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The Pentagon has established an agency to roll out tech ahead of China and Russia. Is it genius or just bureaucracy? PAGE 22

AIAA
SHAPING THE FUTURE OF AEROSPACE

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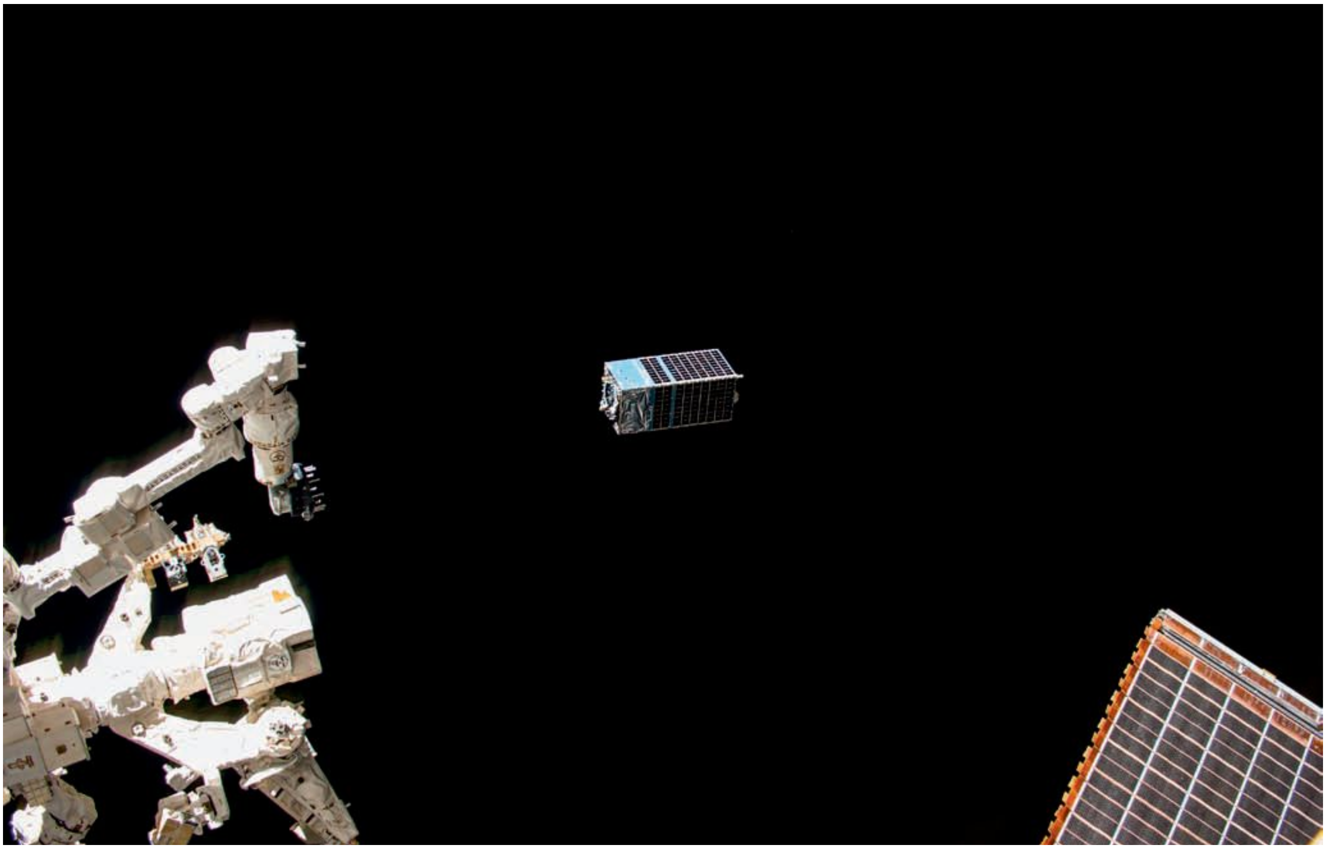

The U.S. Army's Kestrel Eye prototype cubesat after being released from the International Space Station. NASA

AEROSPACE AMERICA

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AIAA SHAPING THE FUTURE OF AEROSPACE

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PAGE 40

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Debra Werner

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

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DEPARTMENTS

Leading in aerospace

▲ Boeing 737 MAX.
Boeing

In a tumultuous world, the U.S. has led the way in applying aerospace technologies toward defining and meeting some of humanity's greatest challenges.

The U.S. created the International Space Station program in the 1990s, setting a template for how deep space might be explored by sharing costs and responsibilities. In 1960, President Dwight D. Eisenhower proposed extending the principles of the Antarctic Treaty to space, the core principle being peaceful exploitation. In 1988, NASA scientist James Hansen sounded the alarm over climate change in congressional testimony that's still debated today. In 1997, the FAA created the Commercial Aviation Safety Team to get proactive about air safety, instead of making changes only after accidents.

I sense this aerospace leadership beginning to slip away.

Instead of leading humanity into space through a mix of international collaboration, diplomacy and military preparedness, the U.S. is focusing mainly on the military part of the peace equation by creating a Space Force and Space Development Agency. These are reactive steps to China's smashing of an old satellite and sending a missile toward the geosynchronous belt and to Russia's shadowing of U.S. commercial satellites. Considered in purely military terms, the U.S. reactions are warranted. But those reactions should not be confused with the international leadership and whole-of-government approach that will be required to create a peaceful, stable economy in space.

On the environment, President Donald Trump "has now signed into law the highest Earth science budget of the history of the United States of America every year he has been the president," NASA Administrator Jim Bridenstine said last month. The problem is, no matter what those space instruments might say about climate change, the U.S. has said it won't aggressively reduce its carbon emissions until China and India do. China "can do whatever they want for 13 years. Not us," Trump complained about the Paris climate accord in 2017. "India makes its participation contingent on receiving billions and billions and billions of dollars in foreign aid."

And of course there was the crash last month of Ethiopian Airlines Flight 302 on the heels of the similar Lion Air crash in October. The U.S. finally followed the lead of the rest of the world by grounding the Boeing 737 MAX aircraft in its airspace. None of us know yet what investigators will conclude about the circumstances of these accidents and the suspected role of the Maneuvering Characteristics Augmentation System software. But a safety pause should have been an easy call, given the apparent similarities and the fact that Boeing was already working on an MCAS enhancement following the Lion Air accident. Notably, air transportation in the U.S. did not come to a halt with 74 planes grounded out of at least 7,000 in the U.S. commercial airliner fleet.

Of course, what I've described here is not the end of the story. They are just a few slices of history. I believe the U.S. can grow in each of these areas and resume a leadership role. ★

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

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Building upon a successful event in 2018, the 2019 Electric Aircraft Technologies Symposium will look at progress over the past year and continue the discussion about the aerospace industry goals for future aircraft. To accommodate rapid growth in emerging markets and ensure sustainability of air travel, one approach being explored is using nontraditional aircraft propulsion: electric, turboelectric, or hybrid-electric powertrains. AIAA and IEEE crafted this unique symposium to bring the aerospace engineers and the electrical engineers together to discuss these topics and their challenges.

The 2019 symposium will focus on electric aircraft technology across three general areas: electric-power-enabled aircraft configurations and systems requirements, enabling technologies for electric aircraft propulsion, and electric aircraft system integration and controls.

TOPIC AREA 1

Aircraft Configurations and Systems Requirements

- System feasibility studies
- Electric-enabled innovative aircraft design and propulsion concepts
- Electrical powertrain performance requirements
- Safety, critical failure modes, certification
- Lifecycle energy, operational cost, and emission analysis

TOPIC AREA 2

Enabling Technologies and Components

- Machines and drives integration for optimum performance
- Conventional, cryogenic, and superconducting
- Energy storage devices and systems
- Electric machine and gas turbine integration
- New material solutions or applications
- Novel thermal management solutions

TOPIC AREA 3

System Integration and Controls

- Electric powertrain architectures
- Fault isolation and reconfigurable systems
- Energy management systems
- Integrated electro-thermal systems
- System modeling tools
- Monitoring and diagnostics
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FLIGHT PATH

Embracing the Future

Recent experience with the International Space Station partners, the European Service Module for Orion, and global aspects of the Boeing 787 Dreamliner illustrate that the trend lines of aerospace tilt toward international cooperation. What does the aerospace profession need to be successful in the future as global interaction intensifies and challenges become increasingly complex? Air travel is reaching new parts of the globe with increased speed and humans are going further into space—for longer duration missions—with moon settlements and eventually to Mars. We must develop and implement the tools, policies, and approaches that enable everyone to participate. Only with diverse perspectives at the table will we, the aerospace community, succeed and thrive.

Over time, it has been proven that a variety of perspectives, backgrounds, and experiences applied to complex problems offers improved technical and more socially forward-thinking solutions. Groups such as Engineers Without Borders working in developing countries have found similar results. We know that if product operators are brought into the initial planning, design, and development, products improve. Automakers are focused on the user experience. It shapes their software and ergonomic design—down to the cup holders and interaction with the vehicle's electronic systems. Our phones and communication devices are all designed and developed by a team of engineers, psychologists, artists, and other skilled professionals. The Boeing 787 took full advantage of technology advances in composite structures to improve the passenger experience with higher in-cabin pressure levels and improved lighting. Boeing used psychologists along with the engineers to create an "airplane for the people." This is all done to make the product appeal to a broader market—and it often leads to lower costs and increased efficiency as well.

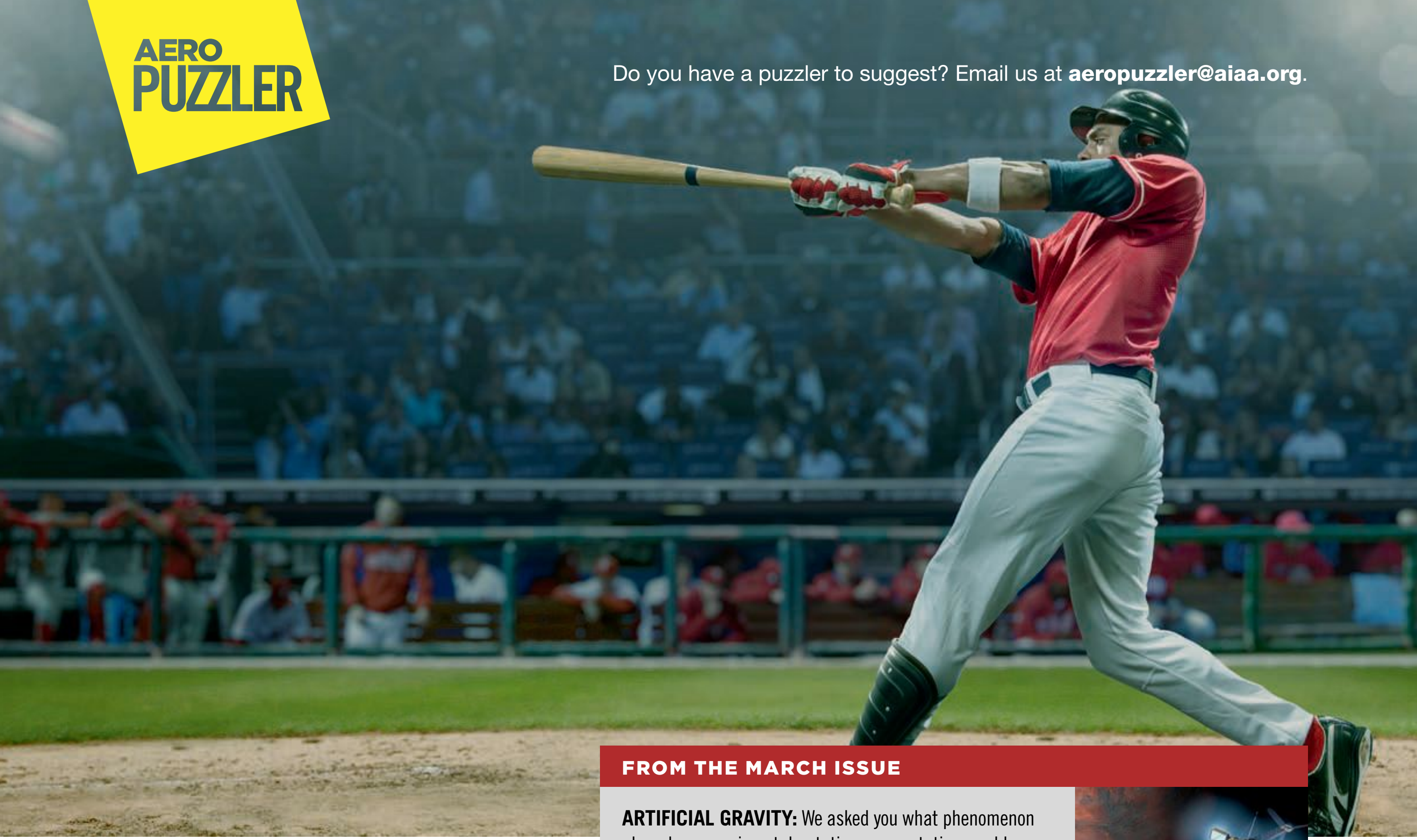
To embrace the future, the engineering workforce must also become more cognizant of the anticipated demographics of the U.S. population. Using U.S. Census data from 2017, the National Action Council on Minorities in Engineering has reported that by 2050 the general U.S. population will be over 51 percent non-white. This same report states that presently less than 34 percent of engineering degrees are awarded to non-white students.

With our local sections, regions, and student branches, AIAA is in a unique position to champion increased diversity and inclusion and make the case for why it is so important. We can partner with schools and education professionals to develop and implement STEAM activities at the local level. Our members can proactively visit local elementary, middle, and high schools. AIAA members can engage with schools in underserved communities and establish mentoring programs to assist minorities through the middle school STEM gap and increase their long-term interest and passion in these areas. We need to show underserved and underrepresented students that they are needed in aeronautics and astronautics. We must help them see themselves in these careers! We can unite with the National Society of Black Engineers, Society of Women Engineers, National Society of Hispanic Engineers, Women in Aerospace, and many other worthwhile organizations to convince the next generation that everyone has a place in aerospace.

We need to show underserved and underrepresented students that they are needed in aeronautics and astronautics. We must help them see themselves in these careers!

Our mission is simple: "AIAA exists to help aerospace professionals and their organizations succeed," but achieving it will take all of us working together. I ask each AIAA section, student branch, and member to join with all of AIAA leadership in being intentional in our actions and to include those who are not typically considered. With these purposeful and deliberate actions we can become more welcoming to a broader community, develop and expand our community, strengthen our existing community, and enhance the industry's ability to address complex challenges. All this will help us deliver exceptional results in our industry with the products and programs we design, build, test, and fly. Let's keep "Shaping the Future of Aerospace" and building the needed broader community. ★

Dan Dumbacher, AIAA Executive Director



AERO PUZZLER

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

And it's outta here!

Q. As an aging slugger, you want to go out with a bang in 2019 with an impressive ratio of home runs to at-bats. You must choose your playing time wisely. Would you rather bat on a 59-degree night in Phoenix in April (with the roof open) or a 97-degree day in Atlanta in June?

FROM THE MARCH ISSUE

ARTIFICIAL GRAVITY: We asked you what phenomenon aboard an experimental, rotating space station would cause astronauts to feel nauseated as they work but normal when they sleep.

Your responses were reviewed by astrophysicist Erin Macdonald, a science fiction consultant and host of "Dr. Erin Explains the Universe" on YouTube, and former astronaut Dr. Michael Barratt, who works for NASA on medical issues related to new spacecraft and human spaceflight. They agreed this was the best answer:

WINNING RESPONSE: The engineers didn't consider the differences between real gravity, which is consistent and homogeneous, versus simulated gravity, which is generated by the centrifugal force of the rotating space station. The issue is that the station's rotation causes not only a centrifugal force, but also causes other more subtle forces.

The bad news is the engineers didn't consider these additional forces, particularly the Coriolis effect, which would be most troublesome for our sickly space trekkers. The Coriolis effect would have the inner ear fluids of our brave test astronauts spinning with little vortexes, which would make even seasoned test pilots queasy. There also would be a subtle difference in the "direction" our intrepid crew feels the force of the simulated gravity, depending if they are walking "with" or "against" the direction of the station's rotation. Even the differences in the amount of simulated gravity felt at their feet, versus the lower gravity felt at their heads (which would be 2 meters closer to the center of rotation) would be an unnatural and disorienting sensation. However, the Coriolis effect would be the primary problem.

The good news is all these sensations would dissipate when they lie down at night.

How can our engineers rectify this in Space Station Version 2.0? By designing the station with a large enough radius from the central point to the habitation ring, and a carefully calculated rotational speed, and arriving at the ideal ratio for a comfortable compromise of radius, angular habitat ring velocity and simulated G-force.

Todd Chamberlain; Prince Albert, Saskatchewan; todd@asktoddanything.com

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

Simulating a water bomber

BY DEBRA WERNER | werner.debra@gmail.com

The pilot and co-pilot of a Canadair CL-415 water bomber must skim the surface of a lake to scoop up as much as 6,100 liters of water in 12 hull compartments. Then, buffeted by turbulence and updrafts, they dip low over wildfires to douse flames.

Simulating such maneuvers has been a daunting mechanical and software challenge, and that's one reason pilots-in-training have never had a full-flight simulator for the CL-415 or any aerial firefighter. That changed in March, when trainees in Italy climbed into a full-flight simulator built specifically for the CL-415.

Such a Class D simulator sways in all directions on electro-pneumatic actuators as it replicates the motion, sound and vibration of the flight.

Engineers from TRU Simulation + Training, an 800-person Textron company, spent two years strengthening parts, making the sound louder and customizing software as they built the CL-415 simulator in Montreal.

"Even the vibrations you feel when moving the flaps has to be exactly like the aircraft," says Thomas Allen, vice president of technology and innovation for TRU Simulation + Training.

Luckily, Textron engineers did not have to start from zero. They had previously worked with the engineers at Viking Air of Victoria, British Columbia, to develop the first full-flight simulator for a different plane, the DHC Twin Otter Series 400 built by Viking. Though not a firefighter, a Twin Otter can be equipped with floats for taking off from and landing on water.

TRU adapted the wave software it had created for the Twin Otter to the CL-415 to emulate surface waves and the waves that show in the pilot's field of view as the aircraft plows across the surface.

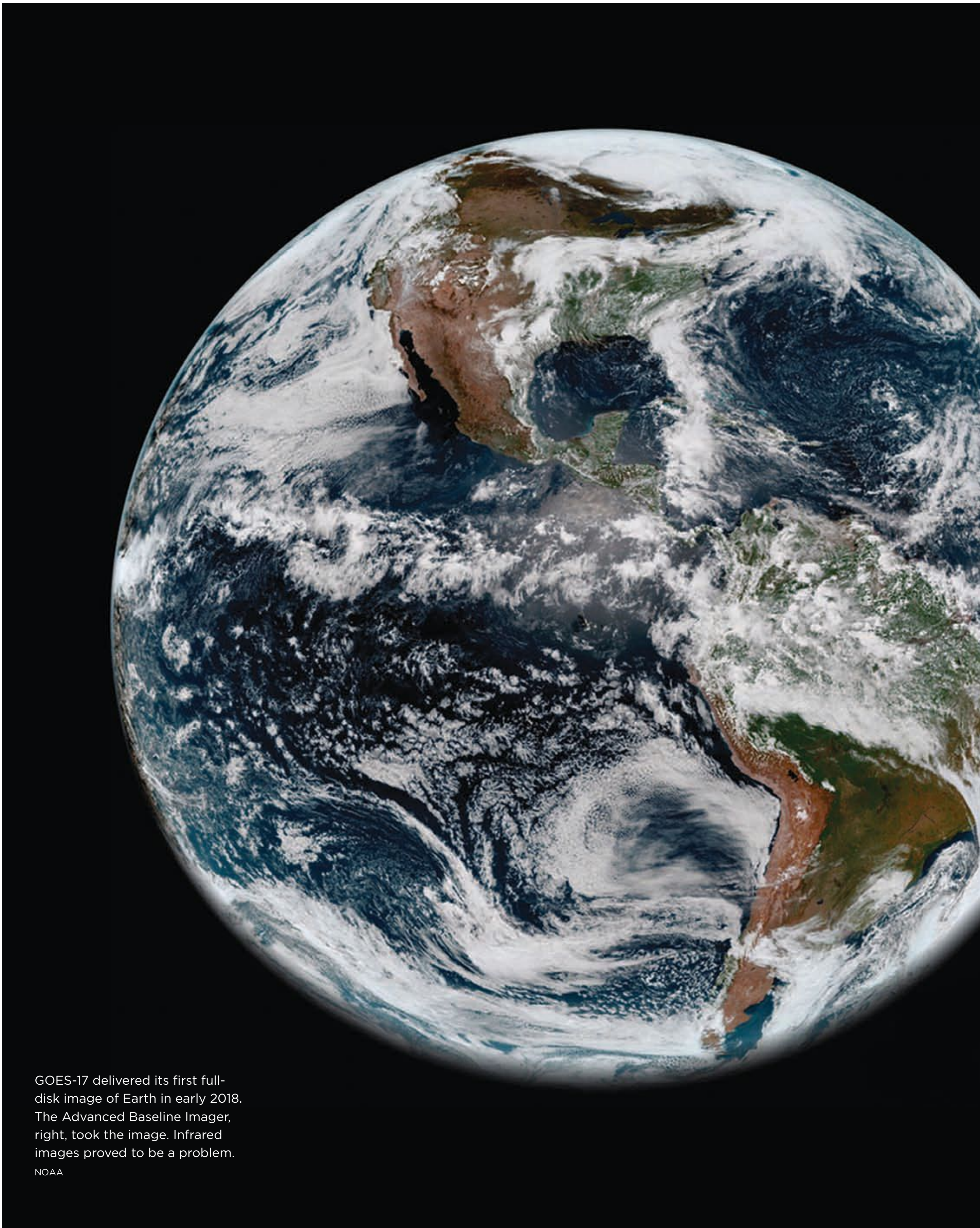
There were entirely new challenges, too. Pilots had to feel what it's like to slam into the water at 100 knots to scoop up water. Also, since the CL-415s were no longer in production, cockpit components had to be re-created.

TRU brought in water bomber pilots to help validate modeling and simulation of the firefighting mission. To attain Level D qualification from the European Union Safety Agency, TRU also filled a CL-415 with sensors and compared the data collected during a practice flight with the simulation.

"We've simulated updrafts and wind shear before, but when you're flying over a very intense fire, those are quite extreme," Allen says. "Our environmental modeling and simulation actually had to be increased quite a bit." ★

▼ **A CL-415 water-bomber simulator** captures the sound, sights and movement a pilot experiences while fighting wildfires in the aircraft.

TRU Simulation + Training



GOES-17 delivered its first full-disk image of Earth in early 2018. The Advanced Baseline Imager, right, took the image. Infrared images proved to be a problem.
NOAA

Saving GOES-17

Cooling pipes were not working inside the camera aboard NOAA's geosynchronous GOES-17 weather satellite, degrading the performance of its crucial infrared channels. It sounded like game over, but not to NOAA and Harris Corp., the company that built the camera. John Van Naarden of Harris and Dan Lindsey of NOAA explain how engineers learned to operate GOES-17 and its camera without those critical cooling pipes.

BY JOHN VAN NAARDEN | john.vannaarden@harris.com
AND DAN LINDSEY | dan.lindsey@noaa.gov

Two months after NOAA launched its newest geostationary weather satellite last year, the NOAA operations team encountered a significant issue with the thermal system of its primary payload, the Advanced Baseline Imager that Harris built at its factory in Indiana. The problem discovered during post-launch testing was serious enough that it threatened to end the GOES-17 mission before it even started. For part of the day and in key channels, the ABI could not gather the infrared images that help tell weather models and forecasters when severe weather is brewing. Nearly 10 months and many sleepless nights later, we are proud to note that on Feb. 12, NOAA declared GOES-17 operational to take over the GOES-West slot over the equator. Looking back, this period was one of the more difficult and stressful times of our careers, but also one of the most rewarding.

Our journey to improve GOES-17's ABI performance was successful. Despite a thermal system operating at only about 5 percent of its capacity, we expect ABI to provide 97 percent of its intended data, far better than initial estimates when we discovered the problem a year ago. Our success would not have been possible without the inherent flexibility in the modern designs of both the ABI and the spacecraft — and a path to optimization that required real-time learning from nearly 36,000 kilometers away.

We had the added pressure of following in the footsteps of GOES-17's sister satellite, GOES-16. With GOES-16 already occupying the GOES-East slot, GOES-17 would complete a two-decade journey toward modernization of NOAA's operational fleet. With the ABI designs already launched on Japan's Himawari-8 and Himawari-9 satellites, GOES-17 would also link advanced capabilities from east to west — covering 85 percent of the Earth. It would be a game changer

in the weather community for improving hurricane and typhoon forecasts across the Atlantic and Pacific oceans. Expectations for GOES-17 were high.

At stake

A single Geostationary Operational Environmental Satellite takes years to build, including its primary instrument, a single 315-kilogram ABI camera. Each ABI instrument provides 90 percent of the data products that enable a GOES satellite to help save lives and protect property. GOES-17 is the second of NOAA's four planned next-generation, advanced geostationary weather satellites. One GOES satellite is always designated as GOES-East off the U.S. East Coast near 75 degrees west longitude, and another as GOES-West located off the U.S. West Coast near 137 degrees west longitude. These sentinels in the sky watch developing weather and other environmental conditions 24 hours a day, 365 days a year, and must deliver data in near real-time.

One of the capabilities that distinguishes ABI is the ability for forecasters to request on-demand observations of evolving severe weather. Going from photons to forecasting products in less than 30 seconds, GOES provides unprecedented near real-time situational awareness about hurricanes, tornadoes and wildfires.

ABI distinguishes itself from legacy geostationary imagers by its ability to collect three times the spectral data with 16 channels (colors) of visible-through-longwave infrared imagery needed for weather forecasting, volcanic ash monitoring, low cloud/fog monitoring and air-quality monitoring.

▲ **GOES-S** with the Advanced Baseline Imager (wrapped in silver thermal blankets) was prepared for launch at Astrotech in Florida. Once in orbit last March, the satellite was renamed GOES-17.

Harris Corp.

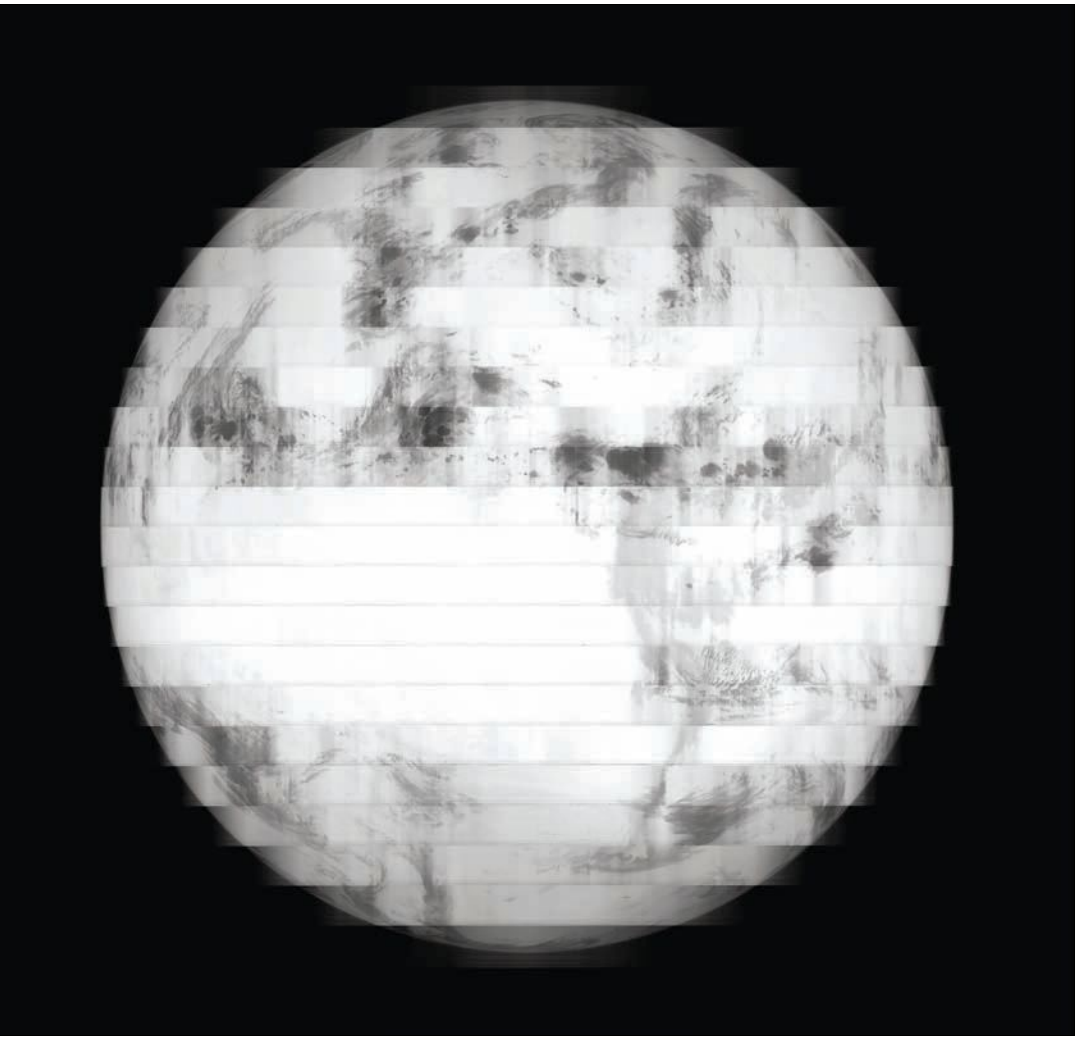
The realization

The ABI on GOES-17 spent the first two months post-launch outgassing, ensuring that none of the contaminants that are inevitably carried from Earth aboard a satellite were deposited on critical optical surfaces. On April 12, 2018, the mission operations team determined it was safe to open our optical port cover and begin taking visible images. The first visible images were incredible, and we looked forward to first light for the infrared channels.

Fifteen days later, we sent commands to tell the ABI's thermal system to cool down the detectors, nearly 39,000 elements, each smaller than a human hair, etched into silicon and mercury cadmium telluride wafers. The ABI's primary thermal components include a cryocooler (plus a backup) that must keep the ABI's detectors at the very cold temperatures required for infrared observations. The visible and near-infrared detectors operate at minus 68 Celsius (170 Kelvin), and the infrared detectors operate at minus 178 C (60 K).

A network of constant conductance, heat pipes circulate ammonia that absorbs heat from the cryocooler, electronics and any components warmed by the sun. The ammonia transports the heat to a central depository called a thermal bus that intersects with what are called loop heat pipes. Propylene inside these pipes warms up and transports the heat to the radiator, which sheds the heat to space. The cooled propylene circulates back to the thermal bus to continue the cooling cycle.

The first signs of trouble appeared a few hours after the loop heat pipes were commanded to start. Parts of the ABI that should have become



cold remained hot. Heat that should have been transferred to the radiator and shed to space did not move. Near midnight, when the sun shined on the far side of the Earth, it also shined directly into our optical aperture and drove temperatures inside the ABI to unsafe levels. We knew within hours we had to do something right away to save the ABI from overheating and potentially suffering permanent damage. The cryocooler's electronics generate most of the internal heat produced by the ABI, so we quickly reduced its power, helping the ABI make it through the night. Saving ABI from excessive heat meant no cold detectors, which also meant no infrared imagery — impacting 13 of the imager's 16 channels around spacecraft local midnight. We could make visible images but lost the full spectrum of capabilities required by forecasters and GOES users. We had prevented damage to the ABI, but the work was just beginning.

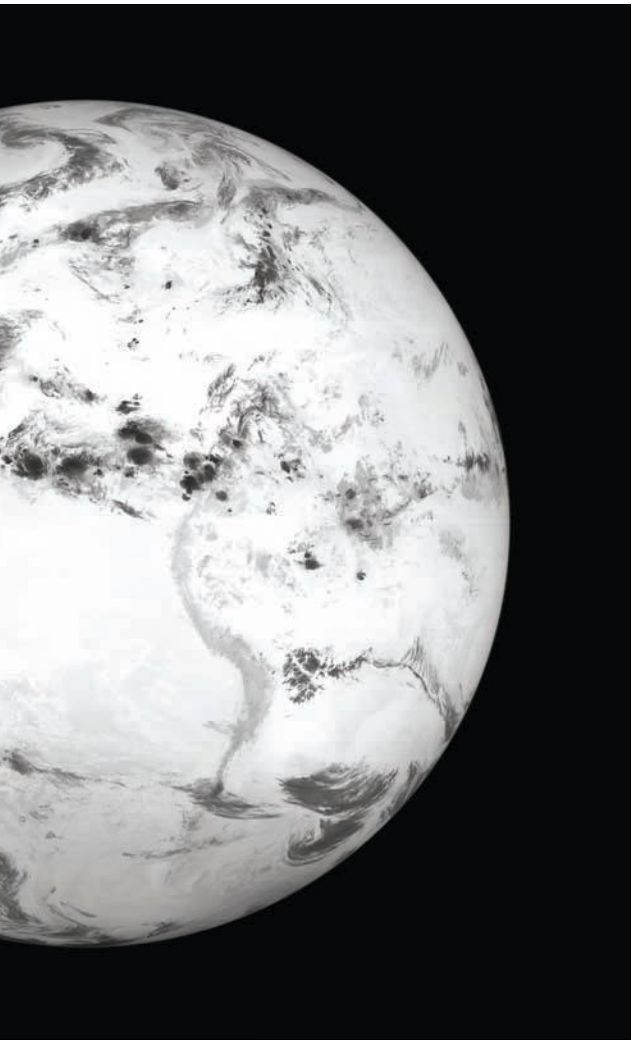
Investigation and backup plans

On-orbit troubleshooting requires a rigorous plan and disciplined action to safely determine root cause. From review of telemetry, we were able to deduce that the propylene fluid flow through the loop heat pipes was not distributing heat across the radiator. Several immediate attempts to restart the loops the following day were also unsuccessful, and again near midnight we turned off the cryocooler.

The investigation and troubleshooting continued over the next few weeks, and after a month of unsuccessful attempts, we realized we may never recover loop heat pipe performance. NOAA, NASA and Harris decided to establish two parallel teams. The first team, augmented by independent reviewers

▲ **In the photo at left,** elevated detector temperatures caused the current to bleed into adjacent detectors, resulting in blurred images. The GOES team solved the problem, right, by adjusting the voltage that controls the flow of photocurrent.
NOAA

"It's always summer on ABI," was the rallying cry.



from NASA and loop heat pipe experts from across the country, continued the root cause investigation and attempted to restore GOES-17 to full operations. The second team assumed the loop heat pipes were unrecoverable and investigated optimizing the ABI's performance with minimal radiator capacity. As time moved on without a solution, NOAA established two more teams — one that considered how to use NOAA's existing satellites to augment GOES-17 and another to investigate supplementing algorithms to compensate for missing data from the ABI. This case study is about the work of the second team, the one focused on optimization.

The optimization effort started in early June at Harris' facility in Fort Wayne, Indiana, with a team that included Harris, Lockheed Martin, NASA and NOAA. The team had one advantage working in its favor on the path to improvement: the ABI's flexible design. When Harris designed the ABI, we wanted to ensure its electronics and software design were reconfigurable by command. We attacked the problem from two directions:

1. Limit the heat buildup and in this way increase infrared channel availability throughout the night.

The GOES-R series

Program cost:
$11 billion
(4 satellites, launch vehicles, ground system and operations)

On-orbit:
2016-2035+

Main instrument:
Advanced Baseline Imager (ABI)

Contractors:
Satellite by Lockheed Martin; ABI and ground system by Harris Corp.

Management:
NASA during construction; NOAA after launch

Sources: NASA, NOAA, Government Accountability Office

2. Improve the imagery at warmer detector temperatures.

Limiting the heat buildup

The beta angle of the sun plays a critical role in determining how hot our infrared detectors will get on any given day. Beta angle is the angle between the orbital plane and the sun vector. For geostationary satellites, this angle varies by plus or minus 23.5 degrees throughout the year and determines how hot our infrared detectors will peak on any given day. The Lockheed Martin spacecraft built for this geostationary satellite series has the capability to yaw flip (rotate 180 degrees about the nadir vector so the north side of the spacecraft now faces south). While this type of maneuver was not planned for nominal operations, it certainly provided a big boost to the ABI optimization. Our thermal models indicated an inverted orientation for six months of the year would reduce sun penetration and restrict solar heat from reaching deep into ABI, reducing the overall heat buildup, thus allowing us to keep the cryocooler running longer and keep the detectors colder overnight.

The day we performed the yaw flip maneuver exhibited an incredible 10 C reduction in peak detector temperature over the previous day. The first major change implemented to GOES-17 operations was a twice-a-year yaw flip near each equinox to keep the sun in its summer geometry — shining down from above. This minimizes how deep the sun can penetrate into the aperture and keeps heat away from critical components. The yaw flip maneuvers guarantee the ABI maintains this advantageous sun geometry year-round. "It's always summer on ABI," was the rallying cry.

Since the cryocooler directly controls the infrared focal plane temperature, maximizing its capability was vital to optimization. We employed several strategies related to cryocooler operation that were key to our success. We designed the ABI with fully redundant cryocooler units, with only one in use in normal operations. In our on-orbit testing, we found that operating both units simultaneously was a much more efficient configuration for GOES-17. With each unit extracting only part of the heat from the detectors, the cryocoolers were more efficient and thus generated less heat to be transported.

Another change we made to cryocooler operation was increasing the maximum allowable temperature at the reject surface of the cryocooler. This surface is the interface to the thermal system and where it transfers its internally generated heat to be "rejected" to space by the radiator. On a normally functioning spacecraft, like GOES-East, the highest operating temperature for the cryocooler reject surface would be 27 C. On GOES-17 we decided to allow the ABI to run up to 57 C each day, which is the maximum we had demonstrated on a life test unit. This increase was necessary because the thermal system was not allowing heat to flow out as it normally would, meaning the ABI routinely reached its maximum safe reject temperature, something that would never happen in normal operations. The new, higher temperature became the limiting factor of our daily operations. We were forced to reduce cryocooler power once that temperature was reached. Increasing the temperature limit allowed us to maximize cryocooler operation throughout the day. Not only did we increase this limit, we modified our entire cryocooler operating procedure around it. A new version of the ABI onboard control software was developed and uploaded from the ground to autonomously control operations near this limit so we could gain every possible minute of imagery for forecasters.

The last significant cryocooler strategy was increasing the nominal operating temperature of our infrared detectors. Driving the cryocoolers to maintain the nominal infrared detector temperature of minus 213 C requires significant power. The colder we tried to keep the detectors during the day, the hotter they became at night, because the thermal system could handle only a certain amount of total heat in a day, and the more heat produced by the cryocooler during the day, the less heat we could accept from the sun at night. We needed to identify an optimum balance between daytime performance and additional hours of infrared imagery. We evaluated 24 hours of images at various set points for the detector temperature ranging from minus 159 C up to minus 148 C. In the end, we settled at minus 157 C (81K). Per assessments by NOAA scientists, this compromise still provided high-quality imagery during the day for all 16 channels while not drawing significant amounts of power to overwhelm the thermal system at night.

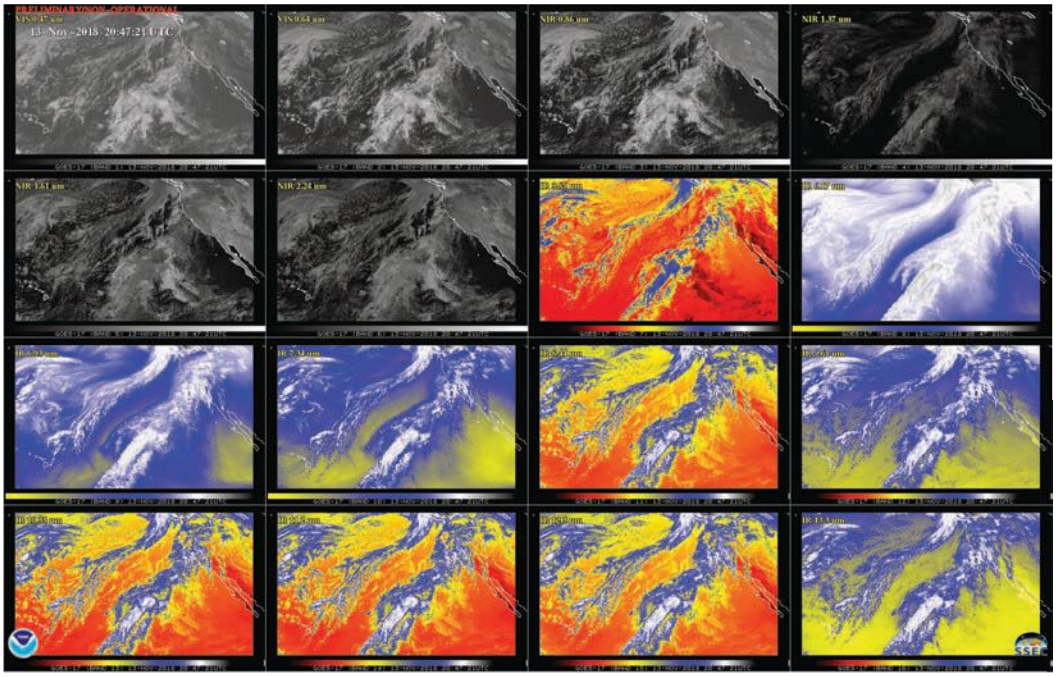
Taking the heat

Despite all the success we had keeping temperatures cooler each day, it was not enough. The detectors were not designed to work at minus 157 C, and they certainly would not perform well at our expected annual peak temperature of minus 129 C. To improve performance at these elevated temperatures, we relied on the flexible configurability designed into the ABI detector operation. The two parameters we found to have the most impact were detector bias, which controls the flow of a detector's photocurrent, and its sensitivity, called gain.

Detector bias voltage is critical to acceptable detector operation. We use it to drive the photocur-

▶ **The 16 channels on** GOES-17's Advanced Baseline Imager show the northeastern Pacific Ocean and western U.S. The infrared bands are those with blue and/or yellow colors.
NOAA/CIMSS

▼ **Engineers install** an Advanced Baseline Imager on the GOES-R satellite.
NOAA



rent from individual detectors in the right direction so that it can be properly read by the electronics. Through our on-orbit testing, we found that the elevated detector temperatures caused photocurrent to flow into adjacent detector elements rather than heading toward the readout electronics. The result was data coming from one part of Earth was measured by detectors staring at other parts of Earth, which caused unacceptable blurring of images at warmer detector temperatures. After reoptimizing the bias voltage value, we observed significant improvement in many of the channels and regained several hours of daily imagery in the 9.61, 12.30 and 13.30 micrometer channels (the most impacted). The 13.30 micrometer channel measures carbon dioxide in the atmosphere, which is critical to several of the cloud property retrievals produced by the ABI. Gaining hours of operation for that channel is a big win.

Detector gain is the other detector parameter we used to great success. Dark current, which is the signal produced by detectors even when no light shines on them, increases significantly with operating temperature. As detector temperatures began to rise each night, the dark current could become larger than the photo current produced by the signal from Earth. The increased dark current saturated our analog-to-digital converters, reducing the number of hours of useful imagery. We dialed back the detector gain settings overnight. Reducing the gain lowers the current value read by the digitizer and allows us to stay in its useable current range for a longer time. We currently operate the GOES-17 ABI with two distinct gain sets. The first set maximizes performance at our new nominal temperature of minus 192 C during the day. We command a second set of reduced gains shortly before night to minimize the impact of increased dark current once temperatures increase. These gain changes occur automatically each day and maximize the hours of useful operation.

The future is bright

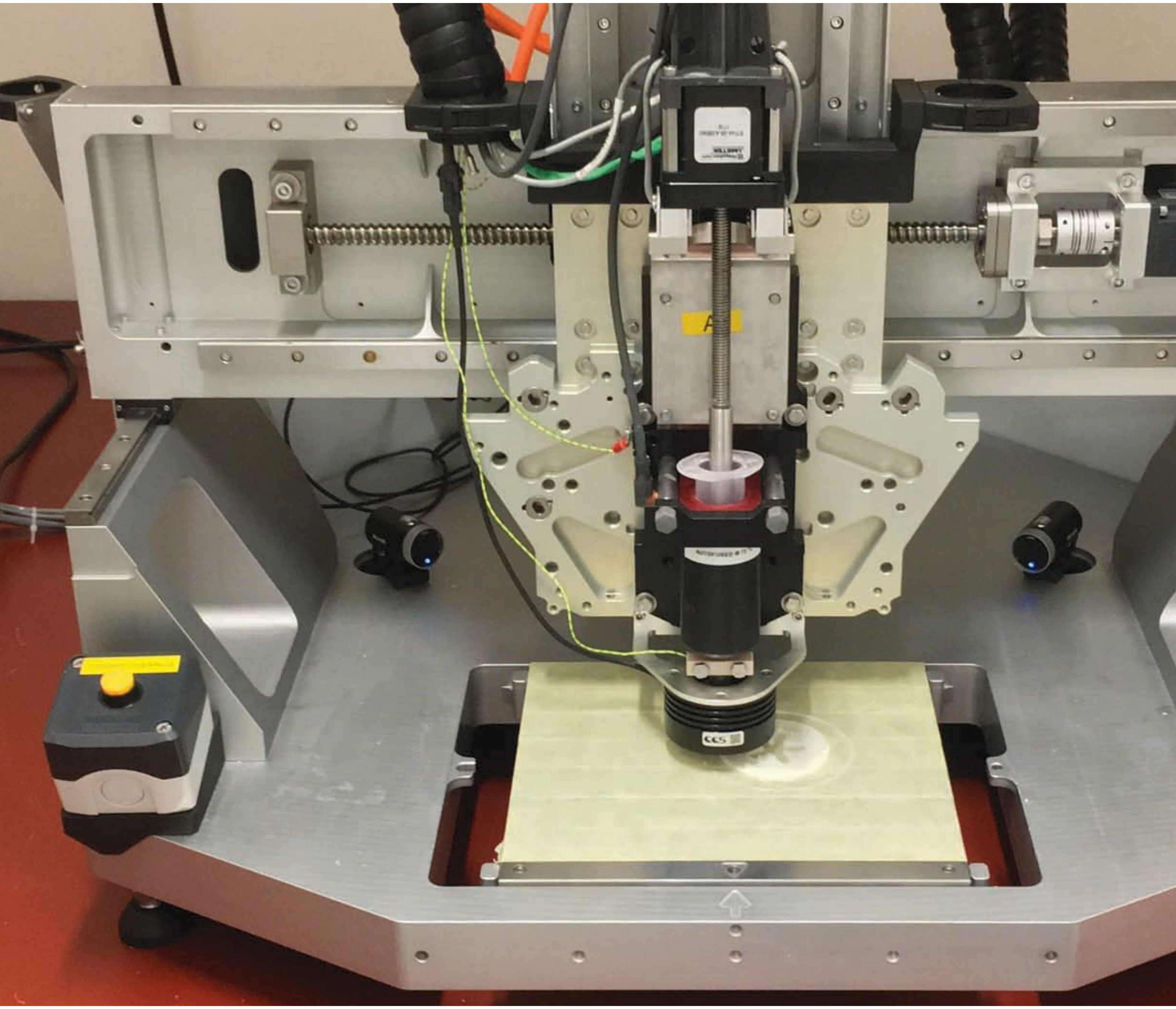
Our experience over the past year has been nothing we ever could have imagined. Through the efforts of numerous people, GOES-17 will be the game-changing weather satellite it was promised to be. We found a way, without use of a radiator, to optimize the ABI performance and reclaim hours of lost operation each day.

NASA and NOAA continue to review options for the future of the third and fourth spacecraft in the series, GOES-T and GOES-U, but the future of GOES-17 looks bright. With the operational approach described in this case study, we expect ABI to provide 97 percent of its intended data over the course of a year, which is an astounding number considering the circumstances. That some of the infrared channels remain unavailable for a few hours each night during times of the year is regrettable, but we are in a far better position overall with GOES-17's optimized configuration and certainly better off from legacy capability.

Our success would not have been possible without the inherent flexibility in the modern designs of both the ABI and the spacecraft. We used that flexibility to identify a multifaceted operations approach that put GOES-17 on the path to success and ultimately to its spot as the operational GOES-West satellite. All from 36,000 kilometers away. ★

John Van Naarden is chief engineer for Harris Corp.'s Advanced Baseline Imager program in Fort Wayne, Indiana.

Dan Lindsey is NOAA's senior scientific adviser for the GOES-R satellite series. He works for NOAA's National Environmental Satellite, Data, and Information Service in Fort Collins, Colorado.



▲ Material extruded from a 3D printer (white disk at lower center) represents part of a solid fuel cylinder with a star-shaped hole, or bore. TNO, based in The Hague, built the printer.
TNO

3D-printed rocket fuel

Solid-fuel rockets contain cylinders of fuel that, depending on the manufacturing method, can take weeks to cure. Plus, it's complicated to design the fuel so that the propulsive force varies in a predictable way as it burns. Keith Button spoke to researchers who think they have a better way to make solid fuel.

BY KEITH BUTTON | buttonkeith@gmail.com

Researchers in the Netherlands learned a rough lesson when they first tried 3D-printing solid fuels like the conventionally cured kind that today power everything from rocket-propelled grenades to space launch vehicles.

The researchers were determined to master the technique because it would speed production compared to conventional methods and give designers new options for tailoring a rocket's propulsive power to their needs.

Working with explosive materials is tricky. Early on, the researchers chose to melt solid propellant, so it could be laid down as a liquid a layer at a time in the 3D-printing process. In one attempt, the chemical was held at the melting temperature for too long and started to decompose. You can probably guess what happened.

Boom!

"Bye, bye printer," says Joost van Lingen, a physical chemist with the Dutch scientific research group TNO in The Hague. He leads the solid-fuel 3D-printing project for TNO, a Dutch acronym for the Netherlands Organization for Applied Scientific Research.

The researchers haven't blown up any printers since that day in 2012, but they still have more to learn. If a new mixing process works as well as hoped in an experiment that was scheduled for March, the researchers will have achieved another step toward that goal.

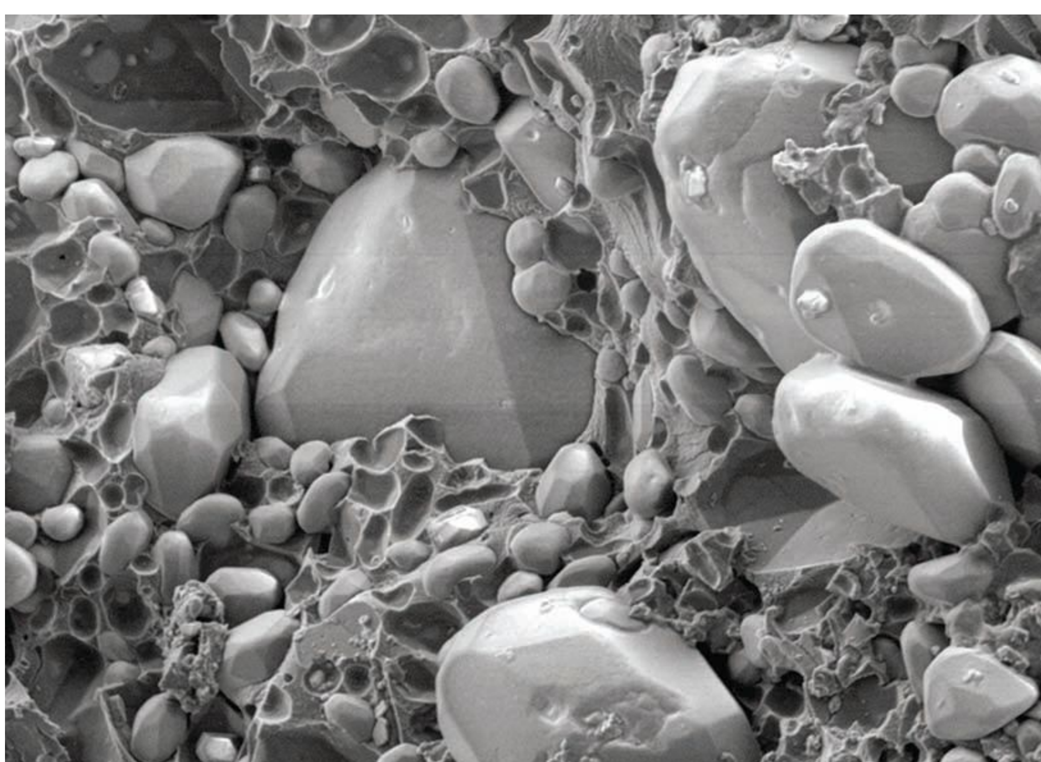
The attraction of 3D printing is that it gives more precise control over the ratio of ingredients in the fuel. That ratio is crucial, because it's one of the factors that determine how fast a cylinder of solid fuel will burn inside its rocket casing. Another factor is the shape of the bore hole in the center of the cylinder. This is where the fuel ignites and burns outward from the interior walls of the cylinder.

Today, these cylinders are made either by casting, which can require weeks of curing time, or by extruding paste through a die with a shorter curing time. A flammable/explosive material, typically ammonium perchlorate, is mixed into the fuel as a confectioners-sugar-like powder while the fuel is still in its liquid state. The greater the number of grains of that powder in a cubic centimeter, the faster it will burn.

These conventional methods make it hard for designers to vary the burn rate and therefore the propulsive power of a solid rocket as it burns. Engineers typically must elect to distribute the material uniformly to produce a consistent and predictable burn rate.

With 3D printing, the percentage of that energetic material can be concentrated at certain points in the cylinder and made less concentrated at others. This is done by controlling the ratio of ingredients in each pixel, or dot, in the cylinder as the 3D printer builds it a layer at a time, sort of like stacking compact disks. Pre-determined variations in power would be handy if a space launch called for greater acceleration at a certain point in its flight and less acceleration at another point, for example.

Today, the rate of burn is controlled almost solely by the shape of the bore hole. If one looked



▶ Crystals of explosive and flammable powder are visible in a scanning electron microscope image. The more evenly the crystals are distributed in a solid rocket fuel, the more evenly the fuel will burn. Also, the more concentrated the distribution, the faster the burn.
TNO

down from above, the hole might look like a star, for example. In that case, the more points on the star, the greater the surface area, the faster the burn rate and the more propulsive power. But as the fuel burns from the center out, the initial star morphs into a circle that grows larger and larger. This surface area then dictates the propulsive power through the remainder of the flight.

With a 3D-printed cylinder, even after the star points are gone, the power can vary because of the varying concentrations of energetic material at different locations.

Today, complex bore shapes are difficult to make, but they would be fairly easy to produce with 3D printing. Burn profiles could be tailored to specific missions and payloads by varying the concentrations of material and also by varying the number of star points or turning to other shapes.

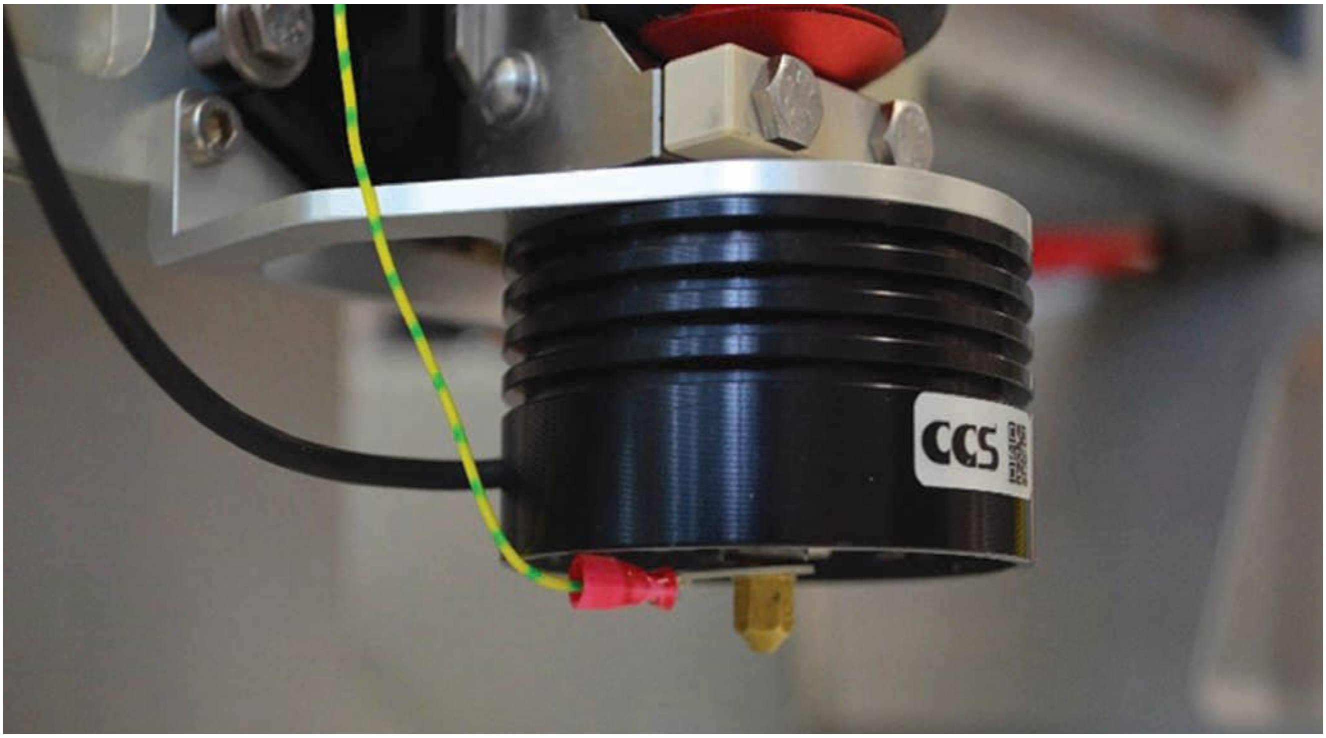
The advantages of 3D-printed solid fuel might convince small-satellite launchers to switch from liquid-fueled rockets, says John Zevenbergen, TNO's principal investigator for advanced energetic materials. Solid fuel is simpler and less expensive than liquid fuel in general, he notes, and now there would be added advantages.

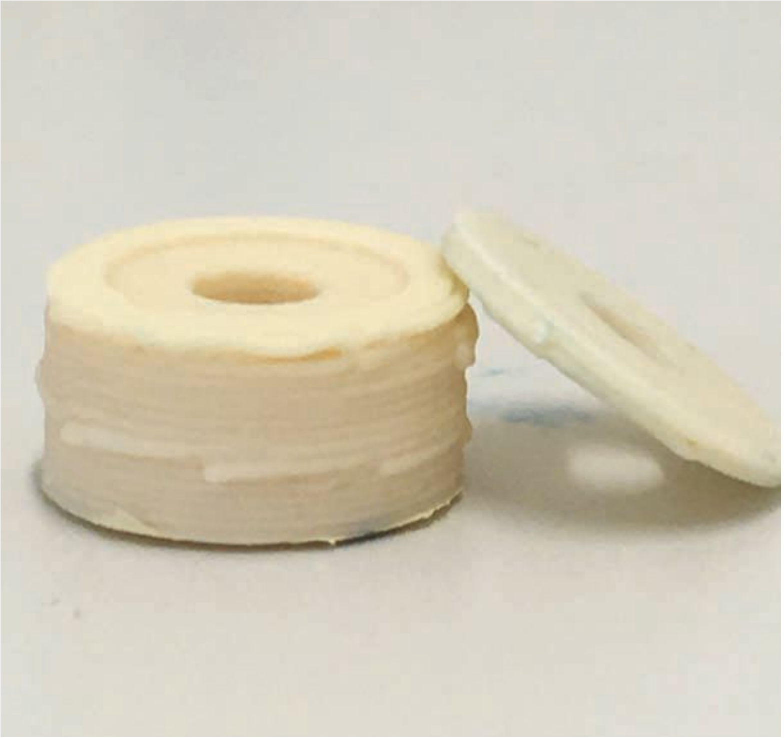
The researchers are still refining their recipe and processes, though. For the March experiment, the TNO researchers were planning to 3D-print fuel with a mix of two pastes containing different concentrations of energetic powders. The researchers long ago moved away from the melting process that caused the boom in 2012. The ratio of these two pastes can be varied to alter the concentration of energetic material in the final product, says Michiel Straathof, a space propulsion engineer and lead researcher on the 3D-printing project. To achieve this, two syringe-like extruders mix the two pastes together as they are pushed out through a 1-millimeter nozzle. The ratio of one to the other is determined by the amount of pressure exerted on one syringe relative to the other. A doughnut-shaped ring around the nozzle points ultraviolet light at the mixture as it is deposited, one thin disk-shaped layer at a time, hardening it. This 3D-printing method is called fused deposition modeling, or FDM.

When TNO began the project, one of the first hurdles was finding a material that had enough energetic ingredients to perform as a fuel but could be printed without blowing up, van Lingen says. At first, they tried melting energetic materials (ammonium dinitramide and TNT) that were deposited

> "In our case, if you have dry powder in the motor, where it's exposed to friction, it can lead to a problematic situation."
>
> **— Michiel Straathof,** Netherlands Organisation for Applied Scientific Research

▼ A UV light attached to the printer's metallic extrusion nozzle (the object resembling a pencil point), cures material as it exits the nozzle through a 1-millimeter opening.
TNO





▲ A fused definition modeling printer builds a solid fuel cylinder one layer at a time. This cylinder was stopped in midproduction when the printer ran out of material.
TNO

on a surface for curing. After the boom and some more experimentation, they eventually settled on methods where the energetic ingredients could be added as a powder. They started with a mixture that they knew contained enough energetic material and then tested whether it would flow through the nozzle and be controlled on the printing surface.

The energetics group worked with chemists in TNO's 3D-printing group to come up with an initial mix and then refined the recipe through trial and error, Straathof says. Their goal is a solid fuel that meets industry flexibility and tensile strength standards, with the required propellant distribution of the grains of powder in a given sample size as checked with a scanning-electron microscope, plus a stable shelf life of 20 to 25 years.

The researchers settled on the syringe-based technique for printing because it could extrude a highly viscous liquid, up to 85 percent of which was the energetic material added in powder form. A plasticizer, also an energetic material, added flexibility to prevent cracking in the solid form. A binder ingredient solidifies the paste when exposed to the UV light.

Bunker mentality

The researchers also had to consider safety requirements in their design for the printer. The energetics experts on the TNO team reminded their colleagues that for everyone's safety the printer would have to operate alone in a reinforced-concrete bunker.

The remote-control requirement and remote viewing for all aspects of the machines was a new concept for the 3D-printing group that forced members to think differently, Straathof says.

In their previous work with nonenergetic materials, "they put [the materials] in a machine and they stand next to it and they see what happens," he says. "Of course, we can't do that. We have to load the machine, and we close the bunker door, and then everything is remote."

For starters, everything on the printer had to be monitored by software and cameras. Two small cameras watched the printer nozzle and printing surface, while a wide-angle camera viewed the whole printer. The software would monitor the status of the printer, including the temperature and pressure in the extruders, Straathof says.

The TNO team designed software that would cut the power to the printer if the temperature or pressure climbed higher than a threshold that could induce an explosion or fire. A redundant fuse would break if the software didn't work. Motors were not allowed to produce more torque or pressure than what was needed for extrusion. If the power was cut to the printer, a brake would automatically engage to prevent the printer nozzle from falling hard on the printed material.

The motors that push the plungers in the extruders had to be monitored to make sure that none of the propellant material dried up. In normal 3D printing, the biggest problem might be getting plastic stuck in a motor and having to replace the motor. "In our case, if you have dry powder in the motor, where it's exposed to friction, it can lead to a problematic situation," such as an explosion or fire, Straathof says.

Static electricity could be dangerous — every part on the printer that might contact energetic material had to be grounded. And after a print trial, before the researchers could open the steel door to the bunker, the UV light had to be off, the extruder plungers retracted and the temperatures normal. All the precautions and remote observation requirements mean that every trial takes much longer to complete than with typical 3D-printing research.

The energetics and 3D-printing groups would sit together in hourlong sessions to think through all of the possible things that could go wrong and how to prevent them, Straathof says. The final design looked nothing like the initial design that was created by the 3D-printing group before the joint analysis with colleagues in the energetic group.

"We really noticed that there are just some things that we didn't think of and some things that they didn't think of in terms of working with energetic materials," Straathof says. "So really, sitting together and going through the process with people looking at it from different angles was the way to do it in the end." ★

CONTROLLING SPA

CE

U.S. strategists once bragged about their school-bus-sized, multibillion-dollar military satellites, but now they're worried these behemoths are a glaring vulnerability in their contingency planning for a war against China or Russia. When it comes to defending them, fresh thinking is needed. Debra Werner looks at whether creation of a Space Development Agency is the best solution.

BY DEBRA WERNER | werner.debra@gmail.com

Eleven months. That's how long it took the Pentagon's Strategic Defense Initiative Organization and its contractors to build and launch Delta Star, a satellite that in 1988 tested SDIO's ability to spot rocket plumes against a complicated natural backdrop. The mission, dubbed Delta 183 for its launch vehicle, was the third space experiment launched in two years by SDIO. At the time, the Cold War was in full swing, and SDIO had a flush budget to meet U.S. President Ronald Reagan's challenge of rendering nuclear missiles "impotent and obsolete" by showing that they could be knocked down from space.

These Delta experiments were "spawned by a rare conjunction of circumstances" that included "a major national need" and "an innovative and imaginative group of people in government, in industry," explained SDIO's then-director of technology, Michael D. Griffin, and his co-author in a 1990 article in Johns Hopkins APL Technical Digest.

Flash forward, and the biggest space issue for the Trump Pentagon is how to make sure that in a hot war, neither China nor Russia nor any other actor could deny the U.S. the high ground of space by hacking, blinding, disabling or destroying the country's military satellites. A February Air Force intelligence report, for instance, concludes that Chinese military units are training with missiles built to destroy spacecraft. As for Russia, since the SDIO days and the dissolution of the Soviet Union, it has morphed into a "frenemy," with cosmonauts and astronauts gliding by each other aboard the International Space Station, while elsewhere in orbit Russian satellites shadow those of the U.S.

One camp in the Pentagon views the situation with China and Russia as the kind of national need cited by Griffin in the 1990 article to justify creation of a separate agency. Last month, U.S. Acting Defense Secretary Patrick Shanahan established just such an organization, the Space Development Agency, under Griffin, who is now the Pentagon's undersecretary for research and engineering.

A bureaucratic and legislative fight could lie ahead for the agency given that the first significant funding would come via the 2020 White House budget request, and elements of the Air Force have pushed back hard in private against the idea. In the meantime, Shanahan is seeking to open the office with funding reprogrammed or moved from another Defense Department account.

The agency will seek to revive fast-turnaround space projects, including "lethal" technology, Shanahan's establishment memo says, for the new Space

Force that is being set up, at least temporarily, under the Air Force.

The Defense Department last month also sent the Space Force plan to Congress.

Defense officials would not speak on the record, but one recent retiree gave a glimpse into the Pentagon's thinking.

"We want to look at new ways of doing space missions, new ways of doing missile warning, new ways of doing communications, new ways of doing GPS," says Doug Loverro, the former deputy assistant secretary of defense for space policy who remains in close contact with his former Pentagon colleagues.

Some in the Air Force are pushing back behind the scenes, arguing that a new bureaucracy is not the best way to do this. The bulk of U.S. military space hardware is today developed and managed by the Air Force Space and Missile Systems Center in California, and this camp believes that SMC can adapt and is, in fact, beginning to.

A dozen current and former Defense Department officials interviewed for this article did not deny that there are issues. A lumbering U.S. military bureaucracy inhibits innovation, they say. They disagree, though, about the wisdom of creating a new agency to address the problems.

If critics are right, the Space Development Agency will divert resources without producing any new satellites or networks that troops can rely on. If supporters are right, the new agency will spur innovation and lead to a new generation of satellite constellations that would be resilient against physical or cyber attacks.

"WE WANT TO LOOK AT NEW WAYS OF DOING SPACE MISSIONS, NEW WAYS OF DOING MISSILE WARNING, NEW WAYS OF DOING COMMUNICATIONS, NEW WAYS OF DOING GPS."

— **Doug Loverro**, former U.S. Defense Department official

▼ **A Defense Support** Program missile warning satellite is deployed from the space shuttle Atlantis. The successor to the DSP, the Space-Based Infrared System, came in nine years late and billions over budget.
NASA

No more juicy targets

The record shows that the Air Force has, in fact, been adapting its strategy in recent years. Military planners, including some in the Air Force, came to realize that the U.S. approach of relying on small numbers of extremely capable large satellites for functions such as missile warning and protected communications was risky because potential adversaries could hack, jam or destroy the satellites. A turning point came in 2017, when Gen. John Hyten, who leads U.S. Strategic Command, announced he would no longer support the development of "big satellites that make juicy targets."

After that, the Air Force established the Space Rapid Capabilities Office at Kirtland Air Force Base in New Mexico to develop and field technologies to protect spacecraft from attack. The service also created the Space Enterprise Consortium at SMC in Los Angeles, where business people who don't traditionally work with the federal government compete for one-page contracts to build prototype sensors, components and spacecraft.

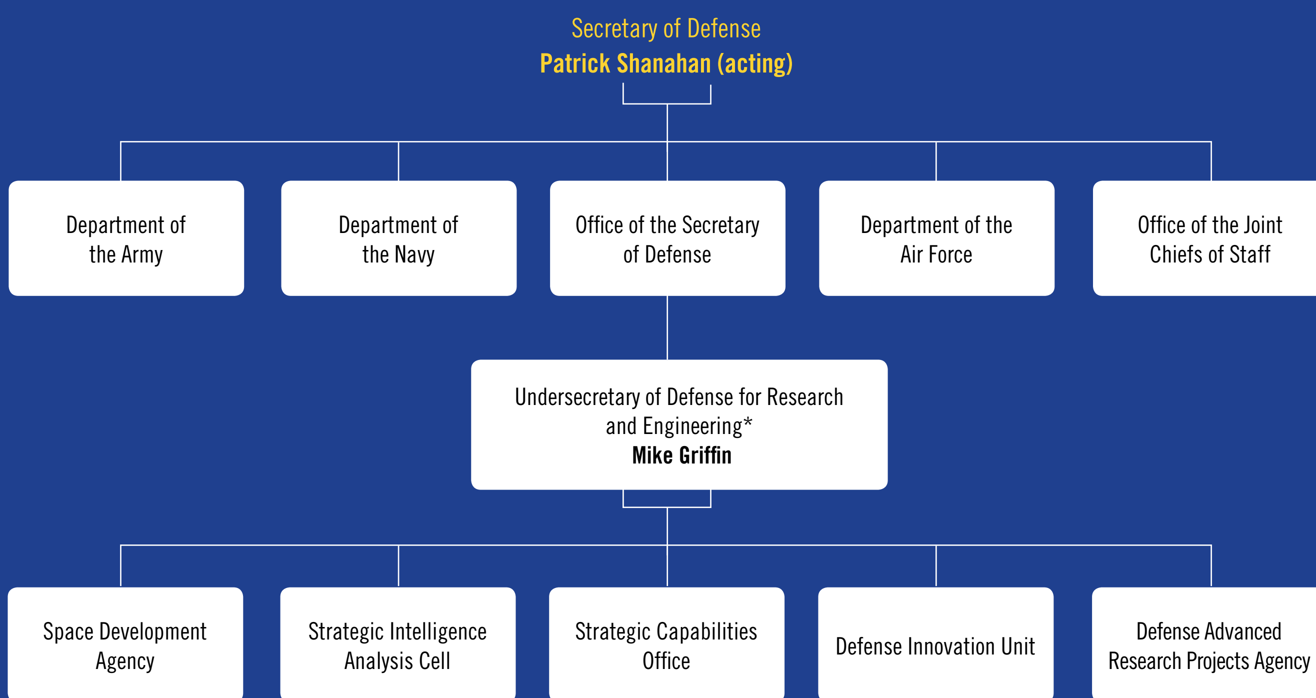
The message? The Air Force space establishment is changing. "Standing up a new agency that lives on the Office of the Secretary of Defense staff is not a way to speed up development of space-based systems," says retired U.S. Air Force Lt. Gen. David Deptula, who leads the Air Force Association's Mitchell Institute of Aerospace Power Studies in Virginia.

That said, an argument against Shanahan and Griffin could prove hard to win, so Deptula has taken to airing a possible compromise. If Pentagon leaders are intent on creating a new agency, he says, they should move it inside U.S. Space Command, a joint command staffed by members of all the services that was re-established by presidential executive order in December after a 17-year hiatus. U.S. Space Command will have the most experience employing space systems, so it makes sense to house the agency responsible for rapid development there, Deptula argues.

Proponents of the Space Development Agency have no intention of embedding the organization

Where the Space Development Agency would fit in

The Defense Department plans to ask Congress for $120 million to $200 million a year for the Space Development Agency, with the mission of getting new technology into space faster than the department's traditional procurement process.



*One of six undersecretaries of defense; the others are responsible for: acquisition, technology and logistics; comptroller; intelligence; personnel and readiness; and policy.

Source: Congressional Research Service

within the Air Force, a service they charge with moving too slowly to field small satellites and with resisting bold new ideas for how to operate them.

They want to go in new directions and even unleash the pent-up talent in the Air Force and other services to help them do that. To understand where those paths might lead, Loverro challenges me to imagine a game of chess with the various pieces representing the array of commercial satellites coming onto the market that the military could purchase. Today, the Air Force looks at all the chess pieces but moves only the king, a powerful figure but one with limited mobility. The king in this analogy would be a large, expensive satellite. The Space Development Agency will consider "how to take all these pieces that have been assembled by the great entrepreneurial forces of the United States and figure out how to create new architectures," Loverro says, using the term for the mix of kinds and sizes of satellites that constitute a constellation.

Take communications networks. For the moment, most military communications flow over giant satellites in geostationary orbit that are owned either by private companies or the Air Force or Navy. To avoid cyberattack, the military could instead create a communications network that includes commercial constellations in low Earth and geostationary orbits as well as military satellites. "Our goal should be to incorporate everything you're doing and everything our allies are doing so this is no longer a juicy target," Loverro told a Silicon Valley audience in October at the Satellite Innovation Symposium in Mountain View, California.

In this view, the clock is the real competitor. Like Silicon Valley, China, Russia and other potential adversaries are innovating rapidly, according to "Competing in Space," the unclassified February report from the Air Force's National Air and Space Intelligence Center, the one that referred to China's anti-satellite training.

The Chinese Embassy in Washington did not respond to requests for comment about its actions and plans in space. The Chinese Academy of Sciences, however, has issued statements saying the country is intent on peaceful application of space technology.

Some are skeptical about China's claims. "We have every reason to believe that the Chinese have offensive capabilities on orbit," says Robert Walker, former Republican chairman of the U.S. House of Representatives Science Committee and an ally of the Trump administration. "They call them other things, but they appear to be capable of offensive operations against our space-based assets."

Risk-averse culture

Fred Kennedy of DARPA fame is Griffin's pick to lead the new Space Development Agency. Kennedy declined an interview request, but he has left a trail of criticism about today's military space establishment. Speaking last August at the Small Satellite conference in Logan, Utah, Kennedy diagnosed a "risk-averse culture" that "wants to spend a lot of time fixing and testing, testing and reviewing. That's a problem because our adversaries are figuring out how to do things more quickly, more cheaply."

In the months leading up to Shanahan's memo, Kennedy led a Defense Department study to define the new agency's mission and organizational structure. Pentagon leaders do not need congressional approval to establish the new agency, but they need an appropriation. The Defense Department plans to ask Congress for $120 million to $200 million per year for the Space Development Agency.

In his years leading DARPA's Tactical Technology Office, Kennedy has encouraged Pentagon leaders to harness commercial innovation like inexpensive small satellites.

In recent years, investors have been pouring money into commercial space technology. Venture capitalists provided $3.25 billion in 2018 to startups around the world working feverishly to build constellations of small satellites for communications and Earth observation as well as rockets, hyperspectral sensors, spaceplanes and laser communications terminals. Much of the new technology draws on mass-produced miniature electronics created for smartphones and automobiles. Many space industry entrepreneurs also have adopted the agile development approach of software suppliers. As soon as they invent new satellites, sensors or ground terminals, they look for ways to improve hardware and software.

Government space programs are completely different animals. Military planners must anticipate their needs well in advance because it may be decades before they can purchase another generation of missile warning or secure communications satellites.

Then, the government goes to its traditional stable of prime contractors and vendors whose businesses are set up to comply with complex federal acquisition rules and cost-plus contracts, meaning they can produce an audit trail for every expense. Those companies offer some of the world's most sophisticated and expensive satellites.

> **"STANDING UP A NEW AGENCY THAT LIVES ON THE OFFICE OF THE SECRETARY OF DEFENSE STAFF IS NOT A WAY TO SPEED UP DEVELOPMENT OF SPACE-BASED SYSTEMS."**
>
> — retired U.S. Air Force Lt. Gen. David Deptula

"If it's the only platform the government is going to buy for the next 10 years, that creates incentives for manufacturers to lard on as much as possible," says Dean Cheng, a Heritage Foundation senior research fellow.

Congress also plays a role. Providing less funding in certain years than the military requests can play havoc with production schedules. Adding money to the budget for satellites the Air Force intended to stop buying can draw out subsequent programs.

Sometimes the process results in satellites launched years late and over budget. The Air Force's Space-Based Infrared System satellites, or SBIRS, are a prime example.

In the late 1990s, the Air Force embarked on an ambitious effort to develop state-of-the-art infrared sensors for satellites in geosynchronous and highly elliptical orbit to detect and track short- and long-range ballistic missiles. At its inception in 1996, the project carried a $4.2 billion price tag for five satellites. By the time the first satellite reached orbit in 2011, nine years late, the Air Force had paid $19 billion for six satellites.

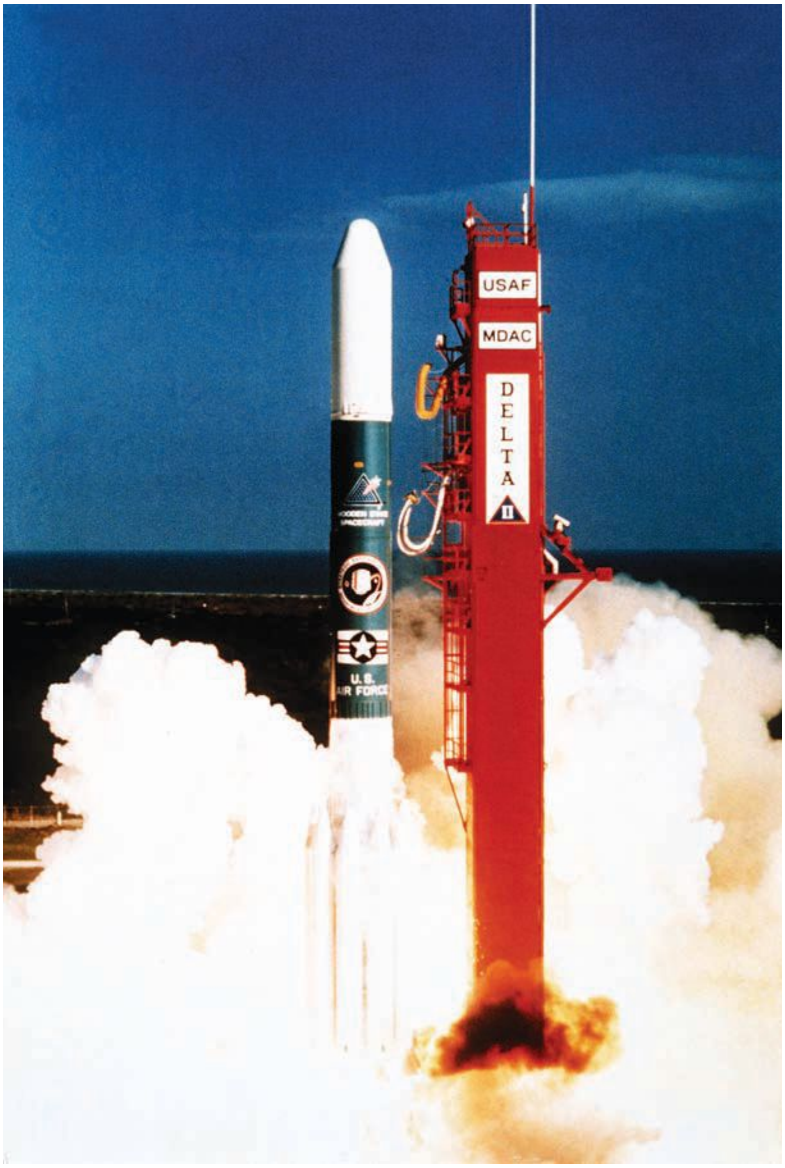
"If the precursor constellation" — the Defense Support Program satellites — "hadn't lasted as long as it did, we would have been without a missile warning capability in space," says a former Defense Department official.

It's not that anyone was gold-plating the satellites or dragging out production schedules. The whole system seems designed to produce massive, expensive satellites at a snail's pace.

"That often means [military] technology has fallen behind commercial capabilities," says Cheng of the Heritage Foundation.

Cheap commercial satellites

The Space Development Agency, with its planned 50-person staff, is supposed to address that problem.



▲ **A Delta rocket carries** the Delta Star satellite aloft in 1989. The satellite was part of a Strategic Defense Initiative Organization experiment.
U.S. Defense Department

"I have to find a way to bring all that wonderful capability out of the private sector and into the Defense Department and the intelligence community," Kennedy said in Utah.

One effort to do that is Blackjack, a DARPA campaign run by Kennedy's Tactical Technology Office to develop a constellation of small inexpensive military communications and surveillance satellites and associated ground systems.

To some Air Force leaders, the idea that the U.S. military can support troops around the world with inexpensive commercial satellites is ludicrous.

"Can you imagine doing missile warning with these cheap commercial things?" asks a senior Air Force official who did not want to be identified.

Before a military satellite is approved for a critical mission, it must show it can identify specific threats and report on them within a limited amount of time with an extremely high rate of reliability. "There is a role for experimentation, but it doesn't

PENTAGON MAKES ITS CASE

The U.S. Defense Department explained the role of the Space Development Agency in its Space Force proposal delivered to Congress on March 1.

"The Department of Defense has undertaken a series of space acquisition reforms to ensure the joint force has the capabilities necessary to deter and defeat threats. These acquisition reforms will continue with the establishment of a joint Space Development Agency (SDA) dedicated to rapidly developing, acquiring, and fielding next-generation military space capabilities. The SDA will transition into the Space Force, when established, to strengthen the foundation for space acquisition," according to a Defense Department brochure dated February 2019.

President Trump proposed creating the Space Force, a sixth branch of the U.S. armed forces, in legislation delivered to Congress in March. While awaiting congressional approval, the Defense Department plans to set up the Space Force within the Air Force.

The Space Development Agency will start out in the Office of the Secretary of Defense under the supervision of Michael D. Griffin, deputy undersecretary for research and engineering. Griffin also oversees: DARPA; the Missile Defense Agency, successor to the Strategic Defense Initiative Organization; the Defense Innovation Unit, which applies commercial innovation to military problems; the Strategic Intelligence Analysis Cell, an organization that assesses capabilities and vulnerabilities of the U.S. and potential adversaries; and the Strategic Capabilities Office, which seeks new applications for existing weapons.

As of early March, the Pentagon was not saying where the Space Development Agency would be located. Former Defense Department officials say it's likely to be in Washington, D.C., or northern Virginia.

— Debra Werner

replace analysis and planning because it has to be integrated in operations. It has to be used," the Air Force official adds.

True, the U.S. is not likely to rely on a commercial satellite for strategic nuclear missile warning, Loverro says, but that doesn't mean "we can't learn from Blackjack." Perhaps the military will end up buying its own 1,000-satellite missile warning constellation, he adds.

Blackjack sounds like a project right out of the Strategic Defense Initiative Organization's playbook. SDIO, precursor to the Missile Defense Agency, focused on rapid experimentation. Projects moved quickly with streamlined management. Program managers had authority to spend money and award subcontracts.

Also, SDIO wasn't focused on technological breakthroughs. Program teams often modified existing technology to achieve 80 percent of their goals within a year instead of aiming for 100 percent in five years, says an SDIO veteran who asked not to be identified.

On Delta Star, for example, an industry team added eight spectral filters to a commercial spectral imager with no filter. While the details are classified, the experiment helped SDIO home in on the spectral signature of a booster firing.

"This work contributed to the color selections for all U.S. ballistic missile defense seeker systems," says the SDIO veteran. "You didn't end up building an intercept that didn't see its target."

Another bureaucracy

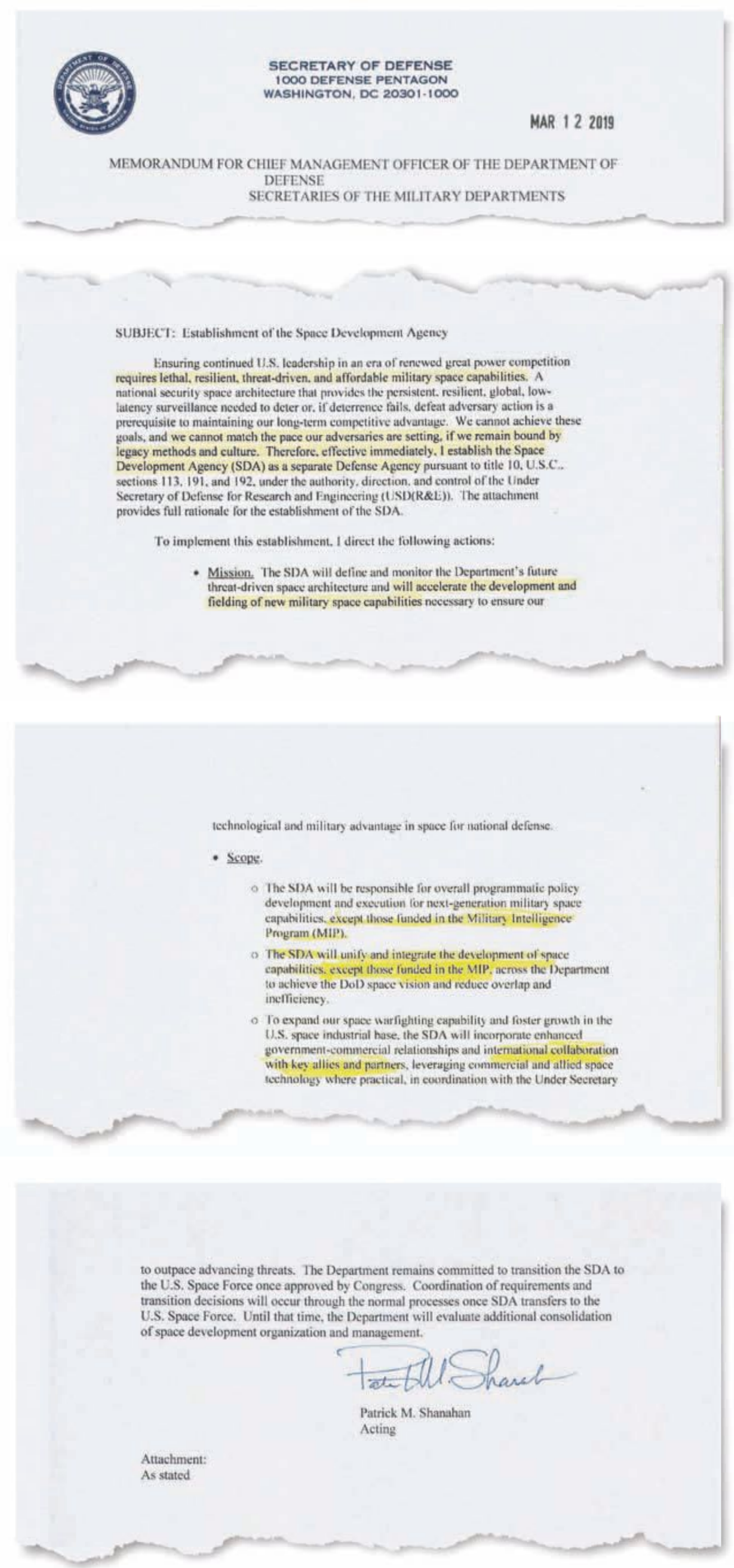
Experimentation and flight testing are valuable exercises, Air Force officials agree, but why establish a new agency for that?

"If you want an organization that can apply commercial technology and do things faster, why not do this in DARPA or the Space Rapid Capabilities Office?" asks the senior Air Force official.

The Government Accountability Office has frequently criticized military space programs, citing fragmented leadership, redundant oversight and the difficulty of coordinating work among numerous stakeholders.

The Space Development Agency will not set out to fix the military acquisition system, but rather to encourage more experimentation and risk-taking. Those who end up working for the Space Development Agency, like the people who worked in SDIO, will be focused on accomplishment, says the SDIO veteran.

Eventually, though, even the most innovative defense agency is likely to succumb to bureaucracy. "This is a government we're talking about, and government by definition spawns bureaucracy," Cheng says. ★



SECRETARY OF DEFENSE
1000 DEFENSE PENTAGON
WASHINGTON, DC 20301-1000

MAR 1 2 2019

MEMORANDUM FOR CHIEF MANAGEMENT OFFICER OF THE DEPARTMENT OF DEFENSE
SECRETARIES OF THE MILITARY DEPARTMENTS

SUBJECT: Establishment of the Space Development Agency

Ensuring continued U.S. leadership in an era of renewed great power competition requires lethal, resilient, threat-driven, and affordable military space capabilities. A national security space architecture that provides the persistent, resilient, global, low-latency surveillance needed to deter or, if deterrence fails, defeat adversary action is a prerequisite to maintaining our long-term competitive advantage. We cannot achieve these goals, and we cannot match the pace our adversaries are setting, if we remain bound by legacy methods and culture. Therefore, effective immediately, I establish the Space Development Agency (SDA) as a separate Defense Agency pursuant to title 10, U.S.C., sections 113, 191, and 192, under the authority, direction, and control of the Under Secretary of Defense for Research and Engineering (USD(R&E)). The attachment provides full rationale for the establishment of the SDA.

To implement this establishment, I direct the following actions:

- Mission. The SDA will define and monitor the Department's future threat-driven space architecture and will accelerate the development and fielding of new military space capabilities necessary to ensure our

technological and military advantage in space for national defense.

- Scope.
  - The SDA will be responsible for overall programmatic policy development and execution for next-generation military space capabilities, except those funded in the Military Intelligence Program (MIP).
  - The SDA will unify and integrate the development of space capabilities, except those funded in the MIP, across the Department to achieve the DoD space vision and reduce overlap and inefficiency.
  - To expand our space warfighting capability and foster growth in the U.S. space industrial base, the SDA will incorporate enhanced government-commercial relationships and international collaboration with key allies and partners, leveraging commercial and allied space technology where practical, in coordination with the Under Secretary

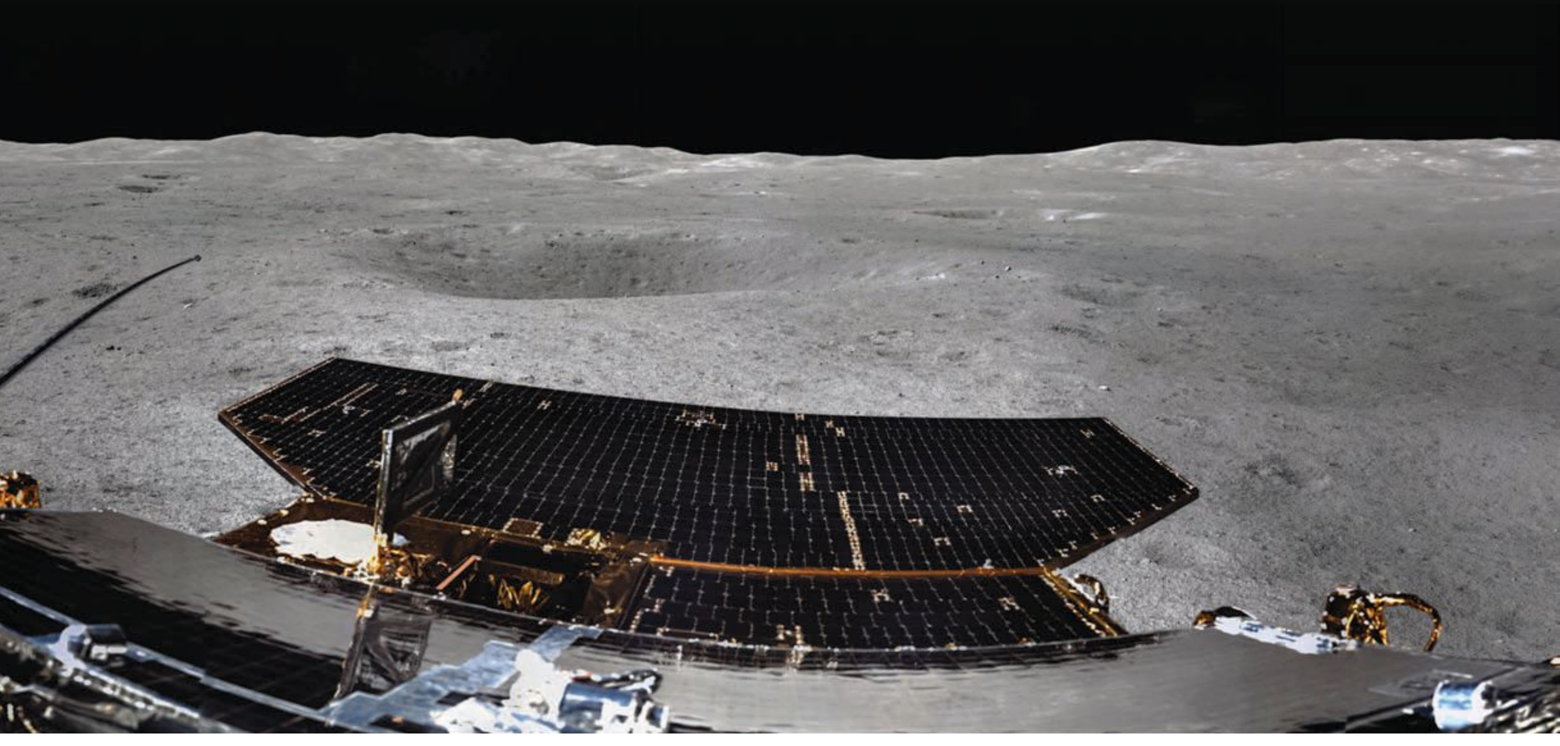
to outpace advancing threats. The Department remains committed to transition the SDA to the U.S. Space Force once approved by Congress. Coordination of requirements and transition decisions will occur through the normal processes once SDA transfers to the U.S. Space Force. Until that time, the Department will evaluate additional consolidation of space development organization and management.

Patrick M. Shanahan
Acting

Attachment:
As stated

Excerpts from the memo announcing the establishment of the Space Development Agency within the U.S. Defense Department.

LUNAR FAR SIDE COMES INTO FOCUS



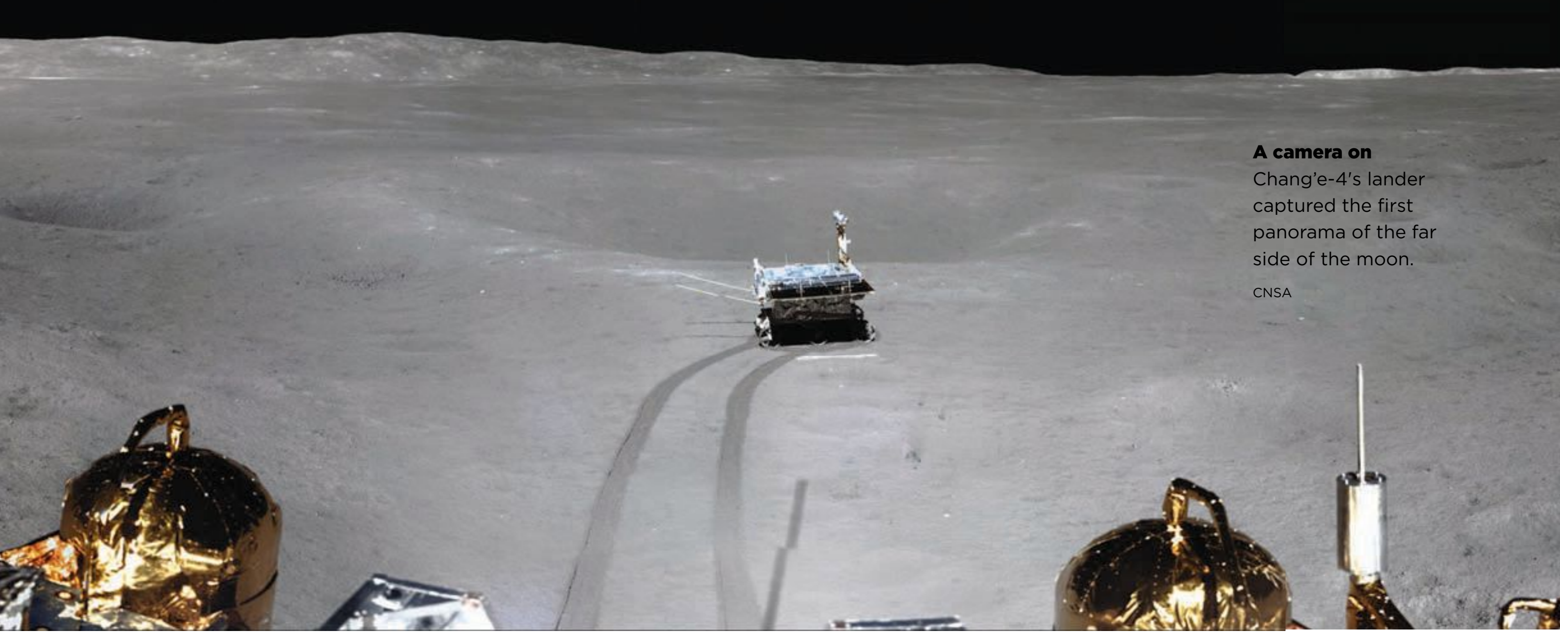
How China's January landing on the far side of the moon is helping open this neglected other half to science and human utilization.

BY ADAM HADHAZY | adamhadhazy@gmail.com

Cue "Star Trek's" Captain Picard pronouncing "to boldly go where no one has gone before." On Jan. 2, 2019, China did just that, landing a probe on the far side of the moon for the first time in human history. The three-month mission, named Chang'e-4, after a lunar goddess, augurs future opportunities for exploration and utilization, potentially impacting international policy regarding the so-called eighth continent.

"It's a remarkable feat," says James Head, a planetary scientist at Brown University in Providence, Rhode Island. "[Chang'e-4] demonstrates a lot of capability. It opens up a new scientific frontier."

It is not just the far side that's been making lunar headlines as of late. Following decades of relative quiet after the space race's heyday, Earth's nearest celestial neighbor is again quite the rage. Nothing had landed there since 1976 until Chang'e-4's predecessor, Chang'e-3, set down in 2013 on the visible side of the moon. This month, an Israeli company, SpaceIL, will attempt to land a spacecraft named Beresheet on luna firma, which would make its parent nation just the fourth to have pulled off the feat. Not to be outdone, NASA has ramped up its lunar activity, selecting nine companies in November to compete for $2.6 billion in contracts to land payloads on the moon (although the agency has not indicated if the far side is being considered). A few months after announcing these Commercial Lunar Payload Services invitees, NASA in February said it will co-develop reusable cargo ships, landers and ascent vehicles with the private sector for landing astronauts back on the moon come 2028.



A camera on Chang'e-4's lander captured the first panorama of the far side of the moon.

CNSA

Amid all this moon activity, the first far-side mission stands as a milestone. The moon, as many of us have gathered, always presents the same face to Earth. Researchers have long wanted to conduct science on the opposite side, known colloquially outside of scientific circles as the dark side (due in no small part to Pink Floyd) even though each hemisphere receives the same amount of sunlight. The reason for this desire: The moon is a tale of two hemispheres. The far side is starkly different, orbiting spacecraft have revealed. The far side exhibits very few maria — the plains of solidified lava flows that evoke famous near-side pareidolic features like the "Man in the Moon." The far side's crust is also thicker and more heavily cratered, for reasons not fully understood. "The far side is 'Luna Incognita'," says Head.

Far side conquest at last

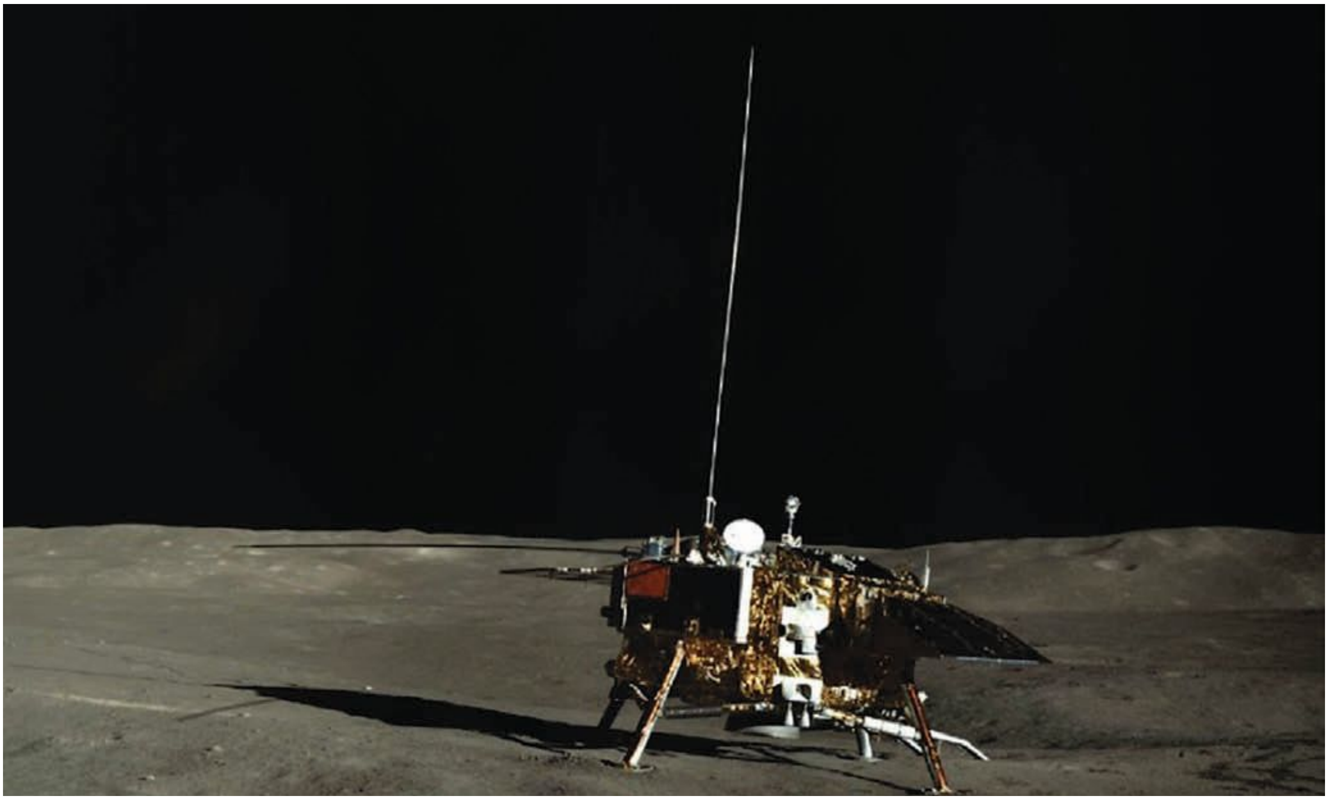
Although the technological capability has long existed to enter the moon's unknown lands, American, European and other planners have prioritized visits to more exotic and far-flung planetary locales. For instance, researchers submitted a far-side mission proposal, called MoonRise, in 2009 and 2017 to the third and fourth iterations of NASA's New Frontiers program, respectively. NASA funded further MoonRise development in 2010, but the OSIRIS-REx asteroid sample return mission proved that round's winner. For the fourth New Frontiers, MoonRise did not advance to the final round, with the winner to be announced in July 2019.

One key reason space agencies have historically balked at lunar far-side missions is the implicit encumbrance to operations there. "You have to create a 'bent pipe' for data to get back to the Earth, because there is no way to transmit it through the moon," says John Horack, the Neil Armstrong Chair in Aerospace Policy at Ohio State University.

The China National Space Agency took this necessary first step last May by inserting a relay communications satellite in a so-called halo orbit beyond the moon, an idea first broached in 1970 by Robert Farquhar, then a mission designer at NASA's Goddard Space Flight Center in Maryland. Farquhar, who died in 2015, suggested orbiting a satellite around the libration or Lagrange point, one of the locations in space where celestial gravity makes it possible to maintain a three-dimensional orbit with little propulsion for station-keeping purposes. "I tell my students to think of the orbit shape like a Pringles potato chip," says David Spencer, a professor of aerospace engineering at Pennsylvania State University. "It was named a halo orbit because the projection on the plane perpendicular to the Earth-moon orbit plane looks like it forms a halo around the moon when observed from Earth."

Today, China's relay spacecraft orbits about 60,000 kilometers beyond the moon, maintaining line-of-sight with both its far side and the Earth. The spacecraft — named Queqiao ("Magpie Bridge," from a folk tale) — has a 4.2-meter radio antenna that keeps mission controllers linked with Chang'e-4,

▼ **The Yutu-2 rover's** camera snapped this photo of the lander.



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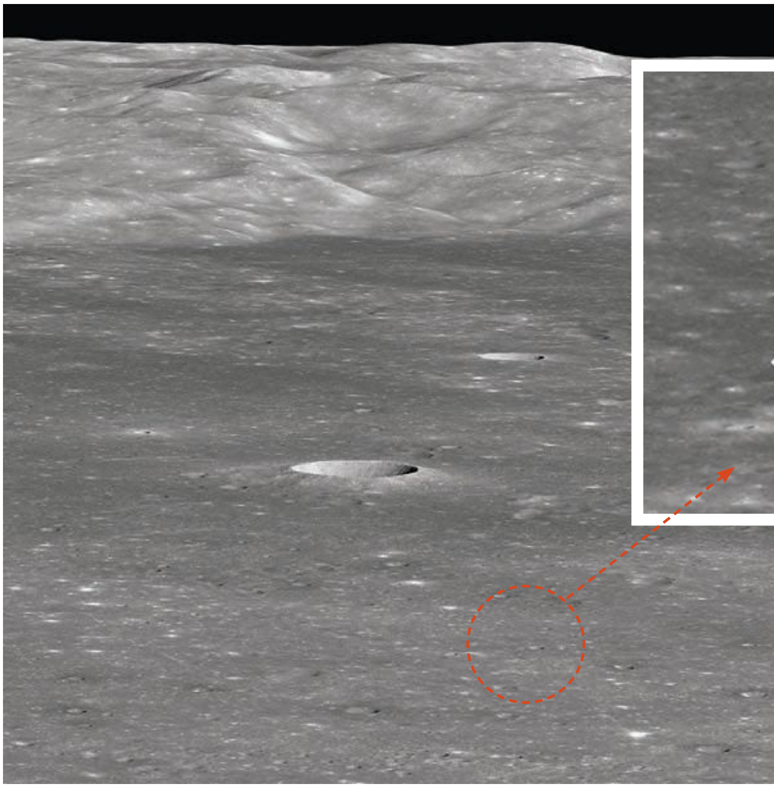
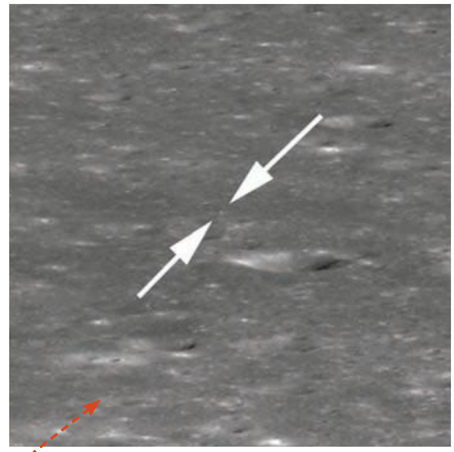


NASA/Arizona State

▲ **Arrows point to the** Chang'e-4 landing site on the moon's Von Kármán crater, which is about 440 meters across. NASA's Lunar Reconnaissance Orbiter shot this photo looking across the floor of the crater toward the west wall. The mountains are 3,000 meters high.



NASA/Arizona State University

◀ **The bright speck** between the two arrows is Chang'e-4.

much like satellites do at Mars for rovers and landers. With human lunar activity likely ramping up, Head suggests that the Chinese should eventually rent out bandwidth on Queqiao to commercial entities and international partners. "That's a really cool piece of infrastructure for future use," agrees Horack.

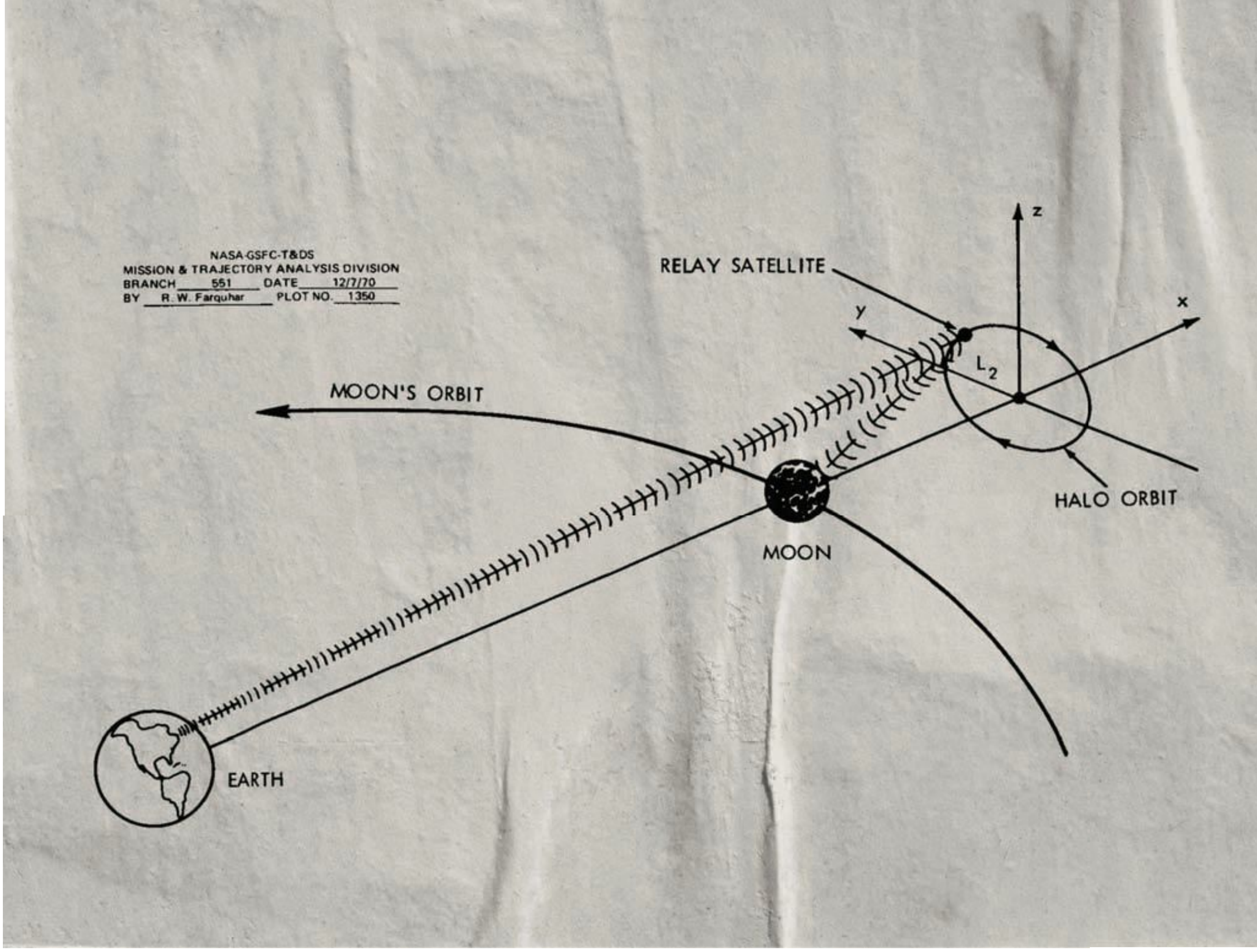
Despite this comlink, an inevitable three-seconds-plus, speed-of-light communications latency meant Chang'e-4 still had to autonomously handle the final stages of its own landing. Starting several kilometers above lunar pay dirt, Chang'e-4's descent camera fed coarse data into landing-hazard-avoidance algorithms, originally developed for and demonstrated with Chang'e-3. Then at around 100 meters, a hovering phase commenced, during which laser scanning gathered more granular data, identifying a safe, level place for Chang'e-4 to finally touch down.

The spot selected is inside the Von Kármán crater, itself inside the oldest, biggest crater on the moon, the South Pole-Aitken basin, which stretches 2,500 kilometers (1,600 miles) across. The basin is a prime science target because the impact that punched it 3.9 billion years ago likely gouged out material from the moon's otherwise-inaccessible upper mantle. Examining this exposed material could offer key insight into the moon's formation and evolution. Ancient Earth rocks could even be lying around in the basin, too, undisturbed since being deposited there by terrestrial meteorite impacts more than four eons ago, back when the young bodies of the Earth-moon system orbited much closer. "All of that record is essentially gone on the Earth," says Head. Finding such valuable terrestrial specimens extraterrestrially, Head adds, could significantly "feed into our knowledge of our own origin and evolution."

Further science opportunities abound on the lunar far side. Astronomers have long dreamed of constructing a radio telescope there in its pristine, electromagnetic-quiet zone — an ideal perch for gathering the low frequencies below 30 megahertz that are blocked by Earth's atmosphere. Radio waves in this band offer a window into a little-understood cosmological epoch, known as the Cosmic Dark Ages, after the Big Bang but before the first stars lit up and flooded the universe with other forms of radiation. Queqiao, the relay satellite, is advancing this endeavor with a Dutch-built radio antenna. Previous attempts in space to capture these frequencies have had to go with limiting, narrowband antennas to avoid picking up interference from the spacecraft itself. The Queqiao-borne instrument accounts for this interference, however, which will allow it to conduct a broadband characterization of radio spectrum characteristics out past the moon, helping demonstrate the potential for a dedicated far-side ground facility. "Radio astronomers would love to be there," says Head. "You can do some really great stuff."

The lunar road ahead

The Chang'e-4 mission is expected to last three months, thus potentially wrapping as of press time. Besides its robotic lander, it also has a rover named Yutu-2 ("Jade Rabbit"), which deployed onto the surface shortly after its mothership's moonfall. Payload-wise, instrumentation on the vehicles includes cameras and spectrometers to study surface composition, ground-penetrating radar, and a neutron dosimeter to study surface radiation. Nations that contributed payloads include Germany and Sweden, while Russia provided Chang'e-4's radioisotope



NASA

A 1970 paper by Robert Farquhar, a mission designer at NASA who died in 2015, first mentioned the idea of inserting a relay communications satellite in a halo orbit beyond the moon.

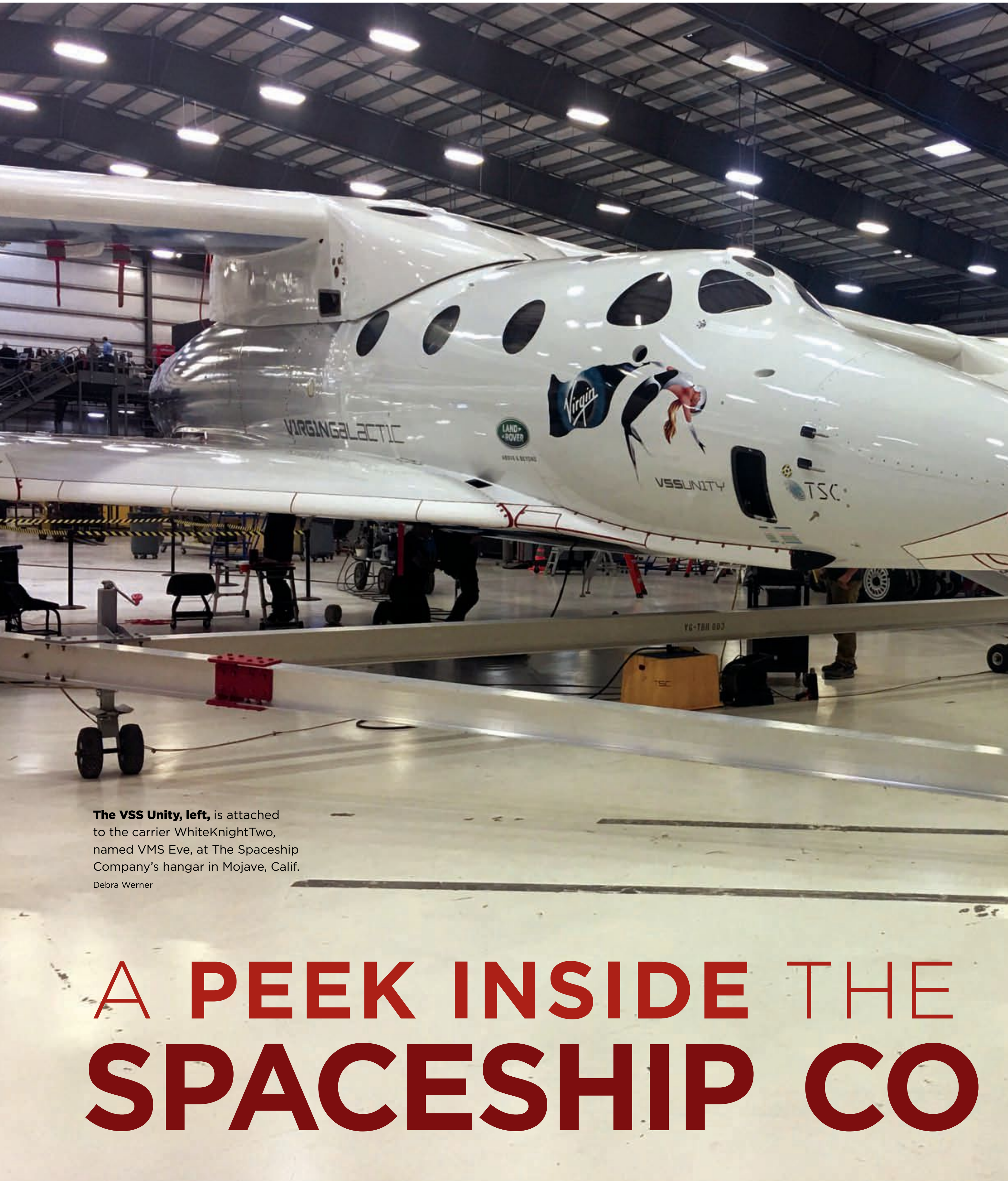
thermoelectric generator. Ground stations run by the European Space Agency are helping maintain communications for mission monitoring and control. The international cooperation extends to the United States, whose Lunar Reconnaissance Orbiter provided publicly available data to help assess Chang'e-4's landing zone, then confirmed its exact location post-landing during an overhead flyby on Feb. 1. Further reflecting the scientific camaraderie around the mission, Wu Weiren, an academician of the Chinese Academy of Engineering, announced that China will open the data gathered by Chang'e-4 to the global community, according to Xinhua, the nation's official state-run press agency.

Looking ahead, China is preparing Chang'e-5 to launch later this year. Operators intend for the probe to scoop up near-side samples of lunar material and rocket them to Earth for detailed analysis, according to other Xinhua reports. CNSA officials have also said that subsequent Chang'e missions might visit the lunar south pole. This region holds special interest because it is studded by permanently shaded craters containing primordial water ices. Lunar water could allow for in-situ resource utilization, perhaps someday by human explorers.

> **"You have to create a 'bent pipe' for data to get back to the Earth, because there is no way to transmit it through the moon."**
>
> — **John Horack** of Ohio State University

China has not announced firm plans for taikonaut missions to the moon as yet. To realistically do so, Horack points out that the country's launch vehicle capability would have to advance significantly to ferry enough supplies for an Apollo-style expedition. "The Long March heavy lift vehicle they've got has not demonstrated its reliability," he says, "and it's pretty small relative to, let's say, a Saturn 5."

Whatever China's lunar timeline — as well as the United States' — ends up being, Horack is optimistic that the next, more-intensive, longer-lasting and likely multinational era of human activity at the moon will proceed peacefully. The broad participation in Chang'e-4 bodes well for continuing scientific collaboration in lunar affairs, Horack says, following the precedent set by the International Space Station. "I'm very hopeful that the moon is the place where we extend the model of cooperation," he says. "Everybody has the moon on their mind. We should find a way to go together." ★



The VSS Unity, left, is attached to the carrier WhiteKnightTwo, named VMS Eve, at The Spaceship Company's hangar in Mojave, Calif.
Debra Werner

A **PEEK INSIDE** THE **SPACESHIP CO**

MPANY

After years of testing and one tragedy, Virgin Galactic plans to start flying tourists to space later this year. Debra Werner captures what the experience will be like.

BY DEBRA WERNER
werner.debra@gmail.com

It's surprisingly quiet when I enter an enormous hangar in Mojave, California, with a group of reporters. This is where The Spaceship Company is building Virgin Galactic's spaceplanes. Over the desert not far from here, Chuck Yeager piloted the Bell X-1 through the sound barrier, and test pilots flew early versions of the SR-71 spy planes and space shuttle orbiters.

Those feats were, of course, paid for and managed by the U.S. government. In contrast, the private companies Virgin Galactic and its rival Blue Origin hope to spark a space tourism economy by rocketing paying passengers to space this year to enjoy the view and some moments of weightlessness. Virgin Galactic has had only minor government assistance (NASA purchased some seats for research payloads, for instance).

George Whitesides, the company's chief executive, explains that some workers left early to rest before the next supersonic test flight scheduled for the following day at 7 a.m. If that schedule holds, a crew will return by midnight to load nitrous oxide propellant into the fuel tank of Virgin Space Ship Unity, the latest in a line of air-launched, rocket-propelled SpaceShipTwo vehicles. If all goes as planned, these vehicles will carry six tourists at a time to space on a 90-minute suborbital joy ride that will cost each passenger $250,000. The vehicle will be carried aloft by WhiteKnightTwo, a twin-fuselage aircraft with a 43-meter wingspan and two jet engines mounted on each wing. The WhiteKnightTwo carrier plane dominates the factory floor with VSS Unity slung beneath the center of the wingspan on three pylons. They also dwarf a red-and-black aerobatic trainer plane parked not far away. Pilots fly the Extra 300L to get used to the three to four G's

Debra Werner

▲ **Virgin Galactic pilots** fly this Extra 300L to acclimate to the G-forces they experience in SpaceShipTwo.

they will experience when WhiteKnightTwo releases them and a RocketMotorTwo kicks in.

Whitesides walks us over to Unity, an 18-meter-long carbon-fiber vehicle with twin tail booms that fold up alongside the fuselage during atmospheric re-entry (a process Virgin Galactic calls feathering). These fold down to act like wings with a 13-meter span for atmospheric flight.

Feathering was implicated in the 2014 accident that killed co-pilot Michael Alsbury and injured pilot Peter Siebold. The National Transportation Safety Board determined the co-pilot unlocked the feathering system of the VSS Enterprise too early, causing its twin tail booms to swing up prematurely. Aerodynamic loads ripped the spaceplane apart at an altitude of 50,000 feet. After the accident, Virgin Galactic modified the controls of the SpaceShipTwo design.

The craft I'm looking at now, I will learn later, traveled to space for a second time Feb. 22, two days after my visit instead of the next morning due to high winds. WhiteKnightTwo released Unity at an altitude of approximately 44,000 feet. Seconds later, chief pilot Dave Mackay and co-pilot Mike Masucci ignited the rocket plane's engine powered by hydroxyl-terminated polybutadiene with the liquid nitrous oxide propellant. Unity completed its first full-duration rocket burn, lasting about 60 seconds as it soared to 89.9 kilometers and reached Mach 3.04 before gliding back to the runway at the Mojave Air and Space Port. The entire flight lasted about 52 minutes.

It was Virgin Galactic's second flight beyond the 80-km mark, where NASA awards astronaut wings, and the first with a third crew member. Beth Moses, Virgin Galactic's chief astronaut instructor, unstrapped her seat belts and floated around the cabin to evaluate the experience for future passengers.

British billionaire Richard Branson, who established Virgin Galactic in 2004 and founded The Spaceship Company with aerospace engineer Burt Rutan in 2005, plans to ride aboard SpaceShipTwo's first tourism flight later this year. Branson's Virgin Group sponsored the test flight of Rutan's SpaceShipOne, the 5-meter-wingspan composite spaceplane that in 2004 won the Ansari X Prize by reaching altitudes of 103 and 113 km during flights five days apart. Virgin Galactic's SpaceShipTwo draws on the design of SpaceShipOne but is much larger with seats for two pilots and six passengers.

As of early March, 600 people from 58 countries had made fully refundable deposits to fly on Virgin Galactic's spaceplanes.

We walk behind a gray curtain in a corner of the hangar and are shown a curved video screen and a replica of a SpaceShipTwo cockpit, including the pilot and co-pilot seats. This simulator is where pilots train, complete with visuals and sound effects. Someone clicks the simulator on, and we see the view awaiting Virgin Galactic's passengers. WhiteKnightTwo takes off and climbs into a

The Spaceship Company

▲ **The carrier plane** WhiteKnightTwo takes off with VSS Unity for its second test flight.

cloudless desert sky. After a few minutes, the spaceplane is released. It falls momentarily and then the rocket roars to life. We climb almost straight up for about 90 seconds, accelerating to about three times the speed of sound. When the rocket motor finishes firing, the spaceplane's momentum continues to carry us higher, but there's almost no sound. "You get a sense of the stillness of the experience," Whitesides says.

The simulated view is breathtaking, and it makes me wonder if someday when space travel becomes more common and the price comes down, I might catch a ride on a spaceplane.

At the apogee, we level off. On a real mission, this is when the passengers would float from their seats to experience between three and five minutes of weightlessness. On the video screen, we see a view like the one out the spaceplane's 12 windows. As Whitesides puts it, it's an "amazing vista of planet Earth beneath us." We start gliding back toward Earth and make a runway landing at Mojave. Test flights are being done here at Mojave before operations begin at Spaceport America in New Mexico, an FAA-licensed facility for vertical and horizontal launches adjacent to the U.S. Army's White Sands Missile Range.

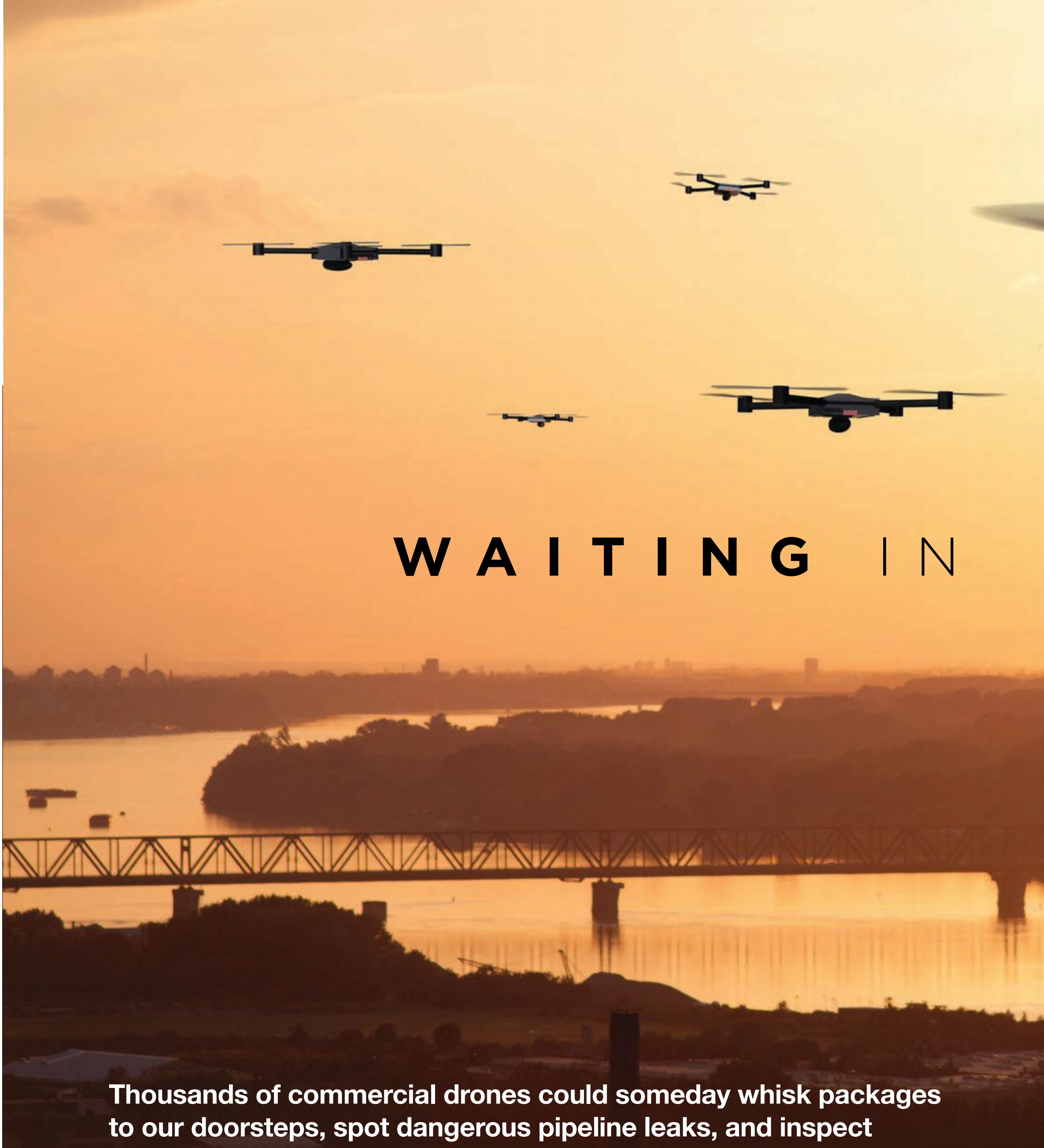
Whitesides won't say how many more test flights he expects, but the next series will focus on making sure Unity "flies that way every time," says Mike Moses, Virgin Galactic president.

Getting 600 passengers to space and back will require operating more than one spaceplane. On the factory floor, Virgin Galactic is assembling its next two. For the first one, the nose and aft portion of the fuselage are nearly completed along with the spherical oxidizer tank that goes in the middle. Workers have also finished building the tail booms in a separate facility.

"We are very close to bonding together the fuselage," says Enrico Palermo, The Spaceship Company president. "The main structural part remaining is the booms and the feather." Over the next year, workers will finish installing the wiring, brakes and other components.

It's taking Virgin Galactic far longer than expected to begin paid flights. When Branson established the company, he wanted to start flying customers in 2007. If it's any consolation, competitor Blue Origin, the commercial space tourism company started in 2000 by billionaire Amazon founder Jeff Bezos, isn't carrying passengers yet either.

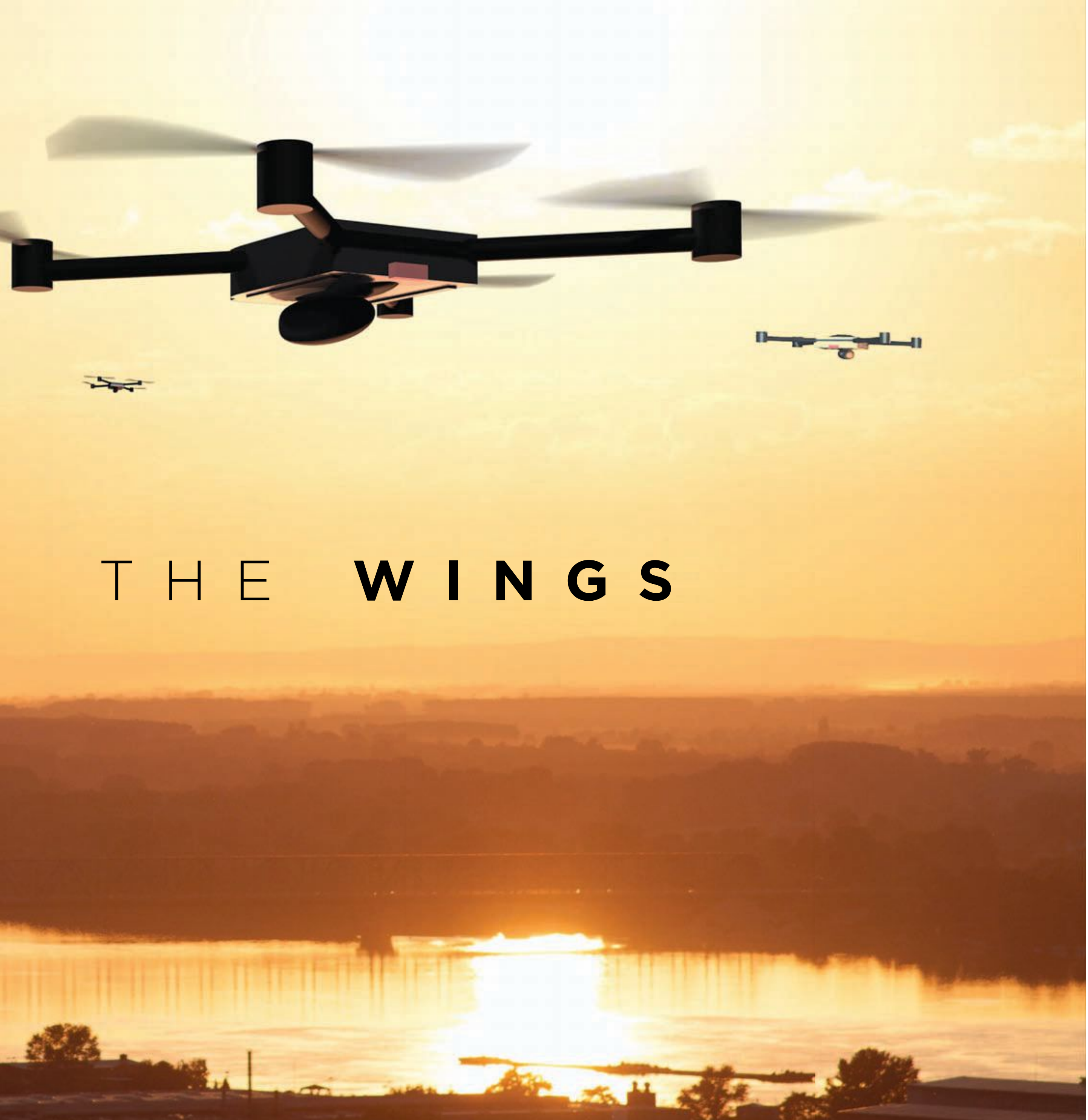
As of early March, Blue Origin had performed 10 uncrewed flight tests of New Shepard, the vertical takeoff and landing spacecraft comprised of a six-passenger capsule and a booster powered by Blue Origin's liquid hydrogen and liquid oxygen-fueled BE-3 engine. Blue Origin's capsule reached an altitude of 106.9 km on Jan. 23 after lifting off from the company's West Texas launch site. Like Virgin Galactic, Blue Origin plans to bring people onboard sometime this year. ★



WAITING IN

Thousands of commercial drones could someday whisk packages to our doorsteps, spot dangerous pipeline leaks, and inspect bridges and crops. A revolution of that scale would require accepting that drones must fly out of visual range of their operators. That can't happen unless the FAA approves a scheme for safely managing thousands of drone flights. David Hughes, formerly an FAA writer and editor, gauges progress on UTM, or unmanned aircraft system traffic management.

BY DAVID HUGHES | dhaviation@gmail.com



THE **WINGS**

Andy Thurling, a former U.S. Air Force test pilot, had an epiphany back in 2012 while analyzing the safety case his employer at the time would need to make to the FAA to win permission to fly 7-kilogram drones beyond visual range for pipeline inspections and other applications. He felt confident that the risk of colliding with passenger planes could be addressed through geofencing, in which software and GPS keep the drones from flying into prohibited airspace, such as near airports. He realized the bigger problem would be proving to the FAA that the drones would not collide with other drones, or with conventionally piloted crop-dusting planes or helicopters that also fly at low altitudes.

As it turned out, NASA had realized much the same thing. Looking into matters, Thurling talked with Parimal Kopardekar of NASA's Ames Research Center in California. Kopardekar was about to start an ambitious multiyear research initiative in collaboration with the FAA to define the best sensors, software and strategy for managing commercial drone flights beyond line of sight.

"As long as you have more than one vehicle going, you need some sort of management system," says Kopardekar, the principal investigator for NASA's UAS Traffic Management initiative, or UTM.

Package delivery to consumers alone could put thousands or hundreds of thousands of drones in the air over the U.S., compared to today's count of about 5,000 conventionally piloted aircraft in the air at any one time.

After seven years, some in the commercial drone field are beginning to get anxious that all the prerequisites for making UTM a reality are not yet in place. FAA has established an overall concept of operations, but not the performance requirements for the drones that would operate within that UTM.

"The friction will come when the drone industry is ready to go and the government is not," says air traffic management consultant Charlie Keegan, who once led air traffic modernization at the FAA and is a former chairman of the Air Traffic Control Association.

Since 2012, Kopardekar's team has spent an average of $18 million a year on UTM and conducted three field tests, and is about to start a fourth. At least one test involves 20 drones in the air plus simulated drones. The focus is on operations beyond the view of operators in airspace below 400 feet. The FAA last May adapted what it learned through the NASA project and released a detailed concept of operations for UTM, which is part of what's needed to make UTM a reality.

The current national airspace system will not be able to handle the growth and air traffic demand that is coming, says consultant John Walker, a former senior official at the FAA who is involved with international regulatory bodies working on UTM.

He thinks emerging aerospace technologies in UTM and other areas of UAS activity such as international flights by larger drones under instrument flight rules will tip the scales to produce the largest changes in civil aviation since the introduction of radar, the jet engine or GPS. And UTM alone is already forcing the international community to establish new flight rules.

For UTM to happen, the system must be safe enough to be verified and approved by the FAA. Only then can commercial operations begin on a large scale and with money-making efficiency. The FAA says in an email the agency is working to achieve this objective but that it must still roll out the rules, policies and standards needed to make it happen. FAA did not offer a timeline.

Today, the FAA permits commercial drone flights only if operators keep their drones in sight over sparsely populated areas, or if they receive waivers. The agency has granted about 2,400 of these waivers so far. The commercial market is already sizeable, with 316,000 of the 1.3 million drones registered in the U.S. listed for commercial use, said Transportation Secretary Elaine Chao to an audience at the U.S. Chamber of Commerce's Aviation Summit in March.

It is one thing to have a single drone inspect a bridge as a pilot on the ground watches and another thing to have multiple drones looking at lots of bridges beyond visual line of sight, says Thurling, who is now chief of technology at the not-for-profit Northeast UAS Airspace Integration Research Alliance in upstate New York. His group runs one of the FAA drone test sites chosen by the agency in 2013 to help integrate drones into the national airspace system.

The FAA is working with NASA to define the requirements for data exchange, communications and navigation. The FAA through a pilot program is demonstrating a prototype of the data exchange approach. "The rollout of UTM will be incremental in nature, and will be done through increasingly complex capabilities, rules, policies and standards," the FAA statement said.

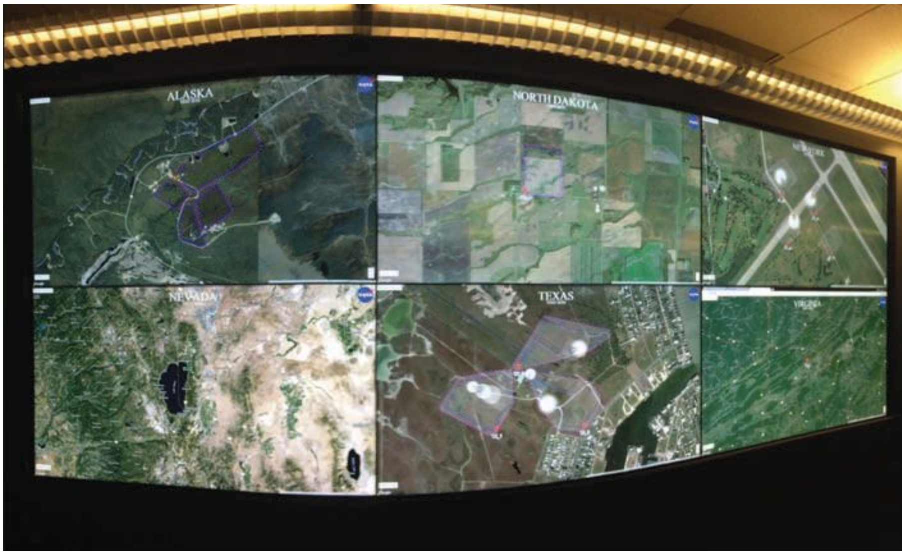
How UTM might work

Because of the anticipated volume of flights, UTM will be different from management of conventional flights, in which a pilot talks over a radio to an air traffic controller and exchanges data. Commercial drones are going to need a good dose of automation to deconflict themselves and stay clear of other aircraft, and one operator might control multiple drones.

Kopardekar explains that in the UTM concept multiple unmanned aircraft would inform each other about their "intents," meaning their flight plans or intended areas of operation. The plans are made from the start to avoid other drones as much as possible and everyone takes some responsibility for separation, he says.

Third parties called UAS service suppliers are expected to coordinate, execute and manage small drone operations in part by sharing information with each other. The FAA sets the rules of the road and provides oversight, but air traffic controllers won't be conducting UTM.

The traditional air traffic control human-in-the-loop scheme won't work for thousands of drones



▼ **In 2015, NASA's Ames** Research Center said it was testing the drone traffic mangement concept at six sites in the U.S.

▲ **European Commission** countries have started a program called U-Space to develop drone traffic management regulations.
European Commission

flying below 400 feet. "Do you think Amazon is going to make any money delivering packages if they have to have one pilot for every drone? That isn't going to happen," says Thurling. "There is no human controller managing individual aircraft in the UTM construct and its counterpart above 60,000 feet [where long-endurance commercial drones may operate]. A team of humans will monitor a large area."

Amit Ganjoo, chief executive officer of ANRA Technologies, a startup that makes UTM software, underscores this point. "Right now in UTM testing there is always at some point a human in the loop, but in the long term most of it is going to be automated and cellphone-driven."

However, an FAA official says when a drone operates where the FAA provides separation of aircraft, it will have to comply with all air traffic rules in that airspace.

Advice from the industry

Some see opportunities for speeding up progress.

"We haven't taken the opportunity to step back and consolidate what we have learned into performance requirements. That is something the community has fallen down on," says Thurling.

Groups that have a stake in the use of low-altitude airspace are asking some hard questions. The Academy of Model Aeronautics, for example, wants to make sure that its members who have been flying model aircraft with an excellent safety record for 80 years are not penalized by unnecessary new requirements. "We want to caution the FAA and industry that they can't push recreation out of the way to make way for new commercial operators," says Tyler Dobbs, government affairs director for the group.

Private-sector money may turn out to be the driving force that makes UTM happen. Venture capitalists are funding some of the proposed business models for drones — such as package delivery — that will need to have a UTM system in place. These private companies aren't waiting on government research or contracts for new technology to trickle down, according to Keegan. "They are using private equity to rapidly build the necessary elements for drone support systems (akin to UTM), collecting information and using it for safer flights with very little oversight from the government," he said in an email.

There is a strategic shortcoming that could stand in the way of getting UTM ready to go, cautions consultant Neil Planzer, who once led Boeing's air traffic management organization and has held senior positions at the FAA and the U.S. Air Force.

The problem is that drone operators and governments around the world are testing the technology needed for safe operations to then create an overall strategy.

"This is a backward way of doing it," he says.

He thinks what is needed is a top-down UTM strategy to produce a system that can be certified as safe. "I would have a blue-ribbon group established by the United States to look at how we are going to integrate unmanned aircraft in the system, not from

The impact of drone control on ATC

New ways of conducting operations and technologies never before used in aviation could filter gradually from the drone world into management of conventionally piloted aircraft.

Those in the air traffic business refer to this as convergence.

Specifically, the Unmanned Aircraft System Traffic Management strategy envisions drones communicating with each other and with private-sector service providers over cellular networks. The service providers would deconflict drone flights by sharing the intended flight paths with each other.

Convergence was the subject of a pivotal meeting at NASA's Ames Research Center in 2017 that attracted lots of luminaries in air traffic management from around the world. The FAA's view is that convergence won't be like throwing a switch even though UTM has the potential to enhance traditional air traffic management in the long run.

At Eurocontrol drone manager Mike Lissone also predicts evolutionary rather than revolutionary adoption of technologies pioneered in the drone world. Pilots flying under visual flight rules, for example, might benefit from the beyond-line-of-sight control developed for low altitude for unmanned aircraft.

"It is time to embrace the future and to see how we can improve the overall system," says Lissone.

The automation coming out of the UTM world might help controllers handle more traffic, predicts air traffic consultant Neil Planzer, formerly of Boeing, the FAA and the U.S. Air Force. He says in an email that automation is the only way to handle high volumes of drone traffic at low altitudes with ATC between controllers and pilots above this level continuing as it works today. Planzer sees no loss of controller positions.

— David Hughes

▲ **A test pilot controls** a virtual drone during a NASA test. His headset connects him to air traffic control.
NASA

a detailed technical but from a strategic standpoint," he says. "What are the policies, procedures and requirements for safety that we need to consider and then move down from the strategy to the tactical." He would give such a high-level group just six or nine months to complete its work.

As an example of the type of group he has in mind, he cites the National Civil Aviation Review Commission led by former Transportation Secretary Norman Mineta. That commission was charged with addressing traffic congestion and safety. The commission's 1997 report prompted the creation of the FAA's performance-based Air Traffic Organization and other changes. Planzer thinks a UTM panel needs to be led by someone of Mineta's stature.

Planzer also suggests a European group might do its own analysis and then the results of the two efforts could guide the International Civil Aviation Organization, which recommends practices to its 180 member nations. Walker says Japan is already doing something along these lines.

Europe has similar concerns about the overall strategy. Mike Lissone, who is the drone manager for Eurocontrol, says nations in Europe need to analyze airspace and set requirements for new entrants. "What is mostly happening now is the other way around as they allow drones to fly and find out later what is actually necessary to operate them safely. That is not the way we ordinarily do things in aviation." Europe's UTM effort is called U-Space, and it is focused initially on altitude below 500 feet, but it is not restricted to low altitudes.

International standards

Thurling and others want the global drone community to develop standards for drone performance that specify the requirements needed for a safe system.

Today, there are at least a half dozen standards and advisory organizations in the United States, Europe and the Asia-Pacific region addressing UTM standardization. The FAA engages with all of them. Safety regulators from 59 nations, including the FAA, are also working together informally on the Joint Authorities for Rulemaking on Unmanned Systems. The group has published a risk assessment methodology to scope out the safety of UTM operations. But when it comes down to implementing a UTM system in the U.S., only the FAA can mandate what has to happen to create a safe system.

> "THE FRICTION WILL COME WHEN THE DRONE INDUSTRY IS READY TO GO AND THE GOVERNMENT IS NOT."
>
> **— Charlie Keegan**, air traffic management consultant

Walker says the Global UTM Association, an international consortium of drone and UTM companies, air navigation service providers and other groups that want to influence UTM developments, is trying to corral all of these efforts around the world. The association is trying to make sure standards and advisory bodies are not duplicating efforts or publishing guidelines that disagree with each other so that everything is aligned, Walker adds. But it won't be easy.

Ganjoo says everything has to be standardized from air vehicle performance to the technical specification of how data will be exchanged between systems. And he worries there will be some level of fragmentation in the next few years as various nations try to own a piece of the puzzle as new things bubble up and go live. Then after the fact, all of the various schemes will have to interoperate.

Whether the international paths will converge remains an open question, as does the timeline for finalizing a UTM system in the U.S. And with the cycle of technology development in the computer age serving up new things in a year and a half while government regulatory cycles around the world run at more like five years, there is probably some conflict on the horizon between commercial drone innovators and government approvers. ★

@CHANG_E_4/Twitter

Johns Hopkins University Applied Physics Laboratory

◀▼ The control rooms of the Chinese Chang'e-4, left, and the U.S. New Horizons probes as they made history on the far side of the moon and in deep space.

There is no space race

The term has been a handy label since the Apollo era, but a space race is not what's playing out today between the United States and China. Space analyst John Logsdon offers a more nuanced view of the dynamic and what it might mean in the years ahead.

BY JOHN M. LOGSDON

After China landed its Chang'e-4 spacecraft and Yutu-2 rover on the far side of the moon in January, the Washington Post published an alarmist opinion essay under the headline "The new space race pits the U.S. against China. The U.S. is losing badly."

Viewing the U.S.-China space relationship as a race was typical of much of the commentary following the Chang'e-4 success. But characterizing U.S. competition with China as a race distorts reality in an unfortunate way, since it underestimates the stakes. The phrase suggests a zero-sum contest to be first to reach a defined finish line. In reality, the situation is nothing like the 1960s when the U.S. and Soviet Union competed to be first to send humans to the lunar surface and return them to Earth. That scenario was indeed a race. Once a race is won, there is little incentive to keep racing. That's why upon winning the race to the moon, the U.S. cut short Project Apollo and lowered its ambitions in space.

The current U.S.-China relationship is not such a race. It is not driven by schedule or deadlines or by seeking a specific goal. Rather, it is an ongoing, high-stakes competition for space achievements and innovative approaches to accomplishing them. Both countries are setting out space plans that reflect their own interests and aspirations rather than the quest to be "first."

Competition in space is taking place in the context of the broader contest of developing advanced technologies such as artificial intelligence, quantum computing, advanced pharmaceuticals and high-value manufacturing. Both countries recognize that a leading position in such areas is the foundation of 21st-century economic and military power. Both aspire to be at the leading edge of technological innovation.

The competition is also geopolitical. The U.S. intends to remain the world's leading power and guarantor of a world order based on democratic politics and free market economics, a position it has held since the end of World War II. China is challenging that hegemonic status, seeking to become the dominant global country, spreading its authoritarian approach to governance and its state-centered approach to social and economic development. Both countries recognize that space achievements, in addition to their tangible benefits, remain potent symbols of a nation's vitality. NASA Administrator Jim Bridenstine, as Chang'e-4 landed, tweeted "this is a first for humanity and an impressive accomplishment!" The recognition that China was first to land on the lunar far side is an example of the continuing propaganda value (defined as "sending a message") of visible space accomplishments. That China got more propaganda benefit from the Chang'e-4 landing than the U.S. did from flying the New Horizons probe precisely by the space rock Ultima Thule 6 billion kilometers from Earth suggests the advantage of being the new entry in the space competition.

In that ongoing competition, the reality is that both countries can take a leading position — there is no need for there to be only one leader. Shared space leadership is not a foregone conclusion, however. Recent history suggests that a democracy like the U.S. faces severe challenges compared to authoritarian China in making a sustained commitment to space. Authoritarian governments with continuity in their leadership have the advantage of setting out a plan and sticking to it. Since 1992, when China first stated its intent to develop the capabilities needed to send humans into orbit, it has announced a series of long-term plans for space and accomplished almost exactly what those plans projected. Meanwhile, as each U.S. administration since 2004 has declared resuming human travel beyond Earth orbit as its objective, strategies for accomplishing that goal have varied widely, and progress has come in fits and starts. If the U.S. is to remain in a leading space position, it needs to carry out the kind of effort that is stated in the Trump administration's Space Policy Directive-1, which calls for NASA to "'lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system."

Here may lie the real challenge to the U.S.: Can our republican system of government, aimed at accommodating diverse interests, retain enough focus on any long-term activity to stay at its cutting edge for decades? Doing so will require combining the energy and ambitions of the U.S. private sector with government interests in space to create an effort that will be competitive with China's open-ended push toward space dominance. There is no finish line in this competition.

There might also be room for cooperation between China and the U.S., in parallel with their competition. Today, the governments consult on issues of space safety and security, but congressionally initiated restrictions block discussions of mutual interests at the space program level. It may be that China's continued flaunting of the rules of international trade and technology exchange make any meaningful collaboration in civilian space activity impossible. But that will be impossible to discover if the two countries' space leaders cannot talk to one another. Meanwhile, European Space Agency astronauts are learning Chinese and training in Beijing for missions aboard China's forthcoming space station, and China has agreed with the United Nations to host international research projects aboard its orbital outpost. It is not in the U.S. interest to stand aside as China reaches out to work with other countries.

Just as the U.S.-Soviet Cold War relationship was the dominant feature of international relations in the second half of the 20th century, competition between the U.S. and China will define the coming decades. Writing in the New York Times in February, David Brooks asked: "If China is an existential threat to the liberal international order, do we have the capacity to improve our system so it can face the challenge — to invest in human capital, to reform our institutions, repair the social fabric and make our political system function once again?" The U.S.-China space competition can serve as one arena for answering that question. ★

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

2019

AEROSPACE SPOTLIGHT

Awards Gala

Wednesday, 15 May 2019

Ronald Reagan Building and International Trade Center
Washington, D.C.

Please celebrate with esteemed guests and colleagues in Washington, D.C., when AIAA recognizes individuals and teams for outstanding contributions that make the world safer, more connected, and more prosperous.

Presentation of Awards

AIAA Goddard Astronautics Award – John L. Junkins, Texas A&M University

AIAA Reed Aeronautics Award – Philippe R. Spalart, The Boeing Company

AIAA Distinguished Service Award – Klaus D. Dannenberg, AIAA (retired)

AIAA Public Service Award – Pamela A. Melroy, Melroy & Hollett Technology Partners and Nova Systems

AIAA Lawrence Sperry Award – Katya M. Casper, Sandia National Laboratories

Reserve your corporate table!

Contact: Chris Semon, ChrisS@aiaa.org | Vickie Singer, VickieS@aiaa.org | Paul doCarmo, PaulD@aiaa.org

aiaa.org/Gala-2019

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AIAA Bulletin

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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).

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

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

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

Calendar

FEATURED EVENT

AIAA AVIATION Forum

17–21 JUNE 2019

Dallas, Texas

The 2019 AVIATION Forum will explore how rapidly changing technology, new entrants, and emerging trends are shaping a future of flight that promises to be strikingly different from the modern, global transportation built by our pioneers. Take advantage of early member rates and register today.

aviation.aiaa.org/register

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2019			
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/StudentConferences)	
4–5 Apr	Region V Student Conference (University of Minnesota Student Branch)	Minneapolis MN (aiaa.org/StudentConferences)	
5–6 Apr	Region I Student Conference (University of Maryland Student Branch)	College Park, MD (aiaa.org/StudentConferences)	
5–7 Apr	Region III Student Conference (Cleveland State University)	Cleveland, OH (aiaa.org/StudentConferences)	
6–7 Apr	Region VI Student Conference (California Polytechnic State University Student Branch)	San Luis Obispo, CA (aiaa.org/StudentConferences)	
2–3 May*	Improving Space Operations Workshop	Santa Clara, CA (info.aiaa.org/tac/SMG/SOSTC)	
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)	

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
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
16–18 Aug	Rocket Testing Workshop at Purdue	Indianapolis, IN	
17–18 Aug	Missile Propulsion Course	Indianapolis, IN	
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
26–27 Sep*	CEAS-ASC Workshop 2019 on Advanced Materials for Aeroacoustics	Rome, Italy (https://www.win.tue.nl/ceas-asc)	
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
14–16 Jan*	2nd IAA Conference on Space Situational Awareness	Washington, DC (icssa2020.com)	
27–30 Jan*	66th Annual Reliability & Maintainability Symposium (RAMS®)	Palm Springs, CA (www.rams.org)	
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)	
14–18 Sep*	32nd Congress of the International Council of the Aeronautical Sciences	Shanghai, China (icas.org)	15 Jul 19

● AIAA Continuing Education offerings

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

2019 AIAA Election Results

AIAA is pleased to announce the results of its 2019 election.

AIAA President-Elect
Basil Hassan, Sandia National Laboratories

Director–Region IV
Sarah Shull, NASA Johnson Space Center

Director–Region V
Orval "Rusty" Powell, Millennium Engineering and Integration Company

Director–Aerospace Outreach Group
Tucker Hamilton, United States Air Force

Director–Integration Group
Peter Hartwich, Boeing Engineering, Test & Technology

Director–Information Systems Group
Allan "Terry" Morris, NASA Langley Research Center

Director–Propulsion and Energy Group
Joaquin Castro, Aerojet Rocketdyne

The newly elected will begin their terms of office in May 2019.

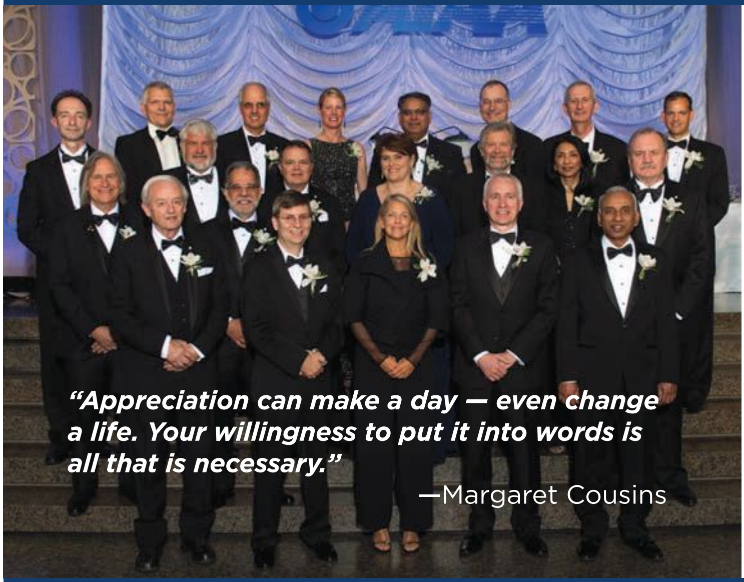
Annual Business Meeting Notice

Notice is hereby given that the Annual Business Meeting of the American Institute of Aeronautics and Astronautics will be held at the Hilton Crystal City at Washington Reagan National Airport, Arlington, VA on Monday, 13 May 2019, at 1:00 PM.

Christopher Horton,
AIAA Governance Secretary

Nominate Your Peers and Colleagues!

Do you know someone who has made notable contributions to aerospace arts, sciences, or technology? Bolster the reputation and respect of an outstanding peer—throughout the industry. **Nominate them now!**



Candidates for SENIOR MEMBER

- Accepting online nominations monthly

Candidates for ASSOCIATE FELLOW

- Acceptance period begins 1 February 2019
- Nomination forms are due 15 April 2019
- Reference forms are due 15 May 2019

Candidates for FELLOW

- Acceptance period begins 1 April 2019
- Nomination forms are due 15 June 2019
- Reference forms are due 15 July 2019

Candidates for HONORARY FELLOW

- Acceptance period begins 1 January 2019
- Nomination forms are due 15 June 2019
- Reference forms are due 15 July 2019

Criteria for nomination and additional details can be found at
aiaa.org/Honors

AIAA
SHAPING THE FUTURE OF AEROSPACE

Recognizing Top Achievements – An AIAA Tradition

For over 80 years, AIAA has been committed to ensuring that aerospace professionals are recognized and celebrated for their achievements, innovations, and discoveries that make the world safer, more connected, more accessible, and more prosperous. AIAA continues to celebrate that pioneering spirit showcasing the very best in the aerospace industry. The following awards were presented from October 2018 to January 2019.

Presented at the Joint Conference of the International Communications Satellite Systems Conference (ICSSC) and the Ka and Broadband Communications Conference (Ka), 15–17 October 2018, Niagara Falls, Canada

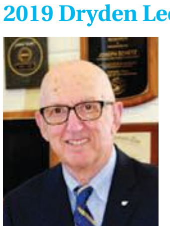
2018 Aerospace Communications Award

John Baras
Professor, Lockheed Martin Endowed Chair in Systems Engineering
University of Maryland
For outstanding technical contributions and commercialization leadership of Internet over satellite, hybrid satellites, and terrestrial networks, with transformational industrial, economic and societal impact.

Presented at AIAA SciTech Forum, 7–11 January 2019, San Diego, California

Distinguished Lectures

2019 Dryden Lecture in Research



Joseph A. Schetz
Holder of the Fred D. Durham Chair
Virginia Polytechnic Institute and State University
"Truss-Braced Wing Designs for High-Speed Transport Aircraft"

2019 Durand Lecture for Public Service

Douglas L. Loverro
President, Loverro Consulting LLC
Former Deputy Assistant Secretary of Defense, Space Policy, U.S. Department of Defense
"Guarding the 'High Frontier' and Preserving Its Capability for Commercial Use – What Is Necessary to Assure a Secure Future for Our Nation and a Thriving Space Industry"

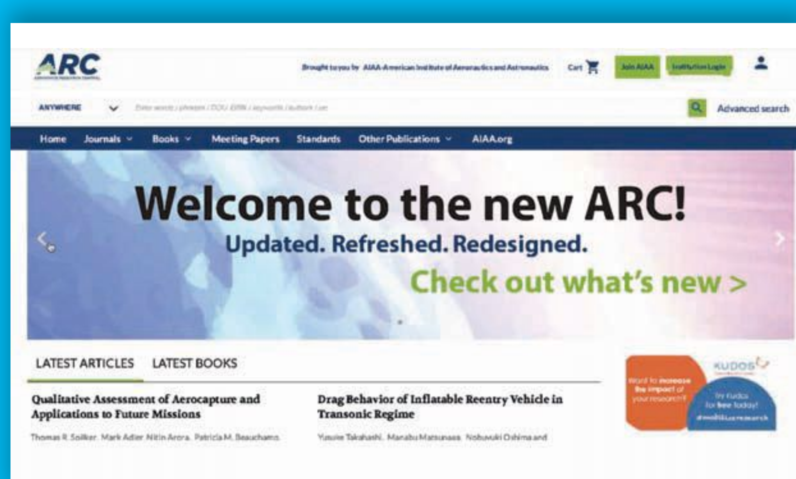
Education Awards

Abe M. Zarem Award for Distinguished Achievement in Aeronautics

Geoffrey Andrews, Purdue University
"A Hybrid Length Scale Similarity Solution for Swirling Turbulent Jets"

Abe M. Zarem Educator Award in Aeronautics

Gregory Blaisdell, Purdue University



Abe M. Zarem Award for Distinguished Achievement in Astronautics

Ken Mitchell
University of Memphis
"Thermal Conductivity and Specific Heat Measurements of an RTV-655/Polyimide Aerogel Compound at 77K and 298K"

Abe M. Zarem Educator Award in Astronautics

Jeffrey Marchetta, University of Memphis

2018 J. Leland Atwood Award

Joseph C. "Joe" Majdalani
Auburn University
For significant contributions to the aerospace engineering profession through sustained technical achievements in the field of propulsion and memorable student development experiences.

Technical Excellence Awards

Aerospace Software Engineering Award

Scott A. Morton
Project Manager, CREATE Aviation Vehicles Project
Department of Defense High Performing Computing Modernization Program Computational Research and Engineering Acquisition Tools and Environments Program, Vicksburg, Mississippi
For over 30 years of significant research and innovations in the software engineering of multi-disciplinary, physics-based simulation tools for the design analysis and virtual test of aeronautical systems.

de Florez Award for Flight Simulation

Ronald A. Hess, Professor, Department of Mechanical and Aerospace Engineering, University of California, Davis
For contributions in the field of simulation fidelity for the improvement of air vehicle simulation and trainers, aircraft man machine interface, and flight control.

Mechanics and Control of Flight Award

E. Glenn Lightsey, Professor, Daniel Guggenheim School of Aerospace Engineering, Georgia Institute of Technology
For far-reaching advances toward low-cost space mission concepts through groundbreaking technological developments in sensor and actuator systems for small satellites.

2019 Walter J. and Angeline H. Crichlow Trust Prize

Larry B. Ilcewicz
Federal Aviation Administration (FAA)
For exemplary technical leadership in establishing a safety and regulatory framework enabling large scale structural application of composites in commercial and general aviation aircraft, rotorcraft and engines.

Service Awards

2019 Diversity and Inclusion Award

Susan A. Frost
NASA Ames Research Center
For shaping AIAA's Diversity and Inclusion initiative and moving it forward throughout the AIAA community and beyond; and for the passion, dedication and leadership role that make her the ultimate role model for everyone who follows her footsteps.

Publication/Literary Awards

2019 Gardner-Lasser Aerospace History Literature Award

Valerie Neal
Smithsonian National Air and Space Museum
Spaceflight in the Shuttle Era and Beyond: Redefining Humanity's Purpose in Space

2019 History Manuscript Award

Tony Chong
Northrop Grumman Aerospace Systems Sector Historian
Northrop Grumman Corporation
Manuscript: "Flying Wings & Radical Things: Northrop's Secret Aerospace Projects & Concepts 1939-1994"

2019 Pendray Aerospace Literature Award

Naira Hovakimyan
University of Illinois at Urbana-Champaign
L1 Adaptive Control Theory: Guaranteed Robustness with Fast Adaptation

2019 Summerfield Book Award

Jack D. Mattingly and Keith M. Boyer
Department of Aeronautics
U.S. Air Force Academy, CO
U.S. Air Force (retired)
Elements of Propulsion – Gas Turbines and Rockets

MAKING AN IMPACT

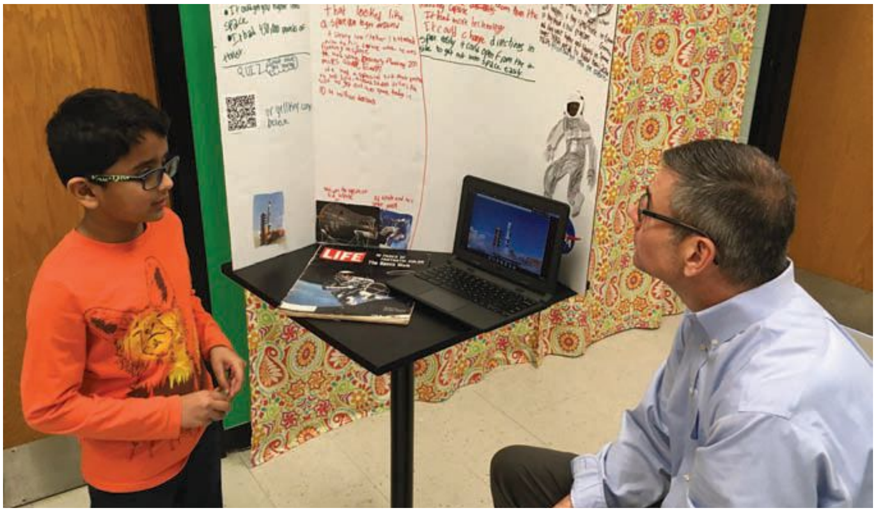
AIAA Foundation Classroom Grant Program

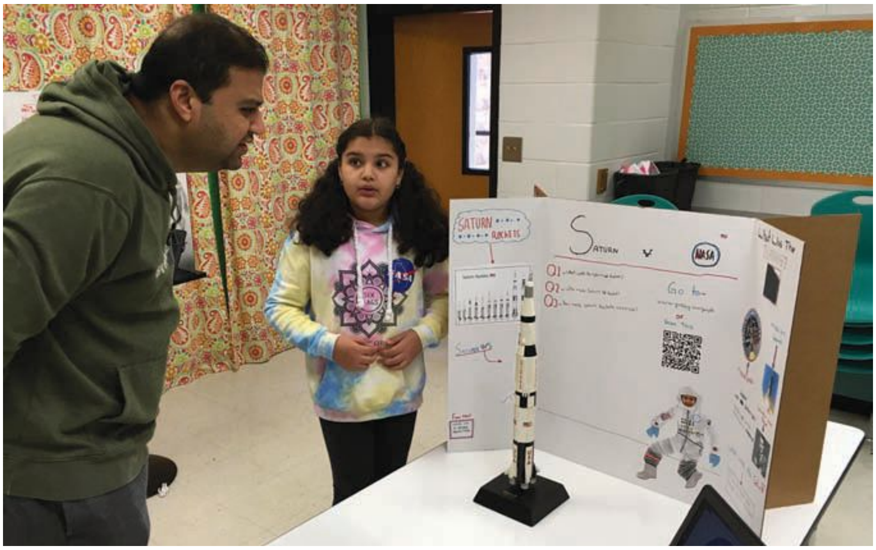
The AIAA Foundation Classroom Grant program provides opportunities for teachers to encourage and support STEM activities in their classrooms. Since the program started in 1998, more than 1,300 grants have been awarded, creating rewarding activities for more than 155,000 students in the classroom. Each school year, grants of up to $500 are awarded to worthy projects that significantly influence student learning.

Each grant supports a clear connection to STEM subjects with an emphasis on aerospace. Applicants must be current AIAA Educator Associate Member (and the membership is free!), and no more than two grants will be supported per school per year. Grant requests have funding STEM demonstration kits and supplies, software, and more.

"I so appreciate the models I have been able to purchase with AIAA Foundation Classroom Grants," said Kati Searcy, a teacher at New Prospect Elementary School in Alpharetta, Georgia, and an AIAA Educator Associate Member. "They say 'a picture is worth a 1,000 words.' If that's the case, 3-D models are worth a million words!

"In our classroom, we have models of the Shuttle Transportation System, the Saturn V rocket, the Orion space capsule, and the Apollo lunar lander. The students love gently touching these models, looking at the details, and comparing/contrasting them. Thank you for your generous funding — you are helping to inspire the next generation of space explorers."





As a NASA Solar System Ambassador, Searcy takes the models on the road with her when she presents programs to groups outside of her classroom and school. "I have gone to several other schools to share space-focused presentations. This summer, I will be presenting at several library summer book club programs."

Kaci Heins, a former teacher at Northland Preparatory Academy and an AIAA Educator Associate Member, added "As an educator, AIAA has been an amazing resource for professional development workshops and grants to enrich classroom curriculum. Students have launched rockets hundreds of feet into the air and soldered circuit boards for the underwater remotely operated vehicles. My hope is to inspire the next generation of scientists and engineers, and AIAA helped me to provide those meaningful experiences in the formal classroom and now the informal science center classrooms at Space Center Houston."

Join us as we continue to inspire teachers and students to advance aerospace by giving to the AIAA Foundation. For more information and to give, please visit www.aiaafoundation.org.If you are a teacher and would like to become an AIAA Educator Associate Member, please visit www.aiaa.org/educator.

News

60th Anniversary Celebration

By Robert A. Malseed, Section Treasurer

The AIAA Albuquerque Section met on 21 February to celebrate the section's 60th anniversary with Robert Malseed giving the presentation. The first Albuquerque section meeting of the Institute of the Aeronautical Sciences (IAS) was held on 17 February 1959. Colonel Paul H. Dane, professor and head of the Thermodynamics Department at the U.S. Air Force Academy was the speaker and the late Alan Pope was the first section chair. In January 1963, the IAS and the American Rocket Society (ARS) merged to form AIAA.

The presentation covered how the section has grown and listed notable accomplishments, annual activities, tours, and outreach activities. One of our members, Hal Behl, joined the IAS as a student in 1940, and joined the ARS later. After the presentation his old IAS and ARS membership certificates were displayed.

AIAA members have been named winners of Aviation Week Network's award program: "Tomorrow's Technology Leaders: The 20 Twenties." The 2019 winners were honored during Aviation Week's 62nd Annual Laureate Awards on 14 March. Photo credit: Chris Zimmer.

Albuquerque Section Participates in Two STEM Events

By Robert Malseed—Treasurer

Several of the AIAA Albuquerque Section officers and AIAA University of New Mexico Student Branch members recently participated in two STEM events. On 2 February, they hosted their annual “Discover STEM Day” at the National Museum of Nuclear Science and History, and on 23 February they hosted tables at the annual “Super STEM Saturday” at the Albuquerque Convention Center. Many families stopped by the tables and flew a desktop flight simulator, learned about space-related subjects, learned how radar and IR-guided air-to-air Falcon missiles worked, picked up some fun toys, and obtained information about careers in aerospace. The DreamFlyer motion-based flight simulator was at both events and young visitors were delighted to be able to fly it.

The AIAA Hampton Roads Section celebrated its 2019 Associate Fellows at a 20 February reception. (Left to right) Jonathan Ransom, Bret Stanford, Kevin Rivers, Tian-Bing Xu, Vanessa Aubuchon, Brian Mason, Michelle Munk, Michael J. Doty, Gautam H. Shah, and Christopher Bahr. Not shown: Bonnie Allen, Jan-Renee Carlson, Jared Grauer, Christopher Johnston, Michael Logan, Lisa Monaco, Travis Turner, and K. Chauncey Wu. Credit: Melissa Carter

Obituaries

AIAA Fellow Broadwell Died in June 2018

James Eugene ("Gene") Broadwell, 97, passed away on 22 June 2018.

Broadwell graduated from Georgia Tech in 1942 with a Bachelor's degree in Mechanical Engineering. In 1944 he earned a Master of Science degree in aeronautics from the California Institute of Technology, having been sent to Caltech for special training while in the Army Air Forces. In 1952, he earned a Ph.D. in aeronautical engineering from the University of Michigan.

From 1942 through 1946, Broadwell served in the U.S. Army Air Forces, working on aircraft engine design and development at Wright Field in Dayton, Ohio.

At Georgia Tech, he was a member of Pi Tau Sigma, Honorary Mechanical Engineering Fraternity and of the Phi Kappa Phi Honorary Scholastic Society. He was elected to the Georgia Tech Engineering Hall of Fame in 2014. At both Caltech and the University of Michigan, he was a member of Sigma Xi, the Scientific Research Honor Society. In 1987, he was elected to the National Academy of Engineering (Aerospace), "For contributions to the understanding and management of turbulent mixing with application to chemical laser design."

Broadwell worked at TRW in southern California for many years. He is the author of numerous scientific papers, often with colleagues at TRW and at Caltech.

AIAA Associate Fellow Phillips Died in June 2018

Frederick C. Phillips, 103, died on 30 June 2018.

After graduating magna cum laude in Aeronautical Engineering from New York University in 1938, and completing the course requirements for a master's degree at M.I.T., Phillips accepted a position as an aerodynamicist at the Glenn L. Martin Co. in Baltimore, where he worked throughout World War II. As well as his aerodynamic work during the war, Phillips also taught the subject at night school at Johns Hopkins University.

In 1947, he took a position as a Professor of Aircraft Design at the Brazilian Air Ministry in Rio de Janeiro, Brazil. In 1951, Phillips moved to the McDonnell Aircraft Corp. in St. Louis, MO, before accepting a position at Canadair Ltd. in Montreal, Canada, in 1955.

After 25 years at Canadair as the director of a variety of aircraft productions, Phillips retired in 1981.

Associate Fellow Blake Died in November 2018

Robert W. Blake passed away 16 November 2018. He was 97.

After living on military bases in Spain and Panama with his family, Blake won a scholarship to MIT where he majored in aeronautical engineering and graduated with a B.S. in 1941. He completed the ROTC Advanced Course, but was not commissioned then due to being under age. In 1944 he joined the Navy V5 program and became a naval aviator during the war.

After graduating from MIT, Blake joined Pan American Airways as an apprentice engineer at Pan American's new seaplane base at La Guardia Field, starting a 41-year career that led him from New York to assignments in Afghanistan, France, Seattle, and back to New York. In his first year at Pan Am he was asked to join the staff of Andre Priester, VP and Chief Engineer of Pan Am, who needed an engineer able to write a good letter. Blake worked as assistant to Priester for ten years, much of that time working with airplane manufacturers—Douglas, Lockheed, de Havilland and Boeing—developing aircraft for Pan Am.

From 1962 to 1965, Blake worked in Afghanistan as VP & General Manager of Ariana Afghan Airlines, an affiliate of Pan Am. Later in his career he was liaison to Boeing for Pan Am. In 1982 he took delivery of the airline's last jets from Boeing and retired from Pan Am the same year.

AIAA Fellow Hood Died in February

Edward E. Hood Jr., former General Electric Vice Chairman, passed away on 3 February. He was 88.

Hood earned his undergraduate and master's degrees in nuclear engineering from North Carolina State University, and then served three years with the U.S. Air Force.

He began his 36-year career with General Electric as a design engineer in the Flight Propulsion Division in 1957. His work with nuclear propulsion and new design concepts for gas turbine engines led to him being named head of GE's Supersonic Transport Project in 1962.

In 1968, he was elected a vice president and became general manager of the Commercial Engine Division, leading GE's re-entry into the commercial aircraft engine market with the development of the DC-10 aircraft engine (CF6). He was promoted to vice president and group executive of GE's International Group in 1972.

In 1979 he was elected vice chairman and executive officer, a position he held until he retired in 1993.

He served as chairman of the Aerospace Industries Association Board of Governors, was elected to the National Academy of Engineering, and served as the vice chairman of the National Electrical Manufacturers Association. In retirement, he served as a director on multiple boards, including Lockheed Martin Corp., Gerber Scientific Inc., Lincoln Electric Co., Martin Marietta Corp. and Flight Safety International.

Associate Fellow Hobokan Died in February

Andrew Hobokan died on 8 February at the age of 96.

Hobokan joined the U.S. Navy in 1941, serving on the USS Matagorda during World War II. After the war, he attended the University of Maryland in College Park, Maryland, graduating cum laude with a B.S. in Electrical Engineering in 1960.

In 1960, he joined NASA, and he managed major segments of the Mercury and Gemini spacecraft programs in St. Louis, MO. In 1967, Hobokan was appointed NASA's Resident Manager Apollo Spacecraft Program Office at the Grumman Corporation in Bethpage, NY, where he guided the production and check-out of the Apollo Lunar Modules. In 1969 he received the NASA Exceptional Service Award.

Later, Hobokan was transferred to Houston where he became manager of the Manufacturing and Test Office for the Space Shuttle Orbiter. He was appointed a Charter Member of the Senior Executive Service by President Carter. He retired from NASA in 1978 and the Naval Reserves in 1980, after attaining the rank of Captain.

AIAA Honorary Fellow Muellner Died in February

Lt. Gen. George Muellner, U.S. Air Force (retired), AIAA Honorary Fellow and AIAA Past President, died on 11 February. He was 75.

In 1967, Muellner earned a bachelor's degree in aeronautical and astronautical engineering from the University of Illinois. He also earned a master's degree in aeronautical systems management from the University of Southern California in 1974, a master's degree in electrical engineering from California State University in 1979, and a master's degree in business administration from Auburn University in 1983.

Muellner entered the Air Force through the ROTC program at the University of Illinois. Most of his career was spent as a fighter pilot, fighter weapons instructor and test pilot with more than 5,300 hours in F-4, A-7, F-15 and F-16 aircraft. He completed 690 combat missions in Vietnam flying the F-4, and during Operation Desert Storm he commanded the Joint STARS deployment, logging another 50 combat sorties. He commanded a classified test squadron, the Joint STARS Squadron and a tactical fighter wing.

As director of requirements at Air Combat Command, Muellner orchestrated the operational requirements for all of the combat air forces and then became the mission area director for tactical, command, control and communications (C3), and weapons programs for the assistant secretary of the Air Force, acquisition. As the program executive officer for the Joint Advanced Strike Technology Program, he created this joint service development activity.

His last assignment in 1995 was as principal deputy for the Office of the Assistant Secretary of the Air Force for Acquisition in Washington, D.C. Muellner retired from the U.S. Air Force as a lieutenant general in 1998 after serving for 31 years.

Muellner then joined The Boeing Company where he served as vice president and general manager and later as president of Boeing's Phantom Works advanced research and development unit. He later became president of advanced systems, integrated defense systems. He retired from Boeing in 2008.

Muellner joined AIAA in 1997 and was AIAA president from 2008 to 2009. An active member, he also served on numerous committees, including as chair of the Honors and Awards Committee, chair of the Crichlow Trust Prize Selection Committee, chair of the Fellow Selection Committee, and chair of the Board of Directors Nomination Committee. He also was a member of the Air Force Scientific Advisory Board, Defense Science Board Intelligence Task Force, and vice chairman of the Board of the Aerospace Corporation. He was a longtime member of the Air Force Association (AFA), as well, holding many positions over the years.

Among his many honors, Muellner received the Defense and Air Force Distinguished Service Medals and the Legion of Merit; he was elected to the National Academy of Engineering; a Fellow of the Society of Experimental Test Pilots; a Fellow of the Royal Aeronautical Society, AFA's Theodore von Karman award; the National Defense Industrial Association's Bob Hope Distinguished Citizen Award; the Aerospace Test Pilot Walk of Honor; and Aviation Week's Curtis Sword Award.

Acknowledging the benefit that he received from a scholarship while at the University of Illinois, Muellner gave back to the next generation by creating scholarships to provide similar opportunities for engineering students. Since 2014, the $5,000 AIAA Foundation Vicki and George Muellner Scholarship for Aerospace Engineering has been awarded annually to an undergraduate student studying in a field of science or engineering encompassed by the technical activities of AIAA.

AIAA Fellow Lee Died in February

Thomas J. "Jack" Lee, former director of NASA Marshall Space Flight Center, died 24 February. He was 83.

Mr. Lee graduated from the University of Alabama in 1958 with a B.S. in Aeronautical Engineering. He later received an honorary doctorate from the University of Alabama in Huntsville.

He began his professional career in 1958 as an aeronautical research engineer with the U.S. Army Ballistic Missile Agency. When it was formed in 1960, Lee transferred to the Marshall Center as a systems engineer with the Center's Centaur Resident Manager Office in San Diego. From 1963 to 1965, he was Resident Project Manager for the Pegasus Meteoroid Detection Satellite Project in Blandenburg, MD, and from 1965 to 1969 was chief of the Center's Saturn Program Resident Office at the Kennedy Space Center.

He served as assistant to the Technical Deputy Director of Marshall from 1969 to 1973 and became program manager of the Spacelab Program Office in 1974. As manager of the Spacelab Program Office, he was responsible for NASA's work with the European Space Agency in the development of Spacelab, a multipurpose reusable laboratory for Earth orbital science activities.

In 1980, Lee became the deputy director of Marshall until his appointment as the Center's director in 1989. He served as the sixth director of the center from July 1989 to January 1994.

After he retired, he cofounded LWI, an engineering consulting firm. He later founded Lee & Associates, LLC, a systems engineering consulting firm, and served as president until his death. In 1992, Lee received the von Braun Award for Excellence in Space Program Management "for exceptional dedication and substantial engineering and management contributions to the science of space flight over the span of three decades."

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1919

April 19 The first free-fall, pack-deployed, parachute drop from a plane, at McCook Field in Dayton, Ohio, is made by Leslie Leroy Irvin, who developed the parachute for the U.S. Army. Because of a clerical error, the company that becomes the major supplier of pack parachutes to most of the world's air forces is known as the Irving Air Chute Co. Francis K. Mason and Martin Windrow, **Know Aviation**, p. 21.

April 19 Capt. E.F. White makes the first nonstop flight between Chicago and New York, in a U.S. Army DH-4, a distance of 1,170 kilometers, at an average speed of 170 kph. **Aircraft Year Book, 1920**, p. 250.

During April 1919
The Imperial Japanese Army establishes the Army Air Division, commanded by Maj. Gen. Ikutaro Inouye. This autonomous unit is formed from members of the Japanese military who had served with the French Air Service during World War I. Subsequently, a French air mission to Japan encourages the Air Division to acquire Spad 13s as fighters, Nieuport 24s as fighter-trainers and Salmson 2A-2s as reconnaissance aircraft. David Taylor, **Flight and Flying: A Chronology**, p. 125; Rene Francillon, **Japanese Aircraft of the Pacific War**, p. 30.

1944

April 3 The German battleship Tirpitz is heavily bombed off Alten Fjord, Norway, by two waves of British Fairey Barracudas escorted by 80 Supermarine Spitfires, Grumman Hellcats and Wildcats, and Vought Corsairs operating from the British aircraft carriers HMS Victorious and HMS Searcher. Three Allied torpedo bombers and one fighter aircraft are lost in the assaults against this heavily armed ship, which is damaged by 15 direct hits and put out of action for many months. It is the first time that the Vought Corsair has operated from an aircraft carrier. **The Aeroplane**, April 14, 1944, p. 402.

April 10 The Joint Chiefs of Staff approves the Matterhorn Plan for the early sustained bombing of Japan by 13 Boeing B-29s based near Kolkata, formerly Calcutta, and staging from Chengdu, China. President Franklin D. Roosevelt originally approved the plan in principle in November 1943. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 313.

April 15 Consolidated Vultee's new commercial transport prototype airplane, Company Model 39, makes its first flight in San Diego. The aircraft is based on the wing, engines, landing gear and vertical stabilizer of the Convair PB4Y-2 Privateer flown by the U.S. Navy. Unlike the previous C-87, which was a cargo conversion of a B-24/PB4Y, the Model 39 has its own airliner-style fuselage. The craft, which incorporates the Davis wing and is powered by four Pratt & Whitney 1,100-horsepower engines, can carry 48 passengers with baggage plus 544 kilograms of cargo up to 4,000 kilometers at a 380 kph cruising speed. **The Aeroplane**, April 28, 1944, p. 461; John Wegg, **General Dynamics Aircraft and Their Predecessors**, pp. 98-99.

April 17 Howard Hughes, president of Hughes Tool and owner of TWA, and Jack Frye, president of TWA, are at the controls of a Lockheed C-69 Constellation that lands at Washington, D.C.'s National Airport after a 6-hour-58-minute record nonstop flight from Burbank, California. The Constellation is under development by Lockheed for TWA as an airliner and for the U.S. military as a transport. It features a dolphin-shaped fuselage, a triple fin tail and tricycle landing gear and is pressurized so it may fly above bad weather. Rene Francillon, **Lockheed Aircraft Since 1913**, p. 222.

April 18 KLM Royal Dutch Airlines completes its 1,000th return flight between the United Kingdom and Lisbon, Portugal. The service, started in July 1940 after KLM reforms in Britain following the Nazi invasion of the Netherlands, uses DC-2s and DC-3s in service to the Allied cause. **The Aeroplane**, April 28, 1944, p. 461.

April 30 The 10th anniversary of the first commercial delivery of 100-octane gasoline is celebrated in ceremonies broadcast over radio. U.S. Army Air Forces Lt. Gen. James Doolittle is a guest speaker, since he was Shell Oil's gasoline representative in 1934. He says that 100-octane gasoline is "virtually the lifeblood of our fighters and bombers" since it increases fighter plane speed by 50 mph (80 kph) and bomber loads by 1 ton (900 kilograms). **Air Transport**, June 1944, p. 97.

During April 1944

• Reynolds Metals announces that it has developed an aluminum alloy as tough as structural steel but so light that it promises to cut thousands of pounds from the weight of airplanes made with it. Designated R-301, the alloy is being used to make new airplanes. **American Aviation Daily**, April 7, 1944, p. 190.

• The 100,000th Rolls-Royce Merlin engine is produced. The Merlin is the powerplant for Lancaster and Halifax bombers, Mosquitoes, Mustangs, Spitfires and Hurricanes. Production of Merlins began in July 1937. Several models, from 1,000 to 1,650 horsepower; are available. **The Aeroplane**, April 7, 1944, p. 374.

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1969

April 1 Pakistan launches its first rocket, a two-stage solid-propellant sounding rocket to investigate the upper atmosphere, according to an announcement by the Pakistan Space and Upper Atmosphere Research Commission. **Washington Post**, April 2, 1969.

April 7 A turbojet-powered "jet belt" developed by Bell Aerosystems Co. is flown in free flight for the first time, near Niagara Falls International Airport, New York. The jet belt is found to be too complex to maintain, too heavy and hazardous for the pilot, who had to land with the weight on his back. The U.S. Army lost interest, and the Bell Jet Flying Belt remained an experimental model. NASA, **Aeronautics and Astronautics**, 1969, p. 103; Frank H. Winter, **America's First Rocket Company: Reaction Motors, Inc.**, pp. 243-248.

Pavel Vanka

April 10 Norway becomes the first European nation to operate the Lockheed P-3 Orion four-engine turboprop anti-submarine and maritime surveillance aircraft when one of the planes is delivered to Fornebu Airport, Oslo. The plane is named Fridtjof Nansen after the Norwegian polar explorer. **Flight International**, April 17, 1969, p. 612.

April 11 A Minuteman 3 intercontinental ballistic missile is test fired from Vandenberg Air Force Base, California. The missile can carry a 1-ton (900-kilogram) payload about 10,000 kilometers. Three Minuteman 3s had been previously fired at Cape Kennedy, Florida. **Aviation Week**, April 21, 1969, p. 17.

April 11 The Soviet Union launches its Molniya 1-11 communications satellite to relay telephone and telegraph communications and TV broadcasts to "the far north," including Siberia, Central Asia and the Far East. **Washington Star**, April 11, 1969, p. A-1.

April 14 NASA's experimental Nimbus 3 weather satellite, designed to pave the way for advanced techniques in weather forecasting, is launched by a Thorad-Agena vehicle from Vandenberg Air Force Base, California. With an infrared sensor, the satellite maps temperature distributions at specified altitudes and interrogates other weather-data sources such as weather balloons, ships, ocean buoys and aircraft. **Flight International**, May 8, 1969, p. 776.

April 16 Alvin Marks, a former college professor in Sacramento, California, achieves a round-the-world record when he lands his single-engine Cessna turbo-system Centurion at Sacramento after covering 37,780 kilometers in 13 days, eight hours and 47 minutes at an average speed of 116 kph. Fitted with long-range tanks, Marks' tiny 1969-model plane has a range of 4,184 kilometers. It also carries two HF radios as well as receivers, a transponder, a marker beacon and autopilot. **Flight International**, May 15, 1969, p. 789.

April 17 The U.S. Air Force's X-24A Lifting Body makes its first free glide flight, piloted by Maj. Jerauld Gentry. The X-24A is carried to an altitude of 45,000 feet by an Air Force Boeing B-52 and released; it lands at Rogers Dry Lake, California. The vehicle is deemed worthy for the NASA-Air Force program, which will study concepts for reusable and maneuverable re-entry spacecraft. **Aviation Week**, April 21, 1969, p. 23.

April 26 The first of seven full-scale firings of a seven-segment, 304-centimeter-diameter solid-propellant rocket motor is carried out at the United Technology Center in Coyote, California. The motor is to be a strap-on booster for the Titan 3M. The 30.7-meter-tall rocket burns flawlessly for its programmed two-minute test, producing 6,227,510 newtons of thrust. **Aviation Week**, May 5, 1969, p. 23.

During April 1969 AIAA's Octave Chanute Award is presented to William C. Park Jr., engineering test pilot for advanced development projects at the Lockheed Aircraft Corp. for flight development of the SR-71 Blackbird reconnaissance aircraft. Park was the first to fly it over its design speed of Mach 3. **Flight International**, April 17, 1969, p. 613.

1994

April 9 Sidney M. Gutierrez is the first Hispanic to command a spacecraft, the Endeavour space shuttle. STS-59 carries Space Radar Laboratory-1, comprised of the Spaceborne Imaging Radar-C and the X-Band Synthetic Aperture Radar. The instruments are designed to produce 3D maps of the Earth and collect data on climate change. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 497, 500, 714.

April 18-19 Synthetic aperture radar carried by the space shuttle takes images over northern Chad that later reveal impact craters under the desert. At first, it is believed the craters date to about 360 million years ago and are from pieces of an asteroid or comet. Later, French geologists make field studies and conclude that at least one of the craters may be 3,500 to 14,000 years old. **Aviation Week**, April 1, 1996, p. 63.

MAGGIE WINTERMUTE, 30

Systems engineer for Honeywell Aerospace

Maggie Wintermute, while growing up in Seattle, often participated in math competitions, encouraged by her parents, a geologist and an accountant. As she explored career paths, Wintermute looked for a field that combined problem solving with continued learning. Now, Wintermute works on Honeywell's Enhanced Ground Proximity Warning System, software to alert pilots of potential hazards it detects while monitoring aircraft altitude, airspeed, latitude, longitude and other factors.

How did you become a systems engineer?

When I started at the University of Washington, I explored a few different programs. What sold me on engineering was the idea of using my skills to build practical solutions to real-world problems. Majoring in aeronautics and astronautics as an undergrad, I had the opportunity to work on cool projects, like an autonomous lighter-than-air vehicle. I developed an interest in dynamics and control systems and decided to get my master's degree in aeronautics and astronautics with a focus on control systems. I was also ready to get out into the industry. During the interview for my current job, I was inspired by the passion that my future co-workers showed for aviation safety. I started working at Honeywell Aerospace and finished up my master's at the University of Washington during my first year on the job. As a systems engineer, I'm responsible for making sure the Enhanced Ground Proximity Warning System functions correctly at the aircraft level. That can encompass anything from defining performance requirements for initial design to investigating issues that occur in the field. We continue to improve and expand the EGPWS by adding features that improve safety, such as an alerting mode that predicts potential runway overruns during landing. I'm proud to work on a product that helps keep people safe every day.

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

Autonomous vehicles and automation in general are exciting areas that are obviously getting a ton of attention right now. Over the next few years and into the future, government and industry are going to be working together to define the role of automation in aerospace. In commercial aviation especially, I think there's a debate to be had about what level of automation makes sense in the cockpit and in the airport environment. By 2050, I think we'll have seen widespread adoption of automated piloting and air traffic control systems, and we'll be continuing to improve our understanding of how humans and technology can work best together.

BY DEBRA WERNER | werner.debra@gmail.com