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NEW TRY THE AEROPUZZLER
PG 11

THE NEW ARMS RACE

U.S. amps up planning, dollars for hypersonic weapons. PAGE 20

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On the cover: A conceptual hypersonic waverider aircraft simulation.

Image credit: Pointwise Inc.

AEROSPACE
★ ★ ★ AMERICA ★ ★ ★

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Keith Button
Keith has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns scandal that kicked off the global credit crisis.
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Henry Canaday
A former energy economist, Henry has written for Air Transport World, Aviation Week and other aviation publications for more than two decades.
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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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Joe Stumpe
A freelance reporter based in Wichita, Kansas, Joe has written for The New York Times, Agence France-Presse and The Huffington Post.
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Debra Werner
A frequent contributor to Aerospace America, Debra is also a West Coast correspondent for Space News.
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DEPARTMENTS

OPINION
Engineers are dogs; scientists are cats. Planetary scientist Ralph D. Lorenz explains the dynamic he sees played out among his research colleagues.

▲ **Take the iceboat challenge** by turning to the Aeropuzzler on Page 11.

Introducing the Aeropuzzler

Many years ago, one of my editing mentors was less than pleased when I dropped the term Reynolds number into a draft article with little or no explanation. When I started working the phones, I quickly discovered that even the experts, or especially the experts, had trouble putting the meaning of this aeronautics formula into words. One engineer finally told me: "Look, all I know is that if the number is above [a certain figure], the plane won't fly."

Boiling a complex concept into words that anyone can understand is a skill that will serve an engineer or scientist well. A member of Congress or a CEO could one day look over to you and say, "It says you want a few million dollars to research flight at high Reynolds numbers. What the heck does that mean?" You'll want to be ready, or if you think you already are, it can't hurt to prove it.

In that spirit, we introduce the Aeropuzzler [Page 11]. The truth is, you could probably solve our inaugural puzzler and those to come in a flash, either with your knowledge, or with the aid of your Google brain. Your challenge isn't just to find the answer. It's to craft a concise, unique and creative explanation of 250 words that anyone could understand. Email that to us, and with the help of experts in the particular topic area, the Aerospace America team will select the best answer and publish it on the Aeropuzzler page of the next issue.

Our hope is that this won't feel like homework or a throwback to it. For some, unraveling a conundrum and making the answer accessible is part of the fun. The weekly "puzzler" was a classic segment of the "Car Talk" radio show. And of course there was the greatest puzzler creator and solver of them all, Albert Einstein. He managed to craft thought experiments that were interesting to some of the smartest people in the world and yet understandable to the nonspecialists who read his popular books. Who among us hasn't stood on a train platform and thought about Einstein's train-car-lightning-bolts experiment? It's such an obvious real-world analog, but so thought provoking that it's still discussed today.

There will never be another Einstein or "Click and Clack, the Tappet Brothers," but maybe each of us can take a bit of inspiration from them. Email your puzzler answers and ideas to aeropuzzler@aiaa.org. ★

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

CORRECTION


U.S. ARMY BRIG. GEN. THOMAS TODD III, PROGRAM EXECUTIVE OFFICER FOR AVIATION

Q&A

Rotorcraft modernizer

BRIG. GEN. THOMAS TODD III

I believe we will take a pretty big leap in capability in performance of these airframes over the next 10 to 15 years.

In the biographical information accompanying the May Q&A ("Rotorcraft modernizer"), we misstated the hurricane deployment of U.S. Army Brig. Gen. Thomas Todd III. Todd deployed to Honduras in 1998 for Hurricane Mitch relief efforts.

AIAA/IEEE ELECTRIC AIRCRAFT TECHNOLOGIES SYMPOSIUM

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The aerospace industry has set ambitious goals for the next three generations of commercial transport aircraft to accommodate rapid growth in emerging markets and ensure the future sustainability of air travel. One approach being explored to meet these targets is nontraditional aircraft propulsion using electric, turboelectric, or hybrid-electric powertrains.

Recent workshops by the IEEE and AIAA have identified the need to bring together electrical engineers and aerospace experts as the industry looks to more electric propulsion technologies for future aircraft. The AIAA Aircraft Electric Propulsion and Power Working Group, the IEEE Transportation Electrification Community, and the College of Engineering of the University of Illinois at Urbana-Champaign are collaborating to organize a new two-day symposium to address these issues. The event occurs on 12–13 July, following the AIAA Propulsion and Energy Forum.

TECHNICAL PROGRAM

The symposium will focus on electric aircraft technology across three programmatic tracks with more than 70 papers:

1. Electric-power enabled aircraft configurations and system requirements
2. Enabling technologies for electrified aircraft propulsion
3. Electric aircraft system integration and controls.

KEYNOTE SPEAKERS

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SYSTEM ENGINEERING NEEDS AND CHALLENGES GENERATED BY ELECTRIFICATION OF AIR VEHICLES

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It's More Than a Tagline

This is my first column as executive director of AIAA. My first few months on the job have been insightful, interesting, and very educational. I look forward to working with all of you in the coming years. Please reach out too and let me know what you think of **your** Institute—what we do well, and what we could do better. The AIAA Engage platform is a great way to connect, or you can email me at Daniel.Dumbacher@aiaa.org. I look forward to talking with you at section events, forums, conferences, or here at our Reston headquarters. I want to hear from you!

Have you ever noticed the "Shaping the Future of Aerospace" motto in the AIAA logo? I have come to realize how little we use this key statement. "Shaping the Future of Aerospace" is a daily and continuous endeavor for AIAA.

AIAA "shapes the future of aerospace" in many ways. Our members are designing, building, integrating, testing, and operating commercial and military aircraft and systems, developing new air traffic control technologies and systems, executing near-Earth and far-reaching science missions, developing next-generation space transportation systems and technologies, all for the benefit of our global society. Your daily work across industry, academia, and government, combined with your passion, makes everyone's lives better and richer.

At a deeper level, what does "shaping the future of aerospace" mean? To me it means that we are constantly challenging ourselves to be future focused—to ask, "where is the aerospace profession headed in aviation and space?" In other words, how do we as Institute members and staff ensure that AIAA remains **relevant**!

Aviation is exploring new technologies in hypersonics, air traffic control, data analytics, and efficiencies needed for the commercial market. Space is transitioning from the past—government funding driving the research and development—to private enterprise increasingly participating and defining new markets, more efficient methods, and new and innovative technologies. Across the profession we should be asking "what do we need to do to prepare for the future 5, 10, 15 years out?" We must adjust to, and prepare for, the coming changes in aviation and space to shape the future of aerospace effectively.

We owe this to the next generation, paying it forward as our mentors did. The leaders of the generation before us set the bar high, challenged us, trained us, and established the programs to address national security, civil space, and aviation needs—all to benefit society. Importantly, they recognized it was a "long-term game." It is imperative that we change with the times, address the new and changing needs, and help mold the future to remain the world's leading authority on aeronautics and astronautics.

The challenge to all of us is that we think and act to continue "Shaping the Future of Aerospace". How do we do that? We recognize that the fast-paced and changing environments in aviation and space require exploring new partnerships and collaborations, new ways of engaging with our current members, former members, and potential new members, both individual and corporate. With this recognition, we seek and develop new relationships, strengthen our current relationships, challenge ourselves to prepare for the future, do it faster, and most importantly prepare the next generation.

As we strive to meet the highest of standards and shape the aerospace profession we must remember that we have a deep responsibility to the future generations of aerospace professionals and society. All of us, with our individual stories, started our career journeys in grade school, proceeded through undergraduate studies (and for some graduate studies), and off to our respective careers. Our desire to make things happen, take control of our futures, and ultimately make a difference is the same desire of the generations following us. We wanted to be relevant, and so does the next generation! All of us—no matter the career stage—can help the generations that follow to "shape the future of aerospace."

We have the tools in place. We have the dedicated and passionate membership. We have the AIAA Strategic Plan for 2018–2021, which you will be hearing more about soon. We have the governance structure we need in place and the process streamlined. We have the AIAA staff to help execute. Let's put our focus on the future, rather than the past, and go make it happen! ★

Dan Dumbacher

Daniel L. Dumbacher, AIAA Executive Director

How technicians search for weakened fan blades

BY TOM RISEN | tomr@aiaa.org

▲ **A Southwest Airlines** technician examines a CFM56-7B engine whose fan blades have been removed, exposing the vanes that direct air through the engine.

Southwest Airlines

The fatality in April aboard a Southwest Airlines flight posed a major challenge for Southwest Airlines and others that fly engines of the kind that broke in flight, spraying debris and causing the deadly cabin depressurization that killed a passenger.

The airlines needed to inspect the 24 fan blades on 3,716 engines for signs of metal fatigue like the six crack lines discovered in the broken blade recovered inside the CFM56-7B engine after the emergency landing in Philadelphia. Southwest said on May 17 that it had completed the fan blade inspections on the engines on its Boeing 737-700 and 800 jets, with "no additional findings of subsurface cracks." Earlier, the airline said a few blades were sent to GE Aviation, based in Ohio, "for further inspections to ensure our conclusions." The CFM56-7B engines are made by CFM International, the joint venture of GE Aviation and Safran Aircraft Engines of France.

The following is how a fan blade inspection unfolds, according to experts in the field. The engines are kept on the wings, and technicians remove and clean the 24 titanium fan blades from each engine. They look for cracks or flaws with their eyes before covering the blades with glycerin, a gel, that transmits the sound from an ultrasound probe to the surface of the blade. In fact, glycerin is often one of the ingredients in the gel that doctors spread on the skin during ultrasound exams, such as those for pregnant women.

If there is an irregularity in the fan blade, such as a microscopic crack, this shows up on a handheld display as a peak in amplitude of the signal that echoed from the crack.

The reading must fall within the acceptable range set by the calibration standard or the inspector will run a separate test in which electromagnetic signals are transmitted into metal. These signals should form eddy currents. Cracks, however, will prevent eddy currents from forming around the compromised section. These gaps will show up on the device's voltage display, and the fan blade will be set aside and replaced. Such eddy tests require attaching separate probes with electromagnetic conductor coils to transmit the current.

In the case of the Southwest engines, GE Aviation is following up on the suspect blades by conducting eddy current tests. If an eddy test indicates a problem, technicians will cut into a fan blade for further inspection.

That can mean cutting a blade in half with a circular diamond-impregnated saw blade while spraying water on it to avoid generating heat, explains Victor Sloan, president of Victor Aviation, an FAA-certified repair center in California. Sloan has a U.S. patented cryogenic nondestructive testing process that exposes a fan blade to extreme cold temperatures and then reheats them to test for internal metallurgic defects and residual stress. ★

Drone tech opens door to Mars Helicopter

BY TOM RISEN | tomr@aiaa.org

NASA's announcement that it will add a tiny helicopter to its planned Mars 2020 rover came after a series of test flights inside a vacuum chamber proved the feasibility of adapting consumer drone technologies into a craft capable of flying in an atmosphere just 1 percent as dense as Earth's.

If all goes as planned, the softball-sized, 1.8-kilogram Mars Helicopter will become the first heavier-than-air vehicle to fly in another world's atmosphere. The Soviet Union in 1985 flew balloons in the skies of Venus carrying the Vega 1 and 2 probes to study the atmosphere. U.S. scientists and engineers have since the 1970s envisioned flying fixed-wing aircraft on Mars. A recent proposal was to fold up a glider inside a cubesat and detach it from the Mars 2020 capsule during descent.

The plan announced by NASA in May calls for the rover to place the helicopter on the surface after it lands in February 2021 and then back away. The helicopter will take off for 30 days of flights that will include numerous takeoffs and landings from the Martian surface.

The closest thing to a science instrument aboard the helicopter will be a color camera. "If we are successful demonstrating [the helicopter] flying on Mars this will open the door to future missions, a next generation of helicopters designed to carry scientific instruments," says Mimi Aung, the project manager for the Mars Helicopter at the NASA-funded Jet Propulsion Laboratory in California.

The minimalist design was made possible by capitalizing on durable lightweight materials, solar cells, lithium ion batteries and autonomous flight software developed for consumer drones, Aung says. Manufacturing of the flight helicopter is due to be completed by the end of the year. NASA JPL is building the fuselage and has been working with California-based drone maker AeroVironment, which is building the landing gear and rotor.

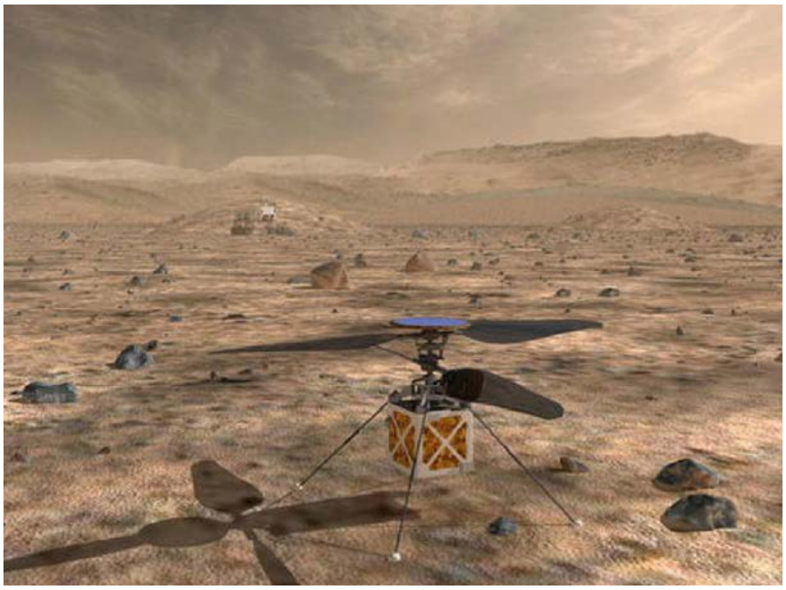
Aung's team test flew a prototype helicopter in January in the Twenty-Five Foot Space Simulator at JPL. "We took it close to near vacuum and backfilled it with carbon dioxide gas to get to Mars atmospheric density," Aung explains.

The twin, counter-rotating blades of the electric-powered Mars Helicopter must spin 10 times as fast as an average helicopter on Earth to get the same lift.

NASA had also considered the glider concept called PRANDTL-M, short for the Preliminary Research Aerodynamic Design to Land on Mars and a reference to Ludwig Prandtl, who is famous for research to reduce drag from wings. Al Bowers, the chief scientist at NASA's Armstrong Flight Research Center and the glider project's manager, says his team will propose flying a glider as part of a future Mars mission. The glider would measure density, pressure and temperature of the Martian atmosphere while gliding to the surface.

Bowers says he is "very excited about the helicopter project's potential to open the door to Mars aeronautics," including his own glider.

In the late 1970s, NASA Dryden Flight Research Center aerospace engineer Robert Dale Reed designed a hydrazine-propelled plane that would have unfolded to fly on Mars. An earlier gasoline-fueled version of Reed's plane called the Mini-Sniffer test flew from 1975 to 1977 to study how to measure pollution from high altitudes on Earth. ★



▼ **The Mars Helicopter**, seen in a screen grab from an animated video, will travel with the Mars 2020 rover.

NASA

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- Supported more than 400 student conferences engaging 13,000 students.
- Sponsored design competitions that have attracted more than 11,000 college students, giving them the chance to apply engineering skills outside of the classroom.

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

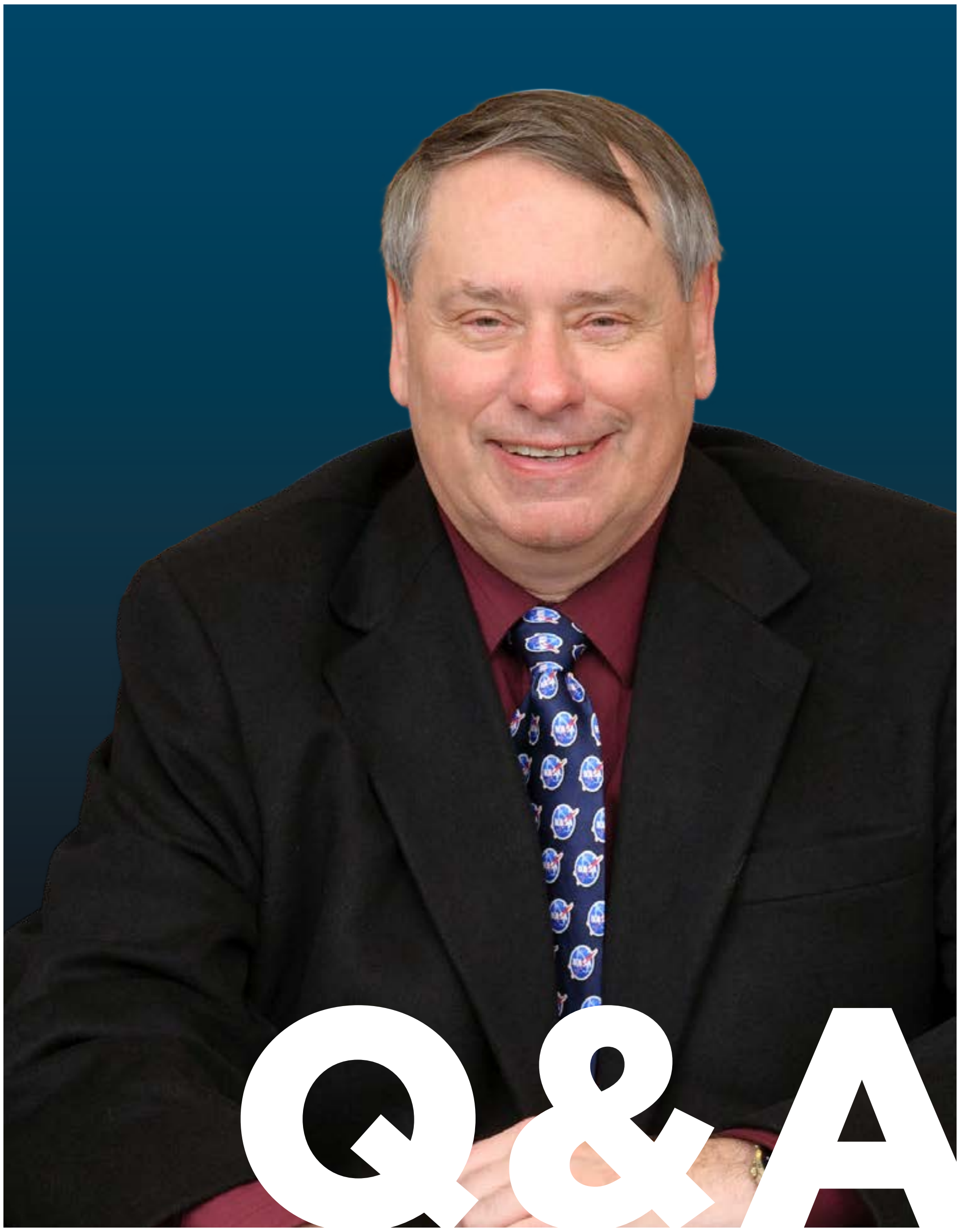
Take the iceboat challenge

You and a friend are bundled up, ready to watch an iceboat race. The wind is blowing 18 mph (30 kph). Your friend, a business student, says, “Gee, I wish it were windier. I’d like to see a boat go faster than 18 mph.” Is your friend correct that an iceboat can’t go faster than the wind? School your friend on the physics.

We’ll choose the most interesting and accurate response and run it here in the July/August issue, along with the next Aeropuzzler.

INTRODUCING THE AEROPUZZLER

Can you boil a complex concept into words anyone can understand? Draft an answer of no more than 250 words to the question at left and send it to aeropuzzler@aiaa.org with your contact information. Look for the Aeropuzzler in the July/August issue to learn whose response we publish.



Interstellar visionary

Pete Worden has long had a reputation for looking far beyond the confines of his career in the U.S. Defense Department and NASA, so it was perhaps not surprising that after a four-decade government career he would find a bold and provocative goal. Worden leads what's expected to be a decades-long, privately funded endeavor to launch a succession of spacecraft, each weighing just a few grams, toward the next star system over, Alpha Centauri 4.3 lightyears away. Worden's team is still figuring out exactly how this might be done, but the current concept calls for accelerating small wafers, called StarChips, to incredible speeds by projecting laser light onto a centimeter-scale lightsail attached to each chip. These StarChips would fly by the exoplanet Proxima-b to beam back images and maybe spectral readings to determine whether it could sustain life. I spoke to Worden by phone about the timing of the Breakthrough Starshot and what it will take to achieve it.

— Tom Risen

SIMON "PETE" WORDEN

POSITIONS: Executive director of Breakthrough Starshot since 2015; director of NASA's Ames Research Center in California from 2006 to 2015; retired from U.S. Air Force in 2004 as brigadier general; special assistant to the director of the "Star Wars" Strategic Defense Initiative from 1983 to 1986 and then deputy for technology from 1991 to 1993.

NOTABLE: While deputy for technology at the Strategic Defense Initiative, Worden ensured funding for the experimental DC-X Delta Clipper vertical takeoff and landing rocket, which first flew in 1993 to test reusable rocket technology. At SDI he also co-proposed an early concept of the Clementine lunar orbiter and ensured funding for the satellite, which the Pentagon launched in 1994 to test sensors related to missile defense; Clementine's readings indicated there is water inside the moon.

AGE: 68

RESIDES: Mountain View, California

EDUCATION: Bachelor of Science in physics and astronomy from University of Michigan; doctorate in astronomy from University of Arizona; graduate of Squadron Officer School at Maxwell Air Force Base, Alabama; graduate of the National War College; degree in National Security Studies from Syracuse University.

FAVORITE QUOTE: "It's better to be lucky than good."

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IN HIS WORDS

Timetable for launch
If all goes well, 25 years from now we'll launch our first interstellar probes.

Proxima-b
We hope we find evidence of what might be a life-bearing planet. Currently the best approach is to try to send [StarChips] to fly by and get images and maybe other kinds of data, spectrum and so forth, to really characterize this planet. One of the ideas is obviously some spectrometer [readings]. We'd like to get close enough, if there's something that looks like forest, to get a spectrum of the forest area versus oceans. A few million kilometers will be our flyby distance.

Images from a super-small spacecraft
What you really need is an optical system, probably a few tens of centimeters [across]. The baseline approach is to actually configure the sail itself, so it acts as an optical [element]. Another idea is that when you get close to the target system, you actually deploy a small, lightweight optical system. So, you need basically some sort of telescope-type function.

Funding the Starshot
Yuri Milner has committed $100 million for the next five to seven years to do the technology. Hopefully after five years, we could begin to construct some sort of major field demonstration. That presumably would take five or so years to build and test. Then sometime 10 to 15 years from now we would start building the full-scale system.

A swarm of nano-spacecraft
The mothership would [release] probably hundreds or thousands of [StarChips and sails]. We're thinking of something that would look about the size of a typical communications satellite, so a few thousand kilograms maybe is the mothership. It would be in a highly elliptical orbit where the apogee would be pointed kind of in the direction of Alpha Centauri.

Laser propulsion
The notional place [for the laser beam] would be the Atacama Desert in Chile. Another possibility may be southern New Zealand. It has to be in the southern hemisphere because Alpha Centauri is not visible from the northern hemisphere. We would only [propel] one at a time. It takes about 10 minutes to accelerate [each StarChip] to 20 percent the speed of light. Then the next day you would launch another one.

Light sailing
The total mass of the light sail plus chip is a few grams at most. It's probably going to be folded up in some way. It should have really low absorption [to avoid heat damage]. It's how much power [the laser] can put on the sail and how long you can focus it. You reflect most of the light. That's what gives you your [propulsion] pressure.

Avoiding collisions
One of the reasons that we're going to send hundreds of them is we're probably going to lose a lot of them. [Collisions with] dust is the most serious issue. You'll have three or four cameras, so if one of them gets hit by a piece of interstellar dust there's other ones to take over.

Optical communications
After you've flown through the system you turn around, lock a small laser on board back on the Earth then we fire the laser signal back. We're convinced that the battery technology as it exists is within the power levels we need.

Starshot contracts in 2018
The next five to seven years we're going to be addressing key technology questions. We've narrowed down to three we consider the real deal breakers. The first is, "Can you build this giant laser array [on Earth] for any affordable cost and get the beam through the atmosphere?" We are writing 13 contracts for the first study phase of that. The second key thing is the light sail and how you attach the [StarChip] to it. We're within a few weeks of releasing our request for proposal on that. The third part is how do we communicate back from Alpha Centauri? Later this year we'll have the RFP for the communications piece.

Other science targets
We're funding efforts of ground-based observatories to see if we can find [other] planets around Alpha Centauri A and B. If we're lucky we'll have several planets to fly by. Between TESS [the Transiting Exoplanet Survey Satellite], the James Webb Space Telescope and these ELT [Extremely Large Telescopes], we will find out in a decade if there is a potentially life-bearing planet, or at least something that seems to show some evidence of life, around one of the nearest stars.

Affordable missions
I think this is a revolution in our ability to explore the solar system and even deeper interstellar space. As we make progress we could send these probes to the Oort Cloud, to the Kuiper Belt. And they'll be cheap. Once you've built the basic system, it's a few million dollars per mission, not tens of millions. Titan [Saturn's largest moon], Venus and Ganymede [the largest moon in our solar system] might have no life but they might have some residual organic matter that would be worth investigating.

Willingness to adapt
You're looking at whatever concept works. There are a number of people who believe that our advances in fusion engines are coming along. If those things mature faster than a light sail, then we'll switch. Nothing has been presented yet that would suggest that we should change.

On the late Stephen Hawking, a Starshot adviser
He kind of made it clear this was one of his dreams, too. He was very concerned about the interstellar medium and so some of the questions he asked, we investigated those in detail. He [thought] eventually we can even send humans. We're skeptical of that but he was very forward leaning on this. ★

ASTRONAUT'S VIEW | AN APPRECIATION

An astronaut rem John Young

After the final space shuttle mission, the crews of STS-1 and STS-135, the first and last missions, gathered in 2011 at NASA's Johnson Space Center. John Young, STS-1 commander, center, was joined by, from left, STS-135 pilot Doug Hurley, STS-1 pilot Robert Crippen, STS-135 commander Chris Ferguson, and mission specialists Sandy Magnus and Rex Walheim. Magnus is the former executive director of AIAA.

embers

NASA photo/Houston Chronicle, Smiley N. Pool

BY TOM JONES
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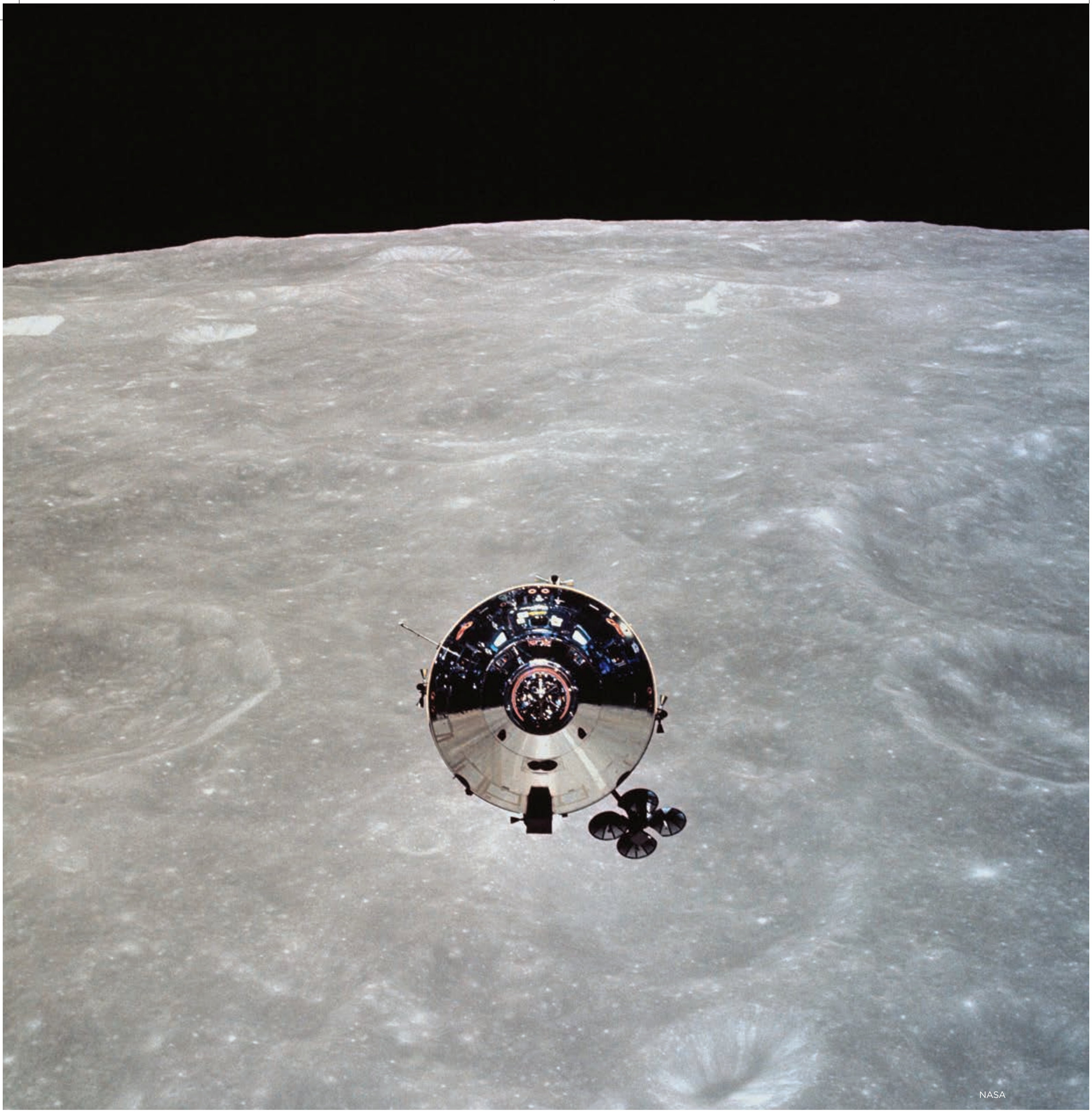
Astronaut John W. Young died at age 87 on Jan. 5. He was the ninth human to walk on the moon, flew six space missions, and served as an astronaut for over four decades. Veteran astronaut Tom Jones, who trained and flew (aircraft) with Young, remembers his personality and character.

When in 1996 NASA planted seven young live oak trees at Houston's Johnson Space Center to memorialize the seven Challenger astronauts, lost in flight 10 years earlier, its most senior astronaut, John Young, advised his younger colleagues to show up at the ceremony. "Y'all better go — you're all going to have a tree of your own out there someday."

In May, John's sturdy oak was dedicated at Johnson's Astronaut Memorial Grove, its base blanketed by red roses laid in tribute by the astronaut corps. A T-38 rocketed upward from its four-ship "missing man" formation in a final, fitting salute to the legendary test pilot and astronaut.

John was NASA's longest-serving astronaut, with 42 years in service to the U.S. space agency. He is unquestionably one of the top flyers ever to have piloted an American spacecraft. He launched into space six times — seven, if you count his Apollo 16 blastoff from the moon. For nearly two decades as NASA's senior astronaut, he employed a watchful eye and insistent voice



▲ **Young piloted the Apollo 10** command module "Charlie Brown" in lunar orbit. On this dress rehearsal for the first lunar landing, Apollo 10 set the record for the highest speed attained by any manned vehicle at 39,897 kilometers per hour (24,791 mph) during its return to Earth on May 26, 1969.

to enhance astronaut safety.

The highlights of John's career are well-known. He served in the Korean War as a fire control officer aboard a destroyer, then trained as a naval aviator and test pilot. In 1962, he set two world time-to-climb records in the powerful McDonnell F-4 Phantom 2 interceptor. Hired with NASA's second group of astronauts in 1962, John flew as Gus Grissom's pilot on the first Gemini mission in 1965. Gemini 3 was aloft for only three orbits, but John and Gus demonstrated the spacecraft's ability to change its orbit, essential for later Apollo rendezvous maneuvers around the moon. During the flight, John famously surprised Gus with a corned beef sandwich he had stashed in his spacesuit pocket, a treat enjoyed by Gus but blasted as a possible safety risk by a few humorless congressmen.

John commanded Gemini 10, and with Mike Collins docked with an Agena target spacecraft, another critical test for Apollo. In 1969, he flew as Apollo 10's command module pilot on a successful lunar orbit rehearsal for Apollo 11's historic first

“The number one job of any astronaut is to keep any other astronaut from getting killed.”

— John Young, as remembered by astronaut Alvin Drew

landing two months later.

He voyaged again to the moon (one of only three humans to do so twice) as commander of Apollo 16, landing in the Descartes highlands with Charlie Duke in April 1972. During their first moonwalk, the pair learned that the U.S. House had approved funds for NASA's planned space shuttle. From the moon, Young radioed, “The country needs that shuttle mighty bad.”

John would command the first space shuttle mission, STS-1, on orbiter Columbia in April 1981 — in my opinion, his crowning career achievement. It was the first time — before or since — that a new spacecraft was launched carrying astronauts on its first voyage. Roaring skyward on the untried shuttle “stack” — external tank, boosters and orbiter — Young and pilot Bob Crippen orbited Earth 36 times and flew Columbia to a perfect touchdown at Edwards Air Force Base, California. The pair's skill and courage were central to the success of what NASA acclaimed as “the boldest test flight in history.”

John's final spaceflight saw him command STS-9, Columbia, in 1983, a mission to carry the first European-built Spacelab module in the orbiter's cargo bay. The crew overcame two flight computer failures and a fire in two of three auxiliary power units driving their aero-surface hydraulic systems. Columbia landed safely after 10 days. Later, Young said, “We didn't know it was on fire. We had no idea. Fact is we landed on Thursday and found out about the fire on Saturday — so that's the kind of fire to have.”

That was “John Young cool.”

Cool, I saw first-hand, did not mean oblivious to risk.

From 1974 until 1987, John served as chief of the Astronaut Office. Piloting a NASA training jet over Cape Canaveral, he witnessed the shuttle Challenger's catastrophic breakup on Jan. 28, 1986. In an internal memo written before the accident, Young warned, “If we do not consider Flight Safety first all the time at all levels of NASA, this machinery and this program will NOT make it.” When the memo leaked to the press in March 1986, the resulting uproar led NASA a year later to reassign him as technical adviser to the director of Johnson Space Center.

The loss of seven of “his” astronauts caused Young to redouble his focus on crew safety. Astronaut Alvin Drew remembers Young saying: “The number one job of any astronaut is to keep any other astronaut from getting killed.”

John continued to write memos — I still have at least three dozen — to the astronauts, Space Center, and headquarters management suggesting design and operational upgrades to improve shuttle safety. Budget limitations kept many of his hardware fixes from implementation, but his innovative ideas for

NASA

▲ **Gemini 10's commander, John Young,** left, and Michael Collins, the pilot, on the deck of their recovery carrier, USS Guadalcanal. The pair conducted two rendezvous with Agena target spacecraft, made two spacewalks, and during nearly three days in orbit demonstrated techniques needed for later Apollo voyages to the moon.

expanding the shuttle's launch abort and emergency landing options eventually became reality.

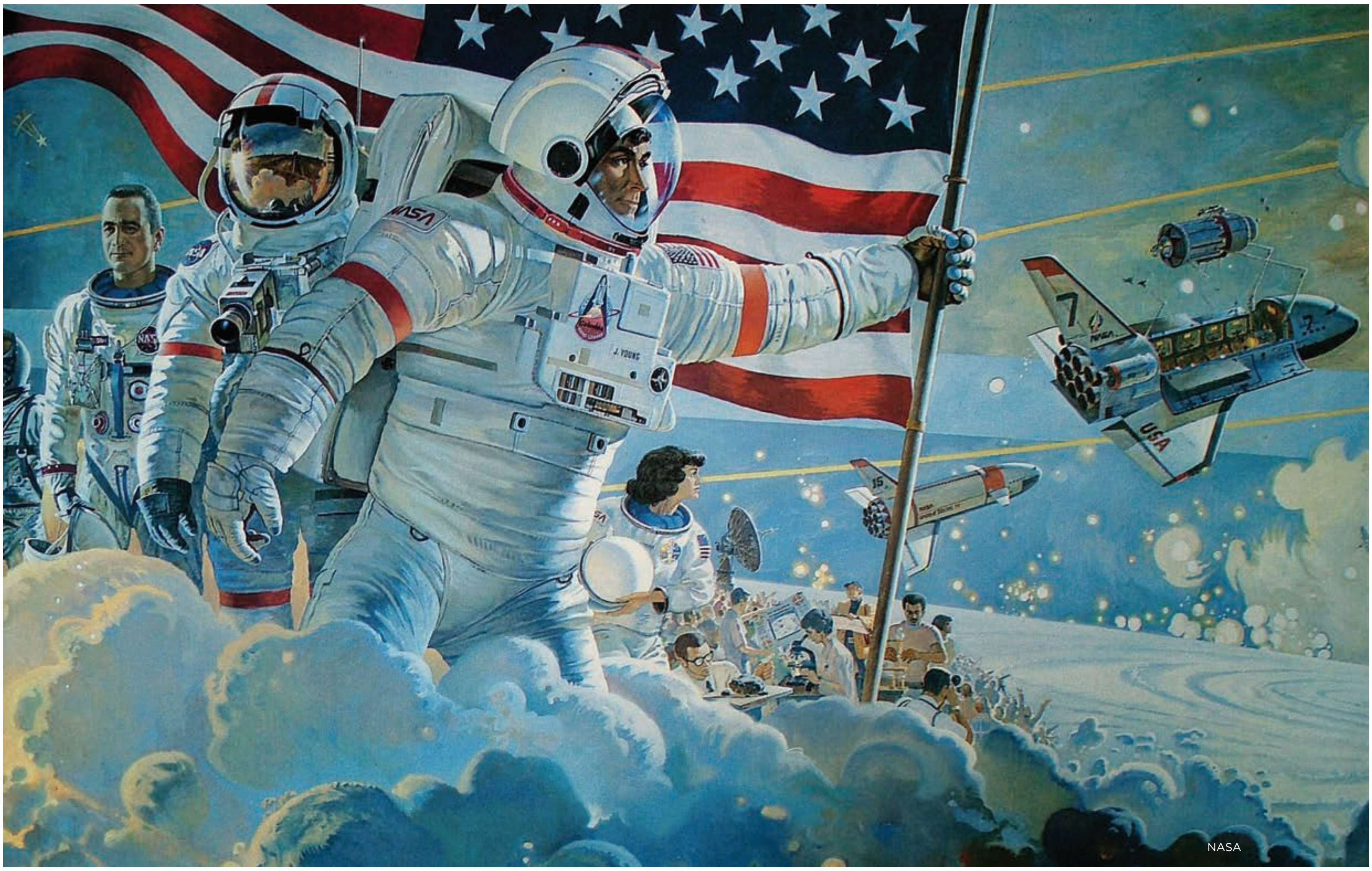
When I became an astronaut candidate in 1990, John in his role as special assistant to the director was a regular at our Monday morning staff meetings. He sat quietly off to the left of the chief's table as the astronauts discussed the week's issues, including ongoing flight preparations, tests and safety questions. We could always count on his laconic commentary on NASA's progress (or lack thereof) in meeting those challenges. He didn't say much, but his words were reliably memorable. He always softened a probing question by adding in his apologetic drawl: "Just askin'."

We astronaut candidates were sometimes lucky enough to draw Young as commander in a shuttle

I'd answer the phone and hear a familiar drawl. "Hey, ol' buddy, this is John Young. Want to go fly to the cape tomorrow? We'll go kick the tires on an orbiter."

On his fourth flight, Young, commander of the Apollo 16 lunar landing mission, leaps from the lunar surface as he salutes the U.S. flag at the Descartes landing site. The lunar module "Orion" is at left rear with the Lunar Roving Vehicle parked in front.

NASA



NASA

▲ **Robert McCall painted Young**, in shuttle spacesuit, carrying the Stars and Stripes in McCall's mural "Opening the Space Frontier, The Next Giant Step" on display at NASA's Johnson Space Center in Houston.

simulator session. No shuttle malfunction or tight corner of the flight envelope fazed him, but once, during a simulated ride to orbit, one of my classmates, the flight engineer, deliberately (and on the sly) shut down one of our main engines. The failure forced John to finesse an emergency abort landing into Morocco. I was aghast, worried that my classmate's practical joke had gone too far; one word from Young and neither he nor I would ever fly in space. But when the gag was revealed, John loved it; a "good one," he said. We came away hopeful that John's tutelage would help us someday strap into the seat of a real shuttle. We came away admiring his ability to laugh with us novices as much as his sure hand at the controls.

Every few weeks I'd answer the phone at my desk and hear a familiar drawl. "Hey, ol' buddy, this is John Young. Want to go fly to the Cape tomorrow? We'll go kick the tires on an orbiter."

Well, John called everybody "ol' buddy," but his invitation was nevertheless a genuine compliment. We'd streak from Houston's Ellington Field in a NASA T-38, soar across the Gulf of Mexico, and touch down at Kennedy Space Center's shuttle landing runway. We'd hop in a van and 15 minutes later be checking out a real space shuttle in its hangar. Any chance to get close to a shuttle was a privilege, but to do it with John Young? Priceless.

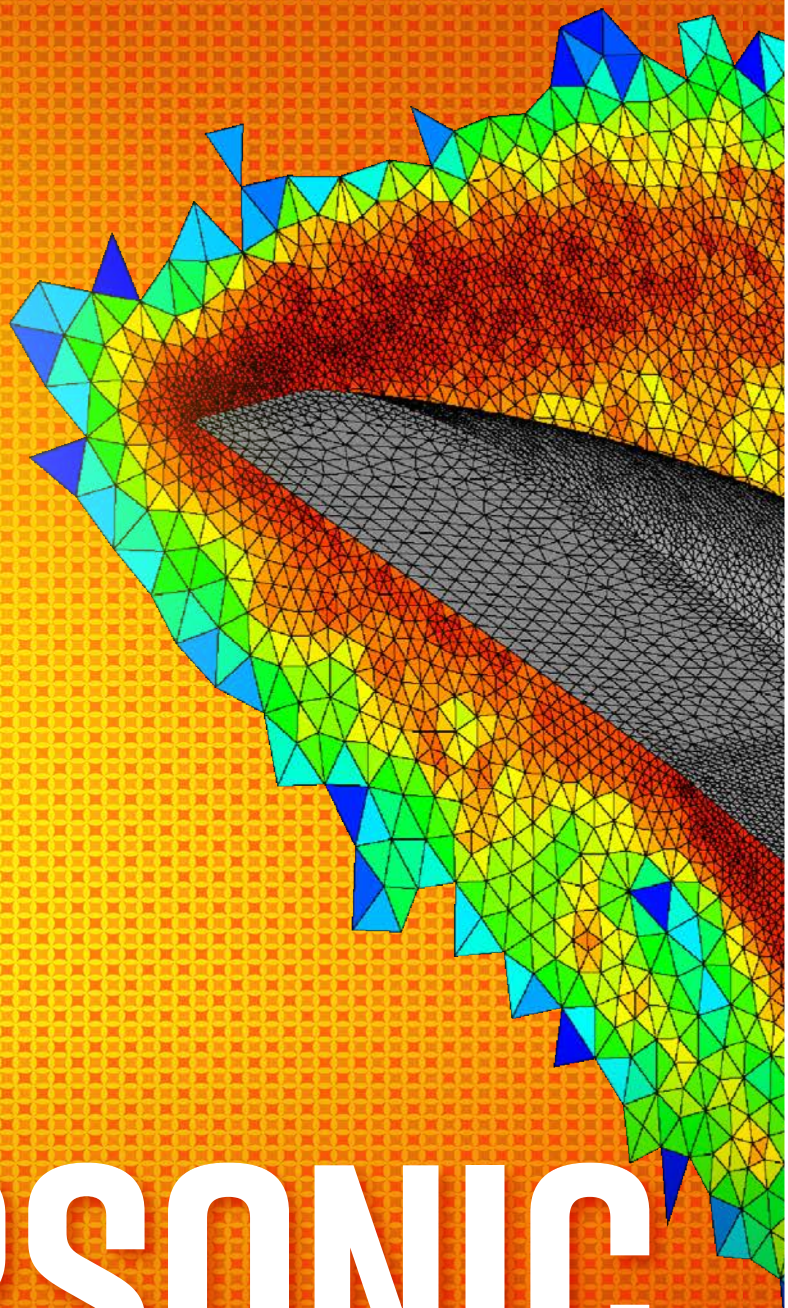
Flying home into the sunset at flight level 380, I'd nudge John from the back seat: What was it like to live on the moon? "Well, for one thing, being able to pour water into a cup in one-sixth G sure beats free fall any day." These flights offered spaceflight readiness training along with a critique of NASA operations or exploration plans, delivered by a man who'd lived it all, from triumph to tragedy.

Young left NASA in 2004, but even after retirement, he continued to write and speak about everything from the nation's need for heavy lift launchers, to the value of the moon in a space economy, to the challenges of protecting the planet from rogue asteroids. Young believed in safety, yes, but he also believed we must explore. Know the risks, work to safeguard the astronauts, but keep pushing outward.

John Young was a pilot, engineer, astronaut and explorer, a Renaissance (space)man, you might say. He wrote in his memoir that he considered his space experiences a marvel. John concluded, "I just want those marvels to continue for the next generations." ★

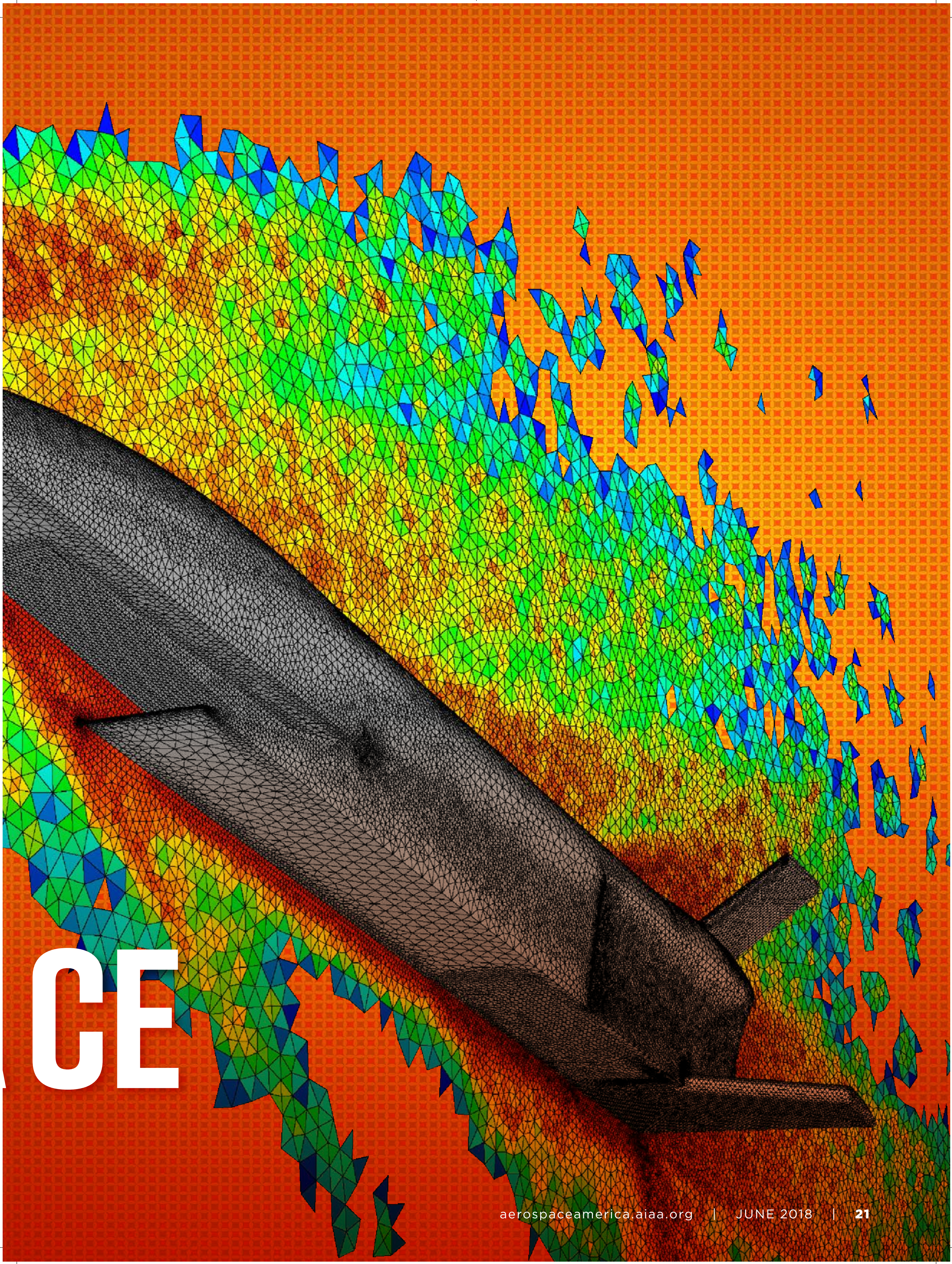
COVER STORY

Even before Russian President Vladimir Putin's saber rattling this year about high-speed weapons, the U.S. was laying plans to sharpen its focus on hypersonic weapons, motivated mainly by China's ambitious research and weapons tests. The Trump Pentagon wants to put this new focus in place in the 2019 budget. Keith Button examines what could be the next great weapons race.



BY KEITH BUTTON | buttonkeith@gmail.com

HYPERSONIC WEAPONS RA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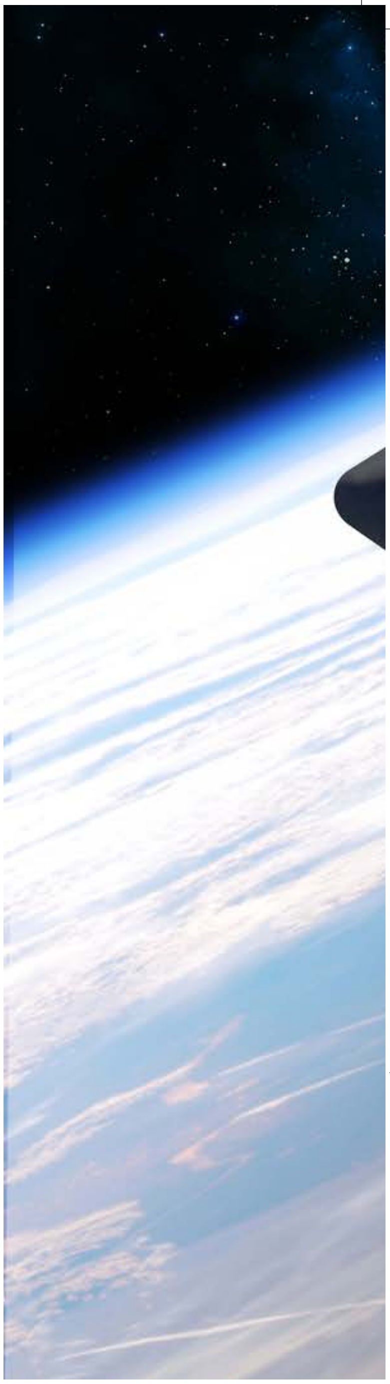


Chinese researchers have been publishing technical papers at a blistering pace about their fundamental research into hypersonic flight, loosely defined as maneuvering in the atmosphere at speeds above 6,000 kph. Flying faster than Mach 5 could be a handy way to travel, but for the leaders in this field — China, Russia and the U.S. — the emphasis has shifted to weapons. At least some of China's research appears to be headed in that direction, based on references to missiles in the published papers, although my inquiries to the Chinese Embassy's press office about the purpose of this research went unreturned. The Pentagon reported to Congress earlier this year that China has conducted 20 times as many hypersonic flight tests as the U.S. The most noteworthy recent test was in November, when China flew a new hypersonic missile, the DF-17, capable of flying 1,800 to 2,500 kilometers, as first reported by The Diplomat website.

Enter Russian President Vladimir Putin. Perhaps seeking not to be outdone by China, in March he delivered his state of the nation address at the historic Manezh Central Exhibition Hall in Moscow and narrated a series of video presentations about Russian high-speed weapons. The Russian TV network Ru-RTR broadcast the speech and posted the videos online, where they were picked up by media outlets throughout the world. One video showed a wedge-shaped "Hypersonic Glide Vehicle" weaving and porpoising through the fringes of space in a shroud of hot plasma, avoiding antimissile defenses. Another video concluded with nine warheads about to descend toward South Florida, the site of U.S. President Donald Trump's Mar-a-Lago resort.

U.S. Air Force Gen. John Hyten, commander of U.S. Strategic Command, which is in charge of the country's nuclear-armed missiles, told reporters at the Space Symposium in April: "You should believe Vladimir Putin. Everything he said [Russia has] worked on." But Hyten said "the operational status of all those capabilities" is a "different issue."

Many experts who watch developments in this area are convinced that it's not Russia but China that has sprung ahead of the U.S. in hypersonics research and weaponry. The view that the U.S. is behind any country, whether China or Russia, is not unanimous, however.

"From what I know, we're not falling behind at all," says Philip Coyle, who was in charge of national security and international affairs in the Obama White House's Office of Science and Technology Policy in 2010 and 2011, and was an assistant secretary of defense in the Clinton administration. "It's very common whenever somebody makes a speech the way President Putin did for members of Congress or people in industry to say, 'We're behind; we're behind.' But I don't think that's the fact."

If China and possibly Russia have gained an edge on the U.S., they've done so by mixing new technologies with proven ones. The Holy Grail of hypersonic research would be a vehicle capable of culling oxygen for combustion from the air instead of lugging it along in a tank as a rocket must. The U.S. set a record for air-breathing hypersonic flight in 2013 when the Boeing-built X-51 Waverider propelled itself for 210 seconds after being released by a booster. Meanwhile, China and Russia chose to focus much of their work on weapons that would be boosted to hypersonic speeds via conventional rockets and then glide to their targets. Hence Putin's Hypersonic Glide Vehicle, for instance.

Feeling behind, the Trump administration proposes pouring hundreds of millions of dollars into a game of urgent catch-up led in part by Michael Griffin, the Pentagon's chief technology officer and under secretary for research and engineering. Much of the emphasis will be on boost-glide concepts, although air-breathing will still be vigorously pursued.

The Air Force and DARPA began collaborative projects in hypersonics in 2014 and 2015 with the goal of feeding lessons into programs of record in the 2020s. "We have simply accelerated the [science and technology] activities into prototypes sooner than planned," says Air Force Col. K. Colin Tucker in the office of the assistant secretary of the Air Force for acquisition.

Griffin told a Senate Armed Services subcommittee that China can field or is close to fielding hypersonic missiles that can reach thousands of kilometers from its shores to strike U.S. aircraft carriers.

"We, today, do not have systems which can hold them at risk in a corresponding manner, and we don't have defenses against those systems," Griffin told the committee. "It is among my very highest priorities to erase that disadvantage, creating our own systems to hold them at risk" and to "provide defense."

The latest budget numbers suggest a major shift in magnitude and emphasis.

In April, the Defense Department awarded Lockheed Martin a $928 million contract to develop and test the Hypersonic Conventional Strike Weapon. These boost-glide missiles would be launched from the air. Lockheed is to develop them from mature technologies as quickly as possible. DARPA is seeking to boost its overall hypersonics spending by $148 million next year. Much of that is destined for the Tactical Boost Glide program to develop technologies for an air-launched hypersonic missile that would glide unpowered at hypersonic velocity after an initial rocket-powered acceleration.

Air-breathing research continues under a pro-

Boeing

▲ **Boeing is building DARPA's** hypersonic Experimental Spaceplane, or XS-1, which Boeing calls Phantom Express and is seen in an artist's rendering.

gram called HAWC, short for Hypersonic Air-breathing Weapon Concept, but funding would be reduced by half in 2019 to $14 million. Another air-breathing hypersonic program, the Advanced Full Range Engine program, would receive $53 million — an $18 million increase — to develop an engine that could accelerate from low-speed takeoff to hypersonic velocities.

The U.S. Air Force, which is a partner with DARPA on the Tactical Boost Glide and HAWC programs, plans to fly demo versions of the missiles by 2020. For developing prototype missiles and other hypersonics research, the Air Force is seeking to spend $500 million next year, up from $258 million this fiscal year.

With all this spending and a new emphasis on gliding weapons, advocates of U.S. hypersonics programs worry that the country does not have a unified strategy, especially for the basic research that feeds into applied research.

"It's not only about how much money, it's how you're spending it, and coordinating it nationally into a more coherent formulation," says Mark Lewis, director of science and technology policy at the Institute for Defense Analyses in Washington, D.C.

When it comes to basic research, "what we have now is a bunch of great people scattered about the country doing great work mostly on their own, but no concentrated effort," says Iain Boyd, a professor, hypersonics researcher and faculty director of government relations at the University of Michigan.

Boyd says the arrival of Griffin is encouraging for the applied research side of things, in which prototypes are created to clear the way for fieldable weapons. "There is a process there, so I would say that that's in better shape," he says.

CHINA'S PROLIFIC AUTHORS

Chinese researchers presented more papers at the 2017 AIAA International Space Planes and Hypersonics Systems and Technologies Conference — 260 — than all the other countries did combined. Here are the top 10[1]:

Country	2005	2006	2008*	2009	2011	2012	2014	2015	2017	Total
China	7	17	4	15	18	31	3	42	260	397
U.S.	61	64	38	38	60	15	18	32	14	340
Germany	11	17	16	30	28	25	10	18	9	164
France	22	13	13	16	16	15	5	18	8	126
Australia	8	24	7	20	10	26	8	13	7	123
Japan	21	17	16	14	13	20	4	7	1	113
Italy	27	10	7	19	16	8	0	7	5	99
European groups[2]	6	6	6	8	9	5	1	8	6	55
Russia	14	5	6	4	3	6	0	5	5	48
U.K.	2	5	0	6	3	4	1	13	4	38
Total	**179**	**178**	**113**	**170**	**176**	**155**	**50**	**163**	**319**	**1,503**

Source: IDA Science and Technology Policy Institute
* International Space Planes and Hypersonics Systems and Technology Conference is not held every year.

[1] Other nations presenting papers at the 2017 conference were Algeria, Belgium, Brazil, Canada, Greece, Hungary, India, Iran, Netherlands, Norway, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan and Turkey.

[2] European organizations

Taking China seriously

Over the last 10 years, China has given experts in other nations glimpses of its hypersonics work by allowing its researchers to publish papers in the same technical journals where researchers from the U.S., Germany, France, Australia, Japan, Italy, Russia and the United Kingdom publish. Boyd, the Michigan professor, says the papers 10 years ago were viewed as poor quality. "They were really just copying what other people had done; really just catching up," he says.

Today, that's no longer the case. Boyd says China has caught up, and then some. The Chinese researchers are respected as peers in the community of hypersonics researchers who share unclassified findings.

In Boyd's view, China's spending on modern research facilities and staffing has started to pay off, both with air-breathing and boost-glide concepts and with related subtopics, such as aerodynamics, propulsion, structures, materials, guidance, navigation and controls.

Boyd says China appears to be ahead of the U.S. in the race to create Mach 5-plus missiles. China's testing of those missiles seems to indicate a boost glide concept, but not definitively, Lewis says.

Today's cruise missiles typically top out at the Tomahawk's velocity, 880 kilometers per hour. By definition, hypersonic missiles travel faster than Mach 5, or more than 6,174 kilometers per hour — more than three times faster than the fastest bullets in the world.

Doubting Putin

Some Western experts are skeptical of Putin's hypersonic claims. In his presentation, Putin said Russia is testing the Sarmat, a 200-ton ballistic missile with multiple hypersonic warheads (the one that was shown targeting Florida); fielding the Kinzhal (Dagger) aircraft-delivered hypersonic missile, which began its "trial service" in December 2017, with a range of more than 2,000 kilometers and velocity of Mach 10; and has tested the Avangard, a "gliding-wing," maneuverable intercontinental missile that flies at Mach 20.

One U.S. hypersonics researcher, who asked not to be named, says that Putin's claims are difficult to believe, based on the country's recent struggles with technology development and its lack of resources. For example, Russia launched the fewest rockets for its space program in 2017 than any year since 1965, and many of its launches were for U.S. missions.

Russia's hypersonics research has stagnated below the U.S., and "way, way, way below China," the researcher says. "They just don't have the money to be playing in the hypersonics space."

For his part, Boyd says he won't comment on whether the Russian claims seem to be truthful, but "separating reality from fiction can be challenging, certainly with respect to President Putin's comments about their new weapons. There's been a lot of discussion about how real are some of those capabilities."

The case for boost-glide

The U.S. continues to pursue air-breathing hypersonics while increasing its focus on boost-glide vehicles.

Charles Miller, president of NexGen Space consulting and a former NASA senior adviser for commercial space, argues that the U.S. government should follow the lead of the private space industry, which has invested heavily in rocket propulsion and passed over the air-breathing hypersonic concepts.

"The free market is saying rockets are the way to do it; scramjets are not," Miller says, using a shorthand term for supersonic combustion ramjets, an air-breathing concept. "One of them has a large commercial market that will drive private investment and make it sustainable; the other does not." With air-breathing hypersonics, he says, "Companies are not going to put private skin in the game. They see no long-term commercial market opportunity. That means it's all going to be cost-plus contracts that the government has to pay for."

It would make sense for the U.S. to look to the technology advances of the private space launch companies and their potential military capabilities, says Jess Sponable, former DARPA program manager for the hypersonic XS-1. The rocket-powered XS-1 Experimental Spaceplane would take off and accelerate under rocket power to nearly orbital altitudes to launch satellites, then glide back to Earth. Flight tests are planned by 2020.

"I think we should leverage the billionaire entrepreneurs at the companies investing in reusable hypersonic launch systems that are rocket-powered, and we should figure out how to take advantage of all that capability that people are literally spending billions of dollars on."

That does not have to mean giving up on air-breathing, he cautions.

The advantage of boost-glide is that the rocket engine technology — how to build them and how they perform — is well known. The critical design limits for boost-glide aren't propulsion; they're aerodynamics and maneuverability, says Lewis of the Institute for Defense Analyses.

"THE FREE MARKET IS SAYING ROCKETS ARE THE WAY TO DO IT; SCRAMJETS ARE NOT."

— Charles Miller, president of NextGen Space consulting

▼ **The X-51A Waverider** achieved Mach 5.1 after launching from a U.S. Air Force B-52H in 2013.

U.S. Air Force

"WHAT WE HAVE NOW IS A BUNCH OF GREAT PEOPLE SCATTERED ABOUT THE COUNTRY DOING GREAT WORK MOSTLY ON THEIR OWN, BUT NO CONCENTRATED EFFORT."

— **Iain Boyd**, a professor, hypersonics researcher and faculty director of government relations at the University of Michigan

Another advantage to boost glide is that its flight is typically through space during the acceleration phase, so the extreme thermal conditions and shock waves caused by trying to push through the air of the atmosphere are avoided during that phase, Sponable says.

Attraction of air-breathing

While both modes of flight present extreme engineering challenges, air-breathing hypersonic flight is the most difficult and least developed option. An air-breathing hypersonic engine — the supersonic combustion ramjet, or scramjet — has no moving parts. The inlet compresses the supersonic air rushing in to mix oxygen with fuel for combustion, and a nozzle at the back of the engine accelerates the heated air out of the combustion chamber to generate thrust.

Igniting and maintaining combustion when air is traveling through the engine at 1.6 kilometers per second is challenging. "It's like trying to light a match in a hurricane, to keep that combustor lit," says Sponable, the former XS-1 manager. Extreme temperatures created by hypersonic airflow — more than 1,500 degrees Celsius (2,732 degrees Fahrenheit) on parts of the vehicle — and the shifting shock waves that buffet the aircraft at the extreme velocities add to the challenge. So far, the longest air-breathing hypersonic flight on record is the 210 second X-51 Waverider flight.

The potential advantage of air-breathing engines would be that at hypersonic speeds, they could have three times the specific impulse — a measure of propulsion efficiency — of the rocket engines that would drive boost-glide vehicles. That could give the weapons an advantage in range.

Research community

In the U.S., most fundamental hypersonics research is handled by universities, while applied research progresses mostly through DARPA, and to a lesser extent through the Air Force Research Lab and NASA. While DARPA receives funding from the Air Force, Navy and Army for hypersonics research, it doesn't have its own laboratories — it farms out the research activities to its private-industry contractors. On the university side, Boyd says about 300 faculty members, graduate students and post-doctorate researchers devote themselves to hypersonics research in the U.S., with about $20 million per year spent on it. The total number of hypersonics researchers is about half of that in China, judging by the publicly available research, he says.

China also appears to employ a more integrated research effort, putting more of its university researchers together to work in one place. In the U.S., the largest individual university hypersonics programs may have 25 people, typically not coordinating together but working individually or in teams of two, Boyd says.

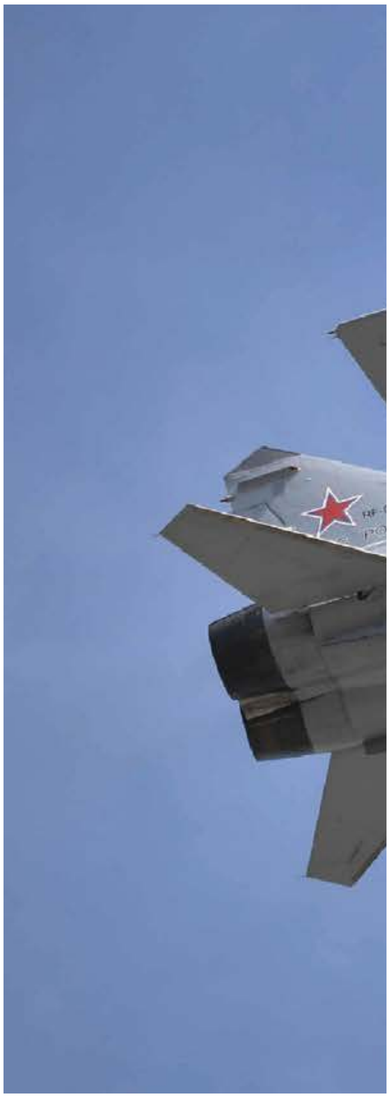
China's spending on hypersonics is also seen in its numerous new research facilities, contrasting with the U.S., which has "a lot of great facilities," but many are in old buildings that are "creaking at the seams," Boyd says.

Importance of basic research

To catch up with China, the U.S. will have to do more, starting with its spending on fundamental hypersonics research, Boyd says. "There has to be more investment, because at the end of the day, China is investing more people and newer facilities than we have. We don't have any really secret sauce, I don't think, to any great extent that's going to allow us to catch up without increasing our effort here."

If the U.S. decides that hypersonics is going to be an important element of its national security strategy, then it's going to have to develop a workforce. Boosting fundamental research spending would help accomplish that: educating and training engineers in the details of a challenging field, as well as germinating the next generation of ideas for new technologies, Boyd says.

At U.S. universities, 60 percent to 70 percent of the hypersonics research is focused on aerodynamics and aerothermodynamics: looking at how gases flow around the hypersonic vehicle in flight, Boyd says. In China, the research described in journal articles shows a more even distribution of efforts across aerodynamics, propulsion, materials and controls. The U.S. needs to take a more balanced, multidisciplinary approach to hypersonics research



▲ **Russia exhibited its air-launched** hypersonic missile Kinzhal during a parade May 9.

Wikipedia

to field operational systems, because every aspect of a hypersonic vehicle affects every other aspect.

The U.S. also needs better coordination, through centers of excellence or a similar centralized approach that promotes cross-over between disciplines, Boyd says.

On the applied research side, the key change for the U.S. needs to be increasing the number of test flights, Boyd says. Demonstration flight programs that fly only one or four test flights aren't doing enough to make any real progress in developing operational systems, especially when compared to other U.S. missile programs.

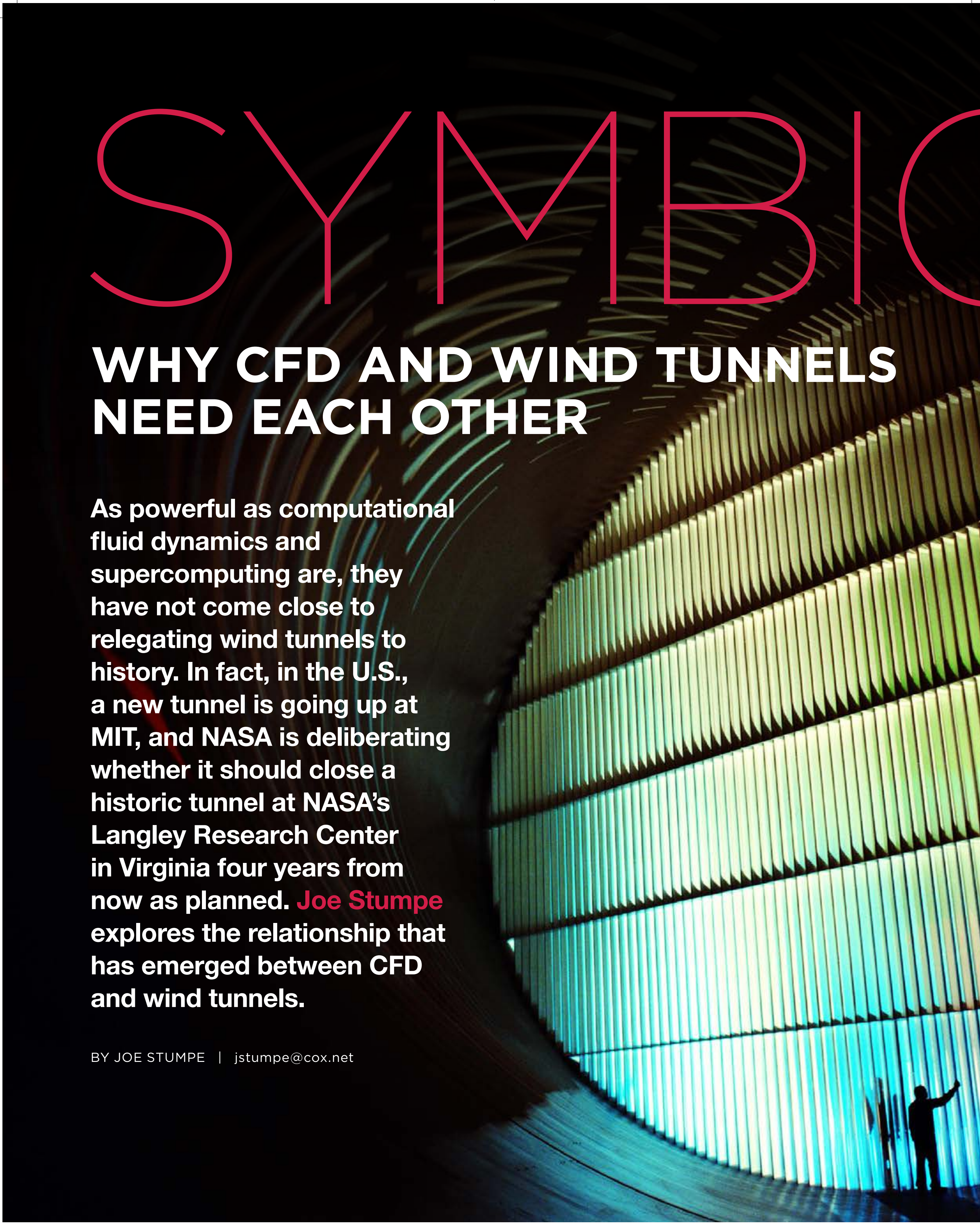
"It's expensive, and it's difficult, but it's like anything — you've got to try it out," he says. "It's like self-driving cars — you've got to put them out there in the actual environment, and learn some hard lessons, probably, to get where you want to go."

Because rocket technology is more advanced relative to the state of scramjet development, probably the easiest gains in hypersonics will initially come with boost-glide concepts, Sponable says. Over the longer term, the best hypersonic propulsion model will be whichever can fly at high speed at the lowest recurring operating costs, and with acceptable environmental impacts.

"If you can implement this stuff operationally, there's merit to it. If you can't, it's just endless hobby shop," he says. "We've got to figure out how to take the low-hanging fruit and pursue those hypersonic systems that we can do. Successes in those areas will justify the investment in the longer term, more difficult aspects of hypersonics."

Based on the current state of hypersonics research, it's still an open question whether the U.S. should pursue both boost-glide and air-breathing concepts, Boyd says. "The motivation for continuing to study both is that they may provide, in the end different, unique and important capabilities. At some point if it's determined that one system just doesn't provide enough of an added value over the other, then it probably will be dropped." ★

Staff reporter Tom Risen contributed.

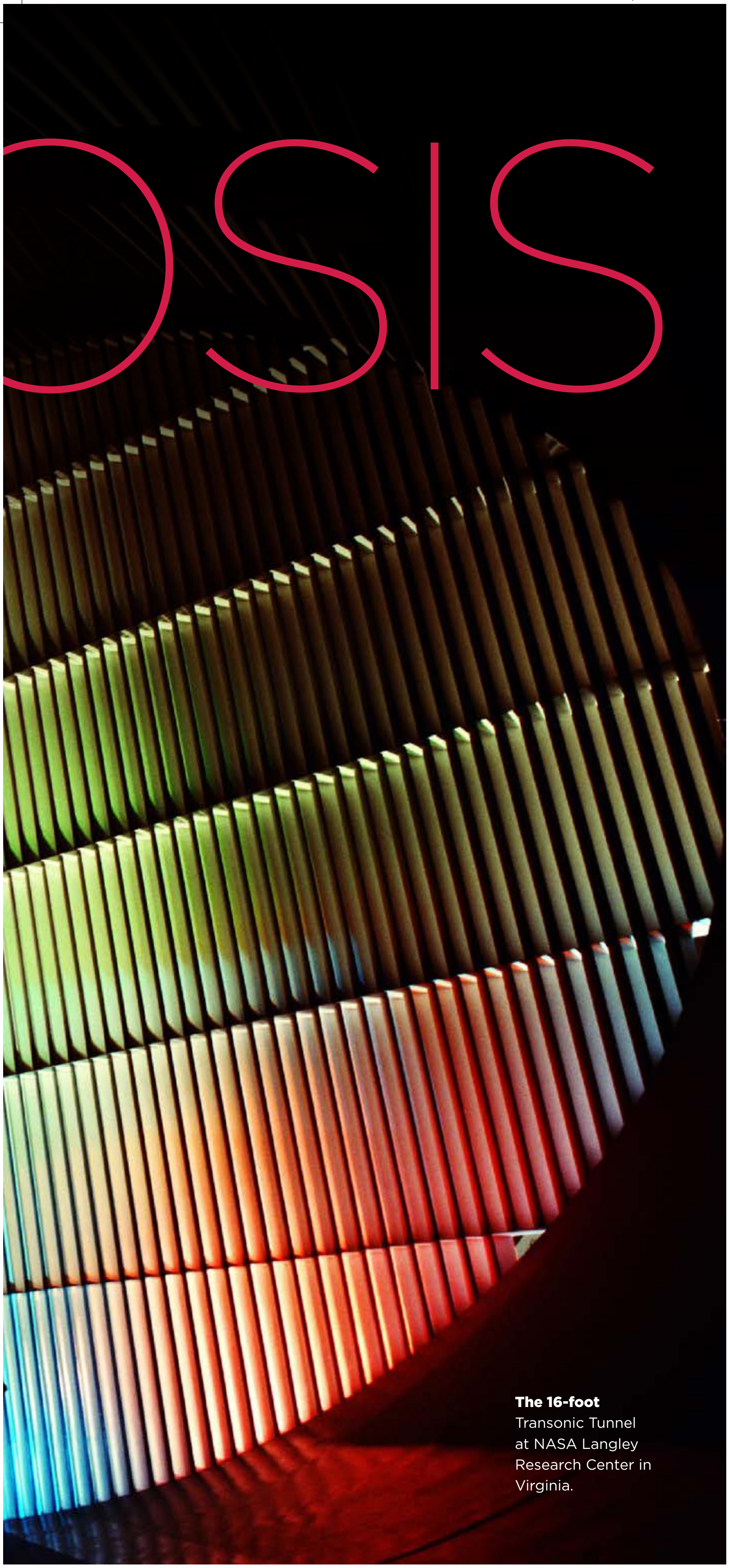


SYMBIO

WHY CFD AND WIND TUNNELS NEED EACH OTHER

As powerful as computational fluid dynamics and supercomputing are, they have not come close to relegating wind tunnels to history. In fact, in the U.S., a new tunnel is going up at MIT, and NASA is deliberating whether it should close a historic tunnel at NASA's Langley Research Center in Virginia four years from now as planned. Joe Stumpe explores the relationship that has emerged between CFD and wind tunnels.

BY JOE STUMPE | jstumpe@cox.net



The 16-foot Transonic Tunnel at NASA Langley Research Center in Virginia.

NASA

As an engineer doing research under contract for NASA in the 1980s, Scott Imlay remembers what it took to fire up the agency's 16-foot Transonic Tunnel in Virginia, whose massive fans were driven by a 60,000-horsepower motor.

"At that time, you could only run it at night, it pulled so much power off the grid," he tells me from his office at Tecplot, an aerospace engineering software company in Washington state where he is chief technical officer.

To gather data, engineers at this and other wind tunnels learned to introduce streams of dye or smoke into the airflow or to attach strings to the airframe or airfoil so they could see air flowing across it.

To Imlay and others, the advent of computational fluid dynamics seemed to promise a more efficient way of determining airflow. For instance, it takes time to repeatedly attach string or set up a smoke wand in a wind tunnel, while a CFD can run certain visualizations in a minute or two — at any time. CFD can also predict performance under extreme velocity, pressure and other conditions that wind tunnels cannot reproduce.

Nearly four decades later, wind tunnels retain a key role in aerospace engineering and probably will for some time. Engineers don't generally take a one-or-the-other view of CFD compared to wind tunnels. CFD reduces the scope of expensive wind tunnel testing, but time in tunnels is still required to validate far-reaching designs or even aspects of conventional designs that CFD software cannot yet model well enough. Researchers attach sensors to models in wind tunnels to measure the pressure exerted on their surfaces. Equations scale up the data to help designers measure how the aircraft would perform if it were actually flying.

"I don't really ever see wind tunnels going away, personally," says Carolyn Woeber of Pointwise in Fort Worth, Texas, which like Tecplot designs software for CFD. "There are still so many unsolved problems when it comes to fluid dynamics."

The most recent count of wind tunnels in operation in the United States that I could find came in a 2010 report by Lockheed Martin researchers. It showed the number falling from 120 in 1985 to 61 in 2009 as CFD became more common.

NASA is a major operator of tunnels, but not the only one. The agency operates 14 "critical" wind tunnels at centers in California, Ohio and Virginia at a cost of about $100 million a year, plus 20 smaller tunnels. These tunnels are not just for NASA researchers. Private industry and other government agencies conduct experiments in them. NASA has mothballed about 60 tunnels over the past several decades.

As one indication of CFD's progress, NASA is evaluating whether to stick with a plan to close a historic supersonic wind tunnel at its Langley Research Center in Virginia in 2022. Everything from Mercury spacecraft in the 1950s to commercial space vehicles from Boeing and SpaceX have been tested there.

But wind tunnels are hardly headed for extinction anytime soon. MIT announced in November that it will replace its 79-year-old subsonic Wright Brothers Wind Tunnel with an $18 million version it describes as "the largest and most advanced academic wind tunnel in the United States."

For wind tunnels to become a thing of the past decades from now, CFD would first have to be brought to the point where it can supply some of the most complex and critical data needed in aerospace design — data that engineers now rely on wind tunnels to provide. One area where the physics of CFD still falls short is in predicting turbulent flows, which are irregular, drag-inducing patterns of airflow created off an airfoil by a high angle of attack and other conditions.

CFD models "work really well for problems that are 'nice,' in quotes," Imlay tells me by phone. "If you're flying in cruise conditions they work really well. If you get out of nice regions, they don't work so well." Engineers can't mimic that turbulence "on computers we have or will have in 20 years."

CFD is also inadequate for modeling conditions at a high angle of attack, such as when the wings are pitched up so high relative to the airflow that the plane is close to stalling. "That's a big concern to airplane companies," Imlay says. "You're close to that region every time you land an airplane."

Aeroacoustics — the sound generated by aircraft — and vortexes created at the tip of helicopter wings are two more areas where the current batch of CFD codes "don't do so well," Imlay says.

David Schuster, a NASA technical fellow at Langley, says CFD "might have advanced further than we anticipated, but it's still not in any position to do a full flight analysis of aircraft and spacecraft." As an example, he says CFD modeling has not proved as helpful as hoped in calculating re-entry conditions for the Orion crew capsule that Lockheed Martin is building to carry astronauts to the moon and Mars.

"We had envisioned that since it was so much like Apollo we would be able to do virtually all of our aerodynamic analysis using CFD," he says. However, Orion's size, construction materials and other features led the agency to rely on wind tunnel testing "as much as with the original Apollo in the 1960s." Schuster adds, though, that the use of CFD in conjunction with wind tunnel testing on the Orion means the agency's analysis is "much more refined" than it would be otherwise.

Schuster predicts that wind tunnels will be used at their current rate for the next 10 years or so.

▲ **An F/A-18 fighter aircraft** is tested for high angle-of-attack aerodynamics in the 80-by-120-foot wind tunnel at NASA's Ames Research Center in California.

NASA

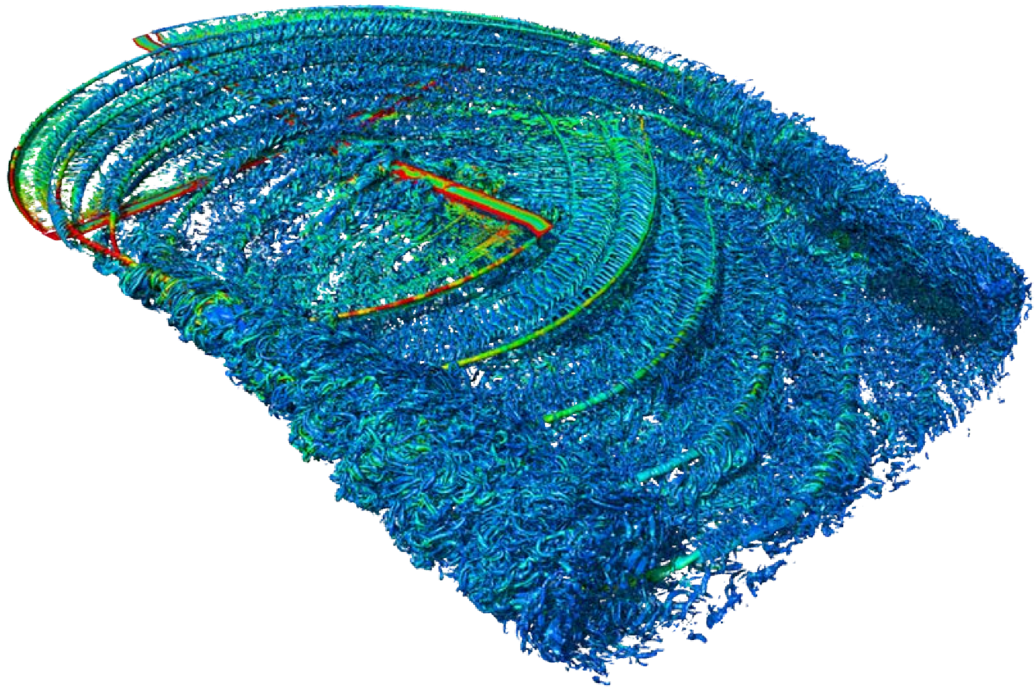
NASA, in a 2014 report titled "CFD Vision 2030 Study," said improvements in CFD would happen only by improving the algorithms, software and hardware, requiring significant infusions of government and private funding.

CFD, as the report noted, has already dramatically altered the aerospace design process. A detailed physical model of an aircraft to be tested in a wind tunnel, made of metal with moving parts, might cost $1 million to produce — not to mention the costs of running a tunnel, which can be $20,000 per hour. By first testing simulated models through CFD, Woeber says, "Maybe instead of making 20 or 30 different models for a wind tunnel, they can narrow it down to the two or three that have the most promise."

As Woeber notes, "Initially when CFD came out, most experimentalists were quite suspicious of it. I think with good cause. We didn't know if we could trust the data."

However, with every successful validation, confidence in CFD increases.

Still, with CFD's limitations, it's more efficient to test certain scenarios in a wind tunnel — for instance, a plane in landing configuration, with its wheels



A CFD simulation of a Black Hawk helicopter rotor in forward flight shows blade vortex interaction and the largest turbulent structures. Red and blue colors correspond to high and low values of vorticity.
NASA

"There are a lot of things you can't compute with sufficient confidence [with CFD]. It's that simple."

— **Mark Drela**, director of MIT's Wright Brothers Wind Tunnel

down and flaps out.

"That's a case where I think most [aerospace] companies do it in a wind tunnel," Imlay says.

Wind tunnels have their own limitations, Imlay notes, such as being unable to simulate the Mach 24 or Mach 26 speeds of a vehicle entering the atmosphere from space. He estimates that the ratio of wind tunnel-to-CFD use in aerospace design is "about 50-50."

"If it's a change to a design, like adding something, it's probably going to be done with CFD. If it's a brand-new airplane, they may do some wind tunnel" tests.

The Wright Brothers Wind Tunnel (named for the aviation pioneers but never used by them) opened at MIT in 1938. The school hopes to break ground on its upgrade in the coming months. Mark Drela, director of the tunnel, says wind tunnels are necessary because "there are a lot of things you can't compute with sufficient confidence. It's that simple. The geometry or physics may be too complicated."

NASA is studying whether it needs the Unitary Plan Wind Tunnel at NASA's Langley Research Center in Virginia. In use since the 1950s, it's scheduled to be dismantled in 2022. However, it could have its lifespan extended if the agency were to decide it's still needed.

The agency plans to compare data from the tunnel with CFD simulations for four vehicles that would fly between Mach 2.6 and Mach 6 speed: an entry capsule, launch vehicle, hypersonic aircraft and capsule that would be subjected to supersonic retro propulsion, as if it were landing on Mars. "Somebody brought up the thought that if there was any speed regime that CFD was ready to take over the wind tunnel in, it was this supersonic regime," Schuster says. "The whole purpose [of the study] is to understand just how true that statement is — if we were to close the tunnel down and rely on CFD, how much more risk would we be taking as an agency in going down that analysis path?"

In addition to accuracy, the agency will consider efficiency. Echoing Imlay's comments, Schuster says there is certain data that a wind tunnel test can generate "in literally 30 seconds," while calculating it using CFD would take weeks. Schuster says the study, in which researchers at all three of NASA's main wind tunnel sites are participating, is expected to take about five years and will be presented to "management at headquarters level." The concern of engineers, Schuster says, "is that a problem we don't envision today will crop up in the future when we don't have the [wind tunnel] test capability and we aren't confident in the CFD for the specific problem under consideration."

Whatever the fate of that wind tunnel, some engineers believe the devices that helped usher in manned flight will never completely disappear.

"We will always need to go into wind tunnels," says Bob Stuever, a safety and certification engineer at Textron Aviation who is part of the team designing the Cessna SkyCourier. Planes "are just too complex. There are things you can't model." ★


SER
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Restore-L, NASA's conceptual servicing spacecraft, extends its robotic arm to grab and refuel a satellite, in an artist's rendering.

NASA

VICING EVOLUTION

Thirty-five thousand kilometers is a long way up, and that's the home of nearly 400 satellites that do anything from sending and receiving telephone, internet and television signals to spotting missile launches. Today, those satellites can't be repaired, upgraded, refueled or rescued if their propulsion fails. Henry Canaday looks at the latest plans to change that.

By HENRY CANADAY | htcanaday@aol.com

The Pentagon's first Advanced Extremely High Frequency satellite looked like a $1 billion lost cause when it was dropped off in space in 2010 with a malfunctioning apogee engine. The U.S. Air Force and its contractors are a resourceful bunch, and they figured out how to get the satellite to its final geosynchronous orbit with its less powerful engines. The bad news was that the ride took 14 months.

For decades, operators of expensive and hard-to-reach geosynchronous satellites have wanted the ability to latch onto a wounded satellite like AEHF-1 and maneuver it to its proper orbit. That would be just one scenario. On-orbit servicing would give them the power to replace faulty or out-of-date parts and refuel a satellite to extend its operating life by years, something especially attractive to commercial operators because of the revenue that could be generated.

On-orbit servicing looked like it would soon be a normal part of business in 1997, when Japan's Engineering Test Satellite-7 (also known as Kiku-7) released a smaller target satellite, chased it down and docked with it, ultimately from as far away as 12 kilometers. Another milestone came a decade later in DARPA's Orbital Express mission, when a pair of satellites rendezvoused from 400 kilometers away and docked with each other to practice refueling and swapping out batteries and computers.

Now, two decades after the Japanese mission and a decade after Orbital Express, industry executives and DARPA officials say the community is truly on the cusp of making on-orbit servicing a reality in the geosynchronous belt.

Notable this time is the vigorous participation of commercial satellite operators and builders. For industry, the choice is between a brute-force option that could be ready soon to restore propulsion for old or wounded satellites, and other, more complex options that are at least a few years off but could deliver a host of services beyond propulsion.

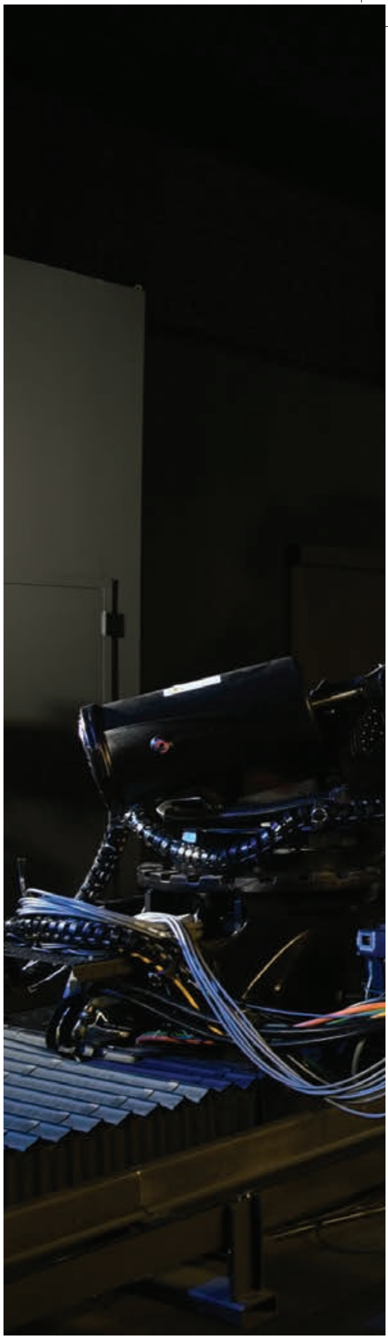
The nearest term option, a service that Orbital ATK of Virginia plans to debut late this year or early 2019, calls for capturing a client satellite with a Mission Extension Vehicle spacecraft that would take over the propulsion. Intelsat, the Luxembourg-based communications satellite giant, has signed two contracts for the service. Intelsat plans to service its Intelsat-901 satellite, launched in 2001, with this life-extension technology. Orbital ATK also has an idea that's still years off for a more elaborate strategy, involving propulsion pods that would be attached to satellites. DARPA, meanwhile, is working with Space Systems Loral on a "DARPA hard" concept involving RSVs — robotic servicing vehicles that would be stationed in geosynchronous orbit, the first in 2021. The program is called Robotic Servicing of Geosynchronous Satellites, or RSGS. SES, another Luxembourg-based operator, is considering having one of its satellites serviced under this program.

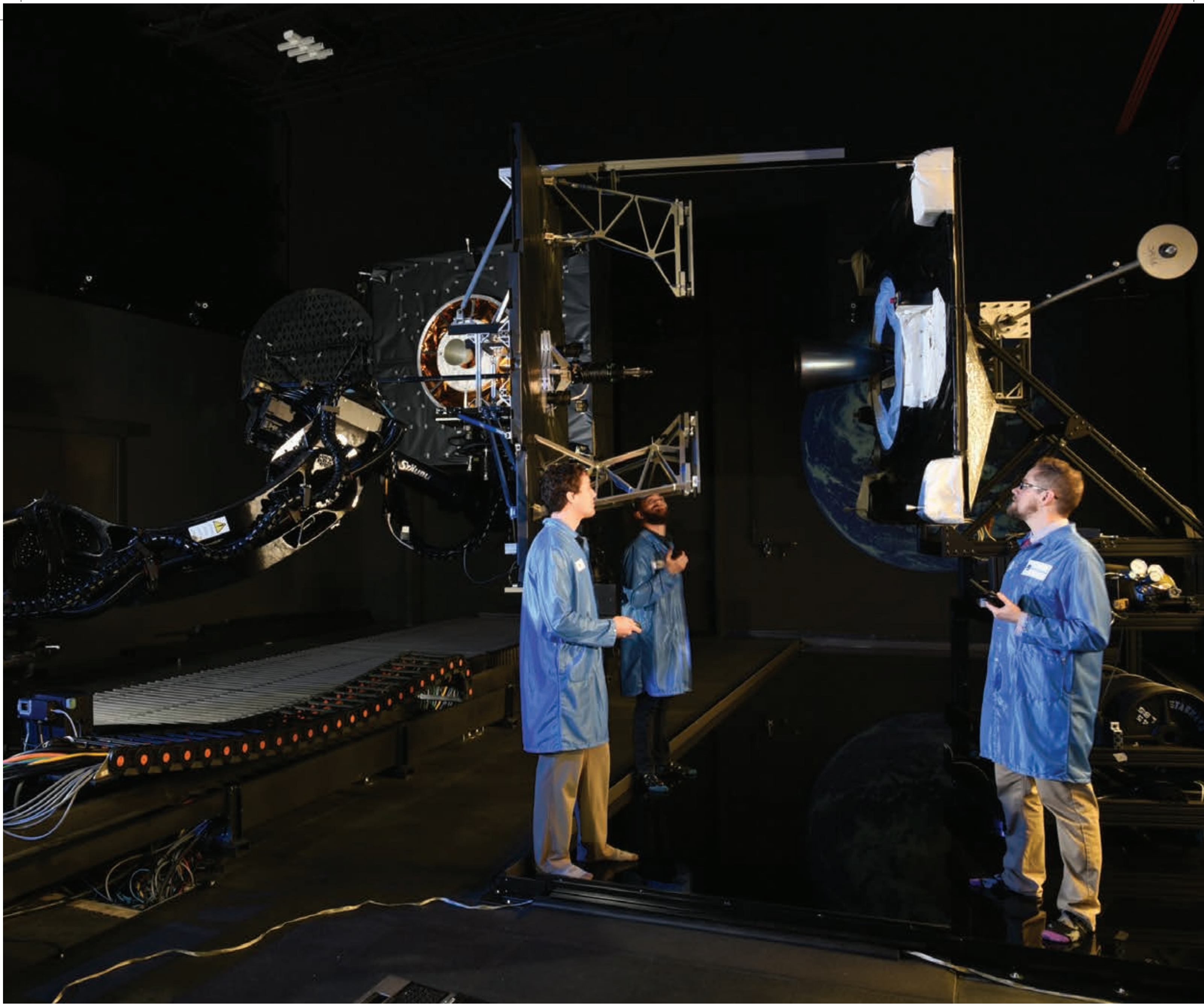
Dock and drive

When Orbital ATK's Mission Extension Vehicle satellite arrives in orbit, it will rendezvous with the client and push a probe into the nozzle of the satellite's main propulsion engine. The probe's mechanical fingers will expand to hold the client satellite while the Mission Extension Vehicle pulls it closer at a rate of a few centimeters per second. The adapter ring that once held the client to its launch vehicle will press on the servicer's three stanchions, locking the two spacecraft together. For the next five years, the servicer's ion thrusters will keep the satellite in its correct orbit with its antennas properly oriented.

"It's a pragmatic, proven technology. And lots of satellites run out of fuel in 15 years, but still work. Docking can give them five more years of life," Intelsat CEO Stephen Spengler says.

Orbital ATK, which is testing the technology at a lab in Virginia, designed the Mission Extension Vehicle from its GEOstar 3 commercial satellite frame, or bus. Engineers equipped the 2,500-kilogram servicing satellite with optical and infrared video cameras to spot the client satellite from 40 to 50 kilometers out, with the precise distance measured





by a LIDAR laser-ranging device. These sensors will feed data to an onboard computer and ground controllers who steer the servicer through a series of waypoints to the client satellite.

Orbital ATK CEO David Thompson told an audience at the 2018 Satellite conference in Washington, D.C., in March that the servicer can work with about 80 percent of current geosynchronous satellites. Orbital is prioritizing this class of satellites because they represent the biggest value in commercial satellites and it is easy to move among the similar orbits. Low Earth orbiters move in different planes, which would require an orbiter to have lots of fuel to maneuver among those different planes. Another executive said Orbital ATK may eventually provide a servicing vehicle for those satellites too.

Orbital ATK is not alone with the capture approach. United Kingdom-based Effective Space plans to have its 400-kilogram Space Drone perform a similar life-extension capture of a geosynchronous satellite by 2020.

▲ **Orbital ATK engineers** guide the Mission Extension Vehicle spacecraft as it docks with a model satellite during testing.

Orbital ATK

Orbital ATK's next step, due in 2021, would be to create a version of the Mission Extension Vehicle with 12 mission-extension propulsion pods and a robotic arm. The robotic arm would attach the Xenon-fueled ion pods, each weighing about 200 kg, to client satellites in the same fashion as the extension vehicle does: by pushing a probe into the nozzle. The vehicle would then draw the nozzle and the pod together. The Mission Extension Vehicle would leave, with the pod attached to the satellite for propulsion. The pods can extend the life of a 2,000-kg satellite, which is relatively small for a communications satellite, by five years. The robotic arm will also do simple repairs of stuck antennas or solar arrays.

This enhanced servicer might someday attach pods carrying new batteries or other internal components, but that would require new satellites to be designed to accept those components.

Refuel and repair

Also in 2021, DARPA and Space Systems Loral plan to launch their Robotic Servicing Vehicle. It will work with a client satellite to conduct a six- to nine-month demonstration. After that, if all goes as planned, the RSV will be declared operational. Under a partnership agreement, the U.S. government would get a discount from Space Systems Loral on servicing of its satellites until the public investment is repaid. Space Systems Loral would then own the RSV entirely, explains DARPA's Gordon Roesler, the RSGS program manager. Ultimately, he expects an RSV to last eight to 15 years and service a ratio of approximately five commercial satellites to each U.S. government satellite. That ratio would reflect today's 5-to-1 ratio of commercial to U.S. government satellites in orbit.

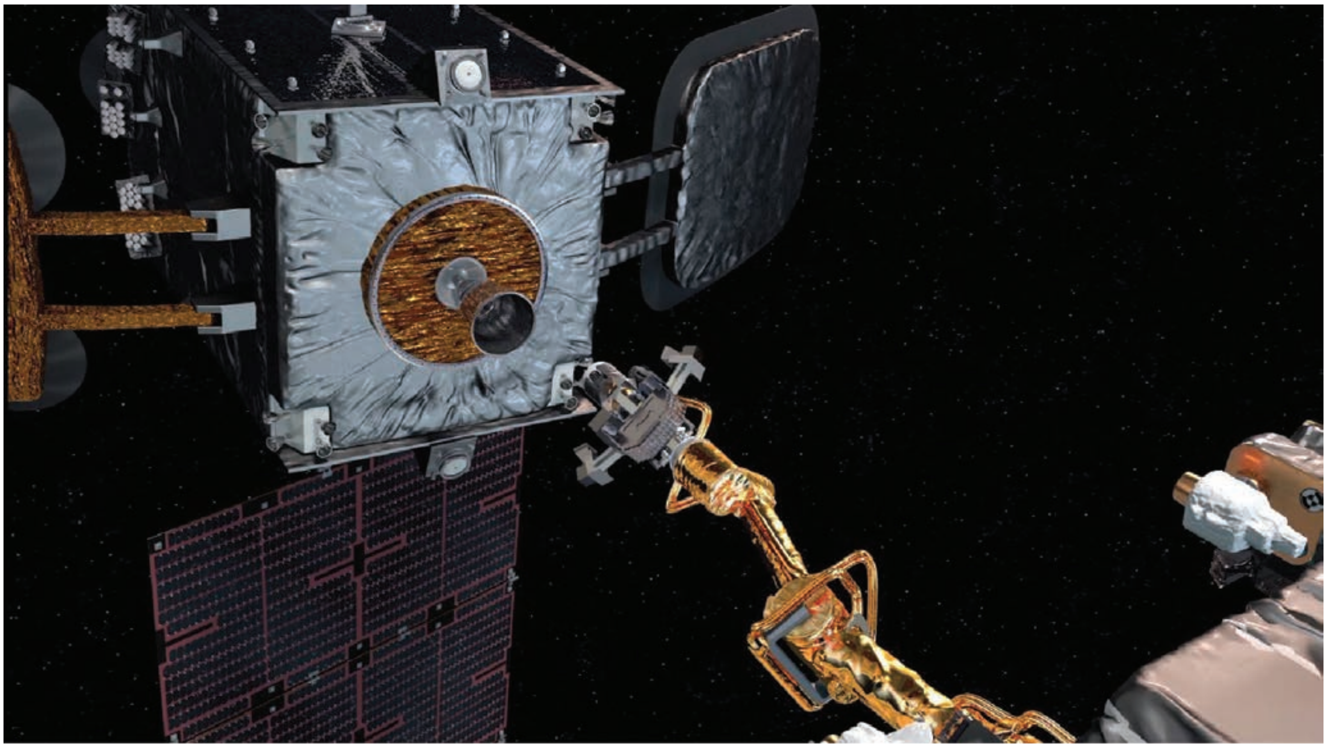
Between now and then, Space Systems Loral will build the RSV based on its SSL 1300 satellite bus, a design that can weigh 3,500 to 7,000 kg, depending on the components added to it. DARPA, working with its contractors, will equip the RSV with servicing tools, including two robotic arms.

Roesler sees an array of goals. For starters, he expects this servicing spacecraft to examine satellites from "inches away"; modify orbits by docking and applying thrust; free stuck antennas and solar panels by applying gentle pressure; and upgrade satellites by attaching new components. Space Systems Loral added a fifth, tougher capability: refueling satellites. This would be done in cautious steps through the same fill-and-drain valve used before launch. Due to insulation and locking wires, the servicer must carefully prepare the client satellite to receive the fuel. "Our robotic arms have tool changers, like socket wrenches," Roesler explains. "That gives us tremendous flexibility."

Refueling, in addition to extending a satellite's operating life, would give ground controllers a new flexibility to maneuver a satellite without fear of running out of fuel. Close inspections could tell commanders whether malfunctions are due to nature, design flaws or hostile action. Such attribution could amount to a powerful deterrent, Roesler says.

Over the long term, Roesler expects satellite manufacturers to redesign satellites to house equipment in modules that can be replaced by an RSV.

The stakes are large. Roesler estimates there are about 300 commercial geosynchronous satellites in orbit costing an average of about $300 million apiece, plus $100 million in launch costs. The U.S. government has put up 50-60 geosynchronous satellites, each worth from $600 million to well over $1 billion. Then there are a few dozen satellites put up by other nations. A bit less than 10 percent of all these satellites could be candidates for life extension or simple repairs, according to Ruy Pinto, deputy technology officer at SES, which has a fleet of 55 geosynchronous satellites and another 12 low Earth



Space Systems Loral

▲ **A robotic arm on** a Robotic Servicing of Geosynchronous Satellites spacecraft is extended to dock with a satellite in an artist's depiction of on-orbit servicing.

“Refueling is tricky, requiring grabbing a satellite, manipulating it to open a valve and inject fuel, all for satellites not designed for in-orbit refueling.”

— Ruy Pinto, deputy technology officer at SES

orbiters. SES is considering the RSV option.

Assembly of spacecraft in space is not part of the mission set. But Roesler says, “If NASA wants to set up a telescope with big reflectors, they could put a package up and we could manipulate it to show the concept is valid.”

Al Tadros, vice president of space infrastructure at Space Systems Loral, notes that his firm has extensive experience with space robotics, having built components for Mars landers (including an arm for NASA’s upcoming Mars 2020 rover); the space shuttle fleet and the International Space Station. And it built 86 of those 300 commercial GEO satellites.

“Our vehicle will have very flexible robotics, with seven degrees of freedom,” Tadros stresses. He describes the RSV as “the first general-purpose servicing satellite.”

He acknowledges refueling in space will be hard, but says: “Everything in space is hard. We demonstrated refueling on the space station, and we refuel on launch when caps are sealed [and must be robotically opened].” Tadros points to U.S. Navy refueling at sea and Air Force refueling in flight as similarly difficult challenges that have been met.

Pinto acknowledges, “Refueling is tricky, requiring grabbing a satellite, manipulating it to open a valve and inject fuel, all for satellites not designed for in-orbit refueling.”

Benjamin Reed, who was deputy director of NASA’s Satellite Servicing Projects Division from 2010 to early 2018, observes that NASA designed the space station to be robotically refueled and was able to safely access the oxidizer valve. However, “propulsion oxidizers are nasty, corrosive, toxic and explosive.” For satellites not designed for refueling, Reed says approach sensors must be tested in the lighting of Earth orbit, “which cannot be duplicated in laboratories.”

Tadros hopes his first commercial customer will be SES, which is evaluating the proposal. Pinto, the SES technology officer, believes the plan has the advantage of one-shot refueling, after which the servicing satellite moves on to its next client. The best candidates for on-orbit servicing are GEO satellites that were designed to last 20 years, still have a working payload but are running short of fuel.

NASA’s near-term servicing focus has been on life extension, repair and augmentation. Medium-term, NASA wants to design satellites to be more cooperative. “We are intensely focused on making future satellites serviceable,” Reed says. The agency has already developed a cooperating fuel valve, about the same size, weight and cost as existing noncooperating valves. “In the past, it has been excruciating to cut wires and remove caps.”

Further out, NASA wants to assemble equipment in space, for example, to look for life on exoplanets. “Looking into their atmospheres requires a very large light-collection bucket, many times the size of James Webb,” Reed notes, referring to NASA’s James Webb Space Telescope currently scheduled to launch in 2020. One possibility is assembling stacked mirrors in orbit.

Another long-term goal might be redirecting a dangerous asteroid to miss Earth. This could require technologies similar to those used in servicing satellites. So Reed is eager to see servicing develop. “We are on the cusp of doing much more with less.”

The first risk is technology. Rebecca Reesman, a policy analyst at Aerospace Corp., a federally funded research firm in California, argues that well-proved autonomy, navigation, flight software and ground operations are necessary to avoid collisions that create debris. “Companies like Orbital ATK and Loral will set precedents for future on-orbit operations. There is a risk of this industry tanking if something goes wrong.” DARPA’s demonstration tests will be important. Orbital says its mission planning, concept of operations, ground controls and on-board autonomous fault protection will prevent accidents. ★

ENGINEERS ARE DOGS, SCIENTIS ARE CATS

You've heard of the book "Men are from Mars, Women are from Venus." It's a tongue-in-cheek title, but one that strikes a chord and perhaps helps us understand each other. Planetary scientist Ralph D. Lorenz went searching for an analog of his own to describe scientists and engineers. This is what he came up with.

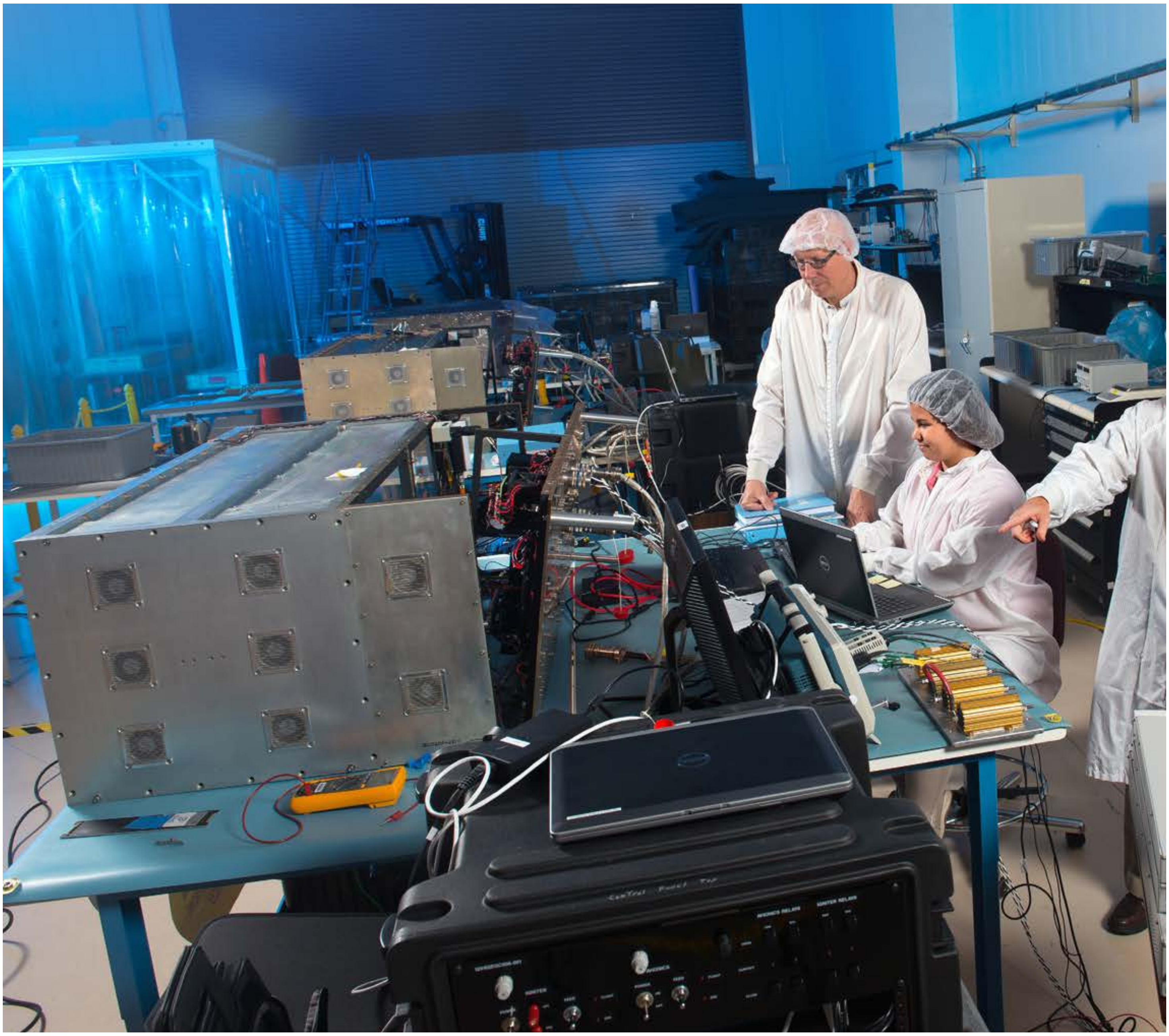
I originally trained as an aerospace engineer, but if someone asks my profession today, I say planetary scientist. In reality, I work at the boundary of these two disciplines in a region of frequent communication challenges between engineers and scientists. Having reached the end of a long-term international project — the Cassini-Huygens mission to Saturn and Titan — on which I started as an engineer but progressively became a scientist, I have had cause to reflect on the difference between these disciplines and the outlooks of the people who make them their professions. Like any other pithy generalization (e.g., "Men are from Mars, Women are from Venus"), what follows is a caricature that is intended to help each side understand the other's point of view. Whatever your preference in pets, no value judgment or offense is intended. The goal is to aid mutual understanding.

Engineers are dogs. They like well-posed problems that have a right answer (often, called the "optimum"), and they know it is the right answer. They just want to make their customers happy. Engineers also typically work in packs, hierarchical social structures that have a clear chain of command. They tend to work serial problems, going where the pack goes — when a project ends, on to the next thing.

Scientists are cats. They like finding new problems just as much as solving old ones, and are comfortable with uncertainty. They often like working alone, or at least don't care whether others are working on the same thing, and certainly don't like being told what to do. Cats are territorial, and scientists often stake out a problem or methodology as "their own" and may often pursue it even when there is little external support to do so.

The lines, of course, are blurred. An engineer may engage in a scientific process, such as correlating test data to build a predictive model. But the exercise is a success if an equation is found that works for the intended purpose, regardless of whether the form of the equation relates to some underlying insight into the physical processes at work. Contrariwise, many scientists build their own experimental apparatus or computer codes, but (like myself) tend to hack something together, without a formal architecture or systems-engineering validation to the process, just getting something that will work quickly.

Engineers and scientists in the space business are solving two nearly equivalent problems.



▲ **Scientists and engineers test** the components for a fire-safety experiment planned for an empty cargo spacecraft after it leaves the International Space Station.

A couple of examples illustrate the value of each perspective. As a Ph.D. student in a science department, I made a study of raindrops of liquid methane on Saturn's moon Titan, assessing how large they could grow and how fast they'd fall. A fellow student asked how I was modeling the intermolecular forces in the drop — a microscopic perspective often adopted in physics. "That's surface tension — that's just a number I look up in a book," I barked. All that this problem needed was the net effect of these interactions, a straightforward force balance problem from an engineering perspective.

Some years later, I was out at an airfield observing the motions of a scale model Huygens probe under its parachute, dropped from a radio-control airplane, to gain familiarity with the dynamics the actual probe would encounter during descent to Titan in 2005, I chatted with some students developing a much more sophisticated experiment. They were participating in an aerial robotics competition, and were using machine vision to perform navigation. A standardized marker (a black disk with a white cross) was used to designate their target, and they had written slick code to extract the marker diameter from images in real-time to deduce the distance to the target. Heady stuff! However, their code was failing at long and short ranges and they asked if I could help. I learned they had diligently — doggedly — placed the marker at a range of test distances, obtained the diameters, and they had fitted these

NASA

data in a spreadsheet with a two-term polynomial. After blinking in incredulity for a second, I suggested, "Isn't this just a similar-triangles problem? Have you tried fitting the distance against the reciprocal of the diameter?" They did so, and were most impressed with the accuracy of the results! In this instance, a little physical understanding of the underlying problem let us pounce on a solution much superior to that from the purely empirical approach sometimes favored by engineers.

Almost all scientist-engineer interactions I encounter in my business involve the engineer requesting a specification from the scientist, usually a single number, sometimes a minimum-maximum range or similar. Over the years I've participated in many such discussions — on both sides — as they relate to specification of the environment against which the engineer must design. The conversations often go like this:

E: I need to design the legs for our Mars lander. I need to know the horizontal velocity at landing, so tell me, what will the wind speed be?
S: I don't know, that's why we're sending a lander with my 4-kilogram meteorology instrument! And it depends.
E: OK, fine, what will the maximum wind speed be at the Tharsis landing site in December 2020?
S: Well, I still don't know, we've never been to this site before. And I can't tell you with certainty what the winds will be here on Earth on that day either. I can tell you that the winds at the Viking lander 2 site were less than 20 meters per second for 99 percent of the time in a three-year period in the 1970s. That's the best data we have. And we have a numerical model that predicts the Tharsis winds to be less than 10 meters per second, but that model doesn't include the latest dust information and [...scientist elaborates with further caveats and interesting complications. ...]
E: [Rolls eyes]. Whatever. I'll say 99 percent winds are 20 meters per second, and I'll add 20 percent as a margin. [Sucks teeth]. I have to make the legs pretty sturdy, they'll be heavy. Can you do your meteorology package for 2 kilograms?
S: [expletive deleted]....

Ultimately, engineers and scientists in the space business are solving two nearly equivalent problems. For the engineer (and, cynically, for NASA as a whole), it is usually a constrained minimization — i.e., cleverly developing the lowest-cost design that will meet the requirements. Or put another way, the scientist customer is asked: "What is the minimum performance you will accept?" The scientist usually looks at the interaction another way, as a constrained maximization: "What is the best performance you can give me subject to the budget cap?" Of course, cost predictions are uncertain, and scientific value is notoriously difficult to estimate or even communicate meaningfully, but those are subjects for another article.

Sociologically, the inherent tension in the two perspectives is what — sometimes uncomfortably — has led to the generally successful missions we see. Hopefully this article, by offering a glimpse into the mindsets involved, may help smooth those interactions. Success usually emerges with the help of scientists who grasp at least some of the engineering realities, and engineers who comprehend the overall scientific intent beyond formally stated requirements. ★

Ralph D. Lorenz
is a planetary scientist at the Johns Hopkins Applied Physics Lab in Maryland. He is the author of several books, including "Titan Unveiled," "Space Systems Failures" and "The Cassini/Huygens Owners Workshop Manual." He has two cats.
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AIAA Bulletin

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Calendar

Notes About the Calendar

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
2018			
4–8 Jun†	DATT (Defense & Aerospace Test & Telemetry) Summit	Orlando, FL (www.dattsummit.com)	
7 Jun	DirectTech Webinar—DEMAND for UNMANNED® presents: Aircraft and Rotorcraft System Identification Engineering Methods for UAV Applications	Virtual (aiaa.org/onlinelearning)	
23–24 Jun	Design of Electric and Hybrid-Electric Aircraft Course	Atlanta, GA	
23–24 Jun	Missile Aerodynamics Course	Atlanta, GA	
23–24 Jun	OpenFOAM® Foundations Course	Atlanta, GA	
23–24 Jun	Optimal Design in Multidisciplinary Systems Course	Atlanta, GA	
23–24 Jun	Practical Design Methods for Aircraft and Rotorcraft Flgiht Control for Manned and UAV Applications with Hands-on Training Using CONDUIT® Course	Atlanta, GA	
23–24 Jun	5th AIAA Workshop on Benchmark Problems for Airframe Noise Computations (BANC-V)	Atlanta, GA	
25–29 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – AIAA/CEAS Aeroacoustics Conference – Aerodynamic Measurement Technology and Ground Testing Conference – Applied Aerodynamics Conference – Atmospheric Flight Mechanics Conference – Atmospheric and Space Environments Conference – Aviation Technology, Integration, and Operations Conference – Flight Testing Conference – Flow Control Conference – Fluid Dynamics Conference – Joint Thermophysics and Heat Transfer Conference – Modeling and Simulation Technologies Conference – Multidisciplinary Analysis and Optimization Conference – Plasmadynamics and Lasers Conference	Atlanta, GA	9 Nov 17
25–29 Jun†	15th Spacecraft Charging Technology Conference (SCTC)	Kobe, Japan (Contact: http://www.org.kobe-u.ac.jp/15sctc/index.html)	
3–6 Jul†	ICNPAA-2018 - Mathematical Problems in Engineering, Aerospace and Sciences	Yerevan, Armenia (Contact:: www.icnpaa.com)	
7–8 Jul	Emerging Concepts in High Speed Air-Breathing Propulsion Course	Cincinnati, OH	
7–8 Jul	Fundamentals of Gas Turbine Engine Aerothermodynamics, Performance, and Systems Integration Course	Cincinnati, OH	
7–8 Jul	Liquid Atomization, Spray, and Fuel Injection in Aircraft Gas Turbine Engines Course	Cincinnati, OH	
7–8 Jul	Liquid Rocket Engines: Fundamentals, Green Propellants, and Emerging Technologies Course	Cincinnati, OH	
7–8 Jul	Propulsion of Flapping-wing Micro Air Vehicles (FMAVS) Course	Cincinnati, OH	
7–8 Jul	AIAA Complex Aerospace Systems Exchange (CASE) Workshop	Cincinnati, OH	
7–8 Jul	4th Propulsion Aerodynamics Workshop	Cincinnati, OH	
8 Jul	Enabling Technologies and Analysis Methods for More-, Hybrid-, and All-Electric Aircraft Course	Cincinnati, OH	
9–11 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – Joint Propulsion Conference – International Energy Conversion Engineering Conference	Cincinnati, OH	4 Jan 18
12–13 Jul	AIAA/IEEE Electric Aircraft Technologies Symposium	Cincinnati, OH (aiaa.org/eats)	15 Feb 18
5–7 Aug†	North Carolina Drone Summit and Flight Expo (NC Drone SAFE)	Greensboro, NC (www.ncdronesummit.com/)	
19–23 Aug†	2018 AAS/AIAA Astrodynamics Specialist Conference	Snowbird, UT (www.space-flight.org)	

AIAA Continuing Education offerings

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
15–16 Sep	Integrating Program Management and Systems Engineering Course	Orlando, FL	
16 Sep	Advancing Propulsion for Hypersonic Flight Course	Orlando, FL	
16 Sep	Space Standards and Architectures Course	Orlando, FL	
17–19 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition) Featuring: – Complex Aerospace Systems Exchange – International Space Planes and Hypersonic Systems and Technologies Conference	Orlando, FL	8 Feb 18
1–5 Oct†	69th International Astronautical Congress	Bremen, Germany	
5–8 Nov†	ITC 2018	Glendale, AZ (www.telemetry.org)	
2019			
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	Ka'anapali, 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)	
3–5 Apr†	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (Contact: www.eurognc19.polimi.it)	
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	1 Oct 18
27–29 May†	26th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru/icins2019/en)	
10–13 Jun†	18th International Forum on Aeroelasticity and Structural Dynamics	Savannah, GA (Contact: http://ifasd2019.utcdayton.com)	
17–21 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition)	Dallas, TX	
19–23 Aug	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition)	Indianapolis, IN	
21–25 Oct†	70th International Astronautical Congress	Washington, DC	

2018 AIAA Aerospace Spotlight Awards Gala

AIAA presented its highest awards at the AIAA Aerospace Spotlight Awards Gala on 2 May, at the Ronald Reagan Building and international Trade Center in Washington, DC. The newly elected Class of 2018 AIAA Fellows and AIAA Honorary Fellows also were recognized at the event.

For more information about the AIAA Honors and Awards Program, contact Patricia Carr at patriciac@aiaa.org or 703.264.7523.

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1 Class of 2018 Fellows and Honorary Fellows.
2 AIAA Executive Director Dan Dumbacher (left) and AIAA President Jim Maser (right) with Mary Snitch, recipient of the 2018 AIAA Distinguished Service Award.
3 George C. Nield, recipient of the 2018 AIAA Public Service Award, with AIAA Executive Director Dan Dumbacher (left) and AIAA President Jim Maser (right).
4 2018 AIAA Lawrence Sperry Award recipient Michael West with AIAA Executive Director Dan Dumbacher (left) and AIAA President Jim Maser (right).
5 AIAA Executive Director Dan Dumbacher (left) and AIAA President Jim Maser (right) with Mark Drela, 2018 AIAA Reed Aeronautics Award recipient.
6 Gwynne Shotwell, recipient of the 2018 AIAA Goddard Astronautics Award, with AIAA Executive Director Dan Dumbacher (left) and AIAA President Jim Maser (right).
7 AIAA Executive Director Dan Dumbacher (left) and AIAA President Jim Maser (right) with Daniel Guggenheim Medal recipient Paul M. Bevilaqua
8 Honda Aircraft Company is the 2018 recipient of the AIAA Foundation Award for Excellence. Michimasa Fujino accepted the award from AIAA Executive Director Dan Dumbacher (left) and AIAA President Jim Maser (right).
9 Incoming AIAA President John Langford (right) accepts the gavel from AIAA Past President Jim Maser at the end of the evening.

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2018 AIAA Lawrence Sperry Award Winner

By Michele McDonald, AIAA Communications

AIAA LAWRENCE SPERRY AWARD

Michael West, Engineering Manager at the Australian Department of Defence

"For significant contributions to AIAA and the Australian aerospace sector through policy, education, and innovative scientific research activities."

The award is presented for a notable contribution made by a young person, age 35 or under, to the advancement of aeronautics or astronautics. This award honors Lawrence B. Sperry, pioneer aviator and inventor, who died in 1923 in a forced landing while attempting a flight across the English Channel.

With a grandmother who flew Tiger Moth biplanes in Africa after World War II and a grandfather who was an electrical engineer, it makes sense that Michael West became an aerospace engineer.

"They inspired me with stories from their careers and their travels around the world," said Dr. West, 2018 AIAA Lawrence Sperry Award winner. "As a child, I always enjoyed solving puzzles and trying to design things. Even though I was interested in becoming a lawyer or an architect, it is no surprise that I got drawn into engineering."

And space held a fascination long before university studies.

"One of my earliest childhood memories is watching Halley's Comet from the front veranda of the family home in a small country town in regional Australia," he said. "Being more than 400 kilometres from any major cities meant that the view was spectacular."

Dr. West knows first-hand how life-changing STEM activities can be for students. His high school science teacher encouraged him to become involved in astronomy and rocketry.

"When I was 14, I won a science competition with two school friends that involved designing an experiment for the Space Shuttle. The prize was an expenses-paid trip to the United States to visit the Johnson and Kennedy Space Centers and see a space shuttle launch. We got a behind-the-scenes tour of the NASA facilities and then saw John Glenn launch back into space on the STS-95 shuttle mission. I was already interested in aerospace, but from that point on I was completely hooked."

Also, while in high school, Dr. West launched two experiments aboard sounding rockets at the Woomera Rocket Range in central Australia. The rockets pulled about 70 G and reached Mach 2 just after liftoff.

"During the second launch cycle, I was allowed to stand in the bunker under the launch pad and press the button to initiate the launch," he said. "The sensation as the enormous concrete bunker shook is something I will never forget."

As a teenager, Dr. West met shuttle astronauts Pamela Melroy and Scott Parazynski, and Apollo 17 astronaut Harrison Schmidt. "Hearing their stories and seeing such accomplished, intelligent and humble people left a real impression on me," he said.

Dr. West wants others to have similar experiences and has worked on STEM outreach to students and the general public. He has organized workshops for school science teachers and regularly participates in outreach activities at air shows, science fairs, school fetes, and other community events.

After being selected as a state finalist in the 2006 Young Australian of the Year Awards, Dr. West served as an Australia Day Ambassador for five years, visiting regional communities and sharing his experiences and passion for space exploration, science, engineering, and innovation.

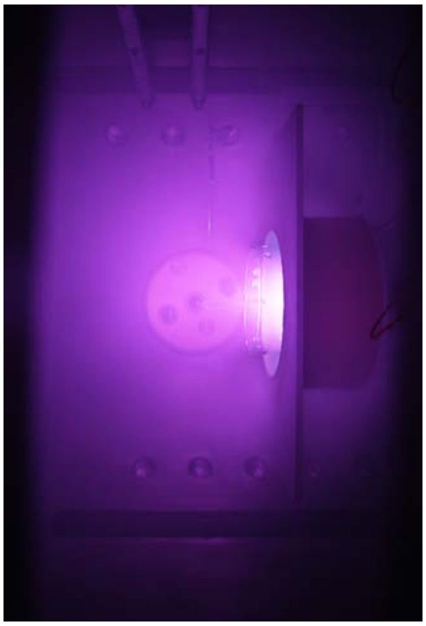
"I am proof that these activities work and that they can motivate someone for a lifetime," he said. "Because of these experiences, space exploration is my passion. Every project I have worked on since has needed to have a space component to it, otherwise I quickly lose interest."

West gravitates to engineering challenges.

Dr. West's nominators cited his Ph.D. work at the Australian National University (ANU) as providing valuable outcomes to the aerospace industry. He conducted the first extensive space simulation tests of the Helicon Double Layer Thruster (HDLT) prototype – a new spacecraft electric propulsion system. Fellow engineers can identify with the hours spent in the lab, testing different approaches and designs and failing often.

Then came Dr. West's eureka moment about a year before finishing his thesis.

"While playing around with the power and other settings for the HDLT prototype, something strange happened and at first I thought I had damaged the apparatus as a bright glow and arcing appeared inside the vacuum chamber," he described. "After turning everything off, taking a breath, restarting the system and trying the settings again, I was able to recreate the effect and the bright glow in the HDLT prototype's plasma source. Later it became clear that I had be able to reproduce a new high density 'blue' mode when operating the HDLT prototype in xenon."



This "blue" mode had only been observed once before, Dr. West explained, when the HDLT prototype was tested at the European Space Research and Technology Centre (ESTEC) several years earlier. He then spent the next few months characterizing this "blue" mode. The findings became an important part of his Ph.D. thesis and led to several journal publications with ANU colleagues.

Dr. West's Sperry award nominators noted that the outcomes of his Ph.D. work provided valuable insights and

experience for the research team as they developed ANU's new $4 million WOMBAT XL Space Simulation Facility – the largest thermal-vacuum facility of its type in the Southern Hemisphere.

Dr. West has worked in research, academia and government, learning from each. "My time in academia and as a researcher taught me valuable critical thinking skills and how to break out a complex problem into its constituent parts and tackle it in a systematic way. Working in government has reinforced the importance of the soft skills – conveying complex information in easy to understand ways, writing clearly and with influence, engaging with diverse stakeholders to get an outcome despite competing goals, priorities and pressures."

When he was 17 and starting undergraduate studies in aerospace engineering, Dr. West joined AIAA. He first became a member for the book discounts, but continued for the career development.

"Being involved with AIAA has expanded my knowledge, helped build my professional network and provided valuable opportunities to develop my leadership and management skills," he said. "The real career value is in the second order benefits. It is the access to the aerospace influencers – those who are shaping the future of the industry. It is the friends I have made. It is the like-minded individuals who I have interacted and worked with and who are such an inspiration. AIAA is the link to all the amazing things happening in the aerospace industry."

As a passionate volunteer, Dr. West reactivated the dormant AIAA Sydney Section and expanded its activities into the Canberra region in 2007. While section chair between 2009–2015, he was instrumental in initiating and implementing career development activities for hundreds of professionals and students, including multiple nationwide lecture tours.

"With natural leadership ability, Michael competently managed a large team of volunteers, spread across two cities and four universities," according to nomination documents. "During Michael's tenure, AIAA membership in Australia grew considerably (now over 500+) and the AIAA is the nation's most active aerospace organization."

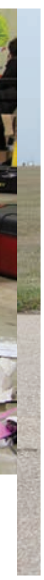
West is honored to have received the Sperry award.

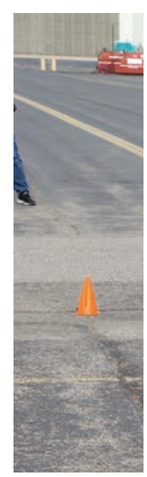
"As an Australian, to be recognised by a prestigious international organisation such as AIAA is really special," he wrote. "Looking at the list of previous winners is really humbling as well. Many of the past recipients are people that I have read about, whose careers and achievements have amazed and inspired me."

Clarkson University Wins 22nd Annual Student Design/Build/Fly Competition

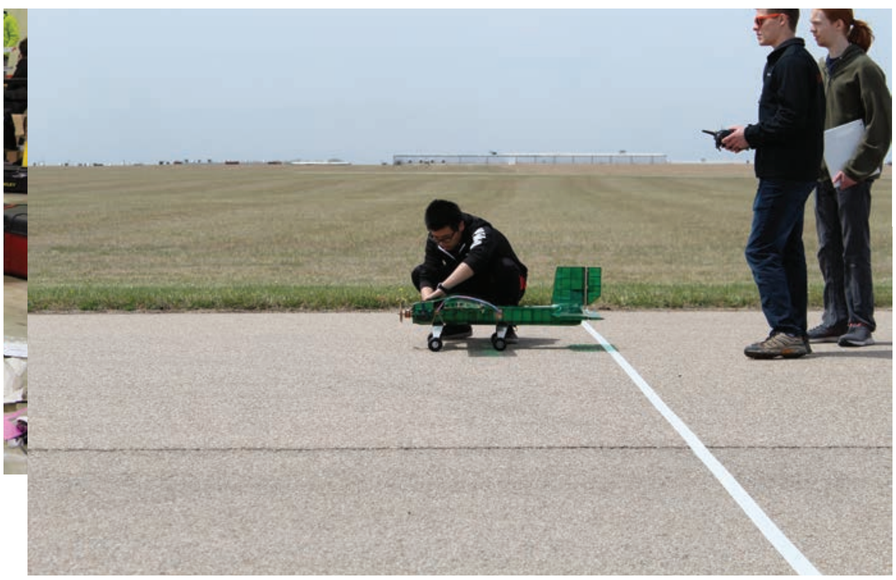
The 2017–2018 Textron Aviation/Raytheon Missile Systems/AIAA Foundation Student Design/Build/Fly (DBF) Competition was held 19–22 April, at the Cessna Pawnee East Field in Wichita, KS. The event included 77 teams and 720 students from 16 countries—a new DBF record! The students had to design a Regional and Business Aircraft. The aircraft was required to fly a combination of passengers and payload as well as demonstrate the ability to conduct LRU replacement in the field. Of the 245 official flight attempts, 153 resulted in a successful score with 50 teams achieving at least one successful flight score and 24 teams successfully completed all three missions. The Clarkson University team won the event by a small margin with Virginia Polytechnic Institute and State University in second place, and Georgia Institute of Technology finishing in third place. The Best Paper Award, sponsored by the Design Engineering Technical Committee, went to the University of Southern California.

Official results and rankings for all participants are available on the DBF website (aiaadbf.org). Thank you to all of our Premier, Gold, Silver, and Bronze sponsors (aiaadbf.org/Sponsors) who help us inspire the next generation. A special thanks to the volunteers who helped make this year a success!








News

2018 TARC National Finals

By Michele McDonald, AIAA Communications

The energy from high school and middle school teams nearly outpaced their rockets on 12 May as they competed in the Team America Rocketry Challenge (TARC) on a grassy field in Virginia. About 100 teams from across the country competed in the TARC national finals for the privilege of going to London for the international competition. Creekview High School from Canton, Georgia, took the top spot. All the results can be found at **rocketcontest.org/competition-results/2018-results**. Teams traveled from California, Texas, Iowa, Ohio, Washington, New York, and Colorado, among other states.

Rocketry helps introduce teens and preteens to engineering, said AIAA President John Langford, as he took a break from flying a drone near the launchpad zone. "I think it's really critical to have programs like the Rocketry Challenge," he said. "It may not have occurred to a lot of these kids to go into aerospace. You don't know who you're going to reach. This may change the lives of some and for the rest, they'll have a lot of fun."

There's more to the Rocketry Challenge than action on the launchpads, Langford, founder and CEO of Aurora Flight Sciences, said, adding the teams need AIAA members as mentors. "The kids are so fun to watch as they collaborate and work through problems," he said. "The best part is watching them prep."

Arianna, a member of Team Rocket from Newark Memorial High School in California, said that the challenge "definitely pushed me in the direction of STEM." She added that she's heading to UCLA in the fall where she plans to join their rocketry club.

"I can put my engineering skills to use into building the rocket," said José, 17, who wants to be a mechanical engineer.

2018 AIAA Regional Student Conferences

AIAA sponsors student conferences in each AIAA Region for student members at both the undergraduate and graduate levels. Students from regional schools have the opportunity to present their research on aerospace topics in a formal presentation. The students' formal presentations are judged on technical content and clarity of communication by professional members from industry. In addition to the competition, the conferences provide a venue for students to share AIAA experiences, participate in social activities, connect with industry professionals, and exchange ideas about current topics in aerospace engineering.

In early 2018, the Lockheed Martin Corporation provided a generous donation to the AIAA Foundation to support

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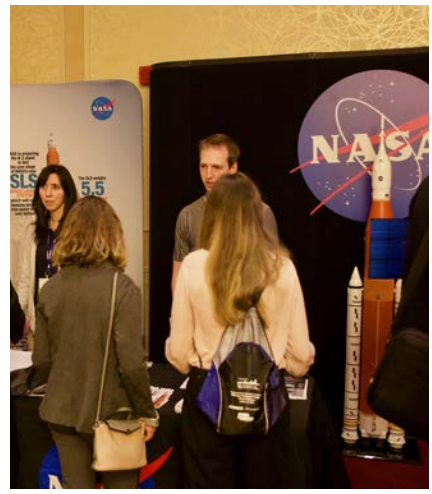
the Regional Student Conferences and the International Student Conference. Funding was provided to the student branch to organize the conference as well as provide prize money for the three categories supported by the AIAA Foundation. The first-place winners in each category (listed below) will be invited to attend and present their papers at the AIAA Foundation International Student Conference that will be held in conjunction with the 2019 AIAA SciTech Forum in San Diego, California, 7–11 January.



Undergraduate Category Winners

Region I: Assessing the Transient Gust Response of a Representative Ship Airwake using Proper Orthogonal Decomposition, Christopher G. Cantillo, United States Naval Academy

Region II: Design for Multi-Axis Fused Filament Fabrication with Continuous Fiber Reinforcement: Unmanned Aerial Vehicle Applications, Paul G. Sinkez and Wout De Backer, University of South Carolina

Region III: Development of an Emergency Response UAV, Mitchell Lozier and Cameron Sickbert, Rose-Hulman Institute of Technology

Region IV: Application of Computational Intelligence for Command & Control of Unmanned Air Systems, Hannah C. Lehman, Texas A&M University

Region V: The Impact of a Notched Leading Edge on Performance and Noise Signature of Unmanned Aerial Vehicle Propellers, Anna C. Demoret and Charles F. Wisniewski, United States Air Force Academy

Region VI: Stability and Control Derivative Estimation for the Bell-Shaped Lift Distribution, Loren J. Newton, University of California, Berkeley

Masters Category Winners

Region I: Characterization of a Hybrid (Steel-Composite) Gear with Various Composite Materials and Layups, Sean M. Gauntt and Robert L. Campbell, Pennsylvania State University

Region II: Characterization of near-Muzzle Ballistic Flow Fields using High-Speed Shadowgraphy, Matthew J. Schwartz and John D. Schmisseur, University of Tennessee Space Institute

Region III: Investigation of Nanosecond-Scale Plasma Discharges at Atmospheric Pressure Using Time-Resolved Imaging, Paul W. Stockett, Ravichandra R. Jagannath, and Sally P.M. Banc, Purdue University

Region IV: Comparison of Linear and Nonlinear Dynamics of a Virtual Telescope, Richard Adcock, University of New Mexico

Region V: Multi-Mode Micropropulsion Systems Enabling Swarm Technology, Matt Klosterman and Shannan Withrow, Missouri University of Science and Technology

Region VI: Velocity Measurements of Projectiles Propelled by Underexpanded Supersonic Jets, Fin van Donkelaar, University of Washington

Team Category Winners

Region I: Stereoscopic Mixed Reality in Unmanned Aerial Vehicle Search

Continued on page 56

Continued from page 55

and Rescue, Saimouli Katragadda, Xincheng Li, and Benedict Mondal, University of Maryland

Region II: The Road to the Karman Line: Development of Liquid-Fueled Propulsion and Flight-Control Systems for Suborbital Launch Vehicles, Suraj Buddhavarapu, Trenton Charlson, Neel Dutta, Akhil Gupta, Gabriel Rizzo, Shrivathsav Seshan, and Ben Zabback, Georgia Institute of Technology

Region III: Liquid Water Micropropulsion System for Small Satellites, Steven M. Pugia, Ryan J. Clay, Matthew F. Fuehne, Margaret N. Linker, Noah C. Franks, Benjamin J. Davis, and Katherine I. Fowee, Purdue University

Region IV: Payload Design and Development for Orbital Structural Health Monitoring, Luke Byrom, Carl Bancroft, Douglas MacNinch, Shane Mckinney, Daniel Pancheco, Michael Underwood,

and Arjun Tandon, New Mexico Institute of Mining and Technology

Region V: Preliminary Engine Cycle Design for Commercial Supersonic Transport, Martin Gleason, Igor Gertsman, Dan Inman, Derek McGuckin, Brennen Poole, Jisung Yi, and Peter Yoon, United States Air Force Academy

Region VI: Spray Cone Formation from Pintle-Type Injector Systems in Liquid Rocket Engines, James Blakely, Johann Freeberg, and Jacob Hogge, University of Southern California

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Call for Papers: Special Issue on "Multi-Core Architectures in Avionic Systems"

Journal of Aerospace Information Systems (*JAIS*) is devoted to the applied science and engineering of aerospace computing, information, and communication. Original archival research papers are sought that include significant scientific and technical knowledge and concepts. In particular, articles are sought that demonstrate the application of recent research in computing, information, and communications technology to a wide range of practical aerospace problems in the analysis and design of vehicles, onboard avionics, ground-based processing and control systems, flight simulation, and air transportation systems.

The journal intends to publish a special issue on multi-core architectures in avionics systems. Guidelines for preparing your manuscript can be found in the full Call for Papers on the *JAIS* page in Aerospace Research Central (arc.aiaa.org). The journal website is **arc.aiaa.org/loi/jais**.

Background: With the growth of the cyber layer in aircraft and the paradigm shift from federated and distributed on-board systems architectures to Integrated Modular Avionics (IMA), there is an increasing demand on higher throughput computing architectures. This is further elevated with optimization efforts to reduce the total number of high-speed computers within an airplane to comply with space, weight, and power (SWAP) requirements and to achieve a better maintainability. Well-known platforms will not be able to satisfy the ever-increasing requirements on SWAP and processing performance. Thus, for new functionality higher performing systems must be implemented using alternative and emerging architectures. Multi-core technology, now being state of the art in standard Information & Communications Technology (ICT), seems to be the most promising path to improve computational capabilities in avionics systems. However, there are still many challenges associated with transition to multi-core architectures.

Topics of interest to this special issue aim toward a focused forum to disseminate the latest research about multi-core architectures in avionics systems. Original research papers are sought in, but not exclusive to, the following topics:

- Multi-core processors for avionics applications
- Certification of multi-core based platforms
- Model-driven development for multi-core systems
- Parallelization of multi-core applications
- ARINC 653 and multi-core
- Worst Case Execution Time (WCET) in multi-core systems
- Virtualization for multi-core avionics systems
- Quality of service (QoS) in multi-core architectures
- Mixed-criticality on multi-core architectures
- Methods and tools related to the usage of multi-core in avionics

Deadline: Submissions are due by **21 December 2018**.

Publication Date: The anticipated publication date of the special issue is April 2019.

Guest Editors: Umut Durak, German Aerospace Center (DLR), umut.durak@dlr.de; Falco Bapp, Karlsruhe Institute of Technology (KIT), falco.bapp@kit.edu.

AIAA Orange County Section Recent STEM and Outreach Activities

By Dr. Amir S. Gohardani, Chair, AIAA Orange County Section

The AIAA Orange County (OC) Section in Southern California has recently taken part in several STEM activities. These activities have primarily been spearheaded by the section's Education Officer Jann Koepke and the section's Member-at-Large Officer and Team America Rocketry Challenge (TARC) mentor, Bob Koepke.

Bradley Dybel, OCEC Secretary (left) and C.T. Bathala, OCEC President (right) presented Jann Koepke with the OCEC STEM Service Award.

Most recently, 11 TARC rocket launches were recorded and the Koepkes also attended a launch event at Holtville Airport for the NASA Student Launch team to test their student rockets. In close collaboration with the Mendez Amateur Radio Club to teach basic electronics and demo Amateur Radio, the Koepkes regularly engage with TARC teams in Orange County, and they recently also held a TARC Qualification Launch for the Starbase TARC teams at Los Alamitos joint military base. The commitment of the Koepkes to support the youth in Orange County is admirable and on 17 February, Jann Koepke was recognized with the Orange County Engineering Council (OCEC) STEM Service Award during the OCEC Annual Banquet.

AIAA OC Section's Table Display for E-Week hosted by Bob Welge (left) and Gene Justin.

In a parallel outreach effort, AIAA OC's Membership Officer Bob Welge and Secretary Gene Justin represented the section at the Boeing E-Week event on 22 February 2018.

AIAA Sydney Section Commemorates the 100th Anniversary of the Fall of the Red Baron

By Michael Spencer, AIAA Sydney Section

AIAA Sydney Section event team (L-to-R): A. Neely; C. Hoke, Vice-Chair; A. Dasgupta, Chair; Thomas Faunce, guest speaker; M. Vella; and Michael Spencer.

German Imperial pilot Baron Manfred von Richthofen was killed in air combat on 21 April 1918. He was unequalled in having shot down 80 enemy aircraft in aerial combat during World War I to become the most celebrated Ace of Aces in the early history of air combat. The British called him the “Red Baron”; the French scorned him as the “le diable rouge (Red Devil)”; he called himself the “Red Battle Flyer.” To commemorate this 100th anniversary of the death of the Red Baron, the AIAA Sydney Section arranged a public event and invited Dr. Thomas Faunce, Australian National University professor of law and medicine, and military aviation historian, to give a lecture that would lead the public through an evidence-based critical analysis of the likely contributing factors and catastrophic decisions leading up to his death and identify who fired that one fatal bullet.

On 21 April 1918, Richthofen pursued a Royal Flying Corps Sopwith Camel low over enemy-controlled territory, breaking one of his fundamental air combat maxims, and was fatally wounded. Richthofen managed to execute a controlled crash landing, on Australian-held battleground, before dying in the cockpit. Australian soldiers were quick to attend the crash site and seek to recover Richthofen.

Although Captain Arthur “Roy” Brown (in a pursuing aircraft) was originally credited with the fatal shot, later medical forensic analyses of the wound ballistics have indicated that Richthofen was struck in the chest by groundfire and not from an airborne shooter. Australia’s Official War Historian, Charles Bean, has gathered eyewitness accounts from the battlefield that indicate it was most probable that Sergeant Cedric Popkin, an Australian Vickers machine gunner in the trenches, had fired the fatal shot that brought down the Red Baron (Bean, C. 1941. First World War Official Histories, Vol V – The Australian Imperial Force in France during the Main German Offensive, 1918. Appendix 4 – The Death of Richthofen. Online at www.awm.gov.au/collection/C1416782).

Richthofen was buried in a military cemetery in France, with full military honours, by members of No 3 Squadron, Australian Flying Corps. A British pilot flew solo over the German air base of 11 Jasta to air drop a message to respectfully inform them of the death of their celebrated commander.

The AIAA Wichita Section hosted AIAA Executive Director Dan Dumbacher at a dinner and presentation on 19 April.

Newly Elected Board of Trustee Members and Treasurer

In May the AIAA Council of Directors elected a new Treasurer and four new Board of Trustees members. Because the Treasurer was an existing Board member, a vacancy was created, which was also filled.

The new Treasurer is **Annalisa Weigel**. New Board members are **Missy Cummings, John Dowdle, R. Steven Justice,** and **David Throckmorton**.

AIAA New England Section Hosts Major STEM Event

The AIAA New England Section hosted an estimated 950 K–12 kids, parents, and teachers at the Rockets and Flight event in the MIT Museum's Science on Saturday series on 10 March 2018 at MIT's Kresge Auditorium. The intensity of the student response was magical. Several of the 65 volunteers put on a one-hour presentation in the auditorium. The students explored our 24 display tables in the lobby for the second hour. This event was the focus of the section's 2017–2018 activities.

The presentations started with Lt. Col. Tucker Hamilton, AIAA's STEM lead who traveled from Edwards Air Force Base for a Distinguished Lecture and this event. Hamilton gave the keynote presentation, impressing the audience with his entrance dressed in his flight suit. Other presenters were student branch members from MIT who demonstrated a wind tunnel built just for this event, students from Northeastern University, UMass Lowell, and the MIT Graduate Women in Aerospace Engineer-

ing who held an orbits demonstration. One volunteer helped kids operate a NASA Mars Lander app.

The volunteers at the display tables distributed 150 AIAA balsa wood model airplanes, 100 protractors, and many paper helicopters and airplanes. The tables were designed to interest K–12 kids with themes covering AIAA model airplanes, Apollo space suits, biomedical

payloads, composite structures, cubesats, Design/Build/Fly aircraft, electric propulsion, exoplanets, jet engines, lunar crater mining, orbits and gravity, paper airplanes and helicopters, parachutes, phoenix mars lander, radars, robotic space spheres, rockets, quadcopters, spacecraft dynamics, space helmets, space suits, straw rockets, trigonometry, and the wind tunnel.

Four volunteers (Yari Golden-Castano, Paula do Vale Pereira, Martina Stadler, and Joseph Vornehm) made significant contributions, and they were honored at the New England Section's Honors and Awards Banquet on 24 April. Contact the New England Section using AIAA Engage for more information (Engage.aiaa.org).

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Assistant Professor (Tenure-Track)/ Associate Professor (Tenure-Track or Tenured) in Space Technology

Young and research-intensive, Nanyang Technological University (NTU Singapore) is ranked 11th globally. It is also placed 1st amongst the world's best young universities in the 2017 QS World University Rankings. The School of Electrical and Electronic Engineering (EEE) at NTU Singapore is one of the largest EEE schools in the world and ranks 6th in EEE in the same QS Rankings by Disciplines.

The School invites outstanding applicants for an Assistant Professor (Tenure-track) /Associate Professor (Tenure-track or Tenured) in Space Technology (ST) position. The ideal candidate is expected to have a strong background in Space Technology that includes but not limited to satellite platforms and formations; space-borne instruments and systems (for optical, infrared and SAR remote sensing, navigation and control, atmospheric research, etc.) He/She is to play a role in the NTU satellite program, grow new capabilities and secure external resources for ST projects. In addition to research, candidate is also expected to achieve teaching excellence in preparing engineering leaders of the future.

Candidates with postdoctoral or relevant working/teaching experience in top research institutes or universities would be preferred.

Emoluments:
Salary will be competitive and commensurate with qualifications and experience. The University offers a comprehensive fringe benefits package.

Application Procedure:
IMPORTANT - Please indicate clearly the post applied for (i.e. Assistant/Associate Professor in Space Technology) when submitting an application or inquiring about this job announcement.

To apply, please refer to the Guidelines for Submitting an Application for Faculty Appointment: (http://www.ntu.edu.sg/ohr/career/submit-an-application/Pages/Faculty-Positions.aspx) and send your application (cover letter and a full CV) via email to:

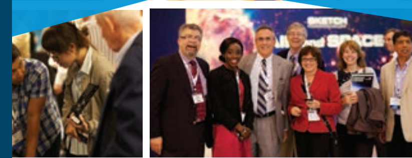
Chairman, School Search Committee
c/o School of Electrical & Electronic Engineering
Email: EEE-Fac-Recruit@ntu.edu.sg

Electronic submission of applications is encouraged. Only shortlisted candidates will be notified.

Application Deadline: Position is open until filled.

www.ntu.edu.sg

MEMBERSHIP MATTERS



Your Membership Benefits

1. **Get Ahead of the Curve –** Stay abreast of in-depth reporting on the innovations shaping the aerospace industry with ***Aerospace America***, and a daily dose of vetted industry news in the ***AIAA Daily Launch*** – both delivered free with AIAA membership.

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1918

June 6 Britain's Independent Force of the Royal Air Force is formed under the leadership of Maj. Gen. Hugh M. Trenchard. This is the world's first strategic bombing force and is intended to attack industrial targets deep in the heart of Germany in order to disrupt the war economy. David Baker, **Flight and Flying: A Chronology**, p. 113.

June 19 Maj. Francesco Baracca is shot down and killed while strafing Austrian lines in his Spad 13. Baracca was Italy's leading World War I ace with 34 victories. J.M. Bruce, **Spad Scouts SVII-SXIII**, p. 5.

During June
The second fighter competition at Adlershof is completed with the Fokker E.5 parasol monoplane judged the winner. Sleek, fast, and designed to be powered by the plentiful Oberursel rotary engine, the E.5 is placed into production as the Fokker D.8 and enters service late in the war. As with other Fokker designs, the aircraft's wing is subject to failure, some say because of poor workmanship and poor available glues. Nevertheless, the D.8 becomes a formidable fighter. David Baker, **Flight and Flying: A Chronology**, p. 113.

1943

June 10 The combined chiefs of staff from U.S. and Britain issue a directive that officially begins the Combined Bomber Offensive Plan of the U.S. Army Air Forces and the Royal Air Force. It calls for them to strike against sources of German war power, with the RAF bombing strategic areas at night and American forces hitting precise targets by day. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 144.

June 11 After intensive Allied bombing, the Italian garrison on the island of Pantelleria surrenders, marking the first time a large defended area is conquered by airpower alone. Arthur Gordon, **The History of Flight**, p. 40.

June 11 Some 168 aircraft from the U.S. Army Air Forces' 8th Air Force attack the Wilhelmshaven U-boat yards in Germany. However, the enemy's fighter attacks prevent the bombers from accurately hitting the targets, demonstrating the difficulty of operating beyond the range of fighter escorts. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 145.

June 14 The British Royal Air Force forms its 1st Tactical Air Force for operations in the Mediterranean and Italy, and establishes the 2nd and 3rd Tactical Air Forces for service in Western Europe and Southeast Asia, respectively. Arthur Gordon, **The History of Flight**, p. 40.

June 15 The Arado Ar234V-1 Blitz, prototype of the world's first turbojet-powered reconnaissance bomber, makes its first flight. J.R. Smith and Antony Kay, **German Aircraft of the Second World War**, p. 40.

June 15 The U.S. Army Air Forces completes the service test modifications of its YB-40 escort bombers. It is hoped that these modified Boeing B-17s, which have been converted to heavily armored aircraft with greater firepower, will solve the problem of long-range escorts for bombers. The YB-40s were previously unable to keep up with standard B-17s and needed modifications to their waist and tail-gun feeds and their ammunition supply systems. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, pp. 140, 146.

June 23 Air reconnaissance photos reveal large rockets at Peenemunde, Germany. British intelligence sources believe these rockets are meant for long-range attack. The rockets are later identified as the A-4, or V-2. B. Collier, **The Battle of the V-Weapons**, p. 32.

June 24 Physicist Joseph S. Ames dies at the age of 78. Ames, a professor for 50 years, is best known for his aeronautical research work. He chaired the National Advisory Committee for Aeronautics, NASA's precursor, from 1927 to 1939; NASA's Ames Research Center is named for him. **U.S. Air Services**, July 1943, pp. 11, 54; E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 102.

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1968

June 4 NASA announces that the Rocketdyne Division of North American Rockwell will incorporate an injector into the Bell Aerosystems lunar module ascent engine of the first Apollo manned lunar module mission. This decision is made when Bell could not solve combustion instability problems with the engine based upon the Bell Agena engine. NASA, **Aeronautics and Astronautics, 1968**, p. 127; **Aviation Week**, Sept. 30, 1968, p. 23.

June 7 The cargo ship Point Barrow arrives at NASA's Michoud Assembly Facility in New Orleans with cargo of a Saturn S-2 stage, five F-1 engines and seven large F-1 components. This is the first time Saturn 5 first-stage F-1 engines are shipped in quantity by water. NASA, Leo L. Jones, **A Chronology of the George C. Marshall Space Flight Center, 1968**, p. 65.

June 9 Barnes Wallis, British aeronautical inventor and the chief of aeronautical research at British Aircraft Corp., is knighted during Queen Elizabeth II's birthday honors. Wallis has been responsible for designs and inventions that have included the R100 airship and the "bouncing bomb" that breached German dams during World War II. **Flight International**, June 13, 1968, p. 877.

June 11 German aerospace firms Bölkow and Messerschmitt announce they will merge into a company to be called Messerschmitt-Bölkow GmbH, with headquarters in Munich. The new company later becomes Messerschmitt-Bölkow-Blohm, or MBB, and its light twin helicopter becomes one of its best-known products. **Flight International**, June 27, 1968, p. 972.

June 12 An X-ray telescope — called "the most powerful yet flown" — is launched as the payload on a British Skylark solid-propellant sounding rocket from Woomera, South Australia. During the flight, the 1.2-square-meter aperture telescope designed and built by the X-ray Astronomy Group at the United Kingdom's Leicester University, makes several sweeps of the sky in a search for a new type of X-ray star. **Flight International**, June 27, 1968, p. 982.

June 13-15 NASA undertakes the first radar tracking of an asteroid; it is named Icarus and passes close to Earth every 19 years. The tracking is accomplished with the 26-meter- and 64-meter-diameter antennas of the Goldstone Tracking Station in the Mojave Desert near Barstow, California. Scientists followed the approach of Icarus' flyby of Earth at 634,868 kilometers at 106,559 km/hour. **New York Times**, June 27, 1968, p. 41.

June 26 McDonnell Douglas Astronautics Co. is formed with the merger of Douglas Missiles and Space Systems Division and McDonnell Astronautics Co. The new company's main office is to be at Huntington Beach, California; the chairman and CEO is Charles Able, formerly of Douglas. The new company employs 25,000 people and is responsible for such programs as the Manned Orbiting Laboratory and the S-4B upper, or third stage, of the Saturn 5 launch vehicle. **Flight International**, July 11, 1968, p. 77.

June 26 The Phoebus 2A nuclear reactor at the Nuclear Rocket Development Station at Jackass Flats, Nevada, achieves a milestone in the development of nuclear propulsion when it generates 4,200 megawatts during a 12-minute run. The amount is twice the power recorded during its test run on June 8 and produces 889,679 newtons of thrust. **Flight International**, July 18, 1968, p. 110.

June 30 The Lockheed C-5A Galaxy intercontinental-range military transport makes its first test flight, for 94 minutes out of Dobbins Air Force Base in Georgia. It is powered by four turbofan jet engines. The C-5 fleet becomes operational in 1969 and supports U.S. military operations in all major conflicts. **Flight International**, July 11, 1968, p. 38.

1993

June 10 The FAA approves the use of GPS for general aviation pilots. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 381.

June 13 One of the original Mercury 7 astronauts, Donald "Deke" Slayton dies of brain cancer at the age of 69. Because of an irregular heartbeat, his planned flight on the second Mercury flight was canceled. Slayon's condition later cleared up and he was approved to fly. In July 1975 he flew with Thomas Stafford and Vance Brand on the Apollo-Soyuz Test Project. For most of his NASA career, he served as chief of flight operations. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 383.

June 21 Spacehab-1, the world's first commercially owned space laboratory, is deployed on the STS-57 mission of the space shuttle Endeavour. Spacehab is partly funded by NASA and has the right to use part of it for its first six flights. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 368, 702.

ARWA AWEISS, 38

Flight test director for NASA's Unmanned Aircraft System Traffic Management Project, Ames Research Center

Arwa Aweiss didn't set out to become an aerospace engineer. Through her civil engineering college coursework, she discovered a love of transportation engineering. Then, a series of jobs and a chance encounter led her to NASA's Ames Research Center in Mountain View, California. Now, Aweiss oversees flight testing for NASA's UTM, or Unmanned Aircraft System Traffic Management Project, an ambitious effort that involves the FAA, industry and academia in finding ways for millions of drones to someday fly in U.S. airspace, even over populated areas and out of view of their operators.

How did you become an aerospace engineer?

I wanted to study civil engineering because it offered a wide array of subjects: transportation, data mining and structural engineering. While earning a bachelor's degree in civil engineering at the University of California, Irvine, I realized I was interested in transportation engineering. I pursued a master's degree at the University of California, Berkeley, where I took great interest in air transportation. After graduation, I worked for Bechtel designing the international airport in Qatar and as an aviation consultant in San Francisco. I was working as a traffic engineer at San Jose International Airport when a friend invited me to join the Ames summer softball team. At a game, I met the Aviation Systems Division branch chief. A couple of weeks later, I got a call. They were hiring and thought I might be a good fit. That was 10 years ago. Now, I'm involved in program management and technical aspects of UTM flight testing. Six FAA designated unmanned aircraft systems test sites are participating. I coordinate with the sites and their partners, develop test objectives and performance measurements, and oversee tests. I also lead the data management team and work with NASA's internal UTM teams focused on human factors, software and data monitoring.

Imagine 2050. What do you think will be happening in unmanned aircraft?

I think we will see millions of small unmanned aircraft systems flying and conducting a variety of public safety, commercial and hobbyist operations in U.S. airspace. Some of these will be beyond visual line-of-sight operations, in proximity to each other, in high-density air traffic and over densely populated airspace. They will perform package deliveries, search and rescue, infrastructure inspection, survey disaster areas, deliver medical supplies to disaster victims and more. I envision these technologies and capabilities will mature and UTM will continue to evolve to maintain the desired level of safety and efficiency to make all this possible. Without a doubt, UTM is a very important project that will have immediate impact on society. I'm very blessed to be working on it at NASA and alongside the FAA, other government agencies, industry and academia. ★

BY DEBRA WERNER | werner.debra@gmail.com


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