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Can this plane reshape air travel?

Zunum Aero leads in betting on the power of hybrid-electric technology. PAGE 24

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JULY/AUGUST 2017, VOL. 55, NO. 7

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

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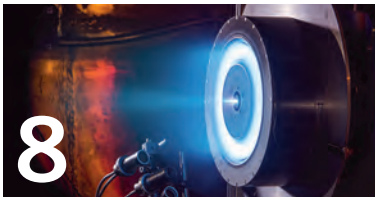

TRENDING
Electric propulsion plan for Mars

TRENDING
Uber, NASA: Stop saying "flying cars"

Blue Origin

▲ The New Shepard booster lands in Van Horn, Texas, on its fourth mission.

Buoyed by the Collier Trophy

I didn't know it, but my soul needed to attend the Collier Trophy dinner in June. We hear so much about fake news and conspiracy theories that it can be easy to forget that the U.S. remains a country of technology entrepreneurs and engineers who live firmly grounded in reality.

If this weren't true, Jeff Bezos' Blue Origin team could never have flown, landed and reused an unmanned version of its New Shepard rocket. Somehow, the company's 1,000 or so employees managed to identify the physical truths of rocketry and find a solution within them. They did this even though they must come with the same sampling of worldviews as any group of smart people.

Maybe not surprisingly, when Bezos took to the podium at a northern Virginia hotel to receive the 2016 Collier award, there was no tearing down of the past to prop up the future. He did not blame government bureaucrats and standing armies of managers and technicians for miring us in exorbitant space launch costs. He offered no claims about saving humanity from sure doom by going to space.

Bezos said simply: "I can assure you it's incredibly humbling to read the names on that trophy. All the work that we have done, and will do and continue to do, is because we get to stand on top of all these people who came before us."

This was not the new-space buccaneer and Amazon.com pitchman that some might have expected. That said, Blue Origin will need to become more open before carrying passengers or receiving more taxpayer dollars, and hopefully that will come.

In a philosophical moment, Bezos raised the question of why humanity should go to space: "One of the common answers — and it's one that I don't share — is that we need a plan B" in the event "we get hit by a comet or we destroy ourselves." Bezos declared his dissent: "I think plan B is to make sure plan A works: We're going to preserve Earth, *and* we're going to space."

It was the night's biggest applause line.

After some thanks to his employees and his parents, that was how the Blue Origin New Shepard joined 101 other recipients whose names are inscribed on the Collier Trophy at the National Air and Space Museum.

The night was a good reminder that our aerospace endeavors once had a unifying effect. The Project Mercury astronauts received the 1962 Collier award at the White House with President John F. Kennedy. Aircraft pioneer Donald W. Douglas received the 1935 Collier from President Franklin D. Roosevelt. President Herbert Hoover presented NASA's predecessor, the National Advisory Committee for Aeronautics, with the 1929 award for developing an engine cowling.

Whether he meant to or not, Bezos gave hope that we can, if we choose, restore the underlying unity that once defined us.

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

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"What makes being here in person so valuable? The exchange of information, the interaction with people in real time…all sorts of things go on in the hallways, in side meetings; and you really need to be here in person to experience that."

—**Jeffrey J. Puschell,** *Raytheon Space & Airborne Systems*

"You have the chance to affect things. Some ideas that I've seen have started in hallway conversations at AIAA forums… have gone far beyond anything I would ever believe."

—**Rich Wahls**, *Strategic Technical Advisor, Advanced Air Vehicles Program, NASA Aeronautics Research Mission Directorate*

17-1860

Advancing Aerospace

For more than 20 years, the AIAA Foundation has touched the lives of hundreds of thousands of students and teachers at the K–12 and university levels. Additionally, the generosity of thousands of individual and corporate members has made an impact on the aerospace community through the Foundation's programming for both students and educators. Donations to the AIAA Foundation are the embodiment of our community's forward-looking spirit, our desire to continuously grow our community, and our promise to do all we can to help the next generation of aerospace professionals. Your contributions not only provide the critical support necessary for the Foundation's activities, but also forge a tangible link between current and future members of the aerospace community.

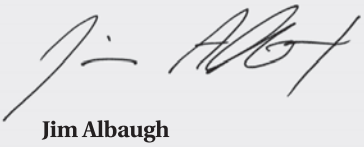
In May 2015, the AIAA Board of Directors approved a matching gift program of one million dollars; a level of giving that we achieved in April 2017. To build on the success of the first program, the matching program was extended with an additional one million dollar match in May 2017. This is yet another example of the Institute's commitment to increase the Foundation's resources and enable it to evolve and support new and existing programming.

Let me take a moment to share some recent examples of the impact that the AIAA Foundation has had in shaping the next generation of aerospace professionals.

- With the leadership of Lockheed Martin Corporation, more than 350 middle-school students attended Generation STEM events at AIAA forums to experience hands-on demonstrations of science and engineering.
- With the leadership of the Raytheon Company and Textron Aviation, 73 teams—including 16 from outside the United States—comprising 754 university students and advisors participated in the 21st annual Design/Build/Fly Competition.
- The AIAA Rocky Mountain Section made a contribution to establish an undergraduate scholarship for students from within the section's geographic boundaries.
- The Numerical Propulsion System Simulation Consortium made a financial contribution to support the Undergraduate Team Engine Design Competition.
- AIAA members participated in the 2017 Intel International Science and Engineering Fair and presented the inaugural "AIAA Look Up!" Award that celebrates exceptional high-school level research to encourage further study in aerospace.
- More than 750 college and university students attended the Regional Student Conferences with nearly half of them presenting technical papers.
- 58 university teams competed in six aerospace design competitions, and more than 425 students participated in paper design competitions focused on solving various engineering problems.
- 10 undergraduate scholarships and seven graduate awards were presented, totaling more than $50,000 to students pursuing aerospace studies.
- 90 classroom grant proposals were submitted and 40 of those proposals were funded—impacting more than 7,000 K–12 students.
- 15 aerospace micro-lessons were developed and distributed to 4,215 AIAA Educator Associates, who are K–12 teachers, to enhance lesson plans with a focus on aerospace principles.
- Our newest program, the FIRST® LEGO® League Grant Program, with leadership from The Boeing Company, encourages AIAA members to coach middle-school students in STEM subjects.

As the AIAA Foundation Board of Trustees continues to enhance our existing educational programming and spearheads the creation of new programming, your support of the Foundation is more important than ever. Your generosity provides the lifeblood of the Foundation and lays a foundation upon which we will build the future of our community. I hope that I can count on you, as a member, to continue this legacy of giving back. Your support ensures that our community will be advancing aerospace for generations to come.

For more information and to make a donation, please visit www.aiaafoundation.org. ★



Jim Albaugh
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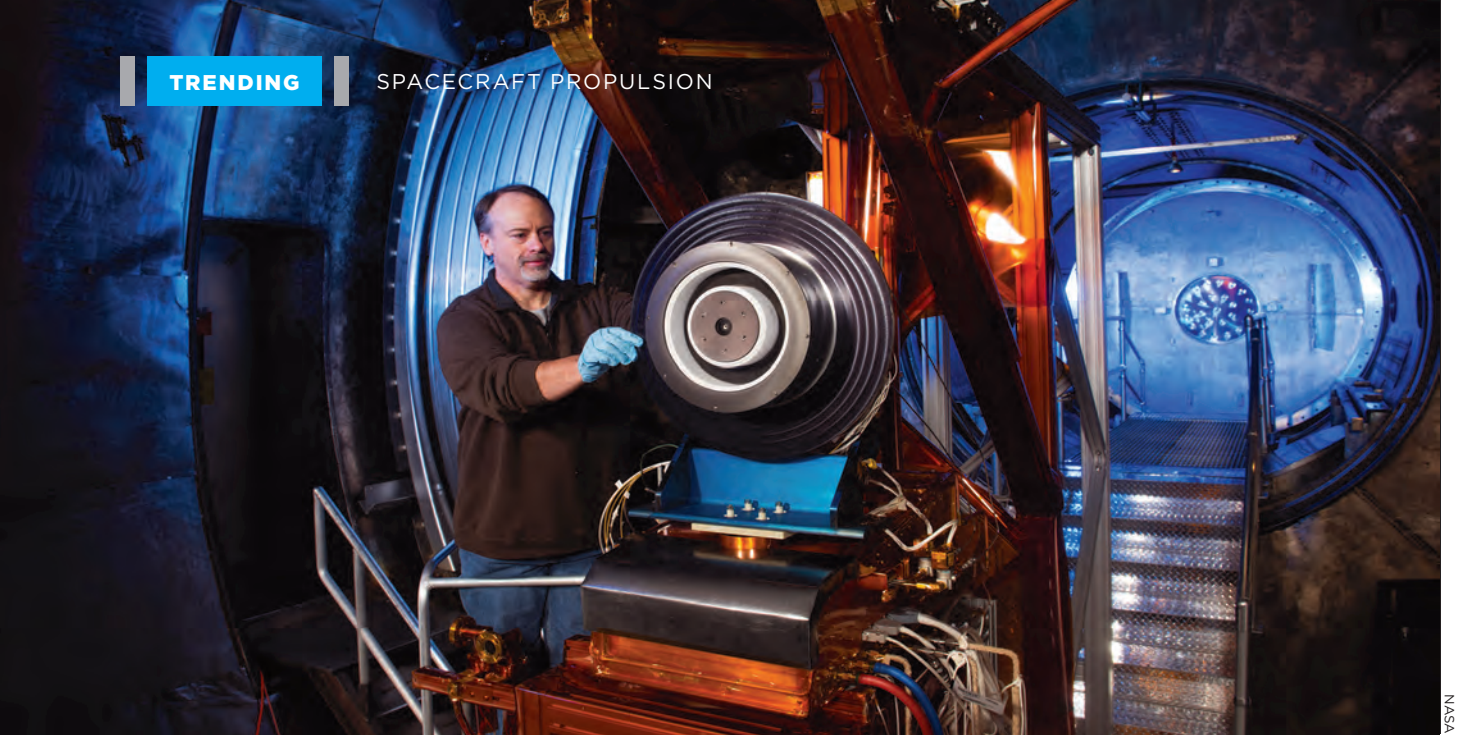

NASA

Coming soon: Electric propulsion plan for Mars

BY KEITH BUTTON | buttonkeith@gmail.com

Aerojet Rocketdyne is scheduled to deliver plans to NASA in August for a solar electric propulsion thruster that could propel the planned moon-orbiting Deep Space Gateway as a precursor to a human mission to Mars.

NASA hired Aerojet Rocketdyne to build the Advanced Electric Propulsion System thruster by 2019 for future NASA space missions, and the technology might have applications for commercial satellites as well. With 13 kilowatts of power available for propulsion, the new thruster would more than double both the power available and the corresponding thrust generated by the current state-of-the-art solar electric propulsion thrusters, which operate at 3 to 5 kilowatts and are becoming routine for commercial communications satellites.

NASA also wants the thruster to deliver a higher specific impulse — for better fuel efficiency — than current solar electric propulsion thrusters and a longer lifespan: 1,700 on/off cycles over a mission lasting at least eight years. Aerojet Rocketdyne will present plans for its preliminary design review in August, then lock in the plans for a critical design review in 2018 before final testing and qualification of the thruster in 2019.

NASA envisions combining three to five of the 13-kilowatt thrusters to propel a spacecraft for humans circling the moon as practice before a human mission to Mars, says David Manzella, chief engineer for NASA's Solar Electric Propulsion Technology Demonstration Mission Project.

NASA had planned to incorporate the technology in its Asteroid Redirect Mission, but that mission was canceled in President Donald Trump's proposed 2018 budget. NASA's first job for the new thrusters would be propelling the Deep Space Gateway spacecraft sometime around 2022. Orion crew spacecraft would dock with the gateway, which would provide a habitat for a crew of four people for up to 42 days.

"Raising the thrust level like we're doing allows us to get to places more quickly," Manzella says. "And that's basically what was necessary to allow solar electric propulsion to be useful for human exploration. You can't put a crew on a thing that's going to take eight years to get from Earth to Mars. You have to make the power high enough so that you can do these transfers more quickly."

The Mars mission is going to need solar electric propulsion because the mass of chemical propellant needed for a deep space mission would overwhelm, says Joe Cassady, Aerojet Rocketdyne's executive director of space. "The reason that it's such a driver for us in the Mars mission is: It saves a tremendous amount of money, just not having to launch that propellant off the planet, to do those transfers to Mars."

Aerojet Rocketdyne is basing its design on the Hall Effect Rocket with Magnetic Shielding, or HERMeS — a 12.5 kilowatt prototype solar electric thruster developed by NASA, Cassady says. ★

▲ NASA Glenn Research engineer Peter Peterson prepares the Hall Effect Rocket with Magnetic Shielding, or HERMeS, for ground testing in a vacuum chamber that simulates the environment in space.

Uber, NASA: Stop saying "flying cars"

BY TOM RISEN | tomr@aiaa.org

Companies are grappling with what to call the highly automated vertical takeoff and landing craft they are developing with plans of soaring commuters and other passengers to their destinations in minutes instead of hours spent in gridlock.

Many who attended the AIAA Aviation Forum in Denver voiced the same message: Please stop calling them "flying cars." "We hate the term flying car," says Mark Moore, the engineering director of aviation for Uber. "It's so misrepresentative of what we are doing."

The notion of flying cars has been joked about and even attempted by some innovators for decades, but dozens of companies hope to make vertical takeoff and landing travel an affordable part of daily life, especially for city commuters.

Many companies in the space prefer the term electric vertical takeoff and landing, or eVTOL, but that term is "kind of goofy," and is also not completely descriptive of every company's design, says Jon Rimanelli, CEO of Detroit-based Airspace Experience Technologies, who wants to rebrand the breed as something other than flying cars.

Rimanelli's company aims to begin production on MOBi in 2020, an electric-powered VTOL craft that he compares to an "air taxi," adding that if it catches on, MOBi could become a verb, as in "you could MOBi people and cargo between cities and airports."

A flying car would only be accurate to describe a craft that can both fly and drive on the road, says Geoffrey Bower, chief engineer of A³, the Silicon Valley-based office of Airbus Group created to bring a disruptive tech culture to the company. Bower doesn't know how to rebrand the concept, but his firm has flown four subscale models of its Vahana eVTOL craft and plans to make the first flight of the full-scale demonstrator craft at the end of 2017 "somewhere on the West Coast," he says.

"We have built major components and it is undergoing structural testing as we speak," he says of the Vahana.

The market includes at least one prototype that drives and flies. But few aviation companies are eyeing a vehicle that can do what the Transition, developed by the Massachusetts startup Terrafugia, can do.

"These are not going to come to your driveway, they are not going to be on every street corner. They are going to be operated from some dedicated infrastructure," Bower says of the confusion between flying cars and eVTOLs.

Uber is not building its own aircraft but it wants to see others do so, so that it can begin aerial ride sharing. Uber's Moore knows the technology hurdles well. Prior to joining Uber in February, he worked at NASA's Langley Research Center in Virginia as the principal investigator for the X-57 plane that will test distributed electric propulsion technology. Moore is using that knowledge of the electric propulsion community to build the Uber Elevate ecosystem, which is partnering with companies that will develop eVTOL aircraft.

The companies face obstacles including proving to regulators and the public that the aircraft are not too noisy and that they can fly many aircraft safely in a city. Class B airspace, which is the FAA designation for most urban airports in the U.S., requires that aircraft stay at least 5 kilometers apart. That separation would make it difficult to fly many of the new breed of craft in those areas.

Moore says he would like NASA to partner with industry on noise reduction, automation and airspace modeling that could make it easier to fly VTOL aircraft, even in Class B airspace.

Ken Goodrich, a senior research engineer at Langley, acknowledges that NASA is discussing how it may partner with industry on research that could help certify an urban eVTOL ecosystem, or to one day make autonomous air taxis, for lack of a better term, possible. The term flying car is "misleading in part because it implies personal ownership," and VTOLs will be too expensive for most people to own instead of ride-sharing, Goodrich says. ★

▼ A³, the Silicon Valley arm of Airbus Group, is developing a vertical takeoff and landing craft it calls Vahana. This is a subscale model.

DJI

AIAA

Air traffic control for drones is coming

BY DUANE HYLAND | duaneh@aiaa.org

With the increased use of unmanned aircraft in the years ahead, an air traffic management system for drones will be a necessity, said John Cavolowsky, director of the Airspace Operations and Systems Program in NASA's Aeronautics Research Directorate.

Cavolowsky shared some of NASA's work on unmanned aerial systems traffic management, or UTM, during "Solutions to UAS Air Traffic Management Challenges" at the Demand for Unmanned Symposium.

UTM development is "a lot like herding cats, except they are smart cats with their own business objectives and needs," Cavolowsky said. A lot of what a UTM system would do, he said, is "enable their access to the airspace in ways that haven't been done before and trying to do that safely so that they can execute their missions successfully."

According to Cavolowsky, a UTM system would be for drones that weigh 55 pounds or less and operate under 400 feet.

"It would be independent of the traditional air traffic management system that exists today," he said, explaining that there "would be multiple UTM systems operating, not a single, large one," which would allow users to tailor the systems to their needs.

Live from NASA's Ames Research Center, NASA's UTM development team showed real-time data from ongoing UTM tests in Virginia, North Dakota, Texas, Alaska and Nevada. They walked attendees through a variety of tests and the findings they have deduced so far from the data. The team said to achieve the tests, it worked with over 250 partners throughout the industry that plan to use drones in their businesses.

Cavolowsky reassured the audience that UTM will not supplant the need for humans in the loop.

"The thought that we will move people from the process anytime soon is not going to happen soon." ★

▲ An air traffic management system for drones is inevitable, according to a speaker at the Demand for Unmanned Symposium.

▶ Matt Knapp, a founder of Zunum Aero, says electric-powered flight could lower costs for regional airports.

Developing drone traffic management is "a lot like herding cats, except they are smart cats with their own business objectives and needs."

— John Cavolowsky, director of the Airspace Operations and Systems Program in NASA's Aeronautics Research Directorate

Changing culture with electric aviation

BY TOM RISEN | tomr@aiaa.org

Electric-powered flight could improve safety, fuel efficiency and convenience, but innovators first have to clear regulatory hurdles and make the technology be accepted as part of daily life, a panel of aviation executives and officials said during the "Aircraft Electric Propulsion: Transforming Aviation" session.

Automakers are leading the way in electric and hybrid electric transportation, but aviation firms have yet to win over consumers and regulators who have "grandfathered in" gasoline as the accepted aircraft fuel, said Joseph Oldham, director of the San Joaquin Valley Clean Transportation Center for CALSTART. The nonprofit Oldham works for is dedicated to the growth of clean transportation technologies.

Switching to electric-powered flight would reduce carbon emissions and save on the fluctuating cost of gasoline, but Oldham said it would also make aircraft safer by removing the risk that aviation gas would explode in a malfunction or crash.

Electric flight could also help lower costs for regional airports and consumers who travel through them, said Matt Knapp, a founder of Zunum Aero. The startup, based in Kirkland, Washington, aims to create a hybrid jet with 10 to 50 seats designed to fly on low-cost trips shorter than 1,000 miles. Zunum's planes would be powered by both jet fuel and electricity and would be designed to be upgraded with "evolving energy storage capacities" as battery technology improves.

"Fuel is a highly volatile price point, and there is a cost to volatility," Knapp said of the benefit of relying less on gasoline.

Fuel efficiency and safety are particularly important to advance vertical takeoff aircraft because hovering requires a stable and low-cost power source, Knapp said. ★

AIAA

AirspaceX

Internet of things could enable drones

BY LAWRENCE GARRETT | lawrenceg@aiaa.org

The "internet of things" will revolutionize the aviation industry, particularly through its application to the growing unmanned flight sector, a panel of experts said during the "Internet of Things as Applied to Aircraft Systems" session.

The internet of things is the networking of devices, vehicles, buildings, and other items with electronics, software, sensors, actuators and network connectivity. The connected objects are able to collect and exchange data, which offers aerospace manufacturers a way to have real-time data communications with their deployed products.

David Loda, executive director of Connecticut-based NCPS Research LLC, said that humans traditionally have had to manually harvest and collect data and then bring it back for design, but the internet of things is providing an autonomous capability.

Leveraging the lessons already learned through the application of the internet of things, Loda said that the industry is now at a "major shift point when it comes to industrial drones."

"Drones are going to change the world from the commercial side," Loda said, explaining that drones will create a "data explosion" through what they are looking at. "It's all about visualization and also about algebraic computation of how we can use new ways to visualize, and understand and mine this data."

David Kasik, senior technical fellow in visualization and interactive techniques at Boeing, cautioned against abandoning data.

"Ultimately, what we want to do with all that data is not do something that I've termed to be write-only data stores, where you just store it and then nothing ever happens to it again," he said. "You want to extract some value from it."

Kasik said the value drones provide "is that now we add visual cues that supplement those digital ones that have been around for literally decades." ★

▲ David Kasik, a senior technical fellow with Boeing, encouraged aerospace community members to be more self-aware about the data created every day.

▶ Airspace Experience Technologies, or AirspaceX, wants to begin production on MOBi, an electric-powered VTOL craft, in 2020.

AVIATION FORUM

2,850 Attendees

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650 Students

Avoiding city traffic with aerospace

BY HANNAH THORESON | hannaht@aiaa.org

A new wave of aerospace entrepreneurs and technology startups is stepping in to try to solve the problem of traffic, and according to a panel of experts, it could be done with vertical takeoff and landing, or VTOL, aircraft.

As any commuter knows, roadway congestion eats up a huge amount of time and energy, and "traffic is taking over our lives," said Jon Rimanelli, founder and CEO of Airspace Experience Technologies.

He cited figures showing that every driver loses about $1,400 in fuel costs and productivity each year due to traffic.

"Key to this future is leveraging the automotive industrial base," he said, adding that his company works with Uber, which has disrupted the taxi and car markets with its ridesharing app.

"Our mission is to support Uber, and their mission is to move people," Rimanelli said.

Mark Moore, engineering director of aviation at Uber, said his company's working on making electric VTOL a reality and plans to test the system as soon as 2020.

But, Moore insisted, "We see many participants in this system."

One such example is Pipistrel, whose director of research and development, Tine Tomažič, explained where electric flight is in terms of development today.

"We understand what happens when you are really challenged with power demands," Tomažič said.

However, he said, some of the problems that still need to be solved before eVTOL is a reality on a mass scale aren't directly related to the vehicles themselves.

"When these vehicles are connected all the time to the service network, one has to think, 'how do you isolate the vehicles from cyberattacks?'" Tomažič said. ★

Q&A

Vincent Capezzuto, chief technology officer of Aireon, at the company's headquarters in McLean, Va.

Alan Lessig

Tracking airliners from space

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The FAA-mandated Automatic Dependent Surveillance-Broadcast network will track aircraft more accurately than today's radars, but this approach of equipping planes to broadcast their GPS coordinates comes with an Achilles' heel. An aircraft must be flying in range of an FAA ground station and tower for these ADS-B messages to enter the air navigation network. One of the technologists working to solve that problem is Vincent Capezzuto, the chief technology officer of Aireon, the Virginia-based joint venture of Iridium and Nav Canada. Aireon plans to plug those gaps by installing ADS-B receivers on Iridium's next generation satellites and relaying the ADS-B messages from one satellite to the next and down to a customer's tracking network. Capezzuto has unique perspectives on the history and status of aircraft surveillance, having worked at the FAA for nearly two decades. I spoke with Capezzuto on the phone after Aireon unveiled flight tests with Nav Canada that vetted its new surveillance data.

— *Tom Risen*

VINCENT CAPEZZUTO

POSITION: Chief technology officer for Aireon

NOTABLE: Joined Aireon in 2014 after an 18-year career at the FAA. Directed air traffic management during part of his FAA tenure; program director for the FAA's Automatic Dependent Surveillance-Broadcast program. Aireon plans to augment the FAA's approach by receiving ADS-B messages in space and routing them to customers via Iridium satellites.

AGE: 56

RESIDENCE: Manassas, Virginia

EDUCATION: Master of Science in Engineering from George Washington University; Bachelor of Electromechanical Engineering from New York Institute of Technology

IN HIS WORDS

Starting Aireon

This space-based surveillance model arose from a series of opportunities that came together. Iridium happened to be changing their infrastructure and had space to put an Automatic Dependent Surveillance-Broadcast receiver on each Iridium NEXT satellite. Why is that important? I don't think anyone would have deployed a satellite infrastructure with just an ADS-B function. The business case would have been very difficult.

Surveillance coverage gaps

Space-based ADS-B offers a bird's-eye view looking down. We will see through the nooks and crannies; we will fill the gaps. Those are critical nooks and crannies in a lot of places. If you can't deploy an ADS-B ground station and tower, like in the Rocky Mountains or up in Alaska, this is a solution set that provides you a service that can create surveillance where it never was before.

Automatic Dependent Surveillance-Broadcast versus ADS-Contract

The flight management system integrated with FANS-1/A [Future Air Navigation System-1/A] coupled to the aircraft communication and reporting system ACARS, provides the mechanism for transmission of messages to the ground. These transmissions can be accomplished with VHF, HF or satellite communication links and the message types are either air traffic control or airline operational. The ADS-C message is an automated pilot report of position and would be considered an air traffic control type message that would share the communication pipe with airline operational data. It's automation of pilot reporting over a multipurpose communication link.

Why is ADS-C important? Just imagine a train going by my office right now as we're talking; I'm yelling into the phone and you're catching every other word. That's what [voice communications] sometimes is like between a controller and a pilot. The communication isn't always perfect, especially over the oceans. You're using the high frequency links from World War II or before.

ADS-C works, but it's noisy and it has delay in it. For surveillance, it's as long as 180 seconds. That's a fair amount of time for planes that are moving fast. We have an update interval of eight seconds and a latency of two seconds.

Preventing more lost flights like MH370

The International Civil Aviation Organization put out a mandate: All assets need to be tracked by the airlines with a 15-minute update interval, and in distress mode it should be able to increase the update interval to one minute. That's the easy part for us because we surveil ADS-B, and ADS-B is already transmitting the information once a second. We can provide a one-minute update interval all the time, and you don't even have to consider the 15-minute one. That's great, but the second piece of the Malaysia Airlines case has to do with the ability to not turn off the transponder. Because we never found the wreckage, you really can't say what exactly happened.

So the question is, could we have prevented it. I would tell you that with this capability and technology, we will know when someone shuts off a transponder. That would be one of those distress triggers. If someone shuts it off, all you will know is that's the last hit I have. I'm not going to say 100 percent we would have prevented it.

Space-based ADS-B offers a bird's-eye view looking down. We will see through the nooks and crannies.

Benefits beyond safety

Safety programs are very difficult to quantify. You have to say, "How many lives did we save?" or "What's the target level of safety in the airspace?" It really is esoteric and difficult to do a cost-benefit analysis, which is typically how people make a business decision. You look at your return on an investment and you say, "I'm going to invest X. How many years does it take for me to break even?" So from any air navigation provider perspective, we've talked about efficiency in the airspace for the airlines. If they improve their services, they should be able to reduce the separation. Safety becomes qualitative and built into the decision as an additional unquantified benefit.

Cybersecurity, GPS

Aireon's data is encrypted, it's not like you can easily break into it. It's not grounded in one location so we're not vulnerable to someone snipping off one teleport network. We have multiple teleport networks to ground that data in, so that's geographic diversity. The data that comes off one aircraft does not necessarily follow the same path every second. Our system is the internet in the sky, and essentially the information coming off an aircraft is composed into packets, and the packets are distributed across the multiple-satellite network, hopping from satellite to satellite before it gets grounded. So an unauthorized person can't recompose the information. We can, because we know what the packets look like and we understand the packet design. Then we put it into one place, and then we have to decrypt it, and then we have to compile it, put it all back together, to create the target position. Then on the space side, first of all, 1090 MHz is being transmitted by aircraft in the clear as an open, nonencrypted message, and we have the ability to receive it. We're 485 miles up in space, so it's not like someone is going to be perturbing the signal. What they could perturb is the GPS signal, not the ADS-B signal. And that is, again, a known phenomenon that, working at the FAA and understanding how the air navigation service providers work, may have other solutions.

So FAA officials have the appropriate protocols and emergency response plans to deal with those scenarios. In fact, I would argue that our system will be able to detect a worldwide GPS jamming session very quickly, because essentially we're monitoring aircraft, aircraft that are transmitting GPS information. ★

This artist's rendering shows a helicopter with robotic landing gear on a ship's deck at about a 10-degree roll angle in Sea State 6 conditions.

Georgia Tech

Robotic landing legs

Helicopter pilots operating in austere terrain or at sea live in fear of rolling over during takeoffs and landings. Georgia Tech researchers are applying software logic and mechanical engineering to find a solution.

BY KEITH BUTTON | buttonkeith@gmail.com

On the fields of a former dairy farm in Greenville, Georgia, a pilot manipulated a helicopter remote controller as a group of students and engineers stood behind him. He steered the unmanned rotorcraft to a sloped patch of ground where no conventionally equipped helicopter would dare land. Four aluminum legs unfolded, and as each leg touched the uneven ground, a microprocessor commanded the joints in each leg to bend exactly as needed to keep the helicopter's fuselage and main rotor disk level. The legs locked themselves into place and the helicopter paused for 20 seconds, then took off to repeat the sequence.

Professors, research engineers and grad students at the Georgia Institute of Technology built this robotic landing gear with funding from DARPA starting in 2012. They attached the legs to a Rotor Buzz 2 unmanned crop-dusting helicopter and conducted a series of test flights from 2013 to 2015. Now the Georgia Tech team is preparing to show how the technology could handle the rolling deck of a ship in rough seas.

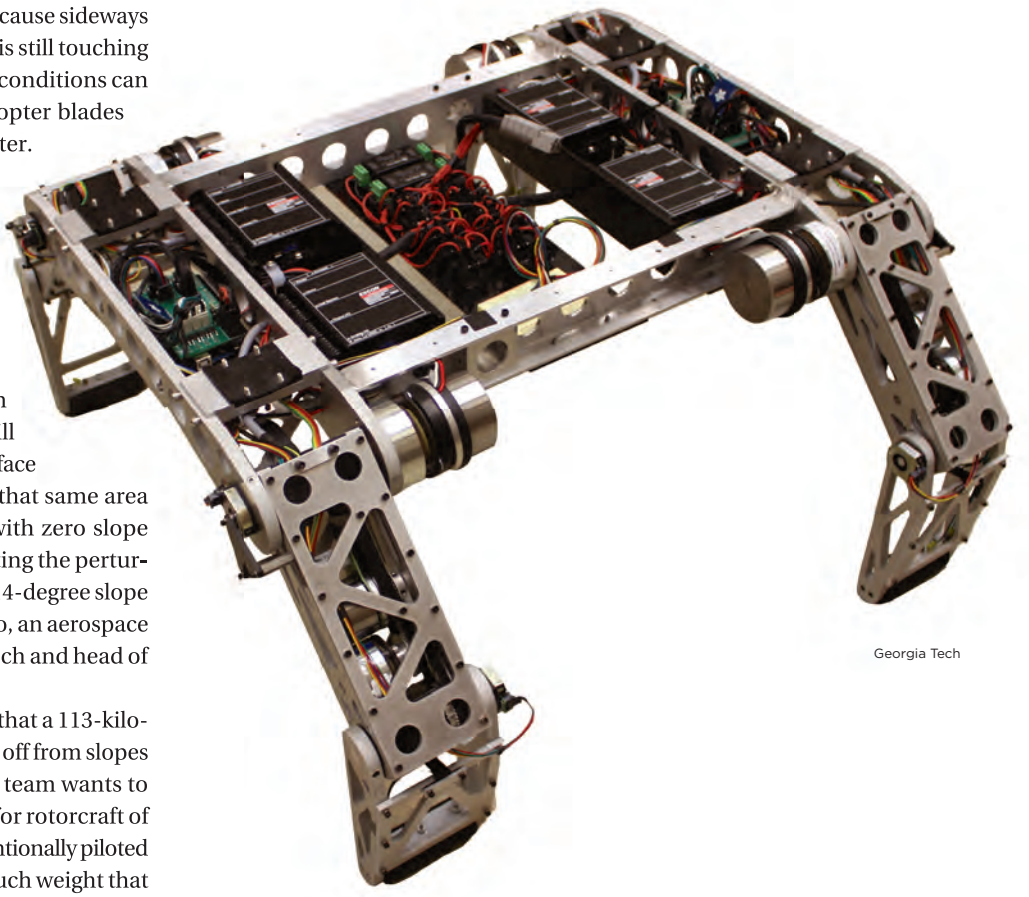
Success at sea and over land could solve a vexing shortcoming of helicopters: They can't land on or

take off from a slope greater than 10 degrees. With steeper slopes, the main rotor disk tilts too much during takeoff or landing, which can cause sideways thrust while part of the landing gear is still touching the ground or deck of a ship. Those conditions can cause a rollover in which the helicopter blades spin into the ground, or deck or water.

Cracking the 10-degree barrier by keeping the fuselage level could open up new possibilities for flights from ships or into rugged terrain for medevac, humanitarian and military missions.

Even away from rough seas, it can be hard for a pilot to assess on the fly what angle a landing site will pose. "If you're on an unprepared surface in an open field, you could land in that same area 10 times, and one time you land with zero slope and another time you may land getting the perturbations in the slope and you have a 14-degree slope that you fell into," says Mark Costello, an aerospace engineering professor at Georgia Tech and head of the robotic landing gear program.

So far, Georgia Tech has proved that a 113-kilogram Rotor Buzz 2 can land and take off from slopes of up to 20 degrees. Ultimately, the team wants to show that the legs will do the same for rotorcraft of up to 3,200 kilograms, whether conventionally piloted or unmanned, without adding so much weight that helicopter makers will reject the idea.



Georgia Tech

▲ A close-up view of the robotic landing gear that a Georgia Tech team built and attached to a Rotor Buzz 2 unmanned crop-dusting helicopter.

A legged solution

Georgia Tech's Costello has three operational concepts in mind for the robot legs: a kit that could switch out a helicopter's traditional skids or wheeled landing gear for the legs; new helicopter designs with the robot legs as retractable landing gear; and futuristic ideas, such as a Humvee designed to carry a detachable helicopter that would be equipped with the legs. The kit concept is probably closest to realization because it is the least expensive and easiest to build option for helicopter manufacturers. With the kit concept, for some helicopter designs the legs will need to fold up on the sides of the fuselage, while for others they will fold up underneath, depending on the helicopter's structure, attachment points, weight distribution and other factors.

The Georgia Tech team divided the robotic legs development duties into two groups: one for the leg structures and another for motion and control of the legs. For both groups, minimizing the weight of the robotic legs was a priority because the greater the weight, the more they cut into the cargo capacity of the rotorcraft.

The members of the structures group knew they needed to select materials, and at the right thickness and shapes, to build legs that were as light as possible while still supporting the necessary loads. They chose aluminum for the metal's light weight and strength. Lightweight legs also provided the benefit of needing less power to manipulate, so the design team could also drive down one of the main contributors to weight: the battery size.

A basic problem for the motion and control group to solve was how to tell the onboard microprocessor about the slope of the landing surface: the elevations of the spots where the robotic feet would set down. LIDAR or other optical sensors were not precise enough to read the landing slope, so the group selected off-the-shelf pressure pads for the feet of the legs. These sense when the feet touch down and how much pressure they are exerting against the ground. With the information provided by the pressure pads, the microprocessor can decide when and how much to move each leg.

The motion and control group also needed to program the control logic for the legs to keep the helicopter level during takeoff and landing. The group came up with three options. One option was to direct the onboard microprocessor to continuously monitor pitch and roll as the helicopter landed. This logic

Georgia Tech

▲ Professors, research engineers and graduate students at Georgia Tech built and attached robotic landing gear to a Rotor Buzz 2 unmanned crop-dusting helicopter and conducted a series of test flights in an open field from 2013 to 2015.

would tell all four legs to move as needed to keep the pitch and roll angles at zero. The team also considered adapting the virtual-model control logic that designers of walking robots rely on.

They chose an entirely different approach for the Rotor Buzz flights. The control logic instructs the microprocessor to command the joints in each leg to bend freely as that leg touches down, once the pressure reading for that foot reaches one quarter of the weight of the helicopter. The microprocessor also coordinates the joints in each leg so that the foot does not move horizontally. This logic is simpler than the other two logic options, so it is less prone to glitches. The other two logic options would require either monitoring of pitch and roll readings while including those readings in a feedback loop to adjust the leg joints, or accessing the pre-set programmed movements of the virtual-model control logic. Plus, the two options would also need the same foot pressure pad readings as the Rotor Buzz flights control logic.

For the at-sea design, the team plans to test both the Rotor Buzz flight control logic and the option that continuously monitors pitch and roll. The engineers will save tests of virtual model control for future robotic leg designs.

In designing the individual legs, the Georgia Tech team knew it needed them to keep the fuselage level during takeoff and landing, and fold up during flight. The researchers chose the simplest design that accommodates both objectives: two joints, with one at the bottom of the fuselage where the leg attaches to the helicopter, like a hip, and one about halfway down the leg, like a knee. The team had an easier time writing the control logic software for two joints per leg than they would have for legs with more joints, plus the legs weighed less with only two joints. Electric motors drive gear boxes in the joints. These gears bend each leg at the two joints while keeping the feet moving straight up and down only, because any sideways motion by the feet could tip the aircraft. With a ground landing, when all four legs have made contact, a brake on each joint locks them in place with the helicopter resting in a level position. The brake is released only when power is applied, so that any power failure will leave the leg joints rigid.

The team needed the legs to keep the fuselage level during takeoff and landing, and fold up during flight.

The team needed the robotic legs unit to be self-contained to avoid the complication of connecting it into a helicopter's power system, avionics and flight control computer. For power, they chose lithium ion batteries. For larger helicopters, such as traditionally piloted models, power for the legs will come from the aircrafts' main hydraulic systems.

For the helicopter tested in Greenville, each segment of the legs — from hip to knee and from knee to ground — was about one-third of a meter long. As the legs are scaled up for larger aircraft, each fully extended leg will measure about the same length as the individual helicopter's fuselage ground clearance with normal landing gear. Other helicopters may swap the four-legged system for three-legged versions, or variations on the two-jointed legs. As the robotic legs are scaled up for larger and larger helicopters, the legs and batteries to power them will take up roughly 7 percent of the maximum payload, Costello says. For a 2,700-kilogram manned helicopter, the robotic legs landing gear would weigh about 90 kilograms.

Sea legs

In May, the engineers built legs like those they hope to take to sea and tested their durability in the university's lab. They attached them to a frame to simulate a helicopter's size and weight, locked the leg joints, hoisted the frame and dropped it. They started these hoist drops from a few centimeters off the ground and worked up to 1.2-meter drops. Demonstrating that the landing gear is durable assures the team that legs will hold up and protect the helicopter in a hard-landing scenario, such as in an emergency landing or if the aircraft loses vertical thrust.

Starting in November at an Arizona test site, the Georgia Tech team will test robotic legs on an unmanned helicopter weighing about twice as much as the Rotor Buzz 2. The testing is funded by an airframe manufacturer that Costello declined to name and by DARPA.

The team will attach the legs to the helicopter and try to land it on a platform that pitches and rocks to simulate the movements of a ship at sea. Next year, they will take the helicopter to sea to test takeoffs and landings on a ship. For manned helicopters, landing on a ship's deck in high seas is one of the most dangerous maneuvers that a pilot can attempt.

So far, computer simulations show that the robotic legs should be able to set the helicopter down on a ship deck under weather conditions creating waves 4 to 6 meters high, Costello says. The legs would keep bending as the deck pitches and rolls, if necessary, to keep the aircraft level while sitting on the deck, before a crew straps it down to the deck, or during takeoff.

Future landings

Robotic legs make the most sense for new and evolving types of helicopters, says Ashish Bagai, a program manager at DARPA who worked with Costello in the early days of the robotic landing gear project. Bagai says he wouldn't advocate putting legs on a 5,500-kilogram helicopter, because the weight of the legs would cut too much into cargo capacity. But for rotorcraft weighing up to 3,200 kilograms with specific missions, robotic legs or maybe landing gear kits that could swap out regular landing gear for the legs would open up new mission possibilities. "What's important is that you apply it to those types of air vehicles that you wish you could do certain things with today but you cannot," Bagai says. ★

Getting out on a bad day

The commercial spacecraft that will carry NASA astronauts to the International Space Station were designed with safety in mind, especially during the critical minutes when the crew is aboard the rocket and awaiting liftoff. Former astronaut Tom Jones looks at how the contractors are applying the lessons of history to give crews new egress options.

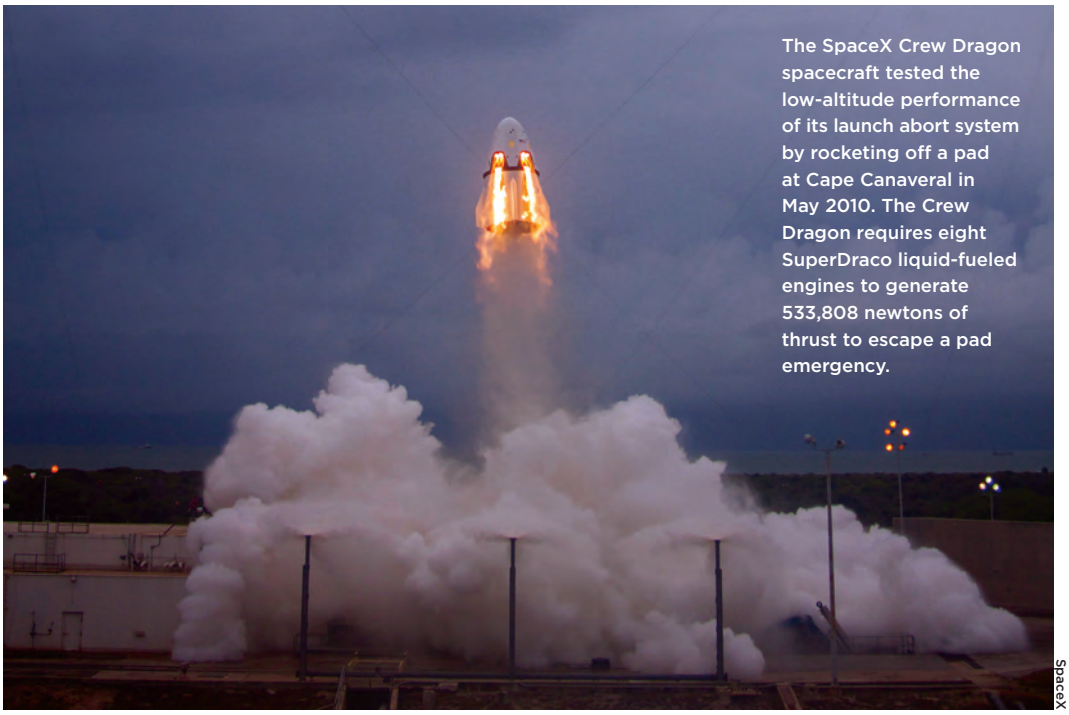
BY TOM JONES | Skywalking1@gmail.com | www.AstronautTomJones.com

Some days, you want to stop the rocket and get off. I know the feeling. My crew's STS-68 countdown in 1994 ended in lots of smoke but only five seconds of fire. A last-second engine shutdown left us still on Earth, swaying atop a fully fueled space shuttle — a volatile bomb, really — unsure of whether flames were climbing our orbiter or our fuel tank was coming apart. I unstrapped to help crewmate Jeff Wisoff prepare Endeavour's hatch for opening, the first step in a possible emergency egress by our six-man crew.

We knew the risks of space travel wouldn't begin with the moment of liftoff. Astronauts on the launch pad sit, sometimes for hours, atop hundreds of tons of stored chemical energy. A pad emergency can threaten a crew's safety as surely as a micrometeoroid strike or a damaged heat shield.

NASA

▲ Engineers test the Emergency Egress System — a zip line — at Space Launch Complex 41 on Florida's Cape Canaveral Air Force Station. The zip line was installed for astronauts flying Boeing's CST-100 Starliner spacecraft atop its United Launch Alliance Atlas 5 booster.



SpaceX

The SpaceX Crew Dragon spacecraft tested the low-altitude performance of its launch abort system by rocketing off a pad at Cape Canaveral in May 2010. The Crew Dragon requires eight SuperDraco liquid-fueled engines to generate 533,808 newtons of thrust to escape a pad emergency.

Ground emergencies like the 1967 Apollo 1 cabin fire, a 1983 booster fire that nearly engulfed the Soyuz T-10a crew, and the explosion of an unmanned Falcon 9 rocket during fueling in September 2016 remind us all that the design and function of ground safety and egress systems are critical. A delay of seconds can mean the difference between survival and immolation.

As the industry gets ready to field two new, commercially owned spaceships, the contractors are working hard with NASA and former astronauts to give crews something we never had during the shuttle program: multiple options to escape from a looming catastrophe on the launch pad — in short, a sure way out on a bad day.

Safe transports

The SpaceX Crew Dragon and Boeing CST-100 Starliner will ferry NASA astronauts to the International Space Station and will later be adapted to carry private passengers and workers to open low Earth orbit to tourism and industry. To perform the ISS missions, these spaceships must meet NASA's exacting human spaceflight safety standards.

Under NASA's Commercial Crew Program, which is helping to fund the new spacecraft, agency engineers were not involved in establishing the detailed designs, but instead left it up to the contractors to choose how to meet the agency's requirements. NASA's ISS crew transportation requirements document, CCT-REQ-1130, says among many safety specifications that crews must be able to exit their spacecraft in less than 90 seconds. How contractors meet these requirements is up to them. "They can come up with their own, innovative design solutions to meet our requirements," says Kathy Lueders, NASA's commercial crew program manager.

Getting out fast

In SpaceX's Crew Dragon, astronauts would lie on their backs, four abreast for launch from Kennedy Space Center in Florida. If the crew's safety were threatened by a spacecraft or Falcon 9 malfunction, they'll have three options for escape. They could exit via the outward-opening side hatch, cross the crew access arm to the gantry, descend the elevator to the pad surface, and drive away in an MRAP, a mine-resistant, ambush-protected personnel carrier. NASA obtained two, surplus from the Army. Second, the four could walk across an access arm 80 meters above Pad 39A and to the opposite side of the gantry. They would jump into escape baskets (the same ones provided for space shuttle egress), and zip down the slidewires to ground level and drive away. SpaceX's choice of Pad 39A gave it the option of employing this shuttle-heritage hardware. Finally, for a fast getaway, the crew could activate Crew Dragon's rocket-powered launch abort system, riding the capsule to a splashdown offshore.

Veteran space shuttle and space station astronaut Garrett Reisman, now SpaceX's director of crew operations, says the company examined past pad failures, including Russian experience on Soyuz, in designing its ground safety and egress systems. On STS-68 and other missions, crews had only the basket-and-slidewire option on Pad 39A or B to escape a shuttle ground emergency. "The way we're safer

than shuttle is that we have a launch abort system that is enabled before we ever flow propellants to the vehicle. You and I sat on a fully fueled shuttle where the fastest way of getting out to safety was a slidewire basket. A Dragon crew will have the option to punch off the rocket in under a second and get out of there. That's a huge advantage that we didn't have, but that crews did enjoy in Mercury, Gemini and Apollo."

After last September's spectacular Falcon 9 explosion during propellant loading, SpaceX CEO Elon Musk tweeted about the fireball: "Dragon would have been fine," he typed, referring to Crew Dragon. SpaceX maintains that a May 2015 test of the Crew Dragon launch abort system showed it's ready to save a future astronaut crew.

> "When you bear the scar tissue of an accident, it stays with you."
>
> **Chris Ferguson,** director of crew and mission operations for Boeing's commercial crew effort

Escape from Starliner

The blast danger area, called BDA, for an Atlas 5 booster for Boeing's CST-100 Starliner has a radius of about 400 meters (1,340 feet) centered on Space Launch Complex 41, the pad at Cape Canaveral Air Force Station near Kennedy.

Chris Ferguson, a former shuttle commander and now director of Crew and Mission Operations for Boeing's commercial crew effort, says that the United Launch Alliance and Starliner teams were highly motivated by past pad emergencies, like the Apollo 1 fire, in designing its egress systems. "When you bear the scar tissue of an accident, it stays with you," he says.

Ferguson explained that the Starliner crew will strap in at L-2.5 hours in the countdown, after Atlas 5 fueling is complete. Ground crews will close the hatch at L-1 hour and leave the pad. At L-9 minutes, the crew access arm will swing away from the spacecraft, nestling against the gantry. Inside L-4 minutes, the Starliner's pusher-rocket launch abort system will become active, enabling a near-instantaneous escape from the blast zone.

Should a ground egress be necessary, the access arm would swing back to the spacecraft in just 15 seconds. "It's really moving out there," says Ferguson. The crew, seated three across with a fourth just beneath in the CST-100, would swing the hatch outward. In 1967, a clumsy, three-piece, inward-opening hatch trapped the Apollo 1 crew; since then, all American spacecraft egress hatches have opened outward.

▼ Engineers evaluate the astronaut seating arrangement inside a mockup of the Boeing CST-100 Starliner. The cabin can take as many as seven crew members; four are planned for International Space Station transport flights.

Boeing

SpaceX

▲ Seats for four astronauts are shown inside a Crew Dragon mockup. The crew must be able to escape the cabin on Launch Pad 39A within 90 seconds.

Once through the hatch and across the access arm, the crew would clear the danger area riding a simpler version of the shuttle's slidewire system. To minimize the modifications necessary to the Atlas 5 pad, the ULA/Boeing team chose an off-the-shelf slidewire harness, the ZipRider, from Terra-Nova, a recreational equipment vendor. Ground crews and astronauts would strap on individual seats and start down from 52 meters (172 feet) above the pad deck, reaching speeds of 65 kph (40 mph) during descent. Riders slow to a safe stop with a manual brake or by hitting a 10 m series of spring dampers at the end of the cable. At the end of the line, the crew would pile into an MRAP and drive to a collection point.

Boeing's Starliner, like the Crew Dragon and NASA's new Orion deep-space module, has a launch abort system to call on if an emergency develops too quickly to allow ground egress. But the abort option should be a last resort: Rocketing off the pad to safety would likely destroy the structural integrity of the booster below and possibly ignite its propellant load.

"I'd prefer to walk out if I can," says NASA's Eric Boe, one of the astronauts training to fly 2018 test flights on the new ships. "But if it looks like the situation's going to become catastrophic, I'd much rather get away in a capsule than be trying to get down a slidewire." The industry teams "are definitely taking space shuttle standards to the next level, adding additional capability if something goes wrong. The shuttle was ahead of its time, but one of the challenges of its design was that it rode right alongside its stack of boosters and fuel tank — there was no good way to get off the vehicle if something happened during launch." By contrast, the new launch abort system designs offer crews an out from the launch pad all the way to orbit. "Think of it as a collective ejection seat," says Boe.

Test ... and test again

For a minute or so after Endeavour's STS-68 engines shut down, my crew was physically ready to exit the orbiter and hustle across the swing arm that had just arrived outside our hatch. It was our only escape route; the shuttle had no rocket-driven pad abort option. But launch controllers were able to verify a safe shutdown — no fire, no imminent explosion. We stayed put inside Endeavour.

STS-68 was the last shuttle pad abort, and thankfully, we did not have to ride the slidewire. But a future commercial transport crew will likely face a critical pad emergency. Their lives will depend on NASA's exacting review of egress and safety system designs, and rigorous tests proving they'll function on the day when they must work.

NASA expects that the commercial transports will be ready for their first piloted tests in early 2018. But no one is going anywhere on a Crew Dragon or Starliner until their ground egress and safety systems are proven. Says Lueders, "We want them to fly only when they — and we — are ready." ★

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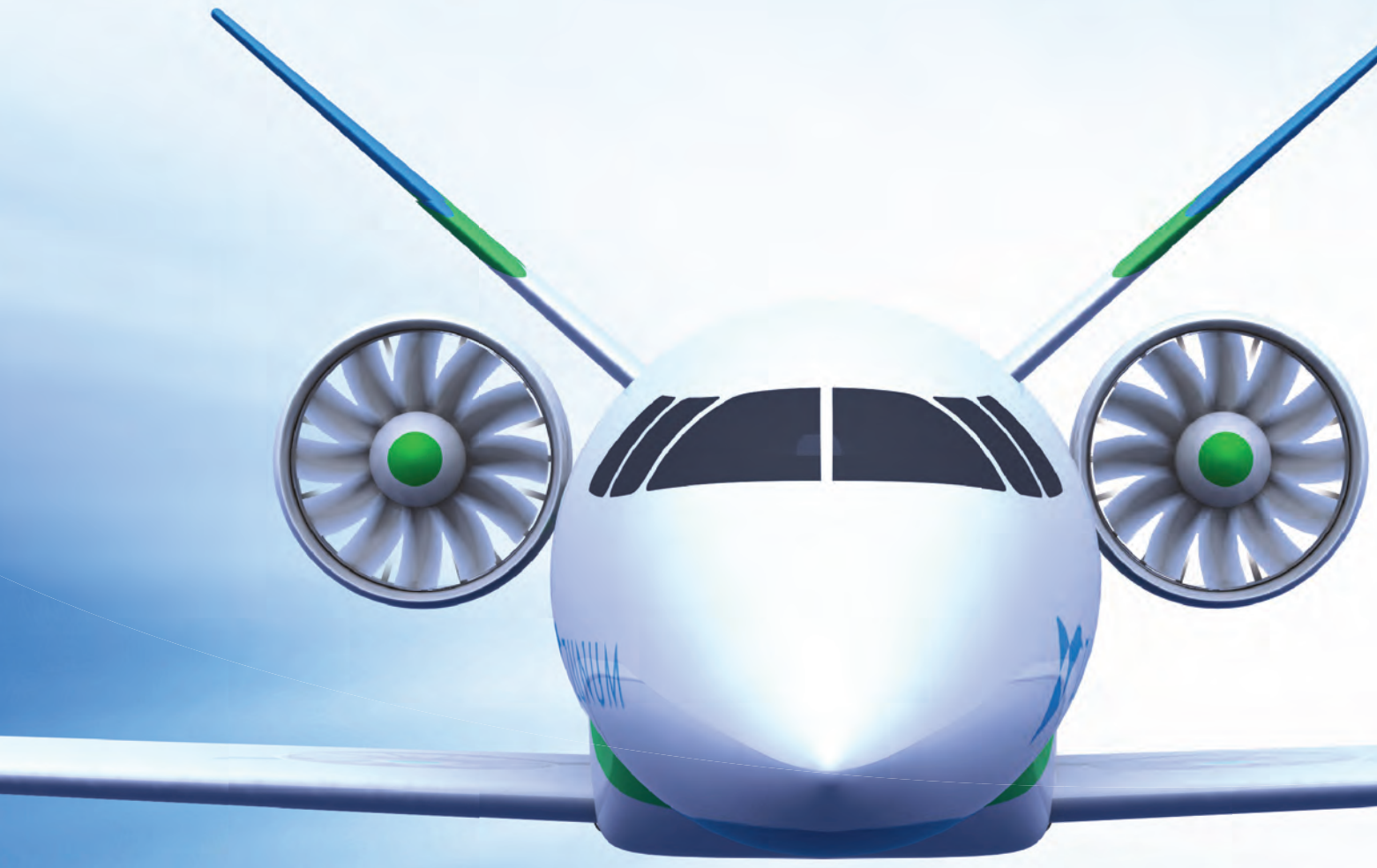
BY ADAM HADHAZY | adamhadhazy@gmail.com



Fly the electric skies

A startup, Zunum Aero, aims to shake up the hub-and-spoke model of modern air travel by reinvigorating short-haul flight with hybrid-electric aircraft. Could the fledgling company change the way we fly? Adam Hadhazy looks at the business case and technology.

Zunum Aero

▲ Zunum Aero is working with Boeing and JetBlue Technology Ventures to develop electric hybrid planes for regional flights. This is an artist's concept.

Just as "all roads lead to Rome" in the old saying, nearly all commercial flight paths lead to a hub airport.

Upward of 95 percent of air traffic in the United States goes in and out of around 140 airports — about 1 percent of the 13,000-plus airports throughout the country. For a traveler looking to get from A to B, this lack of local service often tacks on significant additional travel time to one, if not both ends of a trip.

Commercial aviation as we know it, long driven by the economics and engineering demands of fossil fuels, may be ready for a rethink. Leading aerospace firms, as well as tech titans in Silicon Valley, are increasingly placing their bets that this model can be upended by electric propulsion, probably in tandem with internal combustion on aircraft for some years to come.

In this congested airspace, one such startup, Zunum Aero, has tried to set itself apart by targeting what it sees as neglected, regional, short-haul routes, ranging from a few hundred to a thousand miles. In April, the Kirkland, Washington, company unveiled how it plans to usher in a golden era of regional travel in the United States beginning in the 2020s. To pull off the feat, the company foresees an intermediate step focused on hybrid electric aircraft whose propulsion fans would be driven electrically most of the time and by gas-powered turbines when extra power or range are required. If batteries can be improved enough, though, fleet operators could then opt for all-electric aircraft. Zunum thinks that could be as soon as the 2030s, though some experts think that timeline might be optimistic. Meanwhile, Zunum — the name is drawn from the Mayan word for "hummingbird" — is also developing optimization software intended to milk maximum benefit from its electric powertrain.

"Aviation is shaped by the propulsion that you have. We are 70 years into the jet age, and it's changed our whole lives — we can travel long distances in the country and around the world," says Ashish Kumar, founder and CEO of Zunum. "Now we are entering an era where you have a second, equally powerful propulsion capability" — electric power — "that we think is going to change the face of transportation, just as the jet has done over a long distance."

"Our goal," adds Kumar, "is to be one of the key drivers of that shift."

"Now we are entering an era where you have a second, equally powerful propulsion capability that we think is going to change the face of transportation, just as the jet has done over a long distance."

— Ashish Kumar, founder and CEO of Zunum

E pluribus ... Zunum?

It's a bold vision, and admittedly a mostly unrealized one — Zunum's aircraft are only in the conceptual stage, with many specifics yet to be named. But Zunum has nevertheless secured financial backing from Boeing HorizonX, a venture capital division of the aerospace firm, as well as airline JetBlue's Technology Ventures arm. Boeing did not offer further comment for this story, but HorizonX Vice President Steve Nordlund said in an April statement: "Boeing is investing in Zunum because we feel its technology development is leading this emerging and exciting hybrid-electric market space."

In that statement, Zunum laid out the promise of its approach. By lighting up a vastly underutilized network of regional airports with 10- to 50-seat aircraft, travel times for stretches of a few hundred miles could fall by 40 percent for popular routes, like the one between Los Angeles and Silicon Valley, Zunum says. To take another example: From AIAA's headquarters in Reston, Virginia, to New York's La Guardia Airport, door-to-door travel time would be cut in half from 270 to 135 minutes, Zunum estimates. New York-bound customers could fly out of Leesburg Executive Airport, rather than the hub Dulles International Airport, benefiting from the former's close parking to their flight aircraft, quicker security and baggage screenings, and less taxiing before takeoff. Out-of-the-way connections could see transit times plummet by over 80 percent.

Fares would drop by corresponding amounts, putting many round trips well under $100. Emissions with the initially hybrid aircraft would fall 80 percent compared to conventionally fueled aircraft. Another undesirable — the engine noise from internal combustion engines — would be slashed by three-quarters with an electric drivetrain, according to Zunum.

The company, like others attempting to actualize electric's revolutionary potential sooner rather than later, has numerous obstacles to overcome. Foremost is the technology at the heart of electric transportation, the battery. Improvements continue to be made, spurred in part by the frenzied state of innovation for hand-held devices, like smartphones, as well as electric cars, like at the still-scaling-up Tesla Gigafactory in Nevada. But when mostly or fully electric flight will become economical is still a matter of debate.

Belying Zunum's optimism, for instance, is a 2016 National Academies of Sciences, Engineering and Medicine report, commissioned by NASA to focus its efforts on commercial aviation carbon reduction (covered in Aerospace America's October 2016 issue). The report's committee members concluded that battery-powered regional passenger aircraft are unlikely to fly within 30 years. "We obviously disagree," says Matt Knapp, a founder of Zunum and its chief engineer. "We think their battery forecast is probably conservative." Knapp explains that the committee "tapped all the usual engine makers, who don't really have a vested interest in saying anything other than, 'let's develop more efficient engines.'"

While the traditional major engine firms are indeed looking to squeeze more out of traditional internal combustion engines, to varying degrees they are keeping an eye on not getting left behind by electric's potential disruption. Rolls-Royce, for example, is seriously developing hybrid-electric systems. At any rate, the majors are not battery makers, and will only go as far as energy storage limits allow.

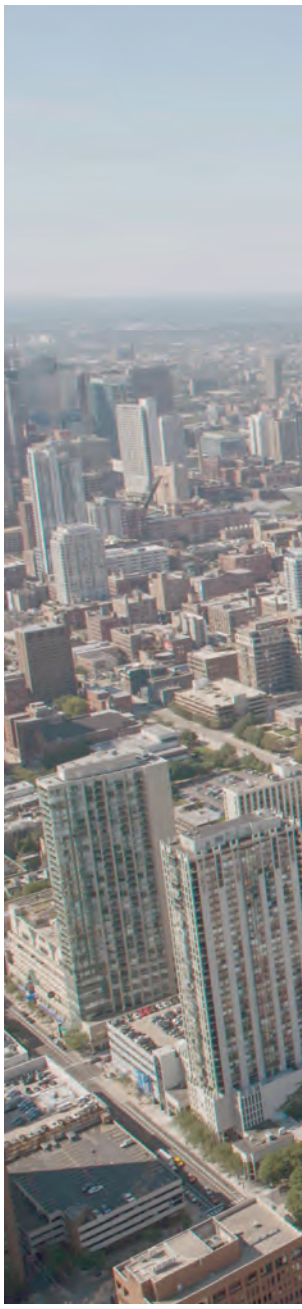
"If we had miracle batteries — just amazing, amazing batteries — then it would be a no-brainer. Everybody would do everything electric," says Rob McDonald, an aerospace engineering professor at California Polytechnic State University in San Luis Obispo, and a member of AIAA's Electric Aircraft/Hybrid Electric Propulsion Working Group. "But we don't have miracle batteries yet, so the interim question becomes, 'what kind of vehicles can you do?'"

In it for the short haul

For many aerospace firms and startups, the answer to that question is to think "small." Airbus is test flying a two-seat, hybrid-electric demonstrator in its E-Fan program. The France-based firm is also looking into relieving car congestion in megacities via drone-like vehicles through its CityAirbus initiative. Meanwhile, Uber — the ride-hailing service for cars — is pushing for vertical, takeoff-or-landing urban shuttlecraft, more akin to helicopters.

"If we had miracle batteries — just amazing, amazing batteries — then it would be a no-brainer. Everybody would do everything electric."

— Rob McDonald, aerospace engineering professor at California Polytechnic State University



NASA/Advanced Concepts Lab/AMA Inc.

Numerous other organizations have gotten involved in the hybrid-electric aircraft space, including NASA with its envelope-pushing X-57 demonstrator, now in construction. For the major aerospace firms, insights gleaned by pursuing modestly sized and purposed aircraft could then set the stage for electrifying long-haul aircraft decades down the road.

Zunum's Kumar, however, thinks the economic case is strong enough now for skipping ahead to larger, multiseat craft. The unexploited market for short-haul routes — covering a thousand miles or less between small cities and suburban areas, historically serviced by aircraft like the aging 10-seat Cessna 402 — has long been recognized through research by NASA and other interested parties.

"There is the potential here to open up high, latent demand," says Brian German, an aerospace engineering professor at Georgia Tech and also a member of the AIAA electric/hybrid working group. "People don't know they want this now because it doesn't exist, and if you could open that up, a lot of trips people would take by car could get pushed into aviation."

Kumar says he does not see his company's main competition as other aircraft makers or carriers; instead, "the real battle is between aircraft and ground vehicles," he says.

Statistics from the U.S. Department of Transportation's National Household Travel Survey bear this out. The survey reports that about 95 percent of domestic trips under 500 miles are taken by car, plus a still-appreciable 42 percent of trips in the 750- to 1,000-miles range. Kumar says analyses conducted by Zunum and for high-speed rail as a general short-haul transportation suggest 7 percent to as much as 15 percent of those long road trippers could be peeled off into paying airline customers.

The regional air market could certainly use the shot in the arm. In the 1980s, Kumar says, nearly 300 operators flew traditional 20-seat planes. Nowadays, 60-some operators fly mostly 80-seat aircraft. While overall air travel in the U.S. keeps setting records year-on-year, regional air travel is stuck at 2005 levels, at around 150 million annual passengers, amid dwindling departures and operator profit margins — not to mention a chronic pilot shortage.

Because fossil fuel-based propulsion systems benefit from altitude and speed, slower and lower-flying 50-seaters cannot compete in cost per passenger miles with long-haul aircraft ferrying hundreds of travelers. "Fuel is a big part of the operational cost pie chart," says German.

Electric motors and batteries might just flip this equation. By taking energy off the grid at discounted bulk prices and in advantageous regions of the country with low electricity costs, an operator "could pay energy costs a good bit lower than aviation gasoline," says German.

Kumar believes that if he develops the Zunum aircraft, both operators and customers will come, as in the film "Field of Dreams." "What happened to our air system doesn't have to do with demand," Kumar says. "It has to do with supply."

Something old, something new

Zunum's aircraft remains very much in the intensive design phase. Yet the company has arrived at what

▲ NASA's X-57 Maxwell, shown in an artist's rendering, will have 14 electric motors.

NASA's air apparent

Zunum's approach of mixing internal combustion with electric power to create a hybrid-electric passenger plane is among the more conservative propulsion concepts in the emerging sector. NASA is taking an even bolder approach with its X-57 experimental aircraft, nicknamed Maxwell. Plans call for placing 12 small electric motors with propellers on the leading edges of the plane's wings for maximum power during takeoff, bookended by two larger motors at the wing tips for cruising. The unorthodox arrangement should generate more lift and ultimately a five-fold cut in energy use at high speeds compared to conventional propulsion systems. A test flight of this modified Tecnam P2006T two-seater may happen as soon as this year.

▲ Airbus' E-Fan Plus is a two-seat electric demonstrator.

it feels are some firm decisions moving forward to meet its goals.

Take the propulsion system. A propeller will be positioned within a cylindrical housing. Two of these ducted fans will likely be mounted near the rear of the aircraft, giving it a look that does not dramatically depart from today's business jets. The fans will be offset from the fuselage to cut down on noise inside the cabin, a chief complaint Kumar and his colleagues have heard from veteran passengers of small planes. People in neighborhoods unaccustomed to airplanes zooming overhead may be surprised at how quiet the design is, Zunum predicts. "Ducted fans are the best way to get low noise and short takeoff in a high-performance package," says Knapp.

What will the batteries initially be like? Although Zunum tentatively plans to go with a lithium-ion variety, with so many promising chemistries in development in labs worldwide, the company wants to keep its options open. "The battery space is changing so fast that we can't afford to commit to one specific chemistry," says Kumar. "We have to design an aircraft that is agnostic to chemistry."

Zunum has a hand in molding these next-generation batteries. A co-founder, Kiruba Haran, is an electrical engineering professor at the University of Illinois Urbana-Champaign. The university leads a National Science Foundation-funded research group known as the Center for Power Optimization of Electro-Thermal Systems, or POETS, which includes scientists from Howard University in Washington, D.C., Stanford and the University of Arkansas, as well as industry partnerships with Zunum and Boeing. POETS' goal: To substantially increase the energy density of batteries, such that a reasonable amount of the cells — not too heavy, not too voluminous — could provide enough juice for hybrid or purely electric flight. Out of the gate, Kumar says Zunum will conservatively assume an energy density of at least 300 watts per kilogram, about what today's best lithium-ion batteries are starting to reliably muster, though increases from there will be where the hybrid concept really starts to take wing.

Airbus

Beyond batteries, Zunum must master energy management, which refers to when the aircraft will semi-autonomously toggle between batteries and gas turbines for efficiency. Engineers have made advances in this area before with municipal hybrid-electric buses, for instance. Building from there, Zunum's engineers are devising software that will decide when to drive the fans with internal combustion, such as when maximum power is required, and when to drive them electrically. The software will run queries every several minutes, before and during flight. It will integrate information from the batteries, fuel tanks and turbines with real-time flight data and weather reports. Adjustments will be made on the fly, as it were, optimizing the aircraft's performance and flight path. "When you're hitting your actuals, like running into wind, or you need to deviate from your original flight path, platform will recompute what is the optimized energy plan for that flight," says Kumar.

Zunum's principals have secured a patent for some of the intellectual property behind this software, as well as their broader systems and methods for "overcoming the disadvantages of the current air transportation system," as the patent states.

Aside from these deeper technical challenges, Zunum is also working alongside other companies with the FAA to create an electric aircraft certification framework, expected sometime next year. Historically, many innovative aircraft concepts have foundered at this stage, given the toughness of the relevant FAA regulations for introducing new technologies. "Lack of certification experience and financing is where a lot of ideas come apart at the seams," says German. He adds, though, that Zunum might well have a leg up in clearing this hurdle. "The Boeing connection [with Zunum] could extend beyond investment to technical expertise," German says, "and if anyone knows how to certify an airplane, it's Boeing."

Furthermore, a lot has changed in the political climate since Zunum's founding in 2013. Although the Trump administration's priorities run counter to those of the former Obama administration on promoting clean energy and addressing climate change, Kumar says that the trajectory envisioned for Zunum does not depend on government regulation or on R&D funding.

Pie in the sky?

Zunum and the other entrants to the nascent hybrid and electric aircraft field have a lot to prove before taking to the skies as viable enterprises. A note of caution is warranted, given how staid the commercial aircraft paradigm has been for decades. Indeed, the frothiness of the electric-hybrid scene has made skeptics out of some analysts, such as Richard Aboulafia, vice president for analysis at the Teal Group, an aerospace and defense industry research firm in Virginia. He dismisses the recently proliferating artists' impressions of supposedly game-changing aircraft as just "1950s Popular Mechanics cover stories."

"The essence of futurism is the tendency to overstate the impact and readiness of exciting new technologies," says Aboulafia. "We're just mainlining that futurism."

Just as the jet engine shook up aviation, eventually something else is fated to as well, and the industry as we know it will change. The inevitable transition to what's next, via hybrid drivetrains, could be right around the corner.

"Hybrids are compelling as an intermediate step, as a stopgap," says Cal Poly's McDonald. "But so many things will be enabled by electric. It will be transformational." ★

Aerospace America staff reporter Tom Risen contributed to this story.

DANCING CUBESATS

Now that architects of satellite constellations want cubesats that can maneuver and propel themselves, companies are vying to come up with the best means of squeezing propulsion into a tiny package. Debra Werner spoke to leaders of this emerging field about some of the promising options.

BY DEBRA WERNER | werner.debra@gmail.com

Space-industry watchers have little doubt that the tally of cubesat launches in 2017 will demolish the previous record set in 2014 when 132 of these miniature satellites were launched. Already, government agencies, universities and companies have launched 142 cubesats as of June 1.

Once seen mainly as a way to give students hands-on experience, cubesats have proved so useful that NASA, the U.S. Air Force, intelligence agencies and Silicon Valley startups are devising multimillion-dollar Earth imaging and communications missions around them. With that newfound importance, come challenges. When cubesats were humble teaching tools, professors were satisfied with whatever data they could obtain before their cubesats succumbed to drag and burned up in the atmosphere. With millions of dollars and key objectives now on the line, many cubesat developers want their spacecraft to have propulsion.

Cubesats could then maneuver to their optimal orbits instead of making the best of their drop-off points after hitching a ride on a rocket with a much larger satellite. The cubesats could resist atmospheric drag and remain in space for years, and at the end of their missions, be de-orbited to avoid creating debris.

Designers would have new options. Constellations or swarms of maneuvering cubesats might take on many responsibilities traditionally reserved for bus-size satellites. Those constellations could be established rapidly. Today, it takes months for San Francisco startup Planet to move its newest cubesats into position through differential drag. With propulsion, that would take just days. For missions beyond Earth orbit, cubesats destined for asteroids, the moon or Mars already are being designed with onboard propulsion.

"Cubesats are doing the same kind of jobs the big satellites are doing. So in the same way that propulsion is good for the big guys, it's good for the little ones," says Jordi Puig-Suari of the California Polytechnic State University, who in 1999 developed the cubesat standard together with Bob Twiggs of Stanford.

The task now is to figure out which new thruster designs will work. "We are dealing with rocket science and plasma physics," says Natalya Bailey, founder and chief executive of Accion Systems, a Boston startup focused on electric propulsion for small satellites. "People can put forth spec sheets and claim things, but flying the engines is going to be the main differentiator."

Some concepts are forms of solar electric propulsion, in which solar cells on the exterior of the cubesat would convert sunlight to electricity that can be applied in a variety of ways to create propulsion. Other concepts are takeoffs on traditional chemical propulsion. Here's a look at some of the technologies on the horizon:

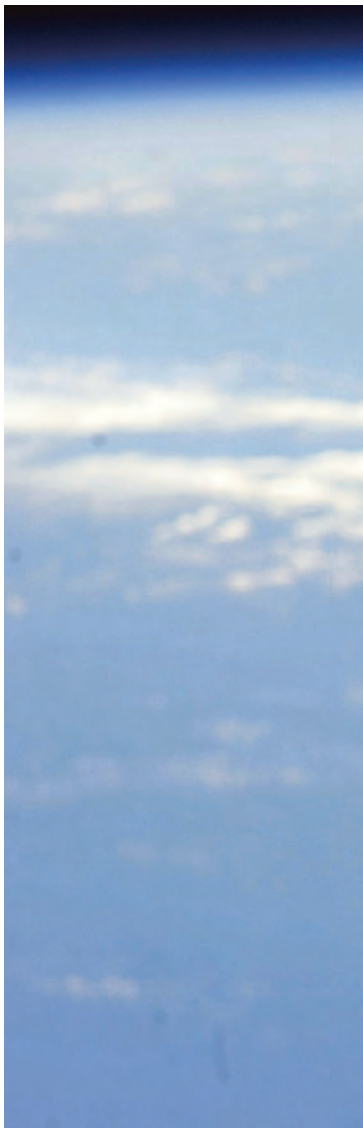
Hall-effect thrusters

These thrusters are named for American scientist Edwin Hall who described how magnetic fields can shape electrical currents. Hall-effect thrusters trap electrons and make them collide with the atoms of a propellant, and the resulting ionized gas is accelerated with magnetic and electrostatic fields.

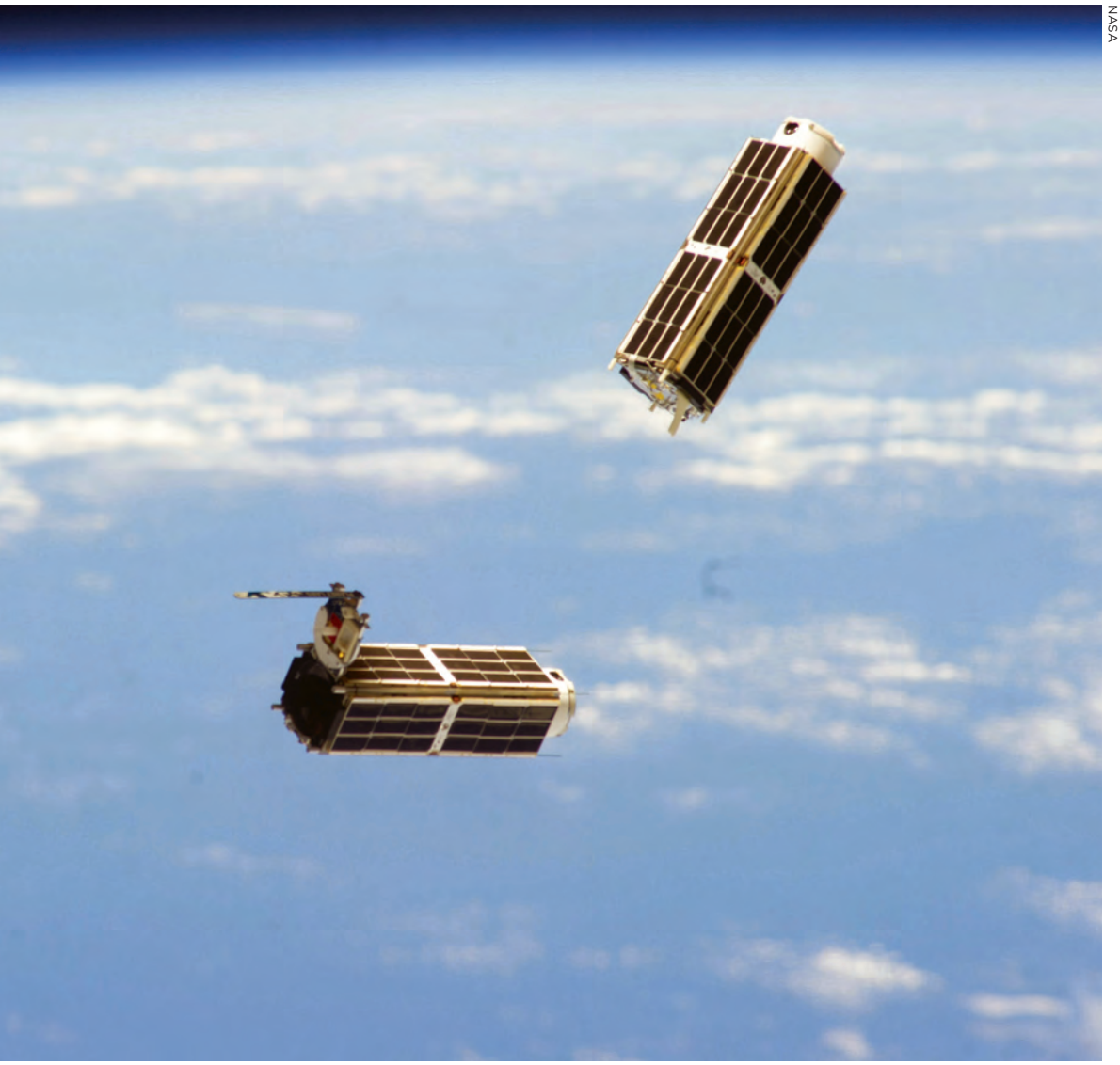
- Busek of Massachusetts, a company well-known for Hall-effect thrusters, is preparing to test one later this year on a 12U cubesat called Iodine Satellite or iSat for short. The thruster, developed with funds from NASA and the U.S. Air Force, will excite an iodine propellant with radio frequency electromagnetic fields. Cubesat developers, including those at the U.S. Air Force Space and Missile Systems Center in California, are eager to test iodine because it's three times as fuel efficient as the commonly flown xenon. Iodine-fueled missions would pack the same power with one-third the fuel. Plus, iodine can be stored as an inert solid in low-pressure plastic tanks, while xenon requires pressurized metal tanks and pressure regulators.
- ExoTerra Corp., a small business in Colorado established by some former Lockheed Martin engineers, has developed what it calls the Halo Hall Effect Thruster. Each would take up one-quarter of a 1U cubesat, weigh 0.48 kilograms, and could be fueled by either xenon or iodine.

"It's the smallest Hall thruster we are aware of on the market," says Michael VanWoerkom, ExoTerra founder and president. "We can package a kilometer per second of delta-V" — change of velocity — "into a 6U cubesat."

In March, NASA awarded ExoTerra a $2.5 million contract to move forward on the technology under the agency's Tipping Point Program, which aims to back projects on the verge of a breakthrough. NASA



▲ An International Space Station crew member photographed this set of cubesats after deploying them. Manufacturers are putting propulsion systems on the ubiquitous small satellites now that their missions have become more valuable.



NASA

▼ VACCO Industries has provided two propulsion units for NASA's JPL Mars Cube One. The units release hydrofluorocarbon refrigerant from a pressurized tank through eight thrusters.

plans to flight test a 300 watt version of ExoTerra's solar electric propulsion system on an asteroid-hunting cubesat scheduled for launch in 2019.

Electrospray thrusters

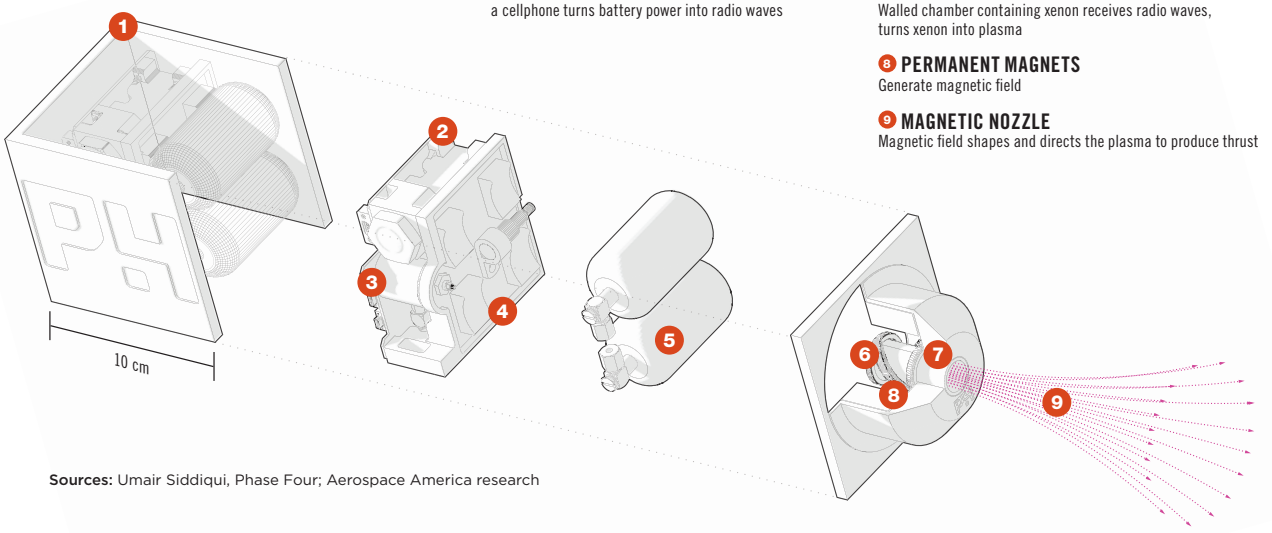
These apply a charge to an ionic liquid propellant before accelerating it with an electric field.

■ Busek of Massachusetts developed the technology for a possible future NASA-European Space Agency effort to detect gravitational waves, the ripples in spacetime predicted in 1915 by Albert Einstein in his theory of general relativity. To make those gravity measurements, scientists will need a three-satellite observatory, and each of those satellites must be held in a precise orientation relative to each other and Earth. Even the most minute disturbances must be counteracted and that's where Busek's electrospray thrusters come in. NASA demonstrated this and

VACCO Industries

BIG POWER IN A SMALL SATELLITE

Phase Four's radio frequency thruster heats and ionizes xenon with radio waves. Magnets force the hot plasma out of a nozzle.



Sources: Umair Siddiqui, Phase Four; Aerospace America research

other required technologies in 2015 on a satellite called LISA, short for Laser Interferometer Space Antenna.

Tyvak Nano-Satellite Systems, an Irvine, California, company founded by cubesat co-creator Jordi Puig-Suari, plans to incorporate a Busek electrospray thruster in a 6U NASA Pathfinder Technology Demonstrator scheduled for launch in 2018. The thruster measures 9 centimeters by 9 cm by 4 cm.

■ Accion Systems is developing a different kind of electrospray thruster based on technology its founders, Natalya Bailey and Louis Perna, developed at MIT's Space Propulsion Laboratory. While earning doctorates, Bailey and Perna worked on prototypes of miniature ion engines that were flight tested on AeroCubes, cubesat technology demonstrators built by the federally funded Aerospace Corp. in Los Angeles, which conducts research and development for the U.S. Air Force. Soon, the U.S. Defense Department began funding MIT's research, and aerospace prime contractors asked whether they could purchase flight systems or license the technology. That's when Bailey and Perna decided to establish Accion. "We knew the trend was toward smaller and smaller satellites and we really felt it when people were knocking on MIT's door trying to buy systems," Bailey says. Since forming Accion in 2014, Bailey and Perna have raised $10.5 million from investors and obtained $6.5 million in funding from U.S. defense agencies, which the firm declines to name. The electrospray engines, which are roughly the size of a pack of cards, run on a

"CUBESATS ARE DOING THE SAME KIND OF JOBS THE BIG SATELLITES ARE DOING. SO IN THE SAME WAY THAT PROPULSION IS GOOD FOR THE BIG GUYS, IT'S GOOD FOR THE LITTLE ONES."

— **Jordi Puig-Suari**, co-creator of the cubesat standard

salt-based liquid propellant that flows through hundreds of microscopic emitters housed in microchips that it prints in a manner similar to how computer chips are made. This manufacturing innovation wouldn't have been necessary "if you needed to make one ion engine a year," Bailey notes. "Given the trends in the industry, we thought it would be wise to pull mature manufacturing techniques from other industries."

Ion thrusters

These accelerate ions with electrical power, and can be fueled by iodine or xenon.

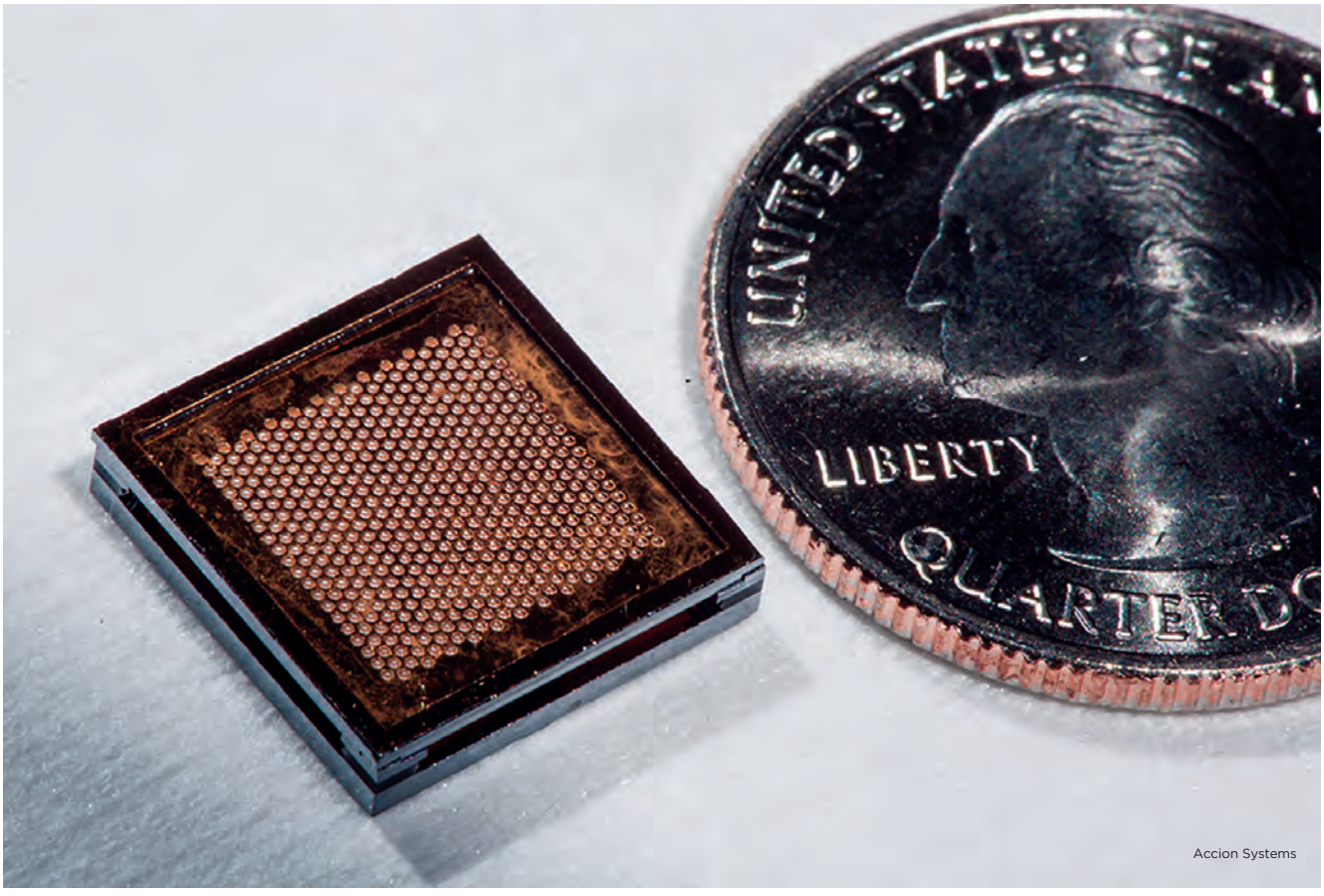
■ Busek of Massachusetts has created iodine-fueled ion thrusters that are scheduled to propel a pair of 6U cubesats to lunar orbit. One is called the Lunar Ice Cube cubesat and is built by Morehead State University in Kentucky. The other was built by Arizona State University and is called the Lunar Hydrogen Mapper. Both are slated to ride on the first flight of NASA's Space Launch System rocket in early 2019. Once released, their thrusters will be so efficient that, if all goes as planned, they will easily reach lunar orbit even with the small amount of propellant that fits in a cubesat. In fact, they should have enough propellant left after reaching orbit to move closer to the moon for scientific observations, says Vlad Hruby, Busek president and founder.

Radio frequency thrusters

These convert electrical power into radio waves that act on a propellant to generate thrust.

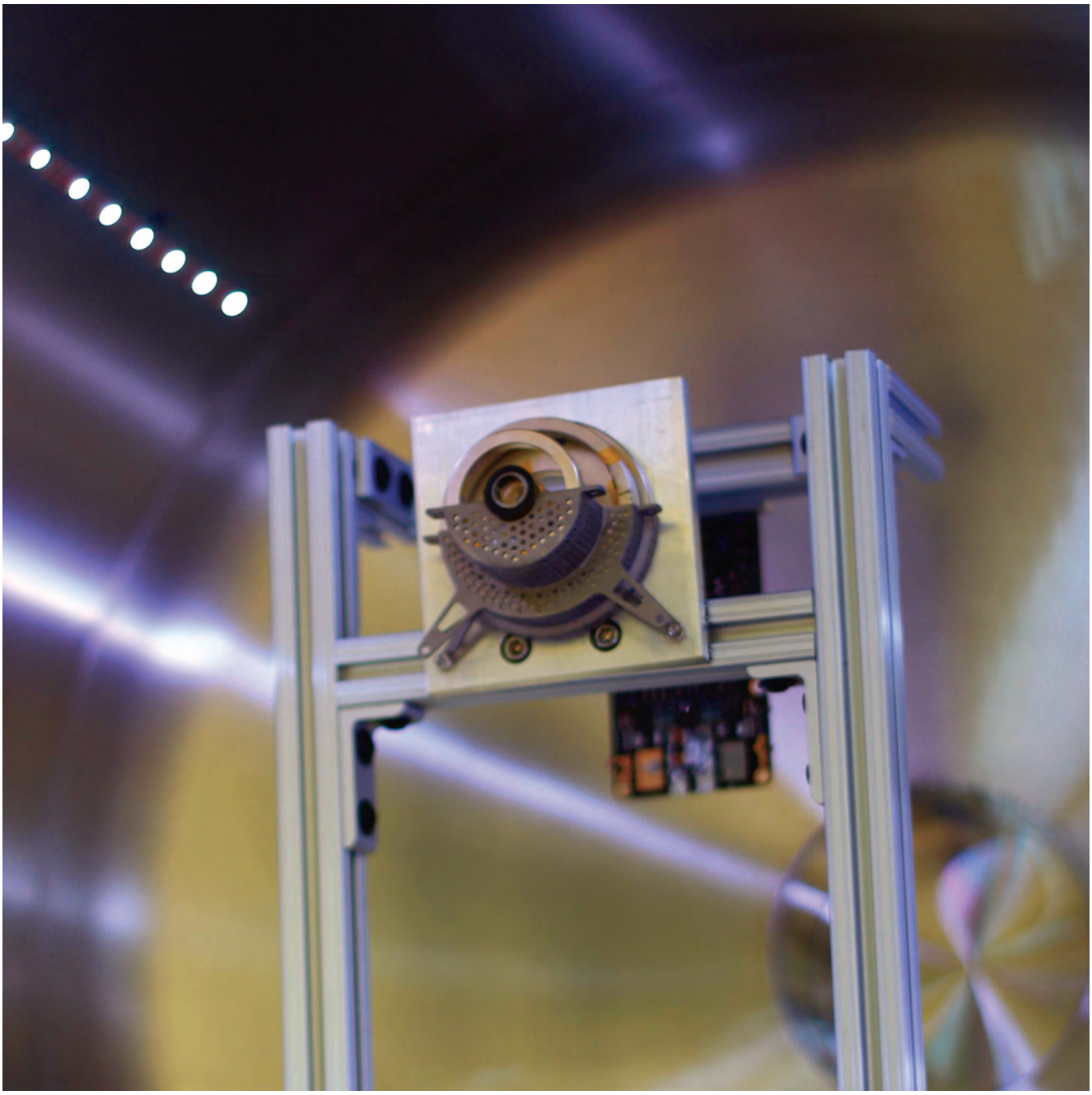
■ Phase Four, a 12-person startup near Los Angeles International Airport, has designed and is scheduled to test the Phase Four Radio Frequency Thruster. These thrusters convert DC into RF power, to ionize and heat xenon. The design does not need cathodes and anodes, relying instead on electronics similar to those in cellphones to generate radio frequency signals that heat and ionize the xenon into a plasma. Magnets then force this plasma through a nozzle to produce thrust. Soon after the company's founding in 2015, Phase Four won a $1 million DARPA contract to build a prototype and associated components. The design is scheduled to make its orbital debut early next year on an agriculture monitoring satellite called Landmapper. It's a 6U cubesat made by Astro Digital, a small company at the NASA Ames Research Park in California.

"From a business perspective, being able to say we have flight heritage will be a huge differentiator," says Simon Halpern, the Phase Four founder.



Accion Systems

▼ Accion Systems' ion electrospray thruster runs on a propellant that flows through hundreds of microscopic emitters contained in a microchip.



Phase Four

▲ Phase Four says its RF thruster provides electric propulsion while being small enough to power cubesats.

In a sign of how anxious the industry is for cubesat propulsion, Phase Four has begun selling a plug and play model for cubesats even though the design has not yet been to space.

Resistojet propulsion

These concepts pass electricity through a resistor to generate heat that produces thrust differently depending on the design.

■ Surrey Satellite Technologies Ltd. of Guildford, England, in 2013 flew its Water Alcohol Resistojet Propulsion, known as WARP Drive, on a cubesat called the Surrey Training Research and Nanosatellite Demonstrator 1. This was a joint effort with the University of Surrey's Space Center. Heat produced by a resistor turns de-ionized water mixed with alcohol into superheated steam that is forced through a nozzle.

Micro-cavity discharge

Electrodes heat the propellant, turning it into plasma in a micrometer-diameter cavity before discharging the plasma through a nozzle.

■ CU Aerospace of Illinois and VACCO Industries of California, have joined forces to create the Propulsion Unit for Cubesats or PUC for short. A PUC unit can

"WE KNEW THE TREND WAS TOWARD SMALLER AND SMALLER SATELLITES AND WE REALLY FELT IT WHEN PEOPLE WERE KNOCKING ON MIT'S DOOR TRYING TO BUY SYSTEMS."

— Accion Systems co-founder **Natalya Bailey**, speaking about the decision to start her company.

be as small as one-quarter of 1U or 10 centimeters by 10 cm by 2.5 cm. A U.S. government customer that CU Aerospace and VACCO say they are not permitted to name purchased several PUCs four years ago for classified cubesat programs. "I was told that I will never know what happened," says Cleve Samson, VACCO's regional sales manager who specializes in the company's micro-propulsion systems.

Chemical propulsion

Various groups are adapting the basic concept of emitting gases or vapors to generate thrust.

■ VACCO Industries of California has developed a propulsion unit that releases R134a, a hydrofluorocarbon refrigerant, from a pressurized tank through eight thrusters, two at each corner of the module. The first two modules, enough to fill a 1U cubesat, are scheduled to fly for the first time in September on the NASA-funded Cubesat Proximity Operations Demonstration. If all goes as planned, two 3U cubesats will rendezvous, operate near one another and dock. The cubesats are made by Tyvak Nano-Satellite Systems of California.

VACCO has also delivered two propulsion units for the first cubesat built for an interplanetary journey, the NASA-funded Jet Propulsion Laboratory's Mars Cube One, called MarCO for short. This 6U cubesat is scheduled to ride toward Mars with a lander called InSight, short for Interior Exploration using Seismic Investigations, Geodesy and Heat Transport. MarCO will stay in space to relay communications between the InSight lander and mission planners on Earth.

■ Cubesat developers can also buy miniature versions of propulsion systems that combine hydrazine with a catalyst to create thrust. Aerojet Rocketdyne, for example, drew on technology from its missile defense thrusters to build the Cubesat High-impulse Adaptable Modular Propulsion Systems, or CHAMPS, a thruster that fills a 1U cubesat and is designed for missions that need rapid acceleration.

"Hydrazine is very quick responding," says Joseph Cassady, who directs Aerojet Rocketdyne's space programs in Washington, D.C. "You can get a little pulse. That's key for a lot of space missions because you are doing fine maneuvers to adjust the trajectory."

With funding from NASA, Aerojet Rocketdyne qualified CHAMPS for flight and is looking for an in-flight demonstration.

■ Due to hydrazine's toxicity to workers, some companies are experimenting with thrusters that will run on nontoxic "green" propellants. VACCO of California is developing a hybrid propulsion system for the Italian company Argotec's ArgoMoon cubesat. VACCO pairs a green monopropellant warm gas thruster, fueled by Sweden's Ecological Advanced Propulsion Systems' High Performance Green Propulsion (which has an ammonium dinitramide base), to push the miniature spacecraft into its desired lunar orbit with four cold gas thrusters for attitude control.

Aerojet Rocketdyne's green propulsion unit, fueled by a hydroxyl ammonium nitrate fuel/oxidizer blend, designated AF-M315E, is slated to fly in late 2017 on NASA's Green Propellant Infusion Mission. To reduce costs, Aerojet Rocketdyne additively manufactured the unit's structure and tank in one piece with mounting brackets for five thrusters. Instead of 50 to 75 parts, its monopropellant subsystem has fewer than 10 parts. "We had to find a way to get the price well below where our traditional propulsion systems would be for these guys to even consider buying it," Cassady says.

• The federally funded Aerospace Corp. in California has developed a nontoxic, nonflammable, nonexplosive, noncarcinogenic thruster fueled by water that is turned to steam. It is scheduled to fly on NASA's Optical Communications and Sensor Demonstration, a two cubesat mission slated for launch later this year to test how well laser pulses can relay data between low Earth orbit and a telescope on top of Los Angeles' Mount Wilson. "It's hard to come up with a mode where a water thruster can cause a problem," says Richard Welle, who heads the Aerospace Corp.'s Microsatellite Systems Department. ★

AT A GLANCE: CUBESATS

The cubesat design standard was devised in 1999 by professors Jordi Puig-Suari of the California Polytechnic State University and Bob Twiggs of Stanford. A basic cubesat measures 10 centimeters on a side, but designers can join multiple units together to form 2U, 3U cubesats, all the way up to 27U. To release the cubesats in orbit, Cal Poly designed the Poly-Picosatellite Orbital Deployer, or P-POD for short. This lightweight metal box attaches to an expendable rocket's upper stage to isolate the cubesats from the primary satellite and eject the cubesats in orbit after the primary satellite has launched. Houston-based NanoRacks produces a deployer to launch cubesats from an International Space Station airlock.

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The Future of Electrified Aircraft Propulsion for Commercial Transports: Perspectives and Lessons Learned from Outside Aviation with **Marty Bradley,** Technical Fellow, The Boeing Company; **Nady Boules**, President, NB Motors LLC. (Retired Director of GM R and D Electrical and Control Systems); **AP "Sakis" Meliopoulos**, Professor, Georgia Institute of Technology; **Rico Rodriguez**, Chief, Electrical Capabilities Global, Rolls-Royce Corporation; and **Venkat Srinivasan**, Director of the Argonne Collaborative Center for Energy Storage Science (ACCESS).

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This course covers the fundamentals of turbulence modeling, beginning with the various equation systems and modeling strategies. Theoretical backgrounds are presented for second-moment closure and practical models are presented and demonstrated. Simplifications and alternative eddy-viscosity modeling strategies are considered that are practical for every-day engineering calculations in an industrial environment.

AIAA

Shaping the Future of Aerospace

WEATHER CONNECTIONS

The days of commercial pilots calling ahead to other pilots or down to controllers for weather updates are dwindling fast. Henry Canaday looks at the weather-data transformation playing out in the cockpit.

BY HENRY CANADAY | htcanaday@aol.com

Aero Icarus

▲ Pilots always want the most up-to-date weather information — for safety's sake and passengers' comfort.

Getting a clear picture of the weather ahead of a flight can be more complicated than it sounds.

For starters, there is turbulence, the chaotic changes in air pressure and flow that can stress out nervous passengers and in rare cases injure them. Flight attendants are especially vulnerable, because they are often last to strap on their seat belts.

Then there are lightning strikes. Even if a lightning strike is merely suspected, the plane must be inspected on the ground, and that equates to costly downtime.

And of course weather has contributed to deadly air accidents. There was the 2009 crash of Air France Flight 447 off Brazil, in which ice is thought to have blocked the plane's speed-sensing pitot tubes triggering a series of deadly missteps. In 2014, the pilots of AirAsia Flight 8501 lost control while attempting to climb over a storm.

Beyond safety, there are economics to consider. Relatively few passengers are injured by turbulence each year (44 in 2016, according to the FAA), but when injuries do occur, the medical expenses, lost income and legal costs rack up quickly. Also, wind direction and speed affect flight time and fuel burn. Making sharp turns at the last moment to avoid a storm might pose no safety risks but impose big fuel penalties.

What all these factors add up to is a strong impetus to deliver richer and timelier weather information to the cockpit, and that's exactly what's happening. It's a revolution fueled by the convergence of broadband satellite communications with the advent of online apps and wireless tablet devices. New players and some established ones are rushing into this market with innovations.

The Atlanta-based Weather Company, for instance, says about 85 percent of U.S. major airlines and 40 percent of the top global airlines subscribe to its services to operate more than 50,000 flights per day. Customers receive weather forecasts, updated every 15 minutes, plus real-time weather data. Dispatchers plan flights with the data and pilots sometimes adjust their routes and altitudes based on it.

As recently as a couple of years ago, matters worked entirely differently. Pilots usually received weather information during preflight briefings and carried the paperwork aboard in their flight bags. During the flight, pilots would review these documents and view displays showing turbulence detected by onboard weather radar mounted on their aircraft's nose or wing. These turbulence readings were limited in range and the types of disturbances they could detect. The pilots would typically request updates from air traffic controllers about turbulence and other weather.

Making the revolution possible

Two changes are empowering pilots to supplement or even replace those traditional sources of weather information.

Pilots now carry tablet computers aboard, and these mobile devices are known as electronic flight bags, or EFBs. Because they are unattached to the aircraft, they do not need certification, and neither do the purely advisory weather services that pilots tap into via these tablets. Without the need to certify, software developers can invent and upgrade better weather services quickly and economically.

Improvements in airliner connectivity have also been made. Data can be sent quicker and more economically over internet broadband links. Honeywell's Weather Information Service, now live with several airlines, gives pilots weather data via radio or satellite broadband, explains Flight Services Director Kiah Erlich. The latest forecasts are displayed on their EFBs, as is near-real-time weather from meteorological agencies such as NOAA and the United Kingdom's Met Office. Different colors depict areas of icing danger, clear-air turbulence and cloud tops, and overhead and vertical views of difficult weather.

Triangles indicate turbulence on the Weather Company's Pilotbrief application. Lightning and radar information are also displayed.

Weather Company

Crowdsourcing

Honeywell and the Weather Company are among those pioneering a technique in which weather data gathered by leading planes is shared with those following behind them.

This crowdsourcing method fills data gaps on difficult routes. Doppler radars, for instance, depict precipitation, but because these radars are projected from the ground at an angle, their coverage doesn't extend far out over the oceans. Plus, Doppler radar coverage is limited in countries, including Mexico, and the data is confidential in China. NOAA's weather satellites observe weather patterns over oceans and foreign countries, but those images and data are meant for forecasters and do not by themselves show enough details to help pilots.

So for these kinds of routes, Honeywell's Weather Information Service displays crowdsourced data on EFBs.

The Weather Company crowdsources information too through an automatic turbulence reporting system. Product Director J.P. Gorsky estimates that this service offers the average large global carrier savings of $720,000 per year, for example, by avoiding turbulence that can injure passengers or crew. All told, he adds, costs can be reduced by $5 million a year through fewer cancellations, better customer loyalty due to improved flight experience and less preflight reporting time for pilots.

EFFICIENCY

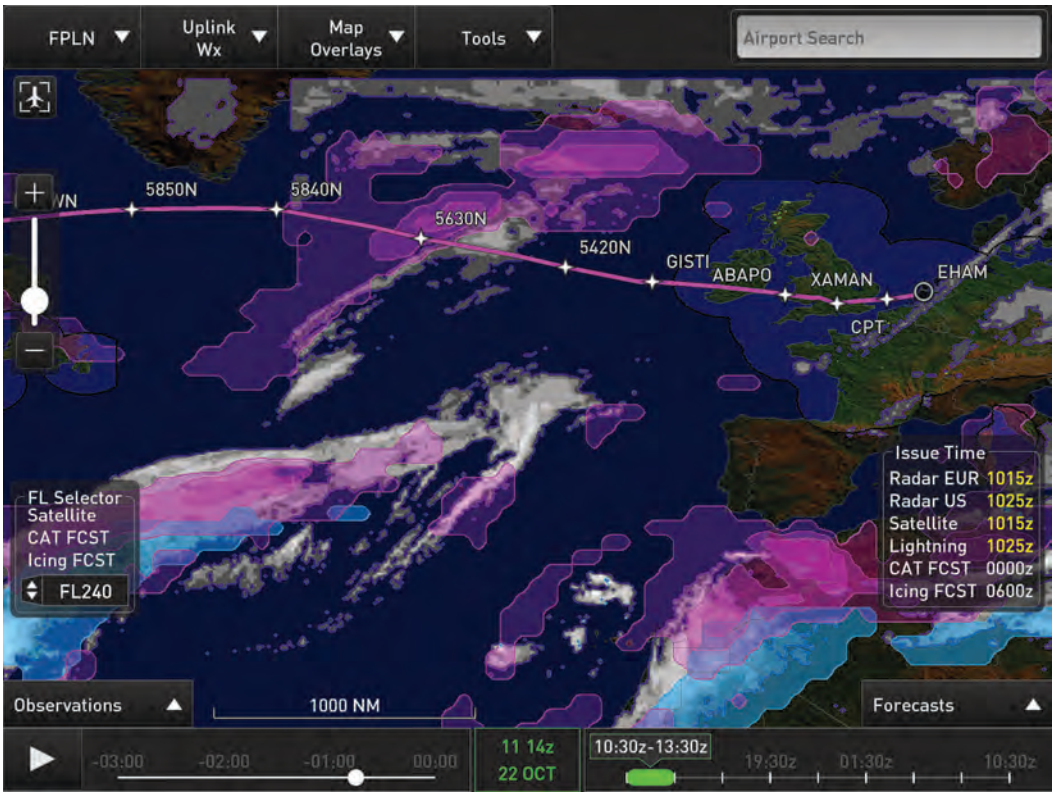
Honeywell is testing software that could improve flight management by advising pilots of the optimum altitude to save time and fuel, based on the latest wind speed and direction.

Multiple weather sources

With so much weather data and so many services emerging, one company, SITAOnAir, the Switzerland-based connectivity arm of aviation software firm SITA, has devised a service to sort it all out for customers.

Its Weather Awareness Solution offers pilots weather data from multiple providers, including Meteo France, the French government's meteorological service; France-based Schneider Electric, whose services include automated weather assessments; and the Weather Company. The SITAOnAir service can anticipate and redraw alternative flight plans, further reducing crew workload, explains Toby Tucker, innovation director for SITAOnAir. Results can be displayed on iPads, iPhones and Windows devices. Data is sent by radio or broadband connection over an Aircraft Interface Device or by connecting the pilot's electronic flight bag to cabin broadband. Customers download the application and subscribe to the service.

Approximately 20 airlines are either using or testing the Weather Awareness Solution, and about 4,000 pilots use it. The firm has added wind and temperature information for each flight level, plus the tropopause, the often turbulent boundary between the lower atmosphere and the more stable stratosphere. It also shows the isotherm for minus-70 degrees Celsius, the point where fuel icing is a concern. And the display gives information on airport headwinds, crosswinds, lightning and low ceilings.



Honeywell's Weather Information Service displays the latest forecasts on pilots' electronic flight bags, as well as near-real-time weather from meteorological agencies. This display represents information about weather on a westbound flight out of Amsterdam.

Honeywell

Some companies are pioneering a crowdsourcing technique in which weather data gathered by leading planes is shared with those following behind them.

Tucker says pilots like the ability to choose among weather providers. The service also allows pilots to share weather information if their employers agree.

Avoiding bad weather

Some vendors are adding weather to other information they provide pilots.

One of them is Germany-based Lufthansa Systems. It is preparing to overlay phenomena, such as turbulence, thunderstorms and volcanic-ash clouds, onto its pilot-charting application for EFBs. "Depiction of weather phenomena can be switched on or off and pilots can see relevant weather, flight plan and own-ship position," explains product manager Ingo Ludwig. "Pilots will not have to switch applications to use it."

Pilots can see Lufthansa's weather displays on Windows or iOS EFBs with internet connections.

Ludwig expects the main benefit to be saving time and fuel by circumnavigating bad weather earlier than is possible with onboard radar. He, too, sees gains in passenger comfort and lower maintenance costs by avoiding severe turbulence.

Lufthansa plans to deliver the new weather capability by the end of 2017 and expects most of the 80 airlines that use its pilot-charting application to adopt it.

Meanwhile, North Carolina startup WxOps has been working with Hawaiian Airlines to give pilots and dispatchers what chief operating officer Al Peterlin calls "a common operating environment" of data. This includes weather data, logistics, flight manuals, ground operations and text messages affecting flight safety and efficiency. Its software operates over broadband connectivity and will eventually work on Windows and other EFBs.

The WxOps application will include its own predictions of clear air turbulence and will offer pilots weather data from NOAA and private providers. The service has been tested on Hawaiian's Boeing 767s and will soon be tested on the carrier's Airbus A330s. WxOps will offer it to other airlines as well.

So there will be plenty of high-tech competition in this rapidly evolving weather front. ★

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AIAA Bulletin

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

Calendar

Notes About the Calendar

For more information on meetings listed below, visit our website at www.aiaa.org/events or call 800.639.AIAA or 703.264.7500 (outside U.S.).

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2017			
8–9 Jul	Emerging Concepts in High Speed Air-Breathing Propulsion Course	Atlanta, GA	
8–9 Jul	Liquid Rocket Engines: Fundamentals, Green Propellants, & Emerging Technologies Course	Atlanta, GA	
8–9 Jul	Missile Propulsion Design, Development, and System Engineering Course	Atlanta, GA	
8–9 Jul	Turbulence Modeling for Modern Industrial CFD Course	Atlanta, GA	
10–12 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – 53rd AIAA/SAE/ASEE Joint Propulsion Conference – 15th International Energy Conversion Engineering Conference	Atlanta, GA	4 Jan 17
20–24 Aug†	2017 AAS/AIAA Astrodynamics Specialist Conference	Stevenson, WA	24 Apr 17
22–24 Aug†	International Conference on Aerospace Science and Engineering (ICASE)	Islamabad, Pakistan (Contact: http://www.ist.edu.pk/icase)	
10–11 Sep	Decision Analysis Course	Orlando, FL	
11 Sep	Space Standards and Architectures Workshop	Orlando, FL	
12–14 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition)	Orlando, FL	23 Feb 17
13–16 Sep†	21st Workshop of the Aeroacoustics Specialists Committee of the Council of European Aerospace Societies (CEAS)	Dublin, Ireland	
25–29 Sep†	68th International Astronautical Congress	Adelaide, Australia	28 Feb 17
16–19 Oct†	Joint 23rd Ka and Broadband Communications Conference and 35th International Communications Satellite Systems Conference (ICSSC)	Trieste, Italy (www.kaconf.org)	8 Jun 17
13–15 Nov†	1st International Academy of Astronautics (IAA) Conference on Space Situational Awareness	Orlando, FL (www.icssa2017.com)	
2018			
6–7 Jan	5th International Workshop on High-Order CFD Methods Workshops	Orlando, FL	
6–7 Jan	Challenges and Opportunities in Aerospace CFD: Achieving the CFD2030 Vision Workshops	Orlando, FL	
8–12 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – 26th AIAA/AHS Adaptive Structures Conference – 56th AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – 20th AIAA Non-Deterministic Approaches Conference – 28th AAS/AIAA Space Flight Mechanics Meeting – 59th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – 5th AIAA Spacecraft Structures Conference – 36th Wind Energy Symposium	Orlando, FL	12 Jun 17
22–25 Jan †	64th Annual Reliability & Maintainability Symposium (RAMS)	Reno, NV (Contact: http://www.rams.org)	
3–10 Mar †	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	

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

AIAA Continuing Education offerings

AIAA Symposiums and Workshops

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
8–10 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum), Featuring: Featuring: – AIAA Missile Sciences Conference – AIAA National Forum on Weapon System Effectivenss – AIAA Strategic and Tactical Missile Systems Conference	Laurel, MD	
28–30 May †	25th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru)	
28 May–1 Jun	SpaceOps 2018: 15th International Conference on Space Operations	Marseille, France (Contact: www.spaceops2018.org)	6 Jul 17
25–29 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – 24th AIAA/CEAS Aeroacoustics Conference – 34th AIAA Aerodynamic Measurement Technology and Ground Testing Conference – 36th AIAA Applied Aerodynamics Conference – AIAA Atmospheric Flight Mechanics Conference – 10th AIAA Atmospheric and Space Environments Conference – 18th AIAA Aviation Technology, Integration, and Operations Conference – AIAA Flight Testing Conference – 9th AIAA Flow Control Conference – 48th AIAA Fluid Dynamics Conference – 12th AIAA/ASME Joint Thermophysics and Heat Transfer Conference – AIAA Modeling and Simulation Technologies Conference – 19th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference – 49th Plasmadynamics and Lasers Conference	Atlanta, GA	9 Nov 17
3–6 Jul †	ICNPAA-2018 - Mathematical Problems in Engineering, Aerospace and Sciences	Yerevan, Armenia (Contact: http://www.icnpaa.com)	
9–11 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – 54th AIAA/SAE/ASEE Joint Propulsion Conference – 16th International Energy Conversion Engineering Conference	Cincinnati, OH	
19–23 Aug †	2018 AAS/AIAA Astrodynamics Specialist Conference	Snowbird, UT (http://www.space-flight.org)	
27–29 Aug	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition) Featuring: – AIAA Complex Aerospace Systems Exchange	New Orleans, LA	

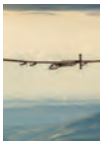
RECOGNIZING TOP ACHIEVEMENTS - AN AIAA TRADITION

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 and more connected, accessible, and prosperous. Today, AIAA congratulates the following individuals and teams who were recognized between April 2017 and June 2017.

AIAA Aeroacoustics Award
Dimitri Papamoschou
Professor, Mechanical and Aerospace Engineering
University of California, Irvine

AIAA Aerodynamic Measurement Technology Award
Joseph Schetz
Fred D. Durham Endowed Chair
Virginia Polytechnic Institute and State University

AIAA Aerodynamics Award
John A. Benek
Director, Computational Sciences Center
Air Force Research Laboratory



AIAA Aircraft Design Award
Solar Impulse Aircraft Design Team
Sebastien Demont, Robert Fraefel, Peter Frei, Ralph Paul, Hannes Ross, and Thomas Seiler

AIAA Chanute Flight Test Award
Lt. Col. William R. Gray III
U.S. Air Force (retired)
Chief Test Pilot
U.S. Air Force Test Pilot School

AIAA Distinguished Service Award
Robert C. Winn
Chairman of the Board, Principal and Director—Aviation
Engineering Systems Inc.

AIAA Foundation Educator Achievement Awards

Kathy Biernat
5th – 8th Grade Science Teacher
Saint Mary's Visitation School

Tracey L. Dodrill
7th Grade Science
Middle School STEM Teacher
Cocopah Middle School

Alexandra Kindrat
Educator & Educational Researcher
Saint Thomas High School
Lester B. Pearson School Board

David A. Root
Applied Technology Teacher/Certified Flight Instructor
Lyons Township High School
Embry-Riddle Gaetz Aerospace Institute

Kevin L. Simmons
Science Educator
The Weiss School
Founder, BLUECUBE Aerospace

AIAA Foundation Award for Excellence
NASA Langley Research Center
Award accepted by David E. Bowles,
NASA Langley Research Center Director

AIAA Fluid Dynamics Award
Miguel R. Visbal
CFD Technical Advisor
Air Force Research Laboratory

AIAA Ground Testing Award
Dan E. Marren
Director, AEDC White Oak Site
Arnold Engineering Development
Complex (AEDC)

AIAA Hap Arnold Award for Excellence in Aeronautical Program Management
Robert A. Arbach
Program Manager, Defense Advanced
Research Projects Agency
President, Arbach Consulting, LLC

AIAA International Cooperation Award

Melissa B. Rivers
Research Aerospace Engineer
NASA Langley Research Center

John C. Vassberg
Technical Lead
BCA Advanced Concepts/Design Center
The Boeing Company

Richard A. Wahls
Strategic Technical Advisor
Advanced Air Vehicles Program
NASA Langley Research Center

AIAA Otto C. Winzen Lifetime Achievement Award
Erich Klein
Balloon Engineer Specialist (retired)
Columbia Scientific Balloon Facility

AIAA Plasmadynamics and Lasers Award
Valentin A. Bityurin
Head of Div. for Plasmadynamics and
MHD Energy Conversion (Retired)
Joint Institute for High Temperatures
Russian Academy of Sciences

AIAA Public Service Award
Maj. Gen. Charles F. Bolden Jr.
U.S. Marine Corps (retired)
Former NASA Administrator

AIAA Reed Aeronautics Award
Edward M. Greitzer
H.N. Slater Professor of Aeronautics
and Astronautics
Massachusetts Institute of Technology

AIAA Sustained Service Award
Richard A. Wahls
Strategic Technical Advisor
NASA Langley Research Center

AIAA Theodor W. Knacke Aerodynamic Decelerator Systems Award
Elsa J. Hennings
Senior Systems Engineer
Naval Air Warfare Center
Weapons Division

AIAA Thermophysics Award
Bruce L. Drolen
Senior Technical Fellow (retired)
Chief Engineer, Thermal Technology
Boeing Defense, Space and Security

Daniel Guggenheim Medal
(Sponsored by AIAA, AHS, ASME,
and SAE)
Walter A. Vincenti
Professor Emeritus of Aeronautics
and Astronautics
Stanford University

Wright Brothers Lecture in Aeronautics
Around the World with Solar Power: An Overview about the Solar Impulse Program
Solar Impulse Aircraft Design Team
Lead Lecturer: Hannes Ross

Thank You, Nominators!

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

AIAA Tennessee Section Holds Trends in Engineering Education Panel

BY TAYLOR SWANSON

In March, the AIAA Tennessee Section held a panel discussion on trends in engineering education. Panelists were Dr. Amrutur Anilkumar from Vanderbilt University; Prof. Wayne Johnson of Tennessee Technological University; Prof. Matthew Mensch of University of Tennesse, Knoxville; Prof. Trevor Moeller of University of Tennessee Space Institute; and Michael Glennon of Arnold Engineering Development Complex (AEDC). Dr. Taylor Swanson, also of AEDC, moderated the panel and asked several questions before inviting questions from the audience.

Several common themes emerged in the discussion. Engineering education has changed greatly, not just over a long time, but in recent years. Four years of undergraduate school are not enough to teach all that is desired: technical competencies inside and outside the major, nontechnical skills including interpersonal and business, and interdisciplinary knowledge. Many of those come later in graduate school, through student design groups, or real-world experience acquired on the job. There is no substitute for experience. Many engineering colleges require internships or co-ops to graduate. Students from the current generation are digital natives, but frequently lack real-world skills. They can program apps and use computers, which are both relevant to an increasingly computerized world, but the fundamentals of dynamics, solid and fluid mechanics, circuits, etc., will never disappear.

Barriers between majors are eroding and the traditional structure of discipline-specific majors may soon change into a track system where students can select tracks currently categorized into different majors. One example given is how electrical engineering interfaces with mechanical and aerospace. Electrical engineering students with an interest in robotics or mechatronics might want to take mechanical engineering courses, but those are not required, nor do they fit, in the electrical engineering undergraduate program. However, a new paradigm may be possible in which a student may take an electronics track and a mechanical design track for his undergraduate program.

Barriers between majors are eroding and the traditional structure of discipline-specific majors may soon change into a track system where students can select tracks currently categorized into different majors.

Student design and other activities develop technical and nontechnical skills highly sought by employers. However, members of this generation tend not to be joiners of groups, like student design groups or professional societies, out of a sense of responsibility or for the desire simply to belong to a group. Students instead only get involved to fulfill a perceived need and then leave once that need is met. As a result, participation in professional societies is decreasing. In addition, the need for networking is filled by online groups and other avenues, and the need for design/team involvement is filled through senior year capstone projects. One possible solution to combat the trend in professional society decline is for faculty to emphasize employers' desire to see leadership skills through professional society involvement and for recent graduates to promote societies also.

Questions from the audience were wide ranging and included the hypersonics race with China paralleling the Cold War space race with Russia, preparedness of graduates for careers, and the decreasing number of undergraduate students who take the Fundamentals of Engineering exam in preparation for Professional Engineer licensure. The event was informative and well received by those in attendance and the panelists enjoyed participating.

AIAA Publishes New Book on Aircraft and Rotorcraft Flight Control Systems

Research engineers from the U.S. Army's Aviation and Missile Research, Development, and Engineering Center (AMRDEC) and Universities Space Research Association (USRA) have written a new textbook to advance the understanding of aircraft and rotorcraft flight control systems titled *Practical Methods for Aircraft and Rotorcraft Flight Control Design: An Optimization Based Approach*, and published by AIAA.

The six authors compiled their extensive experience and lessons learned into a comprehensive and practical resource for academia and professional flight control engineers. The textbook is a product of years of research, software development, algorithm improvements, desktop design, piloted-simulation and flight-test studies, according to AIAA Associate Fellow Dr. Mark B. Tischler, AMRDEC Senior Technologist for flight control technologies, and the lead author.

A central theme in the book is flight control design using multi-objective parametric optimization to directly meet a large number of competing design specifications. "The key advantage of this approach is that the designer chooses an appropriate control system architecture based on the system requirements and airframe capabilities," Tischler said.

Researchers at AMRDEC's Aviation Development Directorate (ADD) at Moffett Field, CA, were inspired to write the book after conducting several short courses and publishing numerous conference papers. They realized that communicating their key advances in an integrated book was the best way to advance the state of the art of flight control technology for both students and professional engineers.

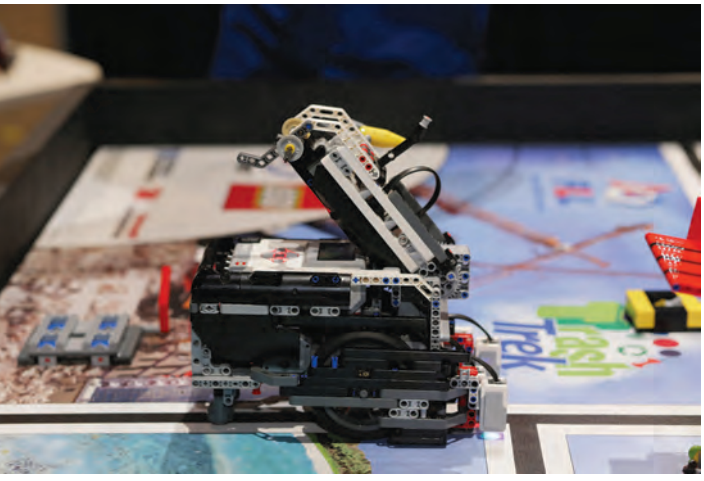
In collaboration with USRA under the NASA Academic Mission Services contract, ADD developed a modern integrated software tool that addresses these technical flight control challenges. This tool, the Control Designer's Unified Interface, or CONDUIT®, is a state-of-the-art flight control design and optimization tool that allows the user to rapidly evaluate and optimize designs against relevant performance specifications and design criteria. CONDUIT is used throughout the book to illustrate the design algorithms for both simple and complex case studies. The book contains student excercises for classroom or self-learning use and comes with a student version of the CONDUIT software.

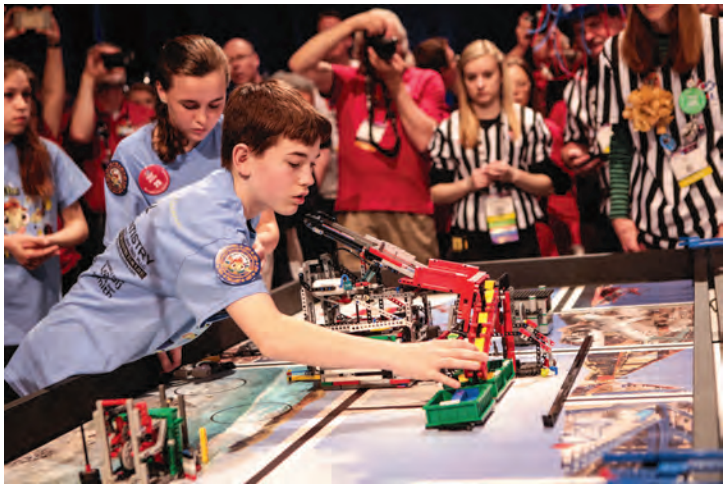
The release of this book coincides with major new flight vehicle programs such as the Joint Multi-Role (JMR) Technology Demonstrator, Future Vertical Lift (FVL), and Future Tactical Unmanned Air Systems (FTUAS), all highly dependent on high performance flight control systems, which can be advanced through the methods and guidelines detailed in this textbook. For more information, or to order the book, please visit https://arc.aiaa.org/doi/book/10.2514/4.104435.

News

Introducing: AIAA Foundation *FIRST*® LEGO® League Grant Program!

To encourage and support AIAA members who coach middle school students in STEM subjects, The Boeing Company has generously provided grant funding for AIAA member-led teams participating in *FIRST*® (For Inspiration and Recognition of Science and Technology) LEGO® League. Teams can receive up to $500 to offset costs of participating in the program. Learn more about the program and submit your grant application at **aiaa.org/FIRSTGrants**. Hurry! Deadline to apply is 1 August 2017.





A Section within an Aerospace Hub

BY DR. AMIR S. GOHARDANI, CHAIR, AIAA ORANGE COUNTY SECTION

Young Professionals (YPs) and Career and Workforce Development represent two of the distinct areas that the AIAA Orange County (OC) Section has most recently concentrated on. As a section within an aerospace hub in Southern California, engaging with YPs is essential as such efforts translate to new career opportunities for students and enable a smoother transition for their entry into the aerospace workforce. Moreover, Career and Workforce Development efforts engage the entire aerospace workforce to actively excel in their respective professions. During 2016–2017, Chase Schulze, section chair, shared similar visions with other council members to focus on the aforementioned areas.

A Distinct Young Professionals Activity

The section noticed the need for a YP event at the AIAA California State University, Fullerton (CSUF) Student Branch. In November 2016, an event was held to foster engagement between industry and the young professional community. A panel of mid-career engineers—including Daniel Tompkins, 2016–2017 YP section officer, and Chase Schulze—was assembled from The Boeing Company and Systems Technology Incorporated to visit CSUF. The panel focused on the transition from university to industry with six aerospace engineers answering questions on topics related to work/life balance, a normal day in the aerospace industry, and strategies for job applications and job hunting, as well as career development. The overall feedback from the event was positive and CSUF believes that it helped to excite students about a career in aerospace.

A Career and Workforce Development Database

In another effort to support career and workforce development, Martin Bayer, 2016–2017 Career and Workforce Development section officer, enabled a Specific Job Tool that is available on the section's website (https://info.aiaa.org/Regions/Western/Orange_County/Job%20Search%20Tools/Forms/AllItems.aspx). This tool represents a database structured into three tabs. The first tab is a listing of potential employers in the aerospace sector within the state, with the focus on organizations that perform at least some level of systems engineering and integration. Most companies herein are located in Southern California. The second tab lists organizations and resources that may help in a job search, such as employment and staffing agencies, recruiters, and job websites, while the third tab links to other aerospace company listings that include "nuts and bolts" manufacturers. (The listing of companies included in the Job Tool is not an endorsement by the AIAA OC Section.)

The AIAA OC Section looks forward to continuing its efforts to engage YPs and in taking additional steps for Career and Workforce Development.

TOP: Orange County Council members at an AIAA OC event (left to right): Bob Welge, Martin Bayer, and Gene Justin.

BOTTOM: Chase Schulze.

AIAA SSTC–STTC STEM Teacher Grant Program Helps Teachers Stimulate Students' Imagination

Since 2010, the AIAA Space Systems Technical Committee (SSTC) and Space Transportation Technical Committee (STTC) have partnered to award grants to K–12 STEM teachers through a nationwide competitive process, providing STEM resources to stimulate student imagination and confidence. For the 2016–2017 school year, five $500 grants were awarded, made possible through donations from NASA Alumni League Johnson Space Center Chapter; Special Aerospace Services, Inc.; Analytical Mechanics Associates, Inc.; Stellar Solutions Foundation; and Space Transportation Technical Committee. This year's winning teachers all used robotics to give students motivation and foundational skills for careers in science and engineering.

Georgia Paul's Pioneer Elementary School students programmed Sphero and Ozobot robots for tasks such as map following and operation on various terrain types.

Georgia Paul, Pioneer Elementary School, Colorado Springs, Colorado – Ms. Paul's 3rd–5th grade students used Sphero and Ozobot robots to learn the fundamentals of engineering design: Ask, Imagine, Plan, Create, and Improve. Students learned about optical sensors, calibration, coding, fixing problems, and real-life applications for robots. They programmed Sphero robots to perform various maneuvers, navigate a maze, and operate on different terrain types, developing geometry, engineering, science and computer programming concepts. They used Ozobots to develop logical reasoning and coding skills through the premise of tiny robots following code on a map. A writing component accompanied each coding task to reinforce understanding and address grade level standards of English/Language Arts communication. The AIAA grant directly inspired additional donations from the school principal and local Barnes and Noble for additional Ozobots and supplementary STEM materials.

Lynnea Shafter, Barbara Morgan STEM Academy, Meridian, Idaho – Ms. Shafter's 3rd–5th grade students used an EV3 robot set acquired via the grant to experience the power of building and programming robots during STEM class and as practice for after-school FIRST LEGO team activities. In class, students met the challenge of creating a robot to help with a real-world task relevant to future space or Earth exploration. They undertook design of a robot that could remove hazardous materials from a disaster site. They successfully engineered their robot to move toward, pickup, and remove hazardous waste boxes to a dump site, and then modified it to remove more than one box at a time. Students came away with improved communication, teamwork, and problem-solving skills, as well as a new level of excitement for programming and engineering opportunities.

Karin Pacot, Ellicot Elementary School, Calhan, Colorado – Ms. Pacot's students in 3rd–12th grade used six Sphero SPRK robots to learn about computer science, something previously missing from the school's STEM curriculum. Students familiarized themselves with Sphero SPRK, learned about the various programming building blocks available, and then spent time coding to address various task challenges, including maze navigation. Students built both LEGO Duplo brick mazes

and taped courses, driving themselves to experiment with different programming and testing techniques before finally all achieving successful results. In true STEM fashion, students solved problems, persevered, and worked together.

Paul McMahon, Kennedy Catholic High School, Hermitage, Pennsylvania – Mr. McMahon's students acquired a VEX EDR robotics control hardware kit, including motors, servos, and a microcontroller. This enabled students to build and exercise robots consistent with the regulations of the Boosting Engineering, Science, and Technology (BEST) competition, in which Kennedy Catholic competes. The hardware gave the students increased hands-on design and practice time, greatly improving their ability to develop and test multiple designs. It also drove them to learn more programming because each design change necessitated a different program.

Kellie Taylor, Galileo STEM Academy, Eagle, Idaho – Ms. Taylor's students in K–8th grade worked with LEGO WeDo 2.0 robotics hardware and software in the school's elementary engineering laboratory and weekly "makerspace" forum. Students worked individually and collaboratively in small groups on building and programming robots, with emphasis on critical thinking and problem-solving skills. The materials provided by the grant allowed each student more hands-on time with robotic kits and programming than in previous years, making it easier to achieve the goal of engaging students in STEM.

The technical committees are now gearing up for the 2017–2018 grant cycle. For more information about supporting this rewarding program please contact John Bloomer at aiaa.k12stemteachergrants@gmail.com.

Recent AIAA St. Louis STEM Outreach

The AIAA St. Louis Section recently organized a Science Night at Hawthorn Elementary in St. Peter's, MO. Volunteers spent helped over 40 children and their families design and build their own long-span wing inspired by Boeing's Phantom Eye. The event included a a short presentation and hands-on demonstrations to help the students understand the concepts of load paths and drag. The kids had a great time experimenting with how additional load paths would allow for a longer and stronger wing.

The section members also organized an activity with YES (Youth Exploring Science), a program that works with 250 underprivileged teenagers throughout the course of their high school career, providing them with an inquiry-based learning environment that focuses on science, mathematics, and technology. Volunteers spent the morning speaking about their career paths, giving a lesson on satellites and solar array deployment, and leading a design challenge in which the teens had to build their own 6-x-6-inch satellite model that included self-deployable solar arrays (out of typical household materials) that would fit inside a 9-inch diameter rocket fairing.

AIAA STEM Resources

The K–12 STEM Outreach Committee would like to recognize outstanding STEM events in each section. Each month we will highlight an outstanding K–12 STEM activity; if your section would like to be featured, please contact Supriya Banerjee (1Supriya.Banerjee@gmail.com) and Angela Diggs (Angela.Spence@gmail.com).

Are you a STEM enthusiast? Are you looking for new STEM lessons to excite your students? Are you ready to trade in your "tried and true" STEM lesson for some new ideas? If you answered yes to any of these questions, we have a resource for you!

The STEM K–12 Committee, with creative direction from AIAA Associate Fellow Dr. John Fay, has been working hard to develop easily digestible STEM lessons focused on aerospace principles. The Micro-Lessons are broken into grade levels, with specific instructions appropriate for grades K–2, 3–5, 6–8, and 9–12. The lessons range from engineering, to mathematics, to physics, to highlighting aerospace anniversaries. They are specifically written to spark conversation and interest in aerospace. A few of the lessons are highlighted:

Living in Space – This lesson challenges students to consider how humans survive in space. Video links and focused questions are provided to engage each grade level in critically thinking through how we can survive in space.

Asteroids and Dinosaurs – This lesson engages students in considering a few aspects of asteroid impacts and near misses. What if the asteroid that hit near the Yucatan Peninsula 65 million years ago and killed the dinosaurs had been a near miss instead?

How Do Airplanes Fly – Help students explore airflow and Bernoulli's principle to understand how airplane stay in the air!

How Long is a Year? – 365 ¼ days, right? This lessons allows students to explore the concept of time, understanding that calculating a more accurate answer may be very simple, or very complicated!

Metric Units of Measurement – This lesson explores how we have defined standard units through the ages and proposed changes.

Antoine de Saint-Exupéry – Best known in some circles for his book, The Little Prince, he also wrote about aviation. This lesson allows students to explore some of de Saint-Exupéry's accomplishments.

Want to know more? Please check out the Aerospace Micro-Lessons on the AIAA website at **http://www.aiaa.org/MicroLessons**.

Obituaries

AIAA Fellow Blottner Died in May

Dr. Frederick G. Blottner, age 84, passed away on 15 May.

Dr. Blottner attended Virginia Polytechnic Institute for his B.S. and M.S. degrees in Aeronautical Engineering and obtained his Doctorate in Engineering Mechanics from Stanford University. He spent 42 years as a research scientist at Sandia National Laboratories.

Dr. Blottner was an active member of AIAA. He was part of the Computational Fluid Dynamics Technical Committee in 1997 and was a member of the Publications Committee from 1986 to 2003. He was awarded the 2002 Thermophysics Award, and in 2005, he was recognized with an AIAA Sustained Service Award for his "five decades of outstanding and sustained service to AIAA's Regional, technical and publication activities."

AIAA Fellow Wu Died in May

Long-time AIAA Greater Huntsville Section member **Dr. Shi Tsan Wu** died on 21 May.

A native of China, Dr. Wu did his undergraduate work at the National Taiwan University, Taipei, Taiwan, in 1955 after which he traveled to Chicago to complete his M.S. in Mechanical Engineering at the Illinois Institute of Technology. He completed his Ph.D. in 1967 at the University of Colorado at Boulder. He also spent two years at the Division of Engineering and Applied Physics of Harvard University and the Plasma Laboratory of Princeton University

He started his career as an Assistant Research Professor in Mechanical Engineering at University of Alabama in Huntsville (UAH) in 1967. He became a Professor in Mechanical Engineering at UAH in 1972. Dr. Wu founded the Center for Space Plasma & Aeronomic Research at UAH in 1986, and served as its Director until his retirement in 2005. He continued his research after retirement as a Distinguished Professor Emeritus at UAH.

A member of AIAA since 1967 and a long-time member of the Plasmadynamics and Lasers Technical Committee, Dr. Wu received many honors and awards including the Greater Huntsville Section's Hermann Oberth and Martin Schilling awards.

He also received the 1996 AIAA Plasmadynamics & Lasers Award and the 2006 AIAA James A. Van Allen Space Environments Award.

The Professor Shi Tsan Wu Memorial Scholarship has been set up at the University of Alabama in Huntsville; online donations can be made at www.uah.edu/giving.

AIAA Senior Member Lundquist Died in June

Long-time AIAA Greater Huntsville Section member **Dr. Charles A. Lundquist** died on 3 June. He was 89 years old.

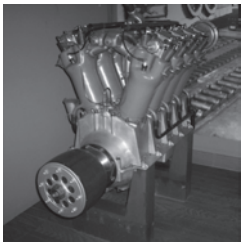
Dr. Lundquist graduated from South Dakota State University (1949) and then completed a Ph.D. in physics from the University of Kansas in 1953. He then accepted a position as an assistant professor of engineering research at Pennsylvania State University before being drafted into the U.S. Army in 1954.

He was sent to work at the Army missile development activity at Redstone Arsenal, which began his professional association with the Wernher von Braun team. He returned to civilian status in 1956, but continued to work at Redstone for the Army until 1960 when the Army rocket team transferred to NASA as the Marshall Space Flight Center. Dr. Lundquist was called to leave Huntsville from 1962 to 1973 to be the Assistant Director for Science at the Smithsonian Astrophysical Observatory in Cambridge, MA, but continued his close association with NASA where he was a member of the NASA Group for Lunar Exploration Planning that informed the Apollo missions. In 1973, he returned to NASA Marshall as the Director of the Space Sciences Laboratory.

In 1981, he retired from NASA and joined the University of Alabama in Huntsville (UAH) where he served in several research positions until his retirement from UAH in 2000. In 2014, Dr. Lundquist authored a book, entitle Transplanted Rocket Pioneers, which is about the 218 immigrants who helped make up the Operation Paperclip team of Dr. Wernher von Braun.

Dr. Lundquist joined AIAA in 1970. He received the Great Huntsville Section's Hermann Oberth Award in 1978 for contributions to the advancement of the astronautical sciences. He was also a member of a member of the American Association for the Advancement of Science, the American Astronomical Society, and the American Geophysical Union, among others.

1917



July 4 Manufacturers deliver the first Liberty 8 aircraft engine to the U.S. Bureau of Standards for testing. David Baker, **Flight and Flying: A Chronology**, p. 99.

July 6 German ace Manfred von Richthofen — the "Red Baron" — is shot down and severely wounded in combat against British F.E.2ds. Richthofen returns to combat in three weeks. David Baker, **Flight and Flying: A Chronology**, p. 99.

July 27 A British de Havilland DH-4 aircraft arrives in Dayton, Ohio, to serve as a model for the volume production of this light bomber by the United States. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, pp. 6-7.

Aug. 2 Royal Naval Air Service pilot Squadron Leader E.H. Dunning makes the first landing of an aircraft on a moving ship. David Baker, **Flight and Flying: A Chronology**, p. 100.

1942

July 3 A U.S. Navy PBY-5A flown by Lt. Cmdr. J.H. Hean makes the first airborne test-firing of a U.S. rocket at Goldstone Lake, California. The rocket is designed to be fired aft with a velocity equal to the forward velocity of the plane so that it will fall vertically. **United States Naval Aviation, 1910-1980**, p. 117.

July 4 The U.S. Army Air Forces conducts its first bomber mission over Europe in World War II. The American crews fly Royal Air Force Douglas Boston aircraft and attack German-held airfields in the Netherlands. Roger Freeman, **The Mighty Eighth**, pp. 9-10.

July 18 The German Messerschmitt Me 262 turbojet fighter flies for the first time, concluding a series of tests begun in May. The Me 262 eventually enters service in April 1944 and immediately demonstrates its superior speed and firepower over its Allied opponents. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-1960**, p. 44; J.R. Smith and Antony Kay, **German Aircraft of the Second World War**, p. 535.

Aug. 5 General of Aviators Hermann von der Lieth-Thomsen, the creator and first and last chief of staff of the old Imperial German Air Force, dies at age 75. **The Aeroplane**, Aug. 14, 1942, p. 177.

Aug. 7 The U.S. Army Air Forces conducts its first World War II heavy bomber attacks in Western Europe when Boeing B-17s are sent against the marshaling yards of Rouen-Scotteville in occupied France. Roger Freeman, **The Mighty Eighth**, p. 12.

Aug. 17 Winston Churchill flies to Moscow on a Consolidated Liberator to confer with Joseph Stalin and Averell Harriman, who is representing President Franklin Roosevelt. **The Aeroplane**, Aug. 28, 1942, p. 224.

Aug. 19 Britain and Canada carry out a major amphibious landing with large-scale air support — including Hawker Hurricanes, Hurricane fighter-bombers, Bristol Blenheims, Douglas Bostons, North American Mustangs and Supermarine Spitfires — against German gun positions and shore defenses around Dieppe, on the northern coast of France. Although the Allies lose 98 aircraft, they gain valuable experience, which they later use in the invasion of Normandy. **The Aeroplane**, Aug. 28, 1942, p. 250.

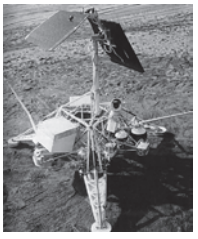
Also during August 1942

Jack Knight, the pilot who flew the first U.S. day and night transcontinental airmail service in 1921, is lent by United Air Lines to the Civil Aeronautics Administration to help accelerate pre-military training. **Aviation**, August 1942, p. 223.

1967

July 4 "Battling" Ray Parer, an outstanding figure in Australian aviation, dies at age 73. In 1920, Parer flew a DH.9 from England to Australia for the first single-engined flight between the two countries. Later that year he also won the first Victorian Aerial Derby in a DH.4, setting a record that stood for a decade. **Flight International**, July 27, 1967, pp. 122-123.

July 6 Renowned physicist Herbert Friedman of the Naval Research Lab announces that an Aerobee sounding rocket launched May 17 with Naval Research Lab instruments aboard had detected X-rays from quasar 3C-273, which is believed to be 1.5 billion light years from Earth; X-rays were also detected from Virgo A, a galaxy believed to be 30 million light years from Earth. **Washington Post**, July 7, 1967.



July 14 Surveyor 4, a soft-landing lunar spacecraft, is launched toward the moon by an Atlas-Centaur from Cape Kennedy in Florida. However, the mission fails when contact is lost 2.5 minutes before touchdown. **Flight International**, July 20, 1967, p. 118.

July 14 Harry Atwood, an associate of the Wright brothers and the first man to fly over New York City, dies at age 83 in Murphy, North Carolina. Also an inventor, Atwood developed a strong lightweight plywood in 1935 for aircraft bodies. **New York Times**, July 16, 1967, p. 65.

July 19 Explorer 35, the second Anchored Interplanetary Monitoring Platform, is launched from Cape Canaveral by a three-stage Delta rocket to study the environment in the vicinity of the moon. **Flight International**, Aug. 4, 1967, p. 197, and Aug. 24, 1967, p. 311.

July 30 The U.S. Geological Survey announces the Nimbus 2 meteorological satellite made the first observation from space of a volcanic eruption, Iceland's Surtsey volcano. **New York Times**, July 30, 1967, p. 41.

Aug. 1 Sheila Scott, Britain's top female aviator, arrives back in London in her Piper Comanche from Cape Town, South Africa, establishing a point-to-point record for light aircraft. **Flight International**, Aug. 10, 1967, p. 202.

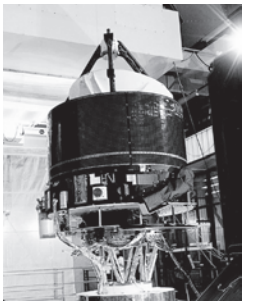
Aug. 3 Astronaut and aquanaut Scott Carpenter, a commander in the U.S. Navy, is detached from NASA at the Navy's request for assignment in its Deep Submergence Systems Project. Carpenter also participated in the Navy's Sealab 2 experiment in which he lived 62 meters under the Pacific surface for 30 consecutive days in a special capsule. NASA Release 67-49.

Aug. 7 Britain's first Polaris missile submarine, the HMS Resolution, returns to Barrow, United Kingdom, on the completion of its sea trials, which began June 22. At Barrow, the sub will undergo its final trials before being commissioned and handed over to the Royal Navy in October. **Flight International**, Aug. 17, 1967, p. 276.

Aug. 8 Scott Crossfield, the famed NACA test pilot who in 1953 became the first man to fly twice the speed of sound (Mach 2), is named the systems director of research and development for flight by Eastern Airlines. In this position, Crossfield is to help prepare the airline for its first Concorde and Boeing 2707 supersonic aircraft. **New York Times**, Aug. 9, 1967, p. 61.

Aug. 19 Hugo Gernsback, the Luxembourg-born inventor, author and publisher who is often called "the father of modern science fiction," dies in New York at 83. Gernsback also played a role in the founding of the American Interplanetary Society in 1930, later called the American Rocket Society and a forerunner of the AIAA. **New York Times**, Aug. 21, 1967, p. 29; Frank Winter, **Prelude to the Space Age**, p. 73.

1992



July 10 The spacecraft Giotto, which took the first images of Halley's comet in 1986, makes a second encounter with a comet, Grigg-Skjellerup, passing within 200-300 kilometers of its nucleus. **Flight International**, July 22-28, 1992, p. 17.

July 31 Franco Malerba is the first Italian in space when he serves as a mission specialist, representing the Italian Space Agency, on the space shuttle's STS-46 mission. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 230-231, 492, 691; **Flight International**, July 15-21, 1992, pp. 34-35.

Aug. 4 Atlantis astronauts launch the joint Italian-U.S. Tethered Satellite System 1 from the cargo bay. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 233.

Aug. 10 Kitsat 1 (also known as Uribyol 1, or Our Star) becomes South Korea's first satellite after it is launched by an Ariane booster. **Space News**, Aug. 24-30, 1992, p. 10; **Spaceflight**, July 1993, p. 246.

CHIHOON SHIN, 32

Aviation engineering investigator for helicopters, Office of Aviation Safety, National Transportation Safety Board

When an air crash involves a helicopter, aerospace engineer Chihoon "Chich" Shin inspects photos of the wreckage with his fellow experts and sometimes travels to the crash site to determine why the accident occurred. This investigative work is at the heart of the U.S. National Transportation Safety Board's mission of continually improving aviation safety.

How did you become an engineer?

I've always been enthralled with aviation and space. I always had a desire to understand how things work, which sometimes meant taking it apart without knowing how I'd put it back together. The field of aerospace engineering seemed like the right fit. After I completed high school, I attended Georgia Tech and received my undergraduate degree in aerospace engineering. After college, I worked at Naval Air Systems Command and was introduced to accident investigation within my first year there when I participated in an investigation of an H-60 helicopter mishap. The engineering side of the investigation was fascinating: trying to figure out what broke, understand why it broke, and develop solutions to problems identified during the investigation. In spring of 2012, an opportunity arose at the NTSB for a helicopter specialist in the aviation engineering division, and I'm grateful I was accepted and that I get to do work in this fascinating field full time. It's not your typical aerospace engineering work; we're not designing and manufacturing a product. My primary focus is determining whether airworthiness, design, or maintenance issues were factors in helicopter accidents and incidents. I support our investigators-in-charge by going to helicopter accident scenes, examining helicopter wreckage, and testing and disassembling suspect components. Helicopter accident investigations come with their own unique challenges, given the unique complexities that come with helicopters and the fact that a majority of helicopters lack cockpit voice recorders and flight data recorders that are key in furthering our understanding of the circumstances that led up to the accident. As I am not specialized on one helicopter model or manufacturer, but rather on investigating accidents involving different helicopter models, I have an opportunity to learn something new on a regular basis. This facet also allows me to see a variety of design and engineering philosophies across different manufacturers in the helicopter industry, from large original equipment manufacturers to smaller shops designing and manufacturing add-on equipment for specialized helicopter missions.

How do you see aviation safety evolving by 2050?

Someone once told me that our aim is to work ourselves out of a job. When I was a child, it seemed like there was a large commercial airliner crash on a regular basis. Lessons were learned, safety systems evolved, and revolutionary approaches in preventing these tragedies have resulted in a remarkable decrease in commercial airliner accidents in today's world. We haven't seen the same rate of accident decrease in the smaller aircraft world. My hope is that by 2050, we'll have better incorporation of safety enhancing technologies on all aircraft, such that there is parity in safety between a large air carrier and a small helicopter operator. ★

By Tom Risen | tomr@aiaa.com

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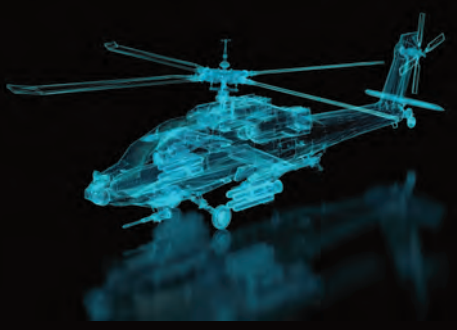
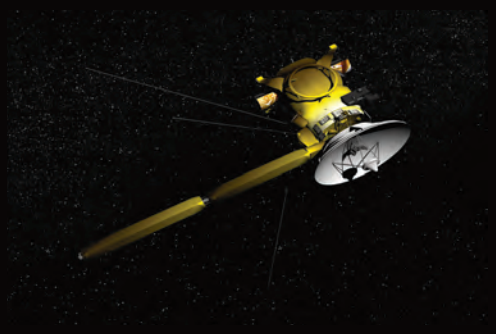

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- Propulsion Test Engineers
- Integration Engineers (Launch Vehicle)
- Systems Engineers
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- Structural Engineers

Huntsville, AL

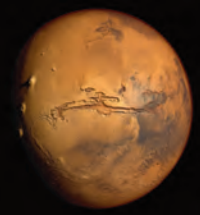
- Software Systems Safety Engineers
- Software QA Engineers
- Industrial Safety Engineers
- Systems Safety Engineers
- Quality Engineers
- Reliability Engineers

Cape Canaveral, FL

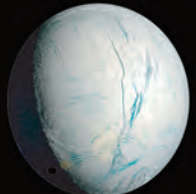
- Integration Engineers (Payloads)
- Integration Engineers (Launch Vehicle)
- Electrical (Power) Engineers
- Instrumentation Engineers
- Mechanical Engineers

Southern California (Pasadena, Hawthorne, El Segundo, Long Beach

- Thermal Engineers
- Radiation Engineers
- Propulsion Test Engineers
- Integration Engineers (Launch Vehicle)
- Integration Engineers (Spacecraft)
- Electrical Engineers (Circuit Analysis)
- Spacecraft Structural Engineers
- Mechanical Engineers
- Electromagnetic Compatibility Engineers
- EEE Parts Engineers
- Reliability Engineers
- QA Engineers & Inspectors
- Additive Manufacturing Engineers
- Environmental Requirements Engineers
- Manufacturing Engineers
- Space Environment Scientists



GALAXY TEK HIRES



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