MATERIALS 14
Sensing strain with light

ASTRONAUT'S VIEW 20
The case for nuclear fission in space

CYBERSECURITY 42
Safer aircraft tracking

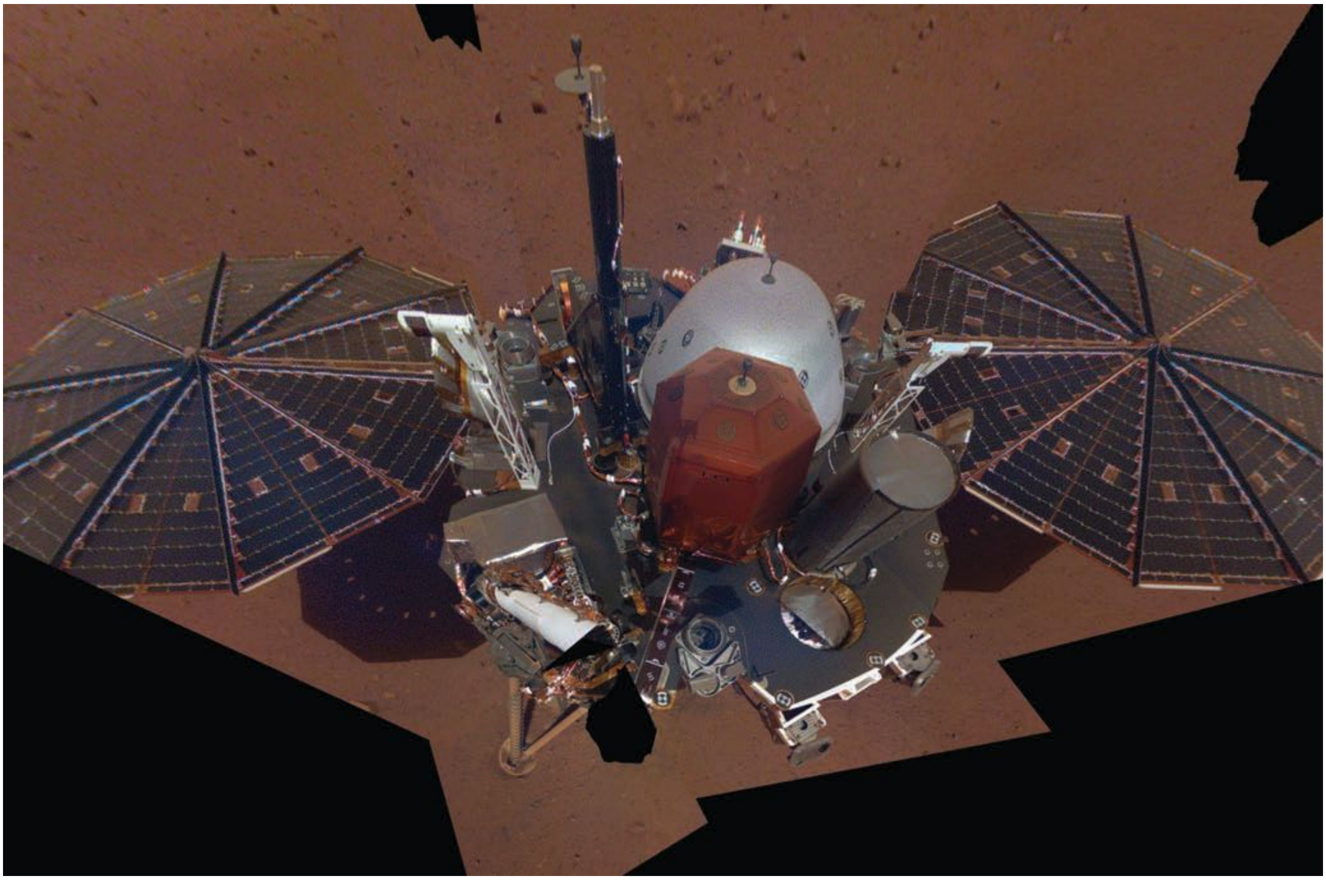
AEROSPACE
★ ★ ★ AMERICA ★ ★ ★

DIGGING MARS

What penetrating 5 meters could tell us about the history of the red planet and habitable worlds. PAGE 26

MARCH 2019 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

AIAA
SHAPING THE FUTURE OF AEROSPACE



26

Uncovering Martian mysteries

The instruments on the InSight lander (seen in a selfie above) are beginning to take the measure of Mars. Scientists are hoping the data will help them learn how the planet and others were formed.

By Amanda Miller

14

Glowing under the strain

Researchers are testing a composite that indicates through light and direct current when an aircraft part might fail.

By Keith Button

34

Managing trash in space

Two companies are developing competing systems to compress and melt garbage generated by NASA astronauts working in space.

By Adam Hadhazy

42

Improving the security of FAA's air traffic plan

As the aviation industry works to meet a mandate to install ADS-B Out by 2020, cybersecurity is a worry.

By Jan Tegler

AEROSPACE
AMERICA

MARCH 2019, VOL. 57, NO. 3

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

IN THIS ISSUE

Keith Button

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

PAGE 14

Adam Hadhazy

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

PAGE 34

Tom Jones

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

PAGE 20

Amanda Miller

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

PAGE 26

Jan Tegler

Jan covers a variety of subjects, including defense, for publications internationally. He's a frequent contributor to Defense Media Network/Faircount Media Group and is the author of the book "B-47 Stratojet: Boeing's Brilliant Bomber."

PAGE 42

Debra Werner

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

PAGE 64

DEPARTMENTS

For innovators, a balancing act

▲ **Engineers practice** deploying a mockup of the InSight lander's seismometer at the NASA-funded Jet Propulsion Laboratory under lighting that simulates sunlight on Mars.
NASA

Progress in matters of aerospace requires a sometimes uncomfortable dance between patience and impatience.

Too patient, and your innovations can't get out the door in time to impact the market. Act precipitously, and you set yourself up for missteps such as production of faulty parts or, in the extreme case, an accident or other failure that sets your innovation back by years or worse.

Consider Tesla, Elon Musk's electric car company. Tesla is rolling ahead well with production of its electric cars, despite much reported upheaval and tension between an impatient Musk and the production team. I have to wonder how sustainable quality production can be in that kind of environment, if indeed the reports are accurate.

Such an environment in the production of rockets or aircraft would be untenable, given that one can't coast to the side of the road when things go wrong. Hopefully, the environment is more positive at Musk's SpaceX company.

Looking to space exploration, development of the Mole, the bullet-ended titanium spear that's about to plunge into Mars, could turn out to be a case of patience and impatience balancing out just right. As anxious as the developers must have been, they tested the device rigorously on the ground and worked for years to get it into space. Let me not jinx them though. No one has dug so deeply into Mars, so the outcome is far from certain.

Then there are the Automatic Dependent Surveillance-Broadcast Out radios that airline companies and general aviation enthusiasts are installing on their aircraft to meet the FAA and European 2020 mandates.

Let's suppose someone had sprung from a boardroom chair years ago and made the case that radars will always be needed as a backup to ADS-B, because of the network's reliance on GPS for tracking aircraft. As our story shows, this need for a radar backup is now widely accepted, but I have to wonder if a patient debate at the outset would have gotten us to this point sooner.

No doubt there are security and resilience challenges, but ADS-B does seem like a wise path in the digital age. In any case, if GPS were taken out or jammed on a large scale by an adversary, air travel might be the least of our worries. Bank transactions, communications networks and power grids rely on the GPS constellation's timing signals. You wouldn't be able to buy an airline ticket anyway. ★

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

LETTER TO THE EDITOR

Early pioneer for GPS as weather tool

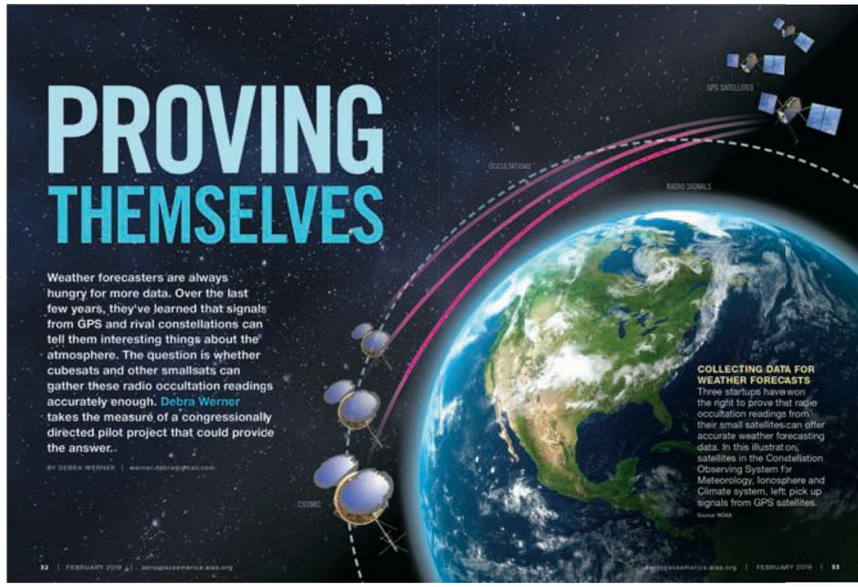
I enjoyed Debra Werner's article, "Proving themselves: Radio occultation is put to the test," in the February issue of Aerospace America. AIAA members may be interested in a bit of the prehistory of weather forecasting using GPS signals received by small, low-orbit satellites.

John McLucas became an early advocate of what he called "GPS Meteorology" in the 1990s, and as a long-serving member of our board of directors urged Orbital Sciences Corp. to work with the University Corporation for Atmospheric Research to include an occultation receiver on our first commercial remote sensing satellite, OrbView-1, which was launched in 1995. This proof-of-concept mission demonstrated the technical feasibility of atmospheric soundings using GPS signals and led to our codevelopment, along with the Taiwan National Space Organization, of the six first-generation COSMIC, for Constellation Observing System for Meteorology, Ionosphere and Climate, satellites, which we launched in 2006.

John was an outstanding leader and space applications visionary who served as secretary of the Air Force, director of the National Reconnaissance Office, administrator of the FAA and president of MITRE Corp., as well as in other important positions. As part of an extraordinary career in aviation and space, he also served as AIAA's president in 1984.

John passed away in 2002, but I am sure he would be delighted to see how far his concept for "GPS Met" has progressed in recent years.

David W. Thompson
Retired president and
CEO of Orbital ATK
AIAA president 2009-2010



Help future aerospace professionals by making a donation to the AIAA Foundation

When you donate to the AIAA Foundation you are investing in the next generation of aerospace professionals through innovative educational programs and recognition. This investment will ensure the continuation of our industry's leadership and contributions to global advancement.

To date, your contributions have:

- Funded more than **1,300 K–12 classroom grants**, impacting more than **132,000 precollege students**.
- Awarded more than **1,300** aerospace scholarships to undergraduate and graduate students.
- Supported more than **400 student conferences** engaging **13,000 students**.
- Sponsored design competitions that have attracted more than **11,000 college students**, giving them the chance to apply engineering skills outside of the classroom.
- Enabled more than **140,000 student members** and **9,000 Educator Associates** to continue learning about aerospace science and technology.

For more information and to make a gift, please visit **aiaafoundation.org**

The AIAA Foundation made an impact on the Diversity Scholars pictured above by helping them attend AIAA SciTech Forum so they could learn about their future workforce!

AIAA FOUNDATION
Advancing Aerospace

MATCH $2 MILLION

Make Time to Engage

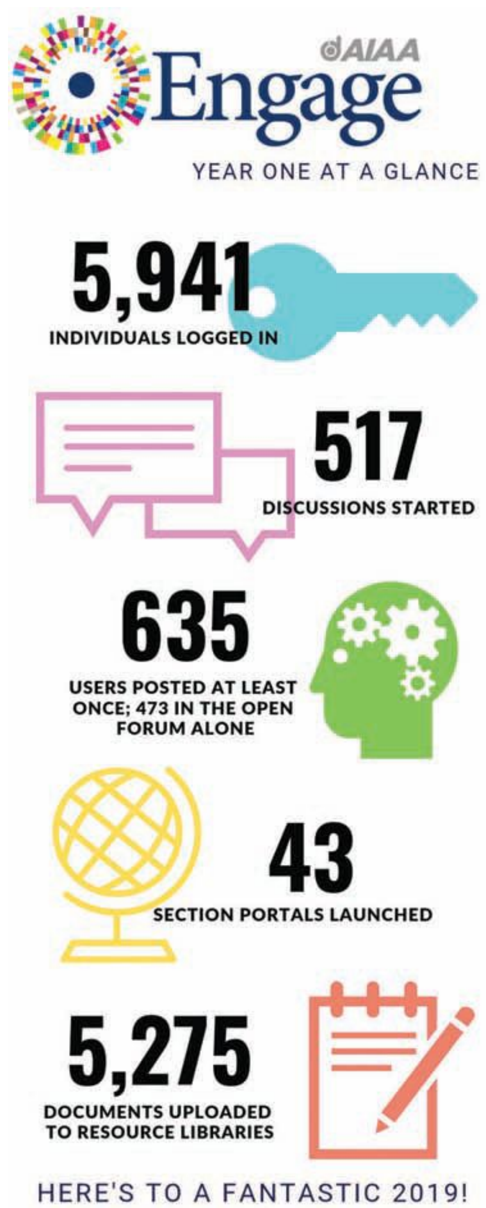
When AIAA launched the Engage platform a year ago, we knew it could be a great way to connect our members, build a stronger aerospace community, and help solve problems. It's now clear you agree. Together, we've built a healthy, thriving community of about 6,000 participating members, and it continues to grow.

One of the great aspects of Engage is how the discussions don't disappear and can be useful today or five years from now. There were 517 threads in 2018, none of which relied on an email chain or listserv. Engage is also a terrific networking tool, connecting you across distance, generations, and interests. Engage is your opportunity to have thoughtful and informative discussions with other professionals.

Some of the popular discussions include Mars Orbit First, Then Land Later?, Space for Everyone, and Deep Space Gateway—Why? Other thought provokers include Where Does Space Begin? Want to learn about the cutting-edge research on in-situ resource utilization experiments or how copper wiring weight affects rockets? Engage has discussion threads dedicated to those topics and more by fellow AIAA members. I encourage you to follow and contribute to these spirited conversations—or start your own.

It's also the place to connect with your local community. Since the platform began, 43 sections launched their own sites on Engage, AIAA technical committee discussions have taken off, and the young professional committee has 100 discussion threads.

Engage is where you will find useful information. The Resource Library is one of the most popular areas. Last year 5,275 documents were uploaded and more are added every day. Workshop for Integrated Propeller Prediction was searched for 177 times in 2018.



The platform can help you get results. Stewart Bushman of the Liquid Propulsion Technical Committee (LPTC) used Engage to seek nominees for awards—he received six nominations for the LPTC student award and seven for the young professional award.

We're hosting new communities of member interest within the platform. Some recent groups include in-space assembly and manufacturing, aerospace workforce development, and complex system sustainment.

Students and young professionals are asking for guidance. They're looking for advice about what kinds of courses to take or want to know what you think of their resume. You can help the next generation.

Engage will continue to become more useful. We're exploring the addition of a new volunteering tool. You'll be able to call for volunteers to help with everything from judging a student conference, staffing a booth at a career fair, or even running for AIAA president.

I know many of you, like me, are hovering in the background sometimes. Sure, we check the email that details the latest discussion, but maybe the day gets away from us and we don't contribute. Let's change that. If you haven't, please post a question, respond to a discussion, or help a student choose their career path. I know you'll find it worthwhile!

Dan Dumbacher, AIAA Executive Director

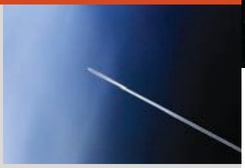
Do you have a puzzler to suggest? Email us at **aeropuzzler@aiaa.org**

Queasy in artificial gravity

Q. Two brave test astronauts aboard an experimental, rotating space station report feeling nauseated and disoriented as they move about in artificial gravity approximating that of Earth's. These feelings go away when they lie down at night. What phenomenon did the engineers not adequately consider in their station design, and how can they mitigate this in the next iteration?

Submitted by astrophysicist **Erin Macdonald**, a science fiction consultant and host of "Dr. Erin Explains the Universe" on YouTube.

FROM THE FEBRUARY ISSUE



Q. This was a two-parter: What would happen if a pilot tried to fly straight instead of following the curve of the Earth? How do airline pilots get from point A to B? Here is the winner as selected by NASA's Mark Guynn and Gary Ullrich of the University of North Dakota.

A. If a pilot attempted to fly in a perfectly straight line, the aircraft would climb, as the Earth curved away, until the plane could no longer generate sufficient lift and thrust to climb any farther due to decreasing atmospheric pressure (not to mention the safety of the passengers and crew). At this point, they would be forced to follow the curve of the Earth. Normally, aircraft will fly at a particular safe or efficient altitude, which will cause the path to naturally curve with the planet. This curvature also affects the other two dimensions. Since the Earth is nearly spherical, what may appear to be a curved line on a flattened 2D map can be the shortest line along the 3D shape of the globe. This is called a "great circle route." For example, the great circle route from New York to Tokyo leaves to the northwest (even though Tokyo is south of New York) and goes through Alaska.

Jeffrey J. Mach; Santa Clara, California
Mach works for Sierra Lobo Inc. as a site manager at the Thermophysics Facilities Branch of NASA's Ames Research Center.

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

More online aerospaceamerica.aiaa.org

Aerospace motivator

Doug Stanley can't help but think about Sept. 26, 2022. That's when his organization's founding cooperative agreement expires with NASA's Langley Research Center in Virginia. Since the National Institute of Aerospace opened its doors in 2002, its researchers have delved into such groundbreaking topics as exotic materials and urban air mobility. Graduate students from partner universities flock to conduct research in its labs and learn from experts at nearby Langley. Meanwhile, NIA's communications team created the popular "Innovation Now" radio series and worked with NASA to create the "NASA 360" television show. It's been a great run, with staff growing to 110, but Stanley can't take for granted that Langley will decide to renew the agreement. I spoke to him by phone to hear about NIA's diversification plans and the latest aerospace research.

— Ben Iannotta

DOUGLAS STANLEY

POSITIONS: President and executive director since 2012; previously NIA's vice president of research and program development; led research and advised students at NIA as a member of the aerospace engineering faculty of Georgia Tech, 2005-2011; program director for advanced flight systems at Orbital Sciences Corp., 1998-2005; senior technical adviser at NASA headquarters, 1996-1998; engineer at NASA's Langley Research Center, 1989-1996.

NOTABLE: At NASA in 2005, led the 400-person team that produced the Exploration Systems Architecture Study, which led to the Constellation rocket program that the Obama administration later turned into the Space Launch System rocket program. Senior technical adviser in the late 1990s to the Reusable Launch Vehicle Program Office that led NASA's X-33 and X-34 vehicle programs. From 1991 to 1993, NASA representative on a team assembled by the Strategic Defense Initiative Office to find a reusable single-stage-to-orbit vehicle to launch Brilliant Pebbles, the "Star Wars" constellation of missile interceptors that was never built. Led the team that evaluated the proposals ahead of the selection of the McDonnell Douglas Delta Clipper Experimental (DC-X), a vertical landing rocket, for low-altitude flights. Undergraduate work at Baylor University included the philosophy of science.

AGE: 54

RESIDES: Williamsburg, Virginia

EDUCATION: Doctorate in engineering management, George Washington University, 2002; Master of Science in astronautical engineering from the George Washington University Joint Institute for the Advancement of Flight Sciences, 1988; Bachelor of Science in physics and math with minors in philosophy of science and French, Baylor University, 1986.

FAVORITE QUOTE: "There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new."
— Niccolò Machiavelli

IN HIS WORDS

Inspired by Challenger disaster

I saw the Challenger accident in the student union at Baylor. That really got me interested in learning more about the whole program and space, and just coincidentally, or as fate may have it, that week, we had kind of a bulletin board in the math department. They were advertising this Joint Institute for Advancement of Flight Sciences called the JIAFS program. That program was resident at NASA Langley and run by the George Washington University. And so, I applied for that because, basically it came with a scholarship that paid all your expenses in addition to tuition. I ended up getting accepted in that program and got my master's at George Washington University, resident, basically in NASA Langley, taking courses and working in the vehicle analysis branch. My master's thesis was on reusable rockets to replace the space shuttle and make them safer. So, it's an interesting turn of events that took me away from philosophy and into engineering of aerospace systems and rocket science, and designing those vehicles. When I graduated from that program, I went to work right here in the vehicle analysis branch. I was always interested in the big picture, which is what philosophy comes from, how it all fits together.

NIA as a startup

NIA was birthed out of NASA Langley under the leadership of Dr. Charlie Harris, who was head of the research directorate at that time. NASA Langley was looking for a strategic partner, and there wasn't a major research university here in this area. They wanted Charlie and others to envision having an institute outside the gates, of multiple universities they could collaborate with. They had the idea to go out for procurement for a National Institute of Aerospace. That was the name that the group that bid on it came up with. I wasn't here at that time.

This group of universities in the mid-Atlantic region ended up winning a 20-year cooperative agreement with NASA Langley, although we do work for other folks in NASA through it as well. NIA was basically a startup. There were three first employees and now there are 110. NIA grew from almost nothing in revenue to now we have our largest revenue in history this year of $35 million. We also have faculties and universities here and students and consultants, so there's really 200 people here on site.

NIA graduate program

We have a unique graduate education program involving nine different universities where a student can come here and typically funded under a grant, often from NASA Langley or other places. They can take courses from all the universities. You can take up to half your courses from other universities in our course exchange program and get master's and doctorate degrees in aerospace-related disciplines that are offered by the universities. We're not a degree-granting institution, but we are a convener and host of the faculty here and the students here on site.

Diversification

Right now, we're really in a growth phase to try to expand beyond NASA. We've been doing that the past several years. We established agreements with the FAA tech center in New Jersey, with the Army research labs, with commercial companies. We're trying to diversify because we established a 20-year co-op agreement that's coming up in 3½ years. So, we are looking at, "What would we be beyond NASA if something were to happen with that co-op agreement?" Of course, we'd love to have that continue and hope that it will get renewed with NASA Langley. That's one event coming up that's kind of focusing us on diversification, and of course, we want to continue to grow our research portfolio and develop new technologies like boron nitride nanotubes and other technologies. We're working on the Smart Airports initiative and technologies related to that. So, there's several different thrusts we have going forward into the future in the next few years.

Uber Elevate Summits

We've been a leader in on-demand mobility, what's called urban air mobility, often now as well. That culminated in Uber getting involved in doing the Elevate Summits, and we've stayed involved. We do about $2.5 million a year in on-demand mobility studies and technology development right now. So, that's been a major thrust for us. We kind of built up the whole ecosystem of industry and NASA and FAA, and small startup companies and the key players and pulling them together. A lot of our university folks in particular have been doing studies for NASA and others in the community, and we continue to do research like noise-reduction technologies and other technologies to support that whole emerging industry.

Upbeat about urban air mobility

There are some very smart venture capital groups investing hundreds of millions, literally over a billion dollars, and companies developing these systems as we speak. It's not just people developing in their garages. There are thousands of people employed and hundreds of millions of dollars being spent doing this. And FAA is very serious. Other countries, they're very serious. I mean, Kitty Hawk, their core vehicle is operating in New Zealand, testing there in a friendly environment. There are companies all over the world testing vehicles. Dubai has been very forward-looking. And of course, the city of Dallas and Los Angeles announced partnerships with Uber to build vertiports and to start experimental operations there. So yeah, absolutely. The automation will follow on to what's happening with the ground vehicles. People are getting used to it, adopting automated vehicles, and I think that will eventually happen with automated aircraft.

FAA and urban air mobility

Markets that are more open to innovation will be early adopters of [urban air mobility and on-demand flight]. Unfortunately, I think a lot of that's going to start overseas because we have so much stricter regulations with FAA. However, the folks at FAA are doing a great job and being very forward-looking. And I think with time, there'll be concepts flying and operational, funded operations in the airspace. I think they'll initially start on an experimental basis. That's the plan now. And you'll see those flying in a few years, but you probably won't have FAA-approved large-scale operations for another decade.

Researching urban air mobility, on-demand flight

We work with our member universities, I mentioned the nine, but we have funded 120 different universities over the past 15 years, to do collaborative research. We bring together teams of multiple universities to attack problems. We've done that for NASA and customers in the on-demand mobility area. Acoustics is something we've looked at, active noise control for rotors, and modeling the acoustics, as well with some of our faculty members here locally. So, that's been an area for us.

Research with Airbus

We've had a collaborative relationship with Airbus now for 12 years. We've probably averaged about a million dollars a year in research and various areas such as nanomaterials, laminar flow control, wireless technologies, uncertainty quantification management, various acoustic technologies like metamaterial, acoustic metamaterial panels that we've built and tested.

Reducing noise, cleaning bugs off wings

Chris Fuller is one of the Langley professors here from Virginia Tech, and he does a lot of work in active noise control and acoustic metamaterials. He prepared panels and tested them in Hamburg. Acoustic metamaterials can be arranged to refocus sound and dampen various frequencies of sound. And so that's something that could be a panel on a commercial aircraft. We've even looked at using surface acoustic waves to vibrate off and displace and dislodge bugs from aircraft edges. We had a big workshop on that with Airbus and NASA, because that's a big issue; when insects remain on the leading edge of an aircraft, [it] can cause drag and inhibit laminar airfoils from working, for example. So, the big issue is how do you clean the airfoil, maybe after you've taken off from South Florida.

Pioneering boron nitride nanotubes

Boron nitride nanotubes, BNNT, is the technology we're best known for in terms of world-class capability. It's something we developed together with NASA and actually the Jefferson Lab right here in Newport News, Virginia, and the original patents. And then we licensed those to a company called BNNT LLC who's developing even more efficient ways to use a laser-based process that grows boron nitride nanotubes. The benefit of boron nitride nanotubes is that, basically, carbon nanotubes are essentially the strongest material based on specific strength on Earth, and boron nitride nanotubes are another stable form of nanotubes like carbon nanotubes. They have about 85 to 90 percent the strength-to-weight capabilities, but things like twice the temperature capability. So, you think of not just using them in polymer-based nanocomposites, but now metal matrix-based nanocomposites to higher temperatures, and aircraft engines, not just structures. They can be good up to 900 degrees Celsius. So, that's twice the capabilities of carbon nanotubes before they start to deteriorate in strength.

Radiation shielding out of boron nitride nanotubes

A couple of other properties of BNNT is that boron is a neutron absorber, so it's something that can provide some level of radiation protection, and it's also piezoelectric. So, if you run an electric current through it displaces, so you can think of nano and micro level actuators and machines as well. NASA was first interested and has actually been testing on it for radiation shielding. So, you can have a multifunctional structure on a space vehicle that provides some level of radiation shielding while providing an integrated nanocomposite. It's much lighter weight to have dual benefits for missions.

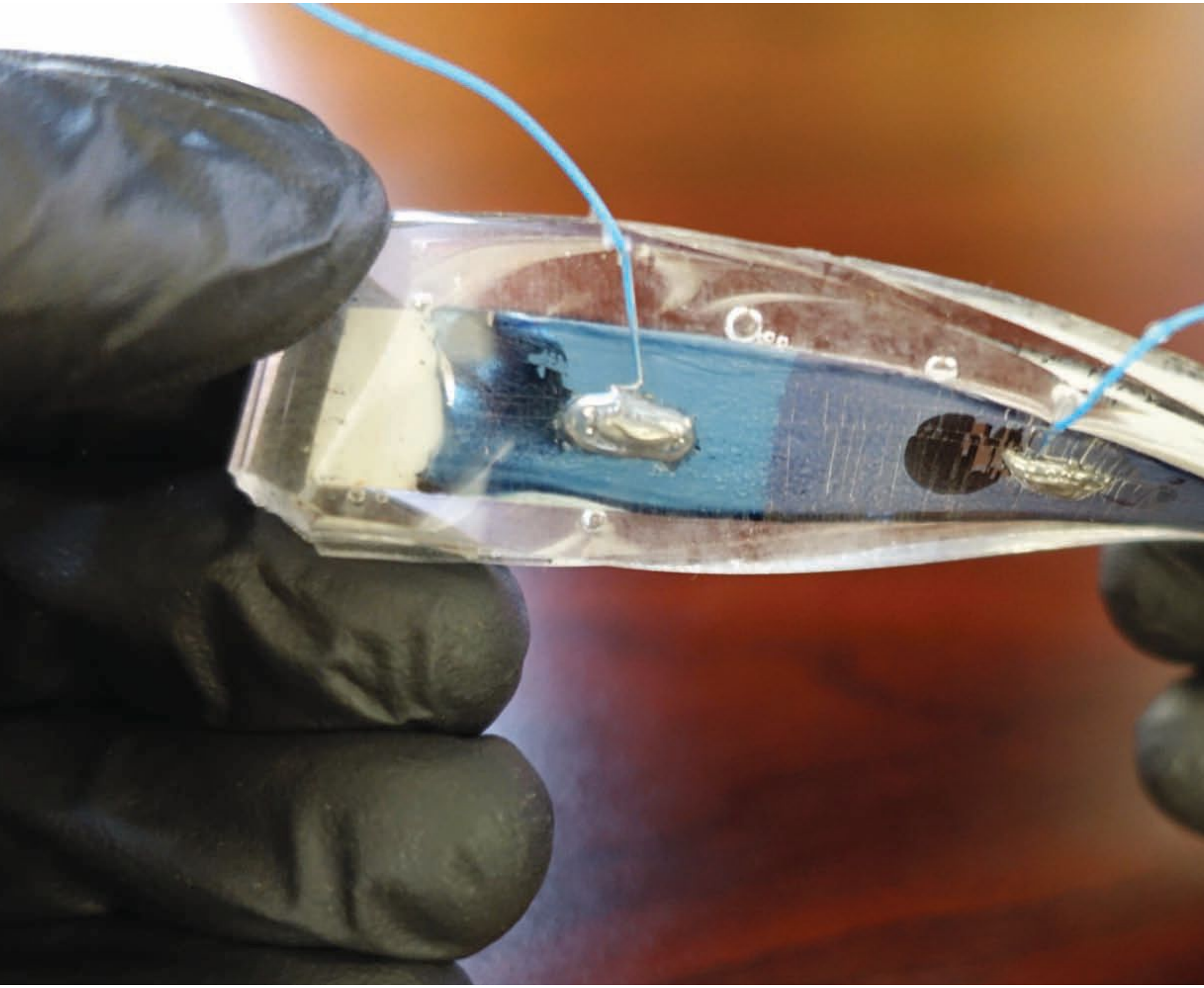
"We do about $2.5 million a year in on-demand mobility studies and technology development right now. So, that's been a major thrust for us. We kind of built up the whole ecosystem of industry and NASA and FAA, and small startup companies and the key players and pulling them together. A lot of our university folks in particular have been doing studies for NASA and others in the community, and we continue to do research like noise-reduction technologies and other technologies to support that whole emerging industry."

Next challenge for boron nitride nanotubes

The biggest issue is commercial yield. The process we use, they're able to make a lot of single- and two-wall tubes, very high-aspect ratio, 1,000 to 10,000, and very high purity, so they don't need as much post processing. And so it's the highest quality way of doing them. The issue though is yield, and some of the other processes that are lower quality have much higher yield. The biggest challenge now is trying to get the product to a commercially viable production level to be useful for large-scale applications. We have licensed this technology company [BNNT LCC] that's improved that by probably a couple of orders of magnitude in terms of the yield to where it's getting capable of that.

Affordable space launch

I did reusable studies early in my career, and at that time we were having 20 or 30 U.S. launches a year at most, and global launches, 70 or 80. There wasn't a whole lot of addressable market. And now that's increased to the hundreds. SpaceX is proving that out and other companies are looking at proving that out as well. The [U.S.] Air Force has got programs with reusable boosters. As you get more reusability, you can reduce cost. So you start a virtuous cycle of increased demand as costs go down with a price elasticity curve as in other industries, and then it's really starting to happen. SpaceX through their vertical integration, showed that even with existing technologies you get costs down from $4,000 or $5,000 a pound — back in my day — to $1,500 to $2,000 a pound. Now, as you start adding reusability and increased demand and volume, you can certainly get under $1,000 a pound, I think, in true commercial markets very soon. ★



▲ A flexible polymer that glows for a split second when held and twisted will be tested to determine how sensitive the material is to the flexing and bending that results from wing vibration.
New Mexico Tech

Glowing under strain

NASA and university researchers could be on the cusp of a new structural health monitoring approach for aircraft and spacecraft. The technique is centered on a two-part composite material that emits light when flexed. Keith Button spoke to the developers of the mechano-luminescent-optoelectronic, or MLO, composite.

BY KEITH BUTTON | buttonkeith@gmail.com

Part of Alexander Chin's job at NASA is to evaluate new technologies. He admits to being a bit skeptical two years ago when a colleague told him about a newly invented material that glowed and produced electric current when damaged.

The flexible material consisted of two polymers: a conductive polymer with a photoactive layer and an elastomer embedded with crystals. The crystal-embedded component glowed green or orange or blue, depending on the formulation, and the other polymer component reacted to this glow by generating an electric current. The marriage of the two materials was invented about five years ago by Donghyeon "Don" Ryu, an engineer in the growing field of smart materials who at the time had just joined New Mexico Tech, where he is an assistant professor. He called his rubbery creation the MLO composite, short for mechano-luminescent-opto-electronic composite. He has a patent pending on the invention.

Ryu showed Chin photos and some of the results of preliminary tests on the polymer composite. The data showed that the electric current was measurable and that the material was sensitive to strain

> The results could point to a better technique for warning when a wing or other structure is enduring excessive wear.

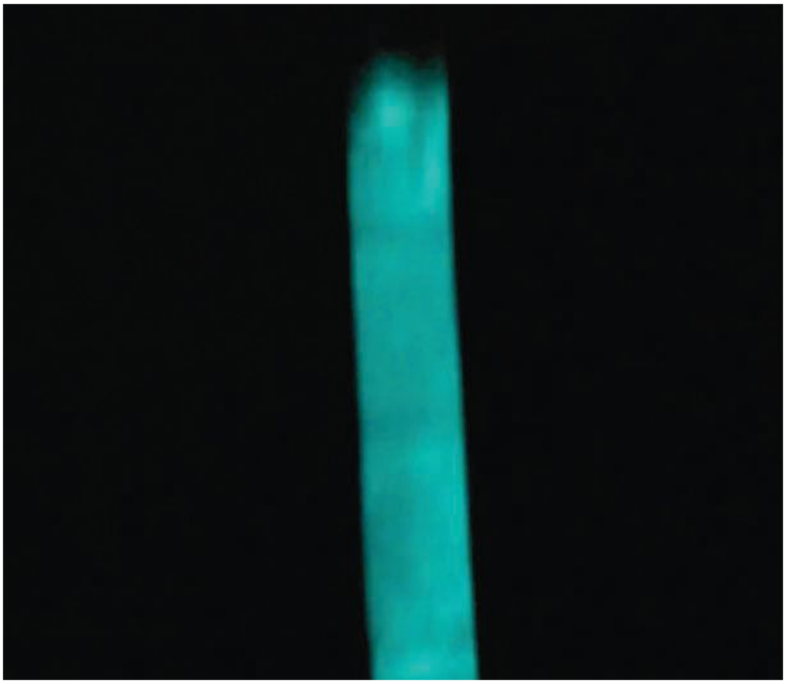
as well as damage.

Chin, who works at the Armstrong Flight Research Center in California, encouraged Ryu to apply for NASA grants.

Now, after a year of NASA-sponsored lab testing on versions of Ryu's MLO composites, Chin considers the technology promising. With more testing, it could prove to be worthy of pushing up NASA's scale of technology readiness levels, he says.

Researchers at the center's flight loads laboratory will soon install a 60-by-90-centimeter section of an MLO-equipped wing built by Ryu onto a heavy bench for a series of tests to be supervised by Chin. Starting in June or July, Ryu's team will shake the wing section to find out how sensitive the material is to the flexing and bending that results from a wing vibration. The data produced by the MLO composite will be compared to that from traditional strain and damage sensors, such as accelerometers and strain gauges.

The results could point to a lighter, more sensitive technique for warning when a wing or other structure of a conventional aircraft or drone or spacecraft is enduring excessive wear or at risk of breaking apart. Embedded as a layer within the entire skin of a wing or fuselage, connected by electrodes to a computer reading its voltage output, for example, the MLO composite could serve as a sensor operating under its own electric power. With the added sensitivity, operators might be able to fly their aircraft harder. And with a reliable, precise sensor, designers would have the freedom to create new designs for more fuel-efficient aircraft. They could build lighter aircraft, with more ambitious designs, without the need to



▲ The mechano-luminescent-optoelectronic composite glows in this screenshot from a video made during testing.
New Mexico Tech

over-build with heavy structures because of unknown in-flight forces at play.

Wing flutter, or severe vibration, for example, has traditionally been a flight condition that airplane designers wanted to avoid by a large margin because it could signal imminent structural failure.

"Normally we would never fly [aircraft] this close to the flutter boundary. But now, suppose we can; suppose we better understand this. At what point do we start trusting our control system; do we start trusting our sensors?" Chin says.

The "Aha!" moment

Ryu didn't set out to create a material that could help revolutionize airplane design.

While working toward his 2014 doctorate, he experimented with a commercial polymer that gives off electric current when exposed to light — a mechano-optoelectronic, or MO, material. The polymer could coat the surface of an airplane wing to help detect cracks and corrosion.

Hook the polymer up to an electrode and shine a blue light on it, and cracks can be detected at points where the voltage given off by the polymer increases. Expose the coating to infrared light, and voltage increases could point to spots of corrosion.

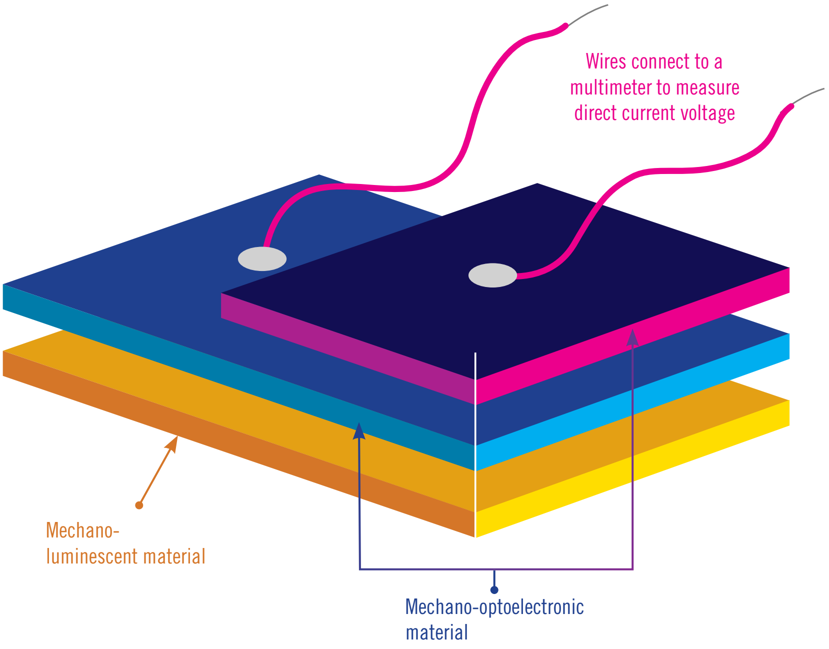
But while the coating might be helpful to someone inspecting an airplane on the ground, Ryu was aiming for a material with structural health monitoring capabilities — a material that could help detect potential problems in real time, during a flight. He needed an independent light source for the MO coating to work while a plane was in the air. Then Ryu found his answer. About seven years ago, he attended a SPIE conference, organized for optics and photonics researchers, and learned about preliminary research into mechano-luminescent, or ML materials, which would glow when subjected to vibration or strain. By 2015, Ryu had combined the MO and ML materials to form his MLO composite.

High hurdle: commercialization

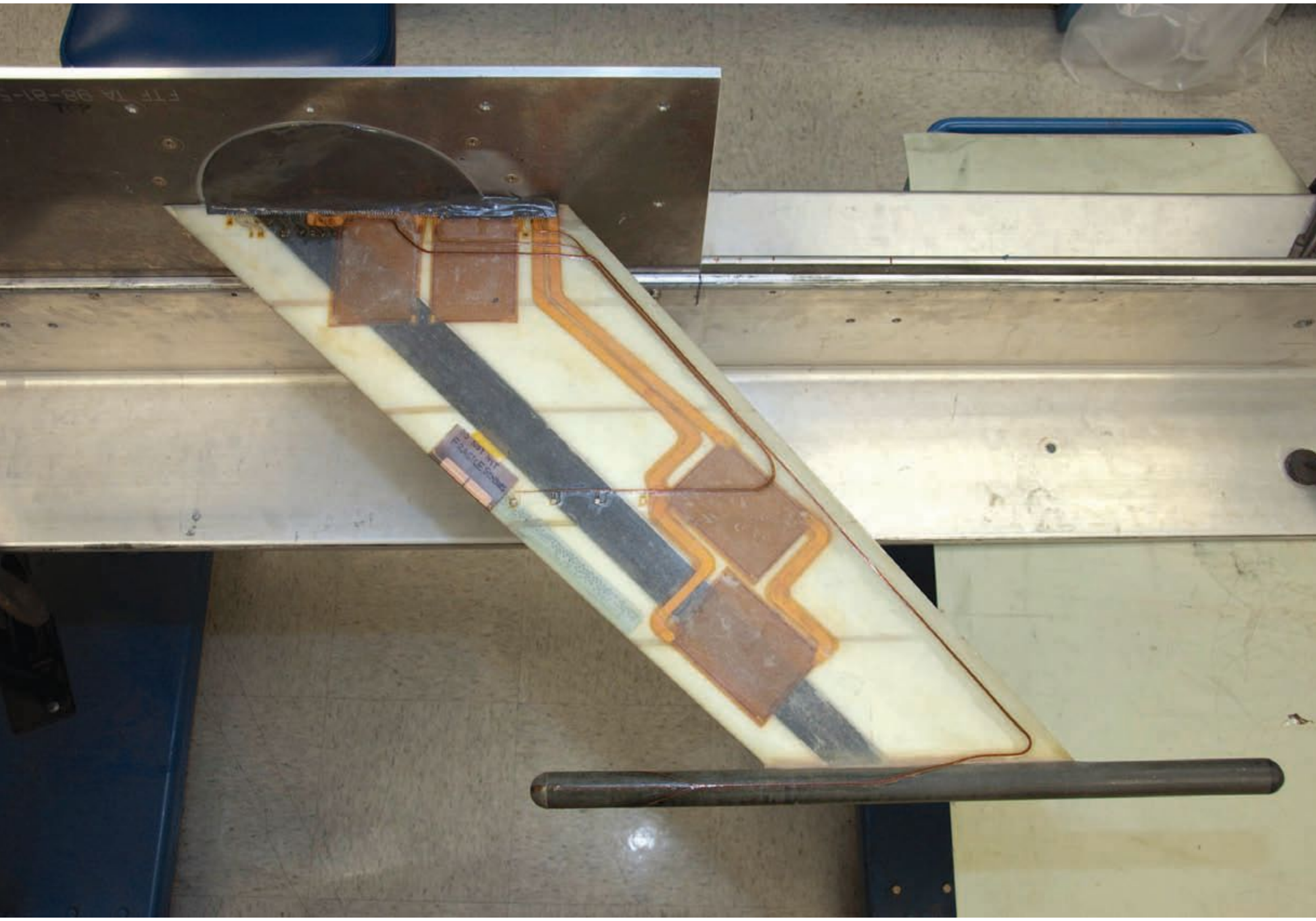
Ryu needs to make sure that MLO can be added to the manufacturing process with simple modifications. MLO composite material can be made in a

The layers of a strain-sensing material

A mechano-luminescent-optoelectronic, MLO, composite combines a mechano-luminescent material, which glows under strain, with a mechano-optoelectronic material, which generates current when exposed to light.



Source: Donghyeon Ryu



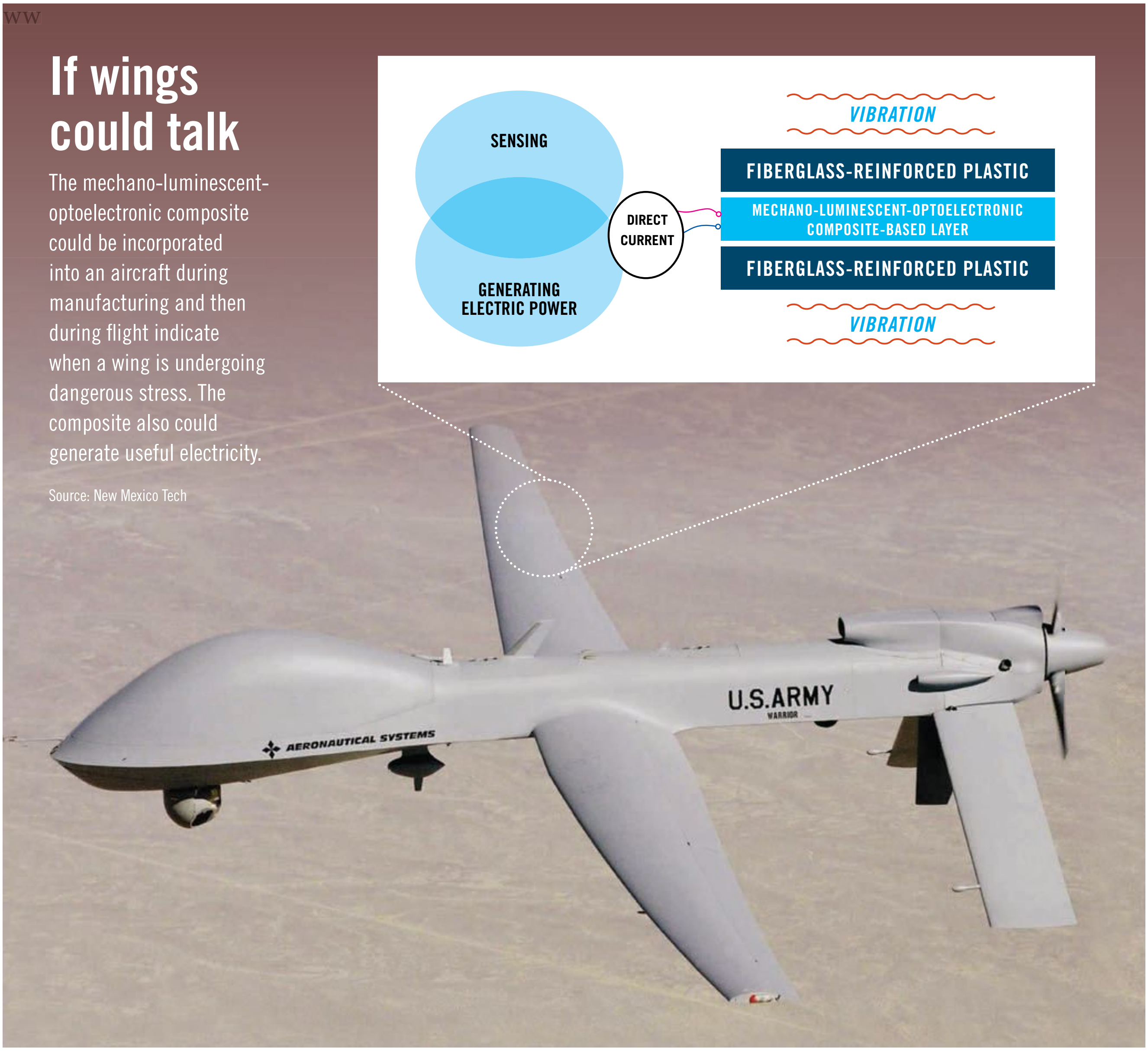
▲ This aerostructures test wing and setup are similar to those that will test the mechano-luminescent-optoelectronic composite at NASA's Armstrong Flight Research Center. The wiring is attached to strain sensors and accelerometers.
NASA

thin film, about 0.5-millimeter thick, and Ryu wants to make it even thinner, which would make it more practical for airplane designers to incorporate. To embed the MLO into a carbon-fiber airplane wing, the builders of the wing could lay the film on a carbon fiber membrane impregnated with resin. From there, the process would be conventional: The carbon composite with the embedded MLO composite would be laid inside a mold and allowed to harden. The wing builders could make the wings with the MLO composite on the inside of the wing, protected from the elements. Multiple layers of the film could provide more information on the structural integrity of the wing — monitoring for both exterior damage and interior strain, for example — although the cost would probably limit the number of MLO layers to two, Ryu says.

One advantage of the MLO composite is that it can be embedded inside structures or on their exterior surfaces.

Another challenge would be figuring out the best methods for collecting and interpreting the electric current generated by the MLO material.

Electrodes picking up current from the MLO material could be located in a grid throughout the structures monitored on the airplane, and they would pinpoint where damage or strain was occurring on the airplane within the areas of that grid. Airplane designers would need to know how many electrodes would be required over a given area and what levels of voltage would signify strain that was cause for worry. For the wing tests at Armstrong, Ryu plans to build three wing segments. The first segment to be tested will have electrodes at just a few points on



If wings could talk

The mechano-luminescent-optoelectronic composite could be incorporated into an aircraft during manufacturing and then during flight indicate when a wing is undergoing dangerous stress. The composite also could generate useful electricity.

Source: New Mexico Tech

the wing to pick up electric current from the MLO composite as the composite senses vibration. The electrodes will be attached to wires carrying the current back to a digital multimeter. The second wing will have more electrodes, and the third wing will have an extensive network of electrodes, similar to how the wing might be designed for a real-world aircraft with structural health monitoring, though Ryu says he hasn't yet decided how many.

An increase in the structural strain would increase the voltage picked up by the electrodes. The same electrodes would harvest electric current generated by the material, and the current could be stored or put to work for other functions on the aircraft.

Today, structural health monitoring, or SHM, is typically limited to experimental or research aircraft. Accelerometers or strain gauges attached to the wing or other structures do the monitoring. In addition to being lighter than the sensors required with vibration-based SHM, MLO doesn't need an external energy source. Another advantage of the MLO composite is that it can be embedded inside structures or on their exterior surfaces, and it can detect strain or damage over a spatial area, not just at points where strain gauges are located, for example.

Unlike with other materials that generate an electric current only from a limited range of vibration or other mechanical energy, MLO composites generate current from any level of mechanical energy, Ryu says.

Development challenges

One challenge Ryu has faced as he improves the MLO composite has been understanding how the properties of the material change when it is under strain or vibration. For example, the wavelength of the light, or color, and the intensity of the light might tell two different things about the type of damage or strain that the material is sensing. And formulating the material to glow a certain color could boost the levels of voltage generated by the material.

Ryu plans to research how to boost the levels of electrical power generated by the MLO material following this year's NASA studies.

The future

After the wing testing at Armstrong, Chin says he would like to see how the MLO material performs in further ground testing under variable and extreme temperature and simulated weather conditions. If the material proves itself in the environmental testing, the next step would be flight testing.

As designers push aircraft structural and performance limits to produce greater fuel efficiency, sensors that can tell pilots or flight control computers about the structural health of an in-flight aircraft will play a more important role, Chin says. They could also help minimize inspections or develop new control laws for aircraft. Computers paired with SHM sensors could identify and avoid the type of severe wing flutter that could cause airplane wings or tail structures to explode into pieces during flight, for example. By incorporating SHM into their aircraft, designers wouldn't have to overbuild the wing structure to stiffen it, which adds weight or bulk to the airplane.

Now, researchers are studying how to incorporate more flexible structures into aircraft, along with creative ways of controlling or suppressing flutter, to make lighter, more efficient aircraft designs possible, Chin says.

A sensor like the MLO composite would have a lot of advantages, because it could be integrated into an airplane's structure, be self-powered, provide information not available from other sensors and save weight, Chin says. But first, such a sensor will have to prove its reliability. ★

▼ An MLO composite sample is mounted in the strain test setup, where researchers apply tension to the composite, pulling on the ends of the sample in a load frame, and then measure the electric current and voltage produced by the composite.

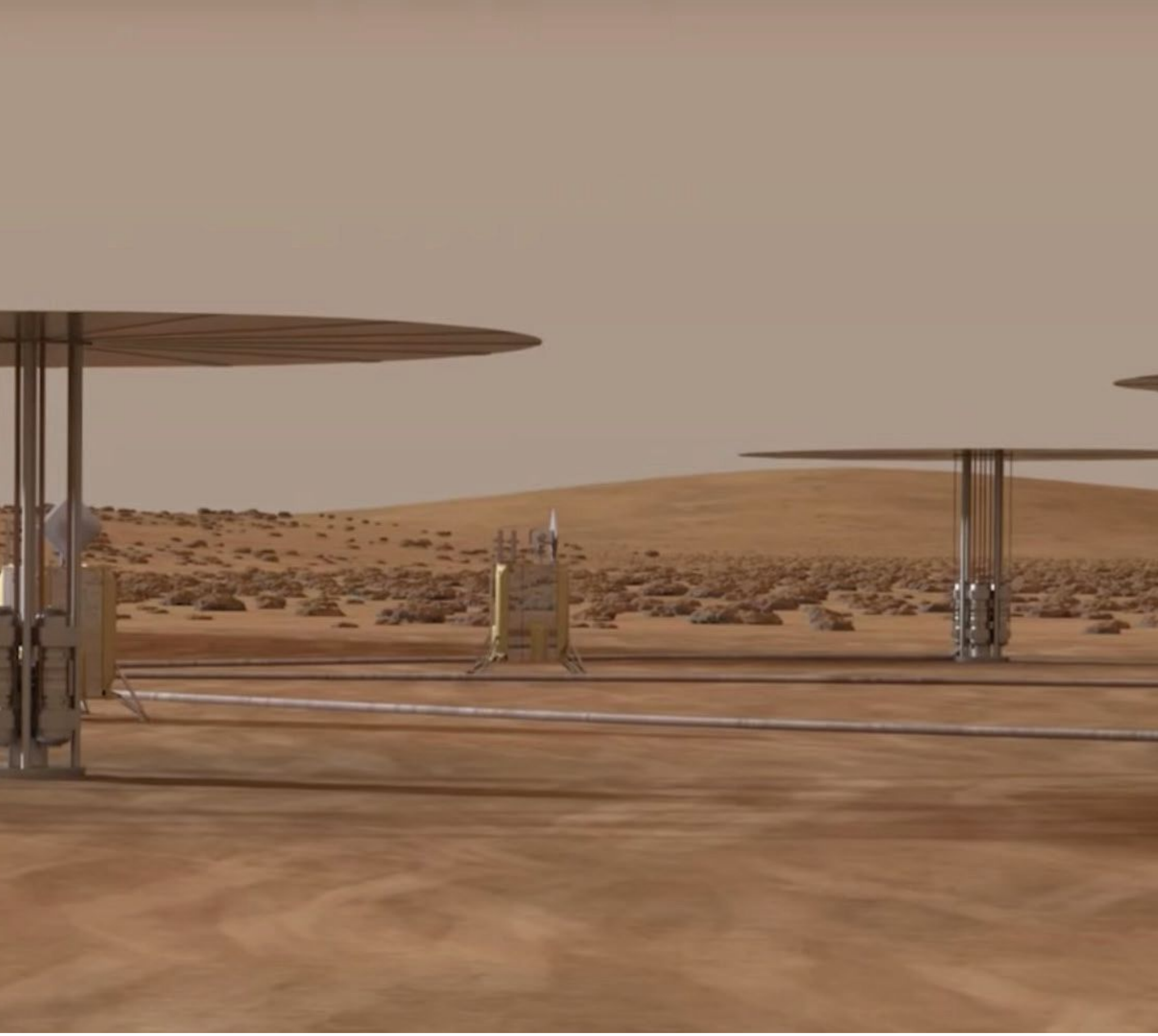
New Mexico Tech

▲ A network of Kilopower reactors, in an artist's concept, could power a Mars outpost without concerns over dust-obscured solar arrays and massive batteries for nighttime use.
NASA

Space nuclear power — seriously

NASA is testing technologies to bring nuclear fission power to human spaceflight. Tom Jones explains why the move is long overdue.

BY TOM JONES | skywalking1@gmail.com | www.AstronautTomJones.com



In space, electricity is life. Remember the Apollo 13 crew's brush with death when an oxygen tank explosion took out their power-generating fuel cells? Or perhaps you've heard how in 1997 astronaut Mike Foale, working on the Mir space station with his two cosmonaut hosts, witnessed the lights go out in his orbital home after a cargo ship collision tumbled the station and pointed its solar arrays away from the sun. The powerless station drifted in the cold of space for over a day until the crew, armed with flashlights, fired up their Soyuz thrusters to coax the arrays back into sunshine. Without electrical power, survival in space is impossible.

Photovoltaic solar arrays worked well on Mir, and they work well on the International Space Station, but they can't convert enough sunlight to electricity to meet the sizeable energy needs of human explorers beyond the moon, or on a planetary surface. Neither can radioisotope thermoelectric generators, or RTGs, like those that powered most of Apollo's deployed lunar surface science packages and that have powered robotic probes heading for regions where sunlight is too weak for solar arrays.

Deep space explorers are going to need a fission reactor, probably a collection of them. Unfortunately, for decades NASA limited its in-space production of nuclear-generated electricity to RTGs, judging fission reactors as too expensive and politically sensitive to develop. Besides, with astronauts limited to low Earth orbit, solar energy sufficed to power the ISS.

Now, NASA is factoring fission reactors into its human exploration plans, and under a project called Kilopower it is laying the groundwork for a future flight demonstration of the technology.

This is long overdue. Fission reactors can be built large enough to not only generate electricity, which is Kilopower's role, but also to drive an efficient rocket engine. For propulsion, the nuclear reaction can supply heat to generate electricity for ion engines or, at higher power levels, blast tons of high-speed propellant out a rocket nozzle. A high-thrust nuclear thermal rocket can haul bigger payloads for the same propellant load or lower the trip times for missions to the moon or Mars. The U.S. flew an electricity-generating, 600-watt fission reactor, SNAP-10A, in 1965. The Soviet Union launched at least 30 small reactors into low Earth orbit to provide electricity for military radar reconnaissance satellites. But these low Earth orbit satellites suffered from failures that dumped a pair of their reactor cores in the ocean and in 1978 scattered another's radioactive debris across Canada. NASA will have to design future reactors to survive launch accidents intact and begin operations only once they are well away from Earth.

▲ **Engineers** install hardware on the Kilopower assembly at the Nevada National Security Site.
NNSS

By the early 1970s, NASA had ground-tested a series of nuclear thermal rocket engines at the Nevada test site; these systems generated up to 4,500 megawatts of thermal power, produced 1.1 million newtons (250,000 pounds) of thrust, about half the thrust of a space shuttle main engine, and accumulated 90 minutes of run time. Unfortunately, this promising NERVA, for Nuclear Engine for Rocket Vehicle Application, space propulsion system was discarded during the agency's precipitous post-Apollo downsizing.

Yet to explore deep space, NASA really has no choice but to get serious again about fission. Solar power has drawbacks: The ISS requires an acre of solar arrays and a massive battery suite to support six astronauts. On the red planet, dust-obscured solar panels spelled doom for Spirit and Opportunity, NASA's two Mars Exploration Rovers. At Mars, solar power is further compromised, because sunlight there is only half as intense as at low Earth orbit or on the moon. Supplying a Mars outpost by solar power alone is a marginal proposition at best.

Nuclear fission offers distinct advantages in supplying the power-intensive needs of human explorers. Nuclear is always on, day or night, eliminating batteries. Reactors are also compact and immune to obscuring dust. And their ample power output gives deep space crews a higher margin of safety.

On the moon or Mars, a compact fission reactor could be landed, deployed and connected robotically before a human crew arrived at an outpost. Fission could supply ample "juice" for drilling, heating, cryo-chilling, materials processing, additive manufacturing, communications, rover recharging and sample collection. Steady, abundant electricity will be essential to produce an expedition's Earth-return propellant from subsurface ice, or at Mars, atmospheric carbon dioxide.

▲ **A fission power** prototype on display at NASA's Glenn Research Center, the reactor core is at bottom, heat pipes at center, and Stirling energy converters at top. One Stirling piston engine generated electricity in a 2018 test called KRUSTY, for Kilopower Reactor Using Stirling Technology.
NASA

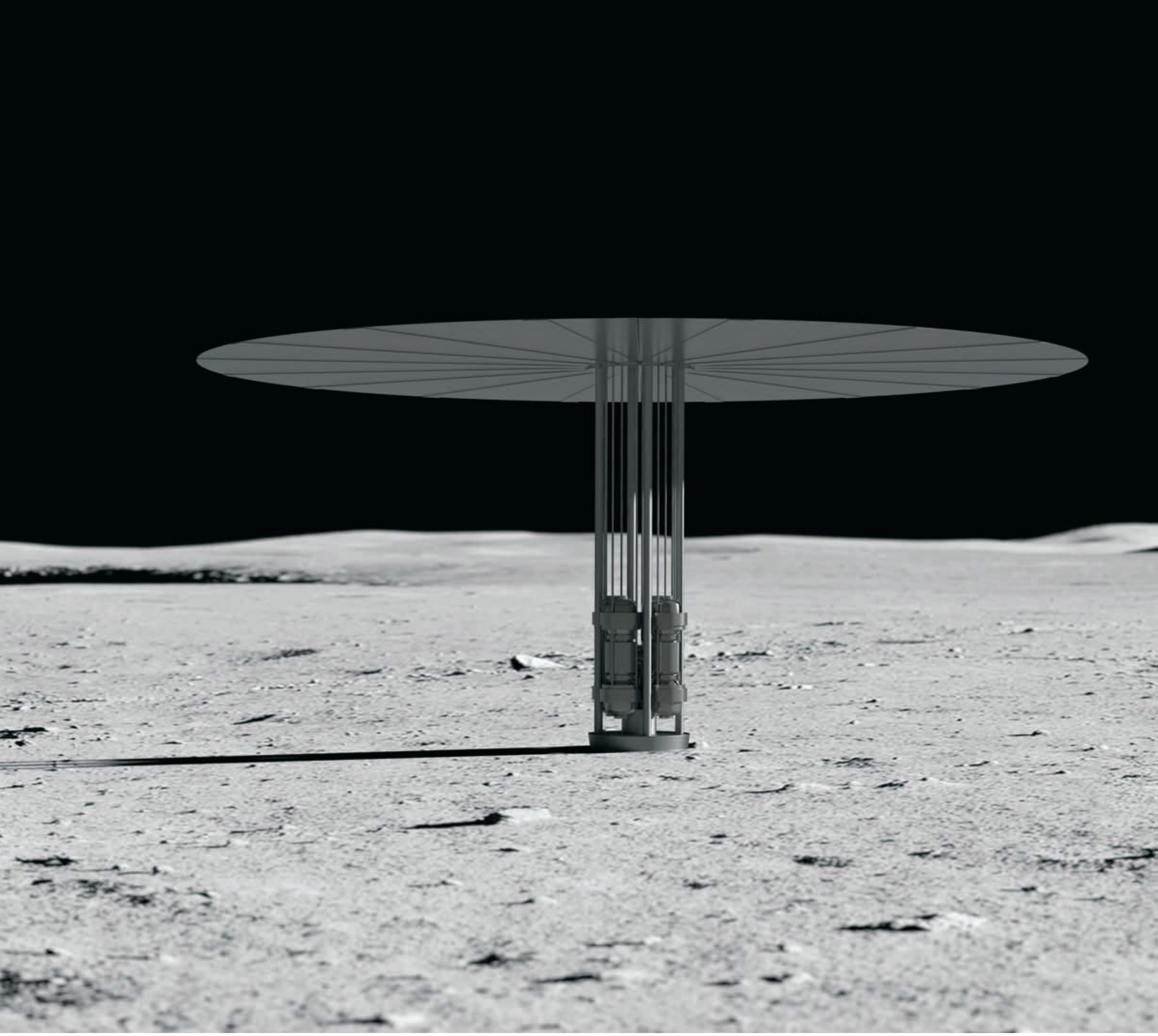
NASA's Kilopower

Kilopower is aimed at developing concepts and technologies that could be used in an affordable fission power system supporting long-duration stays on planetary surfaces. Managed by NASA's Game Changing Development program within the Space Technology Mission Directorate, Kilopower kicked off in 2015, and in less than three years, and for under $20 million, NASA and its government agency partners designed, assembled and operated a uranium-235 fission reactor to produce 10 kilowatts of power under realistic space environmental conditions.

Kilopower's output is small compared to the 84-120 kW produced by the ISS's solar arrays, which could power about 40 homes. Kilopower's 10 kW cannot even match the steady 21 kW produced by my shuttle orbiter's three fuel cells. But it could be networked with several identical reactors to create a surface electrical grid, available 24/7. Nuclear could supply a lunar outpost, for example, with all the electricity needed for life support, communications, active thermal control, rover recharging and propellant production.

At Kilopower's heart is a cylindrical, solid-cast core of uranium-235 about the size of a roll of paper towels. A chain reaction begins only when a cylindrical shell of neutron-reflecting material slides over the core, generating heat then carried by passive sodium heat pipes to Stirling energy converters. These efficient piston engines have run continuously for a decade or more in lab tests, powered by heat from non-fission sources. The electricity they generate is delivered to users while excess heat is dissipated by passive radiators. Kilopower's core is self-regulating: As heat causes the metallic neutron reflectors to expand, they trap fewer fission neutrons, thus slowing the chain reaction.

Fission reactors are of course radioactive, and in space applications the designers must consider hazards not present in solar or fuel cell designs. The fissile material must be protected and contained in case of a launch accident, but Kilopower's U-235 core carries fewer than 5 curies of total radioactivity while inert on the launch pad. That's less than a typical plutonium RTG. By comparison, a hospital's



radiotherapy machine might contain as much as 1,000 curies of a potent radioisotope.

To limit ground hazards, reactor operations would not commence until the unit was outbound from Earth or delivered to a planetary surface. Once there, regolith berms or burial would protect crews and equipment from radiation. Finally, Kilopower is designed to preclude any chance of a meltdown: Loss of cooling would cause a thermal expansion and an automatic reduction in reactor power.

KRUSTY delivers

To test these design features, NASA and its partners — the Department of Energy, the National Nuclear Security Administration, the Los Alamos National Lab, the Y-12 National Security Complex and the Nevada National Security Site — ran a 2018 test called KRUSTY, for Kilopower Reactor Using Stirling Technology. KRUSTY aimed to show the Kilopower system could generate fission electricity and remain stable and safe under space-relevant environmental conditions.

At the Nevada test site, the Kilopower reactor generated a controlled chain reaction, generating from 1 to 10 kW of thermal power while exposed to realistic operating temperatures in a vacuum. After normal operation was achieved, engineers introduced off-nominal situations, such as a failed Stirling converter or failed heat pipes, that might overheat the active reactor core. Kilopower self-regulated its output and maintained safe operations.

Finally, the reactor was put through a 28-hour, full-power demonstration of start-up, ramp-up to full power at 800 degrees Celsius, stability under

▲ **A Kilopower fission** reactor stands on the lunar surface in this artist's concept. Tubular heat pipes would carry energy from the buried reactor core at bottom to the Stirling engines just above the surface. A disc-like radiator dumps excess heat to the cold of space. A network of several Kilopower reactors could power a lunar outpost.
NASA

introduced transients, and a commanded shutdown. NASA Glenn's Marc Gibson, Kilopower lead engineer, said last July in a statement that "the reactor performs very well. … We were able to make the fuel and test the reactor here in the United States using our existing facilities. … I think that gave NASA management a lot of confidence that this isn't just a paper study — this is real."

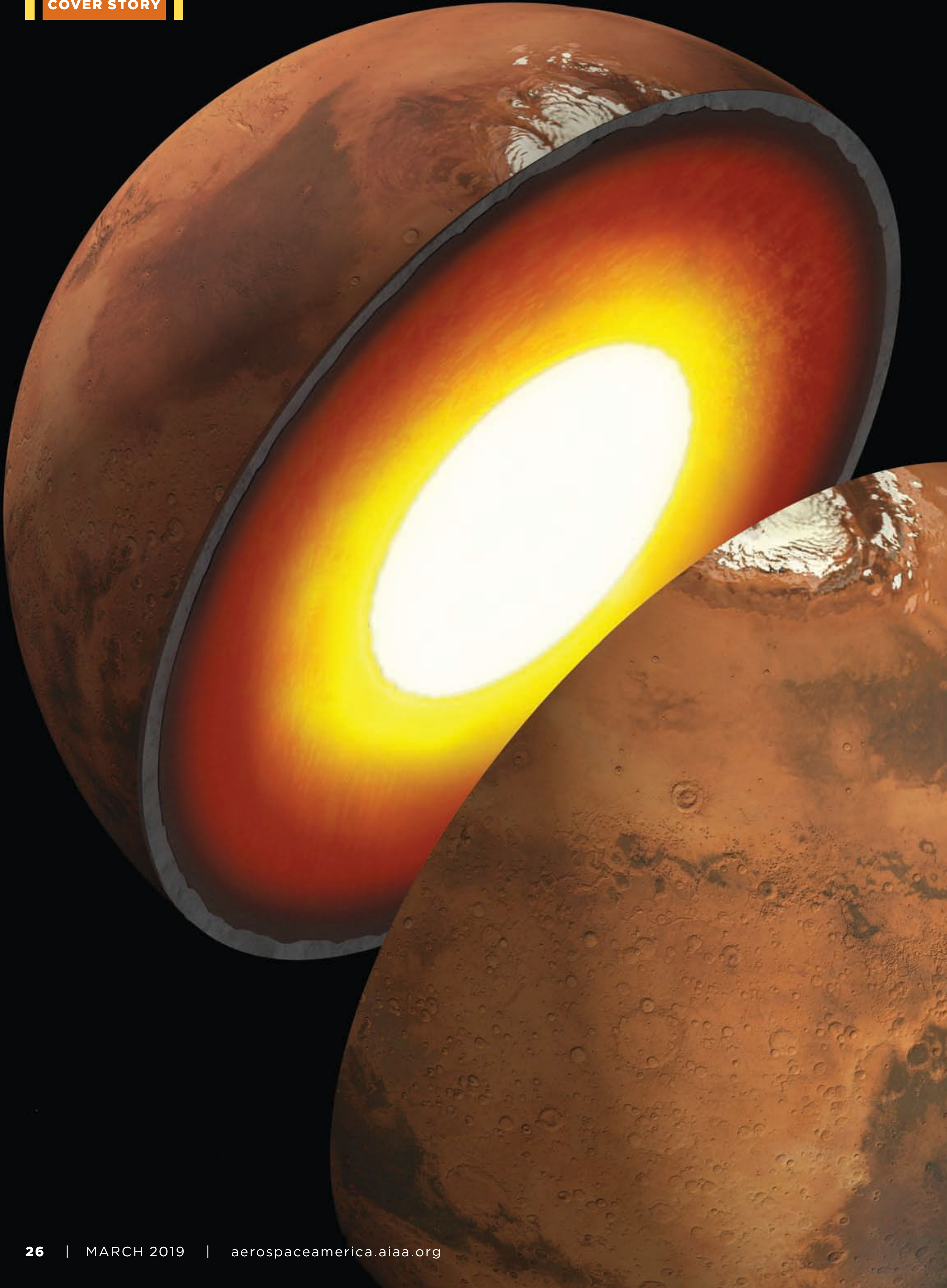
Although the KRUSTY configuration was not a flight system — the reactor lacked a radiator, a full suite of Stirling engines and a startup control rod, and was not subjected to launch loads, flight vibrations or free fall — its performance was an encouraging first step toward practical space fission power.

Next: fission propulsion

The ultimate application of fission power is high-thrust space propulsion, escaping the limitations of chemical rockets. NASA let a contract in 2017 with the nuclear-engineering firm BWXT to examine design and licensing requirements for a full-scale, full-thrust ground test of a nuclear thermal propulsion engine — along the lines of the NERVA tests 50 years ago. The $18.8 million contract includes the conceptual design of a propulsion reactor that, because of its much higher rocket exhaust velocity, would be about twice as efficient as chemical rockets such as the LOX/hydrogen space shuttle main engine.

Such a 500-megawatt (a measure of reactor power) nuclear thermal rocket might have a low-enriched uranium core to alleviate proliferation security concerns and ceramic/metallic fuel elements to deliver a specific impulse, a measure of fuel efficiency, of 900-910 seconds (compared to the shuttle main engine's 450 seconds). Such an engine could halve a Mars expedition's propellant requirements, or greatly increase its payload. Similarly, efficient nuclear propulsion can shorten one-way Mars cruise duration from six months to four, sparing astronauts excessive exposure to space radiation and free fall.

Such an engine is a couple of decades in the future, and making it a reality will not be easy. It will demand courageous political leadership at NASA as much as crackerjack nuclear engineering. But the success of Kilopower is a heartening sign of cold-eyed, purposeful management. As Glenn's Marc Gibson put it: "We've got a team that can go and design, test and build nuclear for space. We can go and use this technology on missions. That's the piece that hasn't been there in the last 50 years — no one ever tested the things that they put on paper." ★



DIGGING INTO MARS

Every square meter of Mars has been photographed from orbit; its dirt has been scooped up and heated to reveal its constituent chemicals; rovers have driven for kilometers. The surface of Mars, though, has never been dug so deep. That is set to change. Cracking the surface of Mars could deliver readings that will upend tenets about planetary evolution.

BY AMANDA MILLER | agmiller@outlook.com

When Apollo astronauts first bored into the moon to take temperature readings below the surface, they established an important fact: The moon is hard. Jagged particles scattered by asteroid strikes are tightly packed by seismic vibrations, and there is no wind or water to loosen the particles or smooth them out.

Nevertheless, the men on the moon made it work. Drills in hand, the Apollo 15 and Apollo 17 astronauts just had to push harder.

That wasn't the case on the Comet 67P/Churyumov-Gerasimenko, where the European Space Agency crash landed its robotic Philae spacecraft in a crevice in 2014 after an 11-year flight. The team commanded Philae to deploy a drill, undamaged as far as anyone could tell, but the drill still couldn't crack the surface.

"We were very naïve at this point," recalls Tilman Spohn, a member of the international team of scientists and engineers who designed Philae's drill.

Now, Spohn, a planetary geophysicist and director of the Institute of Planetary Research at DLR, the German Aerospace Center, will have another chance to crack the surface of a celestial body, this time Mars. He is the principal investigator for a package of instruments that arrived at Mars in November aboard NASA's InSight lander as part of the $800 million mission. This package includes a titanium tube with a bullet-shaped tip that is attempting to hammer — not drill — itself as deeply as 5 meters below the surface to learn, among other things, how much heat Mars sheds to its at-

mosphere. No one has ever gone that deep. The Viking 1 lander dug 22 centimeters down in the 1970s. NASA's Phoenix lander reached 18 cm in 2000.

Just as on the comet, there are no guarantees. The device, nicknamed the Mole, could hit a rock too big to work around before it gets very far, or the Mole's science team could discover that the dirt is denser than suggested by photos from the Mars Reconnaissance Orbiter, spectroscopy from the Mars Global Surveyor and analysis by other landers.

But if all goes as hoped over the next few months, scientists will begin to gather data that could help solve some of the great geophysical mysteries of Mars, including details about its core and what happened to its water — facts that could help exoplanet hunters as well.

For some, the water question is particularly pertinent. "Ultimately, why are people so fascinated with Mars? Because they know it had liquid water on the surface at one point and that the environment could have supported life," says Sue Smrekar, a planetary geophysicist at the NASA-funded Jet Propulsion Laboratory who is trying to find out why Venus, Earth and Mars all evolved differently. Smrekar is also the deputy principal investigator for the InSight mission.

At this writing, the InSight lander — short for Interior Exploration using Seismic Investigations, Geodesy and Heat Transport — is robotically setting out devices on the surface that will make a host of geophysical observations.

▼ A prototype of the Mole on the Heat Flow and Physical Properties Package burrows into simulated regolith in a screenshot from a NASA video. The orange-colored tape represents the science tether that is embedded with temperature sensors.
NASA

Digging for heat flow

When planners at JPL put out an informal call in 2006 for ways to bore into the surface of Mars, they soon realized that a conventional drill would be too big and heavy to transport on a small lander and too difficult to run remotely, recalls InSight principal investigator Bruce Banerdt of JPL, a planetary geophysicist. A drill's motor would need to stay on the surface. To drill 5 meters down, the bit had to be 5 meters long.

Engineers at DLR were already working on a so-called "mole" digging device, but with a future comet mission in mind. That said, it was similar to a device that had reached Mars aboard the British lander Beagle 2 in 2003. Unfortunately, that spacecraft never communicated with Earth after landing.

The 40-centimeter-long titanium tube that would become today's "Mole" — picture a cylindrical cigar humidor about three cigars long — would sink deeper into the dirt with each blow of a hammer housed inside it. To generate a thump, an electric motor would draw the hammer upward to compress a spring. Upon release, the hammer would strike a cylinder that then would bounce off another spring coiled inside the bullet-shaped tip, tapping the tip and tube a little farther into the dirt.

"We realized it could pull down temperature sensors on a cable," Banerdt says.

That was important because the team wanted to record the temperature at various depths as they dug into Mars. Today, these readings, called the thermal gradient study, are half of what's required to calculate the heat flow at InSight's landing site, meaning the rate by which heat is conducted from the interior of Mars to the surface and into the atmosphere.

To gather the balance, the scientists will periodically command the Mole, during its dig down, to warm itself to a specific temperature, and time how long it takes to reach that temperature.

The heat flow results could test some key predictions about the evolution of Mars, such as how hot Mars was when it formed. Spohn estimates that about 10 percent of the heat flowing just below the surface of Mars comes from the planet's core. Scientists also want to see if their heat flow prediction for Mars is correct. They expect the average heat flow just below the surface to be about a quarter of Earth's. For starters, Mars is about half the diameter of Earth, and on top of that, most of the volcanic activity on Mars took place early in its evolution.

The interior heat data could have implications for planet hunting by shedding light on the characteristics of planets that are most likely to be habitable, meaning capable of supporting some form of life. "Is it just a matter of how close a planet is to its star? Or is it more subtle? Would the interior makeup of a planet have implications for its habitability? This is cutting-edge discussion in planetary science these days," Spohn says.

If Mars has water

Only 20 years ago, people on Earth still thought planets got their water delivered by comets.

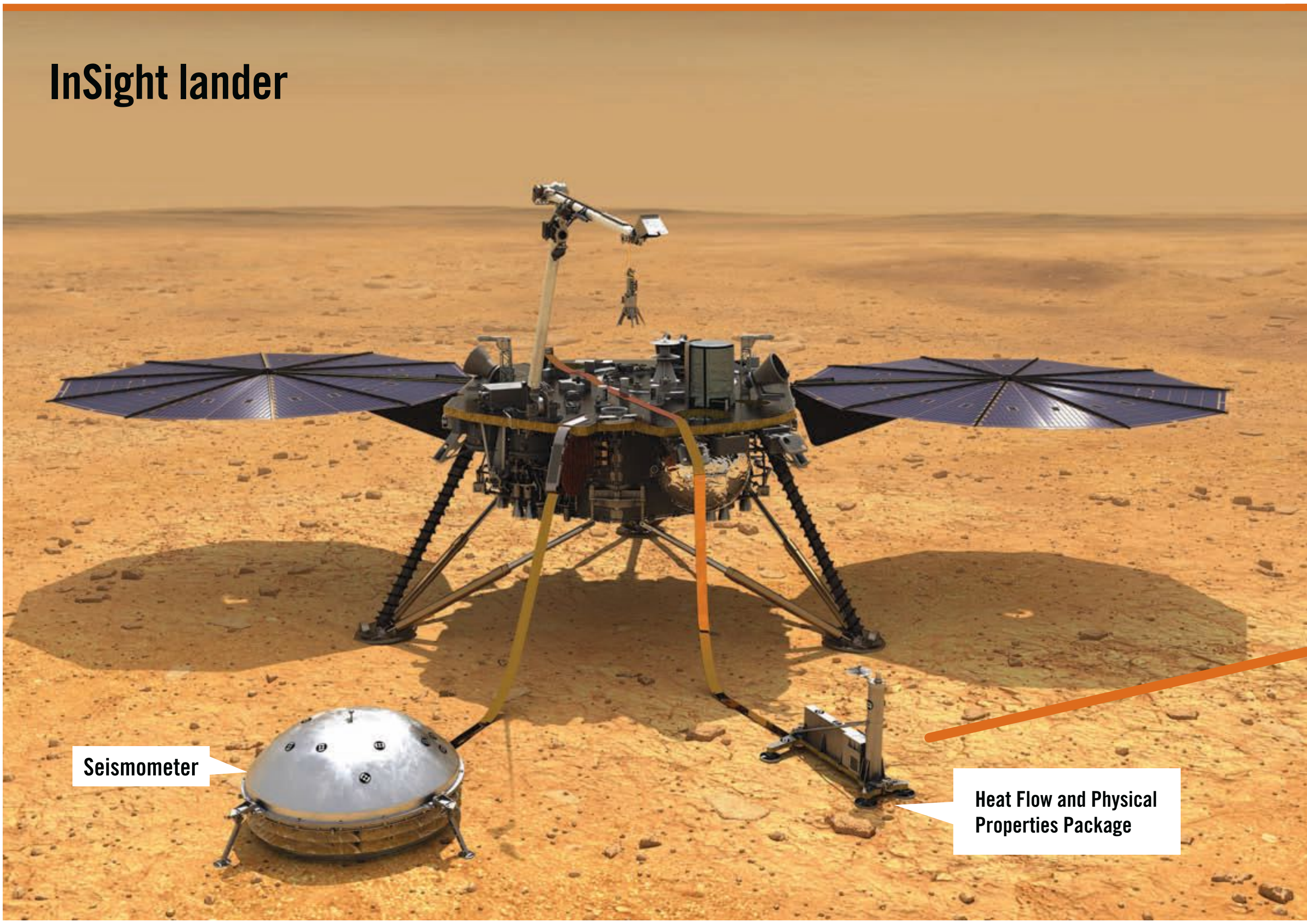
"Now we understand that most of a planet's water comes from the inside," Smrekar says. Geophysicists think most of Mars' volcanic activity happened in just the first 50 million years of its evolution, or "a blink of an eye," as Smrekar puts it. She wonders if a single volcanic eruption could've freed the water that flowed on the surface for the next 1 billion to 2 billion years.

At the same time, planetary scientists wonder whether liquid water is still waiting below the surface. Recording how much warmer Mars gets over those first few meters could help human explorers estimate how deep they will need to dig to reach the zero Celsius point where liquid water could exist.

But for now, the InSight team has only asked NASA's permission to dig as far as 5 meters into Mars, a much shallower depth than Banerdt would expect to find water.

"One of the things we had to worry about was [the surrounding regolith] getting warm enough to melt ice and form water," Banerdt says. "That's a big concern to the planetary protection people — contaminating the surface by incubating things," he says, referring to microorganisms that, despite precautions, might happen to hitch a ride from Earth.

At NASA's Office of Planetary Protection, the job is to make sure people explore the solar system re-



sponsibly, partly to try to keep planets as pristine as possible for more study. The Mole is designed to dig only as deeply as it needs to — 3 meters to 5 meters, according to scientists, to get good data.

"It's already really cold," Banerdt says — around minus 30 or minus 40 degrees Celsius. "So we're only heating it up a little bit."

Testing the Mole

The InSight team feels reasonably confident that they won't suffer a Philae-like disappointment.

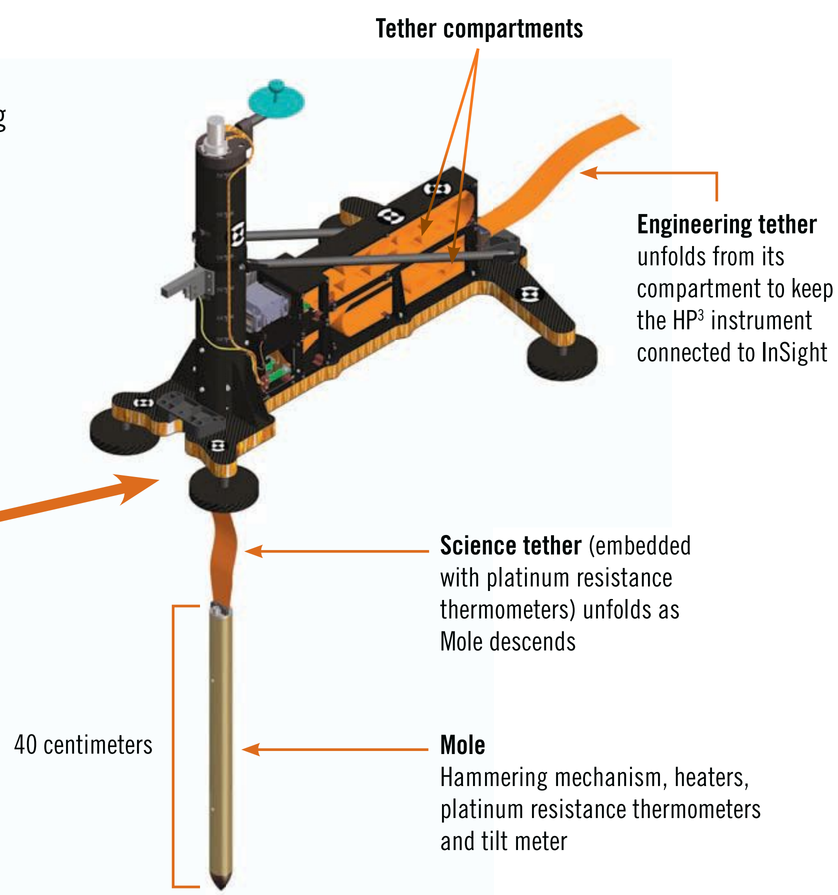
To prove the design, they filled a 5-meter-deep tube at DLR with simulated Mars regolith. The engineers did that for various mixtures, given that no one can know for sure the composition of the regolith that the Mole will encounter. Similar tests were done at JPL, but in only a 2-meter-deep, dirt-filled tube. The advantage was that engineers could pump the air down to Mars-like pressures and temperatures.

The Mole scientists think InSight's flat Elysium Planitia landing site will prove to be most like the fine quartz sand in their testing, with rocks making up only a small percentage — 5 percent at worst.

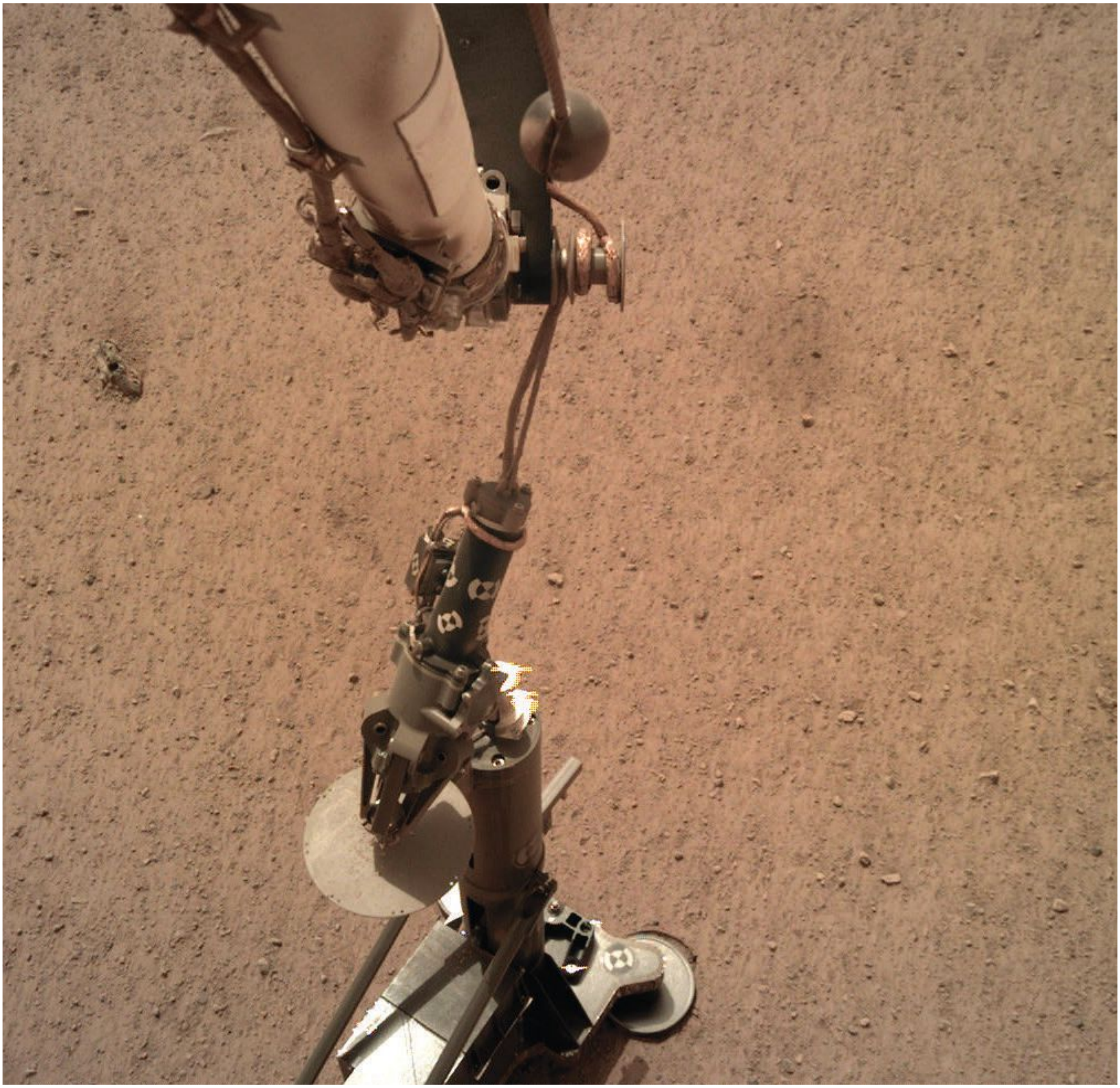
> **"One of the things we had to worry about was [the surrounding regolith] getting warm enough to melt ice and form water. That's a big concern to the planetary protection people — contaminating the surface by incubating things."**
>
> — **Bruce Banerdt,** Jet Propulsion Laboratory, referring to microorganisms that, despite precautions, might happen to hitch a ride from Earth

Digging for answers

Scientists want to know how much heat flows from the Martian interior, including how quickly the dirt, called regolith, warms up as one probes deeper. To find out, a titanium tube with a hammering mechanism inside will plunge as deeply as 5 meters. Scientists have nicknamed the device the Mole. It is part of the InSight lander's Heat Flow and Physical Properties Package, or HP^3.



Sources: Artist's rendering at left, NASA; diagram above, German Aerospace Center, DLR



Prior to the Mole's deployment, Banerdt told me he thought the Mole had a 75 percent to 80 percent chance of reaching 5 meters. That probability came close to a prior estimate, which assumed the Mole could get past rocks up to 15 centimeters in diameter or those oriented with their surfaces at a 45-degree angle to the Mole's path.

Before the landing, members of the Mole's team analyzed the likelihood of reaching 5 meters. The 80 percent chance assumes a "less conservative assumption" than one that showed a 41 percent chance of digging down the full 5 meters, they wrote in the article, "The Heat Flow and Physical Properties Package (HP^3) for the InSight Mission," published last August in Springer Space Science Reviews.

The Mole may have to do as many as 10,000 to 30,000 hammer strokes to get down to the ideal 5-meter depth, but it doesn't have to make it all the way to 5 meters. If the Mole digs only as deep as 3 meters, that should produce the desired temperature readings, with one important adjustment. The team will need to take measurements for a much longer period to account for daily and seasonal temperature fluctuations aboveground that extend down below.

Scientists would need just a couple of Earth months' worth of data to calculate the heat flow if the Mole makes it to 5 meters. Or they may need the full duration of the mission, about two Earth years, Spohn says, if the Mole digs down only 3 meters.

▲ The claw on the InSight lander's robotic arm grasps the handle on the Heat Flow and Physical Properties Package and places the instrument on the Mars dirt. A camera on the lander shot a series of these images on Feb. 12.
NASA

"Ultimately, why are people so fascinated with Mars? Because they know it had liquid water on the surface at one point and that the environment could have supported life."

— **Sue Smrekar,** NASA-funded Jet Propulsion Laboratory

Burrowing was set to begin by late February, with the box that contained the Mole acting as an anchor to keep the self-hammering tube from bouncing off the surface before friction from the regolith takes hold. The hammering could last through March or even into April, if the Mole is able to go deep.

Instrument deployment had fallen behind schedule in January after a few attempts to robotically stow InSight's claw-like grapple, the robotic arm and grapple having already placed another of InSight's instruments, its seismometer, out on the surface.

Could there be regolith surprises?

To come up with their best educated guess as to the ground's composition at InSight's landing site — hoping the dirt proves neither too rocky nor too dense — the researchers looked at photos from the Mars Reconnaissance Orbiter, examining the sides of ridges for clues to what's beneath. The Mars Global Surveyor's spectroscopy data characterized heat emissions from the surface, suggesting its mineral composition. Plus the team took into account the consistency of those scoops of regolith picked up by past Mars probes.

Slight as Mars' atmosphere may be — about 1 percent of the density of Earth's — the red planet's thin covering does give it windy weather. The Mole should have an easier time burrowing through the smooth, weathered Martian sands than it would mitigating the sharp, super-compacted substrate Apollo astronauts encountered on the moon.

If there is trouble, Spohn thinks densely packed regolith — more so than expected — could be as likely as a big rock to stymie the Mole's progress. ★

ORU
WPA
Pump
To PMA2
DECK

TALKING (SPACE) TRASH

NASA

An easily overlooked, yet critical element of long-duration lunar or Martian missions will be dealing with all of the garbage we humans inevitably produce. Adam Hadhazy delves into the efforts to advance astronautical waste management.

BY ADAM HADHAZY
adamhadhazy@gmail.com

◀ **Stowage bags filled** with trash and excess equipment hide an astronaut on the International Space Station. The bags will be loaded on a cargo spacecraft that will undock from ISS and burn up when it re-enters the atmosphere.

The essentials of Earthly life — air, water, food, climate control — can't be taken for granted aboard a spacecraft bound for deep space. Now receiving deserved attention for such a trip is another thing we surface-lubbers take for granted: taking out the garbage.

Over the next few decades, NASA has long-duration missions in its sights. These excursions include a lunar gateway station in cislunar space, as well as pursuing a yearslong crewed voyage to Mars. Both missions will take astronauts away from the convenient, low Earth orbit lifestyles they've grown accustomed to during the space shuttle and International Space Station eras. On Earth's doorstep, trash disposal aboard the ISS is easy: Simply load up a docked resupply vehicle, cut it loose, then let it burn up during atmospheric re-entry. With new vehicle-loads of fresh supplies arriving every few months, there is little need for recovering consumables, although since 2008 astronaut urine has been recovered and converted to drinking water [See "Dealing with nature's call"].

Deep-space crews will be largely on their own, which means NASA is increasing emphasis on the three R's of trash management: reduce, reuse, recycle. In preparing for this future, the agency announced in October that it has selected Collins Aerospace, a 70,000-person company based in Florida, and Sierra Nevada Corp., or SNC, of Colorado to develop competing trash compaction and processing systems. These systems will compress and melt down garbage, slashing rubbish volume and venting to space resulting vapors that could contaminate cabin air. That's the "reduce" in the three R's. The companies are also investigating ways to fulfill the other two R's. Capturing valuable consumables, such as water and potentially useful gases, released during trash processing could enhance mission architectures and scope, allowing for more focus on science instead of crude provisioning.

"We want to 'close the loop' on resources like water and air as much as possible. That'll help us reduce our reliance on resupply," says Shawn Macleod, senior business manager for space systems at Collins Aerospace.

By early 2020, both companies will have completed an initial phase of research and development of their trash compaction and processing systems, for which NASA plans to award between $500,000 and $1 million to each. A preliminary design review will follow, after which a second phase lasting around two years will see the initially satisfactory system (or systems) matured to flight readiness for a technology demonstration on the ISS.

These kinds of systems could deliver benefits beyond keeping trash in check and compensating for severed supply chains. The final solid waste products from both Collins' and SNC's systems are hard, flat tiles. Primarily made of melted, compacted plastic, these dense tiles could double as radiation shielding to mitigate this major hazard of deep-space travel. Any mission outside of Earth's protective magnetosphere, to the moon and beyond, subjects its crew to solar and cosmic particle bombardment that can cause radiation sickness, increased cancer risks and degenerative disorders. "The idea is to repurpose the trash for something, other than just storing it somewhere," says John Wetzel, a program manager at SNC leading the trash compaction and processing unit development.

Should a spacecraft land at Mars, rendering trash into stable, sterile tiles could also address another concern that's always on the minds of planetary scientists. "We want to make sure with our trash that we're not contaminating an environment with human presence," says Macleod. Eliminating bacteria in the smears inevitably left inside of astronauts' food pouches, for instance, will cut down on the risks of Earthly microorganisms infiltrating pristine, extraterrestrial locales where we humans hope to detect signs of alien life. The system could help assure planetary protection.

> "The idea is to repurpose the trash for something, other than just storing it somewhere."
>
> — **John Wetzel,** Sierra Nevada Corp.

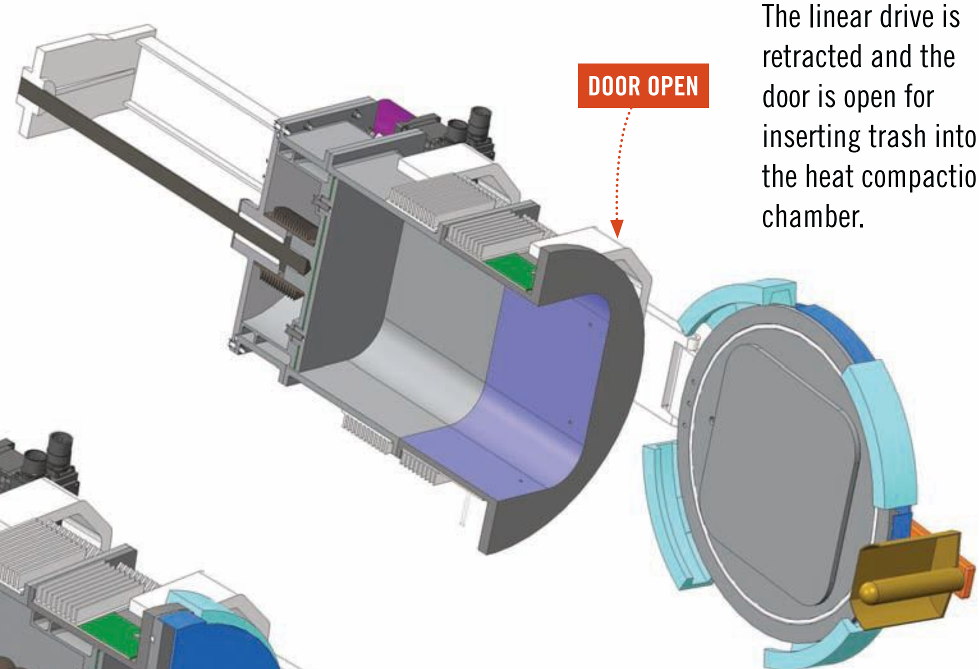
Rubbish routines

Nowadays, trash management on orbit is hilariously low-tech. Station astronauts duct tape their disposables up into small bundles, dubbed "trash footballs." These garbage pods are loaded into a Cygnus or Progress resupply vehicle — whatever happens to be docked — that is later jettisoned for incineration in Earth's atmosphere. Voilà, waste problem solved.

This protocol, such as it is, has worked fine because of the minimal needs for resource recovery and given the amounts of trash generated — on the order of 2 kilograms per astronaut per day. Examples of what astronauts throw out include packaging, paper, tape, filters, food containers, and various personal hygiene items such as cleaning wipes,

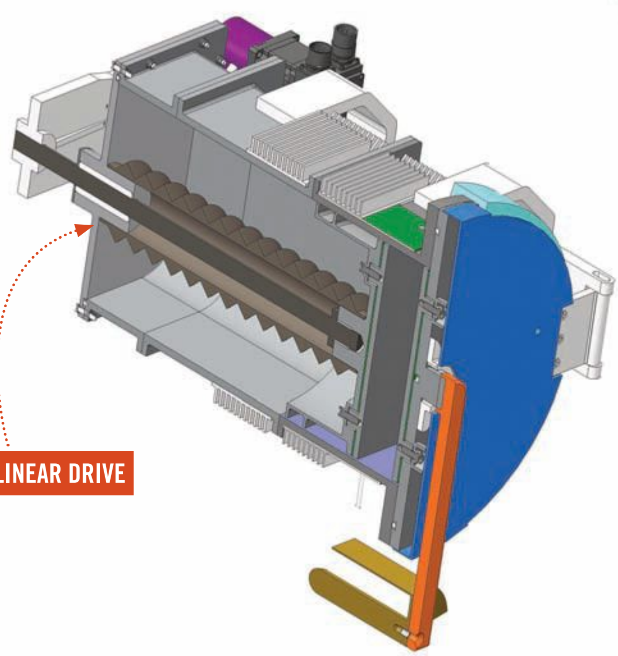
COMPACTING TRASH IN SPACE

A linear screw drive mechanism will move a piston and panel to squeeze the trash in Collins Aerospace's concept.



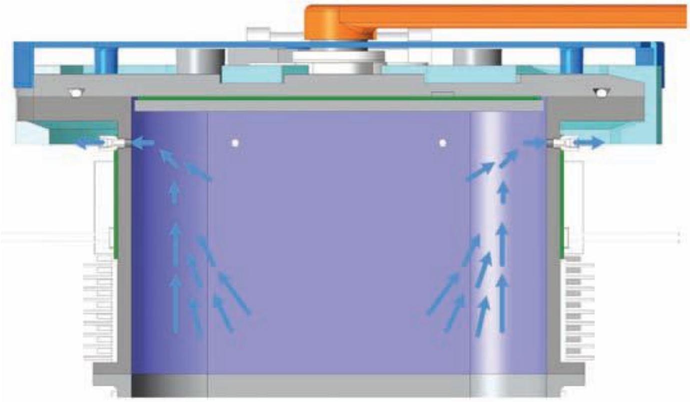
1

The linear drive is retracted and the door is open for inserting trash into the heat compaction chamber.



2

The linear drive assembly compacts trash toward the closed door.



TOP VIEW

A zoomed-in view of the chamber's front end, showing the evacuation of gases (blue arrows) through vent ports as trash is compacted.

towels and dirty clothes (doing laundry on station is not an option).

Without resupply vehicles to serve as dumpsters, one potential trash tactic in deep space would be to simply chuck the waste into space via an airlock. But this comes with drawbacks, says Uday Hegde, who studies aerospace waste management and water reclamation at Case Western Reserve University in Cleveland and who is not involved in either the Collins or SNC projects.

For starters, in space — just as on Earth — practical trash container bags inevitably leak. "None of these bags are totally impermeable," says Hegde. "There is always some leakage of gases and vapors." The problem is compounded in the airlock disposal scenario. The low pressure generated when pumping air out prior to evacuation pulls liquids and gases out of solid waste. These volatiles can then freeze onto airlock surfaces, eventually interfering with proper hatch closures. Furthermore, upon repressurization and thawing, the atmosphere in the airlock would need to be filtered so the gases and vapors do not contaminate the spacecraft cabin's air.

In addition, loading and venting the airlock, or alternatively doing a cubesat-style launch also via the airlock, are astronaut-labor-intensive. Hegde

▲ **This tile is made up of** trash and was generated by an early version of a heat melt compactor developed by NASA. Two companies are competing to produce devices to handle trash on spacecraft and possibly other planets.
NASA

and colleagues have calculated how many trash footballs, along with the number of disposal events, would be needed to stay on top of trash management for gateway and Mars expeditions. Consider a 180-day mission, such as a stay aboard the gateway or the trip to Mars, with a four-person crew. The crew would generate about 3,000 trash footballs requiring at least 800 disposal events. Expand the crew size to six and the duration by another month, and the figures rise to 5,000 trash footballs and at least 1,200 disposal events. "You don't want to be constantly doing these operations, taking up astronaut time," says Hegde.

Furthermore, although littering the vastness of interplanetary space all the while on the way to Mars would not be such a big deal — the chances of another Mars-bound craft ever encountering the debris would be infinitesimal, says Hegde — accumulating garbage in the vicinity of the gateway could begin to pose a "space junk" problem, already increasingly of concern in Earth orbit.

Trash disposal reimagined

The trash management systems by Collins and SNC attack these myriad problems with a broadly similar approach, known as heat melt compaction. Each concept is centered on a sealable chamber. The astronauts would "put the trash inside, close the door, hit 'go,' and the whole process is automated," says SNC's Wetzel. The task is meant to be simple and far less labor-intensive for busy astronauts than chucking garbage into space.

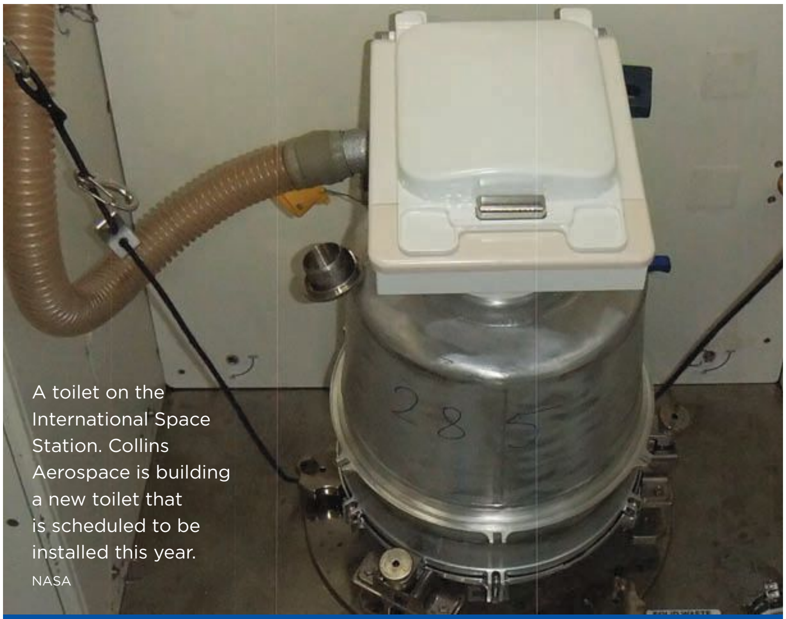
Over a period of hours, low pressure and heat, followed by compression, remove water and other volatiles while reducing the trash's volume. The end result is a solid, flat tile about an inch thick and shaped as wide and deep as the chamber, which in early designs has ranged from 9 to 16 inches square. Both systems are intended to reduce the trash volume by over 90 percent, with percentages in the 70s-to-80s range for air and water content recovery.

This trash management tactic was initially explored by engineers at NASA's Ames Research Center in California. Orbital Technologies Corp., a Madison, Wisconsin-based company acquired by SNC in 2014, worked closely with Ames on these initial efforts under a NASA Small Business Innovation Research program. The NASA test unit developed many of the technologies underlying the approach SNC and Collins are now building upon in their own projects. "We want to take all the lessons learned by NASA," says Macleod, "to mature our trash compactor processing system and make sure it's integrated with the ISS [for the demonstration] as seamlessly as possible."

Collins is further drawing upon experience in designing trash compactors for commercial aviation, for instance in service aboard the Airbus A350 XWB airliner. Collins Aerospace was formed in November 2018, when United Technologies of Connecticut acquired Rockwell Collins, combining it with UTC Aerospace Systems, known in the industry as UTAS. Those companies brought in experience in human waste management as well, again for aviation, but also in space. Collins is under contract by NASA to construct the next-generation space toilet, dubbed the Universal Waste Management System [see sidebar].

Heat melt compaction in action

In appearance, SNC's system looks somewhat like a dorm room-style mini-fridge, while Collins' is more juicer-like. Within each system's chamber, heat melt compaction proceeds as follows. After astronauts pop refuse into the chamber and seal it, the next phase is air and water recovery. The pressures in the chambers plunge below a tenth of normal atmospheric pressure, which at sea level is 101.325 kilopascals, suctioning air and water out of the trash bag. Macleod describes the Collins system as using a relatively low temperature at first for drying, around 60 degrees Celsius. "What we're trying to do is get as much of that air and water out before we start really heating things up and getting contaminants — the nasty stuff from boiling and melting plastic, like nitrile gloves," Macleod says.



A toilet on the International Space Station. Collins Aerospace is building a new toilet that is scheduled to be installed this year.
NASA

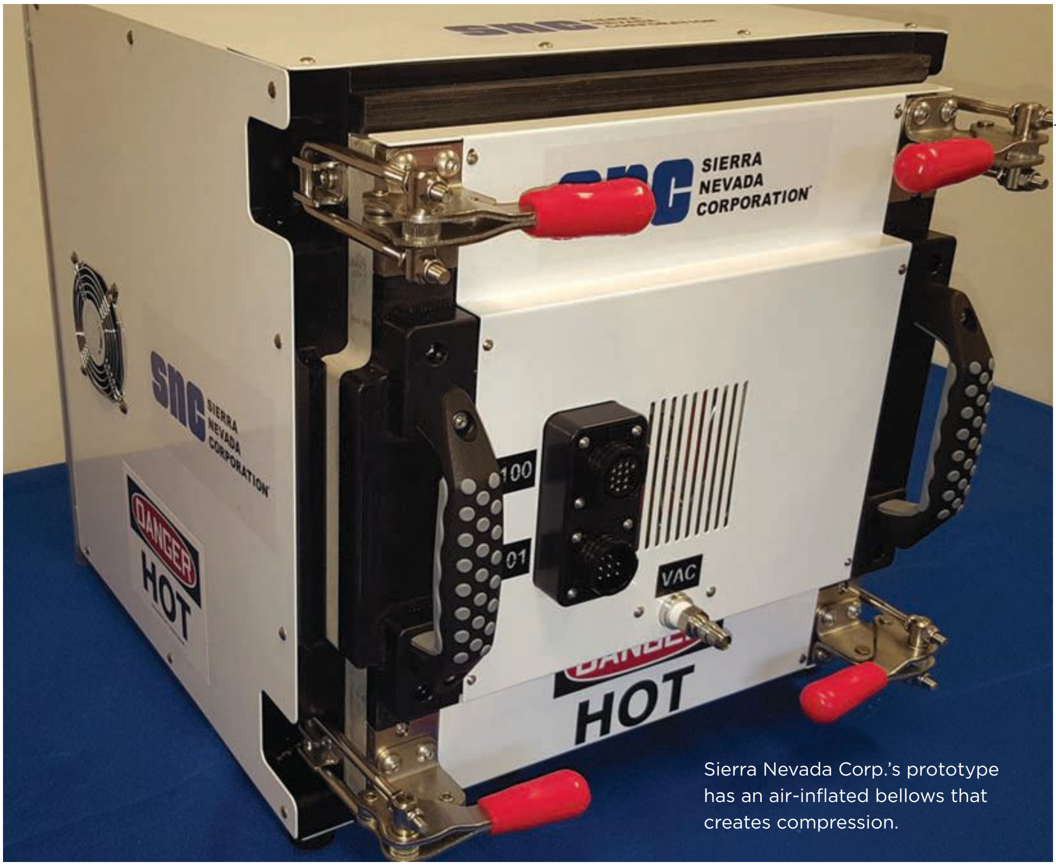
Dealing with nature's calls

The astronauts on the International Space Station should have a brand-new commode installed later this year. This next-gen space toilet, built by Collins Aerospace, is called the Universal Waste Management System, or UWMS. Like its predecessors already onboard, the UWMS relies on airflow to pull waste away from the astronaut — necessary, given the microgravity environment where everything wants to float.

A suction fan for feces and a vacuum tube for urine, specifically, lead into a centrifuge that separates solids, liquids and gases. The gases and captured airflow go through filters to remove odors and are returned to the cabin. A urine processing unit and water recovery system — on station since 2008 — can make potable again around 90 percent of the water when astronauts go number one. With regard to number two, the UWMS is slated to function like the current space toilets by containing feces in a sealed bag. The bag is manually compactable by astronauts to reduce volume for stowage.

This excrement could someday be subjected to heat melt compaction-style reduction, with possibilities for recovery. Feces, after all, is about 75 percent water, representing a significant opportunity. "Recovering water is a big step because it's probably the largest consumable that one would use on long-duration," says Uday Hegde, who studies aerospace waste management and water reclamation at Case Western Reserve University in Cleveland.

By mass, about a quarter of the generated waste by astronauts on the ISS is feces, urine and sweat solids. Ick-factor aside, turning this trash into treasure could be of tremendous value.



Sierra Nevada Corp.'s prototype has an air-inflated bellows that creates compression.

Sierra Nevada Corp.

▲ NASA astronaut Mike Fossum demonstrates in a video how to pack trash before it is loaded on a cargo spacecraft docked with ISS.

NASA

When air and water recovery is mostly completed, the temperature rises and compression kicks in. The SNC system reaches about 150 degrees Celsius. "The goal is to encapsulate trash and defeat microbes," says Wetzel.

The means of physical compression is a key difference between the companies' systems. In SNC's concept, an air-inflated bellows creates a compression pressure that pushes a piston-driven panel through the chamber to mash the trash against an interior wall. By contrast, Collins will move its piston and panel with a linear screw drive mechanism, a common type of electric actuator that appears in applications from DVD drives to aircraft doors. Both these approaches diverge from the NASA unit, which employed a scissors lift mechanism consisting of crisscrossing members that could extend or retract. You've probably seen scissors lifts at work here on Earth. They commonly elevate aerial work platforms for people to change signs and light bulbs, for instance.

Wetzel and Macleod agree that bellows and linear screw drives have fewer moving parts than a scissors lift, offering better potential reliability. "One of NASA's figures of merit, or hot buttons, is reliability," says Macleod. "On a long-duration mission, they can't afford for the compactor to break down, and the more moving parts you have, the more susceptible you are to reliability issues."

Also, in terms of reliability, a problem that has plagued early iterations of heat melt compaction systems is clogging of the vent ports. At this early stage of development, Collins is pursuing a modular design, moving components around to optimize performance and curtail clogging issues. "We've got vent ports all over the place on this thing and all sorts of different areas where we have heaters that we can turn on and off," Macleod says.

All told, trash compaction and processing cycles for the preliminary systems are slated to last approximately six hours, allowing astronauts to run a couple of loads per day. That cycle time might need to decrease to handle all the rubbish on moon and Mars missions.

Trash heap to trash reap

As for the critical recovery of vented gases, including water, this takes place in downstream components of the trash compaction and processing systems. Compared to the chambers, these systems are less fleshed out at this stage of the NASA solicitation.

SNC and Collins each have experience in environmental control and life support systems — dubbed ECLSS, "Ek-liss" — for aerospace. ECLSS includes breathable air, potable water, comfortable temperatures, appropriate atmospheric pressure, fire detection and suppression, and of course, waste management.

"On a long-duration mission, they can't afford for the compactor to break down, and the more moving parts you have, the more susceptible you are to reliability issues."

— **Shawn Macleod,** Collins Aerospace

SNC has worked with Collins previously on developing ECLSS for the Dream Chaser, a spaceplane intended to start ISS cargo runs in late 2020 and that might eventually ferry crew as well. Similar work is also ongoing for Boeing's CST-100 Starliner, which is slated to take astronauts to the ISS for the first time later this year.

Collins' ECLSS experience also extends to the ISS itself. Besides the new space toilet, the company has previously engineered oxygen-generating and water processing systems, the latter of which delivers 3 liters of potable water per day. Collins is reusing components from these well-developed systems, aeronautical and astronautical, for its trash compaction and processing. One example is a fan separator technology for aircraft toilets that sequesters liquids from gases. "We're going to refresh that design and reuse it for application here in our trash compactor system," says Macleod.

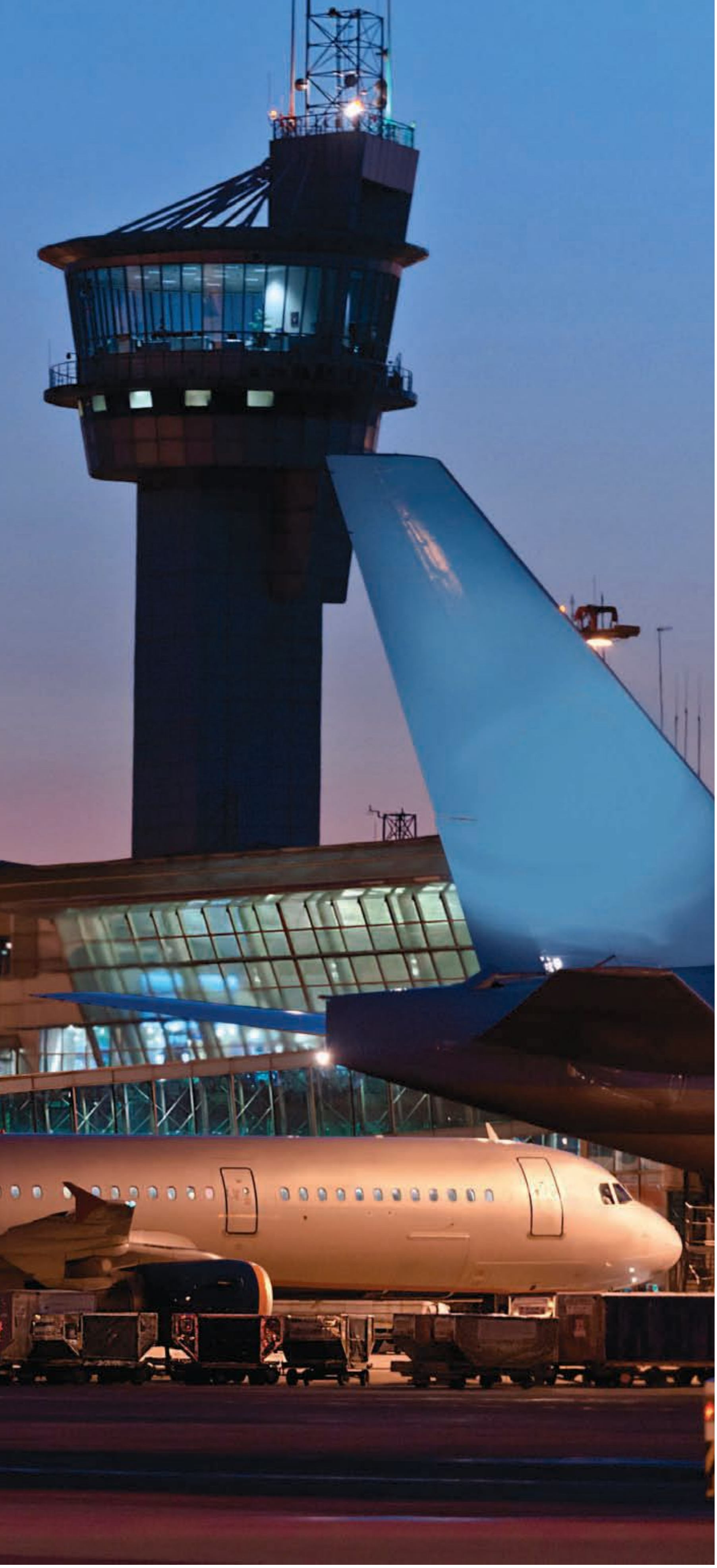
Many details remain to be worked out for SNC's and Collins' systems, and both engineering teams must for now limit themselves to ISS payload rack volume and power constraints — 500 watts in the case of the latter.

NASA hopes the fully realized systems these technology demonstrations lead to will put trash management conveniently into the background of mission activities, letting explorers worry more about exploring than taking out the trash. Indeed, with a bit of automation for storing the output tiles, the systems can be designed in a way that "would mimic what we do on Earth," says Case Western's Hegde, "where we set the trash out, and 'forget' it." ★

AIR **NAVIGATION** JITTERS

Those in the U.S. who have the job of protecting air travelers and assuring the security of military planes have deep concerns as the U.S. and Europe race toward their deadlines for aircraft to broadcast their GPS locations and identities. U.S. agencies are looking for backups and technologies to improve the navigation security of the FAA's NextGen air traffic initiative. Jan Tegler spoke to government and industry officials about the problem.

BY JAN TEGLER | wingsorb@aol.com



Imagine you're on a commercial airliner bound for Chicago's O'Hare International Airport. The flight is progressing well, with air traffic controllers tracking the plane not by radar but by a new technique in which the plane transmits its GPS coordinates and other data from an Automatic Dependent Surveillance-Broadcast Out radio.

Unbeknownst to anyone, a bad actor armed with a computer and maybe a commercially purchased ADS-B Out unit has injected false information into the ADS-B broadcast as the plane approaches O'Hare.

"It's called spoofing," says cybersecurity expert Bob Gourley, "and the threat is very real."

By design and international agreement, ADS-B signals are unencrypted and are available to anyone with the right kind of receiver. Trusting all of the world's air navigation services to manage encryption keys was viewed as too daunting a task. So, with thousands of planes now equipped for ADS-B Out, online services such as FlightAware.com are starting to provide free real-time, in-flight tracking of commercial and private aircraft. FlightAware even sells software so that individuals can build their own ADS-B ground stations.

Back to our hypothetical scenario. Having been easily spoofed, air traffic controllers tell the pilot in command to fly in a direction and altitude that could potentially put the aircraft on a collision course with other airplanes.

This scenario is among the nightmares that are hot on the minds of security experts as the aviation industry races toward the FAA's Jan. 1, 2020, deadline and the European Aviation Safety Agency's June 7, 2020, deadline for installing ADS-B Out. Spoofing is just one concern. Jamming is another. Even when ADS-B works fine, the Pentagon has balked at its aircraft routinely broadcasting ADS-B Out, because of the tactical knowledge a potential adversary could gain, even during peacetime.

The advantage of ADS-B Out over traditional radars for navigation is that, along with other digital improvements, it empowers controllers to safely pack the 5,000 aircraft in U.S. skies (at peak times) closer together on straighter routes. The air transportation industry could meet rising demands for air travel and minimize carbon emissions as the demand soars. The technology is at the heart of the FAA's $21 billion Next Generation Air Transportation System, called NextGen. Lately, though, the FAA has come to recognize that radar surveillance will be necessary as an ADS-B backup, and for the last year the agency has been in the midst of an in-depth examination of options.

Gourley, co-founder and chief technology officer of OODA LLC in Virginia, a cybersecurity and artificial intelligence consultancy, counts himself among those who worry about the security of ADS-B.

"I have seen proposals on ways to mitigate [vulnerability to spoofing], but I have not seen a government action plan that makes me confident that we're going to eliminate the threat," Gourley says.

Radars vs. ADS-B

Specifically, the FAA mandate calls for owners and operators of civilian, commercial and military aircraft flying in controlled airspace — the airspace near sizeable airports and cities — to install ADS-B equipment. ADS-B will soon be the linchpin for controllers, although radar surveillance would remain as a backup. For decades, American air traffic controllers have relied mainly on two kinds of radars. Primary radar antennas at FAA ground stations across the nation send out electromagnetic waves that reflect from the surfaces of aircraft at distances of up to 100 kilometers to determine their distance and azimuth, the term for direction of travel.

A second radar antenna attached to the top of the primary radar triggers the transponders on airliners to report their altitudes, identification codes and any emergency conditions.

Primary radars also contribute to national security, because they provide position information for "noncooperative" aircraft, meaning those without transponders or with their transponders turned off.

The radar system works well for air traffic control, but it is not as precise as GPS, and so controllers must keep a greater separation from aircraft than will be necessary once an ADS-B Out network is fully in place with each plane broadcasting every second.

Early on, there was supposed to be an even clearer cost benefit. Retiring a large number of ground radar stations would save money in addition to the air traffic management benefits of ADS-B. This thinking changed after the Sept. 11 terrorist attacks in New York and Washington, D.C. "The post-9/11 requirement to maintain primary active radar surveillance has decreased the primary benefit-to-cost ratio that was used to initially justify moving to ADS-B in the first place," says George Donohue, the former FAA associate administrator who was responsible for initiating the ADS-B system, by email. The rollout of ADS-B has nevertheless continued. A total of 68,743 aircraft in the U.S. were equipped with ADS-B as of Feb. 1, according to FAA data. This represents somewhere near 50 percent of the American aviation fleet that must be equipped by the 2020 deadline, based on my conversations with the Aircraft Owners and Pilots Association, the National Business Aviation Association, the General Aviation Manufacturers Association and Southwest Airlines.

Once an aircraft is equipped for ADS-B Out, it is required to be used on every flight, says Rune Duke, the senior director of government affairs at the Aircraft Owners and Pilots Association.

Pentagon remains wary

Military strategists in the U.S. don't like the idea of routinely broadcasting position, heading, ground speed and identity. They continue to talk with the FAA regarding when and how military aircraft must broadcast.

The Defense Department "has significant operational security concerns associated with the broadcast nature of ADS-B and other advanced transponder technologies," says Rowayne Schatz, the executive director of the Defense Department's

◀ **ADS-B air traffic is indicated** by white diamonds on the left side of this cockpit screen. A receiver picks up the signals and relays them to the G600 TXi display, which can be installed on single- and twin-engine general aviation aircraft.

Garmin

Policy Board on Federal Aviation. Potential adversaries could learn about U.S. tactics by monitoring nonwartime military flights, he says.

Schatz is the Pentagon's liaison with the Transportation Department and the FAA on federal aviation issues, including aviation cybersecurity. He notes that the Defense Department is also concerned about broader risks to the national airspace system due to the "fragility of the GPS signal" and the risk associated with "using GPS-only for an aircraft's position, altitude, heading and ground speed."

Schatz is among those who think navigation radars will be needed for the foreseeable future as a backup to ADS-B. The question is how to keep those radars technically and financially viable for years to come. A research effort called Spectrum Efficient National Surveillance Radar, or SENSR, may provide the answer starting in about 2025. The goal is "to be able to recapitalize our radar system and keep some ground-based secondary radar as a backup for satellite-based NextGen," Schatz says. Here's how it would work. The FAA, Defense Department, Department of Homeland Security and NOAA are researching the possibility of consolidating aircraft tracking and weather monitoring frequencies into a new part of the radio spectrum. This would free up bandwidth that could be auctioned to the private sector to pay for the SENSR radars that would operate in the consolidated spectrum. In as little as three to five years, Schatz says, SENSR could be in use alongside ADS-B.

Having SENSR as backup would provide reassurance to FAA and security experts, given all the warnings issued by reputable groups about the vulnerabilities of ADS-B and GPS. The list includes a January 2018 report by the congressional Gov-

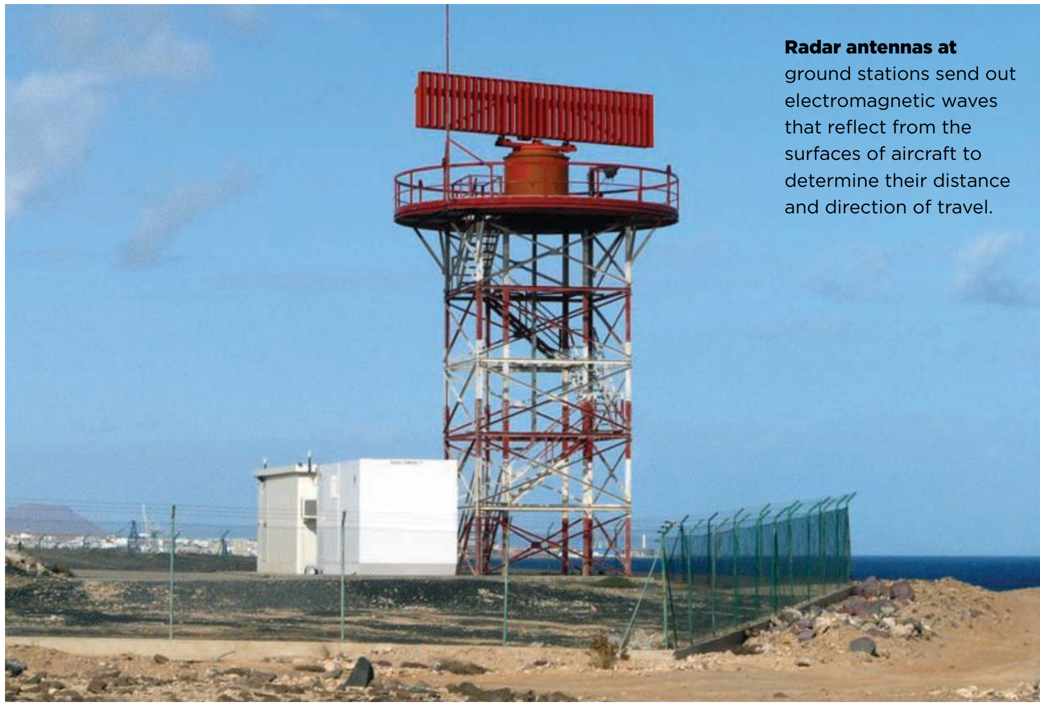
▲ **U.S. military air** traffic controllers work in the control tower at Holloman Air Force Base, N.M. Pentagon strategists are balking at routinely transmitting the GPS coordinates of U.S. military aircraft as part of the FAA's Next Generation Air Transportation System.
U.S. Air Force

ernment Accountability Office, a March 2018 report by the Radio Technical Commission for Aeronautics (a standards organization that works with the FAA), and a 2017 report from the Air Traffic Controllers Association.

Consider man-in-the-middle attacks in which the unencrypted packets of ADS-B information are forged by hackers as the information travels to and from ADS-B ground stations. That's the scenario depicted in our hypothetical flight to Chicago. Another threat would be distributed denial-of-service attacks in which multiple forged packets overwhelm ADS-B ground stations, potentially causing them to go off the air. Gourley says jamming and denial-of-service attacks are more sophisticated than spoofing and therefore harder to carry out, "but they are doable."

Last July, the FAA and the Pentagon signed an agreement committing each side to broader discussions of security and structural risks related to NextGen.

The FAA and Pentagon declined to provide a copy of the document, but Joe Kirschbaum, director, defense capabilities and management for the Government Accountability Office, says the congressional watchdog has reviewed earlier agreements between the FAA and the Defense Department



Radar antennas at ground stations send out electromagnetic waves that reflect from the surfaces of aircraft to determine their distance and direction of travel.

▲ **A formation of F-35As** flies over the Utah Test and Training Range during training. The U.S. Defense Department wants to exempt some military aircraft from the FAA requirement to routinely broadcast position and other details in Automatic Dependent Surveillance-Broadcast transmissions.

U.S. Air Force

pertaining to NextGen. According to Kirschbaum, "none ever talked about security."

Wake-up call for FAA

I reached out to the FAA's NextGen Office to discuss the potential security risks posed by ADS-B and other NextGen technologies, but the agency said, "We are not conducting any interviews nor will we be able to address your questions at this time."

Internally, however, the FAA has recognized the need for a radar backup to ADS-B, and its experts spent much of 2018 looking at the problem.

Schatz says the Pentagon and the FAA are "working very closely to identify a minimum operating network of radars, both primary and secondary, to ensure the surveillance infrastructure meets the mission requirements of all federal departments." He adds that "utilizing and maintaining cooperative and noncooperative surveillance technologies provides a robust and resilient infrastructure that is not overly dependent on any single component."

On cybersecurity, Donohue, the former FAA official, noted that when ADS-B was conceived, "it was before 9/11 and before our current concerns and understanding of the cyber threat. I now share the DoD concerns."

Finding security solutions

The Defense Department, Department of Homeland Security and FAA established an Aviation Cyber Initiative to address the security issues raised by NextGen and ADS-B. As Schatz puts it, the goal is to "reduce cybersecurity risks and improve cyber resilience" in the aviation sector. The agencies are examining potential vulnerabilities from "out-ticketing and reservations centers to aircraft with ADS-B signals and the ability to make sure an aircraft is not able to be tampered with from the ground through an ADS-B signal," he adds.

Tampering is far from the Pentagon's only concern. Schatz gave me an example of why the military strategists don't want to broadcast positions even in peacetime. "If you have F-35 fighters flying out to a local training range, we don't want someone to be able to pull up their website and get an ADS-B feed from those aircraft and be able to watch the tactics, techniques and procedures that they're employing on that training range," he says.

Schatz says the Pentagon is working through procedures with the FAA to allow those aircraft to take off from their home station, fly out to the range and then be able to turn off that equipment for that part of the mission. "There are others we will not equip [with ADS-B] because of the nature of their mission — we really don't want to broadcast where they are."

He explains that the two agencies have agreed to accommodate U.S. military national security missions by exempting military aircraft from the requirement to broadcast ADS-B depending on the nature of their mission.

"We are committed, where it makes operational sense, to make sure that our aircraft are broadcasting [ADS-B Out]," Schatz says. "A lot of our cargo-type aircraft, our air refueling tankers — they tend to operate more in the parts of the national airspace that are more congested with other traffic. We're committed and planning still to equip those aircraft ." ★

AIAA Bulletin

DIRECTORY

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

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

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

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

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

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

Calendar

FEATURED EVENT

AIAA AVIATION Forum

17–21 JUNE 2019

Dallas, Texas

Stay at the top of your field with AIAA's continuing education offerings. Three new courses covering UAS design, hypersonic flight, and eVTOL, along with new workshops on integrated propeller prediction and multifidelity modeling, are being offered at the 2019 AIAA AVIATION Forum. Take advantage of early member rates and register today.

aviation.aiaa.org/coursesworkshops

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2019			
2–9 Mar*	2019 IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
7 Mar	Practical Design Methods for Aircraft and Rotorcraft Flight Control for UAV Applications	Virtual (aiaa.org/onlinelearning)	
20 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (aiaa.org/CVD)	
25–27 Mar*	54th 3AF International Conference on Applied Aerodynamics	Paris, France (http://3af-aerodynamics2019.com)	
29–31 Mar	Region IV Student Conference (University of Texas at Austin Student Branch)	Austin, TX (aiaa.org/2019-Region-IV-Student-Conference)	
3–5 Apr*	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (www.eurognc19.polimi.it)	
29 Apr–3 May	2019 IAA Planetary Defense Conference	Washington, DC (pdc.iaaweb.org)	
4–5 Apr	Region II Student Conference (Florida Institute of Technology Student Branch)	Cocoa Beach, FL (aiaa.org/2019-Region-II-Student-Conference)	
4–5 Apr	Region V Student Conference (University of Minnesota Student Branch)	Minneapolis MN (aiaa.org/2019-Region-V-Student-Conference)	
5–6 Apr	Region I Student Conference (University of Maryland Student Branch)	College Park, MD (aiaa.org/2019-Region-I-Student-Conference)	
5–7 Apr	Region III Student Conference (Cleveland State University)	Cleveland, OH (aiaa.org/2019-Region-III-Student-Conference)	
6–7 Apr	Region VI Student Conference (California Polytechnic State University Student Branch)	San Luis Obispo, CA (aiaa.org/2019-Region-VI-Student-Conference)	

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

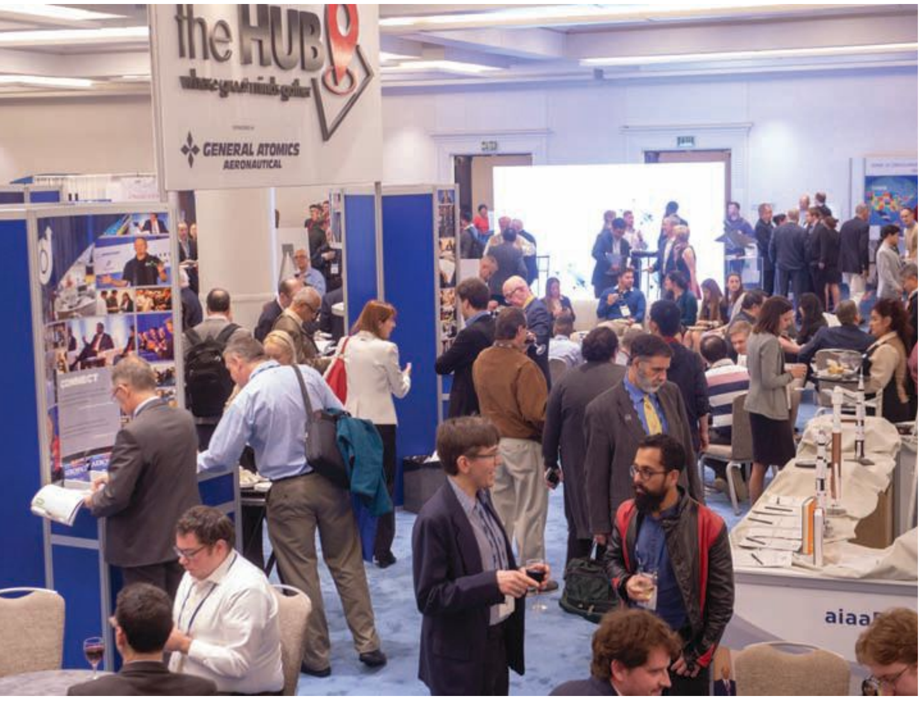
DATE	MEETING	LOCATION	ABSTRACT DEADLINE
7–9 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum)	Laurel, MD	20 Nov 18
10 May	75 Years of Hypersonics Development: History, Resources, References, and Insights	Laurel, MD	
14 May	AIAA Fellows Dinner	Crystal City, VA	
15 May	AIAA Aerospace Spotlight Awards Gala	Washington, DC	
20–23 May*	25th AIAA/CEAS Aeroacoustics Conference (Aeroacoustics 2019)	Delft, The Netherlands	15 Oct 18
27–29 May*	26th Saint Petersburg International Conference on Integrated Navigation Systems	St. Petersburg, Russia (elektropribor.spb.ru/icins2019/en)	
10–13 Jun*	18th International Forum on Aeroelasticity and Structural Dynamics	Savannah, GA (http://ifasd2019.utcdayton.com)	
12–14 Jun*	The Sixth International Conference on Tethers in Space (TiS2019)	Madrid Spain (http://eventos.uc3m.es/go/TiS2019)	
15–16 Jun	Practical Design Methods for Aircraft and Rotorcraft Flight Control for Manned and UAV Applications with Hands-On Training Using CONDUIT®	Dallas, TX	
15–16 Jun	Designing Unmanned Aircraft Systems	Dallas, TX	
15–16 Jun	Hypersonic Flight: Propulsion Requirements and Vehicle Design	Dallas, TX	
15–16 Jun	OpenFOAM Foundations: The Open Source CFD Toolbox	Dallas, TX	
16 Jun	Principles of Electric VTOL	Dallas, TX	
16 Jun	Workshop for Integrated Propeller Prediction (WIPP)	Dallas, TX	
16 Jun	Workshop for Multifidelity Modeling in Support of Design and Uncertainty Quantification	Dallas, TX	
17–21 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition)	Dallas, TX	7 Nov 18
11–15 Aug*	2019 AAS/AIAA Astrodynamics Specialist Conference	Portland, ME (space-flight.org)	5 Apr 19
19–22 Aug	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition)	Indianapolis, IN	31 Jan 19
22–24 Aug	AIAA/IEEE Electric Aircraft Technologies Symposium (EATS)	Indianapolis, IN	31 Jan 19
21–25 Oct*	70th International Astronautical Congress	Washington, DC	28 Feb 19
2020			
6–10 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition)	Orlando, FL	11 Jun 19
7–14 Mar*	2020 IEEE Aerospace Conference	Big Sky, MT (aeroconf.org)	
25–27 May*	27th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (elektropribor.spb.ru/en/conferences/142)	

● AIAA Continuing Education offerings

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

SCITECH FORUM

More than 4,500 attendees – representing 40 countries, all 50 U.S. states, and Washington, DC – gathered for 2019 AIAA SciTech Forum, making it the most attended AIAA forum ever. Experts from industry, government and academia, as well as over 1,400 undergraduate and graduate students, participated in the incredibly energetic and successful forum in San Diego, CA, 7–11 January. The forum featured more than 2,200 presentations covering groundbreaking aerospace technical and scientific research.




AIAA
SCITECH
Responsive Space


AIAA
SCITECH FORUM
NORTHROP GRUMMAN
BOEING
LOCKHEED MARTIN
LINDBERGH INNOVATION FORUM


AIAA
SCITECH FORUM
#aiaaSciTech
Disney Parks, Experiences and Consumer Products
AIAA


AIAA
SCITECH FORUM
#aiaaSciTech
Enabling the Replicator

MAKING AN IMPACT

AIAA Regional Student Paper Conferences

AIAA Regional Student Paper Conferences are the first time for many students to get professional feedback on their research and presentation style. It's a big first step on what, we hope, is a long career path that expands what we know about the world and beyond it.

The AIAA Foundation annually supports six Regional Student Paper Conferences held throughout the United States, plus one in Australia, and an International Student Conference. We encourage AIAA members to reach out to student branches.

The 2019 student conference schedule is: 29–31 March in Austin, TX, for Region IV; 4–5 April in Cocoa Beach, FL, for Region II; 4–5 April in Minneapolis, MN, for Region V; 5–7 April in Cleveland, OH, for Region III; 5–6 April 2019 in College Park, MD, for Region I; and 6–7 April in San Luis Obispo, CA, for Region VI. Region VII (Australia) will take place in November 2019.

For more information on donating and making a difference in students' lives, please visit aiaafoundation.org.

Photos from the 2017 and 2018 Region II Student Conference in Mobile, AL
Credit: G. Alan Lowrey

News

12th AIAA Pacific Northwest Annual Technical Symposium

By Agnes Blom-Schieber, 2018 Technical Symposium Co-Chair

The annual technical symposium organized by the AIAA Pacific Northwest (PNW) Section has been a popular event that local members start to look forward to as soon as the previous symposium is done. Every year we try to build on past year's successes, while expanding the program with new items to increase the variety and keep the symposium interesting year after year.

On 10 November, the 12th annual symposium took place at the Museum of Flight in Seattle and attracted about 170 attendees, a quarter of whom were high school and college students. The program included our traditional components such as plenary lectures, technical presentations, panel sessions, and speed mentoring, while we added a student poster session and resume writing workshop in the Rising Leader's session. Both the technical and the interactive sessions received very positive feedback from our participants. We received thank you notes from all our Raisbeck High School students with positive feedback that summarized the event. Below are a couple of quotes from their notes:

- "During the symposium I was introduced to some amazing people who inspire me to continue my path as a pilot. Without their words of wisdom, I may have lost confidence in myself."
- "I learned a lot about careers I would like to go into, as well [as] have gained a lot of helpful advice."
- "I learned a lot of new information as the talks were super interesting."
- "It's definitely an event I'm looking forward to next year."
- "I had a great time there and particularly enjoyed DARPA and Go Fly's presentations."

The symposium was opened by Dr. Jan Vandenbrande, Defense Sciences Office program manager at DARPA (Defense Advanced Research Projects Agency), who shared some of the groundbreaking research that is being performed with DARPA funding across the country. He discussed the Fundamental Design (FUN Design), Transformative Design (TRADES), and Tailorable Feedstock and Forming (TFF) projects, all aimed at revolutionizing design and manufacturing processes.

Next, the audience had a choice between three parallel sessions, two of which featured technical presentations on the Boeing Advanced Research Center, the importance of end user inputs for the ISS, induced drag of aircraft, smart materials, and design and simulation of the LEO CubeSat constellation. In addition, Lane Slagle, officer and active member of our PNW Section, got to talk about our STEM outreach program and encourage members to contribute to future activities. The Rising Leader's (RL) session was kicked off with a very interesting presentation on systems engineering fundamentals by Adam Wuerl, director of Advanced Concepts and Strategy at Blue Origin.

After a short coffee break the RL session continued with a student poster session with contributions from the following teams: Society for Advanced Rocket Propulsion, Autonomous Flight Systems Laboratory, Washington Superbike, North Seattle Community College Rocket Team, and the Advanced Composites team.

At the same time, on the main podium we had a panel session with representatives from three start-up companies: Echodyne, Space Enterpreneurs, and Synchronous. This was the second time the start-up panel was on the program, after a successful introduction at last year's symposium.

Dr. Bob Winn, a Fellow of both AIAA and the Royal Aeronautical Society, made a special guest appearance as our lunch keynote speaker. He educated the audience about novel techniques used in aircraft accident reconstruction, some of which include using videos shared on social media!

Other afternoon lectures encouraged people to develop near-VTOL personal flying devices capable of flying twenty miles while carrying a single person as part of the Go Fly

1

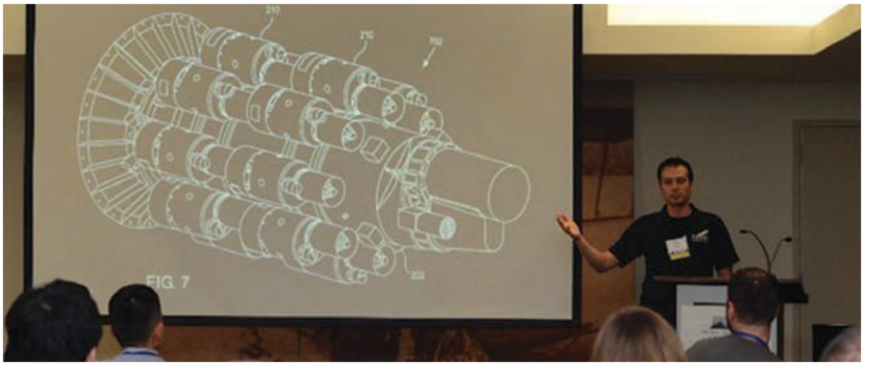
2

1 Management vs Technical Career Path

2 Student Poster Session

3 Rising Leaders keynote by Adam Wuerl

4 Morning Keynote by Dr. Vandenbrande



4

Prize, shared students' lessons learnt while building a carbon-fiber amateur rocket, and educated them on how to weld in space.

In the Rising Leader's session young professionals had a chance to interact with industry experts and ask them questions regarding their career choices, experiences, and anything else they were curious about. Then two wonderful volunteers led a resume-writing workshop for the first time ever at our symposium.

Two other highlights this year were the panel session on the "Management versus the Technical Career Path" and the closing keynote of the day by Brett Smith, CEO of Propeller Airports, who briefed the audience about the latest developments on introducing commercial flights at Paine Field.

Reflecting back on another successful symposium we are already starting preparations for next year's symposium on 16 November at the Lynnwood Convention Center.

Of course we couldn't have done this without a fantastic team of volunteers, as well as our sponsors: Ed Wells Partnership, The Boeing Company, Aerojet Rocketdyne Foundation, and Mr. John Somerville.

We are looking forward to next year and would like to invite anyone interested in presenting, sponsoring, or contributing in any other way to take a look at pnwaiaa.org/ts2019/ or contact the symposium chair at symposium@pnwaiaa.org.

Panelists included:

Dr. Bobby Braun, Dean of Engineering and Applied Sciences, University of Colorado Boulder

Mr. Mike French, Senior Vice President for Commercial Space, Bryce Space and Technology

Mr. Tom Irvine, Aerospace Consultant

Dr. Mark Lewis, Director, Science and Technology Policy Institute, Institute for Defense Analyses

Dr. Sandy Magnus, Former Executive Director, AIAA (moderator)

Aerospace 101

On 6 February, AIAA sponsored an educational briefing covering the importance of government investment in aerospace and its potential to effect the aerospace industry and the nation's economy. Approximately 90 congressional staffers from the House and Senate attended the briefing, which was hosted by the House Aerospace Caucus. No specific programs or priorities were promoted.

Society and Aerospace Technology Integration and Outreach Committee at AIAA SciTech Forum

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

The STEM to STEAM panel session was an absolute success. (Left to right) Mark Pestana (artist/research pilot), Sara Brown (educator lead), Cam Martin (moderator), Michelle Rouch (artist/engineer), Aldo Spadoni (artist/engineer), and Amir S. Gohardani (SAT IOC Chair).

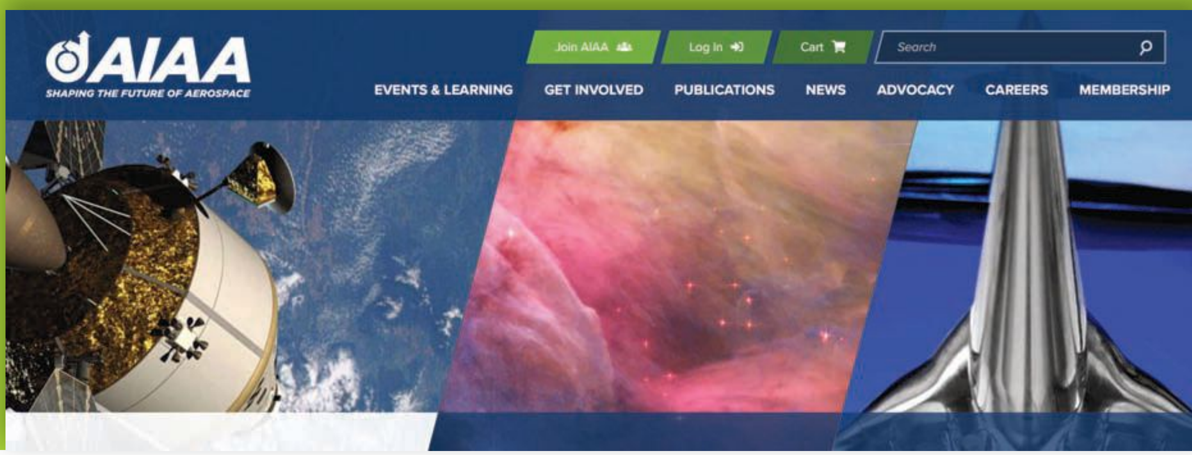
During the 2019 AIAA SciTech Forum, the Society and Aerospace Technology Integration and Outreach Committee (SAT IOC) was involved in a number of activities from chairing papers on reenergizing the U.S. space nuclear power generation to astrosociology and the search for technosignatures. SAT IOC also hosted an inspiring panel session called ***From Functional to Inspirational Aerospace Art: STEM to STEAM***. The goal of this session was to demonstrate how aerospace art is used to visualize advanced concepts, communicate technological advances, build cohesive teams, document historic events, and how it can impact the STEAM classroom.

This session was moderated by **Cam Martin**, who in his Robert McCall Tribute provided an interesting historical journey and set the stage for engineering as a visual art. The nonverbal thought in technology then transformed into visual problem solving through illustrated examples of Dick Whitcomb and the Area Rule. Additional historical milestones observed took the audience to the nonverbal transmission of mechanical knowledge and Leonardo DaVinci's sketchbooks before providing a visual inspiration by means of Walt Disney's "Man in Space" 1955 program with Wernher von Braun.

Following this opening, the panel continued to share their experiences. **Aldo Spadoni** shed light on how advanced concepts could be visualized by providing examples of his art in aerospace engineering and the entertainment industry. An overall objective of his talk revolved around providing engineers with a feel for a problem through visualization. Artist and research pilot **Mark Pestana** emphasized the role of the arts in documenting historical events and the power of the arts in team building that he consistently had observed through his patch and logo designs. **Sara Brown,** an aerospace STEAM education director, discussed the benefits of the arts in the classroom and illustrated how STEAM could take advantage of the ability to visualize and to communicate ideas. Conclusively, SAT IOC committee member **Michelle Rouch** showcased encouraging examples of continuing the quest to use visual arts with students and her success stories of supporting AIAA sections and larger communities with a variety of STEAM endeavors.

COMING IN MARCH:

THE NEW AIAA.ORG



AIAA Associate Fellow Addy Died in November

Alva LeRoy "Tad" Addy died on 16 November 2018 at the age of 82.

Professor Addy graduated with a degree in mechanical engineering from South Dakota School of Mines & Technology in 1958. While working for General Electric he earned a Master of Science degree from the University of Cincinnati in 1960. In 1963 he received a Ph.D. degree from the University of Illinois at Urbana-Champaign, where he then joined the faculty of the Department of Mechanical and Industrial Engineering.

From the earliest landmark publications of his research findings he held an international reputation in the fluid dynamics research community. The U.S. Army Research Office funded the research of Professor Addy and his colleagues at the University of Illinois at Urbana-Champaign continuously for more than three decades. His research was applied to many aircraft, missiles, and rockets including the Space Shuttle and the Concorde.

In addition to being a successful researcher, he was an award-winning teacher at Illinois. Professor Addy's enthusiasm for teaching and support of multidisciplinary student projects made him popular among undergraduates. In 1993, the University of Illinois College of Engineering students selected him as an Honorary Knight of St. Patrick. A Fellow of the American Society for Engineering Education, in 1990 he was honored with the society's Ralph Coates Roe Award for outstanding teaching and notable contributions to the engineering profession.

Professor Addy also served as department head for the Department of Mechanical and Industrial Engineering from 1987 to 1998, and during this time he had a profound impact on the department's direction. Guiding the quality of education provided, research conducted, and public service completed, he influenced the careers of thousands of engineers. During his tenure, the department was consistently ranked among the best in the nation. Further, he contributed to the field of engineering through work with professional societies. A Life Fellow of the American Society of Mechanical Engineers, in 2006 he was named an Honorary Member, which is that society's highest honor. In retirement he served for a number of years as a Trustee of the South Dakota School of Mines & Technology Foundation.

AIAA Fellow Hassan Died in January

Dr. Hassan Ahmad Hassan, 87, passed away on 12 January. Born in the village of Tamra in Palestine, Dr. Hassan spent the vast majority of his professional career as a Professor of Mechanical and Aerospace Engineering at North Carolina State University (NCSU) (July 1962–July 2018), making him the longest tenured professor in the history of NCSU.

He received his B.S. in Mathematics from the University of London in 1952 (via the University of Baghdad) and then attended the University of Illinois where he received his M.S. in Aeronautical Engineering in 1953 and his Ph.D. in Aeronautical Engineering in 1956. After completing his graduate studies, he held teaching positions at the University of Baghdad and Virginia Tech before joining NCSU as a full professor in 1962.

In 1964, NCSU's Bachelor of Science in Aerospace Engineering was created and Dr. Hassan led the aerospace faculty in developing a national reputation in aerospace research that is second to none. He was among a distinguished group of faculty who formed the program's CFD center and later the Mars Mission Research Center. In addition Dr.

Hassan spent every summer through the early 1990s working at NASA Langley Research Center with students alongside NASA researchers. He played a critical role in the development of NASA's in-house computational fluid dynamics codes with the focus on predicting transition and separation—features of aerodynamic flow that continue to challenge engineers today.

Dr. Hassan made many professional contributions in the field of aerospace engineering, including being the lead or co-investigator in over 32 research grants with the following agencies: NASA, the Department of Transportation, Sandia National Laboratories, Army Research Laboratory, Air Force Research Laboratories, and the National Institute for Aerospace. Over 100 former graduate students who studied under him during his long and exceptional career carry on his professional legacy. Among his many awards were the 1987 Alcoa Foundation Distinguished Engineering Research Award, the 1991 Alumni Distinguished Graduate Professor, the 1992 NASA Public Service Medal, the 1993 R. J. Reynolds Co. Award for Excellence in Teaching, Research, and Extension, the 1999 AIAA Thermophysics Award, and the 2004 Alexander Holladay Medal for Excellence—the highest honor bestowed on a faculty member by the NC State trustees. In 2015, the Dr. Hassan A. Hassan Distinguished Lecture Series was established through the generosity of Dr. Hassan's former students and fellow faculty members to honor his contributions to the department and his impact on the aerospace program.

After joining AIAA in 1956, Dr. Hassan was very involved with many AIAA technical committees, including the High Speed Air Breathing Propulsion, the Atmospheric and Space Environments, Fluid Dynamics, Propellants and Combustion, and Thermophysics technical committees. He received the 2007 AIAA Sustained Service Award for his longtime involvement.

Donations may be made to the Prof. Hassan A. Hassan Graduate Award in Aerospace Engineering via www.aiaafoundation.org (include Dr. Hassan Hassan in the "In memory" area) to help carry on his passion for educating the next aerospace professionals from North Carolina State University. North Carolina State University will hold a remembrance celebration of Dr. Hassan's contributions to the profession this spring at the university in Raleigh, NC. Check the Department of Mechanical and Aerospace Engineering website (www.mae.ncsu.edu) for details as they become available.

AIAA Associate Fellow Wolf Died in January

Jack D. Wolf, 84, died on 13 January.

Mr. Wolf graduated from the University of Wichita with a degree in Aeronautical Engineering in 1957 and received his Master's degree from the Air Force Institute of Technology in Dayton, OH. He was a Vietnam veteran and pilot in the Air Force. He received two Distinguished Flying Crosses for his acts of heroism. He retired from the Air Force after 21 years and worked as a Safety Manager at Boeing for 18 years.

1919

March 3 At the instigation of Eddie Hubbard, William E. Boeing opens regularly scheduled airmail service between Vancouver, British Columbia, and Seattle along Foreign Air Mail Route No. 2, a distance of 320 kilometers. The trip was authorized by the U.S. and Canadian post offices. It is Boeing's first foray into commercial air transportation. In 1927, he authorizes the creation of Boeing Air Transport, which becomes the central part of United Airlines. Bill Gunston, et al., **Chronicle of Aviation**, pp. 14-17.

March 17 Lt. Col. M.N. McLeod of Britain's Royal Engineers lectures to the Royal Geographical Society on the possibility of flying airplanes to make aerial maps of unexplored regions of the globe. **The Aeroplane**, March 19, 1919, p. 1142.

Imperial War Museum

March 24 A group from the Women's Royal Air Force is deployed outside the United Kingdom for the first time, arriving in France. Later, a group is sent to Germany. The force will operate between 1918 and 1920, with 30,000 women joining. **Royal Air Force Museum.**

1944

March 6 Long-range penetration troops, members of U.S. special forces, are dropped by gliders onto Japanese lines of communication in central Burma on a strip designated Broadway, but another planned drop site is abandoned because the Japanese block it with fallen trees. Thirty gliders reach Broadway, conveying 539 men, three mules and 30,000 kilograms of supplies, including bulldozers and lighting apparatus. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 286.

March 6 The U.S. Army Air Forces makes its first major bomb attack on Berlin and nearby cities, including Potsdam. Sixty-nine bombers and 11 escort fighters are lost. This is the start of a massive bombardment campaign to destroy the heart of German war production and draw the Luftwaffe up to fight and be destroyed in support of the forthcoming planned invasion of Europe in June. K.C. Carter and R. Mueller, **The Army Air Forces in World War II**, p. 237.

March 9 Capt. A. Roy Brown, famous for allegedly shooting down German ace Baron von Richthofen in April 1918, dies on his farm near Toronto. As a pilot flying Sopwith Camels for the Royal Air Force, Brown was credited with 10 victories, and as a flight commander, he never lost a pilot. After the war, researchers confirmed that Richthofen actually had been killed by Australian anti-aircraft fire as the Red Baron flew low over British lines. **Flight**, March 16, 1944, p. 276.

March 10 The world's largest flying boat, the Blohm and Voss BV 238 prototype, makes its first flight. The massive vehicle is powered by six 1,750-horsepower Daimler Benz DB 603 inverted V-12 engines that give this 91,000-kilogram behemoth a top speed of 425 kph and a range of 6,600 kilometers. It is intended for long-range reconnaissance and bombardment. Only one is built as there is no need for such a large flying boat given that Germany is losing the war and must concentrate on building defensive fighters. William Green, **Warplanes of the Third Reich**, p. 157.

March 11 The Glendale Rocket Society flies its first civilian-developed composite solid-propellant rocket. **Astronautics**, June 1944.

March 16 During a seminar at the Langley Memorial Aeronautical Laboratory in Virginia, the National Advisory Committee for Aeronautics, NASA's predecessor, proposes that a jet-propelled transonic research plane be developed. The idea eventually leads to the rocket-powered X-1 research aircraft, which will break the sound barrier in 1947. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 47.

March 25 The de Havilland Sea Mosquito becomes the first British twin-engine aircraft to land on the deck of an aircraft carrier, Britain's HMS Indefatigable. The all-wood Sea Mosquito is a torpedo bomber modified with folding wings and arresting gear. It also has four-bladed propellers and is armed with four 20-millimeter cannons, two 500-pound (227 kilogram) bombs and up to eight 60-pound (27-kg) air-to-surface rockets in addition to its torpedo. A.J. Jackson, **De Havilland Aircraft Since 1909**, p. 250.

March 25 The U.S. Air Force makes its first combat use of the VB-1 Azon, a guided missile comprising a conventional 1,000-pound (453-kilogram) bomb fitted with radio-controlled tail rudders. Each has a flare to aid the bombardier in steering the bomb to its target. In the China-Burma-India theater, the VB-1s, for Vertical Bomb, carried by Consolidated B-24 Liberator bombers destroy 14 bridges in seven missions, demonstrating the potential for what today are called "smart" bombs. **National Museum of the U.S. Air Force.**

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1969

March 2 André Turcat, Sud-Aviation's chief test pilot, flies the Anglo-French supersonic Concorde 01 prototype airliner in a 28-minute first flight from Toulouse-Blagnac Airport, France. Turcat says the aircraft "behaved perfectly" in a 90-degree sweep around the area. The Concorde is designed to fly 2,253 kph at an altitude of 12,000 feet. **Washington Post**, March 3, 1969, p. A3; **Aviation Week**, March 10, 1969, pp. 283-285.

March 3 NASA's Apollo 9 mission, the first flight with the Apollo lunar module, launches from Kennedy Space Center in Florida on a Saturn 5. Onboard are astronauts James McDivitt (commander), David Scott (command module pilot) and Russell Schweickart (lunar module pilot). The primary objectives of this low Earth orbital mission include command service module-lunar module separation, rendezvous and docking; extravehicular activity; and crew performance. Multispectral photography equipment is also carried for the first time to provide photos of Earth with several film-filter combinations. On March 13, after its 152nd orbit, the command module re-enters Earth's atmosphere, splashes down in the Atlantic and is recovered by the U.S. Navy's USS Guadalcanal. **NASA Press Releases** 69-29, 69-33; **Aviation Week**, March 17, 1969, pp. 18-22.

March 13 The Soviet newspaper Krasnaya Zvezda (Red Star) claims the world heavy-lift helicopter record for the Soviet Union, citing a 30,965-kilogram payload carried to an altitude of 9,682 feet by a V-12 helicopter. NASA, **Astronautics and Aeronautics, 1969**, p. 79.

March 15 For the first time, the U.S. Air Force Thunderbirds flight exhibition team flies McDonnell Douglas F-4 jet fighters to replace their North American Rockwell F-100 fighters. The transition is made at George Air Force Base, California. The Air Force is following the lead of the Navy Blue Angels in transitioning to the F-4. **Aviation Week**, March 24, 1969, p. 13.

March 16 Some 2,000 Americans make reservations with Pan American World Airways for the first commercial trips to the moon. Although not tied to any planned spacecraft, this is part of Pan Am's "First Moon Flights Club" in response to the early public enthusiasm for space travel and was especially stimulated by the success of the Apollo 8 mission in 1968. The club began soon after, and between that year and 1971, Pan Am issues 93,000 "First Moon Flights Club" cards at no cost. The cards become collectors' items. NASA, **Astronautics and Aeronautics, 1969**, p. 81.

March 20 The Dassault Mirage F1 second prototype makes its first flight at the Istres flight test center in southern France. The aircraft reaches a top speed of Mach 1.15 during the 50-minute flight. The French Air Force has ordered 100 F1s. Subsequently, the F1 sees action in a large number of armed conflicts and is also exported to about a dozen nations. **Aviation Week**, March 24, 1969, p. 28, and April 14, 1969, p. 31.

March 20 The initial NERVA, for Nuclear Engine for Rocket Vehicle Application, experimental nuclear rocket engine XE undergoes its first firings at the Nuclear Rocket Development Station at Jackass Flats, Nevada. Three runs are made under the partial simulation of a space flight environment, with each run averaging less than a minute and attaining top power outputs of 200 megawatts. **Aviation Week**, March 31, 1969, pp. 20-21.

March 27 The Mariner 7 space probe is launched by an Atlas-Centaur from Cape Kennedy, Florida, toward Mars, closely following the launch of Mariner 6 on Feb. 25 and therefore marking the first time the United States has two spacecraft flying simultaneously to a planet, as the first dual mission to Mars. Mariner 7, which is identical to Mariner 6, is programmed to swing by the planet's south pole, to look at the polar "ice" cap that seems to have seasonal changes. Both probes later sample Mars' atmosphere and surface with remote sensors, and record and relay hundreds of pictures. **Flight International**, April 10, 1969, p. 607.

1994

March 10 A Delta 2 rocket carries into orbit the 24th in a series of 24 GPS satellites for providing global radio positioning and navigation aids. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 713.

March 13 The initial Taurus small launch vehicle is fired for the first time and orbits the 180-kilogram ARPAsat. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 713-714.

SIERRA GONZALES, 24

Mission operations systems engineer for OSIRIS-REx

Sierra Gonzales had so many interests and extracurricular activities while growing up in Nevada that she struggled to choose a career path. Once she settled on aerospace engineering, she quickly recognized her passion lay in deep space exploration. Gonzales now creates sequences of commands, monitors telemetry and troubleshoots issues for NASA's OSIRIS-REx, a probe that will attempt to retrieve a sample of a near-Earth asteroid in mid-2020 and bring it to Earth for analysis. OSIRIS-REx entered orbit about 1.75 kilometers from the asteroid Bennu on Dec. 31. Gonzales compares her role as a systems engineer to that of an orchestra conductor: "The conductor brings all the instruments together to make the music."

How did you become an aerospace engineer?

Growing up, I had many opportunities to try different things and explore the world, thanks to my grandparents, who exposed me to a variety of art, sports, the planetarium and homemade challenges like building dog houses, designing lamps and sewing my own costumes. In high school, my many interests made it difficult to choose just one thing to do for the rest of my life. I knew that I wanted to pair my interests in math, science, taking things apart and putting them back together, and the "final frontier" with my creative side. I learned that engineering could encompass all of those things.

I earned a bachelor's degree in mechanical engineering at the University of Nevada, Reno. I worked in the DeLaMare Science and Engineering Library, working with 3D printers, 3D scanners, laser cutters and other maker equipment to help patrons build wild creations, products and experiments. During an internship at Lockheed Martin Space within the Commercial Space line of business, I learned about the space industry and the importance of networking. However, I knew I wanted to work in deep space exploration to support science that helps us move forward as a species. To get there, I earned an accelerated master's degree with a focus in autonomous controls. It was one of the toughest things I have done, but it helped me work on my weaknesses and exposed me to a different side of engineering: coding and controls. I fell in love with this challenge. Upon graduation, I went to work in Lockheed Martin's Deep Space Exploration market segment as a systems engineer, a career that challenges me every day and allows me to do all the things I love. I build command products that support the mission's science operations by pointing the spacecraft where the scientists want to study and commanding the payloads to gather science data. In addition, I monitor spacecraft telemetry to make sure the spacecraft operates nominally and troubleshoot any issues if they arise.

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

There is so much left to learn of our universe, let alone our solar system. With the answers we gather from the OSIRIS-REx mission, even more questions arise. In 2050, I see several more deep space exploration missions to a variety of other asteroids and moons of other planets, in addition to newfound research of human stability in space environments for long-term missions. I also see commercialization of space travel so others can share in the fascination of the final frontier.

BY DEBRA WERNER | werner.debra@gmail.com