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SATELLITES TO THE RESCUE

Examining the pros and cons of government vs. commercial satellite-aided search and rescue. PAGE 26

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Russia needs a cultural reboot
PG 36

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AIAA
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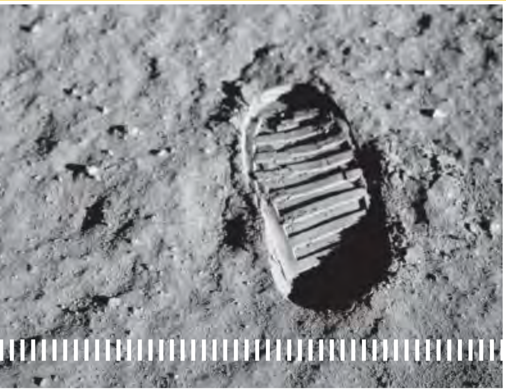

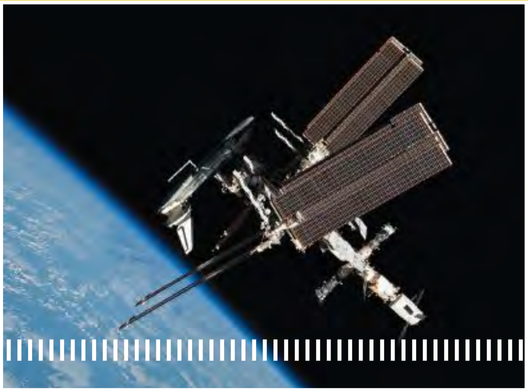

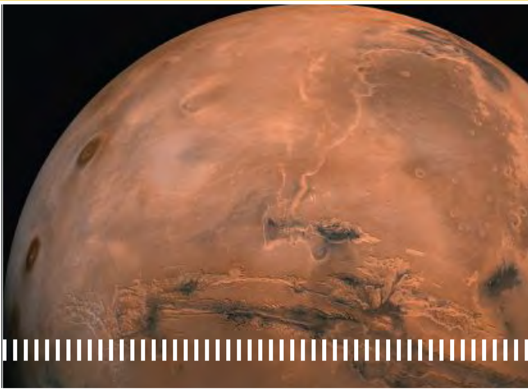


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AEROSPACE AMERICA

NOVEMBER 2018, VOL. 56, NO. 10

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AIAA SHAPING THE FUTURE OF AEROSPACE

IN THIS ISSUE

Adam Hadhazy

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

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Tom Jones

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

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John 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. He is editor of "The Penguin Book of Outer Space Exploration."

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PAGE 10

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

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DEPARTMENTS

NASA

Balancing coverage of space and aviation

▲ **NASA's Ikhana** unmanned aircraft, left, and the jettison motor for Orion's launch abort system, which is scheduled for a full-stress test in April 2019 at NASA's Kennedy Space Center in Florida.

I sometimes wonder about the impact that the written word and other forms of media can have on the career choices of students, such as whether they will get into the space or aviation worlds, or choose an area that spans both, such as materials or computing.

I would not want to exaggerate the possible impacts of a magazine like ours on such decisions. Notably, none of the professionals featured on our monthly Trajectories page have ever cited a magazine article as the reason they got into the business. The closest thing to such an admission came during a 2015 interview with Charles Elachi, the retired director of the NASA-funded Jet Propulsion Lab in California. He told me how as a boy in Lebanon he received a magazine distributed by the U.S. Embassy. Inside was an article about Explorer-1, the first American satellite. This was a turning point for him.

That is very rare. Typically more impactful than anything journalists can produce are interactions with parents, teachers and other mentors, and I'm guessing that Elachi had some of those, too. There is just no substitute for this personal touch.

That said, it does seem logical that the amount and quality of the buzz surrounding specific topics might combine with one's personal experiences to help students set their paths. The desire to give students and professionals information about aviation, space and cross-cutting topics is one reason that we here at Aerospace America work hard to guard against tunnel vision.

Aviation technology is just as important as space exploration, even if space sometimes leaps to the fore with events such as last month's Soyuz accident or policy deliberations over missions to the moon and Mars. Whether to launch such missions and how to carry them out are multibillion-dollar decisions that policymakers must get right. There is also a wild card in what you see or don't see in this magazine, and that's the big story that we were working on that was not quite ready for publication.

But here's another disclosure that might not be a surprise: There's just no denying that space right now has the attention of journalists. That's quite a turnaround for those of us who got into this business a couple of decades ago. I remember telling fellow journalists back in the '90s that I was going to work for a newspaper called Space News. "You mean as in outer space?" I would nod. Now, when I hear from freelance journalists, more times than not the article pitch has to do with space.

Space is cool again. I get it. But there is so much to cover in the world of aviation that affects most of us daily or will in the future. The list includes artificial intelligence, the internet of things, drones in the airspace, personal aircraft, airliner surveillance, cybersecurity, electric propulsion, geared turbofans, high-bypass-ratio engines, design tools, computational fluid dynamics, wind tunnels, safety, especially in general aviation, and more.

Enjoy this issue of Aerospace America and remember nothing in it is the final word. ★

Ben Iannotta,
editor-in-chief,
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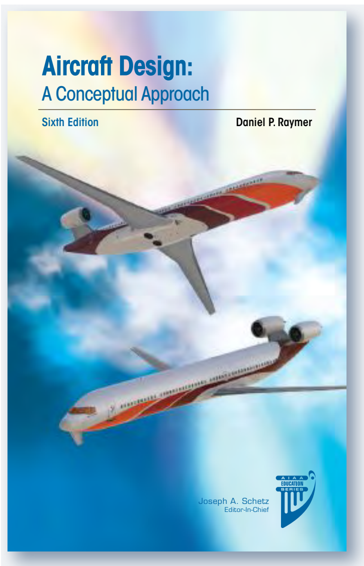
AIAA's #1 Selling Textbook



Winner of the Summerfield Book Award

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WHAT'S NEW?

In this sixth edition Dr. Raymer has expanded and updated his presentation of fast-moving technologies, added lots of new material, and rewritten introductory material to make it even more "user-friendly." Given the ever-growing importance of electric propulsion, Raymer has added a whole new chapter entitled "Electric Aircraft." This chapter presents technologies, design-to guidance, and rules of thumb, and offers electric aircraft performance and sizing equations derived in a format familiar to those designing conventionally-powered airplanes.

This encyclopedic book covers every topic necessary to the understanding of aircraft design. Preliminary sizing, aerodynamics, structures, stability and control, propulsion, configuration layout, performance, cost analysis, and much more are all presented starting from first principles and building to a set of tools allowing the reader to actually do a realistic job of aircraft conceptual design. All topics are presented from the point of view of the aircraft designer, not the specialist in any given topic area.

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IAC 2019: See you in Washington, D.C.!

ZARM, University of Bremen / Cindi Jacobs

By AIAA Executive Director Daniel Dumbacher and IAC 2019 LOC Co-Chairs Vincent Boles and Sandra Magnus

From 21–25 October 2019, Washington, D.C., will become the center of the global space community as AIAA hosts the 70th International Astronautical Congress (IAC).

Last month, at IAC 2018 in Bremen, Germany, the International Astronautical Federation (IAF) flag was passed to the three of us, representing AIAA and the IAC 2019 Local Organizing Committee (LOC). At the closing ceremony, we invited the world to join us in Washington, D.C., to celebrate the 50th anniversary of the first lunar landing—the "one giant leap for mankind" that thrilled the world.

The IAC 2019 theme, "Space: The Power of the Past, the Promise of the Future," reflects how the first human footsteps on the moon inspired the global community to engage in space in increasingly collaborative ways. The theme also reflects the momentum that has been building in the space community with plans to expand human presence beyond low Earth orbit, to the moon and beyond. The Congress will bring together people from all over the world who have been, are, and will be involved in some of the most pivotal space endeavors past, present, and future. Among those in attendance will be international technical experts, scientists, thought leaders, and decision makers who are responsible for the biggest space-related breakthroughs and accomplishments of our day—including those who are on the brink of that next giant leap.

IAC 2019 provides a distinct opportunity for organizations and corporations to highlight capabilities, advancements, and leadership to a wide audience, including domestic policymakers. For many who cannot easily travel internationally, the location of the Congress means that professionals, officials, start-ups, and students who usually don't attend will be able to experience the event and engage firsthand with the international space community.

The Congress will highlight the evolutionary role that international partnerships and cooperation have and will play in exploration, scientific discovery, and research and development. Although the Apollo lunar landing was the result of a space race between two nations, space exploration today is an internationally collaborative effort. Technological and diplomatic achievements—including the Apollo-Soyuz Test Project, MIR, the International Space Station, New Horizons, Rosetta, and the Chandrayaan missions—are brought about by international collaboration among NASA, ESA, JAXA, Roscomos, the China National Space Administration, and the Indian Space Research Organization, along with numerous other national space agencies and industry and academia around the globe.

With new partnerships between governments as well as between governments and industry partners, the space sector is experiencing a burst of growth and creativity. IAC 2019 provides a platform for discussions of new collaborations, current and future global programs, and policy and legal implications. In addition, the Congress will convene the international space community to discuss emerging topics such as the increasingly active industrial sector, with its new economic and business models, and key technical and policy issues such as space traffic management and space law and the importance of international standards of behavior.

Space exploration, technology, and utilization have improved the economic well-being, educational level, and quality of life for billions on our planet. To accomplish all that is needed for space exploration, creating and fostering a space economy, and building a better future for the global community for the next 50 years, we must increase the number and diversity of people pursuing aerospace-related careers. The Congress provides another excellent opportunity to inspire students' passion for space and STEM-related fields to help ensure a robust future workforce.

Hard work—and tough lessons—have led us to where we are today and **we're not stopping**! It's easy to imagine humans living, working, and playing in space in the next 50 years. Greater access to space means that soon people other than professional, government-trained astronauts will be able to travel off the planet to experience our world in a life-changing way. New businesses, markets, and services will be created to meet the expanded activity that will continue to evolve in low Earth orbit and beyond. The future in space is exciting!

IAC 2019 will celebrate the amazing achievements of the last 50 years and will point us unerringly at the future and the next 50 years as we imagine how many exciting accomplishments await. As host, AIAA, with the support of our anchor sponsor Lockheed Martin Corporation and our other sponsors, is committed to building awareness and telling the compelling story of all the innovative and inspiring things happening across the space community. As we invite the world to Washington, D.C., next October, we hope **you** will join us! ★

AERO PUZZLER

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

Noisy airfoil

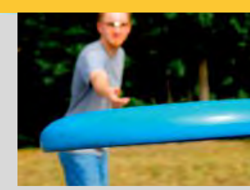
Q The rack on your new SUV comes with two aerodynamically shaped crossbars. On your first drive to work, the crossbars make no discernible wind noise. The next day (same route, wind and traffic conditions) the bars suddenly make an annoying hum. They are just as noisy on the ride home. The next morning, without any adjustments, the bars are quiet again. What was happening on the day the bars were noisy and why did that make them hum?

Draft a response of 250 words and email it by midnight Nov. 8 to: **aeropuzzler@aiaa.org** for a chance to have it published in the December issue.

Did you know? You can get a head start on the next puzzle: @AeroAmMag on Nov. 1.

FROM THE OCTOBER ISSUE

FRISBEE FACT OR FOLLY?



Q: Would a Frisbee thrown identically in the Northern and Southern Hemispheres fly any differently? Ryan James Caverly of the University of Minnesota helped us review your responses and select this winner:

A: If we can imagine all other factors are identical, let's consider spin stability and Coriolis effect.

A Frisbee needs to spin to maintain level flight since the center of lift is forward of the center of gravity. Without spin, it would pitch up and fall to the ground right away. Faster spin lessens its tendency to veer left or right (depending on spin direction) from gyroscopic forces. A typical Frisbee throw will spin the disk to about six revolutions per second. This is half a million times faster than Earth's rotation, so in the most extreme case our right hander would realize a four part per million stability improvement at the South Pole versus the North Pole — a tiny theoretical difference; hard to measure.

Now we'll check for Coriolis effect; the apparent acceleration of a cannonball to the right of target in the Northern Hemisphere, and to the left in the Southern Hemisphere. An unguided missile is really maintaining its course with respect to the inertial reference frame as Earth rotates under it. We can calculate this effect on a 25-meter frisbee throw with a 10-meter-per-second launch speed at 45 degrees North latitude. It's a little over 3 millimeters to the right, so a small difference of 6 millimeters is a fact in our thought experiment — not enough to notice in the real world.

David Mayhew, AIAA senior member
Stratford, Oklahoma
david.mayhew@alumni.usc.edu

Editor's note: David is now a two-time winner. See also "Giant Fruit Fly," September.

Stakes raised for NASA's planned supersonic X-plane

BY TOM RISEN | tomr@aiaa.org

A sometimes-misunderstood reality of NASA's X-59 supersonic demonstrator, the first parts of which are about to be produced, is that the U.S. aviation industry is mainly interested in the plane for the regulatory ground it could break, a point backed by my interviews with executives of companies targeting the supersonic market.

At the moment, passenger and cargo aircraft are barred from flying supersonically overland in the U.S., while abroad, noise regulations make supersonic flights impossible with current technology.

"In the near term," explained NASA's Peter Coen, manager of the Commercial Supersonics Technology Project, the X-59's biggest role will be to help the FAA and the International Civil Aviation Organization "establish standards for acceptable supersonic overland flight noise."

In a series of flights from 2022 through 2025, a pilot will fly the X-59 to Mach 1.5 over U.S. communities yet to be selected. The plane's long nose, swept wing and engine nacelle should space out shockwaves enough to create a "sonic thump," as NASA calls it. If all goes as hoped, residents will find this noise acceptable compared to a sonic boom.

Lockheed Martin in October finalized engineering drawings for the first X-59 parts, and the company plans to start manufacturing those this month.

Also in October, the stakes for the X-59 were heightened by the FAA Reauthorization Act of 2018 signed by President Donald Trump. This law instructs the FAA to take input from industry for an "economically reasonable" and "technologically practicable" noise standard for supersonic passenger planes.

The X-59 flights will provide necessary data for that noise limit. So far, however, no company has stepped forward to say it is interested in adapting the X-59 technologies. Spike Aerospace of Massachusetts aims to be the first to meet the pending FAA noise limit, and it plans to do so with its own design rather than one inspired by the X-59. Spike's planned S-512 business jets would initially fly over oceans at Mach 1.6, but "once NASA's tests are completed and the FAA provides [rules], hopefully by 2027, Spike will be able to fly across the U.S., saving passengers three hours on flights from New York to Los Angeles," CEO Vic Kachoria says.

▲ **A model of NASA's** low-boom flight demonstrator.

NASA

Nevada-based Aerion Supersonic and Colorado-based Boom Supersonic, are not designing for low boom, at least for their initial aircraft. They don't need it, because their business plans center on supersonic flights over oceans, including the route between New York and London flown by the Concordes.

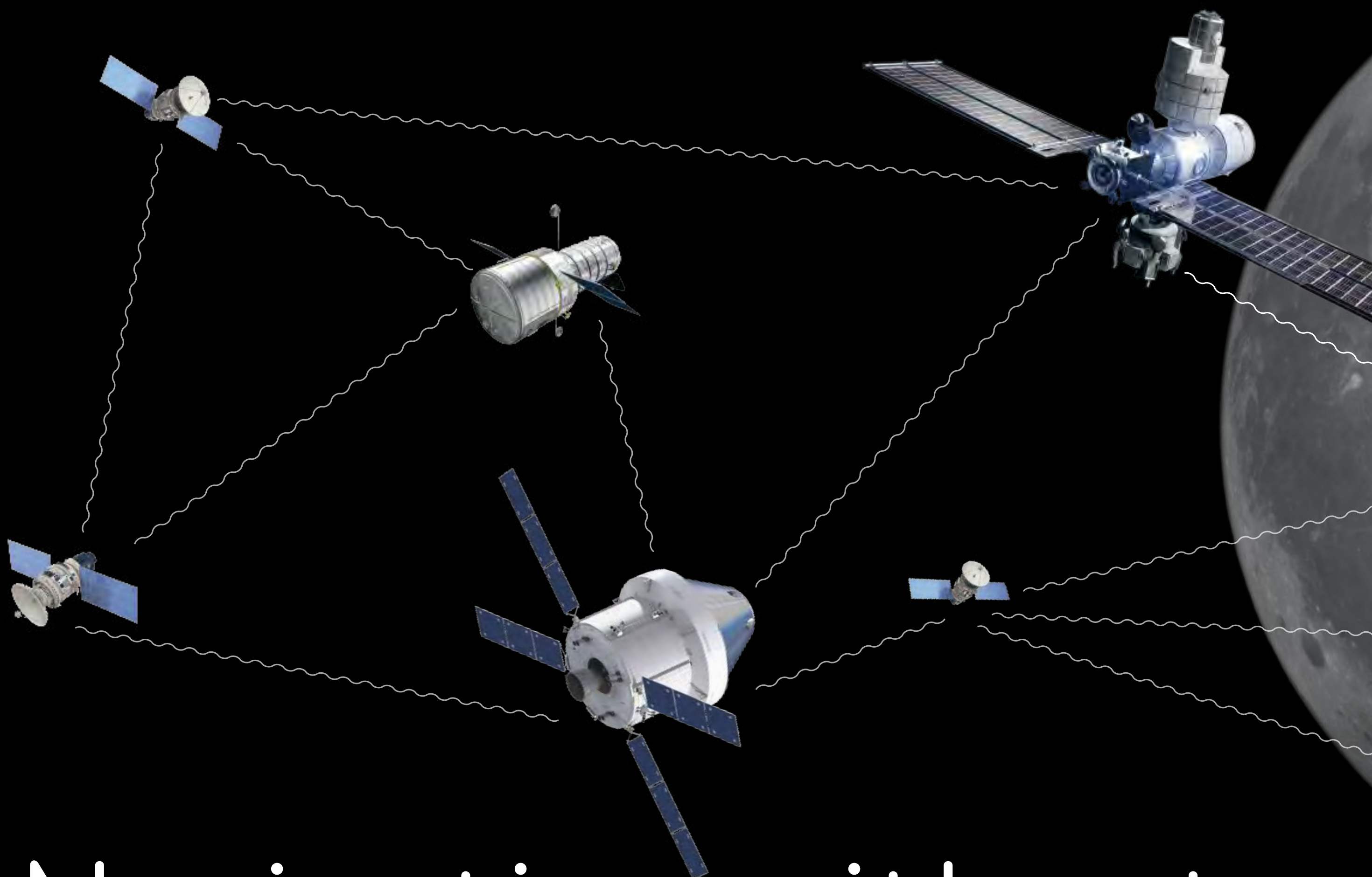
Aerion says that in certain weather conditions its planes could achieve a "boomless cruise" near Mach 1.2, in which the noise would not reach the ground.

Blake Scholl, CEO of Boom Technology, says shaping a plane to reduce sonic boom noise "isn't practical faster than Mach 2," and his company plans to fly at Mach 2.2.

Another player in the supersonic market could turn out to be Georgia-based Gulfstream Aerospace, whose G650 business jet flies just short of Mach 1.

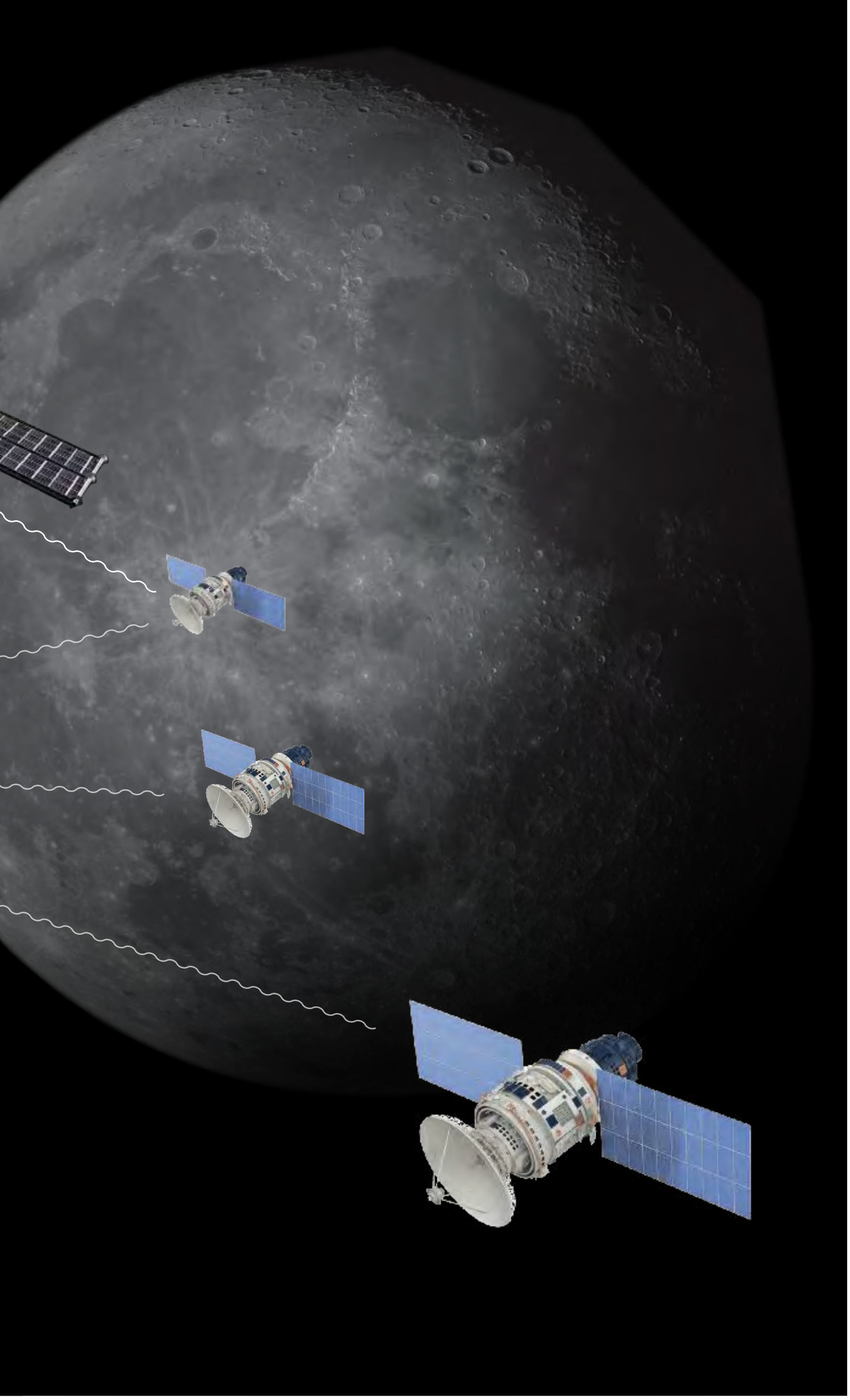
"Anybody can claim they are interested in [the X-59], but nobody is going to move on it" until low-boom technology is proved, regulations are created and market demand for supersonic flight is established, says Robert Cowart, Gulfstream's director of supersonic technology programs.

Will the X-59 and Spike's S-512 succeed at flying quietly enough? The only way to know for sure will be to fly them, says Douglas Hunsaker, an assistant professor of aerospace engineering at Utah State University, who is researching shape-changing supersonic designs. ★



Navigating without the "surly bonds"

Spacecraft in deep space must exchange signals with ground stations so that their owners know where they are. That approach is not going to work if humanity sends swarms of spacecraft to the moon. The Deep Space Network receiving stations and those of other nations would be overwhelmed. Amanda Miller tells the story of a software that could solve the problem, if its developers can convince spacecraft operators to try it.



▲ **Spacecraft orbiting the moon** would navigate mostly by exchanging radio signals among themselves instead of frequently with Earth. NASA is partially funding the software development.

BY AMANDA MILLER
agmiller@outlook.com

Aerospace engineer Bradley Cheetham likes to keep a cubesat frame on a table in his lab at Advanced Space, the mission planning company he co-founded in 2011 in Colorado. The palm-sized frame is a reminder to himself and the company's 14 employees that someday, maybe soon, the moon will be swarming with spacecraft — mostly cubesats, he expects — all of which will need to be tracked as they perform a variety of roles, such as looking for water ice.

Cubesats would be just one class of spacecraft destined for the vicinity of the moon and its surface as space agencies and entrepreneurs seek to pick up where the Apollo astronauts left off in 1972. Lunar advocates want to continue exploring and ultimately commercialize the moon as a tourism destination and source of natural resources, while NASA and some in the private sector want to hone skills needed for a mission to Mars. The enthusiasm is multinational, with German company PTScientists planning to land two rovers on the moon next year, for instance.

If waves of spacecraft indeed are launched toward the moon, Cheetham predicts there is no way that NASA's Deep Space Network and the similar transmitting-and-receiving antennas operated by other nations could, or should, handle so many tracking pings.

"The more we have to use these ground assets in tracking, the less we can use them to relay information," Cheetham says. He's referring to the commands, software patches and upgrades that NASA, private companies and other space agencies must be ready to send to spacecraft operating in deep space. For NASA, the list of spacecraft includes the Curiosity rover on Mars, the planned Mars 2020 rover, and the InSight lander scheduled to touch down on Mars this month. Images and scientific data must be free to flow back to Earth via the DSN antennas in Australia, California and Spain.

Cheetham thinks his company has the solution to the risk of overwhelming DSN or other sites with tracking signals. He wants to simulate and eventually prove in space an entirely new navigation strategy in which moon-orbiting spacecraft would exchange radio signals among each other to estimate their orbits, thus reducing the burden on the ground network.

The foundation for the concept is software called CAPS, short for Cislunar Autonomous Positioning System, which Advanced Space is developing under a series of NASA-funded small business contracts, the most recent being one for $750,000 announced in June, plus a $250,000 grant from the state of Colorado. He's pushing to ready some subset of the software, even just a data-gathering element, for a test in space as soon as mid-2020.

To achieve that schedule, software development must proceed on pace, and Cheetham must find a moon spacecraft that's willing to give CAPS a ride.

Among the software's advocates is NASA's Jennifer Donaldson, a space navigator and mission designer who has been scouting for spacecraft to try CAPS. When she learned about the software, "it just popped straight out to me — this is what we need," she says. She works in the Space and Communications Navigation group at Goddard Space Flight Center in Maryland. "One of our higher-level goals for future technology is to make communication

> “The more we have to use these ground assets in tracking, the less we can use them to relay information.”
>
> **— Bradley Cheetham**, Advanced Space, referring to the commands, software patches and upgrades that operators on Earth must send to spacecraft in space

and navigation services more seamless,” she says.

Today, a spacecraft orbiting the moon requires two-way contact with the DSN, for example. A station sends a succession of radio signals to the spacecraft, which sends the signals back. The ground station times the signals’ round trip, and those times factor into the formulas for estimating the spacecraft’s orbit. This process factors in distance, velocity, estimation theory and statistics. Commands to correct the course go back via the same antennas. Demand for antenna time is already competitive and about to start adding up.

CAPS would be loaded onto a spacecraft’s flight computer during construction. When the spacecraft gets to lunar orbit, the software would tell it when to bounce radio signals off various other spacecraft running the system, producing frequent estimates of a spacecraft’s orbit based on Advanced Space’s proprietary algorithm, or “secret sauce,” as Cheetham calls it.

Navigating on the fly

One challenge for liberating spacecraft from Earth is that today navigation requires atomic clocks at ground stations on Earth. Spacecraft trajectories and orbits are estimated by determining the distance from the station’s antenna, and the change in that distance (aka velocity). This requires sending batches of round-trip radio signals and determining the transit times with atomic clocks.

The problem is that, although NASA plans to launch a prototype Deep Space Atomic Clock this month, today’s spacecraft don’t have such clocks. They would not fit on cubesats anyway.

Cheetham had to make sure spacecraft loaded with his software would not need such clocks. He’ll do that by exchanging tracking signals more frequently and by taking advantage of the spacecraft’s position in the unique three-body system in which the spacecraft’s orbit is significantly influenced by gravity from both the Earth and moon.

Specifically, to figure out how far apart spacecraft are from each other, they would send signals between each other more often than the busy ground stations could permit. This means the software would have more frequent range data, adding up to better accuracy. Only occasionally would the spacecraft need to exchange signals with Earth to determine range.

The technique would not work for satellites in Earth’s orbit, because of our planet’s symmetrical gravity field, which is not heavily influenced by the moon. Attempting to estimate a satellite’s path would produce two possible orbits. That’s not so in lunar orbit, where the gravity fields of Earth and the moon factor into the software’s proprietary math.

Self-monitoring

On the ground, it’s easy to know whether tracking software is working properly. Navigators with particular expertise routinely analyze incoming data to figure out if something is amiss with a spacecraft’s software or computer.

In Cheetham’s scheme, the owner of a satellite wouldn’t have that luxury because the software would be thousands of kilometers away in space. “Nobody’s there to say, ‘Hey, that doesn’t look right,’” he says. “The system has to know, itself, if it’s working or not.”

So the combined team of software engineers and aerospace engineers have been developing tests to automatically check aspects of the software as they are developed. Code would, for example, regularly analyze the location estimates to look for inconsistencies that might suggest that the software needs to be rebooted.

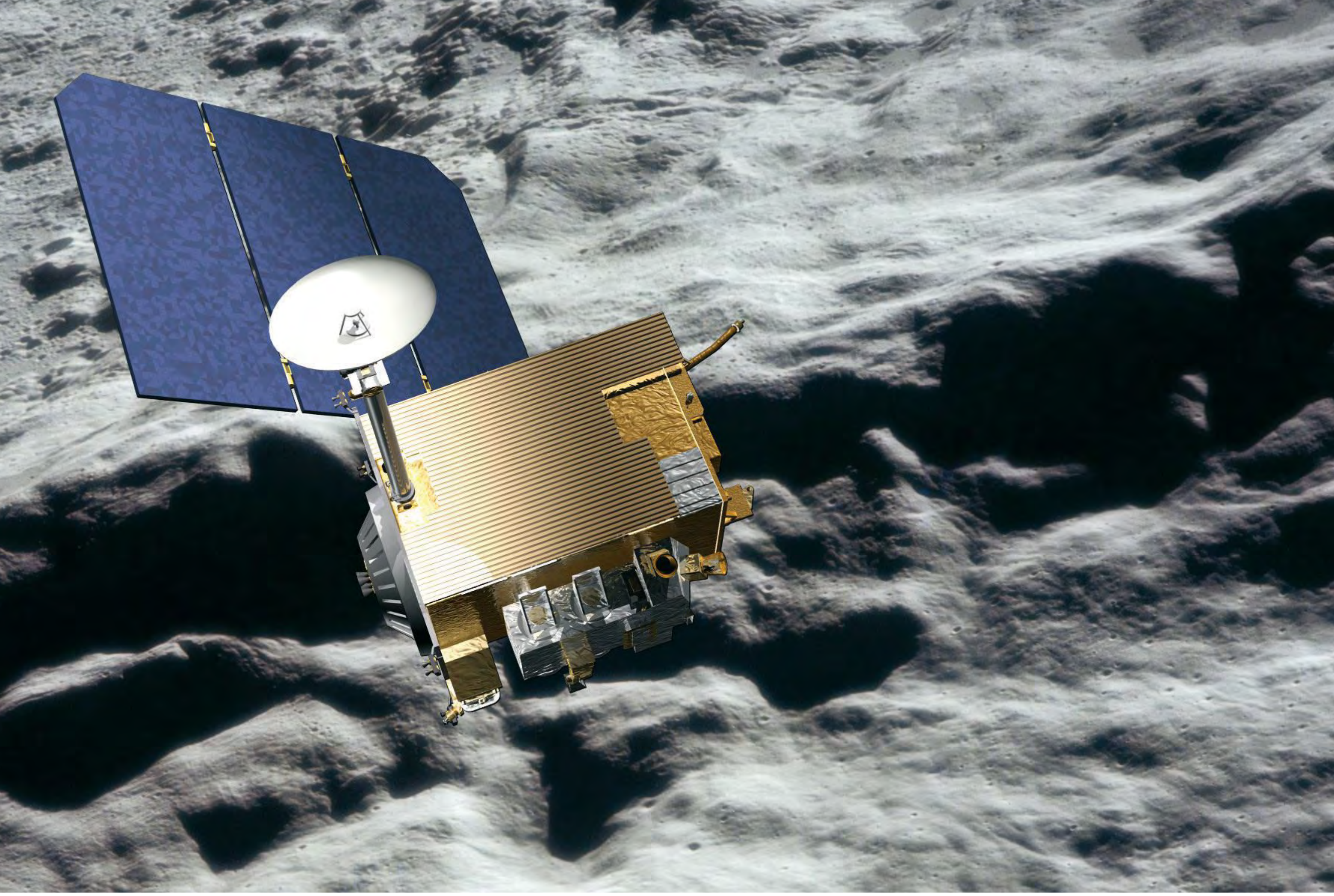
Early versions might not have that full functionality. For the prototype due at the end of this two-year NASA development phase, CAPS could just record the fact that an error occurred. In the future, Cheetham hopes the software will be able to command itself to reboot or revert to a trusted version.

Together but separate

Cheetham’s software would be a new way of doing business for the industry. He needs to convince the people building spacecraft to choose off-the-shelf computers and radios that would be compatible with CAPS.

Just a handful of radios, for example, might perform with a sufficiently consistent signal-turnaround time for the software to calculate a signal’s round trip accurately enough. Plus, radios will need to operate on the same frequencies.

Making sure spacecraft designers have a heads-up about the system’s likely hardware requirements, which are being defined now, is one of Cheetham’s core strategies on the business side. As he finds out from a company or institution which computer it’s using on a particular mission, his developers build a new



▲ **NASA's Lunar** Reconnaissance Orbiter could help Advanced Space prove its software's efficacy.

NASA

simulation to figure how well CAPS would run on it.

Another issue is that companies and space agencies might view themselves as competitors in exploitation of the moon. They might hesitate to join the CAPS network, if they perceive a cybersecurity risk from intersatellite links. To solve that, CAPS will be designed so that when one spacecraft receives a signal from another, the signal arrives in the form of a ranging tone that the radio on the receiving spacecraft simply sends back, with no data left behind.

New software — dated computers

Another challenge is that Cheetham's sophisticated software must run on spaceflight computers whose designs were tested and sealed so long ago that they are 15 years behind consumer laptops in terms of performance. Flight computers lag behind because of the extensive testing they must undergo to assure they can handle the rigors of launch and years in space.

So his team must be careful not to design "in a vacuum from reality," as he puts it.

In the testing lab at Advanced Space, simulations are run on modern processors while several circuit boards — some configured to fit in a cubesat, all judged to perform like proven spaceflight computers — wait at the ready to try out CAPS. This results in a scenario that's closer to real life.

How to beat the rush

To help market the software, NASA could pitch in a third phase of funding at the end of this two-year phase, but that won't be soon enough.

With missions such as the German rovers launching as soon as 2019, "We can't be starting that process of, 'Hey, let's go fly,' in July of 2020," Cheetham says.

So Advanced Space is spending its grant from the state of Colorado to start networking with the organizations that have lunar aspirations. Part of that involves pitching to potential early customers the idea of signing on with the company for conventional tracking at the outset while positioning themselves to upgrade once CAPS is online.

Part of the strategy for having CAPS ready soon comes from sticking with tried-and-true, two-way radio tracking, just doing it between two points in space.

The company has another idea that could help. Rather than having to line up a minimum of two spacecraft to launch with CAPS aboard, Advanced Space thinks it might only need one. The hope would be to get permission to trick a satellite already in lunar orbit — for example, NASA's Lunar Reconnaissance Orbiter — into thinking the new satellite is a DSN site.

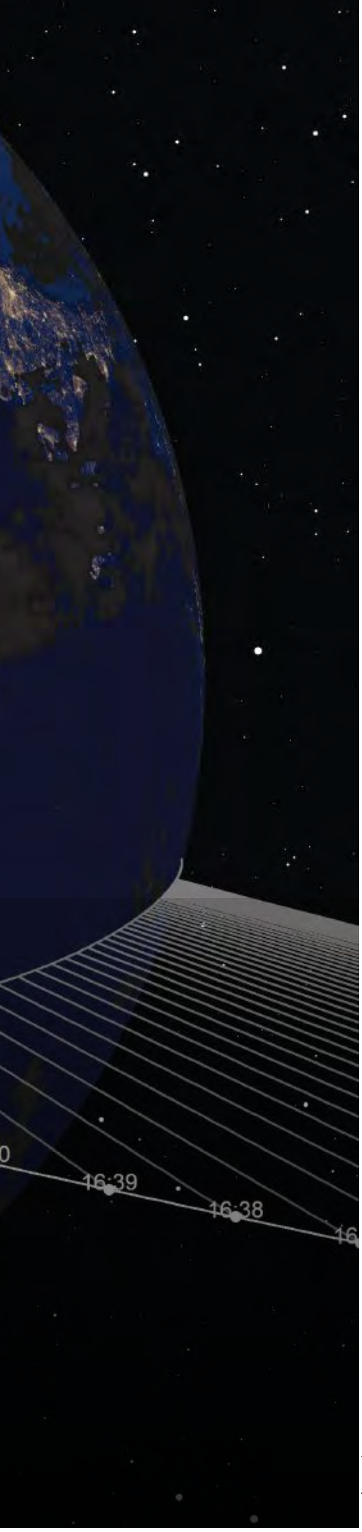
"One of our big fears, one of the things we're trying to prevent," he says, is someone with a good idea being stymied by the ground station logjam. ★

Better asteroid alerts

NASA plans to spend $3.8 million over the next four years adding two telescopes to its asteroid search network to do a more complete job of detecting small objects as they are closing in on Earth. Astronaut and planetary scientist Tom Jones explains how the expanded system can provide last-minute warning of an asteroid impact.

▲ **The final trajectory for** the small asteroid 2018 LA, showing its orbital position with the time (UTC) as it headed for impact on June 2 over southern Africa. ATLAS observations were key to localizing the impact site at the western end of a line of possible entry points from New Guinea to Africa.

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



Tom Ruen/Wikipedia

With the number, location and performance limitations of today's search telescopes, astronomers often discover small near-Earth asteroids only after they've had a close encounter with our home world. NASA is taking steps to improve its ability to find these NEAs in time to issue warnings, given that even an object as small as 20 meters in diameter can deliver enough impact energy to flatten a city center.

The agency is in the process of erecting two telescopes in the Southern Hemisphere that will join the two in the Northern Hemisphere that since 2017 have operated as ATLAS, the Asteroid Terrestrial-Impact Last Alert System.

The new pair, one destined for Chile and the other for South Africa, will add the important ability to detect objects coming from the half of the sky not visible from Maui and the island of Hawaii, where the current ATLAS telescopes are.

"From Chile, we can see all the way down to the south celestial pole, a unique vantage point," Larry Denneau, the ATLAS co-principal investigator, tells me. "Because the skies should be clear over at least one of the four sites, we'll get more frequent sky scans and better warning."

Today's ATLAS system works well where it can see. For example, the telescopes provided key information to pinpoint the possible impact site of an asteroid discovered June 2 by the NASA-funded Catalina Sky Survey telescope, operating near Tucson, Arizona. Preliminary orbit calculations showed that the object, designated as 2018 LA, had a high probability of striking Earth within hours. Follow-up observations refined the orbit and confirmed a pending impact, while brightness measurements showed the object was probably too small to survive atmospheric entry. Based on the refined orbit, NASA's Jet Propulsion Laboratory in California calculated a narrow band of possible atmospheric impact points stretching from New Guinea west across the Indian Ocean to southern Africa.

JPL sent out automated alerts guiding asteroid observers toward further observations, and notified NASA's Planetary Defense Coordination Office in Washington, D.C. No ground warnings were issued, but the news alerted sky watchers along the entry trajectory. Sure enough, at about 16:44 Coordinated Universal Time on June 2, observers on the Botswana/South Africa border reported a brilliant fireball slashing across the early evening sky.

From the explosion's brightness and the infrasound waves it generated, scientists estimated that 2018 LA, traveling at 17 kilometers per second, released 0.4 kilotons of energy in the atmosphere. Its diameter was an estimated 2.6 to 3.8 meters. The asteroid's disintegration caused no ground damage but did shower fragments over the landscape below. Within weeks, meteorite hunters recovered several small pieces for analysis.

ATLAS observations were important in refining 2018 LA's orbit, and confirmed that this object generated the fireball over southern Africa.

How ATLAS works

Operated by the University of Hawaii and its Institute for Astronomy, the ATLAS system is part of NASA's larger, congressionally mandated search

ATLAS

An ATLAS camera on its mount in Hawaii. The 0.5-meter-diameter telescope was built by DFM Engineering in Colorado. Working together, a pair of cameras scans the entire sky visible from Hawaii every two nights, searching for asteroids on their final dive toward Earth.

program to discover 90 percent of the estimated 25,000 near-Earth asteroids that are 140 m or larger in diameter.

The two existing ATLAS telescopes are atop lofty volcanoes 160 km apart on Maui and the island of Hawaii. The two two telescopes weren't specifically looking for 2018 LA; the object turned up during the system's routine nightly sky scans. Spurred by the Catalina discovery, a check of the most recent and the previous night's ATLAS data also pinpointed the fast-moving 2018 LA, adding vital precision to calculations of the asteroid's orbit. The modest ATLAS camera apertures of 0.5 m mean they can't detect distant, dim asteroids, but they can catch small, fast-moving objects that might be sizeable enough to cause damage on the ground.

The current two-telescope system went operational in early 2017. Each telescope is a Wright Schmidt reflector, with a solid-state, digital imager mounted just behind the primary mirror. Each camera can capture images of a swath of the night sky 5.6 degrees on a side, spanning 11 times the apparent diameter of the full moon.

Other NEA search telescopes have larger mirrors to detect fainter, more distant objects, but ATLAS' cameras combine respectable sensitivity with a much wider field of view, rapidly sweeping adjacent patches of sky. In one 20-second time exposure, an ATLAS camera can image objects down to 20th visible magnitude, equivalent to detecting a burning match in New York while observing from San Francisco. Each sector is scanned again 30 minutes later; software compares the images and flags any objects that move or change brightness. Weather permitting, the telescopes cover 500 sky footprints every night, scanning the entire sky visible from Hawaii every two nights.

Denneau, the co-principal investigator, says that ATLAS is set up specifically to complement NASA's other systems, detecting "NEAs that are close, bright, and only a few days out from impact or close approach."

ATLAS can see a 100-m-diameter NEA 40 million km away (a quarter of the distance to the sun), and a 10-m NEA at 4 million km (10 times the distance to the moon). At average asteroid speeds, that's two days of warning for a 10-m object, typical of the small asteroids that were slipping past NASA's other telescopes, making it impossible to alert policymakers and emergency managers. An asteroid that small won't make it through the atmosphere, but its 50-kiloton energy release might damage infrastructure or hurt people below.

Software within the ATLAS network screens moving objects against known asteroids, comets and satellites. Any possible NEA discoveries are checked against the previous night's data to refine the calculated orbit and rule out slower-moving, main belt asteroids. ATLAS then notifies the Minor Planet Center in Cambridge, Massachusetts, part of the International Asteroid Warning Network, about any new objects, especially those that appear headed toward Earth. If the center confirms a high impact probability, it sends an email alert to the observer community and JPL to obtain further observations and refine the impact prediction.

JPL's asteroid-tracking software, called Scout, calculates the range of possible impact points and times. If the asteroid is large enough and the orbit prediction is confirmed by further observations, NASA informs the U.S. government of the potential impact. Meanwhile, the Minor Planet Center shares the prediction with observers and space agencies around the globe.

Today's asteroid surveys will usually provide a few days' warning of a Tunguska-sized asteroid, a reference to the estimated 40-m asteroid that exploded over Siberia in 1908, leveling 2,000 square km of uninhabited forest. An expanded ATLAS will stretch the warning period to a week or so, enough time to evacuate people along the projected impact trajectory. But deflecting a last-minute asteroid is impossible, because mounting a deflection mission would require five to 10 years.

Looking wide, not deep

According to Denneau, ATLAS complements other NASA asteroid search systems, which can see farther into space but have relatively narrow fields of view, by monitoring "shallow but wide" sections of space close to Earth. "The ATLAS telescopes do not go as deep [where asteroids are dimmed by distance] as the other NASA-funded survey telescopes, but they can catch smaller asteroids on an impact trajectory that are not otherwise discovered," says Kelly Fast, NASA's Near-Earth Object Observations program manager. Bigger telescopes continue the hunt for objects 140 m and larger, while ATLAS can address the millions of smaller asteroids that could do isolated damage at Earth's surface. "Complementary survey strategies can make progress on both fronts at the same time," says Fast.

In 2017, ATLAS found 98 NEAs, making it the third-most productive NASA asteroid survey. With an operating budget of about $740,000 annually, the system discovers each year about 100 NEAs larger than 30 m — "small" but still big enough to destroy Honolulu on impact. As of October, ATLAS had discovered 193 NEAs (of which 18 are potentially hazardous) and 12 comets. That's a fraction of the more than 18,000 NEAs now cataloged, but the system is building up valuable statistics on smaller objects, far more numerous yet little observed.

Peter Jenniskens

▲ **This meteorite** is one of the fragments of asteroid 2018 LA, which collided with Earth on June 2 and produced a fireball over Botswana a few seconds after entering the atmosphere.

ATLAS also cues larger telescopes for follow-up NEA observations, which refine the orbit and can sometimes yield spectroscopic compositional information.

Status check

The new funds for ATLAS, programmed through careful planning of NASA's near-Earth object survey budget, total about $1 million per year over four years.

The third ATLAS telescope is headed for the South African Astronomical Observatory some 370 km northeast of Cape Town, with the fourth planned for a site to be determined in Chile. The five-person ATLAS team is still searching for the right site there, one with the highest percentage of clear nights for observing.

The South African ATLAS site will begin operations in 2020, with the Chilean site opening in 2021.

Faster, better surveys needed

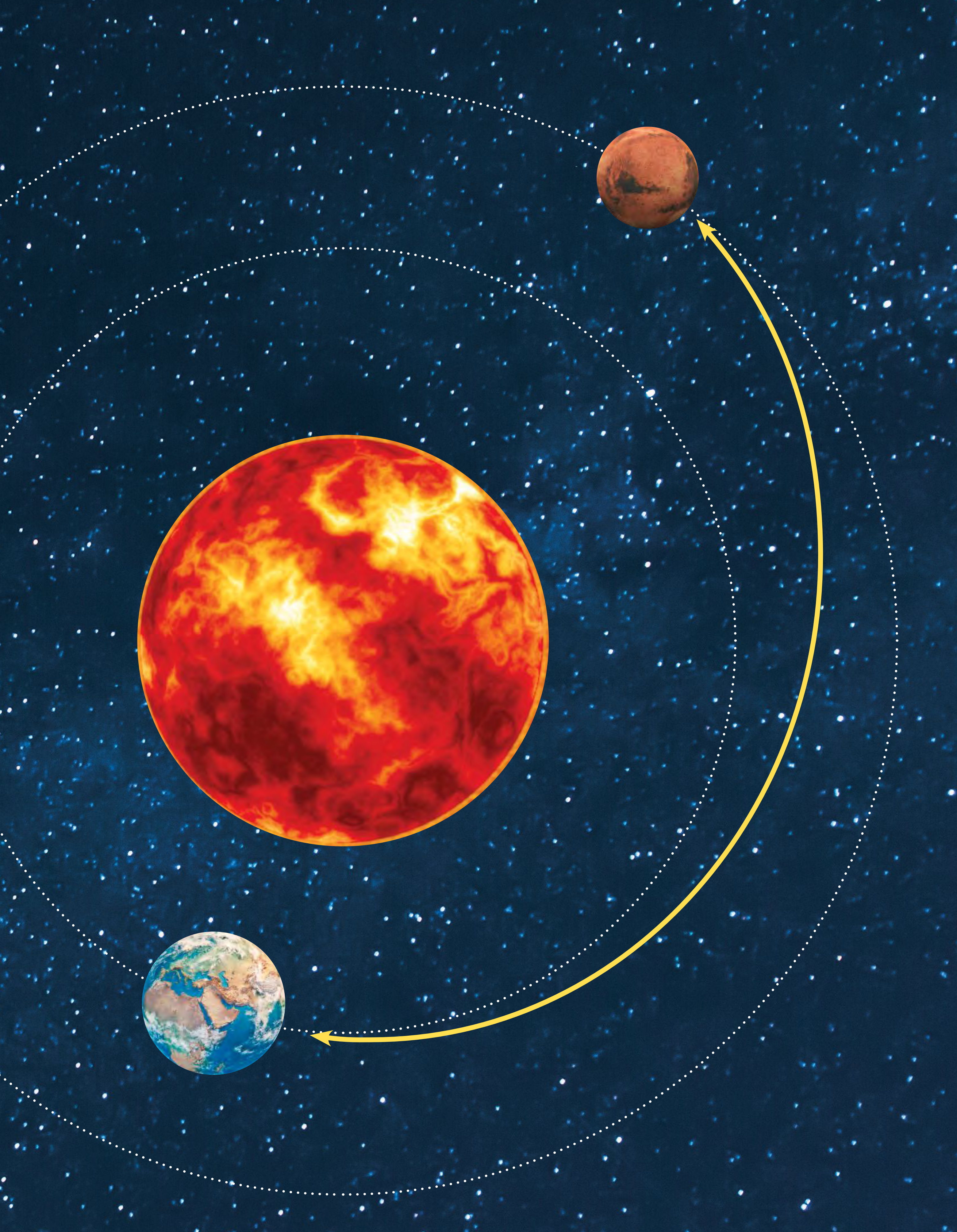
With its $60 million annual survey and research program budget, NASA is pursuing the population of 140-m-and-larger objects, those that could devastate a multistate region in the U.S. NASA's Fast says the agency pursues as one of its missions "safeguarding and improving life on Earth, which would include warning about smaller, imminent impactors like Chelyabinsk [which struck Russia in 2013], only about 20 meters in size." That's where ATLAS comes in.

A space-based infrared telescope would greatly speed the search for NEAs large and small, and mainly complete the 140-m goal with 10 years of observations. Such a mission, however, faces uncertain funding and may not fly for a decade. Until then, an expanded ATLAS provides an affordable chance to warn of a last-minute bullet from space. ★

THE PERIL ROAD TO MARS

Mission planners are now fully coming to grips with the twin hazards posed to astronauts by long durations in weightlessness and exposure to cosmic radiation. Adam Hadhazy surveys the development of faster propulsion technologies to cut down on trip time, as well as a suite of countermeasures, aimed at bringing the red planet safely within human reach.

BY ADAM HADHAZY | adamhadhazy@gmail.com



In the movies, at least, it's when the astronauts actually land on Mars that the trouble starts, vis-à-vis monstrous aliens or a dust storm like the one that stranded "The Martian" Mark Watney. In real life, astronauts will face some of their greatest peril during the journey itself.

The reason is the likely transit time. If propelled by conventional chemical rockets, and depending on the trajectory, a round-trip mission to the red planet including time on the surface could take as long as 900 days. That would mean spending about twice as many consecutive days in weightlessness as the all-time record holder, Russian cosmonaut Valeri Vladimirovich Polyakov, and nearly three times more days than the U.S. record holder, astronaut Scott Kelly.

The surface of Mars, where gravity is about 40 percent of Earth's, would offer a slight respite from total weightlessness but perhaps not a medically significant one. "What does 0.38g mean for us? To just assume that [gravitational] loading is sufficient to preserve health, we don't know that," says former astronaut Jim Pawelczyk, a Penn State associate professor of physiology and kinesiology who has served on the NASA Advisory Council.

Once outside of Earth's protective magnetosphere, the real trouble would begin. Galactic cosmic rays — fragments of atoms flung in all directions by exploding stars and other celestial events — would penetrate their spacecraft hull and tear through human tissue, causing illnesses in the short term and damaging DNA for longer-term consequences. These rays would be even harder to shield against than the solar energetic particles blasted out by our sun from time to time. No one really knows what the long-term effects will be beyond the magnetosphere, because the Apollo crews spent less than two weeks outside this shield.

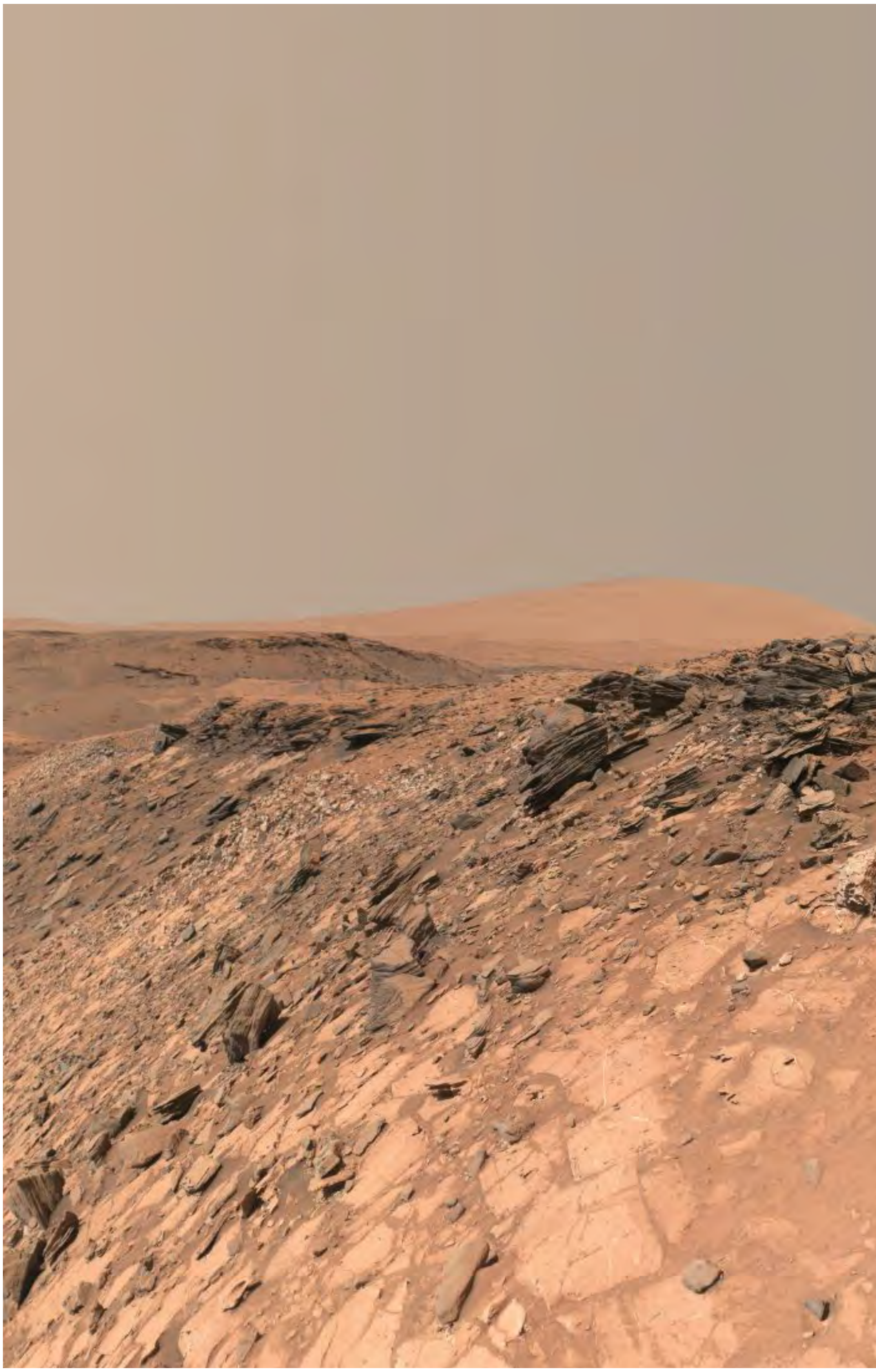
By the time a crew arrives at Mars, each member could be ill from radiation and weak, having lost as much as 40 to 50 percent of his or her musculoskeletal strength. The crew members might be in little shape to effectively explore Mars, and if they make it home, serious health issues could plague them the rest of their lives.

Is there a silver bullet that might save humanity's first mission to Mars? Possibly: "The shorter you can make the mission, the safer we feel like it could be for the astronauts," says Damon Landau, an outer planet mission analyst at JPL, the NASA-funded Jet Propulsion Laboratory in Pasadena, California.

Radiation data from Mars-bound spacecraft, such as the Curiosity rover and its cruise stage, suggest that a crew must get out and back in 200 days, explains Dennis Bushnell, chief scientist at NASA's Langley Research Center in Virginia.

That transit time would be impossible with existing propulsion technology, so NASA knows it needs a game-changing propulsion technology, probably of the nuclear variety, and work is underway to deliver it. The conquest of Mars also would depend on lessons learned in a re-conquest of the moon. NASA wants to get astronauts back there in the 2020s for the first time since "Papa Was a Rollin' Stone" topped the charts in December 1972.

A Lunar Orbital Platform-Gateway would be assembled in orbit around the moon as a base for astronauts. "The gateway is a great opportunity to



▼ NASA's Curiosity Mars rover, in a self-portrait on Mars, collected data on radiation exposure on its way to the red planet. For the self-portrait, NASA stitched together a series of images and edited out photos of the camera and the rover's robotic arm on which it sits.

test the system, reduce the risks, and make sure we understand how we're going to protect the crews and keep them safe," says John Baker, manager of the Human and Robotic Mission Systems Architecture Office at JPL.

Once on the surface of Mars, the radiation exposure would be a third less potent per day than in space, according to measurements from the Curiosity rover. Still, the crew would have to protect itself in a shielded habitat, perhaps setting up base within the subsurface caverns called lava tubes that are open in places to the Martian air.

"On planet, the body needs some 4 meters of regolith or ice" as shielding, says Bushnell. "Reality is different from the cartoons of folks wandering around Mars."

With Mars offering a degree of safe harbor, then, it's the open ocean of space that mission planners must deal with.

Are we there yet?

Part of the trick to compressing the journey would be launch at the right time. As the planets move throughout their orbits, an ideal alignment window

NASA

"ON PLANET, THE BODY NEEDS SOME 4 METERS OF REGOLITH OR ICE" AS SHIELDING. "REALITY IS DIFFERENT FROM THE CARTOONS OF FOLKS WANDERING AROUND MARS."

— Dennis Bushnell, chief scientist at NASA's Langley Research Center

for a launch from Earth to Mars occurs every 26 months. A long-stay, conjunction-class trajectory during this window carries the lowest energy needs for propulsion, and thus mass that must be expensively and prohibitively launched off Earth as well as carried along to Mars. This trajectory lobs the spacecraft into a rendezvous with Mars as the planet swings toward the opposite side of the sun from Earth (called a "conjunction" in astronomy) relative to Earth's location at launch. The return trip does the same in reverse, spending a few hundred days on Mars until an optimal alignment for meeting Earth in conjunction. A conventional, chemical propulsion-based conjunction mission would therefore run 900 or so days, with 240-some days spent on each interplanetary transit leg.

So-called opposition-class trajectories, on the other hand, typically take advantage of this alignment for only one leg of the voyage. The rendezvous with Mars or with Earth occurs, relative to launch, when the planets end up on the same side of the sun, termed an opposition in astronomy. These missions have greater timing flexibility, but higher propulsion requirements to more brute-force the spacecraft's planetary rendezvous. To gain speed on the trip's long leg, the crewed spacecraft can actually fall inward into the solar system, completing a flyby of Venus for a gravity assist. Overall, opposition trajectory-based missions cut down on off-Earth durations, running perhaps half as long — 450 days — as conjunction missions, though with more time spent in space instead of on the Martian surface, where expeditions can last as little as a month.

New paths to Mars

To understand why enthusiasm for nuclear propulsion is growing, it's worth looking at other technologies that might have a role in a compressed mission, but a supporting one. Solar electric propulsion, in which electricity generated from sunlight usually ionizes a gas, such as xenon, that is shot out a nozzle to produce thrust, offers superior specific impulse, a measure of fuel efficiency, compared to chemical propulsion, because of the incredible exhaust speeds. However, the thrust is much lower because of the low amounts of mass streaming out of the engine. Getting a substantial mass up to high speeds, at least with today's versions, would require long acceleration periods or very high available power.

While solar electric should work well for short-haul moon missions, planners do not see it sufficing for relatively massive, long-haul crewed vehicles to Mars any time soon, especially given the drop-off of solar intensity heading away from Earth's vicinity. "With solar electric power, the arrays just become so enormous, it's just not feasible," says Ronald Litchford, the principal technologist for propulsion at NASA's Marshall Space Flight Center in Alabama.

Instead, planners foresee pre-positioning mission elements, such as a lander, at Mars with the technology. "For crewed [Mars] missions, solar electric propulsion isn't quite practical yet," says Baker, "but using it for cargo missions is a great idea."

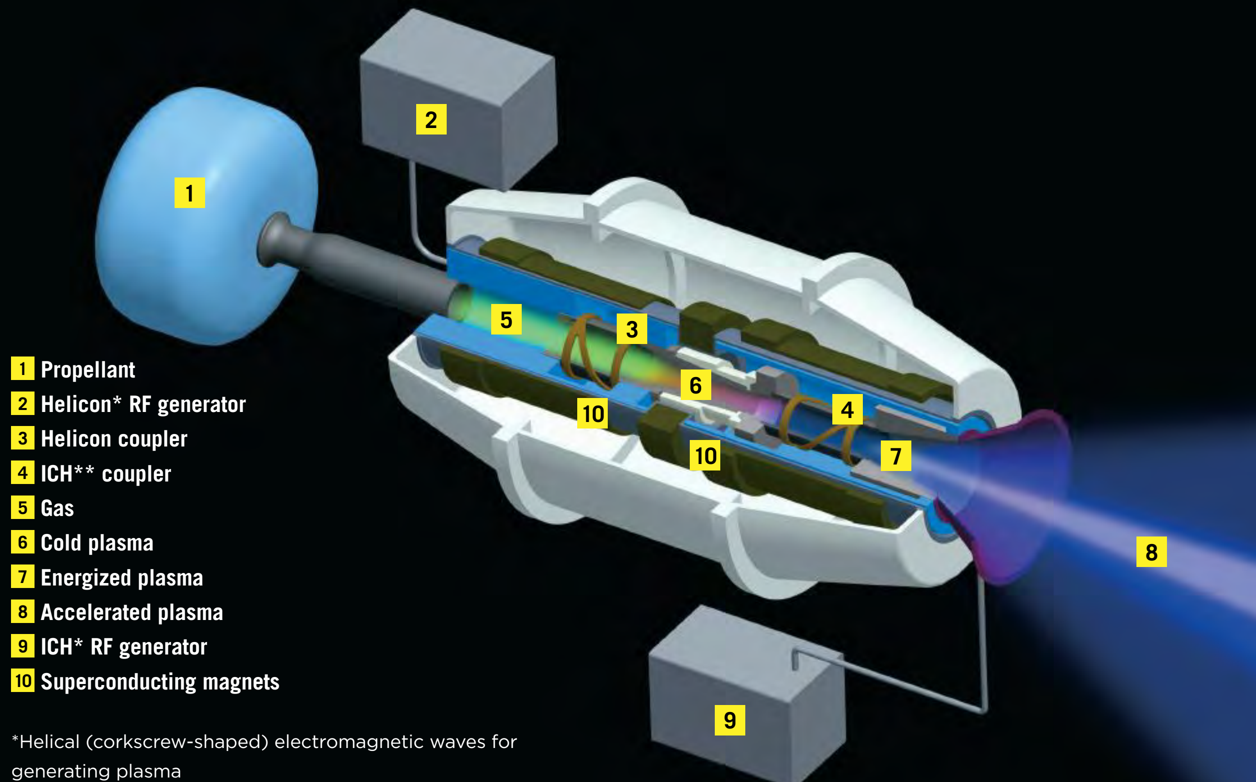
"We really have to get to nuclear if we want to go super-fast," says Litchford.

In the high-thrust nuclear variety, nuclear thermal propulsion, a material such as liquid hydrogen is heated up by the reactor, expanding out a nozzle to generate thrust. Based on NASA's Nuclear Engine for Rocket Vehicle Application, or NERVA, program, which during the 1960s built and tested numerous nuclear thermal reactors and rockets yet was canceled by Congress in 1972 before attaining flight, the specific impulse generated is known to be about 900 seconds — twice that of typical chemical rockets.

Reducing Earth-Mars transit times has reinvigorated interest in nuclear thermal propulsion. In August 2017, NASA awarded a three-year, $18.8 million contract to Lynchburg, Virginia-based BWXT Nuclear Energy Inc. to lead a new program of reactor design and fuel fabrication. BWXT is working closely with Aerojet Rocketdyne, headquartered in Sacramento, California, as it pursues engine and vehicle system development activities through a NASA Research and Technologies for Aerospace Propulsion Systems 2 contract. The goal, says Aerojet Rocketdyne, is to build a prototype system by the mid-2020s fueled by low-enriched, instead of previous efforts' highly enriched, uranium as fuel. Doing so would substantially lower production costs,

Getting to Mars fast

One type of thruster under development for missions to Mars is the VASIMR, short for Variable Specific Impulse Magnetoplasma Rocket, in which a gas is ionized by radio waves. The resulting plasma, which is hotter than the surface of the sun, is contained by magnetic fields. This plasma then passes through a second section of VASIMR where radio waves further energize the plasma. The heated and accelerated plasma is drawn by a magnetic nozzle out of the back of the rocket, generating thrust.



*Helical (corkscrew-shaped) electromagnetic waves for generating plasma
**ICH is short for ion cyclotron heating, a technique to heat plasma

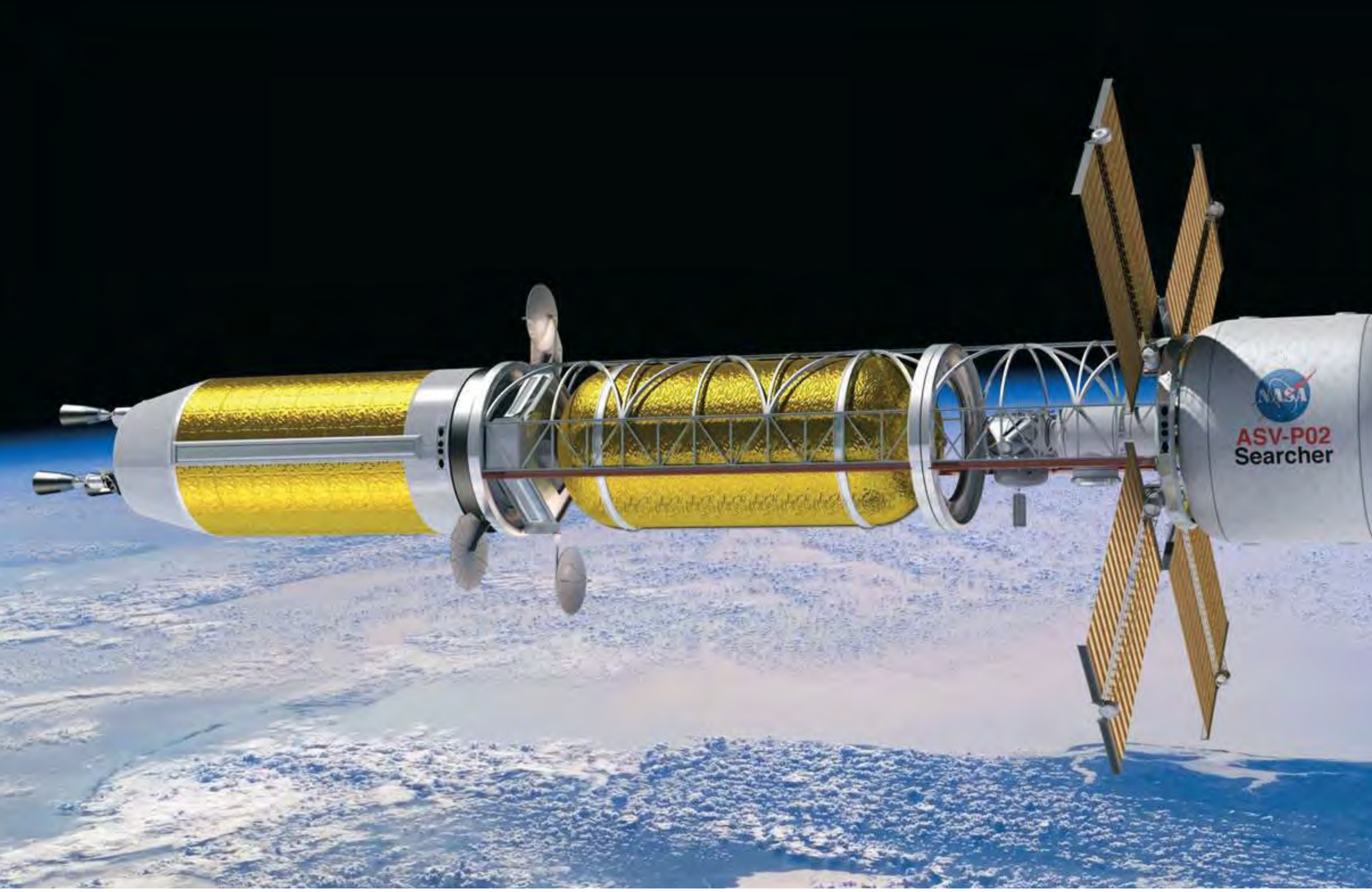
Sources: Ad Astra, NASA, Aerospace America staff research

as well as easing security and handling regulations in place to prevent capture of the weapons-grade material, or a hazmat accident.

In nuclear's low-thrust version, nuclear electric propulsion, a fission reactor cranks out electricity to power an electric thruster. NASA has flown a fission reactor in space only once, back in 1965. But recent progress on a project called Kilopower — covered in Aerospace America's October 2016 issue — could end that cold streak. Kilopower is a purposefully conservative project based on tried-and-true technologies, and given its weight and low power, is geared more for providing power to surface habitats on the moon or Mars. Yet it could help open the door to lighter, spaceborne reactors in the necessary megawatt-range for fast Mars transits. "One of the real benefits of Kilopower is it's a way for us to get through all the regulatory processes and break through that barrier of not having flown a reactor in a long time," says Litchford.

Parallel progress is continuing, with NASA funding, on electric thrusters that could be scaled to handle the desired power levels promised by nuclear electric propulsion. One kind, already deployed with solar electric systems, is the Hall thruster. Within it, electrons trapped in a magnetic field ionize a propellant, oftentimes xenon; the ions then shoot out into space to produce thrust. Another thruster type, called FRC for field reversed configuration, relies on rotating magnetic fields to isolate chunks of plasma in a cavity and then expel them.

A third sort of thruster under development is the Variable Specific Impulse Magnetoplasma Rocket, acronymed VASIMR. Its principle of operation: Radio waves convert a gas (argon, xenon, or hydrogen) into a superheated plasma, which then hurtles out a magnetic nozzle at about 180,000 kilometers per hour (112,000 mph). Ad Astra, the Texas company behind VASIMR, is preparing its latest engine version, dubbed VX-200SS, for a consecutive 10-hour



▲ **NASA is** interested in interplanetary missions propelled by nuclear thermal rockets. In the concept above, a nuclear fission reactor (the left side of the spacecraft) heats liquid hydrogen, accelerating it out of a set of nozzles. The crew would reside in a habitat module at the other end of the spacecraft.

run at 100 kilowatts in a vacuum chamber. Doing so would establish the thruster at Technology Readiness Level 5 on NASA's nine-point scale, indicating validation in a mission-relevant environment. Mark Carter, senior vice president of technology at Ad Astra, explains that the next step is advancing to Technology Readiness Level 6 for an in-space demonstration in 2022.

For some mission planners, VASIMR is particularly attractive, given its blend of specific impulse and thrust, though Litchford says "all three have promise." Longer-term, because of VASIMR's advantageously high scalability, ambitious planners have sketched out revolutionary fast transit architectures with it. Utilizing a 10- to 20-megawatt nuclear reactor, the nuclear electric propulsion system could complete the Earth-Mars and then Mars-Earth transits in 90 and 150 days, respectively. With a 200-megawatt reactor, that interplanetary commute could be slashed further to just two months each way. Assuming a Mars stay itself of two months, a 200-megawatt VASIMR mission architecture would hit the health safety goal of getting astronauts back home in under 200 days. Langley's Bushnell, a proponent, calls VASIMR "wondrous."

Safety is relative

Speeding up trajectories to limit weightlessness and radiation exposure will of course only be part of pulling off humanity's first mission to Mars. It will be an unprecedented long trek, spanning millions of kilometers in total confinement against an utterly hostile void. The psychological stress of confinement and relentless proximity to similarly stir-crazy humans will only become exacerbated by the lengthening communication delays with Earth, which can exceed 20 minutes each way. Real-time conversation — and thus to an extent a connection — with the home world would be severed. "Even with what we call 'fast transit,' it's still a severe environment and it's still severe stress on the astronauts," says Litchford.

NASA's current focus on getting humans out of low Earth orbit and returning to cislunar space could help mature many of the technologies needed to get to Mars faster and sustainably for crews' sake. This moon-to-Mars approach, stipulated in Space Policy Directive 1 issued last December, would use NASA's new Space Launch System and commercial space vehicles to establish the Lunar Orbital Platform-Gateway to support human and robotic missions in the 2020s and beyond.

"The first step is the gateway station," Landau says. "Something where we have the crew in deep space far away enough from Earth where the environment is similar to what you might see on a mission to Mars."

If breakthrough propulsions systems continue to elude, however, the conversation could shift to

NASA

“FOR CREWED [MARS] MISSIONS, SOLAR ELECTRIC PROPULSION ISN’T QUITE PRACTICAL YET, BUT USING IT FOR CARGO MISSIONS IS A GREAT IDEA.”

— **John Baker**, manager of the Human and Robotic Mission Systems Architecture Office at JPL

the broader ethical question of the acceptable risk to which a government agency, such as NASA, can allow citizens to voluntarily submit. Even if misery and death were all but guaranteed, volunteers would still eagerly sign up for a historic voyage to the red planet. “That’s human nature to say, ‘Gosh, I really want to be that first person on Mars,’” says Penn State’s Pawelczyk.

The burgeoning commercial space sector might just beat the legacy astronautics agencies to the punch. SpaceX’s Elon Musk announced in September 2018 the first private passenger trip around the moon slated for 2023, and the company still intends to send both cargo and crew to Mars just one year after, enabled by the amusingly named BFR vehicle, short for either Big “Falcon” Rocket or another F word.

Whether participants in this style of Mars mission would merely need to sign a waiver acknowledging the health risks will remain to be seen. But NASA and the American public will have to decide how much beyond established well-being thresholds we should all be willing to go in our pursuit of destiny at Mars.

“How safe is ‘safe’?” Pawelczyk asks. Ultimately, he says, the issue of astronaut safety is “as hard as we choose to make it.” ★

NEXT-GENERATION SEARCH AND RESCUE

Managers of the international, satellite-aided search-and-rescue network have plans to make it faster and more accurate, knowing that they must do so without jeopardizing the service's famous reliability. Meanwhile, a host of separate commercial SAR services are on the rise, welcomed by consumers for their 21st-century features, but greeted with words of caution by some experts. Jan Tegler looks at the interplay between commercial and government SAR.

BY JAN TEGLER | wingsorb@aol.com

Fifty kilometers east of Fort Lauderdale, Florida, and motoring through unremarkable seas toward Bimini for a New Year's celebration, Chris Hanna had the sickening feeling that he had just "run over something in the middle of the ocean."

Hanna's mate told him he had lost one of the three outboard engines powering the 11-meter vessel. Scanning his gauges, Hanna was momentarily baffled. The engines were running at near full revolutions per minute.

"No!" the mate said, "you lost the actual engine. It's gone!"

Hanna snapped his head around and saw his starboard engine trailing off the right side, connected only by its rigging, and still roaring its 300 horsepower.

He shut down, and the outboard snapped its rigging and sank. When Hanna tried to start the remaining engines, "nothing but alarms went off." A late December family trip to the Bahamian island had gone terribly wrong.

Hanna knew it was time to seek help via satellite.

Not so many years ago, the only way to do that would have been through Cospas-SARSAT, the international search-and-rescue network that in 1985 was declared operational by the governments of Canada, the U.S. and the Soviet Union. Cospas is shorthand for the Russian words for System for the Search of Vessels in Distress; SARSAT stands for Search and Rescue Satellite Aided Tracking. Trigger a distress signal, and this network locates you in minutes with an accuracy of kilometers.

These days, boaters like Hanna, not to mention adventurers and international shipping companies, can also choose from an array of commercial satellite-aided search-and-rescue devices and services. Functions can include GPS forwarding, texting, voice communications and automated acknowledgments, all operating separately from the internationally protected 406 MHz distress frequency for Cospas-SARSAT, a network that is undergoing its own improvements too.

This consumer trend, while welcomed by many, also earns words of caution from some government SAR managers.

"If you're near death, you're going to want 99.9 percent reliability" of a unit certified to communicate over the 406 MHz frequency, says NASA's Lisa Mazzuca, who manages a team of engineers in the SAR Office of NASA's Goddard Space Flight Center in Maryland. Her team develops prototype components whose designs are reviewed internationally and turned into specifications for commercially manufactured Cospas-SARSAT distress emitters, called beacons. Her team also designs

▼ **Chris Hanna** was piloting a boat similar to this Everglades Center Console when he lost engine power and had to activate emergency beacons.

Everglades

NASA

▲ **Devices such** as Emergency Position Indicating Radio Beacons and Personal Locator Beacons broadcast signals at 406 MHz that are relayed to emergency centers whose staff notify responders.

the SAR packages on NOAA weather satellites and Air Force GPS satellites, plus the ground receivers that analyze the distress signals to find the source of transmission.

The overarching message from Mazzuca and others: Don't buy a non-406 MHz device in the belief that you have the same level of reliability as provided by the government SAR network overhead.

Call for help

Consider Hanna's emergency. The first thing he did was activate two devices certified to transmit 406 MHz signals to the Cospas-SARSAT network. One was a hand-held Personal Locator Beacon and the other was a slightly larger device, called an EPIRB, short for Emergency Position Indicating Radio Beacon. Passenger planes carry a third kind of device called an Emergency Locator Transmitter.

Hanna's distress signals triggered a sequence of actions that has saved 43,000 people globally, including 8,400 in the U.S., according to data from NOAA.

The devices radiated homing signals locally for first responders and also sent bursts of signals radiating into space. If all went typically, and there's no reason to believe things did not, these signals were detected by a SAR package on NOAA's GOES-East weather satellite and, most importantly, by one of the five SAR-equipped government weather satellites operated by NOAA and Eumetsat, the European weather agency. Each carries a receiver-transmitter known as a SARSAT. Once in range of a ground station, a SARSAT repeats the distress signal to a ground receiver along with the time of receipt and a record of its shifting frequency. A second SARSAT narrows the location to within 1 to 2 kilometers at best. Collectively, these satellite packages form a network called LEOSAR, short for Low Earth Orbit Search and Rescue. The U.S. Coast Guard was alerted in Hanna's case, given his proximity to Florida.

What was the cost to Hanna of triggering this elaborate rescue network? Absolutely nothing aside from the price of his EPIRB and PLB devices.

Today's Cospas-SARSAT network gets the job done plenty fast and accurately for most scenarios. Hanna and his passengers were back at a dock in Florida in about six hours. If his boat had been farther from shore, or ablaze or sinking, then precious minutes would have ticked by waiting for that first and second satellite to cross through his distress signals. NOAA and its international partners have a plan to sharpen and speed up Cospas-SARSAT, and add a new function popular in the consumer world: The ability to know your signal has been heard.

Job number one: reliability

Hanna's situation was manageable, but for others, waiting to be rescued can be psychologically agonizing without confirmation that help is on the way. The commercially operated and United Nations-certified Global Maritime Distress and Safety System, an option for nonpolar regions, provides such confirmation. Satellite phones and Globalstar's SPOT emergency messaging devices are popular among boaters and adventurers for that reason too.

Government SAR managers, therefore, are considering a receipt service too, while being mindful that today's EPIRBs, PLBs and Emergency Locator Transmitters must always do two simple functions with nearly flawless reliability: Radiate a distress signal into space and transmit a homing signal for local responders.

Part of that reliability is due to Cospas-SARSAT's dedicated frequency of 406 MHz, which prevents interference. Another part of the reliability comes from keeping Cospas-SARSAT-certified devices relatively simple.

"Most people don't know, even the people selling them, that 'Oh, what do you mean I'm down to an 80 percent reliability that my distress signal will get out?'" cautions Mazzuca about the consumer devices operating outside the 406 MHz frequency. As for the Cospas-SARSAT: "We're never going to look like a smartphone. That's for a reason. You will never get 99.9 percent reliability from anything that has a screen on it," she adds.

Consider Hanna's case again. After activating his EPIRB and PLB, he switched on Garmin's In Reach Explorer, a hand-held satellite communicator that produces an SOS signal and enables two-way text messaging via Iridium's constellation of 66 satellites. The device was supposed to allow him to remain in contact with GEOS (pronounced GEE-ohs), a 24/7 commercially operated response center that has a partnership agreement with Iridium and Globalstar. GEOS confirmed that his SOS signal had been received and passed on to a local rescue coordination center. That was reassuring to Hanna, but then the screen froze and went blank.

Despite cautionary tales, Cospas-SARSAT officials have tentative plans to add Return Link Service to Cospas-SARSAT. Someone in distress would receive an acknowledgment and could categorize the kind of emergency: "If you type in a '1,' that [says] it's a medical injury. If you type '2,' it's a fire," explains Mazzuca.

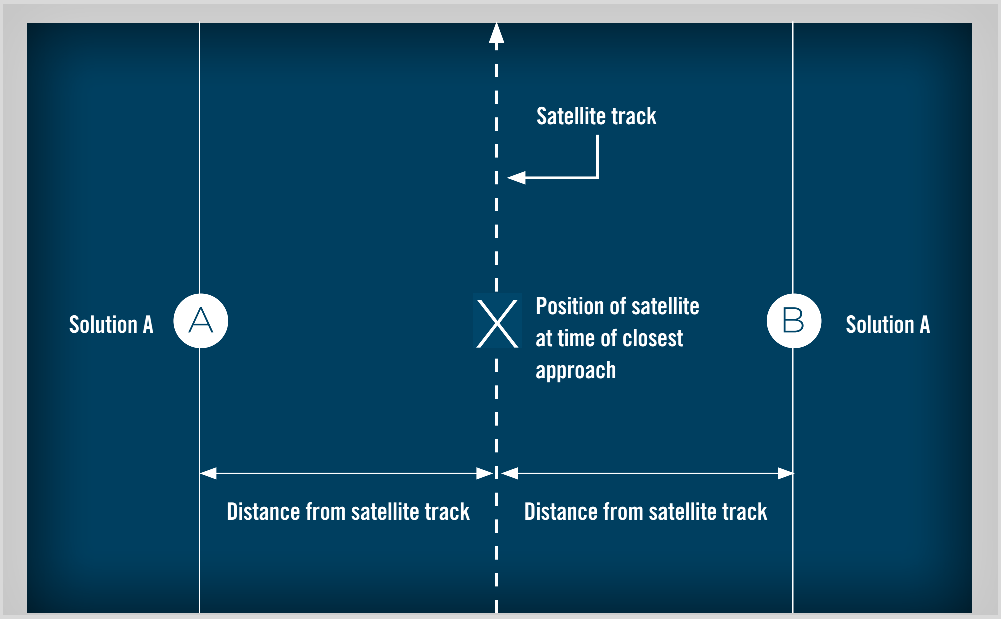
Cospas-SARSAT managers will require lots of testing before including this technology in their internationally approved design specifications for devices.

Then there is the question of why not simply transmit your GPS coordinates to rescuers, given that almost no one leaves home without GPS these days. Globalstar's SPOT devices do this, as do Iridium phones with a push-button SOS function. GPS would avoid the complex process of parsing location from the shifting frequencies of the distress signals as observed by the SARSAT package. This Doppler shift occurs because the SARSAT is in motion relative to the emitter. As the SARSAT approaches the location of the emitter, it's flying into the radio waves, and so the frequency is higher than the transmitted 406 MHz, and then the frequency falls as the satellite flies away. Identify where the frequency is closest to 406 MHz and you can begin to locate a vessel, person or passengers in distress.

Mazzuca cautions against consumers placing too much reliance on GPS though. "There are many areas on the globe where they're 'GPS-starved,' as we say. Then you're getting nothing," she explains. Mountains, for instance, can prevent a GPS device

Finding you faster

Assume you're stranded at sea and sending bursts of distress signals to space. What happens next? A weather satellite streaking overhead in low Earth orbit repeats those signals to a ground station, where software defines two possible locations for you (A and B in the graphic). This is done by comparing your 406 MHz distress frequency to the frequency observed by the satellite. As the satellite flies toward your position, the frequency rises from the perspective of the satellite due to the Doppler effect, and then falls. Finding the places where the frequency is closest to 406 MHz begins to narrow your location. It takes a second satellite pass (not shown) to resolve the ambiguity to 1 or 2 kilometers. This technique has saved thousands since 1985, but the international SAR partners think they can do better. A printed circuit board (photo at right) will transmit stronger signals, more frequently, and this time to medium Earth orbit. MEOSAR payloads on U.S. GPS, Chinese Beidou, European Galileo and Russian GLONASS spacecraft will find you almost instantly through geometry.



Transition plan
NASA's Lisa Mazzuca holds the NASA-built prototype circuit board for the Second Generation Beacon. This new design is for the Medium-altitude Earth-Orbit SAR network now being rolled out.

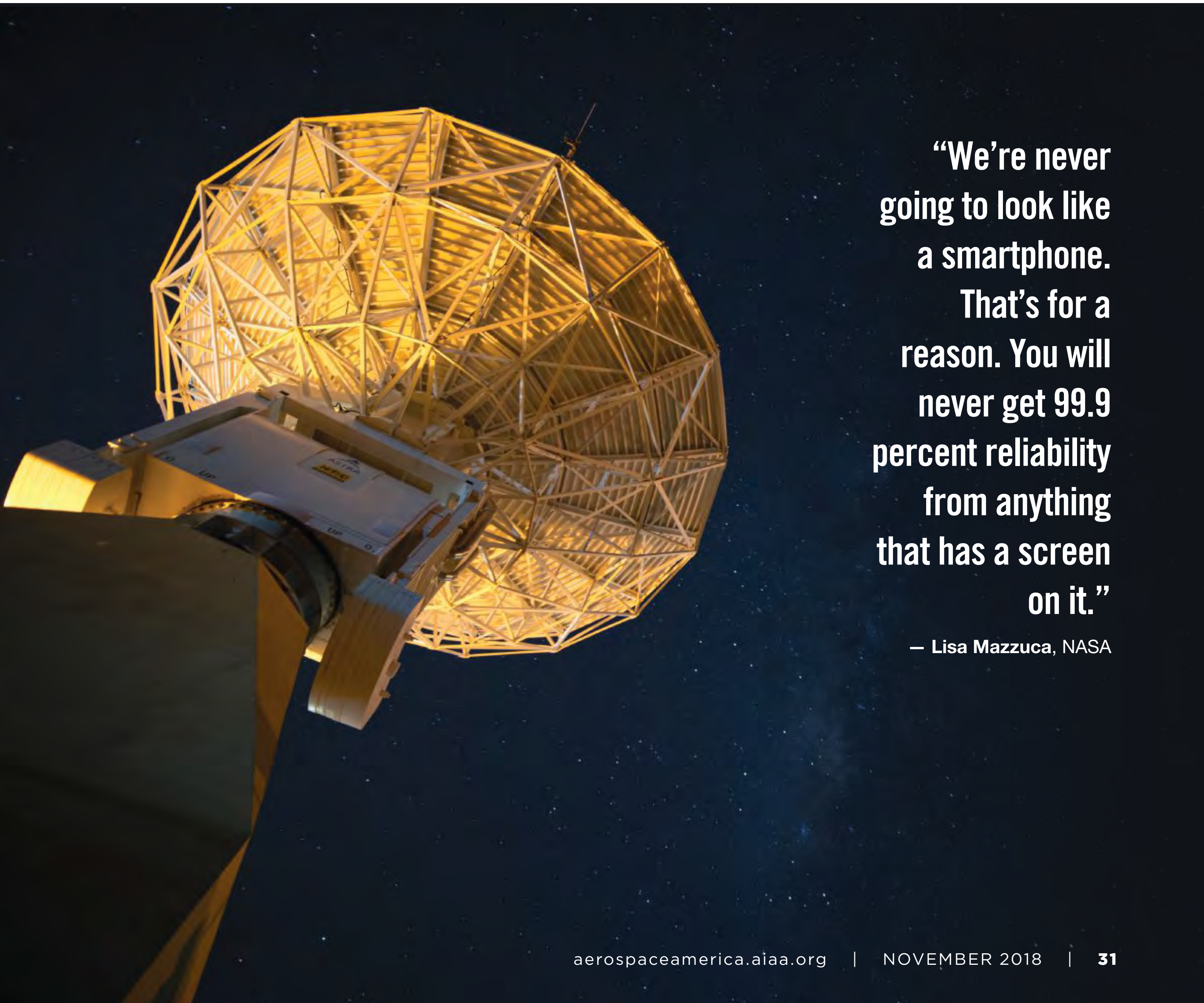
Credits: NASA's Goddard Space Flight Center/Bill Hrybyk from acquiring line-of-sight to enough satellites for an accurate fix. Also, GPS does not cover the full polar regions.

SAR 2.0

Cospas-SARSAT managers have another way in mind to use GPS: Put SAR packages on GPS satellites during manufacturing. Since last December, the U.S. has been testing this network called MEOSAR, short for Medium-altitude Earth-Orbit Search and Rescue. Unlike the LEOSAR satellites, which rise over the horizon and in minutes vanish over the far horizon, multiple MEOSAR packages would always be in line of sight, which is the advantage of medium-altitude orbits. Location would be determined by trilateration, a form of geometry.

Once the transition to this system occurs, a stranded boater like Hanna would be invisibly guarded by multiple MEOSAR units overhead. The result would be "near instantaneous" distress detection, NASA's Mazzuca says. At the moment, her team is developing a printed circuit board whose design would be incorporated into the specifications for Second Generation Beacons, which would be updated versions of today's EPIRBs, PLBs and ELTs. "What's better with the Second Generation Beacon is that we can produce a latitude-longitude position from the first [distress] signal burst," Mazzuca explains. "That's not possible with current beacons."

The U.S. has been installing a MEOSAR package on each new GPS satellite during assembly, and 19 of them are in orbit so far. The U.S. is not alone in rolling out MEOSAR. Europe has MEOSAR units on 11 of its Galileo navigation satellites. China plans to launch a MEOSAR unit on each of its Beidou satellites, and Russia will do the same with its navigation constellation, GLONASS, a Russian language acronym for Global Navigation Satellite System. All



▼ **An antenna** at Europe's Spaceport in French Guiana transmits and receives signals from Galileo satellites, which are among the elements of the MEOSAR network.
European Space Agency

"We're never going to look like a smartphone. That's for a reason. You will never get 99.9 percent reliability from anything that has a screen on it."
— **Lisa Mazzuca**, NASA

Listening for trouble

U.S. and European weather satellites have a side job. They listen for distress signals from ships, aircraft and individuals while orbiting from pole to pole. This is done with packages of electronics called SARSATs, which together form the Low Earth Orbit Search and Rescue, or LEOSAR, network. Here are the five operational SARSATs and the satellites that carry them:

INSTRUMENT	SATELLITE	LAUNCH DATE
SARSAT-7 Canada, France	NOAA-15 United States	May 1998
SARSAT-10 Canada, France	NOAA-18 United States	May 2005
SARSAT-11 Canada, France	Metop-A Europe	October 2006
SARSAT-12 Canada, France	NOAA-19 United States	February 2009
SARSAT-13 Canada, France	Metop-B Europe	September 2012

Metop = Meteorological Operational Satellite
SARSAT = Search and Rescue Satellite Aided Tracking
Sources: NOAA, NASA, EUMETSAT, Aerospace America staff research

this activity eventually will bring the total units in space to about 70.

"When you're talking 70-some satellites carrying SAR payloads, the location algorithms will be exceedingly better because you have more data," says NOAA's Allan Knox, a search-and-rescue analyst.

Mazzuca stresses that the transition to full MEOSAR coverage will take patience. "We're only in what we call 'early operational capability' as an international program. It will be a few more years until we have full operational capability with the rest of the world online and we end up with full-Earth coverage."

Redundancy

Some of the most advanced commercial SAR functions today come from the Global Maritime Distress and Safety System, or GMDSS. Since 1999, the London-based satellite operator Inmarsat has been the sole provider of GMDSS, mainly to shipping companies. Inmarsat provides the service via its ring of geostationary communications satellites 36,000 km over the equator. GMDSS has been a good line of business for the company, in that all vessels of 300 gross tons or more must have the service aboard as required by the Safety of Life at Sea Convention. Inmarsat is about to have competition, however, from Iridium of Virginia. In May, the International Maritime Organization certified Iridium to provide GMDSS with its constellation, a service Iridium plans to start in 2020, once amendments to the convention go into effect.

GMDSS has yet to crack the consumer market because of the cost and size of the equipment, but Iridium thinks it might be able to interest boaters, like Hanna, as well as the traditional GMDSS customers, given the number of the functions that its partner, Lars Thrane of Denmark, has packed into the terminal consisting of a handset, display and antenna, for an anticipated price of less than $5,000.

What about the reliability question? Kyle Hurst, a former marine enforcement officer in Australia and now Iridium's director of maritime safety and security services, points out that no boater or captain should rely entirely on one method of calling for help. "Having been at sea, we had multiple systems on the ships I was on. We had the GMDSS. We had EPIRBs. We had flares, VHF radios, HF radios. We had the old distress flags that no one ever uses," he says. "For me, distress communications are all about getting the word out in any way possible, whether it's setting off a beacon, screaming on radios, firing off flares or waving my underpants — whatever means gets the message out."

Hurst thinks government and private-sector SAR have roles to play. "Take the EPIRB, for example. An EPIRB can float free and be activated. If no human can press a distress alert button and people are in the water, the EPIRB can float free, be activated and send a signal and it will be known that people are in distress. It works the other way as well. If someone can't manage to activate an EPIRB because they can't get to it, but they do manage to press the red button, they can activate a distress alert with GMDSS. As long as there are good standards behind multiple systems, I don't think it matters who runs SARSAT, the government or the private sector."

> **"As long as there are good standards behind multiple systems, I don't think it matters who runs SARSAT, the government or the private sector."**
>
> — **Kyle Hurst**, Iridium

One drawback of GMDSS, at the moment, is that it's not available on polar routes, given that the coverage footprints of geosynchronous satellites don't reach that far. Iridium's 66 low Earth orbit satellites will, by contrast, provide global coverage. Also, the satellites in the new version of that constellation, called Iridium Next, which is almost fully in place, will carry crosslink antennas to quickly route signals among satellites and to a ground station.

Hanna did not have GMDSS aboard, and he might not have needed MEOSAR, though constant overwatch would be reassuring. An hour after losing his engine he managed to contact a nearby mega-yacht. The yacht made contact with the Coast Guard and confirmed that an HH-65D Dolphin helicopter was on its way. The yacht crew helped guide the helicopter directly to the stricken vessel and remained with it while the HH-65 coordinated with a Coast Guard fast-response cutter, which reached Hanna a half hour later.

The cutter dispatched a small response boat which relieved the yacht and stayed with the powerless powerboat while a Sea Tow vessel made its way toward the scene. With storms brewing, the Coast Guard crew towed Hanna's boat until they made contact with the Sea Tow. The ordeal ended after 5 p.m. local time.

The combination of devices Chris Hanna had on hand aided him in getting a distress alert out. However, he's grateful to the mega-yacht crew who were instrumental in helping the Coast Guard locate his boat, and he's looking forward to better tools for satellite SAR. ★

What to call the moon

Earth's moon poses a nomenclature conundrum for publications, including Aerospace America. When English-speakers refer to the moon, is that an informal reference to Earth's natural satellite, or should the moon be considered a proper name requiring capitalization? For some lunar aficionados, the choice to lowercase the "M" shows a lack of respect for this subject of song, myth and human exploration. Space historian John M. Logsdon researched the issue and offers a way out of the conundrum.

BY JOHN M. LOGSDON

▲ **A total lunar eclipse,** Dec. 20, 2010, from Alaska. This series of images was shot over two hours.

U.S. Army

Some publications refer to the moon in lowercase, and I discovered that Aerospace America is one of them while working on the piece "Once We Went to the Moon" [October, Page 30]. That did not seem right to me, given that the moon is Earth's one and only natural satellite and that almost all satellites of the other planets bear proper names starting with a capital letter. I was curious about the origins of the word "moon" and the logic of this stylistic decision. What I learned made me convinced that the Earth's moon should have the dignity of a name that is a proper noun of some kind. The question was whether that proper noun should be Moon or a different proper name, akin to those of other satellites in our solar system like Europa or Titan.

It turns out that there are 155 named satellites of planets, dwarf planets and asteroids. Almost every natural satellite discovered since Galileo's observation of the four moons of Jupiter in 1610 has been assigned a name, most derived from Roman or Greek mythology. Even some closer in size to space debris than a respectable moon now have names. Other small moons more recently discovered have only a Roman number, like Jupiter LXXI, found just this year. But the practice of assigning names has not ceased; in July 2018 a less-than-1-kilometer object orbiting Jupiter discovered in 2017 was named Valetudo after the Roman god of health and hygiene.

There unfortunately remains one glaring exception to this list of properly named solar system satellites — the Earth's moon. Most U.S. style guides for popular and scholarly writing do not capitalize our moon. That includes the AP Stylebook that forms the foundation of Aerospace America's style and also the Chicago Manual of Style. This greatly disturbed world-renowned lunar scientist Paul Spudis, who in the years before his death in August frequently spoke out about the issue. In his 1996 book, "The Once and Future Moon," Spudis argued for capitalizing moon, noting that it was "a complex planetary body with its own history of geological evolution," certainly deserving "the dignity of capitalization." I agree with Spudis.

How did this lack of a capital "M" come to be? According to one NASA website, "until Galileo discovered that Jupiter had moons in 1610, people thought that the moon was the only moon that existed. After other moons were discovered, they were given different names so that people would not confuse them with each other. We call them moons because they orbit planets the same way that the moon orbits around the Earth." That doesn't add much clarity: It seems as if the Earth's moon is just "the moon" primarily because it has always been thus. I even inquired of a colleague who is a senior editor at the respected British journal The Economist about that publication's practice. He responded that it had its own style guide, and of course moon was capitalized, as a continent-sized body like Europe or North America. So the lack of a capital letter in the English language seems to be a U.S. phenomenon.

Further evidence that this is the case comes from the international organization responsible for naming solar system objects. The body is the Working Group for Planetary System Nomenclature of the International Astronomical Union. It was that group that approved the name Valetudo for the Jovian moon, and just recently named two craters on the moon "8 Homeward" and "Anders' Earthrise" in honor of the Apollo 8 mission. It would be that body which approves a new name for Earth's satellite; more to the point, it already capitalizes the word moon when referring to that body. If there were to be a new name in English for the moon, it would have to be approved by the IAU.

The word moon is Germanic in origin, based on a similar-sounding word that came into use a few thousand years ago. Spudis in 2009 suggested that the absence of a capital letter in the name of Earth's satellite could be the result of "some classically educated nitpicker who was forced to sit through endless hours on the joys of the ablative absolute in Latin class" deciding that the "Roman-named objects of the universe were worthy of linguistic worship," but not a "vulgar, barbarian" Germanic word like moon. While that may not be the underlying reality, not capitalizing moon seems very arbitrary. After all, the word Earth when describing our home planet is capitalized. Not according the same treatment to its satellite does not make sense. There seems to me no good reason except inertia to continue with past practice.

Earth's satellite already has a proper name, with a capitalized first letter, in many different languages, including Luna in Latin and Selene in Greek. We speak of "lunar landings" as often as "moon landings,' and the scientific study of the moon's geology is selenology. Robert Heinlein in "The Moon is a Harsh Mistress" called the moon Luna. So there is some precedent for a name change. But assigning a new name is likely to be an uphill battle. Besides, changing the titles of popular songs like "Fly Me to the Moon" to "Fly me to Luna" or "Shine on Harvest Moon" to "Shine on Harvest Selene" just doesn't sound right.

Getting U.S. practice aligned with the rest of the world by assigning the proper noun name Moon, with a capital "M," seems a better course of action. NASA's style guide already calls for a capital letter; perhaps the aerospace community could pressure the more general U.S. style guides to make that change. As we celebrate over the next few years the 50th anniversaries of the Apollo missions, might some organization like Aerospace America's parent, AIAA, or The Planetary Society organize a campaign to this effect. The Associated Press Stylebook is issued annually; wouldn't it be a welcome initiative if the 2019 edition reflected the change as a way of recognizing the Apollo 11 anniversary? It would also be a fitting way of honoring Spudis for his lifetime devotion to studying the moon and advocating its important role in humanity's future.

And perhaps Aerospace America could lead the way, by uppercasing Moon henceforth! ★

Editor's note: By lowercasing moon, Aerospace America means no slight to our celestial neighbor and those who have risked their lives exploring it and those who could well do so in the future. The thing is, we don't capitalize words because we view them as important. We capitalize words that are proper nouns. Despite the arguments in this essay, the word moon does not feel like a proper noun akin to Titan, Europa, Phobos or Deimos. We do love a good semantic debate, though, so keep the arguments coming.

— Ben Iannotta, editor-in-chief

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."

OPINION

SAFETY REQUIRES THE RIGHT CULTURE

Russia's botched launch last month of an astronaut and cosmonaut to the International Space Station was good news in that no one died, and in another sense too. NASA and Roscosmos received a non-fatal wake-up call about spaceflight safety. Those involved in this brush with tragedy should dig below the proximate technical causes of the failure of the Soyuz rocket to examine cultural factors. James Oberg, a Houston-based space expert, explains.

BY JAMES OBERG

At a briefing a few weeks into the Columbia shuttle disaster investigation, board chairman retired U.S. Navy Adm. Hal Gehman stressed how his purpose went beyond the precise causes of this disaster. He intended to delve deeper to the more profound question of how the NASA safety culture could have deteriorated to the point where too many specific countersafety decisions were made.

They were already well long in that process. As a newly hired NBC News space consultant, I pointedly asked him how much of that section of the report he could have written before the accident. He ruefully replied that he probably could have written most of it.

The accident with the Soyuz MS-10 launch on Oct. 11 fortunately did not lead to crew fatalities, but the required investigation otherwise follows an eerily parallel path. The mechanical cause of the booster breakup will be quickly determined and fixed, and flights of the launch vehicle — including carrying crews — will resume.

Solving the broader safety issue will require the Russian space industry to finally dig deeper into its culture. The reality is that there have been years of warning signs and words of caution from observers in Russia and overseas. The span from 2012 to 2016 provided an earlier wake-up call, although none of the failures involved human missions. The Phobos-Grunt Mars probe fell back to Earth in early 2012 because of a poor design and faulty parts. A Proton rocket crashed in 2013 because of overloading in the upper stage propellant tanks. Careless fabrication led to the loss of a Progress supply ship in 2016.

Veteran cosmonaut Georgy Grechko, who died in 2017, spoke to the Interfax news agency about that string of failures. He said, according to a translation, that space hardware is "precision technology that borders on fine art, yet young people are not being trained and old people are leaving." He elaborated: "The scariest thing is that in 20 years everything was brought to ruin, so now no matter what they do, no matter what they pay to save it, nothing will be accomplished in 20 days. ... You need at least 10

◀ Photographers shoot the Soyuz MS-10 spacecraft as it launches.
NASA

"The loss of professionalism and the thoughtless rejection of anything rooted in the Soviet era have led to this."

— Former cosmonaut Yuri Baturin

years to rebuild everything. ... The staff employed are either over 60 or under 30. There is no intermediate age group. A generation was lost for the space industry, when it was struggling to survive." He explained what he saw as the crucial problem: "People, most of them young, energetic and talented, would seek higher earnings in other places. The space industry could not offer them any decent salary."

Since then, under a revolving door of Roscosmos directors, there have been some measures implemented, but clearly not effectively — either not strenuously enough, or possibly not properly aimed at the root problems.

A few days after the most recent accident, former cosmonaut Yuri Baturin pointed to a post-Soviet drop in procedural rigor for quality control. "The loss of professionalism and the thoughtless rejection of anything rooted in the Soviet era have led to this," Interfax quoted him as saying in an article translated from Russian.

Baturin, whose experience was in program management before his two stays aboard Mir and then the International Space Station, pointed to a Soviet practice

▲ The Soyuz MS-10 space capsule sits in a field in Kazakhstan where it crash-landed after the launch failure of a Soyuz-FG rocket booster. Roscosmos cosmonaut Alexei Ovchinin and NASA astronaut Nick Hague were onboard when the spacecraft was launched from Balkonur, Kazakhstan.

TASS via Getty Images

▲ NASA flight engineer Nick Hague, left, meets NASA Administrator Jim Bridenstine after Hague's mission with cosmonaut Alexey Ovchinin of Roscosmos was abruptly ended.

NASA

of independent inspection of industrial products, with precisely defined regulations called GOST, a Russian acronym for state standards. After the collapse of the USSR, he explained: "The [regulations] were canceled. ... As a result, the manufacturers started setting standards themselves. Naturally, they don't want to set themselves requirements higher than they could meet. And this is the result. And this doesn't just concern the space industry. This is about the entire Russian technological industry, which is in the same condition."

He also described a broader demographic problem. "For many years now, they've been gradually discharging professionals from work," he explained. "The principle is: A subordinate cannot be smarter than the boss. The others in the hierarchy act based on the same principle. And so virtually all professionals have been ousted from the manufacturing sector. And those who stayed have left due to their age or have simply died over the past 20 years."

With the departure of the independent inspector teams composed of military officers with engineering training, more fabrication and procedural errors began appearing. The most recent was the small hole drilled, apparently by accident, in the hull of the Soyuz spacecraft currently attached to the space station. Even a decade ago, the ability of the space industry to attract enough high-quality engineering graduates, and to retain those who do initially sign up, was a well-discussed looming crisis.

Baturin's assertion that a procedural flaw in the fabrication process needed to be fixed is an understandable view of a government bureaucrat. But the roots run far deeper and are connected to the vocational culture of the workforce.

The challenge of developing a new generation of well-trained spaceflight industry workers had been exacerbated by another feature of Russian culture that reached its apogee in the space industry — in an environment of possible random firings, the surest strategy for one's own job retention was to be literally irreplaceable because nobody else knew exactly how you did your job. That trick may have been successful on an individual basis, but for any team that must survive the gradual replacement of members, it can be debilitating and ultimately fatal.

Although the Russian space program is heir

NASA

▲ Cosmonaut Alexey Ovchinin of Roscosmos, left, and astronaut Nick Hague of NASA, right, hug loved ones after arriving from the site where their Soyuz capsule crash landed.

to a great tradition of pioneering, the last two decades portray a program slowly retreating from the high-water mark reached in the 1980s. There has not been a single successful Russian lunar or planetary probe in 30 years. Applications satellites are decades behind versions deployed by China and India, much less behind the U.S. and Europe. Plans are creeping along to add a new science module to the space station and rebuild the Luch communications satellite network that collapsed in the 1990s.

The Soviet-era conditions that created the robust, bold space team of the space race included access to

The last two decades portray a program slowly retreating from the high-water mark reached in the 1980s. There has not been a single successful Russian lunar or planetary probe in 30 years.

the best brains of technical schools, perks for workers such as special stores and hospitals, deferment from military service, public prestige and adoration, more-or-less hands-off from ideological watchdogs spying on everybody else, and assistance from state security organs acquiring samples of foreign space hardware and information. Most of all, they offered workers, in exchange for their devotion and commitment, a noble goal for the entire planet as well as international respect for their nation. By any contemporary reckoning, all of those contributory factors vanished long ago, and appear unlikely to be even partially reconstituted. Some new formula for creating a team of devoted, talented and thoughtful specialists remains a quandary nobody seems able to solve.

A particular aspect of Russian culture has always been to express feelings not in speeches or manifestos, but in poetry. The brush with tragedy in Kazakhstan and the hole in the Soyuz at the ISS remind us again of the clarity of vision of Sergey Zhukov, a cosomonaut trainee, spaceflight advocate and high official who worked to introduce advanced technology into the Russian economy. A few years ago, dismayed by trends he observed all around him, he wrote a short poem titled "Epitaph for the Russian Space Agency (1992-2015)."

He wrote it as a man who started as a young, idealistic poet who dreams of space [in my translation from the original Russian, approved by him]. Here are excerpts of what he witnessed:

The students flowed westward
The doctors — who is in China, who in Iran?
Only the movie film's yellowed tape
Preserved the prestige of Russians.
Erecting a heap of paper,
Our officialdom grew sickly and shallow...
And he stands, in tears,
On the threshold of the universe, the poet.
He looks through opened eyes
Into deep space, and there are no Russians there...

Zhukov and many friends of the Russian space industry inside Russia and outside the country hope that these current trends can be reversed. Nothing seems to have worked, so far, but this latest embarrassment, and Zhukov's poem, may ignite the restorative efforts that are long overdue. ★

James Oberg
is a former NASA Space Shuttle mission control specialist who led the orbit design team for the first International Space Station assembly mission in 1998. He is author of a dozen books on space exploration and is a former space consultant for NBC News.

AIAA Bulletin

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Calendar

FEATURED EVENT

AIAA SciTech Forum Courses & Workshops

5–6 JANUARY 2019

San Diego, CA

Innovation in aerospace starts at the AIAA SciTech Forum! Stay at the top of your game by taking advantage of courses and workshops offered the weekend before the forum. There are 11 educational offerings this year including new courses focused on additive manufacturing; aeroelasticity; measurement of plasmas and gases; and guidance, navigation, and control of space vehicles.

scitech.aiaa.org/CoursesWorkshops

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2018			
12 Oct–14 Dec	Online Short Course: Hypersonic Air Breathing Propulsion	aiaa.org/onlinelearning	
5–8 Nov*	ITC 2018	Glendale, AZ (www.telemetry.org)	
8 Nov	DirectTech Webinar—Step-by-Step Process for Designing Weightless Space Habitats	Virtual (aiaa.org/onlinelearning)	
13–15 Nov*	2018 CODER Workshop	College Park, MD (www.coder.umd.edu/coder2018)	
15 Nov	DirectTech Webinar—Pulse Code Modulation (PCM) Processing—Bit Recognition, Frame Synchronization, Decommutation and Real-Time Analysis	Virtual (aiaa.org/onlinelearning)	
2019			
5–6 Jan	2nd AIAA Geometry and Mesh Generation Workshop	San Diego, CA	
5–6 Jan	Aircraft and Rotorcraft System Identification Engineering Methods for Manned and UAV Applications with Hands-on Training Using CIFER® Course	San Diego, CA	
5–6 Jan	Design of Aircraft Structures Course	San Diego, CA	
5–6 Jan	Design of Electrified Propulsion Aircraft Course	San Diego, CA	
5–6 Jan	Diagnostics for Plasmas and Gases Course	San Diego, CA	
5–6 Jan	Fundamentals of Space Systems Course	San Diego, CA	

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
5–6 Jan	Guidance, Control, and Astrodynamics of Space Vehicles Course	San Diego, CA	
5–6 Jan	Integrating Program Management and Systems Engineering Course	San Diego, CA	
6 Jan	A Unified Approach for Computational Aeroelasticity Course	San Diego, CA	
6 Jan	Additive Manufacturing: Structural and Material Optimization Course	San Diego, CA	
6 Jan	Hypersonics: Test and Evaluation Course	San Diego, CA	
7 Jan	AIAA Associate Fellows Awards Ceremony and Dinner	San Diego, CA	
7–11 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition)	San Diego, CA	11 Jun 18
13–17 Jan*	29th AAS/AIAA Space Flight Mechanics Meeting	Maui, HI	14 Sep 18
28–31 Jan*	65th Reliability and Maintainability Symposium (RAMS 2019)	Orlando, FL (www.rams.org)	
2–9 Mar*	2019 IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
20 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (aiaa.org/CVD)	
25–27 Mar*	54th 3AF International Conference on Applied Aerodynamics	Paris, France (http://3af-aerodynamics2019.com)	
3–5 Apr*	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (www.eurognc19.polimi.it)	
7–9 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum)	Laurel, MD	20 Nov 18
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	Saint Petersburg, Russia (elektropribor.spb.ru/icins2019/en)	
10–13 Jun*	18th International Forum on Aeroelasticity and Structural Dynamics	Savannah, GA (http://ifasd2019.utcdayton.com)	
12–14 Jun*	The Sixth International Conference on Tethers in Space (TiS2019)	Madrid Spain (http://eventos.uc3m.es/go/TiS2019)	
17–21 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition)	Dallas, TX	7 Nov 18
11–15 Aug*	2019 AAS/AIAA Astrodynamics Specialist Conference	Portland, ME (space-flight.org)	5 Apr 19
19–22 Aug	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition)	Indianapolis, IN	31 Jan 19
21–25 Oct*	70th International Astronautical Congress	Washington, DC	

● AIAA Continuing Education offerings (first five rows)

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

SPACE FORUM

More than 1,000 attendees, including 211 students, representing a broad range of the space community – from across the United States and 22 other countries – convened in Orlando, 17–19 September, for a successful and well-received AIAA SPACE Forum. The forum comprised 120 sessions, which featured over 300 technical presentations.


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AIAA Announces Class of 2019 Associate Fellows

AIAA is pleased to announce its Class of 2019 Associate Fellows, who will be formally honored and inducted at the AIAA Associate Fellows Recognition Ceremony and Dinner on 7 January 2019, at the Manchester Grand Hyatt San Diego in San Diego, CA, during the 2019 AIAA SciTech Forum.

The grade of Associate Fellow recognizes individuals "who have accomplished or been in charge of important engineering or scientific work, or who have done original work of outstanding merit, or who have otherwise made outstanding contributions to the arts, sciences, or technology of aeronautics or astronautics." To be selected as an Associate Fellow an individual must be an AIAA Senior Member in good standing, with at least twelve years professional experience, and be recommended by a minimum of three current Associate Fellows.

"Each year, current AIAA Associate Fellows recognize the hard work, commitment, and innovative spirit of their colleagues and make them one of their own," said Dan Dumbacher, AIAA executive director. "AIAA Associate Fellows, as a group, are committed to pushing boundaries and testing new theories, resulting in the best ideas that can help transform aerospace across industry, academia, and government."

The Class of 2019 AIAA Associate Fellows are:

Kareem Ahmed, *University of Central Florida*

Bonnie Allen, *NASA Langley Research Center*

David Arenson, *Lockheed Martin Corporation*

Vanessa Aubuchon, *NASA Langley Research Center*

Christopher Bahr, *NASA Langley Research Center*

Michael Bangham, *Bangham Engineering, Inc.*

Saptarshi Basu, *Indian Institute of Science (Bangalore)*

Ron Bessire, *Lockheed Martin Corporation*

Kiran Bhaganagar, *University of Texas, San Antonio*

Barron Bichon, *Southwest Research Institute*

Paul Blelloch, *ATA Engineering Inc.*

Mitchell Bott, *Northrop Grumman Corporation*

Alice Bowman, *Johns Hopkins University Applied Physics Laboratory*

Eric Cardiff, *NASA Goddard Space Flight Center*

Jan-Renee Carlson, *NASA Langley Research Center*

Allison Cash, *PeopleTec, Inc.*

Michael Cawood, *Lockheed Martin Corporation*

Robert Champion, *NASA Marshall Space Flight Center*

Janis Chodas, *NASA Jet Propulsion Laboratory*

John Christian, III, *Rensselaer Polytechnic Institute*

Scott Claflin, *Aerojet Rocketdyne*

Rajka Corder, *Raytheon*

Simone D'Amico, *Stanford University*

Luciano Demasi, *San Diego State University*

Michael J. Doty, *NASA Langley Research Center*

Eric Ducharme, *GE Aviation Engineering*

Srinath Ekkad, *North Carolina State University*

Christopher Elliott, *Lockheed Martin Corporation*

Dale Enns, *Honeywell International*

Brian Evans, *Space Propulsion Group, Inc.*

Edwin E. Forster, *U.S. Air Force Research Laboratory*

Jacob Freeman, *Air Force Institute of Technology*

Stephen Frick, *Lockheed Martin Corporation*

Nicolas Gauger, *TU Kaiserslautern*

Kristen Gerzina, *Northrop Grumman Innovation Systems*

Jared Grauer, *NASA Langley Research Center*

Bob Greene, *Aeronaut Corporation*

Andreas Gross, *New Mexico State University*

John Grunsfeld, *NASA Goddard Space Flight Center*

Mark Gustafson, *DARPA*

Heidi Hallowell, *Ball Aerospace and Technologies Corporation*

Kiruba Sivasubramaniam Haran, *University of Illinois at Urbana-Champaign*

Johanne Heald, *Canadian Space Agency*

Chad Hebert, *Sierra Nevada Corporation*

Marcus J. Holzinger, *University of Colorado Boulder*

Qinglei Hu, *Beihang University*

Wensheng Huang, *NASA Glenn Research Center*

Xun Huang, *Peking University*

Sunil James, *Honeywell Aerospace*

Jeffrey Jepson, *Raytheon Missile Systems*

Christopher Johnston, *NASA Langley Research Center*

Brandon A. Jones, *University of Texas at Austin*

Hao Kang, *U.S. Army Research Laboratory*

Mohammad Kassemi, *Case Western Reserve University*

Daniel Keating, *Charles Stark Draper Laboratory, Inc.*

Yohannes Ketema, *University of Minnesota*

Kyung Kyu Kim, *Lockheed Martin Corporation*

Jeffery King, *Teledyne Brown Engineering, Inc.*

Douglas Lacy, *The Boeing Company*

Mark Langhenry, *Raytheon Missile Systems*

Patrick Lemieux, *California Polytechnic State University, San Luis Obispo*

Michael List, *U.S. Air Force Research Laboratory*

Michael Logan, *NASA Langley Research Center*

Michelle Lucas, *Higher Orbits*

Philippe Mairet, *PhLCM Consulting*

Manoranjan Majji, *Texas A&M University*

Karen Marais, *Purdue University*

William M. Marshall, *NASA Glenn Research Center*

Brian Mason, *NASA Langley Research Center*

Luca Massotti, *RHEA System BV for ESA*

J.D. McFarlan III, *Lockheed Martin Corporation*

Bryce Meyer, *Software Engineering Institute, Carnegie Mellon University*

Lisa Monaco, *Jacobs Tidewater Operations Group*

Brian Motil, *NASA Glenn Research Center*

Michelle Munk, *NASA Langley Research Center*

Vedha Nayagam, *Case Western Reserve University*

Agostino Neri, *European Space Agency, ESRIN Establishment*

James O. Norman, *NASA Headquarters*

Matthew Orr, *The Boeing Company*

Satoru Ozawa, *Japan Aerospace Exploration Agency*

Peter Paceley, *Charles Stark Draper Laboratory, Inc.*

Rafael Palacios, *Imperial College London*

Jonathan Ransom, *NASA Langley Research Center*

Garrett Reisman, *SpaceX / University of Southern California*

Kevin Rivers, *NASA Langley Research Center*

William Roberts, *King Abdullah University of Science and Technology*

Salma Saeed, *Lockheed Martin Corporation*

Vaidyanathan Sankaran, *United Technologies Research Center*

Matthew Santer, *Imperial College London*

S. Alexander Schumaker, *U.S. Air Force Research Laboratory*

Thomas Schwartzentruber, *University of Minnesota*

Inanc Senocak, *University of Pittsburgh*

Calina Seybold, *NASA Jet Propulsion Laboratory*

Gautam H. Shah, *NASA Langley Research Center*

Nat Shankar, *Lockheed Martin Advanced Technology Center*

Reza Sheikhi, *Dena Scientific & University of Connecticut*

John Slater, *NASA Glenn Research Center*

Evan Smith, *Royal Australian Air Force*

Douglas Smith, *U.S. Air Force Office of Scientific Research*

Marlon Sorge, *The Aerospace Corporation*

Rostislav Spektor, *The Aerospace Corporation*

Eric Spero, *U.S. Army Research Laboratory*

Bret Stanford, *NASA Langley Research Center*

Andrey Starikovskiy, *Princeton University*

Adam Steinberg, *Georgia Institute of Technology*

Homer D. Stevens, *Lockheed Martin Corporation*

Pierre Sullivan, *University of Toronto*

Jerry Tarnacki, *Aerojet Rocketdyne (retired)*

Christine Taylor, *The MITRE Corporation*

Roger Thompson, *The Aerospace Corporation*

Joyce Tokar, *Pyrrhus Software, LLC*

Steven Tourville, *Lockheed Martin Corporation*

Albina Tropina, *Texas A&M University*

Travis Turner, *NASA Langley Research Center*

Roelof Vos, *Delft University of Technology*

Ryan Weisman, *U.S. Air Force Research Laboratory*

William A. Welsh, *Sikorsky, a Lockheed Martin Company*

David B. Williams, *Ohio State University*

Ernest Wu, *Engineering, Research, and Consulting, Inc. (ERC)*

K. Chauncey Wu, *NASA Langley Research Center*

Tian-Bing Xu, *Old Dominion University*

Jeanne Yu, *The Boeing Company*

Xinqian Zheng, *Tsinghua University*

News

MAKING AN
IMPACT

AIAA Thompson Scholarship Winner Finds the Right Audience in Aerospace

By Michele McDonald

For **Destiny Fawley**, her love of science began with a 7th grade science fair project after all the easy projects were taken, leaving her with electromagnetic radiation. AIAA's David and Catherine Thompson Space Technology Scholarship winner dived deep and her presentation was so detailed that the teacher asked her to dial it back. Fawley simply hadn't found the right audience yet.

Today, the aerospace engineering junior at the University of Illinois at Urbana-Champaign certainly has found people who share her passion for the detailed and complex. She's focused on fluid flow and aerodynamics, specifically as they relate to space.

"I like aerospace because I like challenging problems," she said. "There's so much about this planet we don't know and we're just learning about other exoplanets."

Fawley met commercial space pioneer and AIAA Honorary Fellow **David Thompson**, who had invited her to attend the AIAA SPACE Forum in Orlando, FL. Thompson is the retired president and CEO of Orbital ATK, now Northrop Grumman Innovation Systems. He co-founded one of Orbital ATK's predecessors, Orbital Sciences Corporation, in 1982.

As well as meeting scholarship recipient Fawley, Thompson was at the forum to kick off the inaugural David W. Thompson Lecture in Space Commerce Award. GPS pioneer Charlie Trimble was the first speaker in the new lecture series.

Thompson has actively championed creating scholarships and lectures,

"To meet young people like Destiny—their determination and passion—leaves me encouraged about the future of our industry," Thompson said

among other philanthropic activities, to help build the aerospace community.

"My wife and I don't come from wealthy families," Thompson said. "We know how demanding these fields are. We want to help students focus on their studies and research."

Thompson, who served as AIAA president from 2009 to 2010, encourages all former AIAA presidents to fund a scholarship. "The scholarship really helps me take full advantage of all the opportunities at the University of Illinois Urbana-Champaign," Fawley said. "There's so much I want to do and want to learn. This scholarship helps me do that—I can focus my time."

Thompson and Fawley swapped stories about how they joined AIAA. For Thompson, it was 46 years ago as an MIT student, but he had previously written to AIAA for information about rockets when he was in the ninth grade. Fawley became involved with AIAA during her freshman year at the University of Illinois and quickly signed up with a 3D-printing UAV project. It was her first introduction to aerodynamics—and she was hooked.

"Earning the scholarship is an early sign that you're going to do great things with your career," Thompson said. "AIAA can help during the early stages of your career, so don't drift away. Stick with it."

Fawley plans to focus on space when she graduates and is working on Heat-shield for Extreme Entry Environment Technology (HEEET) material for atmospheric reentry. She's interned at the NASA Jet Propulsion Laboratory and NASA Ames Research Center.

"I am currently creating a method to count layers of weave in the cross section of HEEET material pre- and post-arcjet test," she said. "I used a template of one layer to get a correlation map across the entire image of how well that area matches, then used a series of filters to get the exact number of layers. The goal is to get a quantitative measurement of swelling by comparing the average height of layers before and after the arcjet."

Thompson understands the pull of space. "Space-based science is a big enterprise and it's been an exciting field for me for a long time," he said.

Earth and planetary science also hold great opportunities, Thompson told Fawley, noting his company recently launched a satellite to measure Greenland's icecaps. "To see where a hurricane is going to hit wasn't possible 50 years ago," he said.

And it's supporting these future possibilities that prompted the Thompsons to invest in students. "To meet young people like Destiny—their determination and passion—leaves me encouraged about the future of our industry," Thompson said. "It's not an easy field. It's challenging but it's very rewarding as well."

And to Fawley, he added: "I'll follow your career with great interest."

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

U.S.-Australian Cooperation Connects Australia's Tidbinbilla with Deep Space

By Dr. Ed Kruzins, Director, NASA Operations, CDSCC Tidbinbilla, and Squadron Leader Michael Spencer, Air Power Development Centre, Royal Australian Air Force

AIAA Sydney Committee and Dr. Kruzins, Director of NASA Operations, CSIRO CDSCC Tidbinbilla.

On 23 August, the AIAA Sydney Section hosted Dr. Ed Kruzins, Director of NASA Operations at the Canberra Deep Space Communication Complex (CDSCC) Tidbinbilla, at a public lecture to discuss some of the complex technology at CDSCC Tidbinbilla, its importance to Australia, and highlight some of the key achievements realized with NASA space missions and space science. CDSCC Tidbinbilla is a NASA facility managed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) on behalf of the Australian government. It operates under a government-to-government, treaty-level agreement, signed in February 1960, which allowed the United States to establish satellite tracking stations in Australia. The activities of the DSN (Deep Space Network), including CDSCC Tidbinbilla, are coordinated by the NASA Jet Propulsion Laboratory. The DSN operates on a multi-mission basis, communicating with many different space missions and experiments concurrently, in 24/7 continuous operations. The lecture attracted a broad and diverse audience including veterans who were first generation operators at CDSCC Tidbinbilla.

Tracking Deep Space Missions

In 2015, CDSCC Tidbinbilla celebrated 50 years of Australian operations in space tracking and data acquisition. During this period, CDSCC Tidbinbilla operations have involved many NASA "firsts," such as NASA's first close-up pictures of the Martian surface from Mariner 4, communications, and telemetry with hundreds of space missions. Recent operations work has included line-of-sight communications with both the NASA Voyager 1 and Voyager 2 space probes, which will continue to keep science instruments functioning and communications with CDSCC Tidbinbilla until at least 2020. In July 2015, when NASA's spacecraft New Horizons made its historic flyby encounter with Pluto, CDSCC received some of the first close-up images of Pluto. CDSCC Tidbinbilla was also NASA's prime station for the Juno Jupiter orbit insertion in 2016, and in 2017 the station received the final signals from the Cassini spacecraft before it was vaporized in Saturn's atmosphere.

Innovations in Space Tracking

In 2015, under a new Australian initiative with NASA, CDSCC Tidbinbilla coordinated the first Southern Hemisphere Planetary Radar System to detect and characterize passing asteroids by operating as the transmitter in a bistatic radar system with the radio telescope receivers stationed at Parkes and Narrabri. NASA's Goldstone Solar System Radar program detects, tracks, and characterizes asteroids and comets passing close to Earth for its Sentry catalogue of Near-Earth Objects (NEO). NASA Jet Propulsion Laboratory manages the Sentry system, scanning the NEO catalogue for possibilities of a future impact. A southern hemisphere sensor allows asteroids approaching Earth from the south to be observed, filling in a blind spot in the global network of asteroid sensors.

Recently, NASA upgraded the automation systems in its DSN stations in a project called Follow the Sun to change the DSN operations paradigm. Now, each one of the three DSN sites operates the global network of three stations during their day shift, handing off control to the next site as the sun sets. To allow for continuous operations, the Australian crews at CDSCC Tidbinbilla manage all of NASA's DSN antennas worldwide for about a third of every day.

Space Science Served to Students on NASA Dishes

CDSCC Tidbinbilla has developed a space science education outreach program for school students called STARS – Space, Technology, Astronomy, Research Students. The program aims to encourage students in STEM by providing them with opportunities to realise hands-on experience and demonstrate the real-world space science applications that are being conducted in Australia with the world. This popular program was 100% booked in 2018 and is already 96% booked for 2019.

Australian-U.S. Partnership Benefits Both Countries

On 25 May 2010, during the 50th anniversary of treaty-level cooperation in space exploration between Australia and the United States, AIAA designated the Tidbinbilla, Honeysuckle Creek, and Orroral Valley Tracking Stations as Historic Aerospace Sites. There is currently a crew of about 90 Australians working at CDSCC Tidbinbilla. Their achievements over the years has inspired new innovations such as the Follow the Sun model and the Southern Hemisphere Planetary Radar System. CDSCC Tidbinbilla is connecting Canberra, Australia, to an active global effort in space science that spans the solar system and beyond.

AIAA Diversity Scholars Attend AIAA SPACE Forum

In September, 37 AIAA Diversity Scholars attended the 2018 AIAA SPACE Forum in Orlando, FL. This was the largest group of diversity scholars to attend a forum to date. The students attended plenary sessions, Forum 360 panels, and technical sessions, as well as the Rising Leaders in Aerospace events and special sessions geared specifically for the scholars.

The AIAA Diversity Scholarship provides students from underrepresented groups with the opportunity to attend AIAA forums and receive additional targeted programming that may help them succeed in the aerospace industry. The AIAA Diversity Scholars Program at AIAA SPACE Forum was sponsored by Lockheed Martin, Blue Origin, NASA Florida Space Grant Consortium, NASA Pennsylvannia Space Grant Consortium, and NASA Texas Space Grant Consortium.

Diversity scholarships will be offered for select AIAA forums throughout the year. The program welcomes applications from students in all disciplines with an interest in aerospace, including but not limited to STEM fields, communications, law, industrial design, journalism, and political science. Please visit aiaa.org/Diversity-and-Inclusion for more information.

"I didn't know that people were this passionate about aerospace. It has changed the way I look at this industry."

—Alex Conrad

Call for Papers for the 2019 AAS/AIAA Astrodynamics Specialist Conference

The 2019 AAS/AIAA Astrodynamics Specialist Conference will be held 11–15 August 2019 at the Westin Portland in Portland, ME. Manuscripts are solicited on topics related to space-flight mechanics and astrodynamics, including but not necessarily limited to:

- Asteroid and non-Earth orbiting missions
- Atmospheric re-entry guidance and control
- Attitude dynamics, determination and control
- Attitude-sensor and payload-sensor calibration
- Dynamical systems theory applied to space flight problems
- Dynamics and control of large space structures and tethers
- Earth orbital and planetary mission studies
- Flight dynamics operations and spacecraft autonomy
- Orbital dynamics, perturbations, and stability
- Orbit determination and space-surveillance tracking
- Orbital debris and space environment
- Rendezvous, relative motion, proximity missions, and formation flying
- Reusable launch vehicle design, dynamics, guidance, and control
- Satellite constellations
- Spacecraft guidance, navigation and control (GNC)
- Space Situational Awareness (SSA), Conjunction Analysis (CA), and collision avoidance
- Trajectory / mission / maneuver design and optimization
- Technology Anniversary: Lessons Learned and Impact
- The history of Astrodynamics: Review of seminal astrodynamical theoretical and practical developments

The abstract deadline is 5 April 2019. Author information can be found at space-flight.org.

Regional Leadership Conference held at AIAA SPACE Forum

Section chairs and officers attended a training specifically to help them in leading their sections' activities. The training provides the opportunity to discuss successes and challenges with their peers, meet their regional leaders, and hear and provide great ideas for section events. Over 30 attendees were able to share and hear ideas on events, membership retention, public policy activities, supporting young professionals and retired members, plus plenty of less interesting but still important administrative guidance. In the evening, AIAA Executive Director Dan Dumbacher presented certificates to those sections who won section awards for their 2017-2018 activities.

AIAA Executive Director Dan Dumbacher presents the Outstanding Activity award to Di Ena Davis and David Fox of the AIAA Delaware Section.

Attendees at the 2018 Regional Leadership Conference in Orlando in September.

Obituaries

AIAA Fellow Gulcher Died in May

Robert H. Gulcher, 92, died on 9 May.

Gulcher answered the call of duty in 1944 by completing an accelerated wartime course in mechanical engineering from the U.S. Merchant Marine Academy so that he could serve the country. That service came as an engineering cadet midshipman in the form of six Atlantic crossings with the U.S. Merchant Marines to the European theater, during which time his convoys sporadically came under German U-boat attack. He received an honorable discharge from the United States Coast Guard and was awarded the Atlantic War Zone Medal and World War II Victory Medal.

Before the war, Gulcher attended Ohio State University. Graduating from Ohio State with a degree in electrical engineering, he used that degree plus the mechanical engineering degree from the Academy to launch a career in aerospace engineering, which commenced in 1951 with North American Aviation (Rockwell International, Boeing). He became Chief Engineer and Vice President of Research and Engineering before retiring in 1991.

AIAA Senior Member Spudis Died in August

Paul Spudis, a lunar scientist and advocate for exploration of the moon, passed away on 29 August. He was 66 years old.

Spudis received his Ph.D. in Geology from Arizona State University in 1982. After graduation, he took a position as a geologist at the United States Geological Survey in Flagstaff, AZ, where he served as the Principal Investigator for NASA's Planetary Geology Program. In 1990 he joined the Lunar and Planetary Institute (LPI) as a staff scientist, serving in 1994 as Deputy Science Team leader of the BMDO/NASA Clementine mission to the moon, and as Deputy Director of the LPI (1999–2002). From 2002 to 2008 Spudis was a principal professional staff member at the Johns Hopkins University Applied Physics Laboratory, during which time he led the Mini-SAR radar that flew on India's Chandrayaan-1 lunar orbiter and was a team member of the Mini-RF instrument on NASA's Lunar Reconnaissance Orbiter. He returned to the LPI as a senior staff scientist in 2008, where he continued his mission work and became more involved in activities focused on living and working on the moon.

Spudis served on many panels and committees including the Presidential Commission on the Implementation of U.S. Space Exploration Policy (2004). His numerous honors and awards included the Columbia medal from ASME's Aerospace division (2016), the National Space Society's Space Pioneer award (2011), and the AIAA von Kármán Lecture in Astronautics (2006). He wrote over 125 refereed papers and four books, including The Once and Future Moon (1994) and The Value of the Moon (2016). He was scheduled to give the Michel T. Halbouty Lecture, titled "The Resources of the Moon" at this November's Geological Society of America conference. An AIAA Senior Member, Spudis was involved with the AIAA Space Colonization Technical Committee from 2002 to 2005.

2018 Best Professional and Student Technical Papers

AIAA Technical Committees (TCs) selected the best professional and student technical papers presented at the 2018 AIAA forums. With a standard award criterion and selection process from their respective TCs, these authors were selected and presented with a Certificate of Merit and recognized at the forums.

BEST PROFESSIONAL PAPERS

AIAA Aerodynamics Measurement Technology (AMT) Best Paper
"First Results of Lifetime-Based Unsteady PSP Measurement on a Pitching Airfoil in Transonic Flow" (AIAA 2018-1030) by Yosuke Sugioka, Taku Nonomura, and Keisuke Asai, Tohoku University; and Kazuyuki Nakakita and Kenichi Saitoh, Japan Aerospace Exploration Agency (JAXA).

AIAA Aerospace Power Systems Best Paper
"Next-Generation RTGs for NASA" (AIAA 2017-4612) by David Woerner, Jet Propulsion Laboratory, California Institute of Technology.

AIAA Aircraft Design Best Paper
"Conceptual Design and Evaluation of Blended-Wing-Body Aircraft" (AIAA 2018-0522) by Malcom Brown and Roelof Vos, Delft University of Technology.

AIAA Applied Aerodynamics Best Paper
"Cart3D Simulations for the Second AIAA Sonic Boom Prediction Workshop" (AIAA 2017-3255) by George R. Anderson, Michael J. Aftosmis, and Marian Nemec, NASA Ames Research Center.

AIAA Atmospheric Flight Mechanics Best Paper
"Performance-Based Ice Detection Methodology" (AIAA 2017-3394) by Christoph Deiler and Nicolas Fezans, DLR – German Aerospace Center.

AIAA Aviation Technology, Integration, and Operations Best Paper
"High-Fidelity Multirotor Unmanned Aircraft System Simulation Development for Trajectory Prediction Under Off-Nominal Flight Dynamics" (AIAA 2017-3271) by John V. Foster, NASA Langley Research Center, and David Hartman, Drexel University.

AIAA Computational Fluid Dynamics Conference Best Paper
"Uses of Zero and Negative Volume Elements for Node-Centered Edge-Based Discretization" (AIAA 2017-4295) by Hiroaki Nishikawa, National Institute of Aerospace.

AIAA Electric Propulsion Best Paper
"A Critical Review of Thrust Models for Applied-Field Magnetoplasmadynamic Thrusters" (AIAA 2017-4723) by William Coogan and Edgar Choueiri, Princeton University.

AIAA Fluid Dynamics Best Paper
"Secondary Stability Analysis of Crossflow Vortices using BiGlobal Theory on PIV Base Flows" (AIAA 2017-1880) by Koen Groot, Jacopo Serpieri, and Marios Kotsonis, Delft University of Technology; and Fabio Pinna, von Karman Institute for Fluid Dynamics.

AIAA Ground Testing Best Paper
"Correlation of Recent and Historical Rough-Wall Transition Data on Hemispherical Nosetips" (AIAA 2017-3986) by Brian R. Hollis, NASA Langley Research Center.

AIAA Guidance, Navigation, and Control Conference Best Paper
"Multiple-Model Adaptive Estimation for Measurements with Unknown Time Delay" (AIAA 2017-1260) by Kyuman Lee, Georgia Institute of Technology; and Eric Johnson, Pennsylvania State University.

AIAA Hybrid Rockets Best Paper
"An Analytical Model to Predict Longitudinal Acoustic Modes Frequency of Hybrid Rockets Combustion Chamber" (AIAA 2017-4645) by Carmine Carmicino, University of Naples; and Dario Pastrone, Technical University of Turin.

AIAA Hypersonic Systems and Technologies Best Paper
"A Comparative Study of Elliptic and Round Scramjet Combustors by Improved Delayed Detached Eddy Simulation" (AIAA 2017-2190) by Wei Yao, Yue-Ming Yuan, Jing Wang, and Xuejun Fan, Chinese Academy of Sciences (CAS), Institute of Mechanics; and Xiaopeng Li, Chinese Academy of Sciences, Institute of Engineering Thermophysics.

AIAA Inlets, Nozzles, and Propulsion Systems Integration Best Paper
"Performance Calculations for a Boundary-Layer-Ingesting Fan Stage from Sparse Measurements" (AIAA 2018-1889) by Stephanie Hirt, John Wolter, David Arend, and Tristan Hearn, NASA Glenn Research Center; Larry Hardin, United Technologies Corporation; and John Gazzaniga, Zin Technologies.

AIAA Intelligent Systems Best Paper
"Aviate, Navigate: Functional Visualizations of Asymmetric Flight Envelope Limits" (AIAA 2017-1297) by Tom Rijndorp, Coen de Visser, Olaf Stroosma, Clark Borst, Max Mulder, and M.M. van Passen, Delft University of Technology.

AIAA Liquid Propulsion Best Paper
"Coil-On-Plug Ignition for Oxygen/Methane Liquid Rocket Engines in Thermal-Vacuum Environments" (AIAA 2017-4666) by John C. Melcher, Matthew J. Atwell, Robert L. Morehead, and Eric A. Hurlbert, NASA Johnson Space Center; and Luz I. Bugarin and Mariana Chaidez, University of Texas at El Paso.

AIAA Meshing, Visualization and Computational Environments Best Paper
"Mesh Generation for the NASA High Lift Common Research Model (HL-CRM)" (AIAA 2017-0363) by Carolyn Woeber, Erick Gantt, and Nicholas Wyman, Pointwise, Inc.

AIAA Modeling and Simulation Technologies Best Papers
- "Evaluation of a Steep Turn Spatial Disorientation Demonstration Scenario for Commercial Pilot Training" (AIAA 2017-1079) by David Klyde, Amanda Lampton, and P. Chase Schulze, Systems Technology, Inc.
- "Effects of Motion Cues on the Training of Multi-Axis Manual Control Skills" (AIAA 2017-3473) by Peter M. T. Zaal, NASA Ames Research Center; and Xander R.I. Mobertz, Delft University of Technology.

AIAA Multidisciplinary Design Optimization (MDO) Best Paper
"Multi-Level MDO of a Long-Range Transport Aircraft Using a Distributed Analysis Framework" (AIAA 2017-4326) by Stefan Goertz, Caslav Ilic, Jonas Jepsen, Martin Leitner, Matthias Schulze, Andreas Schuster, Julian Scherer, Richard Becker, Sascha Zur, and Michael Petsch, German Aerospace Center (DLR).

AIAA Plasmadynamics and Lasers Best Paper
"Measurements and Kinetic Modeling of Radical Species in Diluted Fuel-Oxidizer Mixtures Excited by a Repetitive Nanosecond Pulse Discharge" (AIAA 2018-1194) by Caroline Winters, Zakari Eckert, Kraig Frederickson, and Igor V. Adamovich, Ohio State University; and Zhiyao Yin, German Aerospace Center (DLR).

AIAA Solid Rockets Best Paper
"Biglobal Stability of the Swirling Majdalani-Fist Mean Flowfield in Solid Rocket Motors" (AIAA 2017-4949) by Trevor Elliott, Dillion Sluss, and Wesley Gibson, University of Tennessee.

AIAA Space Architecture Best Paper
"Advanced Solar Sintering for Building a Base on the Moon" (IAC 2017-0914) by Barbara Imhof, Diego Urbina, Peter Weiss, Matthias Sperl, Waltraut Hoheneder, René Waclavicek, Hemanth Kumar Madakashira, Joseph Salini, Shashank Govindaraj, Jeremi Gancet, Makthoum Peer Mohamed, Thibaud Gobert, Miranda Fateri , Alexandre Meurisse, Olfa Lopez, and Clemens Preisinger, Regolight Consortium.

AIAA Space Flight Mechanics Best Paper
"Mapping Connections Between Planar Sun-Earth-Moon Libration Point Orbits" (AAS 17-516) by Zubin Olikara and Daniel Scheeres, University of Colorado, Boulder.

AIAA Theoretical Fluid Mechanics Conference Best Paper
"Towards a Low-Order Model for Transonic Flutter Prediction" (AIAA 2017-4340) by Max M.J. Opgenoord, Mark Drela, and Karen Willcox, Massachusetts Institute of Technology.

AIAA Thermophysics Best Paper
"Evidence of Standing Waves in Arc Jet Nozzle Flow" (AIAA 2017-4452) by David M. Driver, Frank C. Hui, and Imelda Terrazas-Salinas, NASA Ames Research Center; Joseph Hartman, Sierra Lobo, Inc.; Eric A. Noyes, Jacobs Technology, Inc.; and Daniel Philippidis, Aerospace Computing, Inc.

ASME/Boeing Best SDM Paper
"Investigating the Transonic Flutter Boundary of the Benchmark Supercritical Wing" (AIAA 2017-0191) by Jennifer Heeg and Pawel Chwalowski, NASA Langley Research Center.

Collier Research Hypersizer/AIAA Structures Best Paper
"Peridynamic Modeling of Fatigue Damage in Notched Composite Laminates" (AIAA 2017-1140) by Yile Yu and Erdogan Madenci, University of Arizona.

BEST STUDENT PAPERS

AIAA Aerospace Power Systems Best Student Paper
"Analysis of Unsteady Gas Temperature Measurements in the Appendix Gap of a Stirling Engine" (AIAA 2017-4795) by Jan Sauer and Hans-Detlev Kuehl, TU Dortmund University, Lehrstuhl für Thermodynamik.

AIAA Atmospheric Flight Mechanics Student Paper Competition
"Unsteady Fluid-Structure-Jet Interactions of Agile High-Speed Vehicles" (AIAA 2017-3549) By Ryan Kitson and Carlos Cesnick, University of Michigan.

AIAA CFD Best Student Paper
"High Order DNS and LES Simulations Using an Implicit Tensor-Product Discontinuous Galerkin Method" (AIAA 2017-3948) by Will Pazner, Brown University; and Per-Olof Persson, University of California, Berkeley.

AIAA Flow Control Student Paper Competition
"Friction Drag Reduction on a Clark-Y Airfoil Using Uniform Blowing" (AIAA 2018-3374) by Kaoruko Eto, Yusuke Kondo, and Koji Fukagata, Keio University; and Naoko Tokugawa, Japan Aerospace Exploration Agency (JAXA)

AIAA Hybrid Rockets Best Student Paper
"Pyrolysis of Paraffin Using Near-Infrared Diode Lasers" (AIAA 2017-4984) by David Dyrda and Brian Cantwell, Stanford University.

AIAA Solid Rockets Best Student Paper
"The Taylor-Culick Profile for Spinning Rocket Motors" (AIAA 2017-4779) by Orie Cecil and Joe Majdalani, Auburn University.

AIAA Space Architecture Best Student Paper
"Exploration Systems Requirements to Establish a Sustainable Human Presence on Mars" (AIAA 2017-5367) by Elizabeth Marandola, Amy Comeau, Glynn Smith, Noah Gordon, Michael Weiss, Reshef Elisha, Steven Zusack, Benjamin Hilker, Kevin LeCaptain, Luis P. Podesta, Sarag Saikia, Purdue University.

AIAA Space Systems Student Paper Competition
"High-Integrity TLE Error Models for MEO and GEO Satellites" (AIAA 2018-5241) by Danielle Racelis and Mathieu Joerger, University of Arizona.

AIAA Weaver Thermophysics Best Student Paper
"Coarse Grain Modeling and Direct Molecular Simulation of Nitrogen Dissociation" (AIAA 2017-3165) by Robyn Macdonald and Marco Panesi, University of Illinois at Urbana-Champaign; and Maninder Grover and Thomas Schwartzentruber, University of Minnesota.

American Society for Composites Best Student Paper
"Peridynamic Modeling of Damage in Laminated Composites Reinforced with Z-Pins Due to Low-Velocity Impacts" (AIAA 2018-0487) by Forrest Baber and Ibrahim Guven, Virginia Commonwealth University; and Vipul Ranatunga, Air Force Research Laboratory.

Harry H. and Lois G. Hilton Student Paper Award in Structures
"Compressive Failure of Fiber Composite: A Homogenized Mesh Independent Model" (AIAA 2018-0732) by Amanj Hasanyan and Anthony Waas, University of Washington.

Jefferson Goblet Best Student Paper Award
"Flow Properties Through a Ballistically Generated Orifice During a Hydrodynamic Ram Event" (AIAA 2018-0232) by Logan Tatman and Andrew Lingenfelter, Air Force Institute of Technology; and David Liu, Air Force Life Cycle Management Center.

Lockheed Martin Student Paper Award in Structures
"Two-Dimensional Particle Tracking Velocimetry and Flame Front Detection" (AIAA 2018-0490) by Kan Liu, David Liu, and Andrew Wang, Air Force Institute of Technology.

Southwest Research Institute Student Paper Award in Non-Deterministic Approaches
"Using Stochastic Dominance in Multi-Objective Optimizers for Aerospace Design Under Certainty" (AIAA 2018-0665) by Laurence Cook and Jerome Jarrett, University of Cambridge.

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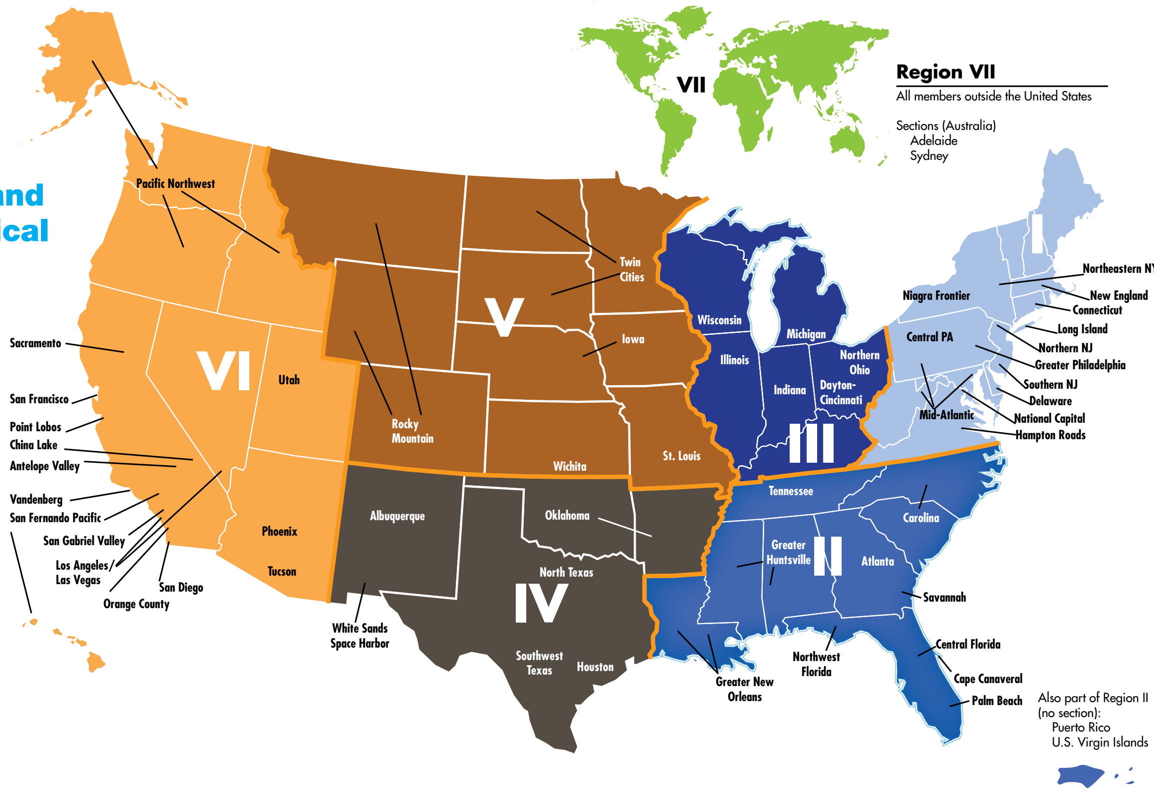

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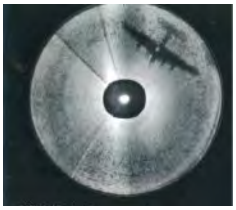
1918

Nov. 1 French Capt. Rene Fonck shoots down a German bomber for his 75th and last aerial victory. This makes him the leading Allied ace of World War I. Fonck fought for 27 months, downing an average of three German aircraft each month mostly with SPA 103, one of the famous Cigognes (Stork) squadrons. David Baker, **Flight and Flying: A Chronology**, p. 120.

Nov. 11 World War I ends on the 11th hour of the 11th day of the 11th month of 1918 as the armistice is signed by Britain, France, Italy and the United States, and Germany and the collapsing Austro-Hungarian empire. By 1918, the airplane has become a proven weapon of war, particularly for reconnaissance. Tactical and strategic bombing are developed, as is the fighter. Roger E. Bilstein, **Flight in America: 1900-1983**, pp. 31-37.

Nov. 11 Hugo Junkers orders his company to stop production of military aircraft and concentrate on designing and building a small single-engine all-metal commercial transport, the F.13. It begins operating throughout the world starting in 1919. John Stroud, **European Transport Aircraft Since 1910**, pp. 294-295.

1943



Nov. 3 The H2X blind-bombing radar (screen at left) operates in combat for the first time on more than 500 Boeing B-17s and Consolidated B-24s during an 8th Air Force attack on the German port of Wilhelmshaven. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 210.

Nov. 6 Rep. Jennings Randolph, D-W.Va., completes the first U.S. flight of a plane powered by coal-processed aviation gasoline. The U.S. Bureau of Mines Experimental Station processed about 35 gallons of gasoline from coal for the flight. **American Aviation**, Nov. 15, 1943, p. 26.

Nov. 18 The campaign to retake the Marshall Islands begins when U.S. naval aircraft from six fleet carriers and five light carriers strike targets on the atolls of Tarawa and Makin in the prelude to the bloody but victorious assault by the U.S. Marine Corps. David Baker, **Flight and Flying: A Chronology**, p. 288.

Nov. 30 The U.S. Navy's 70-ton Martin Mars flying boat, powered by four Wright Cyclone 18 engines totaling 8,000 horsepower, makes its first operational nonstop flight, traveling 7,040 kilometers from the Naval Air Test Station, Patuxent, Maryland, to Natal, Brazil. The plane was designed for patrol work but has been altered for transport service. **Aviation**, December 1943, p. 284.

1968

Nov. 2 President Lyndon Johnson presents the NASA Distinguished Service Medal to James E. Webb, the recently retired NASA administrator, and remarked that "more than any other individual he deserves the credit for the great achievements of the United States in the first decade of space, and for helping man to reach outward toward the stars." The president also presents awards to Apollo 7 commander Walter M. Schirra Jr. and astronauts R. Walter Cunningham and Donn F. Eisele. NASA, **Astronautics and Aeronautics, 1968**. p. 269.

Nov. 8 Pioneer 9, a spacecraft designed to provide continuing measurements of solar storms during heavy solar activity, is launched by a Thrust-Augmented Improved Thor-Delta rocket from Kennedy Space Center in Florida into orbit around the sun. On the same flight is the Test and Training Satellite TETR 2, which is to provide a target for the checkout of the Manned Space Flight Network and training of its operations personnel. **Washington Star**, Nov. 11, 1968, p. A17.

Nov. 10 The famed Soviet aircraft designer and academician Andrei Nikolaevich Tupolev on his 80th birthday is awarded an Order of Lenin. Among Tupolev's important contributions are the development of metal aircraft construction in the USSR during the 1920s and the building of large aircraft throughout his career, including the Tu-154, which during its time in the fleet carried half of all passengers flown by the Soviet airline Aeroflot. He designed 100 types of aircraft, many of which set world records. **Flight International**, Nov. 21, 1968, pp. 809-810.

1993

Nov. 10 The Soviet Union launches its unmanned Zond 6 toward the moon in a circumlunar flight. The spacecraft's scientific payload includes a biological experiment with wine flies, turtles, meal worms, plants, bacteria and seeds. Zond 6 was planned as a precursor to a manned circumlunar flight, which the Soviets hoped could occur in December 1968, beating the American Apollo 8. However, a few hours before re-entry, Zond 6's cabin depressurizes on Nov. 17 because of a faulty O-ring rubber gasket, killing the animal test subjects. Following this, Zond 6's parachutes deploy too early and it crashes in Kazakhstan. **Aviation Week**, Nov. 25, 1968. pp. 16-17; **New York Times**, Nov. 19, 1968, p. 1.

Nov. 11 Dennistoun Burney, the British aviation pioneer responsible for the design and construction of the R.100 British rigid airship, dies in Bermuda at age 79. In 1930, he represented the Airship Guarantee Co., the builder of the R.100, on the airship's acceptance flight from England to Canada and back. In 1911, he came up with a novel seaplane design using a hydrofoil undercarriage and two prototype designs were made by the Bristol and Colonial Aircraft Co. **Flight International**, Nov. 21, 1968, p. 809.

Nov. 12 NASA Acting Administrator Thomas Paine announces at a news briefing that the Apollo 8 mission will lift off Dec. 21 to fly around the moon on a journey lasting just over six days. Apollo Program Director Samuel Phillips says Apollo 8 is the mission "for which the Saturn 5 was designed." **NASA briefing**, Nov. 12, 1968.

Nov. 13 NASA's HL-10 Lifting Body, flown by test pilot John A. Manke, completes its first powered flight after an air launch from a B-52 carrier aircraft near Lancaster, California, to demonstrate the craft's XLR-11 rocket engine, developed and produced by the Reaction Motors Division of the Thiokol Chemical Corp. The XLR-11 is a modification of the original 6000C-4 engine that powered the Bell X-1, which in 1947 became the first plane to break the sound barrier. **Washington Post**, Nov. 14, 1968, p. A-22; Frank H. Winter, **America's First Rocket Company: Reaction Motors, Inc.**, pp. 110-111, 134-137.

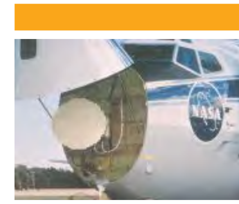
Nov. 16 The USSR launches its Proton 4 satellite, the largest satellite to date at 17 metric tons, from the Tyuratum launch site. Among its scientific objectives are to study energy spectra of cosmic ray particles. **Aviation Week**, Nov. 25, 1968, p. 17.

Nov. 17 The British Aircraft Corp.'s One-Eleven 500 (also known as the Super One-Eleven), a 119-seat "stretched" version of the BAC-111 short-range jet airliner, enters commercial operation with British European Airways. It will become one of Britain's most successful airliners. **Flight International**, Nov. 7, 1968, p. 741.

Nov. 19 The only known surviving example of a Hawker Typhoon, the World War II British single-seat fighter-bomber known as one of the war's most successful ground attack aircraft, is handed over to the Royal Air Force Museum and subsequently goes on display in London. Hawker Aircraft produced 3,300 of the aircraft. **Flight International**, Nov. 21, 1968, p. 809.

Astronaut Dr. David A. Wolf, crew member on Columbia

Nov. 1 The space shuttle Columbia lands at Edwards Air Force Base, California, concluding a two-week mission. It is the longest shuttle mission to date and was designed to test the effects of long-term weightlessness on humans. The crew of seven, including two physicians and a veterinarian, conducted 125 experiments. This is the second mission dedicated only to medical research. NASA, **Astronautics and Aeronautics, 1991-1995: A Chronology**, p. 437.



Nov. 17 NASA announces that its scientists at Langley Research Center in Virginia have developed a radar that can detect wind shear. This technology will allow pilots to "see" inside storms to identify this dangerous phenomenon and fly around it. NASA, **Astronautics and Aeronautics, 1991-1995: A Chronology**, p. 441.

JAMES KROPP, 27

Programming engineer, Norsk Titanium

James Kropp nurtured his love for machines helping his father work on cars and other projects around their home. Those projects included woodworking, where he learned the principles of design and fabrication. More hands-on experience during vocational courses in his Michigan high school sparked a passion for the science of welding and other materials joining processes. He earned a Bachelor of Science in welding engineering technology from Ferris State University in Big Rapids, Michigan. Kropp now works in Plattsburgh, New York, for Norsk Titanium, a Norwegian additive manufacturing company with 150 employees. Norsk produces the first FAA-certified additively manufactured structural titanium parts for a commercial aircraft, Boeing's 787 Dreamliner, through its patented Rapid Plasma Deposition process, which builds parts with layers of melted titanium wires.

How did you become an engineer?

My first encounter with the aerospace industry was through an internship at Woodward Fuel Systems Technologies. I developed weld procedures for F135 engine fuel system components. Next, I worked for United Launch Alliance as a welding engineer, supporting production components for Atlas 5, Delta 2 and Delta 4, and then as a test/propulsion system design engineer, developing and qualifying components for ULA's Vulcan rocket booster. Seeing the potential for the implementation of additive manufacturing during hardware development inspired me to pursue the advancement of the additive technology, which led me to Norsk Titanium. I work alongside Norsk's Part Development teams to establish deposition techniques and process parameters for additively manufacturing titanium components using the Rapid Plasma Deposition process. I work to increase process efficiency and capability, while maintaining customer requirements and product integrity. It is exciting to work with a relatively new process in such an innovative field. There are few areas in the aerospace industry where you can go to work and push the limits of what people believe can be done, on a daily basis. Additive manufacturing is one of them.

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

We will continue to see a push for increased efficiency while maintaining or reducing manufacturing cost. To achieve these goals, I think we will see a shift from traditional manufacturing techniques to lower cost and more efficient methods such as additive manufacturing. This change is starting, but there is still an enormous effort required to reach full industrialization. Within the next five years, industry standards will be established and applied, leading the way for industrial implementation. Additionally, with the significant increase in composite structures utilization, there will be a need to develop new methods for the mating of composite and metal structures. There are substantial opportunities for the development of a hybrid metal/composite additive process on the industrial scale. Creating metal composite structures as a single piece instead of a mechanical assembly will significantly improve aircraft performance by 2050, leading to an increase in societal growth through faster and more economical air travel. ★

By DEBRA WERNER | werner.debra@gmail.com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