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

ASSOCIATE EDITOR
Karen Small
karens@aiaa.org

STAFF REPORTER
Tom Risen
trisen@aiaa.org

EDITOR, AIAA BULLETIN
Christine Williams
christinew@aiaa.org

EDITOR EMERITUS
Jerry Grey

CONTRIBUTING WRITERS
Keith Button, Henry Canaday, Leonard David, Lawrence Garrett, Adam Hadhazy, Irene Klotz, Hannah Thoreson, Robert van der Linden, Debra Werner, Frank H. Winter

James "Jim" Maser **AIAA PRESIDENT**
John Langford **AIAA PRESIDENT-ELECT**
Sandra H. Magnus **PUBLISHER**
Rodger S. Williams **DEPUTY PUBLISHER**

ADVERTISING
Joan Daly, 703-938-5907
joan@dalyllc.com

ADVERTISING MATERIALS
Karen Small, karens@aiaa.org

ART DIRECTION AND DESIGN
THOR Design Studio | thor.design

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Association Vision | associationvision.com

LETTERS AND CORRESPONDENCE
Ben Iannotta, beni@aiaa.org

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IN THIS ISSUE

Leonard David

Leonard has been reporting about space for over 50 years. He is author of "Mars — Our Future on the Red Planet" and co-author with Apollo 11's Buzz Aldrin of "Mission to Mars — My Vision for Space Exploration."

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Irene Klotz

Irene has covered space for 30 years, with particular focus on commercial space and the search for life beyond Earth. She joined Aviation Week & Space Technology in July.

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Henry Canaday

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

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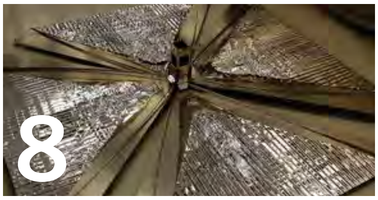
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High-impact research

▲ A research team at Penn State University **suspended a droplet in midair** with acoustic waves created by an ultrasonic levitator during a test examining the causes of aircraft engine icing.
Penn State University

Every day, high-stakes work plays out in labs and test chambers across the aerospace community that doesn't always get much visibility. Sometimes, that's the way technologists want it for classification or proprietary reasons. More often, I suspect, it comes down to corporate culture and personality. I sometimes wonder if reusable rocketry might have continued to languish were it not for the strong personality and Twitter feed of Elon Musk, the SpaceX founder.

The reality is that not all companies and agencies have a Musk at the helm. That doesn't mean that their work is not potentially impactful. If you look at our cover story and beyond, you'll sense our efforts bring that work to light.

A case in point is the Penn State team that devised a technique for imaging partially melted ice crystals, the subject of this month's Engineering Notebook. It would have been tragic if an airliner crashed someday because no one figured out how to fully study the physics of the partially melted crystals that cause this phenomenon. This imaging technique can't solve the problem by itself, but it will be a great help.

Then there's the CanX-7 satellite mission, described in our Trending section. In one 3.6 kilogram package, these researchers managed to take on two hugely important issues. They tested a drag sail technology that could prevent small satellites from becoming dangerous hunks of debris, and they demonstrated an alternative strategy for collecting identity and location information transmitted by aircraft. More fundamentally, CanX-7 proves that the semantic boundaries are breaking down between what constitutes a space technology versus an aviation one and the kinds of services that can be expected from a small satellite compared to a large one.

In the realm of space exploration, so much of the community is excited about the prospects of sending humans to Mars that it's easy to forget that the NASA-funded Jet Propulsion Lab is working on the next robotic rover, Mars 2020, patterned largely after the Curiosity rover. If that team achieves its goal of gathering rock samples and covering more ground than Curiosity, its work could be a testimony to the power of improved algorithms and processing.

In fact, I can imagine a fiscally disciplined NASA freezing the physical designs of space probes and rovers to meet what's required to explore a small set of specific destinations, whether a rocky planet like Mars or an icy moon shielding an ocean. New scientific discoveries could be achieved by tailoring the software and processors on the next iterations of these probes and rovers.★

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


COVER STORY | 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.

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Electric plane viability

As an accomplished engineer and long-time AIAA member, I was disappointed to say the least, when I read July/August's Aerospace America cover article, "Fly the Electric Skies." The article dreamily speculates that battery/electric propulsion is the wave of the future without any supporting evidence. It has no technical content whatsoever, yet the subject screams for it.

First of all, let me say that I am an electric skeptic. There are huge problems in competing with hydrocarbon energy in every sector of energy use. Aerospace is perhaps the most difficult discipline for electric because of the tremendous importance of weight. But I would be glad to read an article that presents the real issues and provides evidence for any reasonable alternatives.

For example, this article could have discussed the weight challenge — where do batteries stand compared to current fuels in energy-to-weight comparisons? What threshold do they need to achieve to create a viable product? There are other demands, as well, that aren't even discussed in the article. The high pressure produced by gas turbines powers airliner Environmental Control Systems — how will electric aircraft cool/heat the cabin, and how does the added weight affect the concept viability? Hydraulics are used for heavy lifting like landing gear and flaps — is there an electric alternative that doesn't introduce unacceptable weight penalties? The airport economics are important, as well. The hub-and-spoke model didn't just develop because of special interest influences — there are real economic benefits to that approach, as there are economic issues with a more distributed regional system. Delving into this topic quantitatively, instead of presenting only qualitative inconvenience issues with hub-and-spoke, would be extremely informative to all of us. The whole article seems to lack objectivity, and just as importantly, any meat.

I realize that Aerospace America is not an AIAA journal. But that doesn't mean it should contain only the fantasies and whims of someone who has a vested interest in seeing them funded. ★

Torger J. Anderson
AIAA associate fellow
Alexandria, Virginia
torg_anderson@hotmail.com

CORRECTIONS

The graphic on Page 26 of the June issue incorrectly described the sequence of events in the 2002 collision between a Bashkirian Airlines jet and a DHL cargo plane. It was the Bashkirian Airlines cockpit crew that followed air traffic controller instructions rather than the TCAS 2 advisories, leading to a collision with the DHL aircraft.

In the caption on Page 4 of tPhe June issue, we incorrectly described the wreckage of a Lockheed L-1049 as a jet. The L-1049 Constellations are propeller planes produced through 1959.

Errors have been corrected in the online versions.

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17-1967

Pipistrel

The Shift to Electric Propulsion

With the advent of the Airbus A380, Airbus A350, and Boeing 787, large civil transports are evolving into increasingly more electric aircraft and platforms that use high levels of electric power for onboard systems. The electrical system produces, conditions, and distributes power to all of the other systems that need it—flight deck displays, flight controls, in-flight entertainment, and more. The power demand on a modern twin-aisle aircraft is now in the megawatt range. This ever-increasing demand requires onboard power generation solutions in addition to engine-mounted generators. The Boeing 787, for example, makes use of two lithium-ion batteries, one for its auxiliary power unit and a second to turn on its flight deck computers.

Despite the shift occurring in large commercial aircraft, electric propulsion is more strongly emerging in general aviation, i.e., personal-sized aircraft. The Pipistrel Taurus G4, the first all-electric four-seat aircraft, is a perfect example of this trend. In addition, electric propulsion development is underway for the commercial class of transports for the thin-haul sector, although this technology is still in its formative stages. In the July/August issue of *Aerospace America*, an article by Adam Hadhazy entitled "Fly the Electric Skies: Reinvigorating Short-Haul Flight with Hybrid-Electric Aircraft" outlines the state of the art of the technologies that are making electric propulsion a reality. For large civil transports, most planners and analysts forecast a lengthy time frame (decades) before hybrid electric propulsion (HEP) or electric propulsion (EP) solutions could become technically feasible. In any event, given the current interest in HEP and EP technologies, ranging from small aircraft to large aircraft, it is not surprising that many companies and organizations are executing robust research and advanced development programs in this area.

So why the interest in more electric aircraft and electric/hybrid electric propulsion systems? Highly variable energy costs, concern for environmental impacts, and more stringent environmental regulations have combined to cause the aircraft industry to look at possible alternative approaches to aircraft power and propulsion systems. The industry is exploring biofuels and other alternative fuels, liquefied natural gas, hybrid electric propulsion and electric propulsion solutions, and fuel-efficient alternative architectures such as blended wing body aircraft.

Technical barriers to electric propulsion development include the management of high-voltage systems, high energy density storage solutions, and thermal issues. Research is underway to find advanced materials needed for large motors. And there are few standards for large aircraft electrical subsystems akin to the old U.S. military standards and although standards are needed, their development must be led via industry consensus.

Because of the wide-ranging impact and the integrated nature of technologies associated with more electric aircraft and electric/hybrid electric propulsion systems, not surprisingly, various communities within AIAA have an interest in these topics. AIAA has identified electric aircraft, hybrid electric propulsion, and energy for aerospace applications broadly as priority growth areas. To coordinate the needs of these communities, an Aircraft Electric/Hybrid Electric Power and Propulsion (AEPP) Working Group has been stood up to engage all interested parties from within and from outside of AIAA to benefit the aeronautics industry by helping it to make advances in EA and HEP technologies.

The Aircraft Electric/Hybrid Electric Power and Propulsion Working Group is considering a myriad of activities and is working many of the technical and non-technical issues that will need to be addressed by our industry in this area. As a first step AIAA supported a two-and-a-half-day Transformational Electric Flight Workshop & Expo at the 2017 AVIATION Forum and a three-day Aircraft Electric Propulsion and Power track at the 2017 Propulsion and Energy Forum. The working group is also organizing a panel session on standards and certification at the 2018 SciTech Forum. In addition discussions are ongoing with IEEE to organize a joint workshop at the 2018 Propulsion and Energy Forum and an IEEE mini-conference in summer 2019. To disseminate the outcomes from the workshops and other activities, summary and outbrief sessions are being organized for three AIAA forums (SciTech, AVIATION, Propulsion and Energy) with the intent of communicating data, research, and information on the status of the technologies surrounding the electric/hybrid electric aircraft and propulsion topics as well as the activities of the working group. Expect to see more electric aircraft sessions at future AVIATION Forums!

From doing energy storage requirements projections, to coordinating with sister technical professional societies such as ASME or IEEE, to standards development, to report outs on systems studies, AIAA is the technical professional society at the forefront of this transformative technology. ★

Thomas B. Irvine
AIAA Managing Director of Content Development

University of Toronto

Drag sails could counter debris

BY DEBRA WERNER | werner.debra@gmail.com

Developers of kilogram-class satellites who want to be good stewards of low Earth orbit now have some flight data to assess about drag sails as a possible means of deorbiting without the need for propellants once their missions are done.

As of Aug. 10, the four drag sail segments that sprang from the CanX-7 satellite in May had reduced the spacecraft's altitude by 5 kilometers, said Bradley Cotten, the CanX-7 project manager at the University of Toronto's Space Flight Laboratory.

Cotten, a researcher at the lab, gave a presentation at the annual Utah State University Small Satellite Conference.

As particles high in the atmosphere strike each sail segment, the force slows the 3.6-kilogram satellite slightly and forces it to sink lower. The technology could be an option for deorbiting spacecraft such as nanosatellites, defined as those weighing 1 to 10 kilograms

Each sail segment has an area of about a square meter and is made of a flexible and lightweight aluminized polyimide. The sails remained folded and stowed away inside modules during CanX-7's secondary mission, which was to demonstrate the ability of a nanosatellite to collect aircraft identity and location broadcasts.

After collecting about 4.6 million of these automatic dependent surveillance-broadcast messages over seven months, the lab sent a command to activate a heating element that melted a cord, made of the polymer fiber Vectran, that held each door closed. Strips of copper beryllium alloy wound into tape springs pushed the doors open, unfurling the segments of the drag sail around the cubesat as they unwound.

The effect on CanX-7's altitude could be seen immediately, Cotten said.

Researchers at the Toronto lab and elsewhere want to give nanosatellite builders the ability to comply with a 15-year-old rule created by the multinational Inter-Agency Space Debris Coordination Committee. The rule calls for satellite operators to deorbit their spacecraft within 25 years of the completion of their missions. Nanosatellite developers fear that if their industry does not follow the rule, governments will impose new regulations.

"This is a bolt-on solution that can go on pretty much any spacecraft in the future to allow it to meet that deorbit guideline," Cotten said.

He expects CanX-7 to burn up in the atmosphere long before the 25-year mark. That could happen in less than three years if the drag sail moves into a position perpendicular to the cubesat's orbit as expected to maximize drag. In the worst-case scenario, it could take 4.5 years. Without the drag sails, CanX-7 would succumb to atmospheric drag in about 178 years, Cotten said. ★

▲ Four drag sail segments attached to the CanX-7 satellite, shown in development, may provide a new way to remove satellites from orbit.

Space station experiment targets Parkinson's

BY ADAM HADHAZY | adamhadhazy@gmail.com

Among the new experiments launched to the International Space Station on a Dragon capsule in August was one for the Michael J. Fox Foundation, the Parkinson's disease research group established by the actor who went public with his diagnosis in 1998.

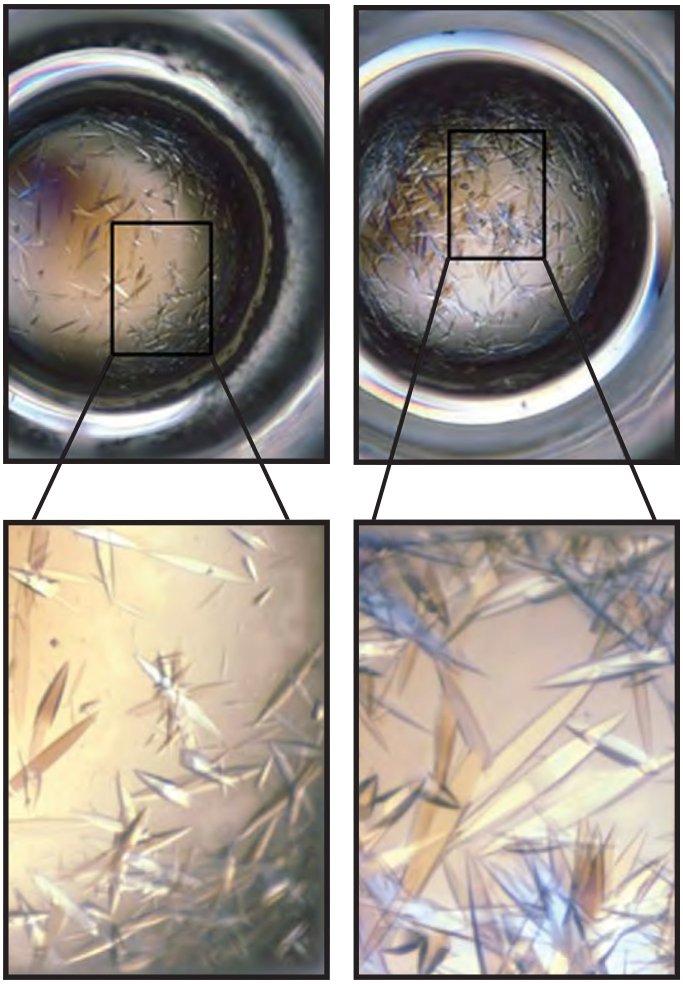
In Parkinson's disease, brain cells that produce the chemical messenger dopamine die off, with the result that patients gradually lose their ability to make coordinated movements. In a subset of Parkinson's patients, mutations in a gene, which produces a protein, can cause the disease. Researchers are searching for a drug that can bind to the faulty proteins, disabling them and potentially stop Parkinson's progression in those patients.

Growing crystals of these proteins in space could be part of the solution. The technique dates back to work in the mid-1980s aboard the space shuttle and later the Soviet-Russian Mir space station. The draw: Under Earth gravity, protein molecules in the lab become compact, clumped and difficult to study structurally. Take away that gravity, and many proteins grow larger and with more neatly ordered structure. Once back on terra firma in solid crystalline form, their structures can be imaged and studied to resolve tiny, but critical facets of their shapes.

Those insights could aid development of precision drugs that would fit lock-and-key with a protein's form, inhibiting its function and potentially treating disease. "The name of the game is finding the right conditions for growing crystals so you can get better pictures," says Michael Roberts, deputy chief scientist at the Center for the Advancement of Science in Space, which manages the ISS National Lab.

The Parkinson's protein of interest — dubbed LRRK2 ("LURK-two") — was shipped in a frozen state to the Kennedy Space Center in Florida. Bits of hardware about the size of Band-Aids, called Microlytic Crystal Former Optimization Chips, held fluidic samples of the protein in 16 tube-like channels; once thawed on orbit, the protein mixed with other chemicals that promote crystallization. After three weeks of crystal growth, 10 of the chip samples were scheduled to return to Earth in September, again aboard Dragon.

Beaming X-rays at the resulting crystals could reveal "druggable" target areas otherwise too scrunched up to visualize in terrestrially reared samples. "Drug developers can really optimize their work if they have LRRK2's atomic structure," says Marco Baptista, associate director of research programs at the Michael J. Fox Foundation. ★



Merck

▲ **Researchers need large, pure crystals of biological proteins** to help them develop treatments for Parkinson's and other diseases. These images from the pharmaceutical company Merck show the difference: Crystals grown in a conventional lab, left, are smaller than those grown aboard the International Space Station.

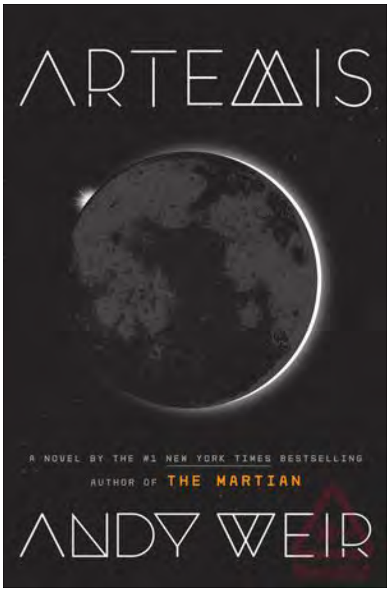
Lunar thriller

"The Martian" author Andy Weir weaves science with more complex characters living in a city on the moon.

REVIEWED BY TOM RISEN | tomr@aiaa.org

How would people breathe, eat, sleep and pass their time in a city on the moon? Who would want to live there and who could afford to vacation there? Speaking of money, what would the city do about currency and law enforcement since no one nation owns or governs the moon? Andy Weir addresses these and other questions in "Artemis," his second novel, due for release in November in the U.S. and Canada.

Weir's fascination with space propelled him to begin writing "The Martian," a hyper-realistic account of a stranded astronaut, as a free blog in 2009. He made a fortune in 2013 when the tale was published as a novel and turned into an Oscar-nominated movie of the same name. He wants to ride that success to new projects, so he has stopped working as a software engineer to be a full-time writer.



ARTEMIS
By Andy Weir

Available Nov. 14
Crown Publishing
$27 hardcover

The focus on science that propelled "The Martian" enriches Weir's second novel without getting in the way of people driving the story.

"Artemis," the name of the fictional city in the novel, continues Weir's emphasis on the science in science fiction that drove action in his first novel, but now he also blends futurism with storytelling through deeper character development.

"Artemis" is set in the not too distant future, when there is enough space commerce to support a city of 2,000 people on the moon, plus tourists who visit for weeks at a time to dance at clubs in lunar gravity or see the historic Apollo 11 landing site. Launching anything into orbit today costs about $10,000 per pound of payload, so the novel is set in a future when the cost of space transport has been driven lower and traffic of supplies and people flows regularly between Earth and the moon. For "about $70,000 in 2015 dollars," Weir told me when I interviewed him several months ago, middle-class people in the novel can take a once-in-a-lifetime vacation to Artemis for a couple of weeks, stay at a hotel, shop and support a tourist industry.

"By far the best advances that can come out of space research right now, in my opinion, are reducing the price of getting people and freight into low Earth orbit," he said.

The internet of things has also taken off in this story, so everyone has a mobile device they call a "Gizmo" that does everything ranging from opening doors to sending messages and paying for things. The moon colony of domes and tunnels has even grown to include Buzz Aldrin Park, where people play lunar gravity Frisbee on real grass near statues of Chinese moon goddess Chang'e and Artemis, the Greek goddess and the city's namesake.

That futurist vision of an international populace living on the moon permeates the book in a way that feels natural, including with its main character Jasmine "Jazz" Bashara, who was born in Saudi Arabia but moved to the moon when she was 6. Jazz is proud to call herself "an Artemisian" and "a moon gal."

Weir's portrait of the future feels realistic, perhaps because of the seeds of internationalization we've witnessed in recent years, such as when the United Arab Emirates founded the UAE Space Agency in 2014 and China sent its Chang'e 3 probe to the moon in 2013. Weir's future reflects the potential of space faring nations cooperating to achieve complex space endeavors.

It would not be surprising if Jazz and other women of color in the story inspire some readers to join a new generation of explorers and scientists. They are also heroines for everyone who's dreamed of partying on the freaking moon.

Will "Artemis" become a movie? Twentieth Century Fox, which made "The Martian," has already snapped up the movie rights for the novel. Whether those rights will be turned into a film depends on how well the book sells. That means the starring role of Jazz in this space age adventure could be a chance for an actress to inspire young women and minorities. If the film is true to the novel, it would likely need a rating of at least PG-13, given the scenes with sex, drugs and combat in lunar gravity.

Characters are more important to Weir's second book. No spoilers here, but the moon-smart Jazz and the people living in Artemis have many more shades of gray that befit a thriller set on a world covered in gray dust.

Character writing took such priority that Weir said he wrote numerous drafts with different casts of characters and he realized Jazz was the most interesting one.

The focus on science that propelled "The Martian" enriches Weir's second novel without getting in the way of people driving the story. Details about such things as welding and chemistry can still be a little distracting from important scenes, but "Artemis" shows Weir has grown by giving spotlight to rich, entertaining characters who also happen to live in the future.

One of the characters references a ballistic orbit that is key to cycling spacecraft between Earth and the moon, for instance. Weir resists the urge to send them, and by extension his readers, on a distracting tangent rich in details of trajectory planning. Conversations and musings during the narrative only scratch the surface of the future space economy and the city's domes built with materials mined, smelted and manufactured on the moon.

Weir has also written a research paper describing the details of how the economics and technology depicted in "Artemis" would work, but he will publish it separately later, because science is great but too much can bog down a story's narrative. "I didn't put it into the book because if we learned one thing from ["Star Wars: The Phantom Menace"], it's don't start a story with a description of supply-side economics," he said. ★

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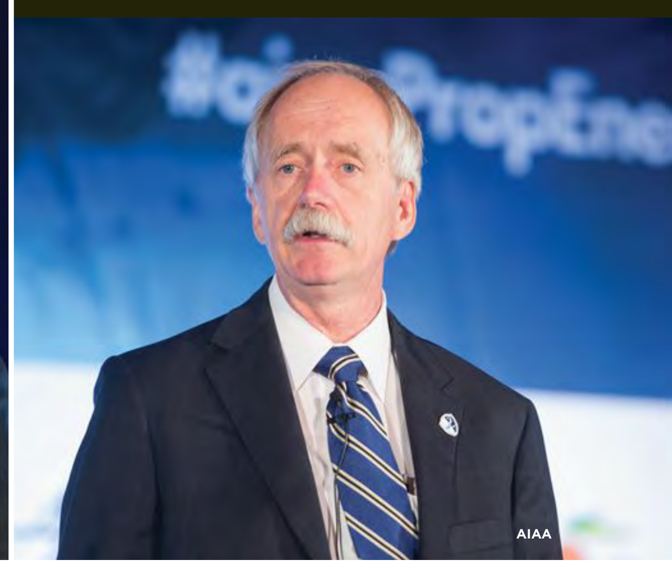
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Getting humans to Mars depends on collaboration, merging technologies

BY LAWRENCE GARRETT | lawrenceg@aiaa.org

To develop the propulsion technologies needed for a manned mission to Mars or other human deep space exploration, merging technologies and collaboration among government, private industry and academia are paramount, a panel of experts said.

Panelists in the "Space Exploration Propulsion" session agreed the key technologies that will help enable a mission to Mars are solar-electric propulsion and advancements in chemical propulsion, such as nuclear thermal propulsion.

"Whether it's electric or some form of chemical propulsion, we think all are necessary," said Steve Jolly, chief engineer for commercial civil space at Lockheed Martin.

Jolly said Lockheed considers solar-electric propulsion a "key enabler."

Darby Cooper, senior manager for integrated analysis of the Space Launch System at Boeing, said that even though solar-electric propulsion has been in operation in space for decades, stakeholders need "to scale it up in size and power to accomplish these human missions."

Cooper cited NextSTEP, which aims to advance the needed technologies for a functioning cislunar outpost, as one example and said work is also underway to design a deep space transport, a larger transfer vehicle "essentially rated for interplanetary travel." He noted that such a vehicle will require the efficiencies of a solar-electric propulsion system able to move large masses but also that possesses "a propellant ratio that will be effective."

"This technology also enables on-ramping of nuclear thermal propulsion, when that technology is mature," Cooper said. ★

▲ Darby Cooper, senior manager for integrated analysis of the Space Launch System at Boeing, said solar-electric propulsion must be scaled up in size and power to achieve a manned mission to Mars or other deep space destinations.

▶ William Gerstenmaier, associate administrator for human exploration and operations at NASA, talked about opportunities for government and commercial collaboration.

"I look at NASA kind of as an orchestrator now, where we take the best that is available from industry."

— William Gerstenmaier of NASA

NASA looks for "best available" from industry

BY TOM RISEN | tomr@aiaa.org

A growing space industry is opening opportunities for business and exploration, and NASA will play a key role by clearing a path for companies to follow, said William Gerstenmaier, associate administrator for human exploration and operations at NASA.

"NASA doesn't need to be developing all the systems, building all the hardware, doing everything," Gerstenmaier said. "I look at NASA kind of as an orchestrator now, where we take the best that is available from industry."

In the "NASA Human Space Exploration" session, Gerstenmaier reviewed NASA's goals, including the construction of the Deep Space Gateway, a spaceport the Space Launch System rocket would send into lunar orbit in pieces. Astronauts could stay at a completed gateway for a few weeks at a time, and that presence in lunar orbit could offer opportunities for companies to launch missions of their own to the moon or its orbit, he said.

Sending humans to Mars is a major goal for NASA, but Gerstenmaier said building infrastructure in deep space — like the gateway — would open opportunities to reach other destinations, including the moon, if water is discovered inside it and lunar missions become a higher priority.

"NASA has a sense of fiscal realism," he said, noting that partnerships with companies and international groups will be key to potentially sending humans to the moon or Mars on a limited federal budget.

NASA is working to open more partnerships by developing voluntary standards for equipment, he said. There is already an international standard for docking between spacecraft, Gerstenmaier said, and NASA wants to develop more such voluntary standards in areas including atmosphere pressure and voltage levels. ★


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▲ Stéphane Cueille, senior executive vice president and chief technology officer at Safran, cautioned that fully powering a large aircraft with batteries is unlikely in the near future.

▶ Doug Freiberg, an engineer at Pratt & Whitney, said engineers are involving airlines earlier in the development process.

Fully electric aviation "unlikely" in near future

BY TOM RISEN | tomr@aaia.org

Despite demand to reduce carbon emissions by researching and developing electric-powered aircraft, executives on the "Aircraft Propulsion — What Does the Future Bring?" panel said they are skeptical that projected battery technology will completely replace gas engines in aircraft.

Working on battery-powered aircraft is an admirable goal, but "we need to keep it realistic for larger aircraft," said Stéphane Cueille, chief technology officer of Safran. A fully electric Airbus A320, for instance, would be weighed down by the many batteries necessary for its engines unless there were a major breakthrough in battery power, Cueille said.

Electric energy is not pollution-free, and swapping gas-powered aviation for electric aviation right now may not produce less carbon dioxide, said Alan Epstein, vice president of technology and environment for Pratt & Whitney.

Business models will also determine the pace at which electric aviation develops. The growth of computer technology, and telecommuting, for instance, could reduce how often people fly, or they may want to fly faster and more often, said Alan Newby, director of aerospace technology for Rolls-Royce.

Newby's advice to those who work in gas turbines: "Don't hang your boots up just yet," because there is also room to optimize gas engines' fuel efficiency. The fuel demands for long-range, large aircraft are so great "it's very unlikely that with current projected battery technology" fully electric engines will completely replace gas turbines, Newby said, adding that there are opportunities for hybrid electric aviation.

Hybrid engines have near-term potential to save fuel costs, however, so Safran has done ground tests for helicopter engines that can switch between gas and electric power, Cueille said. ★

PROPULSION ENERGY FORUM

1,100
Attendees

28
Countries represented

247
Students

Aerospace engineers learn propulsion needs from end users

BY HANNAH THORESON | hannaht@aiaa.org

To help bridge the gap between the expectations of designers and the expectations of end users of complicated aerospace systems, designers could benefit by thinking more like end users.

"We have to think more like an operator to think through how this thing gets designed and maintained through its life," said Doug Freiberg, next generation product family chief engineer at Pratt & Whitney.

Panelists in the "Aircraft Propulsion: The Airline Operations and MRO Perspective" session said the gap is there because the biggest manufacturers of airplane propulsion systems are companies like GE Aviation or Pratt & Whitney — not airlines. And, Freiberg said, airlines have continually raised their expectations for ease of integrating new propulsion systems into their fleets.

"We're no longer able to just throw the engine over the wall to the maintainers," he said. "We're also getting the airlines involved sooner."

On the end-user side, Robert Schultz, director of engine maintenance at Delta TechOps, explained, "When we look at the overall design for an engine — performance, reliability — those things are always optimized. But sometimes what can be left off to the side and not focused on enough is ease of maintenance."

Shawn Gregg, general manager of propulsion engineering at Delta TechOps, highlighted another difference between designers and end users.

Research and development focuses on problems that are a decade away, he said, adding that for airline maintenance problems, "the time scale we are dealing with is right now, right at this immediate minute." ★

Tyvak Nano-Satellite Systems

Jordi Puig-Suari says propulsion is as important for small satellites as for big ones.

Assessing the boom in cubesats

In 1999, professor Jordi Puig-Suari of California Polytechnic State University and his friend Bob Twiggs, then of nearby Stanford University, devised a standard for building miniature satellites and a device to dispense them from other spacecraft. I spoke to Puig-Suari by phone about the surprising transition of cubesats from purely educational tools to potential commercial moneymakers and even interplanetary probes.

— *Debra Werner*

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JORDI PUIG-SUARI

POSITIONS: Aerospace engineering professor, California Polytechnic State University in San Luis Obispo; co-founder and chief executive of Tyvak Nano-Satellite Systems

NOTABLE: Created cubesat standard in 1999 with professor Bob Twiggs. Two cubesats built by his company Tyvak are scheduled for launch in October to carry out NASA's Cubesat Proximity Operations Demonstration. These satellites will dock with each other to show how cubesats might be assembled into structures or be sent to repair or refuel satellites. Tyvak also is building the first cubesats for interplanetary travel under NASA's Mars Cube One, or MarCO, mission. Two radio-equipped cubesats will be launched toward Mars next year to demonstrate how cubesats can relay data from a spacecraft on a planet's surface, in this case NASA's InSight Mars lander.

AGE: 51

RESIDES: San Luis Obispo, California

EDUCATION: Bachelor of Science, Master of Science and Ph.D. in 1993 from Purdue University in Indiana in aeronautical and astronautical engineering

IN HIS WORDS

Spawning a global market

[Cubesats were] truly an educational activity when we started. We probably could see the potential earlier than other people once we started to see how well some of the systems were working and what miniaturized electronics could do. But the initial endeavor was purely a way of doing simple educational satellites.

Why cubesats are so popular

The educational piece was critical because it allowed us to develop something with zero risk. It's hard to understand coming from an industrial perspective, but if we educated students, we had accomplished our goal and that did not require the satellites to work. We were flying commercial off-the-shelf components even though people said, "I don't think these things are going to work in space." Once it started working, that's when things got interesting because you had performance-to-power and performance-to-volume ratios that were completely unheard of. Suddenly, the electronics revolution applied to space, while before everybody was sticking with TRL 9 components [meaning "flight proven" on NASA's Technology Readiness Level scale].

P-POD or Poly Picosatellite Orbital Deployer

When we were working on student satellites and everybody was doing their own size and interfaces, it was hard and expensive and complicated to figure out how to fit them in a rocket. There were a lot of barriers to entry. Once that interface with the launch vehicle was clean and solved, that really helped a lot.

Why cubesats aren't a big debris problem

All the International Space Station cubesats get out of orbit in six months to a year. Out of the 600 and something that have been launched, well over 100 have been on station. Of the rest, everybody is meeting the 25-year rule and most cubesats are in orbit in the range of six, seven, eight years. Look at the Chinese missile test. Something like 3,000 objects came out of that. So we are a relatively small number. Our steady state population is not going to be that large even if we keep up the launch rate.

Cubesat Proximity Operations Demonstration

It's a very challenging mission. It's the first time that we will dock two cubesats. We will do autonomous navigation onboard the spacecraft. And we will demonstrate a spacecraft with active propulsion. As we move forward and look at these satellites working in clusters or swarms or formations, all of those technologies are going to be necessary.

Propulsion for cubesats

Cubesats are doing the same kind of things 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. Sometimes when you are a secondary payload, the launch vehicle doesn't take you where you want to go. You could take that ride and modify the orbit by using your onboard propulsion. People are talking constellations and large numbers of satellites working together in a controlled way. To deploy and maintain those constellations or swarms, propulsion really helps.

> **"If you carry propulsion [for deorbiting], then you can go to higher orbits where drag will not help you meet the 25-year deorbit rule."**

Another one is deorbit. If you carry propulsion then you can go to higher orbits where drag will not help you meet the 25-year deorbit rule. The other thing that is becoming really interesting is people are trying to send cubesats far away. People are looking at asteroid missions and lunar missions. Those all require propulsion.

Size of propulsion units

Some of the propulsion technologies that are coming out are a little big for cubesats. People will say, "I have a propulsion system that is 1u," [one that takes up a 10-centimeter cubical unit within the satellite]. That is a big chunk of my 3u spacecraft. 1u is starting to become a standard for cubesat propulsion, which for 6u and 12u is very nice. For 3u, it's a big percentage. But if you need it, you need it and you use it.

More orbits for cubesats

The cubesats have all been in low Earth orbit. There are plans to leave low Earth orbit though. Recently we've started to manifest things like Mars Cube One. That is going to fly with INSIGHT [NASA's Interior Exploration using Seismic Investigations, Geodesy and Heat Transport] in 2018. The Space Launch System has a few Earth-escape lunar missions on the manifest. There are people talking about sending cubesats to geosynchronous transfer orbit to do radiation experiments and other things.

Pace of progress

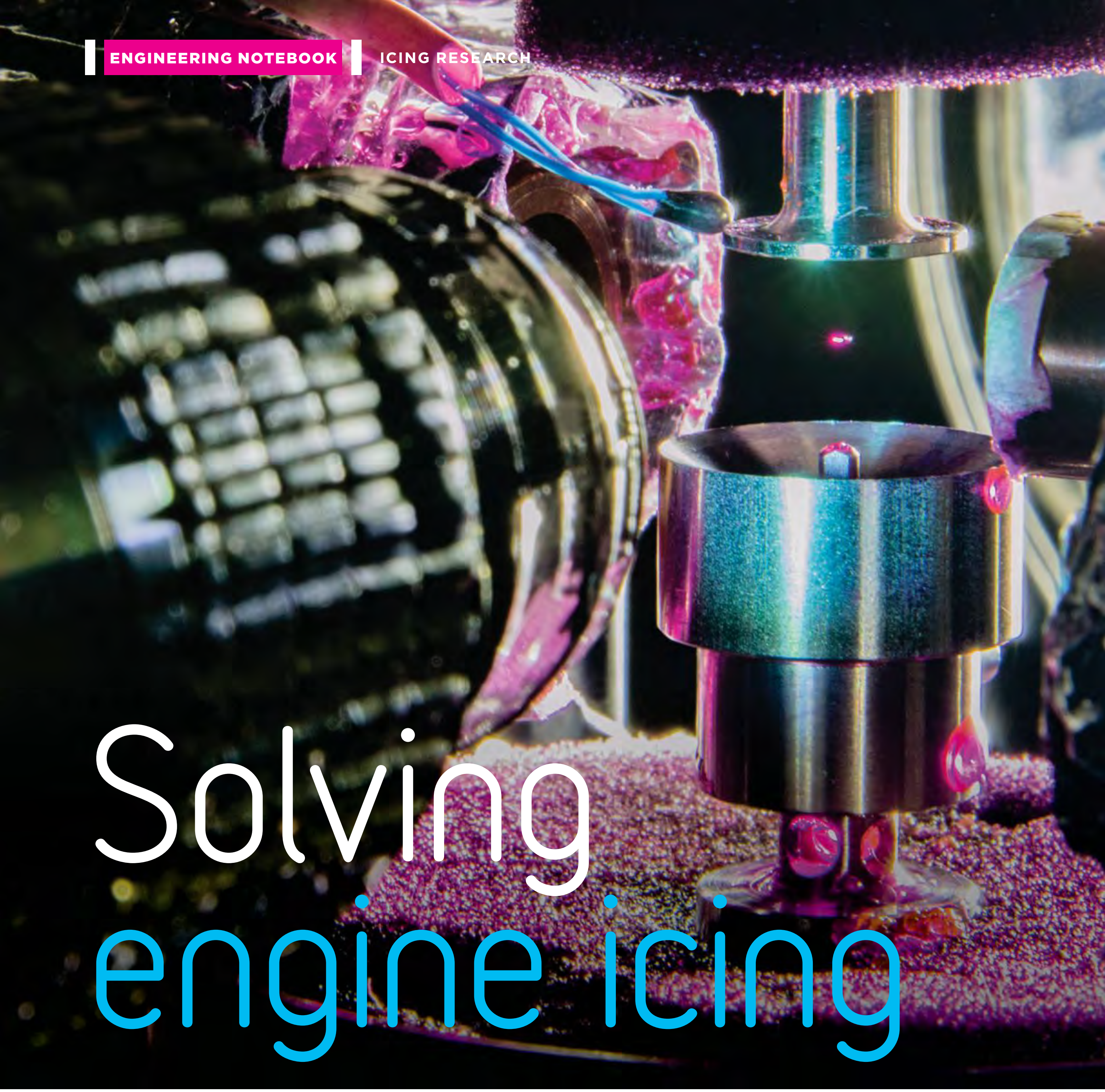
Some of the new cubesat technologies, like the propulsion systems proposed by Accion Systems and Phase Four, are brand new. In the past, going from a new idea to flight would have taken a significant amount of time. The speed at which these things are getting tested is really interesting. It's great.

Investors backing propulsion startups

That's completely new. We haven't had that before.

Flight heritage for propulsion technologies

One of the things that the cubesat community is notorious for is taking a little bit more risk than traditional space has in the past. When you have smaller, lower-cost systems, the ability of people to take some risk and try new things is much higher. Which means as soon as these things are ready to fly, people are going to start putting them on cubesats. People are putting them into designs right now assuming they are going to work. ★



Solving engine icing

Jet engines have a rare but nasty habit of icing up while cruising in seemingly clear air at high altitudes. So far, no fatalities have resulted, but engineers are searching for a solution. One hurdle in their work was always the inability to watch and accurately model the behavior of the villains in this saga: partially melted ice crystals. Keith Button talked to the researchers who solved that aspect of the problem.

BY KEITH BUTTON | buttonkeith@gmail.com

▲ **A droplet is suspended in midair** with acoustic waves created by an ultrasonic levitator during a test carried out by the aircraft icing research team at Penn State University.

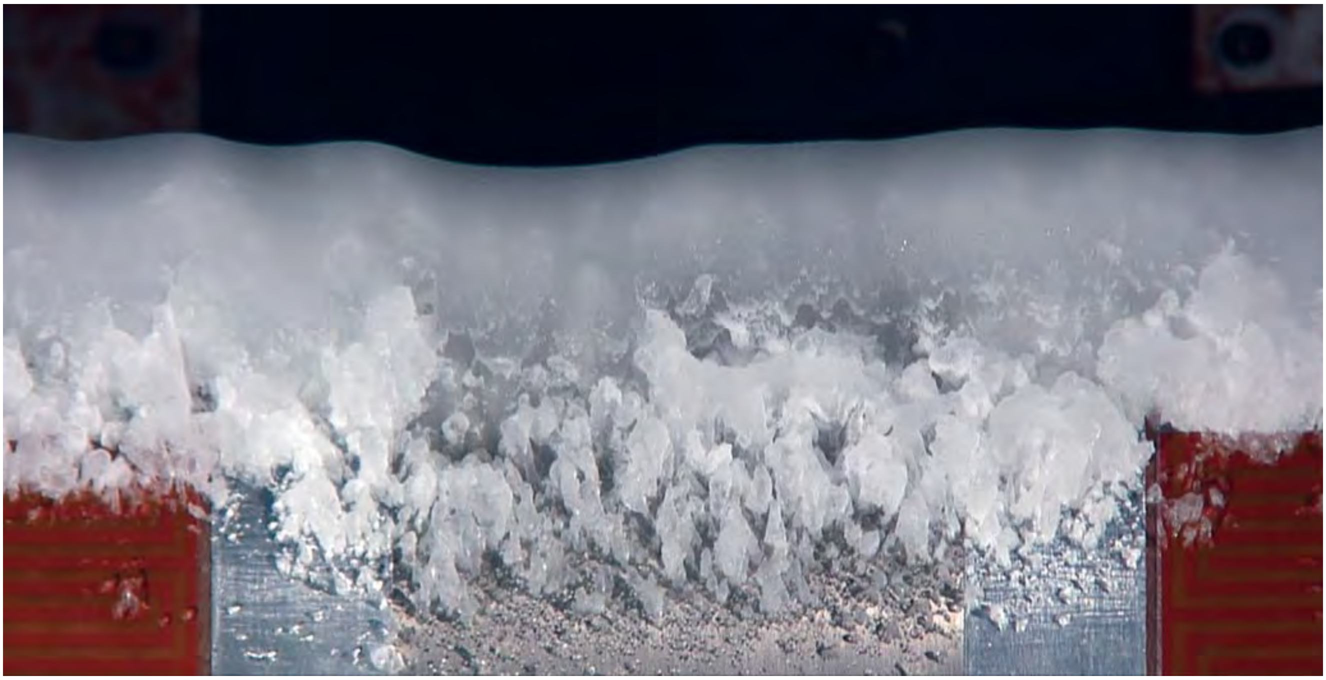
In a freezer room on the campus of Penn State University, a partially melted ice crystal levitates motionless on acoustic waves. Green laser light bathes the crystal to distinguish the liquid exterior from its icy core. On command, an air gun pushes a stainless steel rod toward the crystal at 100 meters per second down a barrel that stops the rod at the moment of impact. The result? The crystal shatters, and specks of ice fuse to the tip of the rod, just as they would if the crystal smacked into a surface inside a jet engine. A high-speed camera records everything for the research team.

This method of capturing a host of characteristics about partially melted ice crystals, from their ice content to how they fracture and splash, was described to me by Jose Palacios, assistant professor of aerospace engineering and head of the aircraft icing research team at Penn State. The team plans to continue gathering data this way through September.

The technique is emerging as a possible linchpin in U.S. efforts to solve the rare but potentially fatal problem of high-altitude engine icing. That happens when a jet cruising in the seemingly clear air around major thunderstorms ingests a high volume of a particular kind of ice crystal that's prone to partially melting and refreezing. The plane's radar can't see these crystals, and the pilot may not immediately notice them bouncing off the exterior like grains of sand no more than 1 millimeter across.

Inside the jet's engines, though, warm air partially melts the crystals before they strike the surfaces of the compressor located before the combuster. The sheer volume of these partially melted crystals cools these surfaces below freezing, causing the drops to accumulate, or accrete, in the form of ice. Chunks as large as a few pounds can build up and break off and snuff combustion or damage the engine. Since 2015, the phenomena has caused a combined 162 cases of either complete engine flameout or stalling, a temporary loss of power due to restricted airflow, and damaged compressors, according to data gathered by Boeing. So far, no crashes have resulted. Right now, pilots cope by flying around huge swaths of weather that might or might not lead to icing. Engine stalls typically last less than a few seconds, but when flameouts occur, as a last resort pilots can descend to 10,000 feet where the ice melts and the pilots can restart their engine or engines.

Researchers want to solve the icing problem before luck runs out. Engineers have over the years made minor modifications to in-service engines to cope with icing. In 2015 GE ordered modifications to some of its engines on Boeing 787s and 787-8s — software to better detect the icing in the engines and to open a duct that ejects ice from the center of the engine, changes to the shape of the housing for a temperature sensor in the air flow path where ice would build up, and new compressor blades and inlet vanes. One hurdle to more progress has always been a lack of knowledge about the precise characteristics of the partially melted ice crystals that are most prone to causing dangerous accretion. Without that data, computer



Penn State University

models can't precisely predict the weather conditions that will cause the kind of crystals that turn into dangerous drops or tell engineers how best to design new engines that will defeat the icing.

This is the story of how the Penn State team came up with a measurement technique that could clear the way for more anti-icing innovations to come.

▲ **Ice accretions on an airfoil were recreated in the Propulsion Systems Laboratory at Glenn Research Center as part of research to understand the physics of icing that can occur inside jet engines.**

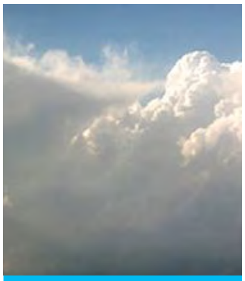
Building a model

The Penn State researchers were motivated by a desire to help NASA run its high-altitude icing wind tunnel experiments with maximum accuracy when testing engine components. In a series of modifications from 2012 to 2015, NASA upgraded test chambers at the Propulsion Systems Laboratory at the Glenn Research Center in Ohio to replicate the low temperature and pressure conditions of high-altitude icing. The trouble is, turning on the nozzles to spray liquid droplets changes the temperature and humidity as the droplets partially freeze before hitting their test surfaces, which could be ducts or the non-moving blades in the compressor section. That makes it especially difficult to set the exact conditions to create partially frozen ice crystals with a specific ice-liquid ratio that hit the surface at a speed typically between 85 and 135 meters per second, says Tadas Bartkus, a senior research associate with the icing branch of the Ohio Aerospace Institute, a NASA contractor.

It's a tricky environment for the researchers to set up correctly. "In general, you see a one- to two-degree change and you think it's not that big a deal. But not when it comes to icing."

Bartkus needed to verify the accuracy of a computer model he created to predict the complex interactions in the icing wind tunnels. If he could make the model accurate enough, testers could calculate the wind tunnel conditions they would need at the beginning of the test to arrive at the conditions they wanted at the end. So NASA asked the Penn State team to assist Bartkus. He needed test data on partially melted ice crystals to help verify assumptions in the computer model about how long it takes them to melt at specific temperatures and how that time changes for different crystal sizes.

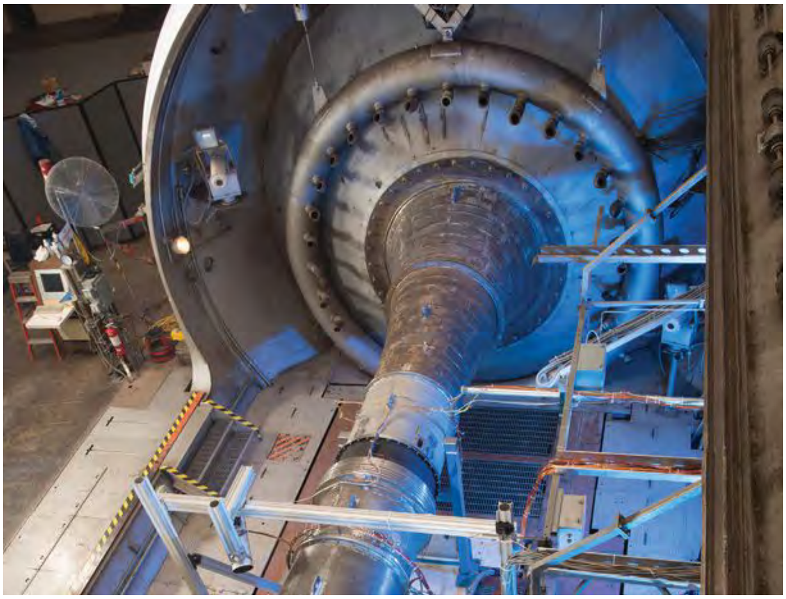
Luckily, in 2015 while working on another project, the Penn State researchers had found a method of creating partially melting crystals and measuring their temperatures and ice/water ratios without touching them. The technique had taken two years of trial and error. At first, they tried shooting ice crystals from a pneumatic gun and passing them through a heating chamber before the partially melted crystals hit a test surface designed to mimic an engine component. But the crystals traveled at 100 meters per second and didn't have time to melt properly. The same problem resulted when they shot crystals through the flame of a blowtorch; it was like quickly passing your hand through a flame, Palacios says. Next, they tried something more complex. They froze a drop of water by letting it fall through a liquid nitrogen-cooled tube, then partially melting it by passing it through a heating chamber before blowing it with air toward the test surface. Nothing worked until they tried an entirely new approach. They started with a drop of liquid water and suspended it in midair with acoustic waves created by an ultrasonic levitator. They blew cold air on the droplet to freeze it, and then stopped the cold air and allowed



Dangerous crystals

Deep convective thunderstorms contain ice crystals that flow out from the tops of billowing clouds. These crystals are all but invisible, and pilots are instructed to give such storms a wide berth. Still, an aircraft's engines sometimes ingest crystals.

If all goes as planned, jet-engine manufacturers could have a computer model to virtual-test their designs for icing risk, instead of building engines and then testing them in wind tunnels.


NASA

▲**This test cell at the Propulsion Systems Laboratory** at NASA Glenn can create ice crystals like those at high altitudes.

warm air to partially melt the drop. This was the approach they would take with the validation testing for the Bartkus computer model in 2016.

Another problem was how to measure the changing amounts of liquid and frozen water in the drop — a key measure for the NASA computer model to show how fast and how much the drop melted under specific conditions. The researchers accomplished that with another method they had developed previously. They infused each drop with Rhodamine B, an ink that glows orange in liquid water when hit by green laser light. Ice does not react to the laser. They compared the laser-lit water layer to the dark ice core in magnified photos.

Bartkus tweaked the computer model, which he has been writing and refining for about two years, based on the Penn State test results for the levitating partially melted crystals. The Penn State results improved the accuracy of the model's assumptions about how the crystals melt under specific conditions they encounter in the PSL wind tunnel. Now, Bartkus is working on improvements to the model so it can more accurately predict test conditions when the spray nozzle droplets are not uniform throughout a given cross-section of the icing wind tunnels.

The Penn State team members continue to study the fracture and splashing dynamics of partially melted crystals. Their tests could help explain why some of the crystals don't shatter, which might be because their watery exterior has a cushioning effect. The tests might also help define the crystal-liquid ratios that create the most freezing after impact. This is the phenomenon they had attempted to test starting in 2013 before they had settled on the acoustic levitator idea. Now, with a stationary partially melted ice crystal, they smash the ice-liquid mix with a moving surface — the pneumatic bullet — to simulate a fast-moving airplane engine. By lighting up the dyed, partially melted ice crystal with the green laser, they can precisely measure its ice and liquid volume before impact.

The pneumatic bullet tests help answer two questions, Palacios says: Are the predictions of fracture dynamics models correct? And how much ice freezes to the impact surface as the ice-liquid mix varies?

"If you can validate these values in the models, then you can have some certainty that your predictions for fracture dynamics are somewhat correct and then you can use these models to model more complicated circumstances," Palacios says. As for how much ice freezes to the surface, the answer to that question can form the basis for new computer models that will predict icing for specific types of partially melted crystals.

If all goes as planned, jet-engine manufacturers could have a computer model to virtual-test their designs for icing risk, instead of building engines and then testing them in wind tunnels. Also, engines designed from the ground up with the specific icing scenarios in mind would be more fuel efficient, powerful and reliable than engines that were retooled after the fact to avoid icing flameout.

"It would be very expensive and challenging to do these fundamental tests on a full-scale engine, rather than just telling you if this engine is going to fail or this engine is going to pass or you have this performance reservation on the engine" based on computer simulations, Palacios says. ★

Hush!

One company's journey toward quieter skies

BY PARTHIV N. SHAH
parthiv.shah@ata-e.com

When ATA Engineering needed to create a prototype of its proposed Engine Air Brake, the company headquartered in San Diego turned to Siemens PLM Software, headquartered in Texas, to create a digital twin of the design. ATA Engineering needed to predict the prototype's performance to be confident it could safely induce quiet drag during aircraft landings. Parthiv N. Shah of ATA Engineering explains.

At the heart of the airport noise problem lies the conundrum of aircraft coming in for landing. Unlike engine-dominated takeoff noise, the noise during landing results mostly from the air disturbed by aircraft structures, such as edges, control surfaces, landing gear, high-lift devices and speedbrakes. While these provide the drag needed to safely maintain the desired trajectory and slow the aircraft, they also generate turbulence that is responsible for much of the excessive noise around airports.

An alternative would be to incorporate quiet drag devices that permit steeper, slower and/or aeroacoustically cleaner approaches. One such device is an Engine Air Brake, or EAB, prototype developed by ATA Engineering, headquartered in San Diego. It consists of vanes embedded in the exhaust nozzle of an engine, which could deploy during landings to induce swirl in the exhaust flow as a source of quiet drag. The EAB prototype was developed under NASA sponsorship, with Williams International of Michigan and Utah as an engine partner, and with subject matter expertise from the Massachusetts Institute of Technology.

On NASA's Technology Readiness Level scale, ATA has now advanced the EAB concept to TRL 6, defined as having a fully functional prototype. TRL 9, the highest level, indicates a system flight-proven through successful mission operations.

Conceiving the EAB

The pursuit of quiet drag received a big boost from the "Silent Aircraft Initiative," a research project carried out in the mid-2000s by the University of Cambridge in England and MIT with a host of aerospace industry partners. I became involved in this initiative in 2004 while working toward my Ph.D. at MIT. The aim was to develop the conceptual design of an aircraft whose noise would be effectively imperceptible outside the perimeter of an average daytime urban airport. This design was unveiled to the public in late 2006 and was a hybrid wing-body aircraft with highly integrated, boundary-layer ingesting engines. Because the aircraft had a high lift-to-drag ratio, it would be "slippery" on approach, meaning it would be difficult to control without intentionally induced drag.

One idea considered by the team was to induce quiet drag with the propulsion system. An early concept switched the engine fan during landing from pumping mode, in which compression work is done on the air by the engine, to extraction mode, in which energy is extracted from high speed air spinning the blades, making it behave like a turbine.

I began to work with MIT professor Zolti Spakovszky at the school's Gas Turbine Laboratory to extend the concept to the introduction of swirl in the propulsion system exhaust. The goal was to generate pressure drag equivalent to that of an equal diameter bluff body, an aerodynamic shape whose airflow has separated over much of its surface. Together, we discovered that a stable, swirling exhaust flow could not only create drag comparable to a bluff body (without the associated separated airflow), but also maintain flow capacity and a low-noise signature. In fact, the swirling flow maintained capacity better than a work extraction device. In essence, introducing swirl into the exhaust broke the high-drag, high-noise relationship of other conventional drag devices. This work was sponsored by NASA's Langley Research Center in Virginia, which afforded the opportunity to validate the noise predictions in tests at the LaRC Quiet Flow Facility using a ram-air driven nacelle with stationary swirl vanes, a so-called swirl tube. Aerodynamic performance was validated at the MIT Wright Brothers Wind Tunnel.

While promising, the concept still presented practical implementation challenges. Since engines at approach idle power are not ram-air driven, Spakovszky and I recognized that propulsion system integration, including deployment of swirl vanes, would be a challenge in today's conventional ducted turbofan environment. Additionally, the ram-air driven nacelle's swirling wake flow would need to be replaced with a fan-driven swirling jet flow, with an as-yet unknown noise signature.

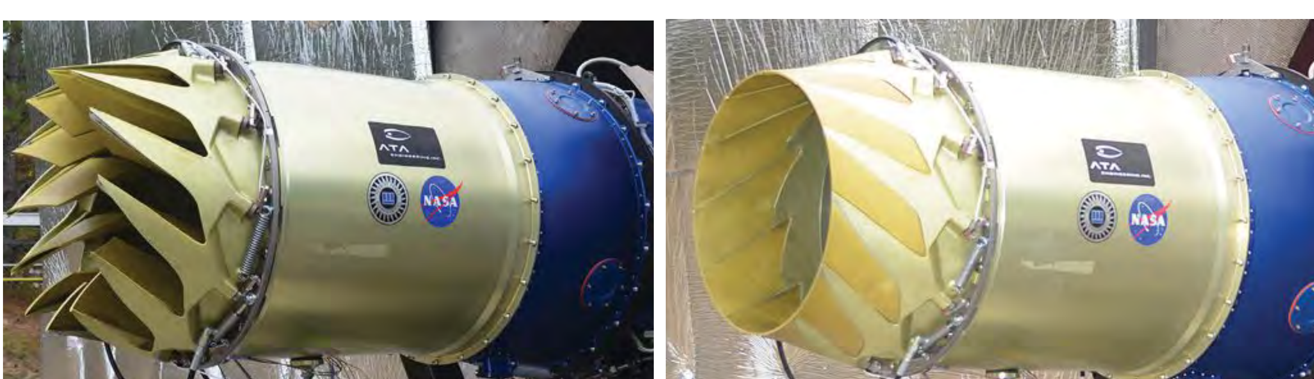
When I joined ATA Engineering in 2007, upon completing my Ph.D., I had the opportunity to address these concerns and take the swirling exhaust flow idea from a promising concept toward a possible commercial product. As part of a Small Business Innovation Research project sponsored by NASA Glenn Research Center in Ohio, whose first phase ran between 2008 and 2011, ATA examined the noise and performance of swirling exhaust flows in high bypass ratio nozzles. In these nozzles the fraction of air passing through the bypass duct is significantly higher than the fraction of air passing through the gas generator core. The work included computational fluid dynamics analysis plus aerodynamic and aeroacoustic evaluation at Glenn's Aero-Acoustics Propulsion Laboratory. The work also examined integration of swirl vanes into a two-stream nozzle with a variable geometry pylon.

As a result of this effort, ATA invented a mechanism that could stow and deploy swirl vanes in an exhaust nozzle while appropriately regulating flow capacity. The EAB would be stowed during flight but deploy a swirl vane mechanism during landing, creating a streamwise vortex from the jet engine exhaust flow. The constant flow of swirling air creates additional drag by reducing thrust and is sustained by the radial pressure gradient from the swirl vanes. The system enables a slower, steeper and acoustically cleaner approach/descent when engine thrust cannot be further reduced. At a system level this can be significantly quieter than a landing where additional drag is induced by flight control surfaces such as flaps and speedbrakes.

Design considerations

In the second phase of the SBIR project, which ran between 2012 and 2015, ATA partnered with Williams International to demonstrate a prototype deployable nozzle on the FJ44-4 engine, a 3,600-pound class, medium bypass, twin spool engine. As with any design, changes somewhere usually result in undesired consequences elsewhere. This becomes more challenging when multiple design considerations are present, such as aerodynamics, thermal and structural integrity, noise, and real estate. As part of the technology maturation program, the team first identified design requirements and technical objectives for the EAB. The technical objectives were:

- Design, fabricate and test a realistic flight-weight EAB on a modern turbofan propulsion system
- Quantify the equivalent drag, effect on operability, noise, cost and weight of the system
- Perform system-level analysis of the proposed impact in terms of steep approach for noise reduction
- For the aerodynamic design of the EAB, the following requirements were identified:
- No measurable thrust or thrust-specific fuel con-



▼ **"Creating drag quietly"**
ATA Engineering's Engine Air Brake prototype opens to create drag during landing.

ATA Engineering

sumption penalty when stowed

- A 15 percent net thrust reduction at fan speeds for "dirty approach" (high-powered approach throttle setting) when the EAB is deployed, measured as a percentage of the stowed nozzle's gross thrust at same condition
- No measurable fuel consumption penalty or flow reduction when fully deployed
- Adequate surge margin during all operation, including dynamic deployment and stowing
- Meet stow/deploy time requirements (0.5 seconds and three to five seconds, respectively)

Other design requirements included structural and packaging constraints that ensured the EAB could be integrated into a typical aircraft installation, such as the Cessna CJ4, without performance penalties while providing the noise reduction benefits. The design activity involved performance assessment of various systems, including aerodynamic, mechanical, acoustics and structures. To model the performance before constructing the EAB prototype, we created a digital twin of the EAB with the STAR-CCM+ and NX, tools in the Simcenter Portfolio from Siemens PLM Software. This accelerated the readiness of the technology.

Parametric solid modeling with the NX for Design tool from Siemens PLM Software created the 3-D computer-aided-design geometry of the EAB. Researchers could then rapidly generate designs with varying parameters based on aerodynamic performance. The various design parameters for the numerical simulation included vane count, swirl angle, deployment rotation angle, chord length and cutout (area relief) depth.

One of the foundations for the maturation of the EAB technology is the analysis-driven design effort using STAR-CCM+ to quantify flow performance and operability and to predict the thermal operating environments of the design. With the power of computational fluid dynamics, design optimization and computing hardware, ATA was able to analyze the full aerodynamic design space before identifying the final design that was estimated to meet all the aerodynamic requirements in simulation. The fluid domain was discretized with polyhedral finite volume cells. Prism layers captured the boundary layer flow. The final designs had a mesh count of 3 million to 5 million cells. Total pressure and temperature were specified as boundary conditions at the fan, core and freestream inlet. Steady RANS (Reynolds-averaged Navier-Stokes) simulations with ideal gas and a k-omega Shear Stress Transport turbulence model were carried out. Cir-

cumferentially periodic boundary conditions were used, enabling modeling of one-seventh of the upstream region. A mixing plane interface was used to cope with the non-uniformity of the flow emanating from the 14-lobe mixer. The reduction of the computational domain in this way enabled faster exploration of the design space. Full-annulus simulations were carried out on final designs to verify consistency and the performance prediction.

ATA Engineering applied the Siemens tools throughout its analysis-driven design process to define the final configuration. The multiphysics capabilities of STAR-CCM+ enabled performance and gap leakage analysis with RANS CFD, thermal analysis with conjugate heat transfer modeling, unsteady loads calculation with large eddy simulation capability and flutter assessment. Thus, a digital twin of the EAB was created that validated the aerodynamic performance of the final design. Structurally, NX Nastran from Siemens PLM Software was used for finite element analysis, fatigue analysis and prediction of thermal/structural deformation. The deployment mechanism was challenging to design due to limited space and syncing the operation of the 12 vanes. Solid modeling in NX with assembly constraints allowed for visualization of the deployment and checking for interference between parts. Manufacturing of the physical EAB prototype was done through a combination of a 5 axis mill and handwork to bring the nozzle up to specifications.

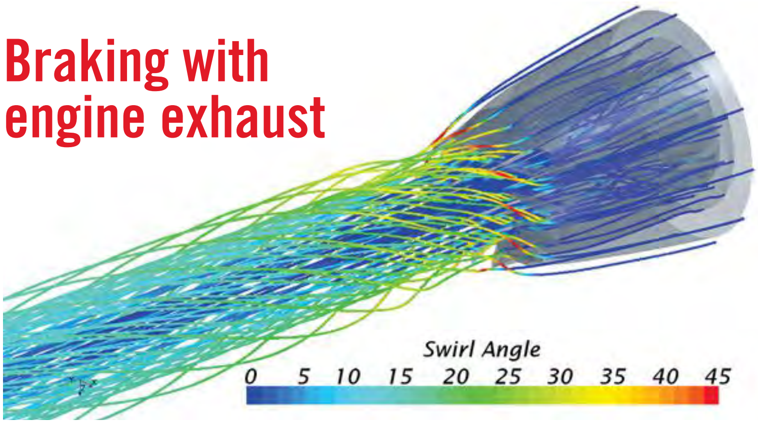
Maturation to TRL 6 with ground testing

ATA performed the analysis, design and fabrication of the nozzle prototype to be integrated with the WI FJ44-4 test engine. The EAB ground demonstrator consisted of a spool piece, an aluminum nozzle, 12 high-temperature aluminum vanes, 12 stainless steel shafts, 12 dogleg lever arms and adjustable linkages, three hydraulic rams, three extension springs, a stainless steel actuation ring and a string potentiometer.

Full-scale ground testing of the final EAB design was conducted at Outdoor Test Facility Number 2 at Williams International's complex in Walled Lake, Michigan, in October 2015. The testing confirmed the predicted performance of the EAB prototype:

- Drag and flow/operability targets were met
- Noise was favorable compared to analysis
- Dynamic deployment (less than five seconds) and stow (less than 0.5 seconds-faster than required engine spool up time during a go-around maneuver) were demonstrated
- Fuel burn on deployment was reduced
- Mechanism fits within a notional cowl
- Thermal performance matched prediction and no structural dynamic concerns were found
- Quiet steep approach glideslope potential was demonstrated in a system simulation

Braking with engine exhaust



ATA Engineering

The Engine Air Brake, or EAB, would reduce thrust during landing by imparting swirl into the exhaust stream. This would be a quiet alternative to the conventional technique of inducing drag during landing by extending flight control surfaces. Angles between 25 and 35 degrees in this simulation depict optimal thrust reduction. Too high an angle breaks down the vortex into chaotic flow.

Testing confirmed the performance of the EAB as a function of the vane rotation angle, which had been predicted with the digital twin. STAR-CCM+ predictions agreed well with test results for all configurations, reinforcing the use of STAR-CCM+ as a valuable design tool to bring this new technology to life. A steep approach flyover analysis predicts a 1 to 3 dB reduction in noise on the ground, confirming the performance of the EAB as a system noise-reducing device.

A quieter future beckons

With the initial success, desired next steps are ground testing the reliability and durability of the system and an eventual flight test demonstration.

With EAB at Technology Readiness Level 6, getting to TRLs 7, 8 and 9 will require light-weighting of the assembly (the prototype was developed for a ground demonstration), additional ground testing for reliability, and participating in a flight demonstration program to show the potential for quiet steep approaches. Our team is actively looking for a well-suited flight demonstration opportunity where we could partner with an airframer, engine manufacturer, and/or nacelle supplier to bring the technology to the skies. An estimate for time to introduction to market would be five to 10 years, if the steps detailed here are completed.

ATA Engineering hopes that future aircraft designs will incorporate the EAB, and that the device may also be retrofitted to existing aircraft. With innovative devices like these helping to reduce noise pollution, there may yet be a day when the general population is lining up to live in close proximity to airports. ★

Prashanth S. Shankara of Siemens PLM Software contributed to this article.

Parthiv N. Shah is a senior technical adviser at ATA Engineering. He holds a Ph.D. in mechanical engineering from MIT, a Master of Science degree in mechanical and aerospace engineering from Rutgers University, and a Bachelor of Science degree in aerospace engineering from the University of Virginia.¶

BEATIN
CURIOS

G
SITY

While the U.S. deliberates over a possible human mission to Mars in the 2030s, a team at the NASA-funded Jet Propulsion Laboratory has started fabricating a next generation robotic rover that could start rolling across the surface in 2021. Leonard David spoke to the team about the innovations needed to achieve the project's lofty goal of out-exploring today's Curiosity rover.

BY LEONARD DAVID | newsspace@aol.com

Once NASA's car-sized Mars 2020 rover reaches the surface, it must roll about the same distance in two Earth years as the Curiosity rover has traveled in five. NASA wants it to zip, in rover terms, from one scientific feature to the next. It must do this without the excessive wheel wear that has slowed Curiosity's journey. It also must do something Curiosity was not equipped to do: drill solid samples from Martian rocks with a device called a corer; deposit the samples in tubes and drop the tubes on the surface for a future explorer, probably another robot, that would send them to Earth. Scientists would scour those samples for evidence of ancient life such as microbes. Much of that science hinges on improved navigation during the landing, so the rover can dare to land somewhere even more interesting than Curiosity's site.

Here is the catch. The NASA-funded Jet Propulsion Laboratory in California must achieve these goals while staying as close as possible to the heritage design of Curiosity. That's the only way managers will be able to stay within the project's $2.4 billion estimated price. Months of testing lie ahead that should tell us whether they have taken the right steps to wring the most out of the new rover.

The blueprint passed its critical design review in February, and the first components are arriving at JPL, where personnel will build Mars 2020. Subsystem development continues along with testing of engineering models. All this is in preparation for rigorous system level tests beginning in 2019 ahead of the planned 2020 launch in July or August.

Daredevil landing

In most but not all ways, getting the rover to the surface will be like Curiosity's "seven minutes of terror," as engineers dubbed the plunge from the top of the Martian atmosphere to the surface.

Here's what will be the same: The Mars 2020 descent will begin with the spacecraft dead reckoning its initial position and velocity from the transit time of radio signals from the Deep Space Network, followed by data from an onboard inertial measurement unit. At this point, the spacecraft consists of the rover and the Sky Crane landing apparatus tucked inside an aeroshell consisting of a heat shield and backshell. The heat shield must protect Mars 2020 from temperatures that will soar to 2,100 degrees Celsius due to atmospheric friction.

Closer to the surface, a parachute will deploy and the heat shield will drop away to expose the rover-Sky Crane assembly and provide a clear view of the surface for a radar.

Seconds later, onboard software will start calculating higher fidelity velocity and altitude from the radar data to determine when to fire up the vehicle's eight retrorockets.

NASA

▲ **An image shot by** Curiosity's MAHLI camera shows the wear on one of the rover's wheels. The team working on the Mars 2020 rover believes that its new navigational instruments and an altered wheel design will prevent the same sort of damage.

HOW FAR WILL THE ROVER ROVE?

The Mars 2020 vehicle will be designed to travel a total of 20 kilometers over the course of its mission from a still to be selected landing zone. This requirement is the same as for Curiosity, which as of late July had driven 16.94 kilometers since 2012.

Before those rockets fire, the backshell and parachute must separate, leaving the rover-Sky Crane assembly in free fall temporarily. The rockets then fire to slow and maneuver away from the falling backshell and parachute.

Within meters of the surface, the Sky Crane will unspool the rover via an "umbilical cord" and bridle. After touchdown, pyros will cut the ropes and umbilical cord so the Sky Crane can rocket away and crash a safe distance from the landing site. Mars 2020 will be ready to roll.

Here's what will be different:

NASA wants the rover to touch down "close to the fun stuff," meaning scientifically interesting features, says JPL's Allen Chen, the lead for the Cruise and Entry, Descent, and Landing Phase. "If we have to spend the entire lifetime of the rover just driving to get to the first sample site, that's not good," Chen says.

Even a few kilometers of accuracy will matter in the landing, because Mars 2020, although faster than Curiosity, will still reach speeds of only tens of meters per hour. So NASA has tightened the landing ellipse around the target from Curiosity's requriement of 25 kilometers by 20 km to 16 km by 14 km for Mars 2020.

Daring to set the rover down near this "fun stuff" will mean diverting around large rocks, cliffs, scarps or other slopes.

Taken together, the goal of tightening the ellipse and taking on difficult terrain will require two techniques that Curiosity was not equipped for.

One is called Range Trigger, and it's intended to shrink the ellipse by triggering the parachute deployment based on the location of the aeroshell relative to the surface. By contrast, Curiosity deployed its parachute when a particular velocity was reached.

The beauty of Range Trigger is that it will require no additional sensors, Chen says. It will crunch the

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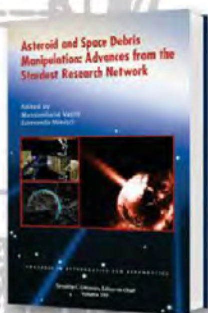

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inertial readings that already would be collected in the heritage design to determine where the aeroshell is relative to the surface. "Based on the mass of the vehicle and the predicted aerodynamics, we have a pretty good idea how far the spacecraft will travel between parachute deploy and landing," Chen explains. In fact, curiosity "knew" it was slightly beyond the desired parachute deployment point when it released its parachute, Chen says.

The other new technique is terrain relative navigation or TRN. It's why scientists feel emboldened to land amid challenging terrain.

After heatshield separation, cameras will photograph the surface as the aeroshell descends under the parachute. The TRN software compares those images to a stored digital map created from images taken by NASA's Mars Reconnaissance Orbiter. If the rover is headed for a hazard, the software identifies a safer spot on the map and steers the rover and Sky Crane assembly there once the parachute and backshell are jettisoned and the rockets are firing.

To put it simply: "Terrain relative navigation gives us the ability to dodge things," says Chen.

Scientists have agreed on three possible landing sites for Mars 2020, and Chen says "we feel comfortable going to any of the three selected landing sites."

NASA had planned to test TRN in the field next year on a helicopter under various lighting conditions and classes of terrain, but has bumped that to 2019. In similar airborne tests a few years ago, NASA evaluated the underlying math for TRN. "We have shown that the algorithms work and that's kind of the magic sauce," Chen says.

NASA also plans to gather sights and sounds during the descent phase this time. Cameras and microphones will record the craft's parachute deployment, for instance. Once on the surface, microphones on the rover are expected to capture a variety of sounds, including the turning of the rover's wheels, drill operations, perhaps even the winds of Mars. Aside from the intrigue the public might get, engineers also see this as a diagnostic tool to assess the performance of components.


NASA

▲ **The cache camera** will give NASA personnel on Earth this kind of view looking down into a sample tube after the rover has drilled a core specimen. This photo was shot using a commercial macro lens and only intended to show the type of view the CacheCam will be capable of.

Possible landing sites

Earlier this year, scientists spent several days narrowing a set of eight previously picked go-to spots for the Mars 2020 rover. The down-selection process was led by a Mars 2020 Landing Site Steering Committee, co-chaired by NASA and the Center for Earth and Planetary Studies at the National Air and Space Museum. Here are the remaining options:

Jezero Crater: Hosts a dried up Martian lake that might be a repository of past microbial life.

Northeast Syrtis Major: A dormant volcano created almost entirely by lava flowing and cooling. This shield volcano abuts a huge impact crater and an area thought to be warm and wet long ago.

Columbia Hills/Gusev Crater: Previously surveyed by NASA's Spirit rover, this site appears to be flush with sinter deposits from a long-gone hot spring. Similar sites on Earth are known to support microbial life.

Addressing technical risks

Working off the design of Curiosity has been a "blessing and a curse," says Jennifer Trosper, the deputy project manager for Mars 2020. As a member of the Curiosity team a few years ago, she led the study group that determined the adjustments that would be required to the design of Curiosity, also known as the Mars Science Lab.

The blessing is that "we're not sitting here with a blank sheet of paper like we were with MSL," she says. As for the curse, Mars 2020 can't be "fully heritage" largely due to the elaborate sample caching system. Toss in for good measure, the challenge of avoiding problems such as the small holes discovered in Curiosity's wheels.

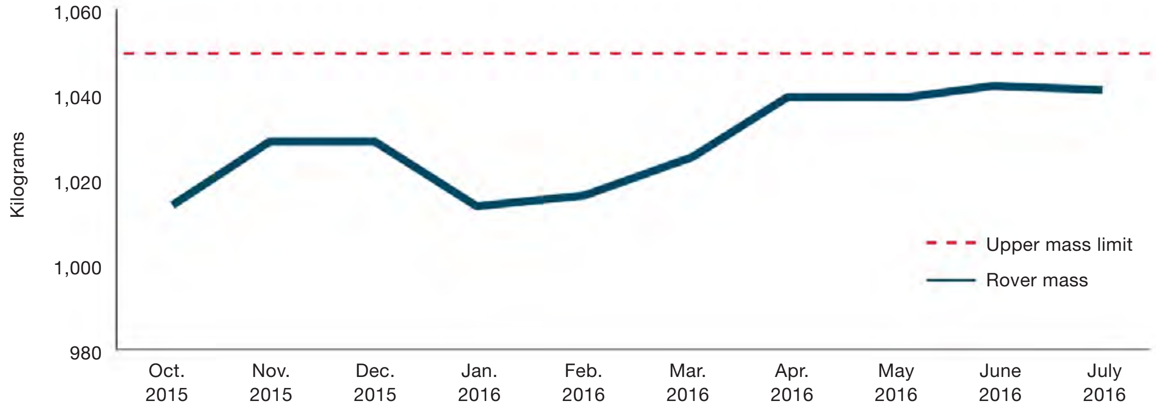
"The main thing we're doing is not skimping on the verification program. We're testing everything again with its new purposes, in its new environment," she says.

So subsystem tests will be followed by system level tests and functional tests of everything required for cruise, entry, descent, landing and rover operations on Mars.

CONTINUED ON PAGE 30

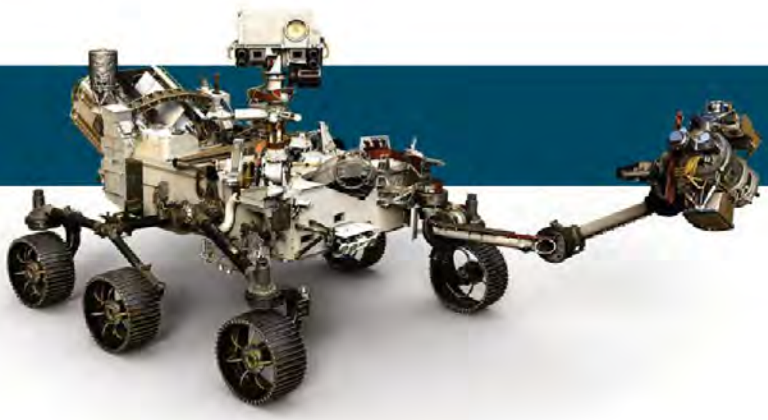
MINDING THE MASS

The Mars 2020 rover's mass has steadily increased since 2015 as NASA engineers judge which instruments are critical for the mission.



Source: NASA

MARS 2020



Length: 3 meters (10 feet)

Width: 2.7 meters (9 feet)

Height: 2.2 meters (7 feet)

Mass: 1,050 kilograms (2,314 pounds). Curiosity weighed 899 kilograms at launch.

Wheels: Skin thickened to avoid Curiosity's excessive wear.

Propulsion: Multi-mission radioisotope thermoelectric generator turns the heat from the radioactive decay of plutonium into electricity to power the rover's batteries. The RTG produces 110 watts of power at launch (*identical to Curiosity's*).

KEY INSTRUMENTS

ALL NEW

Planetary Instrument for X-ray Lithochemistry, or PIXL: Has an X-ray spectrometer to identify chemicals at a tiny scale, a camera to shoot pictures of rock and soil textures as small as a grain of salt. This information will help look for signs of past microbial life.

ALL NEW

Radar Imager for Mars' Subsurface Experiment, or RIMFAX: examines ground with radar waves.

ALL NEW

Mars Oxygen In-Situ Resource Utilization Experiment, or MOXIE: NASA says this MIT instrument is designed to produce oxygen by consuming electricity.

SuperCam: An upgrade of rover Curiosity's Chemistry & Camera instrument because it can perform Raman spectroscopy, which will provide information about potential samples, and produce high-resolution images with a remote micro-imager.

Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals, or SHERLOC. The instrument is new except for the WATSON camera on the turret, which is like Curiosity's MAHLI * camera.

Other camera upgrades: Additional descent cameras and microphone will improve the chances of capturing the landing on video. Upgrades to the engineering cameras will help humans on Earth operate the rover, scan it for maintenance and provide data to allow the rover to operate autonomously. In addition there will be a cache camera inside the rover's underside to provide a view of the top of the sample tube.

Also, various atmospheric, environmental and radiation detectors.

SAMPLING

The rover will drill into the Martian rock with a corer to extract solid samples, store them in hermetically sealed tubes and leave them on the planet to possibly be collected later and launched to Earth by an ascent vehicle.

* Mars Hand Lens Imager

The wheel deal

Since Curiosity's landing in August 2012, wheel wear has been discovered beyond the anticipated dings and dents.

"Everybody wants that fixed," Trosper says.

Engineers will do that by making the skins of the Mars 2020 wheels about twice as thick as Curiosity's (1.65 millimeters compared to .75 mm), and by streamlining the pattern on the treads, called grousers. "Essentially the grouser pattern on MSL allowed for stress concentrations we wanted to eliminate," Trosper says.

It turns out that Curiosity's auto navigation mode, which was tried early in the mission, might have contributed to the excessive wheel wear by steering the rover over small, pointy rocks.

Faster roving

Understandably, the fear of causing wheel wear "makes you not want to use the auto nav," Trosper says of Curiosity. Indeed, controllers at JPL's operations center now prefer to drive Curiosity in the ground-directed mode, which means sending fresh navigation commands daily. With the rover stopped, controllers receive images of the terrain ahead of its navigation cameras. Controllers can assess the landscape for perhaps the next 100 meters, but beyond that distance, the resolution of the images becomes too coarse to reveal obstacles. The next navigation commands are uploaded in a planning process that can take 10 hours.

The story should be different for Mars 2020. Trosper predicts that controllers won't hesitate to drive the new rover in auto nav, because they won't be afraid of causing wheel damage. With its finer resolution navigation cameras and smarter auto nav algorithm, Mars 2020 will spot areas likely to have pointy rocks and avoid them.

These improvements are one reason managers expect Mars 2020 to zip, relatively speaking, from one science target to the next. Don't expect wheels to be spitting dust and dirt airborne, though. Mars 2020 will cover up to 225 meters in three hours at speeds up to 75 meters per hour. Even if Curiosity could operate in auto nav, the best it could manage would be 15 to 20 meters per hour or 45 to 65 meters in each three hour span.

Still, for a rover manager like Trosper, Mars 2020's speed amounts to putting "the pedal to the metal."

Making this smarter auto nav possible required adding a second computer processor to Mars 2020 compared to Curiosity's one. The additional processor freed up the main processor to perform navigation calculations, while the second processor will be dedicated to rapidly processing images from the rover's navigation cameras.

Mars 2020 will do "image processing and driving at the same time," also known as "thinking and driving," Trosper says. By contrast, Curiosity's auto nav software, when in use, runs in series to acquire images, process them, select a path and then drive.

The difference should be profound. If Mars 2020 spots a rocky obstacle it could decide to straddle it and drive over it. "MSL's algorithm would throw up its hands and go, 'I can't find a path!"

It'll take more than technology, though, to speed up the action on Mars. The Mars 2020 team wants to get the 10 hours of work required in the operations center down to five hours partly by having teams of operators working in parallel. NASA runs the operations center from 6 a.m. to midnight, so a shorter timeline reduces the odds that work will spill from one day to the next.

Weight watching

Achieving all this without busting the rover's mass allowance has been a chore. The decision to add the second processor added some mass, but most of the mass growth so far comes from an increase in the expected mass of the instruments and the corer, the device on the turret at the tip of the rover's 2-meter-long arm. Also, a camera called Watson, short for Wide Angle Topographic Sensor for Operations and Engineering, was added to the turret.

The NASA Office of Inspector General, which routinely audits agency projects, discussed the mass issue in a January report. At a preliminary design review in February 2016, project managers expected the rover's mass would be 1,013 kilograms. The report notes that the estimate had grown to 1,041 kg, close to the rover's 1,050 upper mass limit.

Trosper says all is "OK" right now on the mass issue.

In the final analysis, it could turn out that managers had no choice but to approach the mass limit for Mars 2020 if they were to outperform Curiosity. When it comes to navigation, "We absolutely have to spend our time in the selected regions of interest, looking at targets and deciding what to sample. We can't spend our time driving," Trosper says. And once at those targets, Chen's fun can begin. ★

Ben Iannotta contributed to this report.

FAMILIAR POWER CHOICE

Like the Curiosity rover, the Mars 2020 vehicle will generate electricity from the heat given off by a radioactively decaying nuclear fuel. The unit is called the Multi-Mission Radioisotope Thermoelectric Generator. Inside, plutonium pellets slowly shed radioactive particles, generating heat as they do. The generator converts this heat into electricity to charge the rover's batteries. The heat also keeps the rover's tools and systems operating in the cold of Mars.

Launch day

NASA's Mars 2020 rover will be launched atop a United Launch Alliance Atlas 5 in July or August 2020 for a six-month journey to Mars inside a cruise stage. The window was chosen because Earth and Mars are in good positions relative to each other for landing on Mars. The rocket will lift off from Launch Complex 41 at Cape Canaveral Air Force Station, Florida.

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RECYCLING ROCKETS

Early steps toward rocket reusability by Elon Musk's SpaceX are inspiring innovation in the once conservative world of expendable launch vehicles. For this trend to revolutionize access to space, the underlying economics must bear out and customers must come to trust the technology. Irene Klotz tells the story.

No one, not even SpaceX, is ready to write an epitaph for expendable rockets, which have shouldered the vast majority of some 5,700 orbital launch attempts since a modified Soviet intercontinental ballistic missile lofted the first Sputnik satellite 60 years ago. Instead, SpaceX and others are incorporating reusability into today's expendable rockets or the blueprints for next generation versions to find out just how far the trend can be taken.

The Hawthorne, California, company this year completed two commercial satellite launches with Falcon 9 first stages that previously landed on drone ships. During November's debut of the Falcon Heavy, SpaceX will try to land the core stage and two strap-on first stage boosters. The company is also actively wooing its customers with earlier launch dates and small discounts if they choose to fly on a rocket containing used components.

Competitor United Launch Alliance, a joint venture of Boeing and Lockheed Martin, has embraced the concept of reusability for its forthcoming Vulcan rockets by proposing to recover spent stages via helicopter. "As we develop the technology and use it in the marketplace, we're going to find out who's right. That's kind of the beauty of competition," says Tory Bruno, the CEO of ULA.

In Europe, ArianeGroup (formerly Airbus Safran Launchers) wants to someday fly back first stage engines for runway landings and reuse them.

If SpaceX and these competitors succeed, the result could be dramatically reduced space transportation costs, an aspiration that dates back to the space shuttle days. Technological and business hurdles lie ahead, though, including whether the U.S. Air Force, which is responsible for delivering the country's military and spy satellites safely to orbit, can be convinced to trust the technology.

Ambitious plans

Ultimately, SpaceX aims to recover and relaunch much more than the Falcon 9's first stages, which account for about 70 percent of each rocket's cost. The company wants to recover the payload fairings and second stages, as well as Falcon 9 and Falcon Heavy core stages. Unlike the reusable parts of the space shuttle, which were refurbished and reflown only after months of painstaking, labor-intensive and expensive work, SpaceX chief executive and lead designer Elon Musk wants his team to recover, refuel and relaunch a Falcon within 24 hours.

Not to be outdone, ULA, which is targeting a 2019 debut of Vulcan, wants the booster's two main engines to separate after shutdown and parachute back through the atmosphere for a midair helicopter recovery, saving the company about 65 percent of the rocket's cost, says Bruno. Whether either approach will prove economically viable and reliable — especially for U.S.

▼ Blue Origin's Blue Shepard lands at its West Texas spaceport.

Blue Origin

"We're going to find out who's right. That's kind of the beauty of competition."

— Tory Bruno on ULA's strategy for reusability compared to SpaceX's

government launches — remains to be seen.

Musk, who founded SpaceX in 2002, exuded confidence in a July speech in Washington, D.C. "I think we are entering a new era of space exploration, which is extremely exciting," he said at the International Space Station Research and Development conference. "It's not just SpaceX," he said. "There's a number of other companies that have developed new approaches." But he said the "biggest thing" to happen "is the landing of the Falcon 9 rocket booster."

Luxembourg-based SES bought the first ride on a previously flown Falcon 9. The company has been upbeat since the March launch of its SES-10 communications satellite. "When you go to the airport you don't ask if it's a new Airbus or a new 777. You get on it and you fly. It's a service that is being offered and you know the reliability of the vehicle is such that it's safe. I think that's where we're headed. It's not going to happen overnight, but I think that within 24 to 36 months you're going to see this," says Martin Halliwell, the company's chief technical officer.

The Air Force and NASA, the two biggest customers for U.S. launch services, are beginning to mull what inspections, tests and risk assessments they will need to certify used rockets are safe for reflight. The Falcon 9 first stage, like most aerospace structures, is made of aluminum alloy. During atmospheric re-entry, the lower part of the 14-story tall booster experiences extremely intense heating, which can change the mechanical properties of the metal. "How do you make sure that you haven't heated this aluminum structure up so that it will fail the next time? I'm sure SpaceX has some inspection technique, but there are all kinds of technical challenges like that," says Wayne Hale, a former shuttle program manager who serves as director of human spaceflight at Special Aerospace Services, an engineering consultancy.

So far, the Air Force and NASA have certified only new Falcon 9s for flight. "I don't view reuse for the near-term," says the Air Force's Claire Leon, who oversees launch service acquisition under the Evolved Expendable Launch Vehicle program, which has been dominated by ULA's Atlas 5s and Delta 4s but now includes two contracts with SpaceX. "For us to use

▼ **A Falcon 9** first stage arrives in port after landing on a drone ship.

SpaceX

reused hardware — or flight-proven hardware as SpaceX likes to say — we would have to go through a whole nother certification process and we're just getting through the initial certification process, so it'll take another increment of joint effort between us and any contractor that's proposing reuse," she says.

The Air Force does intend to study how to certify for reuse, she adds. "It's very important for the Air Force. We really are trying to reduce the cost of launch, so if this is the offering from commercial providers, then we need to get onboard, we need to figure out how to do that. It's just going to take us a little more time, but it is something that we are starting to study."

"All you do is inspections, and no hardware is changed, not even the paint."

— **Elon Musk** describing what it will take to relaunch a SpaceX Falcon 9 stage within 24 hours

NASA grappled with shuttle reusability for 30 years before ending the program in 2011. Each orbiter's three liquid-fuel main engines was designed to fly 10 times before inspections were necessary. However, during ground tests engineers discovered parts in the pumps that needed to be checked after every flight. So for the first 20 years of the program, the engines, built by Aerojet Rocketdyne, were removed between flights so the pumps could be taken out and sent back to the factory in California for inspections. Sometimes the pumps were torn down, then shipped to NASA's Stennis Space Center in Mississippi and hot-fired to make sure they had been put back together properly. The engines were then returned to the Kennedy Space Center in Florida and installed into an orbiter.

"Toward the end of the program, we got to the point where the engines could fly a couple of times, but we never got to 10," Hale says.

That won't work in today's competitive market. "If you have to dissemble the vehicle after every trip, X-ray all the parts, put it all back together, that is not real reusability. It has to be aircraft-like reusability. And it's going to be hard to get there," noted Jeff Bezos in his June acceptance speech for the Collier Trophy for New Shepard, a reusable suborbital spaceship developed by his space company, Blue Origin.

Former shuttle launch director Michael Leinbach warns that reusability has a hidden cost, which might not surface for years. "There is a natural human tendency to start accepting a little bit of creep in problems with reusing the same vehicle. A minor problem may become a moderate problem and then it might become a major problem. It is very difficult to get over the natural tendency to say, 'Well, it didn't hurt us last time. It won't hurt us this time.'

"Most of the high-energy systems are operating almost right at the edge of failure every time," he adds. "When you look at SpaceX's rocket when that thing jettisons the payload and then it fires its engines again and turns around and flies in its own exhaust to reverse momentum to get back toward the Cape, those are very, very difficult environments to deal with. To me, they are going to get into reuse issues where they're going to talk about minor issues that occurred during

Reusable rocket milestones

April 13, 2015
United Launch Alliance releases a plan for its proposed Vulcan rockets; concept calls for recovering each rocket's main engine by helicopter as it falls Earthward under a parachute.

June 5, 2015
Airbus Defence and Space reveals the design for Adeline, a winged upper stage — in the works since 2010 — that would carry a reusable rocket engine to a runway landing.

Nov. 23, 2015
Blue Origin sends its New Shepard suborbital rocket to an altitude of 100.5 kilometers; it touches down base first at the company's West Texas launch site without incident.

the previous flight," Leinbach says. "People are going to accept minor deviations where maybe they shouldn't. My counsel would be, when the hardware starts talking to you, pay attention to it."

Try, try again

SpaceX initially tried to recover its Falcon 9 first stages by parachuting them into the ocean, but the aerodynamic stress and heating of plowing into the atmosphere proved too taxing. The company switched to a propulsive landing technique and practiced with a suborbital rocket called Grasshopper. It also began experimenting with its orbital rockets' first stages, which conducted engine burns to reduce re-entry velocity and hover vertically over the ocean before succumbing to a hard splashdown.

SpaceX then attempted landing on a drone ship floating in the ocean, failing twice before finally returning a booster intact in December 2015 with a touchdown on the ground at Cape Canaveral Air Force Station. By July 2017, SpaceX had accomplished the feat either on the ground or on a drone ship a dozen more times. It returned two of those boosters to service, dispatching SES-10 into orbit in March and BulgariaSat-1 in June for Sofia-based Bulgaria-Sat. Four more pre-flown boosters were due to launch before the end of the year.

In his July speech, Musk said SpaceX would start reflying its Falcon boosters within 24 hours "probably by next year," and he gave a glimpse of the company's strategy. "The key," he said, "is that all you do is inspections, and no hardware is changed, not even the paint." The company also aims to recover its payload fairings, which cost around $6 million, and eventually will attempt return of its upper-stage boosters as well, Musk added.

SpaceX is still working off a backlog of business that piled up after a September 2016 launch pad accident, which grounded Falcon flights for four months. Two of those customers, SES and Bulgaria-Sat, say they were offered earlier launch opportunities if they agreed to fly their satellites on recycled boosters rather than new ones. SES-10, which launched in March, would have been delayed at least another three months if it had waited for a new rocket, says SES' Halliwell. In May, the satellite entered commercial service, adding an estimated $2.2 million per month in revenue to the company's coffers. "It's been cash out essentially for the last three and half years. It's good to turn the corner," he says.

SpaceX, which lists the base price of a Falcon 9 rocket at $62 million, offers customers a slight discount if they opt for a pre-flown booster. But if the company can learn to recover and reuse more than just the rocket's first stage, the goal would be to shave prices by about 30 percent, says SpaceX President Gwynne Shotwell. First though, SpaceX needs to recoup its investment in the landing technology, which Musk pegs at about $1 billion. "I want to see more reaction on the price points," says Halliwell. "I don't think anybody, including SpaceX themselves, really understands what the pricing is going to be longer term."

Whether launch price cuts will pave the way to a renaissance in space is unknown. Satellite services, manufacturing and ground equipment accounted for $255 billion in annual global revenue in 2016, according to a Satellite Industry Association report released in June. The space launch industry's worldwide revenue was about $5.5 billion.

"The cost of launch is not driving the industry," says Carissa Christensen, founder and chief executive of Virginia-based Bryce Space and Technology. "Coming up with $100 million upfront for a launch is not trivial, it's very capital intensive, but even if you reduce launch costs to zero you're not

Dec. 21, 2015
On its third attempt, SpaceX lands a Falcon 9 first stage; the stage touches down base first at Florida's Cape Canaveral Air Station; two previous boosters crashed on the company's drone ships.

Jan. 22, 2016
Blue Origin relaunches the same New Shepard rocket flown in November; it reaches an altitude of 101.7 kilometers and lands without incident at the West Texas launch site.

April 8, 2016
A SpaceX Falcon 9 first stage touches down without incident on a drone ship off the Florida coast in the first successful drone ship landing.

Coming in November 2017
On its first launch of a Falcon Heavy, SpaceX plans to fly back the rocket's two side boosters and core.

— DEBRA WERNER

going to see five more direct-to-home TV satellite ventures launching."

Cheap access to space, however, might pave the way for a new low Earth orbit economy that includes asteroid mining, commercial space stations, tourism, and off-planet workers and residents, but it likely will be decades before any of those ventures are economically viable, Christensen adds.

The passionate billionaires

The wildcard in the new space economy is what Christensen calls "the passionate billionaires" — people like Musk, Amazon founder Bezos, Virgin Group's Richard Branson and Microsoft's Paul Allen — who have invested personal fortunes in launch companies. "These are not simply hobbies," she says. "But the motivation for investment, the magnitude of the investment and the duration of the investment is driven by their passion and their vision, as opposed to a financial tradeoff. It's really interesting how it is driving the economics of reusable launch."

Like SpaceX, Bezos' Blue Origin bases its rocket designs and business plans on reusable hardware, beginning with the New Shepard launch system, which is undergoing unmanned test flights. Bezos said company astronauts and engineers could begin flying before the end of this year, followed by paying passengers in 2018. New Shepard, which launches from Blue Origin's West Texas spaceport, is designed to autonomously fly up to six people to an altitude above the Karman line, 62 miles (100 kilometers) above Earth. From that vantage point, passengers will be able see the curvature of the planet set against the black sky of space and experience a few minutes of weightlessness. Blue Origin also is working on an orbital-class rocket called New Glenn, which it says will debut in 2020, launching from Cape Canaveral. The company has disclosed six launch contracts for New Glenn, one for Eutelsat and five for startup OneWeb, which is developing a constellation of low Earth orbiting satellites for global, high-speed internet services.

Branson's California-based Virgin Galactic plans to fly tourists, researchers and payloads aboard reusable air-launch winged suborbital space planes collectively known as SpaceShipTwo. The fleet is expected to fly from New Mexico's Spaceport America. Another Virgin company, Virgin Orbit, marries the air-launched system with an expendable rocket to deliver small satellites into orbit, with a debut launch expected this year. Allen's Stratolaunch envisions similar services, but on a much grander scale, using a mammoth jet that can carry payloads up to 250,000 kilograms. The airplane is undergoing test-

VARIATIONS ON REUSABILITY

Airbus

Sprouts propellers and landing gear to carry an engine to a runway landing for reuse, according to a company animation of Adeline, the conceptual winged first stage whose name is short for ADvanced Expendable Launcher INnovative engine Economy. Airbus initially said the concept could be applied to Ariane 6, the new rocket fleet for its customer Arianespace, but Arianespace has not committed to incorporating reusability into the Ariane 6 fleet.

Blue Origin

Lands base first by sprouting air brakes and relighting its engine for a powered descent. New Glenn, the company's next rocket, will add an expendable second stage for launching satellites while the reusable first stage heads back to Earth. The company flew its first rocket, New Shepard, in 2015 and 2016 to demonstrate reusability for a vehicle that would launch adventure tourists or microgravity research projects to the fringes of space. New Shepard's capsule separated at the end of the mission while the rocket made a powered descent.

SpaceX

Lands base first, sometimes on drone ships and sometimes on land, by restarting engines. SpaceX does not use air brakes, but it does use its landing legs to increase drag. Founder Elon Musk said in 2014 that the landing legs cut the terminal velocity in half. SpaceX also uses grid fins to adjust the trajectory of the rocket during landing. SpaceX has demonstrated this technique with Falcon 9 first stages so far. On the debut of the Falcon Heavy in November, the company will try to land the vehicle's two liquid-fuel side boosters and its core booster, but Musk cautioned on Instagram, that there's a "lot that can go wrong." Musk tweeted in April that he was "fairly confident" SpaceX could retrieve and reuse Falcon 9 upper stages by late 2018.

United Launch Alliance

Plans to recover rocket engines with a heavy-lift helicopter as they fall toward Earth after launch. A module containing the two engines will be slowed by a parafoil and will release a tether that the helicopter will grab. ULA says it will fly entirely expendable Vulcan rockets first before beginning this recovery technique in 2024 with reusable Blue Origin BE-4 engines.

— Debra Werner

SpaceX

SpaceX's Grasshopper vertical takeoff, vertical landing vehicle was a prototype reusable rocket that had eight test flights and landings in 2012-2013.

ing in Mojave, California. For now, Stratolaunch is not focused on human spaceflight.

With their deep pockets, investor allure and independence, the billionaire rocketeers have presented a challenge to United Launch Alliance and Europe's Arianespace launch services company. "Everybody is trying to play catch up with SpaceX," Teal Group senior analyst Marco Caceres said at a launch industry seminar in June. "The Europeans are scared to death. Boeing and Lockheed, I think, are scared to death because there is just no way that they can develop and deploy launch vehicles that are going to be able to offer prices anywhere close to what Falcon 9 offers and still make a profit," he said. He predicted that Falcon 9 will "get cheaper and cheaper and cheaper as it becomes more reusable."

With their decades of experience, the old guard has no intention of walking away. Arianespace is making plans with prime contractor ArianeGroup to field a fleet of Ariane 6 expendable rockets meant to lower launch costs, whether or not they include reusability initially. For the longer term, Arianespace is considering reusable technologies, including ArianeGroup's proposed reusable engine Prometheus, and Adeline, a conceptual winged rocket stage that would sprout propellers and landing gear to carry an engine down to a runway for reuse. "The question is what is the best solution for the future? We do not really know right now — nobody knows," says Jan Woerner, director general of the European Space Agency, which is investing about 2.9 billion euros ($3.3 billion U.S.) in the Ariane 6 program.

United Launch Alliance not only is battling competition from SpaceX and Blue Origin but also an export ban on the Russian engines that power its workhorse Atlas rockets. To address both concerns, as well as retire the pricier Delta 4 line, ULA is developing the Vulcan to have recoverable first-stage engines and an upper stage that can be repurposed for a variety of transportation needs in orbit. "They become the trains of cislunar space … like a trucking fleet," says ULA's Bruno.

In the background of the reusable rocket debate are NASA and the U.S. Air Force, the biggest buyers of launch services in the United States. Both have taken advantage of SpaceX's cut-rate Falcon 9 prices — SpaceX will launch a GPS satellite for 40 percent less than what ULA charged, for example — and both see reusable rockets in their future.

NASA is considering previously flown Falcon boosters for SpaceX cargo runs to the International Space Station, said William Gerstenmaier, associate administrator for human exploration and operations. And Gen. John "Jay" Raymond, head of Air Force Space Command, said in April he is open to the idea of flying military satellites on recycled rockets. For now, however, a draft solicitation for military launch services beginning in 2022 still calls for "evolved expendable launch vehicles," or EELVs. "We'll have to figure out what to do with that extra 'E,' " quips SpaceX vice president Hans Koenigsmann. "We'll have to rename it. Maybe 'extraordinary'?" ★

Staff reporter Tom Risen contributed to this report.

Going broadband

Airline passengers and crews love their broadband, even though it is not cheap. Henry Canaday looked into the technology that lies ahead and found some bold innovations on the horizon.

BY HENRY CANADAY | htcanaday@aol.com

The number of airliners equipped for broadband connectivity from ground stations and satellites could nearly quadruple to 24,400 by 2026, estimates Florent Rizzo of Euroconsult, a space-market consultancy with offices in France, the United States, Canada and Japan.

Business passengers want to stay productive in flight, and leisure passengers want to be entertained and to remain in touch. Broadband also gives the crew, with cyber-security in mind, better weather data and bigger data pipes for downloading operational and maintenance data. All customers want more bandwidth and less expensively.

The question is how best to provide that bandwidth. For satellite connectivity, communications companies are vying to improve the equipment required on the aircraft. A move is underway to replace heavy, drag-inducing mechanically steered antennas with electronically steered antennas, or ESAs, which are on the horizon. There may even be

▲ **Honeywell flew** this aircraft around the world to showcase its Wi-Fi technology.

a way of shedding the need for satellite connectivity altogether. Why not use the massive fleets of commercial aircraft themselves as the link in a giant mesh network of broadband connectivity for both aircraft and other users?

Here is a rundown of the technical choices:

Better antennas

Aircraft connectivity started in the United States with ground stations linking to small antennas on the bottom of fuselages. As aircraft began to fly over oceans and areas with less ground infrastructure, satellites links became necessary. For broadband, these have generally been satellites in geosynchronous equatorial orbits 35,000 kilometers over the equator launched by firms like SES or ViaSat. Aircraft link to these satellites with dish antennas that mechanically change directions to focus on the satellite and maximize reception.

Dish antennas have some downsides. They must be protected against airflow with radomes, 21 or more centimeters in height. Radomes add drag, especially on takeoffs and landings. The mechanically steered antennas inside add weight. Including structural strengthening, radome and the antenna itself, this option typically weighs about 182 kilograms (400 pounds), according to David Brunner, global sales vice president of Panasonic Avionics. Panasonic and similar firms assemble connectivity equipment and services and offer the package to airlines.

ESAs could eventually be a much better choice. These are software-controlled, phased-array antennas whose beams are electronically steered in different directions without moving the antenna. They can lie flat, conforming to the shape of the fuselage, eliminating drag. ESAs can be light and, with no moving parts, much less prone to breakdown.

Aircraft ESAs have been made for military uses, but expensively, up to $10 million. More affordable ESAs have been developed for the L band, from 1 to 2 gigahertz, in 2003 and are now available for S band, from 2 to 4 GHz. But these are relatively narrow bands sufficient for limited messaging by pilots and perhaps a few passengers, not well suited for the massive volumes of data desired on commercial aircraft.

Broadband connections must work in the much more spacious Ku or Ka bands, from 12 to 18 GHz or 26.5 to 40 GHz, respectively. Here the challenges include maintaining connections at high latitudes, limiting power requirements and ensuring performance under extreme temperatures, all while getting costs down.

David Helfgott, CEO of Arlington, Virginia-based Phasor, believes he is nearing the goal of an effective broadband ESA for commercial aircraft. "We have been working hard for years, we are way ahead and well-positioned," Helfgott says.

Making even conventional antennas for Ku and Ka bands is tougher than for the narrower S and L bands because regulations set much stricter rules on how beams must behave, can be used and interact with satellites. This usually requires a larger antenna, heavier and with a taller radome.

Supporting broadband with phased-array ESAs is also hard. Phasor combines microchips with a network of omni-directional patch antennas, 5 millimeters by 5 millimeters, which are the radiating elements. These elements combine and steer communications electronically. About 500 elements are grouped in a module.

An aircraft ESA might have six, 12 or more of these modules. The modules would be 6.4 centimeters thick, with covers, versus 21 or more centimeters for radomes. A six-module Phasor ESA weighs less than 12 kilograms.

No moving parts should mean much less maintenance. For example, United Kingdom-based Cobham expects to get 100,000 hours mean time between removals from its L band ESAs, versus 20,000 hours for its mechanical models. Helfgott of Phasor says his ESA should be much more reliable than traditional antennas.

Perfectly flat ESAs may lose connectivity at latitudes of 55 to 58 degrees because their look angle to geosynchronous satellites over the equator is blocked by the horizon. Helfgott says his conformal ESAs, which wrap around the curve of the fuselage top, will maintain connections farther north, but acknowledges they will eventually lose connection as the poles are approached. He expects that widely dispersed constellations of low Earth orbit satellites in the near future, such as those planned by OneWeb, Telesat, LeoSat, Kepler and perhaps SpaceX, will eliminate this problem.

He says the Phasor ESA's ability to send and receive two beams on a single aperture will enable it to manage two links simultaneously, essential to manage handoffs smoothly among low Earth orbiters.

Active phased arrays require power, and though each chip needs only micro-current, the entire array requires much more. Helfgott says his ESA has constrained the power required to well below that available on commercial aircraft, and has ensured that dissipating the heat from this power will not be an issue.

Aircraft antennas must work over a wide range of ambient temperatures, from as low as minus 70 degrees Celsius in the air to as high as 90 degrees Celsius on desert tarmacs. Helfgott says active phased arrays will deal with cold temperatures and Phasor has solved the desert problem.

On cost, Helfgott says his ESA was designed from the beginning for efficient manufacture and will use global supply chains for both chips and printed circuit

Phasor Solutions

▲ **Under cover:** Multiple core modules, made up of microchips and patch antennas, comprise Phasor Solutions' electronically steered antenna, shown with their protective cover. For satellite connectivity, an antenna can be attached to the top of an aircraft.

boards. Panasonic's Brunner notes that making ESAs for an addressable market of tens of thousands of aircraft should also enable scale economies. Helfgott says he will be able to offer efficient, flexible ESAs at prices comparable to the best mechanical models.

The Ku-band version of Phasor's ESA antenna has completed Technology Readiness Level 7, having demonstrated a prototype in an operational environment. Beta testing for TRL 8, demonstration and certification of the actual system, will begin in the third quarter of 2017. This certification step could take six to 18 months, and Helfgott hopes to offer this first aircraft ESA to the market in the second half of 2018.

Other firms are also active. Redmond, Washington-based Kymeta is developing flat, light broadband antennas to connect satellites to mobile platforms, including ships, trains, buses, cars and aircraft. It is working with firms that supply inflight connectivity to commercial aircraft.

Kymeta's approach differs from the phased arrays used by Phasor, stresses Steve Sybeldon, vice president for business development. Kymeta uses metamaterials, artificially engineered materials similar to those used in liquid crystal display television sets. The tunable metamaterial elements create a holographic beam that transmits and receives signals, and software points the beam. This technology does not require active phase shifters, so it requires very little power.

Kymeta products have met environmental requirements for maritime operations, but aviation will require even lower temperatures. The firm is working with suppliers to modify its components for certification on aircraft. Trials and evaluations are underway for the aircraft version of Kymeta's product, which it calls the mTenna.

Euroconsult's Rizzo expects phased-array ESAs to enter the market in 2018, including one made by QEST, based in Holzgerlingen, Germany. He predicts Rockwell Collins and Gilat Satellite Networks, based in Gilat, Israel, will also offer ESAs in coming years. NLR, the Netherlands Aerospace Center, has been working with private partners on ESAs. As always with commercial aircraft, certification must follow innovation to yield practical application.

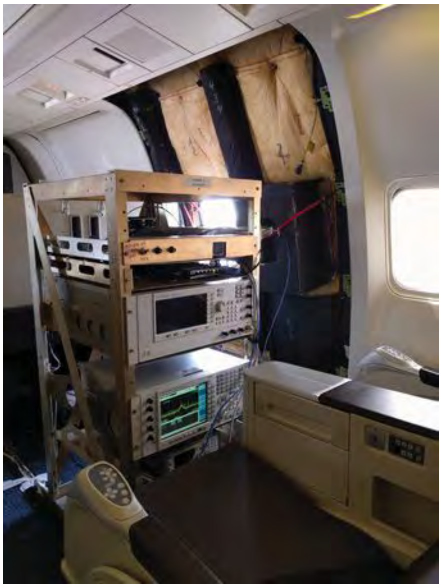
Brunner is eager for effective ESAs but cautious on timing. He judges practical and economic ESAs won't be ready for 24 to 48 months. In the meantime, Panasonic might install hybrid ESAs, which are thinner and lighter than today's equipment and change direction partly mechanically and partly electronically.

A mesh network of aircraft?

Even the best ESAs need satellite links, so connectivity must cover the cost of satellites and their launches. A new high-throughput satellite — which provides two to 20 times the broadband capacity of older satellites — costs about $250 million, and launching it can run from $60 million to $130 million, according to Euroconsult's Rizzo. Each month, an airline must pay about $3,400 for each megabit per second of capacity from older satellites or about $600 per megabit per second provided by a high throughput satellite. That price difference is one reason more airlines are adopting broadband.

Rizzo expects satellite connectivity costs to decrease another 30 percent in the next three years due to next-generation satellites. Even so, with tens of thousands of passengers downloading files or streaming movies each day, those capacity charges mount up to serious money.

Enter Airborne Wireless Network, a startup based in Simi Valley, California. To reduce the need for aircraft to communicate via satellite, it wants to develop a mesh network of aircraft that would relay broadband signals among them and to other users. The network would link to ground stations wherever it chose based on least-cost considerations. "The more ground stations we have, the more we can reuse spectrum and the more capacity we will have," explains Marius de Mos, vice president of technical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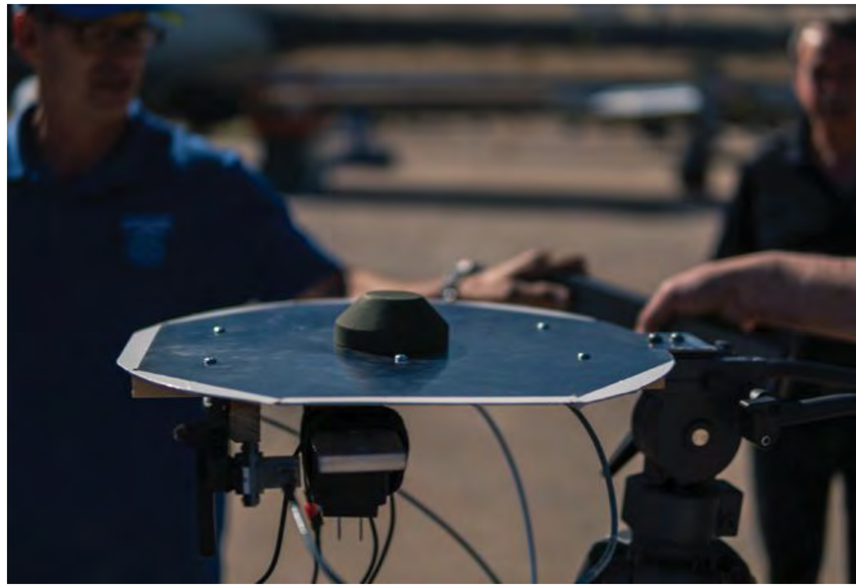
Airborne Wireless Network

affairs and development.

For the U.S., with about 5,500 aircraft flying, that would eventually mean about 200 ground stations, but Airborne could start with much fewer. It might begin by equipping several airlines on designated corridors and building a couple of dozen ground stations, de Mos says.

Aircraft would need radios, modems and antennas to repeat signals. The system would supply broadband to aircraft, but could also serve other users, especially in rural areas not covered by ground networks. Airborne would not compete with aircraft connectivity providers, but supply them by supplementing satellite or ground connections.

The system can work at 240 nautical miles (444 kilometers) between aircraft, even 600 nm (1,111 km) over oceans. But at full U.S. implementation, the network should average about 60 nm (111 km) between planes. “The more density, the more bandwidth,” de Mos notes.

Outside of densely populated tracks, fewer aircraft fly over oceans, so Airborne might put some repeating equipment on ships.

De Mos says the network would start by supplying megabits per second, then move to 10s of gigabytes, enough for both aircraft and other users on the ground. When fully built out, it could handle terabytes. “No one else could do that,” he stresses.

Airborne initially would mount three to four antennas on top and bottom of a fuselage. These would be low-profile, low-drag hybrid ESAs in radomes about 15 centimeters high, until full ESAs are available. Eventually, full ESAs would be used.

Radios and modems would be standard equipment, customized for Airborne’s purposes. One advantage is that these devices could be upgraded quickly by just swapping boxes, as technology improves. Satellites, in contrast, are designed two years before launch and then operate for five to 10 years. By definition, old satellite technology stays in use for a long time.

▲ **Mesh network:** At left, an antenna, modem and power amplifier in the cabin of a Boeing 767 transmitted through a window to another 767. This plane then transmitted data to a mobile mast ground station, right, during Airborne Wireless Network’s demonstration.

And the mesh approach means that when one link is down or blocked by weather, another can instantly replace it. Each aircraft would have three repeaters. Quick repair of connectivity is not possible with current satellites.

In May 2017, Airborne completed a proof of concept using two Boeing 767s for a ground-to-air-to-air-to-ground link. Next in 2018 will come a test on 20 aircraft emulating a global network. This test will use production-ready equipment. De Mos expects rollout in 2019.

De Mos acknowledges he needs a critical mass of aircraft to make the approach work. He is talking to Air Lease, which leases several hundred aircraft to airlines and has ordered several hundred more. He expects airlines to line up because they want much more reliable connections for passengers, and Airborne’s mesh approach would support that. Also, by supplying connectivity to other users, airlines might convert a pure cost burden into a revenue earner.

“The science is there, and they are smart guys,” says Brunner. “The problem is how to penetrate a critical mass of aircraft.”

Broad adoption seems to be a condition to make sure aircraft stay connected in the mesh network, Rizzo observes. Still, “the solution could be a complementary service to provide connectivity.”

In any case, several paths to better aircraft broadband are opening up. It’s a tricky but happy dilemma for airline managers. ★

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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			
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	
17–21 Sep†	36th Digital Avionics Systems Conference (DASC)	St. Petersburg, FL	
25–29 Sep†	68th International Astronautical Congress	Adelaide, Australia	28 Feb 17
3–4 Oct†	Drone World Expo	San Jose, CA	
11–12 Oct†	International Symposium for Personal and Commercial Spaceflight	Las Cruces, NM	
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
23–26 Oct†	International Telemetering Conference	Las Vegas, NV (www.telemetry.org)	
13–15 Nov†	1st International Academy of Astronautics (IAA) Conference on Space Situational Awareness	Orlando, FL (www.icssa2017.com)	
4–8 Dec†	Flight Software Workshop	Laurel, MD (www.flightsoftware.org)	28 Aug 17
2018			
6–7 Jan	5th International Workshop on High-Order CFD Methods	Kissimmee, FL	
6–7 Jan	Challenges and Opportunities in Aerospace CFD: Achieving the CFD2030 Vision Workshop	Kissimmee, FL	
8 Jan	2018 Associate Fellows Recognition Ceremony and Dinner	Kissimmee, FL	
8–12 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – AIAA/AHS Adaptive Structures Conference – AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – AIAA Non-Deterministic Approaches Conference – AAS/AIAA Space Flight Mechanics Meeting – AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – AIAA Spacecraft Structures Conference – Wind Energy Symposium	Kissimmee, FL	12 Jun 17
22–25 Jan †	64th Annual Reliability & Maintainability Symposium (RAMS)	Reno, NV (Contact: http://www.rams.org)	
21 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (www.aiaa.org/CVD)	
1 May	2018 Fellows Dinner	Crystal City, VA	
2 May	Aerospace Spotlight Awards Gala	Washington, DC	

†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
3–10 Mar †	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	
8–10 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum) Featuring: – AIAA Missile Sciences Conference – AIAA National Forum on Weapon System Effectivenss – AIAA Strategic and Tactical Missile Systems Conference	Laurel, MD	
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: – AIAA/CEAS Aeroacoustics Conference – AIAA Aerodynamic Measurement Technology and Ground Testing Conference – AIAA Applied Aerodynamics Conference – AIAA Atmospheric Flight Mechanics Conference – AIAA Atmospheric and Space Environments Conference – AIAA Aviation Technology, Integration, and Operations Conference – AIAA Flight Testing Conference – AIAA Flow Control Conference – AIAA Fluid Dynamics Conference – AIAA/ASME Joint Thermophysics and Heat Transfer Conference – AIAA Modeling and Simulation Technologies Conference – AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference – Plasmadynamics and Lasers Conference	Atlanta, GA	9 Nov 17
25–29 Jun†	15th Spacecraft Charging Technology Conference (SCTC)	Kobe, Japan (Contact: http://www.org.kobe-u.ac.jp/15sctc/index.html)	
3–6 Jul†	ICNPAA-2018 - Mathematical Problems in Engineering, Aerospace and Sciences	Yerevan, Armenia (Contact: http://www.icnpaa.com)	
9–11 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – AIAA/SAE/ASEE Joint Propulsion Conference – International Energy Conversion Engineering Conference	Cincinnati, OH	
19–23 Aug†	2018 AAS/AIAA Astrodynamics Specialist Conference	Snowbird, UT (http://www.space-flight.org)	
17–19 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition) Featuring: – AIAA Complex Aerospace Systems Exchange	Orlando, FL	
1–5 Oct†	69th International Astronautical Congress	Bremen, Germany	

2017 Joint Conference

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The Joint Conference will be held in Trieste, Italy, at the Savoia Excelsior Palace Hotel. Trieste is one of the most important Italian seaports as well as a capital of literature and music. A combination of geographic and historical factors has made Trieste a dynamic, diverse city and a fascinating place to visit.

The rapid technology revolution, large-scale services integration, new launch options, the LEO and GEO constellations competition and the integration of markets are driving and pushing toward a big transformation in satellite systems. Application and services integration are changing technology and market perspectives. The development of sensor systems and high-speed data links for small satellites and drones holds open the promise for a revolution in global sensing markets. The development of many new LEO systems and small satellites, stratospheric platforms, and GEO systems, together with the future exploitation of the new Q/V and possibly W frequency bands, are creating a major competitive environment. The 2017 Joint Conference will cover industry transformations, propose and discuss new uses, and provide a forum for the exploration of the economic, marketing, technical and regulatory issues affecting these new challenges.

The program will include:

- The **35th AIAA ICSSC Colloquium on High Throughput Satellite (HTS) Broadband Opportunities: Orbits, Architectures, Spectrum, Interference and Markets** on 16 October.
- Keynote Address by **Badri Younes**, Deputy Associate Administrator for Space Communications and Navigation, NASA, and **Greg Wyler**, Founder and Executive Chairman, OneWeb
- **Plenary Panels:**
  - **Commercial Space Applications: Transformation, Fusion and Competition**
  - **Optical Technology and Systems**
  - **Emerging New Markets in Aviation and Autonomy**
  - **Disruptive Broadband Systems — NGSO and GEO HTS**
- The 4th General Assembly of the **Alphasat Aldo Paraboni Propagation Experimenters (ASAPE) Group**
- Speakers include representatives from around the world: CFG Engineering, ESA, Eutelsat, NASA, NICT, OneWeb
- 32 technical sessions with more than 140 papers addressing the most relevant topics in Broadband Satellite Communications, Navigation, and Earth Observation

The deadline for the final paper submission and Early-Bird Registration pricing ends 6 September 2017.

A Deeper Look into the Program

FOCUSED PANELS

Commercial Space Applications: Transformation, Fusion and Competition

The panel will discuss the rapid technology revolution, the large-scale services integration, new launch options, the LEO and GEO constellations competition, and the integration of the markets that are driving toward a big transformation in satellite systems, market perspectives, and are massively increasing competition in the environment.

Optical Technology and Systems

Space-based free-space optical communications is a concept that has been around since the invention of lasers in the 1960s. In the last few years there has been an impressive amount of activity to demonstrate and launch satellites that carry on-board optical technology. These optical links are being utilized not only for inter-satellite links, but for space-ground links where gigabit data rates are a big enough draw to overcome the large propagation losses they can encounter in the atmosphere and additional pointing requirements. This plenary panel will discuss the state of the art of optical technologies and the optical systems in play today.

Emerging New Markets in Aviation and Autonomy

Rapid new uses of airspace coupled with recent advances in autonomy will change the nature of how people live and work. The growth of civilian drone services (Unmanned or Remotely Piloted Aircraft Systems) took market analysts totally by surprise, but this coupled with the tremendous research taking place in autonomy and its applications to self-driving cars and drone operations could cause an exciting new opportunity for satellites. Come hear what is happening in these growth fields.

Disruptive Broadband Systems — NGSO and GEO HTS

Historically, GEO satellites have taken advantage of broad area coverage to identify their sweet spot, which enabled the growth of video distribution services (DBS and DTH) to the consumer. Today, the desire is for broadband services for anyone, anytime and anywhere. This slow and steady trend to streaming broadband data to individual users has given rise to competing technology solutions. This has led to a mismatch of supply and demand and the disruption of long-standing $/MHz pricing models. Where will this all lead?

15th BroadSky Workshop: One More Asset for the 5th Generation

The new wave is coming to the satellite communications world with Super HTS and Super LEO Constellations. At the same time, terrestrial mobile communications are moving into 5th Generation (5G). 5G will provide various kinds of communication capabilities by users' requirements, such as very high throughput, very low latency, very high density of terminals, and so on. Though satellite communications seldom appear in discussions of 5G, it is included in the concept of 5G. Satellite communications can provide some unique advantages to the 5G environment.

35th AIAA ICSSC Colloquium on High Throughput Satellite (HTS) Broadband Opportunities: Orbits, Architectures, Spectrum, Interference and Markets

The Colloquium will look across a broad range of satellite-based proposals and architectures to explore both competition and complementarity. The session will review specific applications for satellite access and how they might fit in an increasingly LTE and ultimately 5G world. Having identified these applications, the session will then look at the variety of proposals and the issues surrounding those proposals including Orbits, Spectrum Availability and Use, Potential Interference, both between systems and with terrestrial wireless, and the real challenge of big numbers including initial deployments, constant replacement and replenishment, orbit congestion and debris removal and the viability of competing business models in common markets.

Information & Inquiries

Ka Conference Technical Program Co-Chairs at **rtgedney@centurytel.net** and at **franco.marconicchio@gmail.com**

ICSSC Technical Program Chair at **icssc.otung@southwales.ac.uk**

Joint Conference Organization at **info@kaconf.org**

For additional details and to register, visit

www.kaconf.org

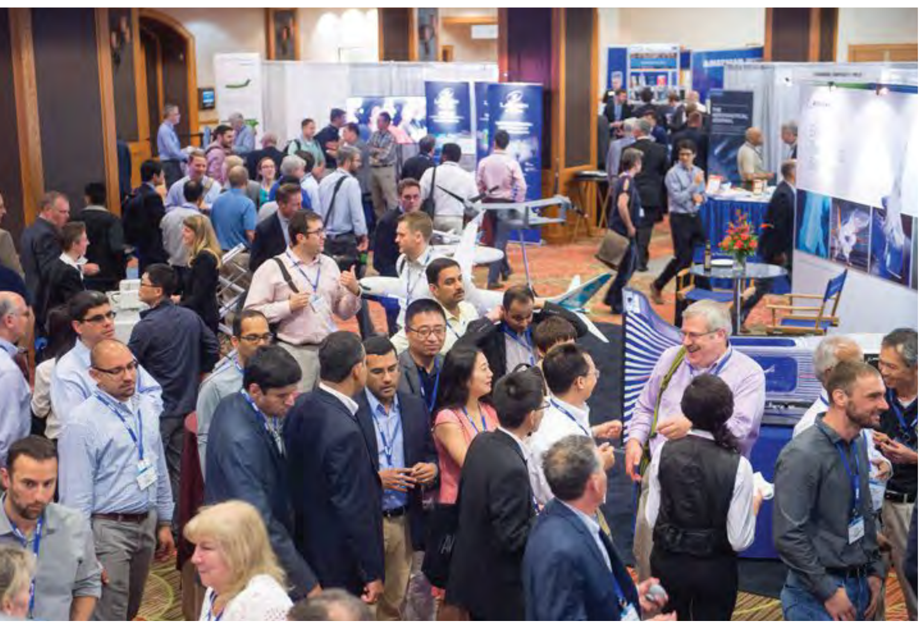
AIAA

Shaping the Future of Aerospace

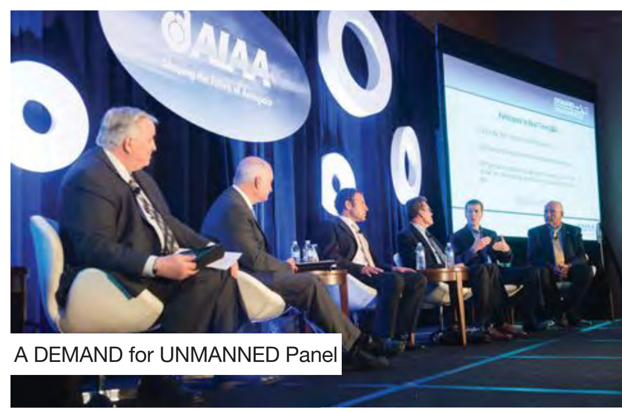
17-1996

AVIATION FORUM

More than 2,800 attendees representing a broad range of the aviation community – from across the United States and 39 other countries – gathered in Denver, 5–9 June, to help make it the most successful AIAA AVIATION Forum to date. The forum included more than 600 students and featured 1,576 technical presentations.



Supersonic Transport Panel

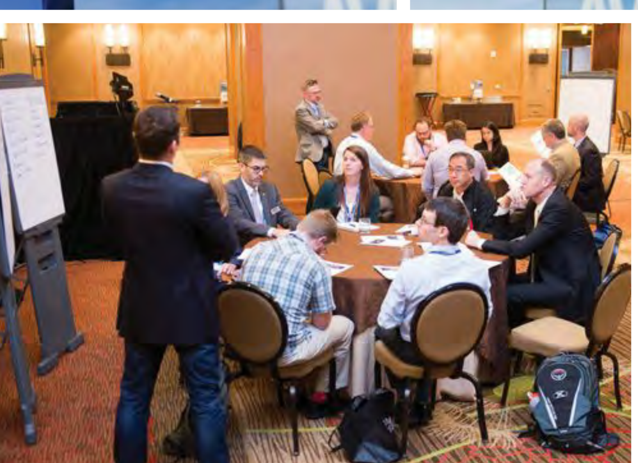


A DEMAND for UNMANNED Panel


David Mindell, Beyond the Robots


Mark Moore, Uber


Hannes Ross Wright, Lecturer



Innovation and Disruption Opportunities Panel

News

Hello? Is This Outer Space?

On 9 June, students at Leeds Elementary School in Elkton, MD, made the ultimate long distance phone call to a human-occupied outpost orbiting 250 miles above Earth. Audience members sat spellbound as astronaut Col. Jack "2Fish" Fischer on the International Space Station (ISS) squeezed three brown coffee balls out of a straw and caught them deftly in his mouth as he was watched by members of the AIAA Delaware Section, Orbital ATK, and the students and staff at Leeds Elementary. This In-Flight Education Downlink allowed students and educators to interact with an astronaut aboard the ISS during a live question-and-answer session. Downlinks provide the opportunity to learn first-hand from space explorers what it is like to live and work in space. NASA Johnson Space Center's (JSC) Office of Education facilitates these events, which are designed to enhance student learning, performance, and interest in STEM. The downlink at Leeds Elementary was made possible through partnership between the AIAA Delaware Section, Orbital ATK Missile Defense & Controls Division, and Cecil County Public Schools (CCPS).

Planning for the event began back in January 2016 when the AIAA Delaware Section applied for a downlink during Expedition 49/50. A committee evaluated their application and selected them, but due to mission constraints, NASA could not accommodate the section's event on their schedule. The Delaware Section began the process again in fall 2016 for Expedition 51/52 . . . and . . . success! The section and school were notified in January 2017 that the ISS was scheduled to conduct a downlink with the school in late spring 2017.

Immediately, the Delaware Section, Orbital ATK, and Leeds Elementary School began to prepare for the event. Orbital ATK contributed by sponsoring a Franklin Institute (Philadelphia, PA) traveling science show assembly at the school that presented the subject of "Life in Space" where the students embarked on a trip to space and explored the scientific and engineering challenges of getting to space, living and working in orbit, and safely returning to Earth. The AIAA Delaware Section participated with classroom presentations on human space exploration and guiding the students through astronaut training and launching sodium bicarbonate rockets. In the weeks leading up to the downlink, students followed 2Fish on social media and watched his spacewalks via NASA TV. Art classes were used for students to design their own planets, and teachers integrated discussions about space station life into their curriculum. "There's a lot of planning that goes into this event," said Tim Dominick, Public Policy Chair with the Delaware Section and lead organizer of the event. "We wanted to help prepare the students, get them excited, and give them as much background as possible to interact well with the astronaut."

On the day of the event, many local, state, and federal elected officials attended. The event began with the Leeds Elementary band playing the theme from Star Wars and the school chorus entertained everyone by singing "I.S.S. (Is Somebody Singing)" written by retired Canadian astronaut Chris Hadfield and Ed Robertson (Bare Naked Ladies). Leeds Elementary Principal Nikole MacDowell made the opening radio call with Jack Fischer, and Cecil County Executive Dr. Alan McCarthy welcomed Col. Fischer to Cecil County. Then 20 students, preselected by their teachers, each asked 2Fish a question ranging from "What is your favorite thing to eat in space?" (coffee balls!) to "What tools are you using to study the effects of microgravity on bones?". The questions were generated by each classroom and had been sent to NASA JSC's Office of Education ahead of time to ensure that the astronaut was prepared and in case audio difficulties prevented him from hearing the students' questions. Throughout the downlink, the 400 kids sat quietly while listening to his answers and watching him perform "Astronaut Tricks" on the large screen. The downlink wrapped up with Vice Principal Allyson Veasey thanking 2Fish for sharing this experience with the students.

A packed house listens intently to 2Fish's answers to the students' questions during the downlink.

Leeds Elementary School is the second school in Maryland to host a downlink with astronauts on the ISS, and it was the sixth downlink ever to occur in Maryland. Four of the previous downlinks were hosted by either NASA Goddard Space Flight Center or the Maryland Science Center. The number of in-flight education downlinks varies each year based on mission operations, but on an average year, NASA conducts around 12 to 14 with educational organizations across the country. Downlinks have been performed continually on the ISS since Expedition 1.

Two days after the downlink, the ISS made a pass over Elkton. The AIAA Delaware Section made posts on social media with viewing information to alert students and families to go outside to watch the ISS pass and wave "hi" to 2Fish. It was inspiring to see the connection the students made between just having had the downlink and now seeing the ISS pass overhead.

To view the entire downlink, visit https://www.youtube.com/watch?v=xwAb4tYG9w8&t. For more information on hosting your own downlink, contact the NASA JSC Office of Education at JSC-Downlinks@mail.nasa.gov.

AIAA Leadership Takes Part in NASA Langley Centennial Symposium

By Hannah Thoreson

From 12 to 14 July, a symposium was held at Hampton Roads Convention Center as part of the celebration of NASA Langley Research Center's 100 years of technical excellence. Tom Irvine, managing director of Content Development at AIAA, moderated a panel titled, "Aeronautics Research Partnerships: Celebrating the First 100 Years and Looking Forward to the Future." Irvine said, "The contributions and the research and the work done at Langley, either as government research or as cooperation and collaboration with U.S. industry, has truly been a success story that makes aviation what it is today." Robert D. Gregg III, Tom L. Wood, Dr. Robert H. Liebeck, and Dr. Mark Lewis also discussed advancements in aeronautics.

AIAA Executive Director Dr. Sandra Magnus also moderated a panel at the symposium: "Future of Aerospace in the Next 20–30 Years." She explained that projecting out maybe 100 years is a purely creative problem, but that a more narrow focus, like 20 or 30 years out, has constraints that are a bit easier to understand. Magnus added, "20 or 30 years is long enough and far enough into the future that there are still going to be some curveballs that come at us from outside the community as well as breakthroughs that come out within the community." Panelists Gregory Williams, Stephen G. Jurczyk, Dennis Andrucyk, and Robert A. Pearce spoke about the innovations to come in the next decades.

Call for Awards Nominations

Nominate Your Peers and Colleagues for Technical and Management Awards!
Do you know someone who has made notable contributions to aerospace arts, sciences, or technology? Nominations are now being accepted for many AIAA awards (http://www.aiaa.org/AwardsNominations) and must be received by 1 October.

Greater Huntsville Section members (left to right) Naveen Vetcha, Kurt Polzin, Tammy Statham, Ken Philippart, Brandon Stiltner, Alan Lowrey & Lisa Philippart. (Image by Matt Statham)

AIAA Greater Huntsville Section Named Huntsville's Society of the Year

By Ken Philippart

The Greater Huntsville Section was named the 2017 Society of the Year by the Huntsville Association of Technical Societies (HATS). HATS is a nonprofit organization supporting Huntsville area technical and professional societies, dedicated to the advancement of science and engineering and representing over 18,000 professionals across 19 member organizations. The section was selected as Society of the Year for its initiatives to recruit, retain and groom Young Professionals (YPs) for leadership positions within the section. Greater Huntsville also has a vigorous, innovative program focused on the needs of YPs that included conducting the first YP technical symposium, and holding regular YP mentoring brunches, socials and networking events. Past Chair Brandon Stiltner and Chair Naveen Vetcha accepted the award on behalf of the section and thanked the section's 1,200 members for a true team effort in winning the honors.

Several Greater Huntsville Section members also were recognized individually during the dinner. Alan Lowrey was recognized as Greater Huntsville Section's Professional of the Year (PoY), Jim Parsons was named PoY for the American Society of Mechanical Engineers, and Ken Philippart was selected as the Rocket City Tau Beta Pi Alumni Chapter's PoY. HATS instituted a new award this year, Young Professional of the Year (YPoY), which was awarded to Greater Huntsville Section YP Director Tammy Statham. Congratulations to the Greater Huntsville Section and members on their awards.

AIAA Fellow Laura McGill, vice president of Engineering, Raytheon Missile Systems, speaks to scouts.

AIAA Tucson Section Helps Scouts Fly High at Raytheon Scouts Day

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 Elishka Jepson (elishka.jepson@raytheon.com).

On 2 February, Raytheon Missile Systems held its 8th annual Scouts Day, an event where engineers volunteer their time to assist nearly 300 scouts in their quest to acquire a STEM-related merit badge. Volunteers developed lessons and activities that cover all of the requirements for specific merit badges. This year, 13 different badges were offered, ranging from robotics to space exploration. The AIAA Tucson Section was pleased to offer the Aviation merit badge as a part of this program.

In 2011, several Tucson section members volunteered at the second Raytheon Scouts Day. They were so impressed by the event, and the positive impact on the scouts, that they decided to develop their own merit badge curriculum. They decided on the Aviation merit badge, a logical fit for AIAA. The Tucson Section held its own Aviation merit badge day later in 2011. With a developed curriculum in hand, and some experience under their belt, the section approached the Raytheon Scouts Day organizers about adding the Aviation merit badge to their event. AIAA was welcomed enthusiastically, and has participated in every Raytheon Scouts Day since 2012.

During the day, Aviation merit badge participants gain a variety of aerospace knowledge. They start with a lesson on how an aircraft flies, then move on to the fundamental aircraft flight instruments and how to read them. Scouts then rotate through a series of activities, including foam glider construction, and taking the controls of a Cessna 172 flight simulator. The section also provides career speakers for the scouts. One of the long-time aviation merit badge volunteers, Tom Mouch, is an engineer and former Air Force Academy instructor; the scouts always learn a lot from his experience and career path.

If you are interested in hosting an Aviation merit badge day in your section, please contact Elishka Jepson at tucsonaiaa@gmail.com. The Tucson Section would be more than happy to share their slides, handouts, and activities, and offer any assistance in helping you start your own program.

2017 AIAA Space Systems Technical Committee Essay Contest—Juno Spacecraft

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

Seventh and eighth graders were asked to write about the 2017 essay topic: "Choose one of the aspects of the Juno spacecraft, and describe how it works and why it helps discovery about Jupiter." Nine sections, including Cape Canaveral, Greater Huntsville, Greater New Orleans, Hampton Roads, Long Island, Niagara Falls, Rocky Mountain, Southwest Texas, and the "At-Large section," submitted official entries to the contest. For each grade, there were first-, second-, and third-place winners, which included \$100, \$50, and \$25 awards for the students, respectively, plus \$250, \$150, and \$100 for their classroom toward STEM materials or activities. The six students also receive a one-year membership with AIAA.

The first-place winner for 8th grade was Nikhil Keer (and teachers Leslie Maynard and Vanessa Kowalczyk) from Levittown, NY. The second-place winner for 8th grade was Spencer Tanenholtz (and teacher Rob Stannard) from Denver, CO. The third-place winner for 8th grade was Julia Gignac (and teacher Tracy Thomas) from San Antonio, TX.

The first-place winner for 7th grade was Taylor Honeycutt (homeschooled by Kim Honeycutt) from Harvest, AL. The second-place winner for 7th grade was Gary Nepravishta (and teachers Leslie Maynard and Vanessa Kowalczyk) from Levittown, NY. The third-place winner for 7th grade was Ana Gent (and teacher Jill Whitacre) from Melbourne, FL.

All 2017 winning essays can be found on the Aerospace America website in the September AIAA Bulletin section. The topic for 2018 is "In 2017, NASA selected 12 new astronaut candidates. Describe the role of astronauts and their impact on NASA, their impact on the future of the United States, and their impact on international partnerships." If you, your school, or section is interested in participating in the 2018 contest, please contact Anthony Shao (ant.shao@gmail.com), or your local section for more details.

SAT IOC committee leadership hand-off (left to right): Amir S. Gohardani and R. Steve Justice. Credit: AIAA SAT IOC.

Society and Aerospace Technology Integration and Outreach Committee (SAT IOC)

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

The Society and Aerospace Technology Integration and Outreach Committee (SAT IOC) marks the new name for the former Society and Aerospace Technology Technical Committee under a new AIAA governance structure. SAT IOC combines different activities linked to AIAA's mission to inspire and advance the future of aerospace for the benefit of humanity. One of the strengths of this IOC is the diverse interest of its membership ranging between Astrosociology to more traditional perspectives of measuring the societal impact of aerospace activities.

Recent committee endeavors included collaboration with the AIAA Tucson Section for a joint booth at the Phoenix Comic Con. This event was attended by over 100,000 people and exemplifies a new way to enable the members of the general public in gaining unprecedented insight into AIAA activities. During the AIAA forums, SAT IOC generally supports the Space History, Society, and Policy Track examining the history of our time in space, space law and policy, international cooperation, the societal impacts of aerospace technologies and an educated and trained workforce, and the evolution of our spacefaring society.

At a recent event, R. Steve Justice, SAT IOC Past Chair (2015–2017), was recognized for his committee leadership and commitment. "I would like to thank Mr. Justice for his exceptional committee leadership and for his many contributions that have assisted in shaping a diverse and active committee. We will continue pursuing key committee objectives with the same enthusiasm as before," the new SAT IOC Chair, Dr. Amir S. Gohardani stated. SAT IOC looks forward to collaborating with other AIAA committees.

AIAA Members Recognized

Several AIAA members were recently recognized with a NASA Distinguished Public Service Medal.

Dr. Forman Williams, Professor Emeritus at the University of California at San Diego and AIAA Fellow, was awarded the NASA Distinguished Public Service Medal for his outstanding contributions to the field of combustion science and for his pioneering work using microgravity space experiments to reveal new phenomena in combustion.

Kauser Imtiaz, Technical Fellow, Structures & Mechanisms, Space Exploration, The Boeing Company, and an AIAA Associate Fellow, was awarded the NASA Distinguished Public Service Medal for distinguished service and leadership in international cooperation and advancements in International Space Station Structural Integrity and Fracture Control.

Roger D. Launius, NASA's Chief Historian from 1990–2002, and an AIAA Associate Fellow, was awarded the NASA Distinguished Public Service Medal for distinguished service, promoting our nation's history in aeronautics, space, and selfless leadership in promoting the highest standards in federal historical endeavors.

National Technology Day Award to Dr. PC Jain

Dr. PC Jain, AIAA Senior Member and a scientist with Defence Research & Development Laboratory (DRDL) Hyderabad, has been given the National Technology Day Award. Dr Jain, an alumnus of IIT Roorkee, IIT Bombay, and BOYSCAST (DST) fellow from Pennsylvania State University, is an expert in the areas structural optimization, structural dynamics, and nonlinear structures technologies. He has significantly contributed toward the success of various national projects. Dr. Jain delivered the Technology Day Oration on the topic Aero Structures Technologies - Criticalities and Challenges. The talk focused on critical technologies, methodologies adopted, and the resulting robust products.

Shri MSR Prasad, Distinguished Scientist and Director DRDL Hyderabad, presented the National Technology Day Award to Dr. Jain.

Call for Papers

ICNPAA 2018 World Congress: Mathematical Problems in Engineering, Sciences and Aerospace

3–6 July 2018
American University of Armenia (AUA), Yerevan, Armenia

On behalf of the International Organizing Committee, it gives us great pleasure to invite you to the ICNPAA 2018 World Congress: 12th International Conference on Mathematical Problems in Engineering, Aerospace and Sciences, which will be held at the American University of Armenia (AUA) Yerevan, Armenia.

Please visit the website, http://www.icnpaa.com, for all details. This is an AIAA, IFIP cosponsored event.

Obituaries

AIAA Fellow Lynn Died in May

Bell Helicopter and American Helicopter Society leader **Robert R. Lynn** passed away on 27 May. He was 90.

Lynn received his B.S. degree in mechanical engineering and his M.S. degree in aeronautical engineering from Princeton University. He later attended MIT's senior executive program.

In 1950, Lynn began his career as a draftsman with the Bell Aircraft Corporation, in Buffalo, NY. The following year, he was transferred to Bell's new division in Fort Worth, TX. He served as a project engineer and later as Bell Helicopter's chief of research and development, director of test and evaluation, and director of design (1974–1977). He retired in May 1991 as senior vice president for research and engineering. During his time at Bell, he was instrumental in the design of the Huey Cobra and the Osprey.

Lynn joined the American Helicopter Society (AHS) in 1952; he earned status as part of the AHS Gold Circle Club (1977) and then as an AHS Emeritus Member (2002). He was the recipient of the prestigious 1983 AHS Alexander Klemin Award and was the 1992 AHS Alexander A. Nikolsky Lecturer. He served AHS in many capacities, including as editor-in-chief of the Journal of the AHS (1970), technical director, president (1978–1979), chair of the board (1979–1980), and chair of the AHS Vertical Flight Foundation (1980–1981; 1982–1983).

Lynn was also the recipient (with Robert J. Tapscott) of the 1973 AHS Paul E. Haueter Award for "outstanding technical contribution to the field of vertical take-off and landing aircraft development other than a helicopter," as well as the 1983 AHS Harry T. Jensen Award for "outstanding contribution to the improvement of vertical flight aircraft reliability, maintainability, and/or safety through improved design."

A Fellow of AIAA and the Royal Aeronautical Society (RAeS), and an AHS Honorary Fellow, he authored more than 40 publications and held multiple patents. In 1996, Lynn presented the Cierva Lecture to the RAeS. He was a registered professional engineer in Texas, and a chartered engineer in Great Britain.

Lynn served many organizations such as National Aeronautics and Space Administration (NASA), the US Army, the NATO Advisory Group for Aerospace Research and Development (AGARD), the Federal Aviation Administration (FAA), AHS, the Aircraft Industries Association's Technical Council, the White House's Office of Science & Technology Policy's Aeronautical Policy Review Committee, North Texas Association of Higher Educations Council of Business and Industrial Executives, Engineering Advisory Boards for Georgia Tech and University of Texas in Arlington, the National Research Council's Aeronautics and Space Engineering Board, and the FAA Technical Oversight Group on Aging Aircraft (TOGAA); he later received the FAA Award for Extraordinary Service for his participation with TOGAA.

AIAA Fellow Ghia Died in June

Professor Kirti "Karman" Ghia, aerospace educator, research scientist, and pioneer in the field of Computational Fluid Dynamics, passed away on 13 June. He was 80 years of age.

Ghia came to the United States from India in 1961, following his baccalaureate degree in Mechanical Engineering. He completed his M.S. and Ph.D. degrees in Mechanical and Aerospace Engineering at the Illinois Institute of Technology. For 47 years he was a faculty member of Aerospace Engineering and Engineering Mechanics at the University of Cincinnati (UC), where he founded the Computational Fluid Dynamics Research Laboratory. He received the university's Rieveschl Award for Distinguished Scientific Research, the George Barbour Award for outstanding Student-Faculty Relations, the Dolly Cohen Award for Excellence in Teaching, and was named University Distinguished Professor. Ghia held visiting appointments at NASA, the Air Force Research Laboratory, the Polytechnic Institute of New York University, the University of Southern California, and Brown University, as well as at international institutes.

Ghia's pioneering CFD research has provided fundamental solutions for three basic incompressible flow problems: the driven-cavity, curved square-cross-section duct exhibiting Dean's instability, and the backstep geometry. These have served as benchmark solutions for numerous subsequent incompressible flow code developers.

His separated-flow work on 2-D pitching airfoils led to unmasking the mechanism for dynamic stall; and a key result from this work was published in the Smithsonian. His co-authored editorial statement on Numerical Uncertainty became the cornerstone of ASME's policy on numerical uncertainty, and AIAA's current statement is drafted around this policy.

Ghia was very involved with AIAA, including as a faculty advisor to the AIAA UC Student Branch, a member of the AIAA Fluid Dynamics Technical Committee, and an associate editor of the AIAA Journal. He was a technical chair for serveral conferences, including Fluid Dynamics for the 2001 Aerospace Science Meeting, technical committee chair for the 7th AIAA Computational Fluid Dynamics Conference (1985), technical committees for the 16th Fluid and Plasma Dynamics Conference (1983), and 2nd CFD Conference (1975).

AIAA Fellow Leavitt Died in June

Laurence D. (Larry) Leavitt died on 21 June 2017.

He earned a B.S. Degree in Aerospace Engineering from North Carolina State University in 1975, and an M.S. Degree in Fluid Dynamics from The George Washington University in 1980.

In 1975, he was employed as a research engineer at NASA Langley Research Center. While working as a researcher in the Propulsion Aerodynamics Branch, he was involved in research aimed at the improvement of aircraft performance, primarily military high performance aircraft. He worked on many technologies, but was known for his work in multi-axis thrust vectoring exhaust nozzles, thrust reversers, and propulsion simulation test techniques. Mr. Leavitt was involved in the development of an efficient propulsion airframe integration on the B-2 Stealth Bomber. In 1987 he became the group leader for the Advanced Nozzle Concepts Group within the Branch. In 1990, he became the assistant head of the Propulsion Aerodynamics Branch and was responsible for the research program and operations of the Langley 16 Foot Transonic Wind Tunnel. In 1997, he was named the head of the Configuration Aerodynamics Branch and remained in that role for 12 years. In 2008, Mr. Leavitt was selected as chief engineer for Aerosciences within the Research Directorate. Prior to his retirement in 2015, he served as acting chief engineer of the Langley Research Center.

Mr. Leavitt was an active member of the NATO Research and Technology Organization and a member of the Applied Vehicle Technology Panel from 2001–2013. He chaired the Performance, Stability and Control, Fluid Physics Technical Committee. Mr. Leavitt received many individual and group awards including two of NASA's prestigious honor awards — the Outstanding Leadership Medal and the Exceptional Service Medal.

An AIAA Fellow, Mr. Leavitt was an active member for over 40 years serving in every office of the Hampton Roads Section, on the Region I Advisory Committee, and on multiple national committees. In 2005, he was the recipient of the section's highest honor receiving the Allen Taylor Memorial Award for sustained, significant volunteer contributions. At the time of his death, Mr. Leavitt was an active member of the Air Breathing Propulsion Systems Integration Technical Committee and the Green Engineering Program Committee, and was serving as Chair of the Associate Fellows Committee.

AIAA Associate Fellow Rosenberg Died in July

M. David Rosenberg died on 5 July at the age of 87.

Mr. Rosenberg received his degree in Chemical Engineering from New York University in 1950 and was a Registered Professional Engineer in Delaware and New York. From 1951 to 1952 he served as a lieutenant in the U.S. Army Chemical Corps in the United States and Korea. He began his career as an assistant engineering manager for Stein Davies Co. in Long Island. In 1958, he was hired as a program manager for Thiokol Propulsion (now Orbital ATK) in Elkton, MD.

For 37 years (1958–1995) Rosenberg served as a program manager and team leader at the Thiokol Propulsion facility (now ATK Alliant Tactical Systems) for a wide variety of solid propellant rocket motors, gas generators, and ordnance devices. He was a program manager on Air Force contracts to improve solid propellant specific impulse, to extend propellant shelf life, and to evaluate and extend operational temperature limits for propellant performance. Derivatives of the high performance propellants evaluated were later used for the Space Shuttle Rocket Motor.

Programs that Rosenberg managed included development and production of Subroc rocket motors, Poseidon Fleet Ballistic Missile TVC and Post Boost Propulsion Gas Generators, Trident D5 Gas Generators, Peacekeeper (MX) Launch Eject Gas Generators, and Stage Separation Motors for the LMSC Theatre High Altitude Area Defense (THAAD) Missile. He also was a program manager for development and production of ordnance safe-and-arm devices for STAR™ space motors and ignition and flight termination systems for use on Titan II, Koreasat, GPS, and other launch vehicles.

After retiring from Thiokol in 1995, he worked as an engineering consultant for The CECON Group. He was a consultant for a variety of missile programs for Thiokol (ATK) including the Extended Range Guided Munition (ERGM), the AEGIS Third Stage Rocket Motor, the Air Force Tactical Hybrid Rocket Motor, the Vertical Launch ASROC Program, and the Solid Divert and Control System for the SM-3 Missile.

An AIAA Associate Fellow Rosenberg was involved with the AIAA Delaware Section since 1958 when it was the American Rocket Society. He served in every office on the Delaware AIAA council including chairperson, vice chair, secretary, treasurer, historian, membership chair, newsletter editor, etc. Rosenberg was the Delaware Section Regional Activities Committee (RAC) Representative for 15 years and also served as National Membership Deputy Director for AIAA Region I. He also served as the coordinator of the Delaware Section Evolution of Flight (EOF) Program activities. He was a speaker and lecturer on rocket propulsion at local public schools, civic associations, and at the University of Delaware.

AIAA Associate Fellow Heubusch Died in July

Henry Ph. Heubusch died on 11 July. He was 92 years old.

Mr. Heubusch earned bachelor's and master's degrees in chemistry from Canisius College. He worked as quality control manager for the Direct Sales Pharmaceutical Co. before joining Bell Aerospace in 1951.

He was chief chemist at Bell Aerospace from 1951 to 1984. A research scientist and expert in propellant chemistry, he designed, staffed and directed Bell's Propellants Research Laboratory. Heubusch also worked on projects for NASA, including the Mercury, Gemini, Apollo and Minuteman II projects. He did work for the U.S. Army, Navy and Air Force. Among his consulting clients were ARDE, British Aerospace, Ford Aerospace, General Dynamics, Lockheed and Lorel Aerospace.

At Bell, Heubusch was the author of numerous papers. He held seven patents and was the recipient of the NASA Medal for support of efforts to land the first man on the moon. After retiring from Bell, he joined the faculty at Canisius College and set up a propellant consulting business. In 1992, the college gave him an honorary doctorate for his work in aerospace.

A member of AIAA since 1961, Heubusch was involved with the AIAA Niagara Frontier Section, and served a term as chair of the section.

Technical Committee Nominations

Membership nominations are now open for AIAA Technical Committees (TC) for 2018/2019.

The TC chairs and the Technical Activities Division (TAD) work diligently to maintain a reasonable balance in 1) appropriate representation to the field from industry, research, education, and government; 2) the specialties covered in the specific TC scopes; and 3) geographical distribution relative to the area's technical activity. TAD encourages the nomination of young professionals, and has instituted a TC associate member category (see associate membership guidelines). Associate members, with identified restrictions, are included on TCs in addition to the 35 regular member limit.

If you currently serve on a TC, do not nominate yourself. You will automatically be considered for the 2018/2019 TC year.

Enclosed are instructions for nominations. Nominations are submitted online. The TC nomination form can be found on the AIAA website at **www.aiaa.org**, under My AIAA, Nominations and Voting, Technical Committee Online Nomination. We look forward to receiving your nominations. If you have any questions, please call Betty Guillie at 703.264.7573.

Nominations are due by **1 November 2017**.

Current AIAA Technical Committees

Adaptive Structures
Aeroacoustics
Aerodynamic Decelerator Systems
Aerodynamic Measurement Technology
Aerospace Power Systems
Air Transportation Systems
Aircraft Design
Aircraft Operations
Applied Aerodynamics
Astrodynamics
Atmospheric and Space Environments
Atmospheric Flight Mechanics
Balloon Systems
Communications Systems
Computer Systems
Design Engineering
Digital Avionics
Electric Propulsion
Energetic Components and Systems
Flight Testing
Fluid Dynamics
Gas Turbine Engines
General Aviation
Ground Testing
Guidance, Navigation and Control
High Speed Air Breathing Propulsion
Hybrid Rockets
HyTASP
Information and Command and Control Systems
Inlets, Nozzles, and Propulsion Systems Integration
Intelligent Systems
Life Sciences and Systems
Lighter-Than-Air Systems
Liquid Propulsion
Materials
Meshing, Visualization and Computational Environments
Microgravity and Space Processes
Missile Systems
Modeling and Simulation
Multidisciplinary Design Optimization
Non-Deterministic Approaches
Nuclear and Future Flight Propulsion
Plasmadynamics and Lasers
Pressure Gain Combustion
Product Support
Propellants and Combustion
Reusable Launch Vehicles
Sensor Systems and Information Fusion
Small Satellite
Software
Solid Rockets
Space Architecture
Space Automation and Robotics
Space Colonization
Space Logistics
Space Operations and Support
Space Resources
Space Systems
Space Tethers
Space Transportation
Spacecraft Structures
Structural Dynamics
Structures
Survivability
Systems Engineering
Terrestrial Energy Systems
Thermophysics
V/STOL Aircraft Systems
Weapon System Effectiveness

Instructions for Completing

1. Nominations are submitted online via www.aiaa.org, My AIAA, Nominations and Voting, Technical Committee Online Nomination. Nominees who are not selected for committee membership for 2018 will automatically be considered for membership in 2019. As the nomination forms are held for an additional year, it is not necessary to resubmit a form for someone not selected for the 2017/2018 term.

2. You do not have to be nominated by someone else; you may submit an application for yourself.

3. A resume or biographical data can be uploaded with the online nomination form.

4. Membership is usually restricted to one technical committee (TC) at a time. Please list the TCs in order of preference if applying to two TCs. If accepted to the 1st priority, the nominee will be added to that TC. All information should be detailed and complete.

5. The Technical Activities Division (TAD) strongly suggests that special consideration be given to members 34 years of age and under or who obtained their professional degree less than 10 years ago. See attached Technical Committee Associate Membership Guidelines.

6. All TC members must join AIAA (if they are not already members) within 45 days of their appointment to a technical committee.

7. TC membership is generally for one year with two additional years possible, but contingent upon committee participation, ongoing projects, and AIAA membership. It is not necessary to send a new nomination form for someone who is already on a committee. All committee members are automatically considered for a second and third year of membership.

8. Deadline for receipt of nominations is **1 November 2017**. Nominations received after this date will be held for consideration until the next year.

Technical Committee

1. Associate membership is restricted to those who have not yet reached their 35th birthday, or who obtained their professional degrees less than 10 years ago.

2. Associate membership is a one-year term renewable to three years.

3. Associate membership is restricted to current AIAA members.

4. Selection to associate membership is based on technical merit. The associate members should show promise within the field of the technical committee.

5. Associate members may attend TC or subcommittee meetings and will assist in carrying out committee work.

6. At the discretion of the TC, associate members may be assigned a volunteer full member as a counselor. The counselor will advise and guide the associate member on TC procedures and activities.

7. Associate members will not count toward the TC regular membership limit.

8. Application forms for associate membership are the same as those of full membership, but a resume is a required attachment. Applicants for full membership who were not selected may be considered associate members provided they meet the age restriction.

9. At least two associate members should be appointed to each TC. At no time should the number of associate members exceed that of full members.

10. An endorsement statement from the nominee's department head, indicating that the nominee may travel to two meetings per year and have some time to devote to committee business, must be completed during the online process.

ASSISTANT/ASSOCIATE PROFESSOR AEROSPACE ENGINEERING

The Aerospace Engineering Department, within the College of Engineering at Cal Poly, San Luis Obispo, CA invites applications for a full-time, academic year, tenuretrack faculty position at the Assistant or Associate Professor rank. The projected start date is September 13, 2018.

The College of Engineering at Cal Poly is committed to building a diverse faculty of teacher-scholars who collaborate to provide a multi-disciplinary and hands-on approach to student learning and applied research. We believe that individuals from diverse backgrounds strengthen our programs and positively impact student success. We encourage qualified applicants from all backgrounds to apply for consideration. Cal Poly emphasizes Learn by Doing, which involves extensive lab work and projects in support of theoretical knowledge.

Duties include teaching Aerospace Engineering courses; building a vibrant and innovative research program; and supporting and developing students into engineers ready to thrive in the modern aerospace industry. This position is open to candidates with experience in all areas of aerospace engineering, including aeronautics, astronautics, and advanced technologies. Candidates with research or private industry experience are encouraged to apply.

Cal Poly is committed to the teacher-scholar model. As teachers, all faculty members are expected to exhibit strong pedagogic skills and to remain proficient and current in the disciplines. As scholars, faculty members are expected to be engaged in scholarly work that contributes to the prestige of our programs, and the University.

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

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

For details, qualifications, and application instructions (online application required), visit **WWW.CALPOLYJOBS.ORG** and apply to requisition #104554. Review of applications will begin November 1, 2017 and will continue until the position is filled. EEO.

Aerospace Engineering

San Diego State University

Faculty Position

The Department of Aerospace Engineering invites applications for a tenure-track faculty position at the Assistant or Associate Professor rank. A preference will be given to applicants in autonomous aerospace systems. The areas of interest include but are not limited to: autonomous air or space vehicles, sensing and estimation, guidance and control, networks, multi-vehicle and swarm systems, hybrid systems, and onboard autonomy. Exceptional candidates in other areas of aerospace engineering including propulsion and structures may also be considered. The faculty member will be expected to develop a vigorous, externally funded research program in his/her area of expertise, while teaching undergraduate and graduate courses in Aerospace Engineering. Applicants must have an earned PhD in Aerospace Engineering or a closely related field. Recent graduates as well as those with industrial or university experience are welcome to apply.

The department offers the BS and MS degrees in Aerospace Engineering and participates in Joint Doctoral programs with the University of California, San Diego, and Claremont Graduate University. The department has nationally and internationally recognized research programs in aerodynamics, fluid mechanics, structures, and guidance and control. A new state-of-the-art Engineering and Interdisciplinary Sciences Complex is currently under construction to significantly expand and enhance facilities. The city of San Diego enjoys a renowned mild climate year-round and is a family-friendly urban environment. The metropolitan area is the hub of major defense contractors and aerospace companies. San Diego and Southern California offer exceptional opportunities for research partnerships with extensive aerospace industry. For additional information about the department and the university, please visit http://aerospace.sdsu.edu and http://www.sdsu.edu.

Additional information and application procedures are available at https://apply.interfolio.com/42821. Inquiries should be directed to Prof. Ping Lu, Department Chair, plu@sdsu.edu.

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הטכניון – מכון טכנולוגי לישראל
הפקולטה להנדסת אוירונוטיקה וחלל

Technion – Israel Institute of Technology
Faculty of Aerospace Engineering

Meir Hanin International Memorial Prize

The Faculty of Aerospace Engineering at the Technion announces the Meir Hanin International Memorial Prize of US$10,000 from the Hanin Endowment, in memory of Prof. Meir Hanin, a prominent researcher in theoretical aerodynamics and member of the Faculty of Aerospace Engineering from 1955 to 1999.

The prize is awarded once every two years for substantial scientific and/or technological achievements in aerospace sciences. Nominees from any country, regardless of religion, race, sex, or nationality, must have some association with the Technion and can only be nominated by the following: Technion faculty members, previous Hanin Prize winners, members of the Israel Academy of Science, Presidents and Members of the Board of Institutes of Higher Learning, and CEO's of companies specializing in aerospace products.

Nominations, together with all relevant supporting material, should be sent to Prof. Jacob Cohen, Dean of Aerospace Engineering, Technion – IIT, Haifa 32000, Israel (aedean@ae.technion.ac.il) by October 10th.

The prize will be awarded in March 2018 at the Israel Annual Conference on Aerospace Sciences, which the winner must personally attend. In addition, he/she will give at least two public lectures at the Technion.

(The Hanin Endowment will cover the winner's accommodation and travel expenses, up to 5000$).

SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY (SUSTech)
Assistant/Associate/Full Professors
Department of Mechanics and Aerospace Engineering

The Southern University of Science and Technology (SUSTech) Department of Mechanics and Aerospace Engineering invites applications for a number of tenured or tenure-track faculty positions. Candidates with research interests in all areas of Mechanics and Aerospace Engineering are encouraged to apply. We are seeking applications with experience in specific areas, including, but not limited to, solid mechanics, vibration, control, and the general area of aerospace engineering. Candidates should have strong commitment to teaching and demonstrated excellence in research. A doctoral degree is required at the time of appointment. Candidates for senior positions must have an established record in conducting globally recognized research and securing external funding.

Established in 2012, the Southern University of Science and Technology is a public institution funded by the municipal of Shenzhen, a special economic zone city in China. SUSTech is a pioneer in higher education reform in China. The mission of the University is to become a globally recognized institution which emphasizes academic excellence and promotes innovation, creativity and entrepreneurship. The University currently has over 200 faculty members, and is planning three faculties: Faculty of Science, Faculty of Engineering, and Faculty of Life and Health Science. The target faculty number will be 200 for Science, 300 for Engineering, and 150 for Life and Health Science Faculty.

The newly founded Department of Mechanics and Aerospace Engineering is one of the nine departments in the College of Engineering. The department expects to add more than twenty new faculty members in core research areas in Mechanics and Aerospace Engineering.

SUSTech offers internationally competitive compensation packages with fringe benefits including medical insurance, retirement and housing subsidy. Salary and rank will commensurate with qualifications and experience.

To apply, please provide a cover letter identifying the primary area of research, curriculum vitae, and research and teaching statements, and arrange for at least three recommendation letters, all forward to hiring@sustc.edu.cn.

THE UNIVERSITY OF ARIZONA
COLLEGE OF ENGINEERING
Aerospace & Mechanical Engineering

DEPARTMENT HEAD

UA DEPARTMENT OF AEROSPACE AND MECHANICAL ENGINEERING

We seek an engaging and articulate leader to guide this successful department as it secures additional faculty appointments and expands and enhances its undergraduate and graduate programs, research impact and visibility, and industrial partnerships.

The successful candidate will have a proven record of transparent, collaborative and effective strategic planning, communication and resource management. A distinguished record of achievement in scholarship, research and/or professional practice commensurate with an appointment at the rank of professor with tenure is required. Full posting (#F20856) and application instructions are at **https://uacareers.com/postings/16156.**

The department is dedicated to innovative interdisciplinary research and teaching in both aerospace and mechanical engineering. The department's research specialties include active flow control, aerospace guidance navigation and control, astrodynamics, biomechanics, computational and experimental fluid and solid mechanics, mechatronics, multibody dynamics, nanotechnology and renewable energy.

Research at the University of Arizona is strongly multidisciplinary and the department works extensively with, among others, the UA Department of Planetary Sciences, Arizona Health Sciences Center, BIO5 Institute for Collaborative Bioresearch, College of Optical Sciences and the Program in Applied Mathematics, all of which enjoy international recognition as centers for world-class academic programs and research.

The University of Arizona is located in Tucson, which has a vibrant, multicultural community – in 2016 UNESCO named it a World City of Gastronomy – and is home to a thriving industrial sector that includes Raytheon, Rincon Research, Paragon Space Development and Vector Space Systems.

1917

Sept. 7 The Naval Radio Station at New Orleans receives signals transmitted by a Navy R-6 seaplane from some 225 kilometers away while it is in flight from the naval air station at Pensacola, Florida. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 6.

Sept. 11 Legendary French ace Georges Guynemer, with 53 victories to his credit, disappears over Poelcappelle, Belgium. Neither his body nor his aircraft is ever found. David Baker, **Flight and Flying**, p. 101.

Sept. 23 Werner Voss, arguably Germany's best combat pilot with 48 victories, is killed during air combat when he and his Fokker Dr.1 triplane take on six SE.5a's from the Royal Flying Corps' famous 56 Squadron. Outnumbered 7-to-2, Voss manages to shoot holes through all of his British opponents before he is brought down. David Baker, **Flight and Flying**, p. 102.

1942

Sept. 1 The U.S. Naval Air Forces, Pacific, is established for the administrative control of all air units in the Pacific theater. This organization replaces the offices of commander carriers, Pacific, and commander patrol wings, Pacific. Rear Adm. A.W. Fitch commands the new organization. **United States Naval Aviation 1910-1980,** p. 118.

Sept. 6 A Japanese Yokosuka E14Y-1 reconnaissance floatplane is launched from a submarine off the U.S. West Coast. It makes two flights near the Oregon-California border, dropping four bombs and causing a small forest fire. Rene Francillon, **Japanese Aircraft of the Pacific War**, p. 451.

Sept. 6 The U.S. Naval Air Transport Service completes its first flight from Argentina to Newfoundland, marking the beginning of American air transport expansion. During the month, this service briefly extends to Iceland and reaches southward to the Canal Zone and Rio de Janeiro. **United States Naval Aviation 1910-1980**, p. 118.

Sept. 21 Boeing's XB-29 Superfortress, which will become an indispensable aircraft in the Pacific theater during World War II, makes its first flight near Boeing's Seattle plant. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 44.

Sept. 23 Robert Goddard's liquid oxygen gasoline jet-assisted takeoff units are tested on a Navy PBY on the Severn River at Annapolis, Maryland. Lt. Charles Fischer is at the controls as Goddard observes the flights from a nearby Navy boat. Seven flight attempts are made with the JATO units, which produce 3,558 newtons of thrust for 20-30 seconds. Despite some difficulties, the first six tests are successful; in the final test a fire breaks out, but it is quickly extinguished. The JATOs' purpose is to shorten the takeoff distance and time for heavily loaded seaplanes. E.C. Goddard and G.E. Pendray, eds., **Papers of Robert H. Goddard, Vol. III**, pp. 1,479-1,482.

Sept. 23 Brig. Gen. James Doolittle is named commander of the U.S. Army Air Forces' 12th Air Force. Donald L. Miller, **Masters of the Air**, p. 243.

During September 1942
Cmdr. Kenneth Mackenzie-Grieve, navigator to British pilot Harry Hawker in his May 1919 attempt to fly across the Atlantic, dies in New York. While crossing the Atlantic, the Sopwith flown by Hawker and Mackenzie-Grieve suffered a choked cooling system, causing the engine to boil away its water. The flyers ditched the plane, and a Danish steamer rescued them. **Flight**, Oct. 1, 1942, p. 373.

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1967

Sept. 4 Michael Gluhareff, the Russian-born engineer and associate of helicopter pioneer Igor Sikorsky, dies in Bridgeport, Connecticut, at age 74. Gluhareff served as the engineering manager of Sikorsky Aircraft, a division of United Aircraft. His patents include a dart-shaped aircraft, a glider, a tailess aircraft with rear-mounted propeller, and a device to increase the speed and load of a plane with its engine exhaust. **Washington Post**, Sept. 6, 1967, p. B8.

Sept. 4 For the first time, NASA conducts sounding rocket launches from Puerto Rico when three Nike-Apache rockets fire from the Vega Baja Airport near San Juan. The rockets carry instruments to probe the lower regions of the Earth's ionosphere up to 200 kilometers with measurements taken on electron and ion densities and temperatures and solar radiation. **Flight International**, Sept. 7, 1967, p. 412.

Sept. 4 Mussarat Hussain Zuberi, Pakistan's communications secretary, announces the government plans to establish a communications satellite link between widely separated provinces of East Pakistan. **Flight International**, Sept. 14, 1967, p. 463.

Sept. 7 Biosatellite 2 is launched by a two-stage Thrust-Augmented Improved Delta into low Earth orbit. The 426-kilogram satellite includes a re-entry vehicle with a retrorocket and heat shield and parachutes and radio beacon to aid in the recovery of an experimental capsule carrying frog eggs and other life forms. Altogether, Biosatellite carries 13 experiments to determine the effects of the space environment on various life processes. On Sept. 9, aircraft recover the Biosatellite in midair over the Pacific. NASA reports that it obtained good data on the effects of weightlessness and radiation exposure upon amoeba, wheat seeds, a pepper plant and other specimens. **Aviation Week**, Sept. 18, 1967.

Sept. 8 NASA's Surveyor 5 unmanned spacecraft is launched toward the moon by an Atlas-Centaur. The spacecraft is to soft-land on the moon in an area considered as one of the potential landing sites for the upcoming manned Project Apollo missions. Surveyor 5 is the first of these craft to carry an instrument to study the chemical characteristics of the lunar soil and the first to attempt a landing in the eastern portion of the potential Apollo zone. The Surveyor lands Sept. 10 in the Sea of Tranquility where the first Apollo mission, Apollo 11, lands two years later, in July 1969. The Surveyor transmits back some 18,000 high-quality photographs later in September. **New York Times**, Sept. 30, 1967, p. 67.

Sept. 10 Resonance trials on the Concorde 001 prototype aircraft conclude at Sud-Aviation, Toulouse, France. The tests subjected the aircraft structure to controlled vibrations to evaluate its flight dynamics. The prototype of the aircraft enters the final stage of equipment and furbishing for ground testing. **Flight International**, Sept. 21, 1967, p. 474.

Sept. 12 A U.S. Army Pershing missile is accidentally fired into Mexico during training launches from Utah; the missile lands in the Mexican countryside and causes no injuries or damage. **Washington Post**, Sept. 13, 1967.

Sept. 15 The inaugural Moscow-Montreal service, on an IL-62, begins and Russia's deputy minister of civil aviation, Leonid Zholudyev, is aboard. The IL-62 is a long-range narrow-body jet airliner with a capacity of about 200 passengers and crew. **Flight International**, Sept. 21, 1967, p. 474.

Sept. 22 The merger of North American Aviation Inc. and Rockwell-Standard Corp. becomes effective. The new company is named North American Rockwell. Ivan Ertel, et. al., **The Apollo Spacecraft — A Chronology, Vol. IV**, p.158.

Sept. 27 NASA launches the fourth Intelsat II series commercial communications satellite for the ComSat-Corp, designated Pacific II, and the second covering communications in the Pacific. A Thrust-Augmented Delta vehicle launches and places the satellite into a near-synchronous orbit. The satellite's mission includes supporting the upcoming Apollo program. **ComSat-Corp Releases 47-45 and 67-48**.

During September

A rocket motor developed by the Rocket Research Corp. of Redmond, Washington, sets an endurance record of being pulsed 1 million times for durations varying from 1/100th second to one minute. The motor uses hydrazine as the propellant. **Flight International**, Sept. 21, 1967, p.502.

1992

Sept. 10 Hispasat 1, the first Spanish communications satellite, is placed into geosynchronous orbit by an Ariane 4. The satellite includes five TV channels. **Flight International**, Sept. 30-Oct. 6, 1992, p. 22.

Sept. 12 American astronaut Mae Jemison is the first African-American woman in space, and Mamoru Mohri is the first Japanese. They are crew members of shuttle Endeavor's STS-47 mission, the 50th mission by the shuttle fleet. Endeavour carries Spacelab J, a joint project of NASA and the National Space Development Agency of Japan. This is the first shuttle mission devoted to Japanese research. Endeavour also carries the first married couple in space, Mark Lee and Jan Davis. The smaller, Get Away Special experiments include an Israel Space Agency experiment about hornet behavior in weightlessness. **NASA release.**

KEVIN MILLER, 37

A principal propulsion engineer at SpaceX

SpaceX's campaign to slash the cost of space travel and make human beings an interplanetary species rests largely on the firm's ability to recover and refly rockets. Interplanetary transportation will also be needed, and that's where Kevin Miller comes in as a principal propulsion engineer at SpaceX. After managing upgrades to the Falcon 9 Merlin first stage engine, Miller is now focused on developmental testing of Raptor, an engine for interplanetary transportation fueled with methane and liquid oxygen.

How did you become an aerospace engineer?

My grandparents took me to a space museum when I was in middle school where the Apollo 9 command module was on display along with a Redstone rocket and an F-1 rocket engine. I became fascinated with these machines and what they had achieved almost 30 years prior. From that point on, I was hooked on spaceflight, and read and watched everything I could about the history and mission of NASA. Growing up in Indiana, it was a natural choice for me to attend Purdue University and study aerospace engineering. I also had the opportunity to join NASA's cooperative education program where I got to see a lot of the agency's wide-ranging work in liquid propulsion from the space shuttle to advanced projects. In grad school, I studied combustion instability in liquid rocket injectors and performed experimental research at Purdue's Zucrow Laboratories. I graduated with my master's degree in 2005 and joined SpaceX right out of school. The last 12 years have been pure adventure. I started as a development engineer with the first version of the Merlin engine for Falcon 1, managed successive upgrades to the engine for Falcon 9, and am now focused on the development testing of the staged-combustion, methane-fueled Raptor engine.

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

I believe the achievements of SpaceX and others in this decade have established that reuse in spaceflight is the future. Of course, there was partial reuse on shuttle, but expendable launch systems were still the norm for new designs after shuttle was operational. Today, it is hard to envision launch vehicle designs in 2050 that would not incorporate reuse capability. With reuse, we will finally realize an order-of-magnitude cost reduction of mass to orbit, and that cost will only get further driven down by the hardware and operational improvements from lessons learned across a growing flight experience base. Continued competition in the industry along with different overall mission objectives should translate to multiple reusable vehicle concepts with varying extents of hardware reuse and service life. Overall, that should mean many more flights, a share of those with people onboard, entering orbit, on a daily basis. I believe there will be a considerable amount of on-orbit assembly of larger spacecraft, and the start of deep space missions will occur from low Earth orbit rather than terrestrial launch pads. Ultimately, the most exciting and inspiring of those exploration missions will be humans setting out for Mars to establish a permanent outpost there. ★

By Debra Werner | werner.debra@gmail.com

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Technical conferences meeting as part of the 2018 AIAA SciTech Forum include:

- AIAA/AHS Adaptive Structures Conference
- AIAA Aerospace Sciences Meeting
- AIAA Atmospheric Flight Mechanics Conference
- AIAA Information Systems—AIAA Infotech @ Aerospace
- AIAA Guidance, Navigation, and Control Conference
- AIAA Modeling and Simulation Technologies Conference
- AIAA Non-Deterministic Approaches Conference
- AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference
- AIAA Spacecraft Structures Conference
- AIAA/AAS Space Flight Mechanics Meeting
- Wind Energy Symposium

Registration Opens in September 2017!

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