ENERGY
FORUM




F-35 INTEGRATED AIR VEHICLE SUBSYSTEMS
PROPULSION
ENERGY
F-35 INTEGRATED AIR VEHICLE SUBSYSTEMS

Recognizing Top Achievements – An AIAA Tradition

For over 80 years, AIAA has been committed to ensuring that aerospace professionals are recognized and celebrated for their achievements and innovations that make the world safer, more connected, accessible, and prosperous. AIAA celebrates the following individuals who were recognized between July and September 2018.

Presented at the 48th International Conference on Environmental Sciences, 8–12 July, Albuquerque, New Mexico

2018 Jeffries Aerospace Medicine and Life Sciences Research Award

Dava J. Newman
Apollo Program Professor of Aeronautics and Astronautics
Massachusetts Institute of Technology
For sustained, exceptional contributions to the mechanics and energetic requirements of human performance across the continuum of gravity, advanced space suit design, and navigation aids for EVA astronauts.

Presented at the AIAA Propulsion and Energy Forum, 9–11 July, Cincinnati, Ohio

2018 Aerospace Power Systems Award

Peter Carian
Aerospace Fellow
The Aerospace Corporation
In recognition of technical excellence in space power systems architecture, electronic component design, and anomaly resolution.

2018 Air Breathing Propulsion Award

Gabriel Roy
President
CPnE Consultants
For contribution to Air Breathing Systems by envisioning and managing over 500 R&D projects leading to innovations, increased range and speed, and reduced emission and noise.

2018 Energy Systems Award

Brian Edward Launder
Professor of Mechanical Engineering
University of Manchester
For leading modelling, measurement, and computational research in turbulent flows for 50 years with diverse energy-related applications including, especially, gas-turbine blade cooling.

2018 Liquid Propulsion Young Professional Award

Drew Damon
Propulsion Engineering Manager
SpaceX
For early achievements in liquid propulsion and demonstrated potential for a successful career in the field.

2018 Liquid Propulsion Student Award

Darren Tinker
Vanderbilt University
Bowling Green, Kentucky
For outstanding work as an undergraduate or graduate student in liquid propulsion.

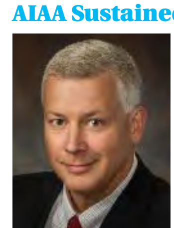
2018 Propellants and Combustion Award

Hai Wang
Professor, Mechanical Engineering Department
Stanford University
For pioneering contributions to the theory and practice of homogenous and heterogeneous combustion kinetics.

2018 Wyld Propulsion Award

T. Kent Pugmire
Technical Representative (Ret.)
AVCO Space Systems/ Standex Engineering and Technology Group
For pioneering contributions to the design and development in-space propulsion systems including the creation of electro-thermal ammonia/hydrazine propulsion systems used in hundreds of spacecraft.

AIAA Sustained Service Award



Robert Stuever
Senior Engineering Specialist
Textron Aviation
For sustained service to the Institute at both the national and section levels with a variety of roles and responsibilities.

2018 AIAA Engineer of the Year

Rodger E. Farley
Chief Systems Engineer
World View Enterprises
For the system design of a controlled lighter-than-air vehicle capable of station keeping in the stratosphere.

Thank you to all the nominators and supporters of these award winners.

Learn more about the AIAA Honors and Awards program at aiaa.org/HonorsAndAwards

Presented at the AIAA SPACE Forum, 17–19 September, Orlando, Florida

2018 von Kármán Lecture in Astronautics

Christopher J. Scolese
Director
NASA Goddard Space Flight Center
Lecture: "Strategies for Technology Infusion and Risk Mitigation at NASA"

2018 George M. Low Space Transportation Award

Garry Lyles
Chief Engineer, Space Launch System
NASA Marshall Space Flight Center
For visionary leadership in the development of NASA's Space Launch System Vehicle.

2018 Haley Space Flight Award

Daniel W. Bursch
Astronaut (Ret.)
Naval Postgraduate School
In recognition of Dan Bursch's advancement in the art, science, and technology of robotics and unexpected challenges during the early stages of the International Space Station.

2018 Hypersonic Systems and Technology Award

Robert A. Mercier
Deputy for Technology
Air Force Research Laboratory, High Speed Division
In recognition of over 20 years of dedicated, sustained effort to advance air-breathing propulsion to a level of maturity that makes practical hypersonic vehicles a reality.

2017 Space Automation & Robotics Award

Robotic Refueling Mission (RRM) Team
NASA Goddard Space Flight Center
In recognition of the Robotic Refueling Mission Team for their work in advancing the state of robotic servicing technology enabling the routine serving of satellites.

2017 Space Operations and Support Award

ISS Loop A Response Team
Anthony Vereha, Todd Quasny,
ISS Flight Controller
NASA Johnson Space Center
For leadership and innovation in working the External Thermal Control System Loop A Flow Control Valve failure on the International Space Station.

2018 Space Sciences Award

Interface Region Imaging Spectrograph (IRIS) Science Team
Lockheed Martin Space Systems
Award accepted by Gary Kushner, Program Manager
For successfully operating the IRIS observatory and delivering high resolution images and UV spectra of the sun's interface region.

2017 Space Systems Award

Juno Mission Team
Jet Propulsion Laboratory
For exceptional achievement in the development and implementation of the Juno mission, resulting in groundbreaking data that is revolutionizing our understanding of Jupiter.

2018 Sustained Service Award

Bob Greene
Aeronaut Corporation
For dedication and tireless efforts over 20 years of continuous service to the Atlanta Section as Programs Chair, CVD state team Captain, Section Chair and officer, and STEM programs promoter.

2017 Von Braun Award for Excellence in Space Program Management

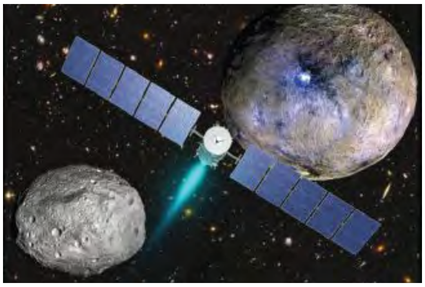
Maj. Gen. Roger W. Teague
Director, Space Programs
Office of the Assistant Secretary (Acquisition), U.S. Air Force
For exceptional achievement in space missions through innovative strategic thinking, revolutionary program management, and inspirational leadership on program execution.

2018 von Braun Award for Excellence in Space Program Management

Maj. Gen. (ret.) Thomas Taverney
Senior Vice President, Space Systems
Leidos
Major General (Retired) Tom Taverney has contributed significantly to the Space Mission as both a senior military leader and Aerospace Industry Executive.

2018 Space Systems Award

Dawn Flight Team
Jet Propulsion Laboratory
Award presented to Marc Rayman, Dawn Project Manager
For accomplishing a unique interplanetary mission to orbit and explore two alien worlds, Ceres and Vesta, displaying exceptional space engineering with a rich scientific return.



AIAA Announces Section Award Winners

AIAA has announced its 2017–2018 Section Award winners. The Section Awards honor particularly notable achievements made by member sections in a range of activities that help fulfill the Institute's mission. The Institute believes that vital, active sections are essential to its success.

Section awards are given annually in five categories based on the size of each section's membership. Each winning section receives a certificate and a cash award. The award period covered is 1 June 2017–31 May 2018.

The **Outstanding Section Award** is presented to sections based upon their overall activities and contributions through the year. The winners are:

Very Small: **First Place: Delaware,** David Fox, section chair; **Second Place: Adelaide,** Mark Ramsey, section chair

Small: **First Place: Savannah,** Suzanne Swaine, section chair; **Second Place: Sydney,** Arnab Dasgupta, section chair; **Third Place: Palm Beach,** Randy Parsley, section chair

Medium: **First Place, Long Island,** David Paris, section chair; **Second Place: Tucson**, Eric Hoffman-Watt, section chair; **Third Place: Wichita,** Linda Kliment, section chair

Large: **First Place: San Diego,** Ioana Brome, section chair; **Second Place: Northern Ohio,** Peggy Cornell, section chair; **Third Place: Orange County**, Amir Gohardani, section chair

Very Large: **First Place: Dayton/Cincinnati,** Marc Polanka and Michael List, section chairs; **Second Place: Hampton Roads,** Gregory Buck, section chair; **Third Place: Greater Huntsville,** Naveen Vetcha, section chair

---

The **Career and Professional Development Award** is presented for section activities that focus on career development, such as time management workshops, career transition workshops, job benefits workshops, and technical versus management career path workshops. The winners are:

Very Large: **First Place: Hampton Roads,** Elizabeth Ward and Hyun Jung Kim, career and professional development officers

Large: **First Place: San Diego,** Ioana Broome, section chair

Small: **First Place:** Savannah, Scott Terry and Ricky Odey, career and professional development officers, and Ashley Roper, programs officer; **Second Place:** Sydney, Arnab Dasgupta, section chair; **Third Place:** Utah, Scotty Nowlin, public policy officer, Caite Beck, young professional officer, and Trevor Floyd, communications officer

The **Communications Award** is presented to sections that have developed and implemented an outstanding communications outreach program. Winning criteria include level of complexity, timeliness, and variety of methods of communications, as well as frequency, format, and content of the communication outreach. The winners are:

Very Small: **First Place: Delaware,** Chrissy Larson, communications officer

Small: **First Place: Northwest Florida,** Chi Mai, section chair; **Second Place: Utah,** Trevor Floyd, communications officer; **Third Place: Savannah**, Kevin Shea, secretary

Medium: **First Place:** Tucson, Alan Jennings, webmaster; **Second Place:** Long Island, David Paris, section chair and newsletter editor

Large: **First Place: Northern Ohio,** Edmond Wong, communications officer; **Second Place: San Diego,** Jin Oh, secretary; **Third Place: Cape Canaveral,** Matthew Zuk, communications officer

Very Large: **First Place: Hampton Roads,** John Lin, newsletter editor; **Second Place: Greater Huntsville,** Erin Walker, communications officer; **Third Place: Dayton/Cincinnati**, Michael List, newsletter editor

---

The **Membership Award** is presented to sections that have increased their membership by planning and implementing effective recruitment and retention campaigns. The winners are:

Very Small: **First Place: Delaware,** Noah Gold, membership officer

Small: **First Place: Twin Cities,** Kristen Gerzina, section chair; **Second Place: Savannah**, Nusrat Rehman and Michael Wolff, membership officers; **Third Place: Utah**, John Metcalf, section chair

Medium: First Place: Tucson, Rajka Corder, membership officer

Large: First Place: San Diego, Kathy Kucharski, membership officer; **Second Place: Orange County,** Bob Welge, membership officer; **Third Place: Northern Ohio,** Erin Tesny, membership officer

Very Large: First Place: Greater Huntsville, Naveen Vetcha, section chair; **Second Place: Dayton/Cincinnati,** Caleb Barnes, membership officer**; Third Place: Hampton Roads,** Marlyn Andino, membership officer

---

The **Public Policy Award** is presented for stimulating public awareness of the needs of aerospace research and development, particularly on the part of government representatives, and for education section members about the value of public policy activities. The winners are:

Very Small: First Place: Delaware, Tim Dominick, public policy officer

Small: First Place (tie): Savannah, Scott Perry, public policy officer; **First Place (tie): Twin Cities,** Cristin Finnigan, public policy officer; **Third Place**: **Utah**, Scott Nowlin, public policy officer

Medium: First Place: Tucson, Bradley Williams, public policy officer; **Second Place: Long Island,** David Paris, section chair and public policy officer; **Third Place: Michigan**, Austin Harper, public policy officer

Large: First Place: Northern Ohio, Victor Canacci, public policy officer; **Second Place: San Diego,** John Kucharski, public policy officer

Very Large: First Place: Greater Huntsville, Chris Crumbly, public policy officer; **Second Place: Dayton/ Cincinnati,** Oliver Leembruggen, public policy officer; **Third Place: Hampton Roads,** Steven Dunn and Michelle Lynde, public policy officers

---

The **STEM K–12 Award** is presented to sections that have developed and implemented an outstanding STEM K–12 outreach program that provides quality education resources for K–12 teachers in the STEM subject areas. The winners are:

Very Small: First Place: Delaware, Elishabet Lato, STEM K–12 outreach officer

Small: First Place: Northwest Florida, Angela Diggs, STEM K–12 outreach officer; **Second Place: Palm Beach,** Kevin Simmons, public policy officer**; Third Place: Savannah,** Alex Rummel, STEM K–12 outreach officer

Medium: **First place: Tucson,** Elishka Jepson and Allie Kunkel, STEM K–12 outreach officers; **Second Place: Southwest Texas,** Joan Labay-Marquez, STEM K–12 outreach officer; **Third Place: Long Island**, David Paris, section chair

Large: **First Place: Orange County,** Janet Koepke, STEM K–12 outreach officer; **Second Place: San Diego**, Cristian Paunescu, STEM K–12 outreach officer; **Third Place: Northern Ohio,** Julie Kleinhenz, STEM K–12 outreach officer

Very Large: **First Place: Dayton/Cincinnati,** José Camberos, STEM K-12 outreach officer; **Second Place: Hampton Roads,** Karen Berger and Amanda Chou, STEM K-12 outreach officers; **Third Place: Greater Huntsville,** Naveen Vetcha, section chair

---

The **Young Professional Activity Award** is presented for excellence in planning and executing events that encourage the participation of the Institute's young professional members, and provide opportunities for leadership at the section, regional, or national level. The winners are:

Very Small: **First Place: Delaware,** Daniel Nice, young professional officer

Small: **First Place: Savannah,** Cameron Carson and Libin Daniel, young professional officers; **Second: Utah**, Caite Beck, young professional officer

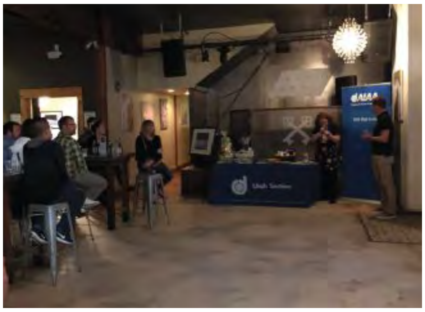
Large: **First Place: San Diego,** Lindsay Sweeney, young professional officer; **Second Place: Northern Ohio,** Roger Tokars, young professional officer

Very Large: **First Place: Greater Huntsville,** Tamara Statham, young professional officer; **Second Place: Hampton Roads**, Vanessa Aubuchon and Michelle Lynde, young professional officers; **Third Place: Dayton/Cincinnati**, Ashlee Youngpeters, young professional section officer

---

The **Outstanding Activity Award** allows the Institute to acknowledge sections that held an outstanding activity deserving of additional recognition. The winners are:

Very Small: **Delaware**, David Fox, section chair. **International Space Station In-Flight Education Downlink.** As part of an existing program within NASA, the AIAA Delaware Section applied for and was competitively awarded an In-Flight Education Downlink with NASA Astronaut Col. Jack Fischer. The downlink was hosted at Leeds Elementary School in Elkton, MD, by the AIAA Delaware Section in partnership with Orbital ATK and Cecil County Public Schools (CCPS). As part of the downlink, 20 students from grades Pre-K to 5 at Leeds Elementary were able to ask questions of Col. Fischer and see/hear his responses during a 20-minute live broadcast from the International Space Station. Seven local elected officials were in attendance along with staff members from U.S. Senator Van Hollen's Office, the Maryland Office of the Governor, Maryland Senator Wayne Norman's Office, and Maryland State Department of Education, as well as the CCPS Superintendent and other leaders in the CCPS administration. AIAA Delaware Section Public Policy Chair Tim Dominick presided over the event as the Master of Ceremonies. In addition to the 400 students participating in the event at Leeds Elementary, 590 students across CCPS and the country watched the event live via NASA TV.



Small: **Sydney**, Arnab Dasgupta, section chair. **Astronaut Stories Australia**. Astronaut Stories Australia was a keynote series of public outreach events that had resounding success: spreading an inspirational message directly to over 5,000 individuals, engaging with over 1,000 students, connecting with 150,000 people over social media and 3.5 million with traditional media. The principal goals of the events were to inspire and inform the general public: to educate on the wonder and importance of space exploration, as well as motivating support of scientific and technical exploration. To achieve these goals, Astronaut Stories Australia aimed to take advantage of the large number of astronauts coming to Australia for the International Astronautical Congress in Adelaide by organizing for astronauts to stop in Brisbane, Sydney, Canberra, and Melbourne. In each city, an astronaut headlined both a STEM workshop for high school students and a large public presentation.

The student event, From STEM to Space, was designed to spark an interest in young students prior to their subject selection years with the goal of encouraging them to consider a

career in STEM. These events included a presentation and Q&A section with a panel of astronauts and local STEM role models, followed by hands-on science and engineering activities.

The public event, An Evening of Astronaut Stories, aimed to bring together a broad audience to foster a passion and interest for space activities, as well as motivating support of scientific and technical exploration. An astronaut shared stories from their career and from being in space, followed by an audience Q&A session, moderated by an Australian voice.

Medium: Wichita, Linda Kliment, section chair. **Engineers and Educators**. Wichita Section hosted its second Engineers as Educators program on December 5, 2017. The training and the lessons all took place at a local public elementary school. This year, the volunteer educators increased in numbers and included some flight test pilots in addition to engineers. The volunteers came from Textron Aviation, Spirit, Bombardier, and Wichita State University. Before meeting with the volunteers, the organizer of the program spent time with the principal and teachers at the school to determine projects that would fit into the curriculum. The program organizer then held a workshop to train the volunteers, after which they were scheduled for their class lesson and given information about their project. The increase in volunteers allowed AIAA to cover all of the classrooms on a single day. The lessons were 45 minutes in length and over 400 students participated.

Large: San Diego, Ioana Broome, section chair. **Atlas First Launch Pioneers Celebration - 60 Year Anniversary**. The Atlas Pioneers Celebration featured a panel of General Dynamics Convair - Astronautics Space Systems Division employees who had a part in the early days of the Atlas program, leading up to the first launch of an Atlas on June 11, 1957. It was moderated by one of the youngest of those Atlas Pioneers, Bill Ketchum. Jackie Collins, another Atlas veteran, introduced and showed the video, "50 Years of Atlas." Mr. Ketchum and the other six panelists each had a chance to say a few words and show some mementos from the Atlas program. Later, Mr. Ketchum asked if any veterans of the Atlas Program in the audience would like to say a few words. This opened the discussion, making it a lively evening.

The celebration had originally been planned as a low-key 60-year event with those employed by the program at the time of the first launch. The section proposed to join efforts with Bill Ketchum and plan it as a version of the section's Aerospace Heritage Night. Aerospace Heritage Night is our yearly panel discussion with our senior members talking about their experiences in the aerospace profession. We received an unexpectedly large response. We had over 100 people in attendance, with almost 40 Atlas Pioneers; seven of them on the formal panel, while many of the Pioneers in the audience were able to tell us about their own experiences.

Very Large: Los Angeles-Las Vegas, Robert Friend, section chair. **Student Branch Mini-Conference**. The mini-conference was planned by the Education and Program chairs working cooperatively. It was held on a Saturday at the Northrop Grumman S Café in Redondo Beach and was designed for the section's student branch members with several objectives: increasing communication between the branches, enabling students to meet other student members; gain presentation experience by presenting on topics of interest to them; and learn from industry representatives about what it takes to work in the field, how to make their resumes look attractive in job applications, and make contacts for networking.

News

Sneak Peek — AIAA Gets an Updated Look

Big news! AIAA is updating our brand identity, specifically the AIAA logo, brand colors, and corporate font. Why you might ask? Well, we've had this look for a really long time, so long in fact, that nobody on our staff can remember the last time our logo changed, and we have staff members who have been around over 30 years. However, AIAA has changed a lot in the last 30 years. With our members' help, we've launched new member benefits, built an online community, brought the marketplace new collaborative forums, and celebrated countless wins in the aerospace community together, but our logo had lines down the middle. We don't want lines in between us anymore. Needless to say, it was time for a refresh. Don't worry, we are not changing our look completely. Our design goal was to adjust just what was needed to solidify the look, and make our logo friendly online, in social media, and in print.

So here is your sneak peek! You'll see this new logo everywhere you see AIAA—at an event, on our new website (coming early 2019), Facebook, Twitter, and soon you'll see it incorporated into all of our products as well. We hope this new look shows our members that we are also continually advancing our promise to you to help aerospace professionals and their organizations succeed, even if it's just a little creative change to make us sharper and more connected.

AIAA Young Professional Named Among 2018 IAF Young Space Leaders

By Lawrence Garrett, AIAA web editor

Jackelynne Silva-Martinez, an AIAA young professional, was recently named as one of three International Astronautical Federation (IAF) Young Space Leaders (YSL) for 2018 (iafastro.org/iaf-young-space-leaders-2018). Silva-Martinez was invited as a guest of the IAF President to attend the 69th International Astronautical Congress Gala on 5 October, in Bremen, Germany.

Born in Cusco, Peru, Silva-Martinez attended Rutgers University, where she earned bachelor's degrees in Mechanical and Aerospace Engineering and Spanish Translation and Interpretation. She went on to earn a Certificate in Lean Six Sigma from Lockheed Martin's Greenbelt Program, a Certificate in Engineering from Drexel University, a Master's degree from Embry-Riddle Aeronautical University in Aeronautical Science with a concentration in Human Factors Aviation/Aerospace Systems, and a second Master's degree in Aerospace Engineering with a concentration in Space Systems Integration from Georgia Institute of Technology. In addition, Silva-Martinez is an alumna of the 2015 Space Studies Program from the International Space University.

Silva-Martinez works at NASA Johnson Space Center performing research on crew autonomous scheduling for the ISS in NASA's Flight Operations Directorate as part of the International Space Station Mission Planning Operations team. She also supports ground tests for the agency's Lunar Orbital Platform-Gateway. Previously, Silva-Martinez worked as a mechanical engineer and test operator at NASA Jet Propulsion Laboratory, and as an antennas mechanical engineer and systems integration and test engineer for commercial and government satellites at Lockheed Martin Space Systems.

An active AIAA member, Silva-Martinez has served as chair of the AIAA Space Architecture Technical Committee's Habitability and Human Factors Subcommittee, and as a member of the AIAA Young Professionals Committee. She is also active in STEM initiatives, having founded the Centro de Ciencia, Liderazgo y Cultura, which presents lessons on science, leadership and culture to younger generations throughout the world.

Glassman Honored with Guggenheim Medal

Princeton University Professor Emeritus **Irvin Glassman** was awarded the 2018 AIAA/ASME/SAE International/VFS Daniel Guggenheim Medal on 18 August "in recognition of his profound impact on the application of combustion science and engineering to propulsion research and the successful development of propulsion systems."

(Left to right) Inder Chopra, 2018 Guggenheim Board Chair; Emily Carter, Dean of the School of Engineering and Applied Science, Princeton University; Irvin Glassman, and Domenic Santavicca, nominator. (Credit: Frank Wojciechowski)

Known affectionately by his colleagues as the "Grand Old Man of Combustion," Glassman retired from the Department of Mechanical and Aerospace Engineering in 1999 after 49 years. He received his B.E. (1943) and Dr.Eng. (1950) in Chemical Engineering from Johns Hopkins University before joining Princeton University. Promoted to full professor in 1964, Glassman was appointed as the Robert H. Goddard Professor of Mechanical and Aerospace Engineering in 1988. He is an AIAA Fellow, Member of the National Academy of Engineering, and member of the New York Academy of Sciences.

AIAA Foundation Awards for Distinguished Achievement in Aeronautics and Astronautics Awarded

Geoffrey Andrews from Purdue University has won the **2018 AIAA Foundation Abe M. Zarem Award for Distinguished Achievement in Aeronautics** for his paper "A Hybrid Length Scale Similarity Solution for Swirling Turbulent Jets." He was invited to participate in the student paper competition of the 31st Congress of the International Council of the Aeronautical Sciences (ICAS).

Andrews is in his second year as a Ph.D. student in aerospace engineering at Purdue where he also earned his master's degree. He has a bachelor's degree in mechanical engineering from Lehigh University.

Andrews's faculty advisor for the winning project was **Gregory A. Blaisdell**, an AIAA Associate Fellow and a professor in the School of Aeronautics and Astronautics at Purdue University.

Ken M. Mitchell from the University of Memphis has won the **2018 AIAA Foundation Abe M. Zarem Award for Distinguished Achievement in Astronautics** for his research paper "Thermal Conductivity and Specific Heat Measurements of an RTV-655/Polyimide Aerogel Compound at 77K and 298K." He was invited to participate in the student paper competition of the 69th International Astronautical Congress.

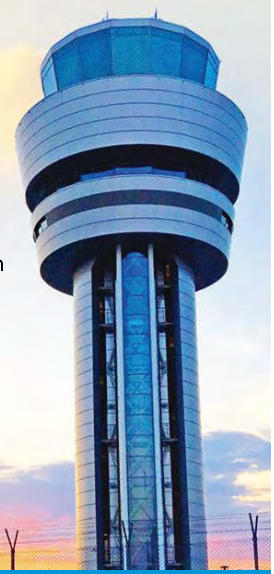
A 2nd-year mechanical engineering graduate student, Mitchell also is working in the Bio, Nano, and Space Materials Lab within the Physics Department. He received his undergraduate degree in mechanical engineering at the University of Memphis. Mitchell's focus in graduate school has been to measure thermal conductivity and specific heat of polydimethylsiloxane (PDMS) and aerogel at room temperature and cryogenic temperature using the transient plane source technique.

Mitchell began working with advisor **Jeffrey Marchetta** as an undergraduate. Marchetta is a professor of Mechanical Engineering and faculty advisor of the AIAA University of Memphis Student Branch. An AIAA Senior Member, he received the AIAA Abe Zarem Award for Distinguished Achievement in Astronautics Research in 1999.

AIAA Honorary Fellow Dr. Abe Zarem, founder and managing director of Frontier Associates, established the award to annually recognize graduate students, in aeronautics and astronautics, who have demonstrated outstanding scholarship in their field. For more information on the award, contact Felicia Livingston at felicial@aiaa.org or 703.264.7502.

AIAA/AAAE/ACC Jay Hollingsworth Speas Airport Award

CALL FOR NOMINATIONS



Nominations are currently being accepted for the 2019 AIAA/AAAE/ACC Jay Hollingsworth Speas Airport Award. The recipient will receive a certificate and a $7,500 honorarium.

This award honors individuals who have made significant improvements in the relationships between airports and/or heliports and the surrounding environment; specifically by creating best-in-class practices that can be replicated elsewhere. Such enhancements might be in airport land use, airport noise reduction, protection of environmental critical resources, architecture, landscaping, or other design considerations to improve the compatibility of airports and their communities.

For nomination forms, please visit **aiaa.org/speasaward**. Presentation of the award will be made at the AAAE/ACC Planning, Design, and Construction Symposium, scheduled for February 2019.

DEADLINE: 1 November 2018
CONTACT: AIAA Honors and Awards Program at awards@aiaa.org

This award is jointly sponsored by AIAA, AAAE, and ACC.

aiaa.org/speasaward

AIAA | AAAE | ACC AIRPORT CONSULTANTS COUNCIL

AIAA Foundation Presents Graduate and Undergraduate Awards

The AIAA Foundation annually awards financial aid to graduate and undergraduate students in science or engineering programs related to aerospace. Over the past 20 years, the AIAA Foundation has provided more than 750 scholarships and graduate awards to students at more than 150 colleges and universities.

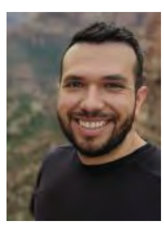
Graduate Awards for the 2018–2019 Academic Year

Each academic year the AIAA Foundation presents the Orville and Wilbur Wright Graduate Awards. These $5,000 awards, given in memory of the Wright brothers' contributions to the evolution of flight, honor full-time graduate students. The winners are:

Tobias Niederwieser, University of Colorado Boulder, Boulder, Colorado

Joshua Wagner, Rice University, Houston, Texas

In addition, **Emily Matula**, University of Colorado Boulder, Boulder, Colorado, received the Neil Armstrong Graduate Award. This $5,000 award honors the character and achievements of the late astronaut, military pilot and educator, Neil A. Armstrong, the first human to set foot on the moon.



Regis Thedin, Pennsylvania State University, University Park, Pennsylvania, received the John Leland Atwood Graduate Award. The $1,250 award, sponsored by endowments from Rockwell and what is now The Boeing Company and named in memory of John Leland "Lee" Atwood, former chief executive officer of Rockwell, North America, recognizes a student actively engaged in research in the areas covered by the technical committees (TC) of AIAA.

Three AIAA TCs also presented graduate awards:

Nicoletta Fala, Purdue University, West Lafayette, Indiana, received the General Aviation Systems TC's $1,000 William T. Piper Sr. General Aviation Systems Graduate Award.

Andrew Harris, University of Colorado Boulder, Boulder, Colorado, received the Guidance, Navigation, and Control (GNC) TC's $2,500 Guidance, Navigation and Control Graduate Award.

Bharvi Chhaya, Embry-Riddle Aeronautical University, Daytona Beach, Florida, received the Modeling and Simulation TC's $3,500 Luis de Florez Graduate Award.

Debolina Dasgupta, Georgia Institute of Technology, Atlanta, Georgia, received the Propellants and Combustion TC's $1,250 Martin Summerfield Propellants and Combustion Graduate Award.

James Braun, Purdue University, West Lafayette, Indiana, received the Air Breathing Propulsion TC's $1,000 Gordon C. Oates Air Breathing Propulsion Graduate Award.

AIAA JOURNALS ANNOUNCEMENT

In January 2019, *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)* will 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 (**arc.aiaa.org**).

Undergraduate Scholarships for the 2018–2019 Academic Year

The $10,000 Daedalus 88 Scholarship, endowed by current AIAA President John Langford, CEO & President, Aurora Flight Sciences, was presented to **Samuel Zorek**, Rice University, Houston, Texas.

The $10,000 David and Catherine Thompson Space Technology Scholarship, named for and endowed by former AIAA President David Thompson, Retired President and Chief Executive Officer, Orbital ATK Inc., and his wife Catherine, was presented to **Destiny Fawley**, University of Illinois at Urbana–Champaign, Urbana, Illinois.

The $5,000 Vicki and George Muellner Scholarship for Aerospace Engineering, named for and endowed by former AIAA President Lt. Gen. George Muellner, U.S. Air Force (retired) and president of advanced systems for Boeing Integrated Defense Systems (retired), and his wife Vicki, was presented to **Connor Bray**, Colorado School of Mines, Golden, Colorado.

The $5,000 Wernher von Braun Scholarship, named in honor of German rocketeer and founder of the U.S. space program, Wernher von Braun, was presented to **Camille Bergin**, University of Tennessee, Knoxville, Knoxville, Tennessee.

The $1,250 Leatrice Gregory Pendray Scholarship, awarded to the Foundation's top female scholarship applicant, was presented to **Diana Nguyen**, University of Virginia, Charlottesville, Virginia.

Six AIAA Foundation scholarships were presented by AIAA Technical Committees (TC) to students performing research in the TC's area:

The Liquid Propulsion TC presented a $2,500 scholarship to **Katherine Schneider**, Colorado School of Mines, Golden, Colorado.

The Space Transportation TC presented a $1,500 scholarship to **Gabriel Roper**, Embry-Riddle Aeronautical University, Prescott, Arizona.

The Digital Avionics TC presented four scholarships fo $2,000 each:

The Dr. James Rankin Digital Avionics Scholarship was presented to **Miguel Recabarren**, Embry-Riddle Aeronautical University, Prescott, Arizona.

The Dr. Amy R. Pritchett Digital Avionics Scholarship was presented to **Bezawit Alemu**, Saint Louis University, St. Louis, Missouri.

The Ellis F. Hitt Digital Avionics Scholarship was presented to **Rebecca Loiacono**, Saint Louis University, St. Louis, Missouri.

The Cary Spitzer Digital Avionics Scholarship was presented to **EliseAnne Koskelo**, Pomona College, Claremont, California.

The Rocky Mountain Section presented a $500 scholarship to **Anastasia Muszynski**, University of Colorado Boulder, Boulder, Colorado.

For more information on the AIAA Foundation Graduate Awards and Undergraduate Scholarship Program, please contact Felicia Livingston at felicial@aiaa.org or 703.264.7502. Join us as we continue to inspire teachers and students. For more information and to donate, please visit www.aiaafoundation.org.

AIAA Scholarships and Graduate Awards site is now accepting applications for the 2019–2020 academic year. The application deadline is 31 January 2019. For more information, visit us online: aiaa.org/scholarships.

Tenure-Track Assistant, Associate, or Full Professor, Aerospace Engineering

The Department of Aerospace Engineering at The Pennsylvania State University invites nominations and applications for multiple full-time, tenure-track faculty position starting in Fall 2019. The anticipated positions are intended for the rank of Assistant Professor, although exceptional applicants at more senior ranks may also be considered.

Outstanding candidates working in all subject areas relevant to aerospace engineering will be considered. One position has special emphasis in the area of vehicle design, particularly towards the design of novel aircraft, rotorcraft or spacecraft enabled by new technologies, new business models, and/or pervasive on-board sensing and computation. A second position is focused on space systems, including space and rocket propulsion, launch vehicles, entry-descent-landing (EDL), and the design, fabrication, and launch of small satellites. Further positions will be considered for exceptional candidates with expertise in other foundational areas of aerospace engineering, including air breathing propulsion, applied aerodynamics, aeroacoustics, hypersonics, and rotorcraft. Applicants should articulate their plans to set up a research program to attract outside research sponsorship, contribute to the aerospace industry, and result in published research findings. Further, applicants should describe how they would collaborate with the disciplinary strengths already in place within the department and across the University in support of cross-disciplinary collaborative research and in support of the department's undergraduate and graduate programs.

The Department of Aerospace Engineering at Penn State is strongly committed to our educational mission. Successful candidates should demonstrate interest in, and commitment to teaching undergraduate and graduate courses.

Applicants must have an earned doctorate in aerospace engineering or a related field by the time the positions begin. Responses received before December 17, 2018 are assured full consideration, but the search will remain open until the position is filled. Applicants should submit electronically a single pdf file that contains a cover letter, a CV, a statement of research and teaching interests, and the names and contact information for at least three references.

The Department of Aerospace Engineering enjoys an excellent international reputation in aeronautics and astronautics. The department currently has 20 full-time faculty members, more than 350 juniors and seniors, and more than 120 graduate students. Annual research expenditures exceed $6 million.

Penn State at University Park is a land-grant institution located within the beautiful Appalachian mountains of central Pennsylvania. State College and nearby communities within Centre County are home to roughly 100,000 people, including over 40,000 students, and offer a rich variety of cultural, recreational, educational, and athletic activities. State College is a wonderful community in which to raise a family and has an excellent public school system.

We especially encourage applications from individuals of diverse backgrounds, as the department seeks to grow in the diversity of its faculty. Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to minorities, females, veterans, disabled individuals, and other protected groups.

Employment with the University will require successful completion of background check(s) in accordance with University policies.

Apply online at **http://apptrkr.com/1274563**

CAMPUS SECURITY CRIME STATISTICS: For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to http://www.police.psu.edu/clery/, which will also provide you with detail on how to request a hard copy of the Annual Security Report.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

KU THE UNIVERSITY OF KANSAS

Aerospace Engineering
University of Kansas

The University of Kansas Aerospace Engineering Department invites on-line applications for a tenure track/tenured faculty position at the rank of Assistant or Associate Professor. The Aerospace Engineering Department is seeking to expand in the area of space systems, to include small satellites, space robotics, and related sub-specialties (GNC, structures, propulsion), to supplement our existing strength in suborbital remote sensing and precision orbit determination. The ideal candidate will have substantial experience in the design of small satellites.

Applications are sought from candidates with earned doctorates in Aerospace Engineering or closely related fields by the time of appointment. The successful candidate will be results-oriented, have a record of superior scholarship, have a promising vision for externally funded research, have experience in externally funded research commensurate with the rank of appointment, develop or maintain an externally funded research program, and teach high quality courses at both the undergraduate and graduate levels. Research productivity at KU is evaluated with respect to publications in respected academic journals as well as success in acquiring external research grants, and financially supporting and mentoring PhD and MS students. Our department values diversity in pedagogy and curriculum, in outreach to students, and research.

Review of complete applications will begin on January 1, 2019 and continue until the position is filled. Successful candidates must be eligible to work in the U.S. prior to the start date of the appointment, August 18, 2019. Salary is commensurate with experience.

For additional information or to apply, go to **https://employment.ku.edu/academic/12837BR** Applications should include a letter of application, curriculum vita, three references, a statement of research interests and future plans, and a statement of teaching interests and future plans including efforts to diversify the field of engineering. KU is an EO/AAE. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex (including pregnancy), age, national origin, disability, genetic information or protected Veteran status.

TOP 10 REASONS TO **PUBLISH BOOKS** WITH AIAA

1. **Competitive contract terms** and royalty payment models, including complimentary copies and author discounts.
2. **Personalized support** during manuscript development and professional full-service copyediting, composition and design, indexing and printing.
3. **Promotion** through AIAA publications, conferences, aligned technical society meetings and international publishing events.
4. **Visibility** through opportunities for author presentations, book signings and other appearances.
5. **Distribution worldwide** via major industry channels, including Amazon, Ingram, and Baker & Taylor. Overseas partners are located in Europe and Asia. AIAA's partnership with KUDOS elevates social media reach of your research.
6. **Translation agreements** with reputable foreign-language publishers expand the potential audience for your material.
7. **Inclusion** in online collections such as Knovel, Books24x7 and ebrary.
8. **Long-term support** of print and eBook versions.
9. **Community of authors** dedicated to the advancement of their field.
10. **Nonprofit** model keeps our titles accessibly priced while supporting AIAA programs.

For more information, contact
David Arthur, AIAA Books Acquisition and Development Editor, at davida@aiaa.org or 703.264.7572.

AIAA
Shaping the Future of Aerospace

UNIVERSITY OF MINNESOTA

AEROSPACE ENGINEERING AND MECHANICS
AEROSPACE STRUCTURES AND ADVANCED MATERIALS
UNIVERSITY OF MINNESOTA

The Department of Aerospace Engineering and Mechanics (AEM) seeks to fill one tenure-track faculty position in Aerospace Structures and Advanced Materials (ASAM). Researchers engaged in the development and application of modern experimental methods in ASAM are particularly encouraged to apply, but applications are invited in all areas of the mechanics of solids. Current research in the AEM department includes the development of nanoscale mechanics (molecular dynamics, lattice statics, quasicontinuum method, applied quantum mechanics) and continuum mechanics (theory of phase transformations, phase field models, micromagnetics, theory of stability and bifurcation) for the understanding and discovery of advanced materials and structures. The AEM department has close ties with on-campus multidisciplinary centers, and convenient access to outstanding shared experimental and computational facilities, such as the Minnesota Nano Center, the Characterization Facility, the Center for Magnetic Resonance Research, and the Minnesota Supercomputing Institute. Information about the department is available at **http://www.aem.umn.edu/**

Applicants must have an earned doctorate in a related field by the date of appointment. The successful candidate is expected to have the potential to conduct vigorous and significant research programs and the ability to collaborate with researchers with a wide range of viewpoints from around the world. This candidate will participate in all aspects of the Department's mission, including (I) teaching undergraduate and graduate courses to a diverse group of students in aerospace engineering and mechanics; (II) participating in service activities for the department, university, broader scientific community, and society; and (III) supervising undergraduate and graduate students and developing an independent, externally-funded, research program.

The intent is to hire at the assistant professor rank. However, exceptional applicants may be considered for higher rank and tenure depending upon experience and qualifications. It is anticipated that the appointment will begin fall 2019.

The AEM department is committed to the goal of achieving a diverse faculty as a way to maximize the impact of its teaching and research mission. The University of Minnesota provides equal access to and opportunity in its programs, facilities, and employment without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran status, sexual orientation, gender identity, or gender expression. To learn more about equity & diversity at UMN, visit **diversity.umn.edu**.

To be considered for this position, candidates must apply on-line at: **https://humanresources.umn.edu/jobs** and search for Job ID No. 326059; OR Visit: **https://z.umn.edu/3odn**

Please attach your: 1) cover letter, 2) detailed resume, 3) names and contact information of three references, and 4) a statement of teaching and research interests as one PDF.

Application Deadline: The initial screening of applications will begin on December 1, 2018; applications will be accepted until the position is filled.

The University of Minnesota is an equal opportunity educator and employer.

USC University of Southern California

The Department of Aerospace and Mechanical Engineering at USC is seeking applications for tenure-track or tenured faculty candidates. We seek outstanding candidates for a position at any rank. The Viterbi School of Engineering at USC is committed to increasing the diversity of its faculty and welcomes applications from women, underrepresented groups, veterans, and individuals with disabilities.

We invite applications from candidates knowledgeable in all fields of aerospace and mechanical engineering, with particular interest in advanced manufacturing, robotics and autonomous systems, and aerospace structures and aeroelasticity. Applications are also encouraged from more senior applicants whose accomplishments may be considered transformative. Outstanding senior applicants who have demonstrated academic excellence and leadership, and whose past activities document a commitment to issues involving the advancement of women in science and engineering may also be considered for the Lloyd Armstrong, Jr. Endowed Chair, which is supported by the Women in Science and Engineering (WiSE) Program endowment.

Applicants must have earned a Ph.D. or the equivalent in a relevant field by the beginning of the appointment and have a strong research and publication record. Applications must include a letter clearly indicating area(s) of specialization, a detailed curriculum vitae, a concise statement of current and future research directions, a teaching statement, a succinct statement on fostering an environment of diversity and inclusion, and contact information for at least four professional references. This material should be submitted electronically at **http://ame.usc.edu/facultypositions/** no later than December 15, 2018. Any applications received after Dec. 15 may not be considered. Review of applications and interviews may start in November, as soon as this ad is published.

USC is an equal opportunity, affirmative action employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, protected veteran status, disability, or any other characteristic protected by law or USC policy. USC will consider for employment all qualified applicants with criminal histories in a manner consistent with the requirements of the Los Angeles Fair Chance Initiative for Hiring ordinance.

1918

Oct. 2 In a test of Charles Kettering's aerial torpedo at South Field, Dayton, Ohio, the unmanned automatic machine, a forerunner of the guided missile, remains aloft for nine seconds, reaching 67 kph. Kenneth P. Werrell, **The Evolution of the Cruise Missile**, pp. 12-16.

Oct. 4 The Navy-Curtiss flying boat completes its first flight. Powered by three 360-horsepower Liberty engines, the NC-1 is the first in a series of flying boats designed for anti-U boat operations over the Atlantic. Three NC aircraft attempt to cross the Atlantic in May 1919; the NC-4 completes the trip in five legs, becoming the first aircraft to do so. Peter Bowers, **Curtiss Aircraft, 1907-1947**, pp. 115-120.

Oct. 27 Canadian ace William Barker shoots down five German aircraft while flying his Sopwith Snipe, bringing his total victory count to 50 enemy aircraft. He receives the 19th and last Victoria Cross awarded to British or Commonwealth airmen. David Baker, **Flight and Flying: A Chronology**, p. 119

1943

Oct. 3 The NACA Aircraft Engine Research Laboratory in Cleveland tests the first U.S. afterburner for turbojet engines. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 46.

Oct. 14 The U.S. 8th Air Force attacks Schweinfurt, Germany, in its second attempt to destroy ball bearing factories there. The Luftwaffe resists, destroying 60 Boeing B-17s and Consolidated B-24s of the approximately 320 aircraft dispatched. The German factories soon returned to production. David Baker, **Flight and Flying: A Chronology**, p. 287.

Oct. 26 The tandem, twin-engine single-seat Dornier Do-335 Phiel ("Arrow") completes its first flight. With a DB603 in the nose and one in the tail, the Do-335 becomes one of the fastest aircraft of the war, with a top speed of 760 kph. It is also one of the first aircraft equipped with an ejection seat. J.R. Smith and Antony Kay, **German Aircraft of the Second World War**, pp. 136-142.

Oct. 27 Navy Day is celebrated at Goodyear Aircraft's airdock at Akron, Ohio, with the christening of the M-1, the newest and biggest Navy blimp and the largest nonrigid airship ever built. The almost 91-meter-long M-1 has a capacity of 650,000 cubic feet and is powered by two Wasp engines. **National Aeronautics**, November 1943, p. 29.

1968

Oct. 1 On the 10th anniversary of NASA, the National Space Club presents a special award to President Johnson at the White House, citing his legislative and administrative leadership of the national space program. As a senator, Johnson had played a key role in formulating the Space Act in 1958. James E. Webb, the retiring NASA administrator, is also recognized for his "outstanding contributions to the national space effort." Webb retires on Oct. 7. **Astronautics and Aeronautics, 1968**, p. 248; NASA, **New York Times**, Oct. 1, 1968.

Oct. 1 MIT physicist and radio-astronomer Bernard Burke and teams of scientists measure signals from newly discovered quasars with the National Radio Astronomy Observatory's 43-meter "Big Dish" antenna in Green Bank, West Virginia. The experiment is a radio astronomy test of Einstein's general theory of relativity in an attempt to discover the gravity effect on the universe. **Washington Star**, Oct. 1, 1968, p. A9.

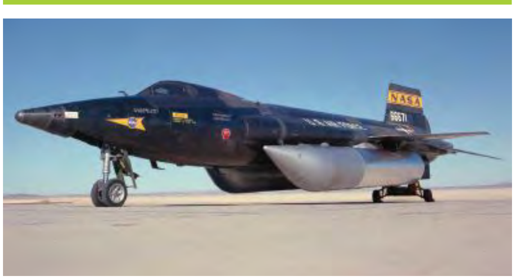
Oct. 2 The Soviet Union launches Cosmos 244 in a test of its Fractional Orbital Bombardment System, the second such launch made this year. The weapon is part of the Soviets' ICBM program in which a nuclear warhead is launched into a low Earth orbit and then de-orbited for an attack. The primary objective is to bypass the weapon detection systems in the United States. **New York Times**, Oct. 9, 1968, p. A10; **Aviation Week**, Oct. 14, 1968, p. 20.

Oct. 3 The Aurorae, or Esro 1 satellite, is launched by a four-stage U.S. Scout booster. Designed and constructed by the European Space Research Organisation, the 84-kilogram cylindrical satellite carries eight experiments to study the aurora borealis, or northern lights, and other related phenomena of the polar ionosphere. **Washington Star**, Oct. 4, 1968.

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

Oct. 5 The Soviet Union launches its Molniya 1-10 communications satellite into a highly elliptic orbit to relay telephone and telegraphic communications besides TV programs to the far northern and far eastern USSR and central Asia. NASA, **Astronautics and Aeronautics, 1968**, p. 244; **Flight International**, Oct. 17, 1968, p. 629.

Oct. 11-22 NASA's Apollo 7, the first crewed mission of the Apollo lunar landing program, launches on a Saturn 1B booster from Kennedy Space Center, Florida. Astronaut Walter Schirra Jr. is the commander, Donn Eisele the command service module pilot, and R. Walter Cunningham the lunar module pilot. After testing equipment and procedures for future missions, the crew completes the 163-orbit, 11-day mission when the spacecraft splashes down in the Atlantic Ocean. **Washington Post**, Oct. 12-23, 1968; **Flight International**, Oct. 31, 1968, pp. 722-723.



Oct. 18 U.S. Air Force test pilot Maj. William "Pete" Knight is named the recipient of the Harmon International Aviator's Trophy as the "world's outstanding pilot for exceptional individual piloting performance" for his record-breaking flight of the X-15 No. 2 on Oct. 3, 1967, in reaching 7,274 kph (Mach 6.72), a record that still stands. **New York Times**, Oct. 20, 1968, p. 84.

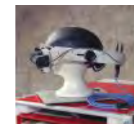
Oct. 21 NASA's Goddard Space Flight Center tracks the Explorer 36 satellite in daylight with a ruby laser, an important milestone in the development of laser satellite-tracking systems. NASA, **Astronautics and Aeronautics, 1968**, p. 259.

Oct. 24 X-15 No. 1, flown from Edwards Air Force Base, California, by NASA test pilot William Dana, reaches 255,000 feet (77,725 meters) and 5,925 kph (Mach 5.38) in the 199th and last flight of the X-15 program. Another flight had been scheduled for Dec. 20 but is canceled due to snow at Edwards. **Washington Post**, Oct. 25, 1968; Dennis R. Jenkins, **X-15**, p. 658.

Oct. 25-26 The Soviet Union orbits its uncrewed Soyuz 2 spacecraft, then on the next day launches its crewed Soyuz 3, carrying cosmonaut Georgy Beregovoy. During its first orbit, Soyuz 3 made an automated approach to within 200 meters of Soyuz 2, but Beregovoy fails to dock. **New York Times**, Oct. 27, 1968; **Flight International**, Oct. 31, 1968, p. 684, and Nov. 7, 1968, p. 756.

Oct. 31 William Pickering, director of the NASA-funded Jet Propulsion Laboratory, and Lee DuBridge, president of the California Institute of Technology, preside at the unveiling of a historical marker at JPL that commemorates the test-firing of a small alcohol-fueled rocket motor on Oct. 31, 1936, by students of Cal Tech's Guggenheim Aeronautical Laboratory, also known as the GALCIT Rocket Research Project. With the firing of that motor, Cal Tech became the first U.S. university to sponsor rocket research. The work of GALCIT led to the founding of JPL as well as the Aerojet Engineering Co. in March 1943 to manufacture JATO (Jet-Assisted-Take-Off) rockets for the war effort. **Los Angeles Times**, Nov. 1, 1968.

1993



Oct. 4 NASA announces a team of scientists will test "telepresence technology" in Antarctica with a TROV, short for Telepresence-Controlled Remotely Operated Vehicle, to explore 245 meters below the surface of McMurdo Sound. Researchers hope the technology eventually will be applied to exploring Mars. **NASA Release 93-178**.

Oct. 18 Space shuttle Columbia is launched with its crew of seven and a medical research laboratory that includes 48 mice. This is only the second shuttle mission to concentrate solely on medical research on the effects of prolonged spaceflight on the human body. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 433.

Oct. 29 NASA begins flight testing fiber optics instead of conventional copper wiring on the digital fly-by-light system that NASA hopes will replace fly-by-wire. Installed on a McDonnell Douglas F/A-18 fighter, the fiber optics are lighter, take up less space, and can carry more electronic data. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 435.

JENNIFER DAWSON, 37

Technical director for the Robotic Servicing of Geosynchronous Satellites program at SSL in California

Jennifer Dawson knew little about engineering before a class and movie sparked her interest in studying and then teaching the subject. After two years as an assistant engineering professor at York College of Pennsylvania, Dawson in 2010 moved to Palo Alto, California, to join SSL. She leads a team of 40 engineers working on the Robotic Servicing of Geosynchronous Satellites program, a public-private partnership that in 2021 plans to launch a satellite equipped with two robotic arms plus sensors and tools to repair, upgrade, extend the life of and move satellites that were never designed for on-orbit servicing.

How did you become an aerospace engineer?

With no engineers in my family, my interest in engineering was sparked by my eighth-grade science teacher who assigned engaging hands-on design projects. I was also struck by a scene in the movie "Apollo 13" where a group of engineers tries to fix an air filter. They dump parts on a table and have to use those parts to make a square filter fit in a round hole. I remember thinking, "That's a job? That sounds so cool!" With this rather naive impression of engineering, I went to Bucknell University [in Pennsylvania]. I majored in mechanical engineering. During the summers, I worked as a Stanford University intern for the Gravity Probe B program, a satellite-based physics experiment. I completed a master's degree in mechanical engineering at Stanford, and my doctoral research focused on another satellite development program, Satellite Test of the Equivalence Principle. I spent two years as a tenure-track professor [at York College in Pennsylvania] teaching, amongst other things, a senior elective in aerospace engineering, before I decided to work in industry. I left academia to join SSL. As SSL's technical director for Robotic Servicing of Geosynchronous Satellites, I'm working in a public-private partnership with DARPA to develop a highly capable robotic servicing vehicle based on the SSL 1300 platform equipped with a robotic payload developed by the Naval Research Lab.

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

Within the next five to 10 years, we are going to see revolutionary changes in space infrastructure. By 2050, space infrastructure will be deployed, maintained and upgraded like much of our terrestrial infrastructure. Currently, we launch spacecraft and, outside of the space station, there is almost no capability to change satellite equipment over the life of a satellite or to recover from setbacks. Aerospace is the only industry where companies and governments invest hundreds of millions of dollars in equipment with no ability to repair or update the technology. The on-orbit servicing and assembly capabilities developed through programs like DARPA's Robotic Servicing of Geostationary Satellites, NASA's Restore-L servicing mission, and SSL's Dragonfly on-orbit satellite assembly program are going to change the paradigm of static spacecraft, facilitate new spacecraft architectures, enhance fleet resiliency and provide unprecedented flexibility for operators throughout the spacecraft life, which will ultimately provide better services and value for our customers and build a better world. The robotic capabilities we are demonstrating today are laying the foundation for a future ecosystem of habitats, way stations and gateways to the moon, Mars and beyond. Before people can safely inhabit deep space destinations, robotics will be used extensively to build the infrastructure. I'm convinced this is coming. ★

By DEBRA WERNER | werner.debra@gmail.com