AEROSPACE AMERICA

SHOWTIME FOR WEBB

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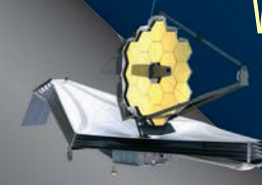

SPACE RESCUE

Human spaceflight's Achilles' heel — stranding customers without a rescue plan PAGE 22

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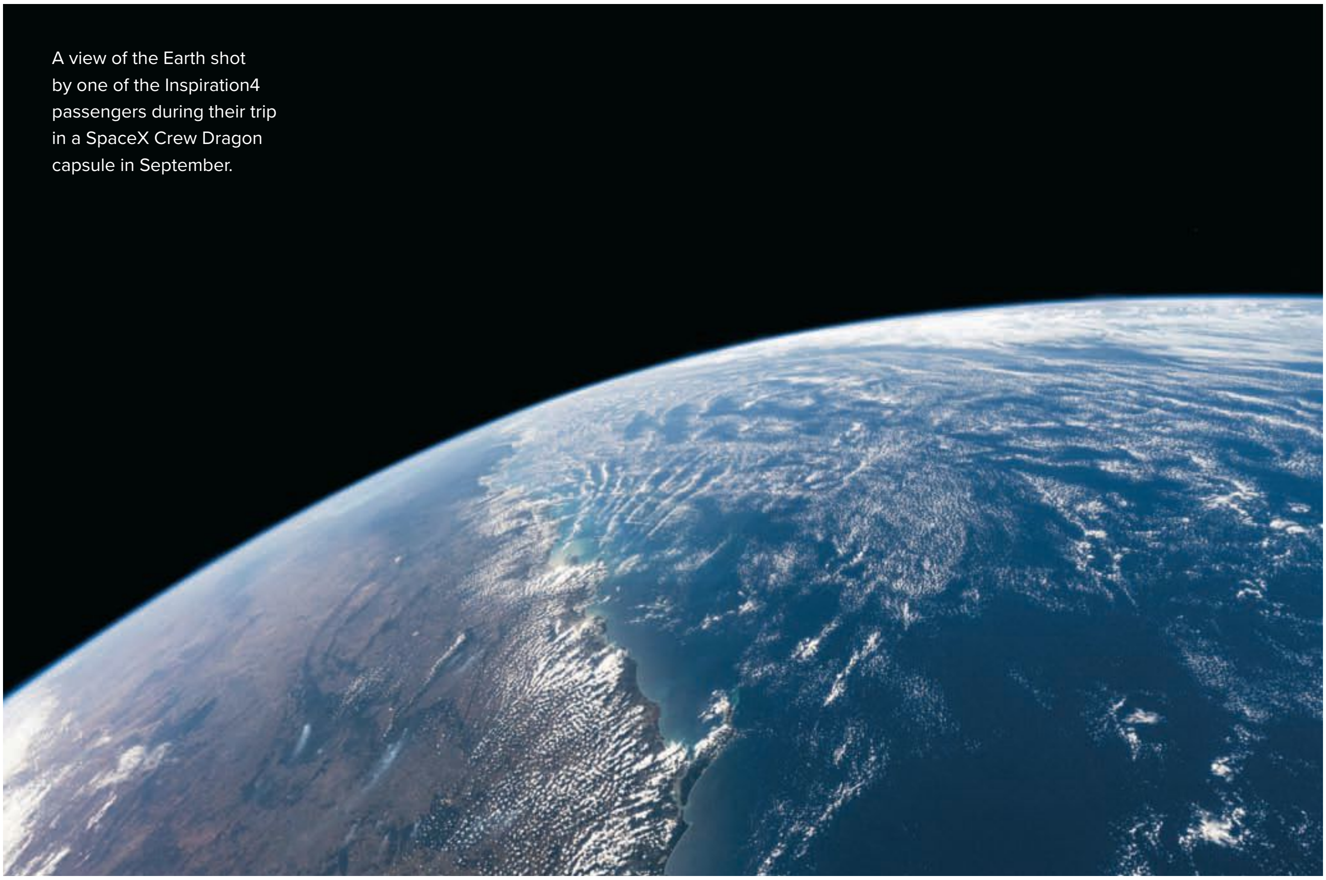

A view of the Earth shot by one of the Inspiration4 passengers during their trip in a SpaceX Crew Dragon capsule in September.

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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Adam Hadhazy

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

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Cat Hofacker

As our staff reporter, Cat covers news for our website and regularly contributes to the magazine.

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Moriba Jah

Before becoming an associate professor at the University of Texas at Austin, Moriba helped navigate the Mars Odyssey spacecraft and the Mars Reconnaissance Orbiter from NASA's Jet Propulsion Lab and worked on space situational awareness issues with the U.S. Air Force Research Laboratory.

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Paul Marks

Paul is an award-winning journalist focused on technology, cybersecurity, aviation and spaceflight. A regular contributor to the BBC, New Scientist and The Economist, his current interests include eVTOL aircraft, new space and the history of notable inventors — especially the Wright brothers.

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DEPARTMENTS

A note to "all the crew of spaceship Earth"

I've been thinking all wrong about the role of tomorrow's aerospace engineers in diversifying their profession and ensuring that our home planet becomes a healthier, cleaner place. That's the lesson I drew from a short address delivered by a student at Aviation Week Network's annual Laureate Awards in Virginia last month.

This was the line that jolted me: "For all our pursuits to truly make a difference for the most urgent crises of our generation, of climate and race, I'd like to call on all leaders in this room to not only applaud the initiatives led by these change makers" — meaning the honorees — "but also to lean into the discomfort of what change truly entails," said Rikhi Roy, a graduate student at Georgia Tech and one of AvWeek's "20 Twenties" honorees.

The words "lean into" struck me hard. Baby boomers — and I include myself in this — have been known to throw up our hands at our generation's inability to shift society to clean energy and full equity. Those are now up to the next generation, we say. I've said as much to my college-age daughters. It took Roy's words for me to understand why my declaration did not sit well.

The problem with tossing up our hands is that baby boomers and Gen Xers do the hiring, set the research agendas, craft the integrated communications strategies and decide where the money goes. As brilliant as the "twenties" are, they can't change the world without us, and we can't finish our careers feeling good without them. We need each other. Forgetting that was the mistake of the 1960s, when the young weren't supposed to trust anyone over 30 and the elders looked down with suspicion. As Roy put it, change will require "all the crew of spaceship Earth."

So, I've taken down my hands. This magazine will continue digging into the issues related to the positive future that the next generation seeks to create in collaboration with all generations.

Of course, the weighty topics of sustainability and equity in the workforce will not be the only subjects we will cover. This issue of the magazine is a case in point. The world won't be saved by rescuing space travelers, capturing the first light of the universe or flying around the moon crewless, but I suspect you might find some articles useful in surprising ways. When someone tells you that this or that can't be done because of the cost, you will know that, taken together, the United States spent $47.7 billion on the James Webb Space Telescope, Space Launch System rocket, Orion capsule and ground equipment, an amount roughly equivalent to two years of NASA's entire budget.

Overall, a clean planet linked by affordable air and space transportation is a strong aspiration for all of us to work back from. ★

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

The real debris problem

The article, "Dodging Debris," by Paul Marks in the July/August issue of Aerospace America threw me a curve ball. With a title like that and two-page graphic of low-Earth orbit, I thought the article would be about the critical issue of orbital debris. I was wrong. The article was about the risk of aircraft hitting surviving orbital debris during flight. The article's introduction quotes safety engineers as saying, "a vigorous search for solutions is necessary, right now." Really? That hit me like writing an article about the risk of falling debris when your ocean liner is sinking.

For anyone paying attention, the real problem is a cascading series of satellites or orbital debris hitting existing and newly created debris in orbit, usually referred to as the Kessler Syndrome. Those calling attention to this acute issue include Moriba Jah on the pages of this magazine, as well as Hugh Lewis, Thomas Schildknecht and Jonathan McDowell. However, most people are not paying attention, and some choose to ignore it because "It's bad for business." Those calling attention to this issue recognize that it is a super-wicked problem: Time is running out, there is no central authority, those seeking to solve the problem are also causing it, and policies discount the future irrationality.

There are roughly 2,200 operational satellites in orbit, plus roughly 30,000 pieces of orbital debris larger than 10 centimeters. Once a major collision occurs, either by accident, gross negligence, or malicious intent, there is no return. With the resulting economic, national security, social and political chaos, I suspect that worldwide leadership will claim "plausible deniability." It's the in thing.

William Oberkampf
AIAA fellow
Georgetown, Texas
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Let us hear from you

Send letters of about 250 words to letters@aerospaceamerica.org. Letters may be edited for length and clarity and may be published in any medium.

A better focus

The September 2021 issue contains articles on three subjects — Mach 5 air travel, billionaires going to space and electric vertical takeoff and landing urban air mobility vehicles — that highlight how much the aerospace industry is built around the needs — or fantasies — of wealthy and uber-wealthy individuals. Our world is facing some critical challenges, including most importantly global climate change, and these challenges disproportionately impact low-income individuals around the world. The cover story on "Jet fuel from smokestacks" was encouraging in this regard. But we need to see more articles like this, focusing on how the aerospace industry is tackling critical issues that affect broad segments of the world's population and focus less on small niche applications of aerospace technology that only impact the 1% — or 0.001% — crowd.

Kyle K. Wetzel
AIAA associate fellow
Atascocita, Texas

The Outlook on the Next-Generation Aerospace Workforce is Bright

One of the most rewarding aspects of being involved with AIAA is meeting early and mid-career professionals and students. They are the future innovators and leaders of our industry. I have had the opportunity lately to meet with some of these young people in person. I am inspired by them, as well as challenged to ensure we are doing all we can across AIAA to embrace their ideas and energy. We are building the most technically, professionally, and culturally diverse space workforce pipeline on the planet.

We see AIAA members move through their career journey from aspiration to inspiration. Along the way, students are navigating the climb. As they become young professionals, we see them building the future. These phases on their journey give AIAA the opportunity to support them in the most meaningful ways.

Recently I had the chance to spend the day with an alumnus of the AIAA Diversity Scholars Program. What I heard from this young man – who is now working for a major employer in the aerospace industry – is how impactful the program was to him. He began building his professional network through his experience as an AIAA Diversity Scholar, which he continues to build during these early years of his career. He expressed a desire to pay it forward by serving as a mentor to a new AIAA high school member. The energy I felt from him – around learning from and sharing with others – feels electric. It is a special factor that I believe will make a difference in his career, and those like him.

We are looking forward to getting to know even more young people when we welcome the next class of AIAA Diversity Scholars to 2021 ASCEND in November and to 2022 AIAA SciTech Forum in January 2022.

AIAA also has announced a collaboration with the Aerospace Special Interest Group of the National Society of Black Engineers (NSBE Aerospace SIG) to increase diversity and inclusion in engineering and aerospace. We share a deep commitment with the NSBE Aerospace SIG to increase active participation by Black professionals in the engineering profession specifically, and the aerospace industry more broadly. This agreement is an important step in our daily efforts to increase the diversity of the aerospace workforce. There is a natural local connection for members of both groups to align on university campuses and in cities across the United States. AIAA members can find the NSBE chapter near them and take advantage of discounts on membership dues with NSBE, and access member rates for NSBE events.

I recently had the great pleasure of meeting with several members of NSBE, along with members of the AIAA University of Minnesota Student Branch and the AIAA Twin Cities Section. Again, I witnessed energy and enthusiasm to discover common interests between the groups and plan activities together for the future. I anticipate this model of local member gatherings, whether virtual or in person, will continue based on our new agreement.

Another AIAA initiative is with AstroAccess, a mission dedicated to advancing disability inclusion in space exploration, where we are providing technical expertise and guidance. AstroAccess selected and flew a crew of 12 ambassadors on a parabolic flight with the Zero Gravity Corporation (ZERO-G) in October. I have been following their mission with interest as they advance disability inclusion in space exploration for the benefit of humankind. AIAA is honored to help AstroAccess remove barriers to space as part of these disabled crew members' experience in microgravity – their mission photos showed faces filled with pure joy.

Through these different relationships, I'm reminded that our future aerospace workforce will be diverse. We all know that it will include diversity of race, gender, age, and other demographic factors. It will also include diversity of thought and diversity of physical abilities, inviting systems thinkers and those with interdisciplinary training and education all to be full contributors. Especially when thinking of our off-world future, aerospace workers will need several abilities and skills that will serve them well on Earth too. The history of our industry shows that diversity leads to innovation. Innovation will accelerate the future. Our young AIAA members are showing us how bright that future is – shaping the future of aerospace together. ★

Dan Dumbacher
AIAA Executive Director

The AIAA Diversity Scholars Program seeks to provide opportunities for underrepresented university students who have an interest in or are pursuing a degree in aerospace to attend an AIAA forum or event. During their immersive event experience, Diversity Scholars learn about professional opportunities available to them in industry; meet with thought leaders from government, business, and academia; and take full advantage of the expansive technical program as guests of AIAA.

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

Escaping the Bermuda Triangle

Q The stretch version of a passenger jet has made an emergency landing in the Bermuda Triangle. The cockpit crew has vanished along with all the plane's paperwork, including the weight and balance manual. As luck would have it, also on this small island are 27 ageless U.S. Navy flyers who disappeared in 1945. There are enough seats for them, but they must figure out how to fly the jet, starting with the takeoff. Over a spotty radio connection, one of the flyers tells the manufacturer that the runway looks short but he thinks he can still get the nose up in time. Amid the static, he hears the words "don't forget your angle of —" and then the connection ends. The pilot looks out at the jet and to an old bulldozer near the runway. He runs out and instructs the other flyers to help him dig a trough in the center of the runway toward the far end. Why?

Draft a response of no more than 250 words and email it by noon Eastern Nov. 15 to aeropuzzler@aiaa.org for a chance to have it published in the December issue.

FROM THE OCTOBER ISSUE

COSMOLOGICAL REDSHIFT: We asked you to explain the Doppler effect's link to what the James Webb Space Telescope will detect in the infrared.

WINNER: When the first stars and galaxies began to form, there was a lot of heat and light. This light is still in space traveling in waves just like sound waves. However, the longer these waves are in space, the longer the waves become. This is because space is forever expanding and the light coming from these initial formations continues to stretch. The longer these waves of light travel, the more stretched they become. This is known as astronomical redshift. The light created millions of years ago from the birth of stars and galaxies would be so stretched now that it is in the infrared spectrum. This expansion of light waves as a result of the expansion of space is known as redshift. It is actually an example of the Doppler effect. Doppler shifting occurs from the relative motion of a source of movement and an observer. For instance, a train coming toward a stationary person. As the train approaches, the sound waves get closer and closer together and then the reverse happens as it moves past the observer. Astronomical redshifts differ in that they occur due to the expansion of space itself even though the objects themselves can be stationary. Wavelengths from the formation of stars and galaxies are very far apart because they have been in space for a long time.

Linda Nowicki of New Port Richey, Florida, volunteers as an education ambassador for ARISS, Amateur Radio on the International Space Station.

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

Volocopter

Earning public acceptance

If seeing is believing, the couple of hundred people in the image above may now be believers of Volocopter's plans to begin ferrying cargo over European cities via a fleet of electric-powered drones.

The Germany-based company's inaugural public flight of its VoloDrone design at the Intelligent Transport Systems World Congress in October was the first of several demonstrations Volocopter plans to conduct over the next year ahead of a planned entry into service in late 2022.

The company aims to showcase "relevant applications" for the VoloDrone design, says Volocopter CEO Florian Reuter. The October flight, conducted near the Port of Hamburg in Germany, illustrated how VoloDrones could quickly ferry goods between ships in different parts of ports: During the three-minute flight, a VoloDrone loaded with 200 kilograms of boxes on a wooden pallet took off, its 18 rotors propelling the aircraft to a maximum altitude of 22 meters before returning for a gentle landing.

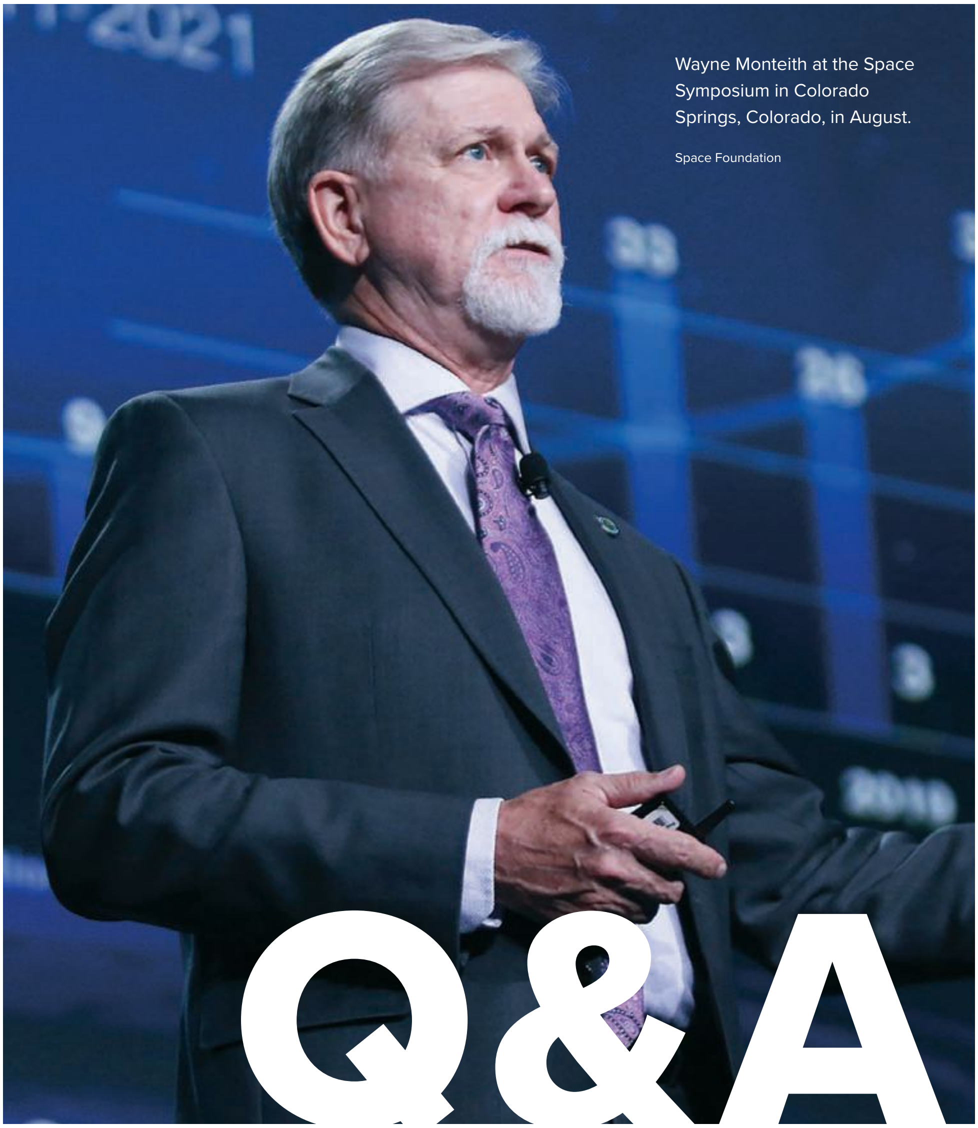
Future VoloDrones could follow a similar flight path to "bring in a pallet from one side of a channel in the port to the other," Reuter says.

The crowd of observers for the October flight illustrates the second objective of Volocopter's demonstrations: "to really create public acceptance" by familiarizing people with the sight and sound of electric-powered aircraft passing overhead, Reuter says, because if all goes as planned, the company's cargo drones won't be its only product. Volocopter is targeting 2024 for its VoloCity air taxis to begin passenger transport in Paris and Singapore.

And while city planners and government agencies are conducting ongoing studies about the noise generated by the electric aircraft in development by Volocopter and its competitors, for his part, Reuter doesn't expect complaints.

The 18 rotors on the VoloDrone and VoloCity designs generate a buzzing "no louder than a car passing by," he says. "Even at takeoff and landing, this would blend into the existing noise landscape that you have in the bigger metro areas." ★

— *Cat Hofacker*



Wayne Monteith at the Space Symposium in Colorado Springs, Colorado, in August.

Space Foundation

Space safety regulator

When passengers reach space inside privately owned and operated spacecraft, they do so backed by U.S. government launch licenses that do not include a safety blessing from regulators. A Congress-imposed moratorium, or learning period, prevents FAA's Office of Commercial Space Transportation that Wayne Monteith leads from regulating suborbital and orbital human spaceflights until late 2023, but the increasing number of tourism jaunts similar to the one William Shatner and three others took last month aboard a Blue Origin capsule could make the case for ending the learning period much sooner. I spoke with Monteith via Zoom about whether the U.S. can afford to wait. — *Cat Hofacker*

More online aerospace america.aiaa.org

WAYNE MONTEITH

POSITIONS: Since 2019, head of FAA's Office of Commercial Space Transportation, or AST, its designation within the U.S. Transportation Department, where he oversees a 117-person office that licenses commercial space launches. 2015-2018, commander of the 45th Space Wing of the U.S. Air Force (now Space Launch Delta 45 under the U.S. Space Force) at what is now Patrick Space Force Base in Florida. 2009-2011, commander of the Air Force's 50th Space Wing at what is now Schriever Space Force Base in Colorado. 2007-2008, director of navigation warfare in the Office of the Secretary of Defense overseeing GPS and related programs.

NOTABLE: At AST, has overseen a quarter of the 417 launch licenses granted since the division's creation in 1984, including the first FAA license of a crewed mission to orbit in November 2020 when four NASA astronauts were launched aboard a SpaceX Crew Dragon to the International Space Station. During his three years leading the 45th Space Wing, granted final approval for 66 launches and 23 booster landings from what is now Cape Canaveral Space Force Station in Florida. Retired from the Air Force in 2018 with the rank of brigadier general.

AGE: 61

RESIDES: Alexandria, Virginia

EDUCATION: Master of Science in national resource strategy, Eisenhower School for National Security and Resource Strategy in Washington, D.C., 2007; Master of Science in business administration and general management, Lesley University in Massachusetts, 1994; Bachelor of Science in geography, University of New Mexico, 1989; Associate of Science in computer programming, University of New Mexico, 1987.

Q: FAA's definition of a "commercial space vehicle" doesn't account for whether these company-owned and operated rockets and capsules get government funding. Should it?

A: For us, essentially if it's not government then it's commercial. If you look through the manifest, you'll see that the way we're transitioning is there are even government payloads that are contracted on commercial rockets that we do regulate. When I started out in the rocket business, that never happened. When the government has much more oversight of the rocket manufacturing, there's a sense that you can control the manufacturing process, you can control the reliability of the vehicle. But over the course of decades we've shown that that's not always the case. One of the things that government has to be careful of is they want to buy COTS, commercial off-the-shelf products. That's great because then theoretically you've got all of the development and a lot of the nonrecurring engineering costs done upfront by the company. If you come in, though, and now you dictate what that COTS product should look like, it's no longer COTS. You can't say, "I want to buy this widget, but this widget has to be blue; it's got to be 4 centimeters on each side; it's got to weigh a certain amount or produce a certain amount of energy." What we're seeing is a greater acceptance on the government side to actually use COTS-type products — for instance, Falcon 9. The Department of Defense and NASA both contract with SpaceX to get payloads to orbit without additional requirements on those rockets.

Q: There's now a growing number of tourist flights aboard privately owned and operated vehicles that AST is not permitted to regulate for passenger safety. Should the moratorium be lifted before 2023?

A: Number one for us at AST, it's all about safety. FAA is a safety organization, so to the extent that we're allowed to regulate something, we're going to do it very well. From that perspective, when you go back to when the office was given the statutory authority to regulate the space tourism industry, Congress immediately put in the learning period, or what we call a moratorium, back in 2004. At the time, because it was a nascent industry without a whole lot of activity there, that made a certain amount of sense. Here we are 17 years later, and it's probably time to start asking ourselves, "What are we still hoping to learn?" NASA has been flying humans for 60 years, and we've got three U.S. companies right now flying nongovernment astronauts. On the other side of the coin, we've got to ask, "How much longer are we willing to accept as a nation this level of risk?" The risk is that a significant portion of the flight envelope is not regulated by AST from a personal safety perspective. What helps me most is clarity, so will the moratorium sunset on 1 October of 2023 or not? If it's going to sunset on that date, that gives me time to start working on the next iteration of regulation, hire enough people, to get fully engaged. But what will be unhelpful is if we don't know what the status of that moratorium will be until we get deep into 2023. Bottom line: If it sunsets, great; if it doesn't sunset, fine. We'll continue to operate like we do today.

Q: By not ending the moratorium early, it seems like there's a significant risk that these tourist flights won't result in a serious injury or loss of life.

A: So as I look into my cloudy crystal ball, I see one of four things that would drive a change in the current regulatory construct and potentially drive the learning period to be sunset. Number one is sheer cadence: Is it 50 launches a year? One hundred launches a year? There's probably a magic number out there at which folks would no longer be comfortable if we exceeded that and we didn't have more regulatory certainty. That could come either from government or could come from industry or could come from paying passengers. Number two is number of providers. The launch companies we deal with today we know are safe, but that doesn't guarantee all future companies will be. The third driver is the sense of the people going up, the passengers: Am I going to pay this amount of money — fill in the blank depending on which company you fly — without a guarantee that I'm

> "Here we are 17 years later, and it's probably time to start asking ourselves, 'What are we still hoping to learn?'"

▲ SpaceX's Crew Dragon Resilience splashes down in the Atlantic Ocean in September with the four passengers of the Inspiration4 mission. Monteith cites the 72-hour-flight as an example of how the Congress-imposed learning period limits FAA's authority: The agency licensed the launch and landing, but "the 69 hours in the middle were unregulated," says Monteith.

Inspiration4

actually going to arrive safely? When you get on an airplane, you don't think about arriving safely to your destination; you just assume you will because the safety is regulated. And then the fourth driver is what you alluded to, a catastrophic failure. So the way we're set up right now, I don't regulate the design of the spacecraft, but if we have a catastrophic failure [in space or on the ground], we do have the ability within statute to go in and look at that and recommend direct design changes post an anomaly, or what we call a near miss. But short of that, I can tell you that we have validated that the space vehicle will operate in the environment that it's designed to operate in; I can tell you that your family on the ground will be safe; but I can't certify your safety as a passenger. We do not certify these spacecraft like we do in the aviation industry.

Q: Using the investigation into Virgin Galactic's airspace violation during the July flight as an example, how does this limitation of authority affect the information AST has access to during investigations?

A: We have full and open access to all information that's available to the company. When a mishap investigation is initiated, we oversee the investigation, depending on what the nature of the mishap is. We oversee all facets of the information, and if we do not believe that the company has looked at the right material or provided the right data to us, we simply ask for more. Our FAA inspectors sit in on these meetings; they sit on all the technical interchange; they sit in on the anomaly analysis meetings. I personally review the reports that come in and keep updated on these things as they progress. But it's also important to keep in mind that what we're looking for are things that impact public safety. We're not directly looking for things that lead to what we call mission assurance or mission success — so if there is a mishap and the rocket is lost, as long as it failed safely, that's OK.

Q: In other words, you're looking to make sure the rocket didn't rain down debris on a kindergarten school, not that it delivered its payload to orbit.

A: Right. So from a public safety perspective, if it fails safely then we can actually clear the company to start operating again even before they're done with the full investigation of what may have led to, say, a satellite incorrectly deploying. All of our focus right now is on safety, not on making sure that the

mission went the way it was supposed to. That would put me in the business of helping business make more business, and that's not what we're here for. I'm a safety regulator.

Q: But because that moratorium limits the safety regulations AST is allowed to make, are you concerned that undermines your authority with these companies?

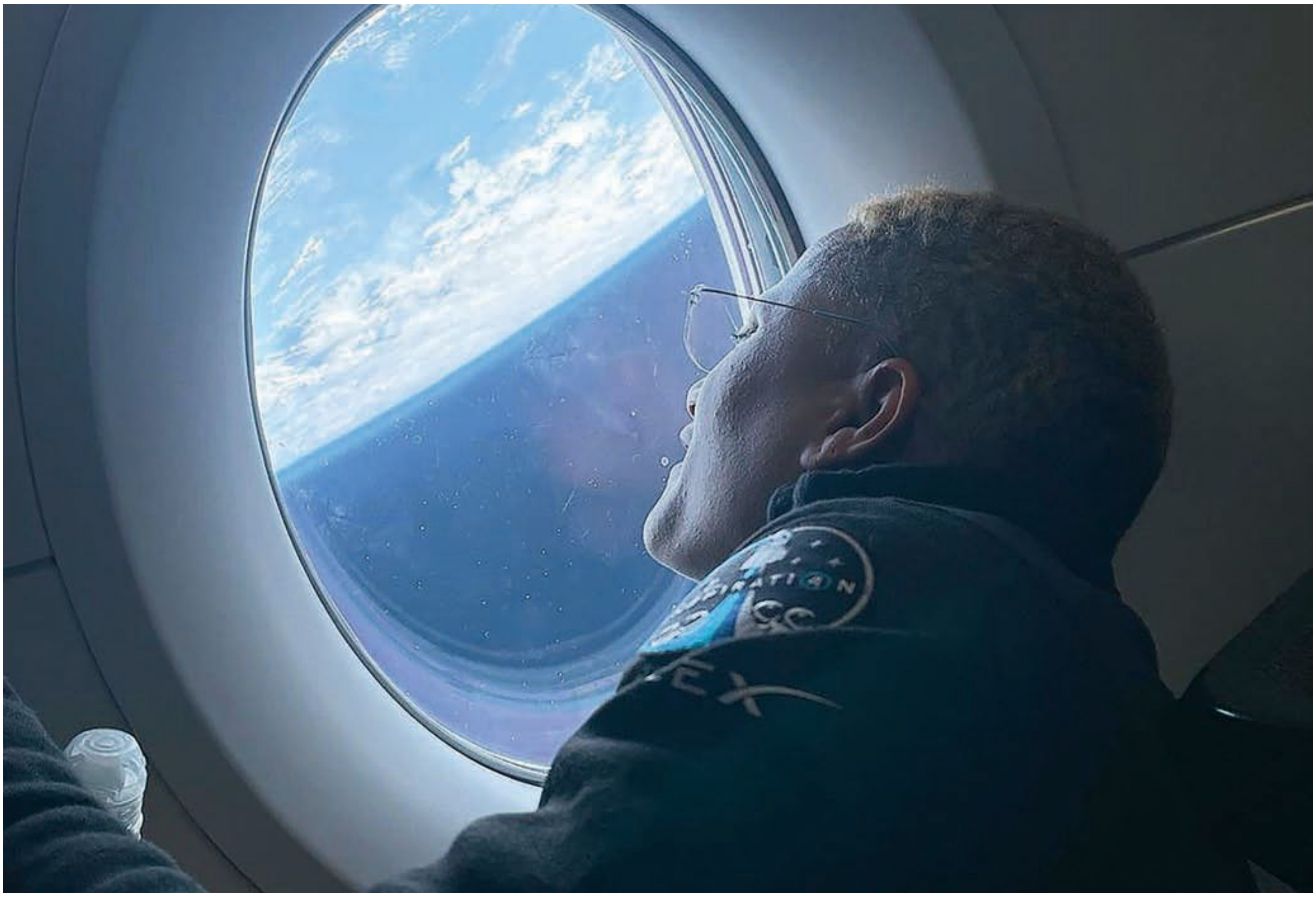
A: Not at all. Number one, we have a tremendous working relationship with these companies. Number two, they clearly understand our role. And number three, at the end of the day, if a company is not abiding by the terms of their license — in this case we'll talk a launch license — we can either send them a strongly worded memo, depending on what the level of their violation is we can potentially fine them, we can suspend their license, which means they can't operate, or we can revoke their license, which means they can't fly at all. And so they clearly understand that they need to meet the regulatory requirements. As I mentioned earlier, they're not unsafe companies; there is no business case to be made for being an unsafe company in this business and continually blowing things up or dropping a rocket on a neighborhood. They want to be successful. Even though we don't regulate the safety of the humans on board directly, we do monitor all facets of the mission. In the case of Virgin Galactic, we did a thorough oversight because it involved an airspace violation. We were able to leverage other agencies within the FAA, principally our Flight Standards Organization and our Air Traffic Organization. The three of us working together looked at all the events that surrounded that violation to determine what happened and how to prevent it from happening again.

Q: So when the moratorium does expire, what's the end goal for regulating the space tourism and commercial space industries at large? Some equivalent to FAA aircraft certification?

A: You can have a couple of assumptions — one assumption could be you're very similar to aviation and you're to look at everything: You're going to look at environmental systems, you can look at people. There's a tremendous spectrum that you could look through to regulate the safety of the people on board. It could be a much lighter touch too. A lot of that will be driven by Congress and what actually goes into the statute. As far as certifying vehicles, that is one of the things that we're looking at being more aviation-like. That will also depend, though, on cadence. Right now,

▲ Actor William Shatner climbs out of Blue Origin's RSS First Step capsule that took him and three others to the fringes of space and back last month in Blue Origin's second flight with people aboard. A Congress-imposed moratorium prevents FAA's Office of Commercial Space Transportation from making regulations about the capsule's design to ensure the safety of passengers.

Blue Origin



▲ Inspiration4 passenger Sian Proctor gazes out one of the four windows on SpaceX's Crew Dragon Resilience. FAA's Office of Commercial Space Transportation was responsible for overseeing Inspiration4's launch and landing, or about three hours of the 72-hour flight.

Inspiration4

we license vehicles and we license operations as opposed to certifying vehicles, which works really well right now because of the low cadence. I talked about at what point do you get so many flights that it makes sense — the certification process is sort of the same thing. Let's say Virgin is flying 200 times a year. At that point, does it make more sense to certify that vehicle, or does it make more sense to stay on the path that we're on, licensing the operation? We'd have to look at the pros and cons of that and do what makes the most sense, from both a regulatory perspective and an industry perspective. And it might be different for different companies based on how they operate. One of the things that we have done earlier this year is our new Part 450, the Streamlined Launching and Reentry Licensing Requirements. That took us from a prescriptive approach to regulation — where not only did we tell you what the requirement was, we told you how to meet the requirement — to a performance-based model where we tell you what the requirement is and it's up to you to tell us how you're going to meet that requirement. What that does is it enhances safety, but what it really does is open up the aperture for innovation; it allows U.S. companies to continue to lead the world in the sector while not reducing safety. On the flip side, it also puts an additional burden on my organization because now we've got to figure out whether or not these proposals actually meet the safety requirements. It's quite a different mindset for my team, and so we're still working through that, but at the end of the day, we've got to approve their solution. That lays the foundation of how we'd like to look going forward, because one of the concerns industry has is that AST will promulgate regulations on human safety that will cover a wide range of vehicles. Well, we do that today. Our new Part 450 regulation can handle Virgin Galactic, Virgin Orbit, Blue Origin, United Launch Alliance, Rocket Lab, SpaceX, Relativity Space, Aevum. All of these different companies can be handled under this new regulatory construct or framework, and we would look to develop human spaceflight standards the same way: performance-based enough that we accomplish the safety goal without limiting their ability to innovate.

Q: It seems the aircraft certification analogy only goes so far because there are some big differences in terms of the envisioned flight cadence, for instance.

A: Yes, the scale is quite a bit different. If you look at the National Airspace System in 2019, there were almost 10.4 million flights within the aviation industry. Compare that to about 30 rocket flights. The other thing that I think is important to keep in mind is that in aviation, you don't have a single large company designing, manufacturing, maintaining and operating a vehicle like we see on the commercial space side. The rules are set up differently for the different aspects of aviation safety, whereas in my industry it's all within the same company. In the space industry, almost everything is being done in house, and so it really lends itself to a different regulatory approach.

Q: Can you elaborate on the planning AST is doing now so it's ready to lay out new regulations in 2023 once the moratorium expires?

A: What I want to do is make sure my organization is prepared so that we aren't the limiting factor in the ability for Congress to make a decision to sunset that moratorium. The foundation for future rule-making will be the best practices and the guidelines for crew safety that we started in 2014. We continue to work with particularly NASA on making sure these things are up to date, but the next big step will be standing up the Aerospace Rulemaking Committee. As we stand up this organization, we'll start bringing folks together from industry to discuss how we are going to be doing this and what makes the most sense. My experience doing Part 450 was that the approach that suboptimizes the outcome is trying to do this all too quickly. It was a herculean job getting Part 450 promulgated. Start to finish, it was about 2½ years when normally it would take about seven years, and so what you had to sacrifice was a lot of the upfront work and the interaction with industry. I want to avoid both of those with human safety rules. I want the time to do this right, and I want the time to work closely with industry to get this as right as possible. So we're already talking to our industry operators on how this would look; we're looking internally at how we do this from a performance-based perspective so that we can handle the different operating concepts, from suborbital to orbital — and potentially, cislunar at some point when these craft go around the moon. One of the things that I find fascinating with the current construct is if you look at the Inspiration4 mission from a regulator's perspective is that it was about a 72-hour flight, but I was only responsible for about the first 12½ minutes as the capsule traveled to orbit, and then I was responsible for about the last three hours as it prepared for landing. The 69 hours in the middle were unregulated. Now, is that good, is that bad? That's for Congress to decide, but there are a lot of things that can go on in those 69 hours, and some things could go on that do not have a good outcome.

Q: As launch rates increase, how do you balance the need to grow the office while staying agile enough to keep pace with the industry?

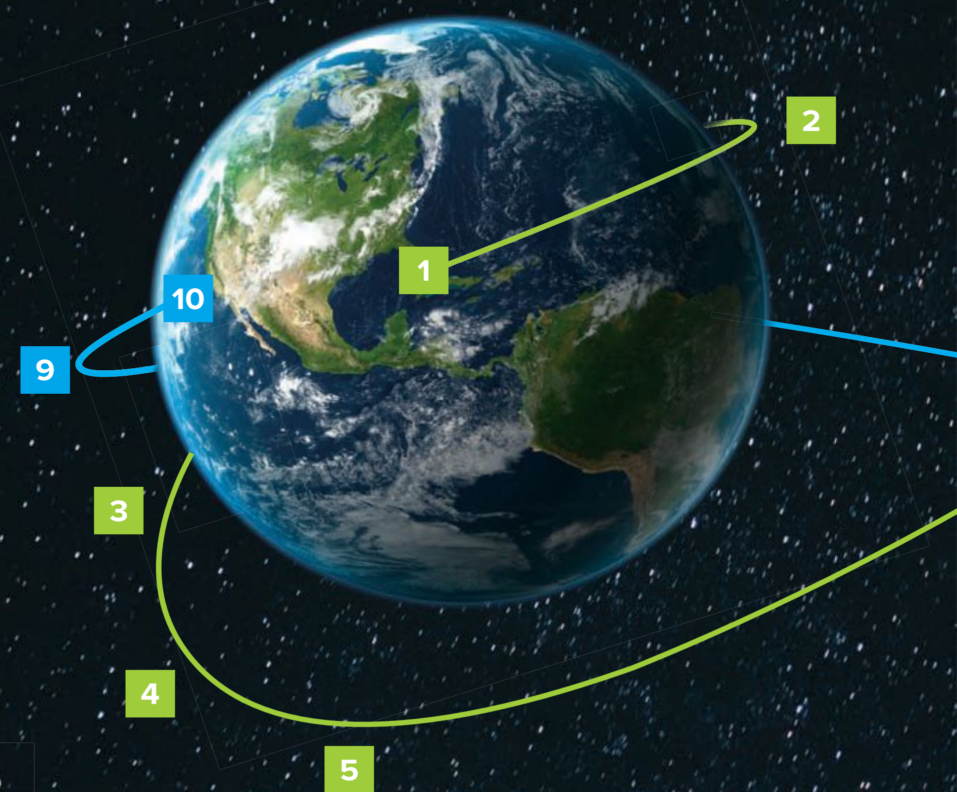
A: In the last three years, we averaged about 30 launches a year with 108 people. This year, fiscal 2021, we closed out at 59 launches with 117 people. That's almost a 100% increase in work with a 9% increase in personnel. I joined AST in January 2019 after I retired from the Air Force, and I started during a government shutdown, so I had a lot of time to think. So we did a major reorganization of the office; we aligned like functions, we brought more accountability and responsibility within the organization, and we set up a construct that could scale. We essentially got all the right people in the right boxes. Then we looked at all of our internal processes. When we're licensing one or two launches a year or a month, you can be pretty darn inefficient and it doesn't show up, necessarily. When you're doing a license launch about every five days, it shows up real quickly if you're not efficient and effective at what you do. We addressed that by taking a look at all of our processes, where we were losing time, and we continue to look at that. That's how we've been able to keep up without a tremendous increase in staff so far. And now that we've got this construct set up, I can look forward and go, "OK, if we double again, how does that impact operations?" We're also doing things like starting the process to move to electronic licensing. You would think in the 21st century, we would have something like that now, but when I showed up, we were still accepting a lot of paper products and faxes. So you have to change all of these things, and you have to get folks not just externally, but especially internally, to embrace change so that we can prepare for the future, we can maintain our safety posture but not become irrelevant. The worst thing we can do is throttle industry because we haven't looked forward.

Q: Looking to the future, if this explosive growth of launch and space tourism comes true, could it be necessary to move AST out of FAA and make it its own office under the Department of Transportation, as it was originally?

A: There's a possibility of that, but it'll be decided way above my level. Depending on how the industry develops, I think there's some sense that if you can make a business case out of the space tourism part, then the next logical step may very well be suborbital point-to-point travel. If you can go from New York to Sydney in half an hour, that might not be bad. The industry will drive a lot of this, but eventually there may be a need to fully recognize this as a separate mode of transportation. Right now the Department of Transportation is set up under different modes: You have highways, you have rail, you have maritime, you have aviation. While AST is part of aviation right now under FAA, there may come a point in the future where it makes sense to designate space as a separate transportation mode within DoT. But I don't see that happening immediately. ★

LUNAR REHEARSAL: YOUR MISSION GUIDE TO ARTEMIS I

NASA will conduct an uncrewed lunar practice run to test its Space Launch System rocket before it carries astronauts. This upcoming mission, Artemis I, will be a precursor to a similar crewed flight to be followed by a lunar landing targeted for 2024. Pull out this guide and refer to it as Artemis I unfolds.



LIFTOFF

LAUNCH +0

1 A NASA Space Launch System rocket blasts off from Kennedy Space Center, Florida, in the design's inaugural launch, from Launch Complex 39B, notable as the pad for the Apollo 10 "dress rehearsal" for the 1969 moon landing. Three minutes after liftoff, Orion capsule jettisons its launch abort rockets and protective shroud.

CORE SEPARATION

+8 MINS

2 SLS core stage separates at 161 kilometers for disposal into the Atlantic Ocean, while upper stage, service module and Orion capsule continue climbing.

SOLAR ARRAYS OUT

+16 MINS

3 Orion service module deploys four solar arrays.

INJECTION BURN

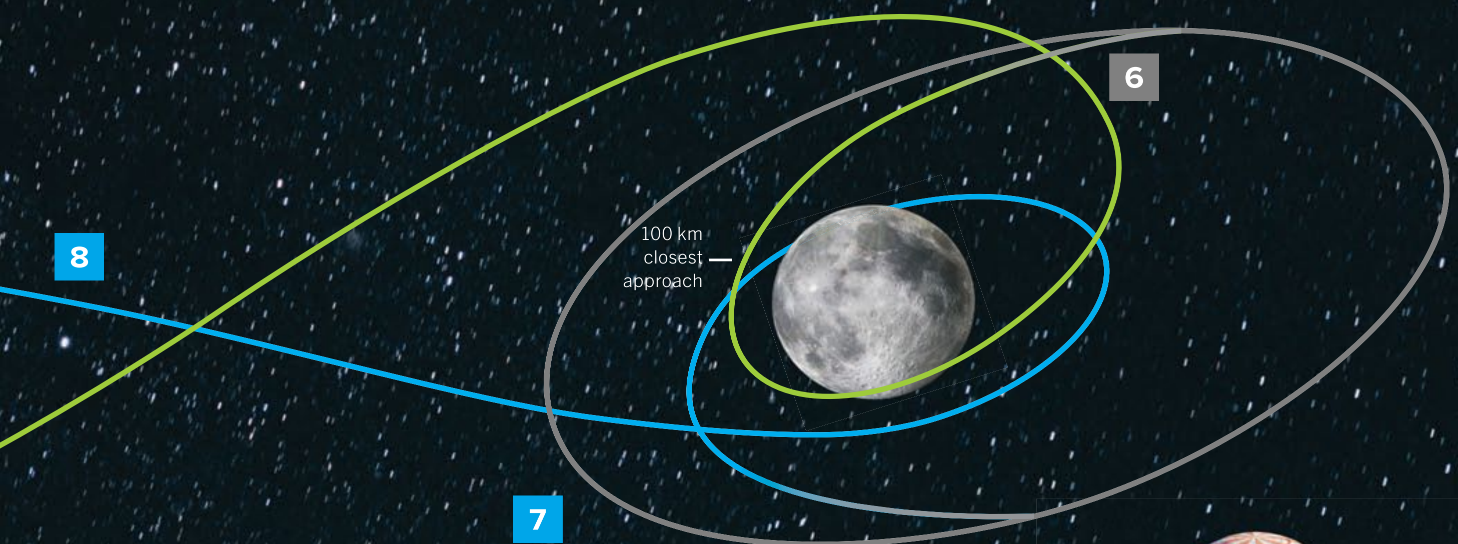
+1.5 HRS

4 Upper stage (Interim Cryogenic Propulsion Stage) fires its RL-10 engine for 20 minutes in a 110-kilonewton translunar injection burn, setting Orion on a lunar trajectory.

UPPER STAGE DISPOSAL

+2 HRS

5 Upper stage separates from Orion crew and service modules, which continue toward the moon. Ten cubesats spring free from the adapter attached to the stage, which fires its engine for a final time to send it into an orbit around the sun.



MISSION TIME 26 OR 42 DAYS

CHOICE DEPENDS ON POSITION OF
EARTH AND MOON AT LAUNCH

ORBITAL PHASE

DAYS 5-16 (SHORT)

DAYS 5-24 (LONG)

6 Orion's service module fires its main engine in a 26-kilonewton burn that slows capsule for capture into a distant retrograde orbit. Orion spends 7 or 16 days traveling about 70,000 kilometers beyond the moon, orbiting in an opposite direction to how the moon orbits Earth.

RETURN TO EARTH

DAYS 16-19 (SHORT)

DAYS 24-32 (LONG)

7 Orion service module fires main engine to leave distant retrograde orbit, then again on lunar approach to accelerate Orion for a slingshot around moon and back toward Earth.

SERVICE MODULE SEP

DAY 25 (SHORT)

DAY 42 (LONG)

8 After a 6 or 10-day transit, during which Orion's service module fires main engine as needed to adjust course, service module jettisons from crew capsule and later burns up in the atmosphere.

REENTRY

DAY 25 (SHORT)

DAY 42 (LONG)

9 Orion crew capsule plunges into atmosphere, its heat shield protecting it against temperatures of about 2,700 degrees Celsius.

SPLASHDOWN

DAY 25 (SHORT)

DAY 42 (LONG)

10 Orion capsule releases 11 parachutes in succession to slow itself before it splashes into the Pacific Ocean, as most Apollo capsules did.

Preventing a bad day for SLS

High up the stack of NASA's first Space Launch System rocket is a component that will play a critical role in proving the rocket's safety during the upcoming Artemis I mission. This is its story as told by Keith Button.

▲ Technicians with Janicki Industries of Washington state piece together the composite layers of a dish-shaped barrier that must prevent propellant gases from collecting near the Orion capsule atop a Space Launch System rocket, posing an explosion hazard.

Janicki Industries

BY KEITH BUTTON | buttonkeith@gmail.com

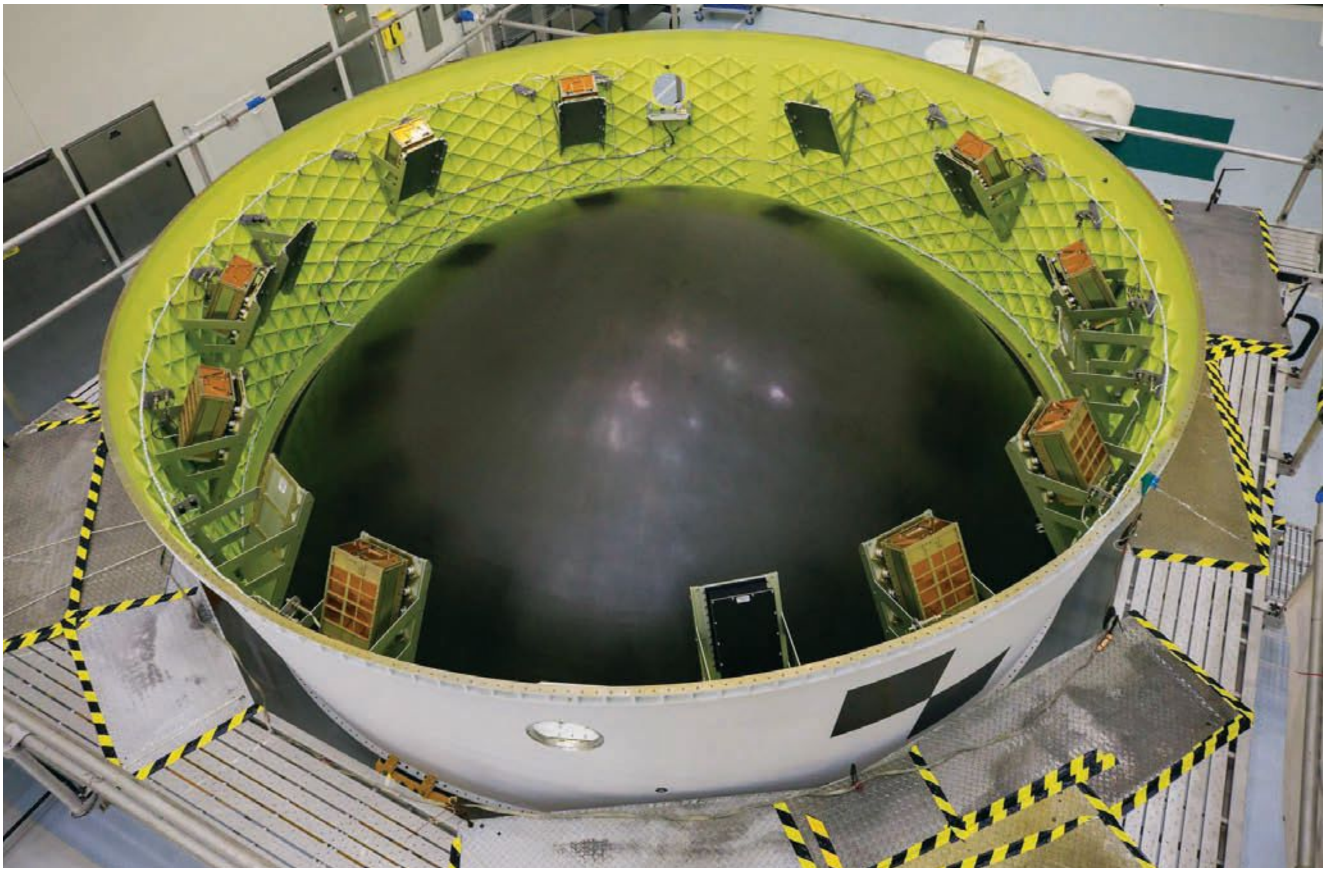
Engineers at NASA's Langley Research Center in Virginia received a challenging assignment in 2011: Design a barrier to keep propellant gases from accumulating near Orion astronauts before and during their ride atop a Space Launch System rocket.

Now, a decade later, an updated version of this Langley design is poised to be demonstrated on an SLS rocket for the first time in the uncrewed Artemis I mission scheduled for February 2022. Once NASA begins crewed Artemis flights, the barrier's role will be one of life and death, and its development story is fittingly complex given those stakes.

The story begins with the hydrogen and oxygen propellant gases that, as with other rockets, must be vented off SLS on the launch pad and during the first seconds of liftoff. This venting avoids overpressurization of the propellant tanks in the core and upper stages given that some of the propellant inside them inevitably warms and turns to gas.

Without a barrier above the upper stage, called the Interim Cryogenic Propulsion Stage, any gas from below that was not vented off board could leak into the sections above. Those sections are the Orion Stage Adapter cylinder that joins the core and upper stages to the Orion service module and Orion crew spacecraft. Even separately, oxygen or hydrogen gases present a fire or explosion hazard, but if they mix together they're a particularly combustible brew.

The dome-shaped barrier — known as the Orion Stage Adapter diaphragm — creates a space within the adapter that will be purged of gases by blowing nitrogen gas into it. Were it not for this purging, in essence, "You're making fuel there, and you don't want that in a closed space like the adapter," says Robert Parker, who headed the



Langley team that designed the first version of the barrier. "It's like carrying a can of gas in your trunk: It's not going to start a fire by itself, but you get all those vapors in your trunk, that's a bomb waiting to happen."

Confident in the design

Engineers at NASA's Marshall Space Flight Center in Alabama who adopted the project in 2013 stuck largely to the design crafted at Langley and tested in 2014 during the uncrewed Exploration Flight Test-1 mission in which a Delta IV rocket sent an Orion spacecraft up for two orbits of Earth culminating in a splashdown off the California coast.

They knew that some strengthening would be required to launch the diaphragm on SLS with its 8.8 million pounds of thrust compared to 2.1 million pounds for the Delta IV.

But the 2014 launch left them confident in the basic design begun three years earlier at Langley. At that time, the Langley team's orders from the Spacecraft Payload Integration and Evolution Office at Marshall were to create a vapor barrier to trap gases in a void above the interim stage that could be purged. Initially, Parker and his team weren't told the dimensions or weight requirement for what would become the diaphragm, but they knew the basic shape would probably be similar to the dome structures that had served a similar function on United Launch Alliance rockets.

The team came up with 11 options for the diaphragm, including a welded metal structure, an inflatable barrier, metal structures shaped by bending and riveting, stamped metal, spun metal, structures made from other metal fabrication methods and a carbon-fiber composite structure. The inflatable option was ruled out because the structure would have to be rigid to withstand a pressure differential between the Orion Stage Adapter and the section above it.

Not long after they made this list, word came down from the Marshall payload office that the barrier would need to weigh no more than 180 kilograms. That ruled out the metal options, the lightest of which weighed 340 kilograms. That left only one option: the composite structure, and this became the material for the diaphragm.

They were also given instructions about the geometry for the barrier. It had to be 5 meters in diameter to fit over the cryogenic tank that rides below the stage adapter. So they decided a dome design, and one that is the largest government-furnished composite structure ever on a NASA spacecraft, according to Parker.

The next step was to choose the specific composite material. Some composites had properties that matched those they needed for the diaphragm, such

▲ The black dome is a protective diaphragm inside the Orion Stage Adapter. Both are now on the Space Launch System rocket that's being readied for the Artemis I mission, the SLS debut from Kennedy Space Center in Florida. Some of the 10 cubesats that will be released are visible along the periphery of the adapter.

NASA

Barrier against explosive gases

The Orion Stage Adapter with its internal diaphragm will ride on top of the Interim Cryogen Propulsion Stage and beneath the Orion Multi-purpose Crew Vehicle on the first Space Launch System rocket.

NASA

as adequate tensile and shear strengths over the required temperature range.

But the problem with these well-understood composites was that they either required a long lead time for ordering, because they were in high demand for military projects, or a large autoclave for curing, and the engineers weren't sure they could access one.

As an alternative, the team chose NB321, a composite that was readily available and due to its use in aircraft had well-established properties at temperatures close to what the engineers needed for the diaphragm. But they had to test the material to make sure it would be reliably strong enough at the lower temperatures.

Material testing

To make samples of the composite for testing, the engineers laid out the woven carbon fiber — pre-impregnated with resin — in layers, placed the material in plastic bags with ports to vacuum the air out and heated the material to cure it in ovens at Langley. They repeated the process to make sure their testing results were consistent through several bagging and baking sequences, and through more than one purchase of the material from the supplier.

For strength testing, they bent cured samples by placing cylinders of metal spaced at certain points below and on top of the sample, then compressed the sample to see if it would shear. For tensile strength testing, they clamped the sides of a sample and pulled to see if it would pull apart.

To determine if the fibers and the resin had melded together properly, the engineers cut and polished samples and examined them under a microscope, looking for voids in the microstructure. They also sent out samples for chemical analysis to see if the fibers and resin had meshed properly during the curing process.

In addition to strength testing, Parker and his team tested the composite for how much it expanded or contracted at different temperatures. These thermal characteristics were important because the metal ring that the diaphragm would be bolted to in the stage adapter would also expand and contract with temperature changes. The engineers had to factor into their design the structural stress caused by these differences in expansion and contraction rates.

With the strength and thermal testing results in hand, the engineers knew how many layers of the composite they would need at the areas of the diaphragm that required the most strength. Where the structure required the most strength — along the bottom ring where it bolts to the stage adapter — their design called for 35 layers; where it needed the least strength, at the top of the dome, only 19 layers.

Under pressure

The team calculated that the biggest structural stress the diaphragm could face would be a pressure differential that increases as the launch vehicle rapidly gains altitude, Parkers says. As the atmospheric

> "It's like carrying a can of gas in your trunk: It's not going to start a fire by itself, but you get all those vapors in your trunk, that's a bomb waiting to happen."
>
> — Robert Parker, NASA

pressure drops, each section of the rocket — except for the pressurized crew module — must let the air inside escape to the outside to prevent internal pressure from building up. However, if the sections above and below the diaphragm vent at different rates, then the barrier could experience structural stress.

With the design ready, NASA contracted the composites engineering firm, Janicki Industries in Hamilton, Washington, to construct the diaphragm for EFT-1.

A hurdle was the lack of prototype to run past the breaking point in ground testing.

"Ideally you're building prototypes and then you're testing with huge loads," Parker says. His team would have to test EFT-1 flight hardware with a smaller, but adequate, load number.

To find the right number, they calculated the largest potential air pressure differential that the diaphragm could experience due to the large volume of air space inside the rocket above the diaphragm and the small volume of air space below it. To provide a safe margin, they calculated that they should test to 1.2 times this maximum. They sent the diaphragm to Marshall, where the stage adapter was being assembled for EFT-1. Technicians sealed the diaphragm's bottom ring onto a floor and vacuumed out air until the pressure difference was 1.2 times the maximum. They monitored the walls of the diaphragm with strain gauges to check for buckling potential, and the structure held up.

As planned, the diaphragm that Parker and his team designed was launched with Exploration Flight Test-1 and burned up with the stage adapter as it reentered the atmosphere. After the flight, engineers confirmed from instrumentation data taken near the diaphragm that it performed as expected.

Tweaking the design

With the basic design proven, next came the effort by engineers at Marshall to strengthen the version for Artemis I, the SLS debut launch.

The Marshall team added more layers of composite material to the diaphragm design, but they discovered an issue that they thought might call for a more extensive design overhaul.

To maximize the strength of a composite material, typically the directions of the swaths of woven carbon fiber are at 90 and 45 degrees to each other as the layers are stacked in a layout, before curing. But as the Marshall engineers were building the diaphragm for Artemis I, they discovered that the 90- and 45-degree angling method was thrown off because of the dome shape, especially along the walls of the dome, which would make the structure weaker than what its designers had predicted with a consistent 90-45 layout method.

"We were partway through the build before we stumbled upon this issue," says Allyson Thomas, who led Marshall's 2013 design team for the diaphragm. Thomas and her team considered cutting smaller pieces of the woven carbon fiber for the layout, which could have adhered better to a 90- and 45-degree layout pattern. But they decided against it because smaller pieces would have introduced other problems, such as more joints in the structure, creating points of weakness.

After updating their computer models to revise their analysis of the "as-built" diaphragm without the consistent 90-45 layout pattern, the engineers found that the structure was strong enough where it needed to be, says Thomas, who is now deputy lead for the section of the rocket between the Orion spacecraft and the core stage. They made no changes beyond adding more layers.

NASA was confident enough in Parker's Orion-related work, including the initial design of the diaphragm, to present him with a Silver Snoopy Award for going above a normal day's work to "ensure flight safety." The agency is counting on the diaphragm to perform just as well on Artemis I as it did on EFT-1.★

TECHNICAL DISCIPLINE HIGHLIGHTS

- **Aerodynamic Measurement Technology**
- **Applied Aerodynamics**
- **Fluid Dynamics**
- **Guidance, Navigation, and Control**
- **Intelligent Systems**
- **Multidisciplinary Design Optimization**
- **Propellants and Combustion**
- **Propulsion**
- **Space Exploration**
- **Spaceflight Mechanics**
- **Structures**
- **Thermophysics**
- **Unmanned Systems**

SPEAKER HIGHLIGHTS

- **Steve Bradford**, Chief Scientist, NextGen, FAA
- **Victoria Coleman**, Chief Scientist, U.S. Air Force
- **Lynne Hopper**, Vice President and General Manager, Engineering Strategy and Operations, The Boeing Company
- **The Honorable Steven J. Isakowitz**, President and CEO, The Aerospace Corporation
- **Brig. Gen. Leon A. Johnson, USAF (Ret.)**, Immediate Past National President, Tuskegee Airmen, Inc.
- **Pamela Melroy (Colonel, USAF, Ret.)**, Deputy Administrator, NASA
- **Albert Pisano**, Dean, Jacobs School of Engineering, University of California, San Diego
- **Tom Prevot**, Air Taxi Product Lead, Joby Aviation
- **Óscar Rodríguez**, President, Bajio Aerospace Cluster
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SHAPING THE FUTURE OF AEROSPACE

SPACE RESCUE

The lessons from history that could save lives

The fact that more civilians are going to space has sparked a realization by at least one spaceflight analyst that something may be missing: A way to rescue astronauts or spaceflight participants in disabled spacecraft.

BY PAUL MARKS | PaulMarksNews@protonmail.com

▲ Jared Isaacman and Haley Arceneaux collect biological data during their time in space as part of the four-person civilian Inspiration4 flight.

Inspiration4

Grant Cates' wife confronted him with what seemed like an obvious question last February when he told her he had entered the lottery for a seat on Inspiration4, the first all-civilian orbital space mission: How could he be rescued if something went wrong?

"I said the worst-case scenario is that something goes wrong and I float around the Earth for a couple of weeks and the air goes bad. But I would get to say goodbye." Unimpressed, his wife said to him that he'd "better figure out a way" to rescue himself, Cates says.

All this turned out be moot. The anonymous winner of the St. Jude sweepstakes gifted the coveted seat to Lockheed Martin engineer Chris Sembroski, who splashed down in SpaceX's Crew Dragon Resilience spacecraft in September with three fellow space enthusiasts.

The experience, however, set Cates' mind in motion: The senior engineering specialist at the Aerospace Corp.'s space architecture department in Chantilly, Virginia, followed his wife's advice and researched all the current in-space rescue capabilities available in the United States — under the auspices of the federally funded corporation's latest offshoot, the Space Safety Institute, which it has established to provide independent safety advice to spaceflight organizations based in the U.S.

What Cates — a former NASA space shuttle ground crew chief — found is surprising, especially given that, if one listens to the growing clamor from space enthusiasts, humanity is at the dawn of a massive outward expansion into the final frontier.

"The U.S. government and commercial spaceflight providers have no plans in place to conduct a timely rescue of a crew from a distressed spacecraft in low-

Earth orbit, or anywhere else in space," Cates writes in his analysis, which was published in the September edition of the Journal of Space Safety Engineering. He found that some of the lessons learned by NASA early in the human space program have been all but forgotten: from the way the Apollo 13 crew implemented the option to turn their lunar lander into a lifeboat to conserve fuel and electricity in their damaged command module, to the fact that standby launch vehicles and spacecraft were ready on the pad in case rescue missions were needed in both the Skylab and space shuttle programs.

"The risks involved in space travel are many, and they are magnified by the fact that there are no plans and attendant capabilities in place for the timely rescue of a crew from a disabled spacecraft," he writes. It's a solvable problem, he contends: The United States "as the world's greatest spacefaring nation has the wherewithal to develop and employ effective in-space rescue capabilities."

More people in space

Cates' analysis comes as civilian launches are poised to increase. Up next after September's Inspiration4 three-day jaunt will be the Axiom-1 mission to the International Space Station led by Axiom Space of Houston. Former NASA astronaut Michael López-Alegría, Axiom's vice president of business development, will fly with three space tourists to ISS in February 2022 aboard a Crew Dragon. Axiom plans at least three similar missions and aims to build the first commercial space station, too.

Then there are the movies in the works: On Oct. 5, Soyuz MS-19 delivered a Russian film crew, comprising actor Yulia Peresild and director Klim Shipenko, to the ISS on a 12-day visit to shoot their film "The

“We really need to put in place rescue capabilities before we need them, before we have a crisis.”

— Grant Cates, Aerospace Corp.

Challenge.” Late next year, actor Tom Cruise and director Doug Liman reportedly plan to shoot their own movie on the ISS. In 2023, SpaceX plans to conduct a crewed lunar flyby — the mission is called dearMoon — with its in-development Starship vehicle consisting of a Super Heavy booster and Starship crew spacecraft, while Boeing’s delayed Starliner spacecraft and Sierra Nevada’s Dream Chaser spaceplane are perhaps further options for future civilian trips to LEO and beyond. Blue Origin’s future New Glenn and New Armstrong launchers could carry crews, too.

Meanwhile, NASA under its Artemis program is planning an initial 2024 moon landing in which a Space Launch System rocket would launch an Orion spacecraft and astronauts toward lunar orbit. The crew would rendezvous directly either with Starship, if a lawsuit by losing bidder Blue Origin fails, or first with a planned lunar Gateway space station that might or might not be ready. More landings under NASA’s Artemis program would follow, while China and Russia are planning a joint base at the moon’s south pole.

Despite all this activity, Boeing, SpaceX, Blue Origin and the Inspiration4 team either did not respond or declined to discuss any rescue plans they might or might not have. SpaceX said it was “an incredibly demanding time for the team” and that they did not have anyone available to comment. Boeing initially thought the issue an “interesting angle” but later deferred questions on rescue to NASA, its customer for Starliner services. Axiom Space and Sierra Nevada did not respond to emails.

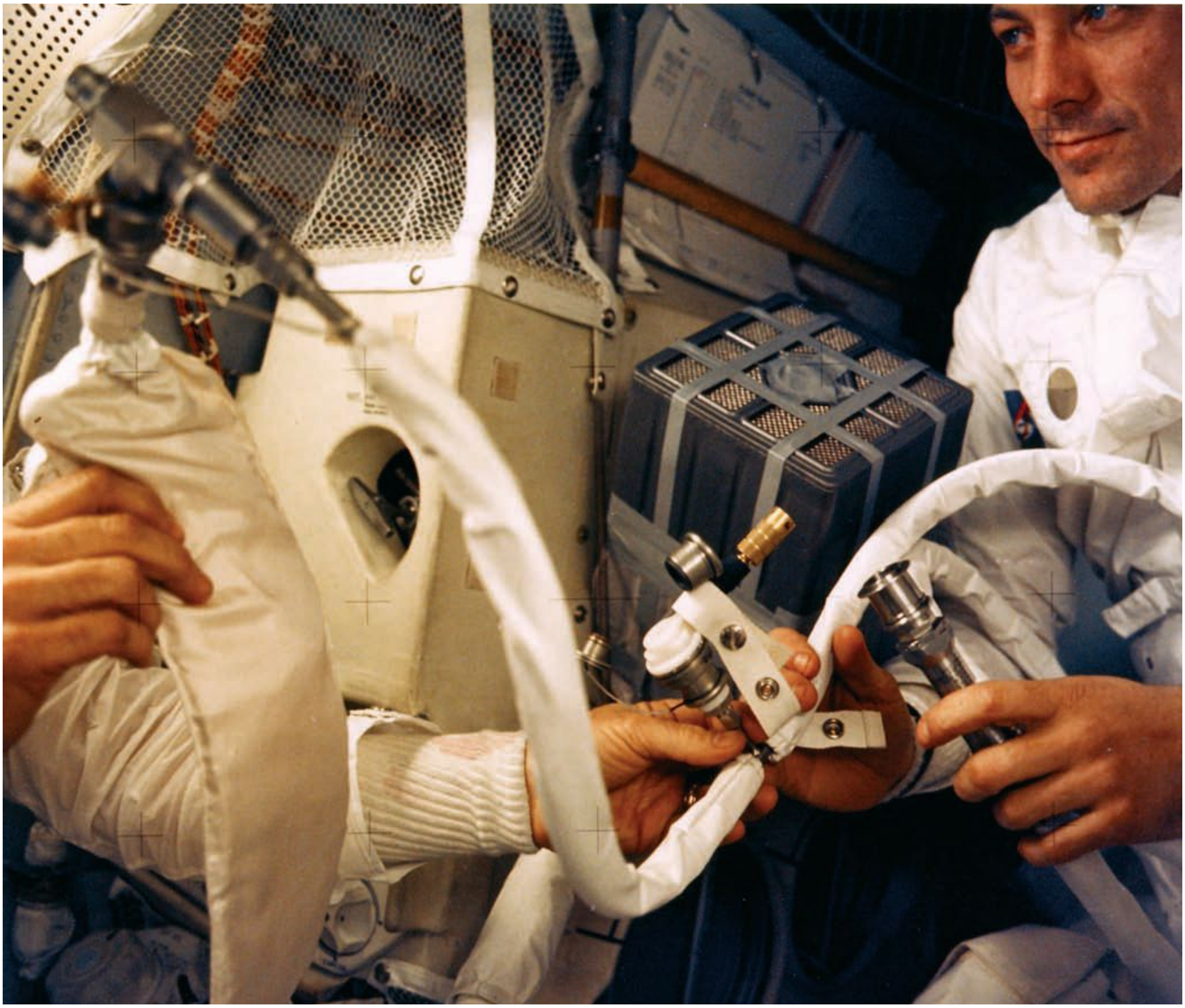
If such space operators want to be prepared with rescue contingencies for these and other missions, history shows it’s doable, says Cates. “It doesn’t need to cost a great deal and doesn’t require any new technologies that don’t already exist. They do exist. We really need to put in place rescue capabilities before we need them, before we have a crisis,” he tells me.

In cases where dispatching a rescue ship would be the only solution, there is no legal mandate for national space agencies or commercial spaceflight firms to provide any in-space rescue capability. In fact, at the urging of heavily pro-innovation groups including the Commercial Spaceflight Federation, the U.S. Congress has ensured that through at least October 2023 the FAA must only regulate space launches as far as it affects protecting the “uninvolved public,” meaning people on the ground or in aircraft. FAA does not regulate for the safety of astronauts or spaceflight participants, which means all is needed is informed consent about the risks (of hypersonic flight in a vacuum surrounded by volatile fuels and space debris).

FAA’s Office of Commercial Space Transportation, however, is aware that change could be coming. If it were to regulate for passenger safety, the office likely would not require a commercial operator to have a rescue launch vehicle and spacecraft at the ready. “I don’t foresee in the course of my career having that type of capability,” says Wayne Monteith, head of the FAA space office, in an Aerospace America Q&A **[Page 10]**. Rather, the approach might be to “regulate on what is controllable,” he says, meaning “the things that are actually on the capsule itself: how redundant your life support systems need to be, how much extra consumables do you need to have on board to have a safe margin.”

Could international regulations come into play? By its title, the Agreement on the Rescue of Astronauts, part of the United Nations’ 1967 Outer Space Treaty, sounds like the answer to a stranded astronaut’s woes. But its scope is mainly about search and rescue on the surface of Earth. “If the personnel of a spacecraft lands in the territory of a state, that state has to take all possible steps to rescue them,” says Joanne Wheeler, a space lawyer and managing partner with Alden Legal in London. “But that requirement regarding search and rescue only applies if the state is ‘in a position’ to help.” So the treaty does not order nations to develop and provide space rescue services — just help if they can.

But with what Wheeler calls the “changing dynamics” of spaceflight — with new nations, new



▲ Aboard Apollo 13, Jack Swigert, command module pilot, holds some of the temporary hose connections that would be necessary when the three astronauts moved from the command module to use the lunar module as a "lifeboat" after an in-flight explosion.

NASA

commercial operators and space tourists entering the field — she says the issue of rescue "does need to be looked at again." Would the rescue agreement, for instance, apply to "astronauts" and civilian "spaceflight participants" alike? "Once we establish a rescue mechanism, I doubt there will be a difference between both categories for the purposes of a rescue," she says.

A history of rescue plans

What is clear in Cates' analysis is that the space industry has considered contingencies before and developed rescue mechanisms, but today's space operators show little sign of having drawn on that history.

In his book "Moon Lander: How We Developed the Apollo Lunar Module," the late Grumman chief engineer Thomas J. Kelly revealed that, at a 1964 Apollo Mission Planning Task Force meeting on contingencies, they had been "postulating the effect of various command and service module failures on the outbound leg of the mission." The planners realized, he wrote, that they could counter "a number of" those failures by using the lander as a lifeboat, "utilizing its propulsion, guidance and control, life-support and other systems" to return the combined command, service and lunar module to near-Earth space.

Providing this rescue capability meant increasing the amount of consumables like oxygen, water and electrical power above the basic mission specs by 10% to 15%, which appears to have been relatively easy to action because the lander existed only on paper at that point. "Six years after it first appeared in the AMPTF's report, this vital crew rescue mode was dramatically utilized on Apollo 13," Kelly wrote.

But luck played a part, too. "Without a doubt it was one of NASA's finest hours since it brought the crew home safely," says Roger Launius, a former associate director of the Smithsonian National Air and Space Museum, and before that head of the NASA History Office. "Personally, I think NASA got lucky with Apollo 13. For instance, what if the crew had been unable

▲ The crew of Apollo 13 jettisoned the mission service module (right) after an explosion severely damaged the spacecraft. This photo was taken from the lunar module, the "lifeboat" that Jim Lovell, Jack Swigert and Fred Haise took shelter in until climbing on board the command module for reentry.

NASA

to repower up the command module for reentry since there was no capability to send a mission from Earth to rescue the crew?"

Nevertheless, Apollo 13 "was a tremendous lesson," Cates tells me, highlighting the power of two coupled spacecraft on a long mission between two celestial bodies, to save lives. "It definitely demonstrated the clear benefit that one gets if you have a redundant capability."

In his research paper, Cates points out that Constellation, NASA's abortive return-to-the-moon program that ran from 2006 to 2010, was similar to Apollo in that it had an Orion spacecraft pushing the Altair lunar lander to the moon, giving it an Apollo-style lifeboat redundancy.

That is not the case with Artemis, however: After an uncrewed Artemis I demonstration mission that NASA plans to carry out in February 2022, the Artemis II crew will ride to lunar orbit and home in their Orion capsule without a second pressurized volume available to them in an emergency. Even on the first landing mission, Artemis III, the crew won't have a lander available as a backup on the outbound trip. They'll rendezvous with a lander in lunar orbit. "Consequently, the crew will have limited capability to save themselves in the event of an emergency," says Cates.

Which brings us to his next pain point: What has happened, he asks, to the practice of readying the next rocket due on the pad early, poised to launch in case a rescue is needed? After Skylab was launched on a Saturn V in May 1973, three crews were rotated through the lab that year. When the first crew was launched on a Saturn I, the second crew's rocket was on the pad and ready to fly should the first crew's mission hit trouble, and the same went for the third crew's rock-

> **"Personally, I think NASA got lucky with Apollo 13. For instance, what if the crew had been unable to repower up the command module for reentry since there was no capability to send a mission from Earth to rescue the crew?"**
>
> **— Roger Launius, former associate director of the Smithsonian National Air and Space Museum**

et when the second crew was on orbit. For that final crew, a spare Saturn I was lined up as rescue cover. "That's just one example in which they were able to use assets that were already planned for launch to provide a rescue capability," says Cates — and with no new technology requiring development, it just took some thoughtful scheduling.

Fast forwarding to July 2005 and that launch-on-need rescue practice was adopted again as the space shuttle program returned to flight — after the Columbia orbiter disintegrated on reentry, killing all seven aboard in February 2003. A chunk of main tank foam insulation punctured a wing on liftoff, allowing plasma into the aluminum wing box and fuselage on reentry, melting the orbiter's core structure. Cates had ceased his role as ground crew chief for Columbia a year before the tragedy, but, like many NASA staff, was involved in the recovery operation in a debris field in Texas, a task he describes as "absolutely shocking."

"After that accident, I led the subsequent efforts for analyzing what it would take to rescue a future space shuttle mission. So for each future space shuttle mission, we put in place a contingency plan that if that orbiter that was launched had a problem, the next space shuttle in the queue to be launched could go up and rescue them." For instance, the seven-person return-to-flight mission flown by the shuttle Discovery, whose destination was the ISS, was backed up by a flight-ready Atlantis.

With the shuttle long retired, such launch-on-need backups have also become history at NASA — but not everywhere: The China National Space Agency announced in June that it is parking rescue rockets on the pad while its taikonauts are on the Chinese Space Station, partly in case of a space debris strike. Shenzhou-13 was placed on its pad "as the backup emergency ship" at the same time as Shenzhou-12 launched, China's state TV reported.

NASA's strategy is to minimize issues that might demand any such rescue. "NASA has designed the Orion spacecraft and each lunar mission with multiple abort options from prelaunch through splashdown. Mission trajectories for early flight tests will leverage physics to bring crews home safely while taking the cause of any anomaly into consideration to manage any unplanned issues. In targeted areas, dissimilar systems are employed to add robust levels of redundancy across the spacecraft," NASA said in response to my inquiry.

Ensuring standardized docking

Another major plank of NASA's rescue strategy, and one Cates describes as vital, is to ensure docking mechanisms are standardized and in use across all its ISS, Orion, Gateway and other future exploration systems.

These are based on the International Docking System Standard established initially for the ISS by NASA, Roscosmos, the Japan Aeropspace Exploration Agency, the European Space Agency and the Canadian Space Agency. These docking adapters allow spacecraft docked at the ISS — some of them lifeboats — to be moved to other ports as operational needs dictate.

The IDSS format traces its evolution back to the Apollo mission that followed Skylab in 1975: The Apollo-Soyuz docking in low-Earth orbit, which involved unprecedented Cold War-era cooperation between the Soviet Union and the U.S. to develop a docking adapter-cum-tunnel big enough to allow a cosmonaut and an astronaut to enter and shake hands inside for all the world to see "détente-in-space" on TV.

Apollo-Soyuz was a prime example, says Tommaso Sgobba, executive director of the International Association for Advancement of Space Safety, IAASS, in Noordwijk, Netherlands, of how political and diplomatic moves can seriously shift the cause of space safety and rescue forward — and boost international spaceflight cooperation in the bargain. At meetings that followed the Apollo-Soyuz mission, Sgobba says, the Soviets, Americans and Europeans further honed docking compatibility standards. That eventually led to cooperation on space shuttle visits to the Soviet Mir space station — and later to the formation of the In-

▲ Space shuttle Endeavour (background) was ready at Kennedy Space Center in Florida in 2008 in case the crew of the shuttle Atlantis (poised for launch in the foreground) needed to be rescued.

NASA

ternational Space Station consortium.

But compatible docking adapters are little use unless a rescue rocket or spacecraft can get to a spaceship in distress. Cates likens the situation to that in the early days of submarines, when little could be done for submariners stranded in crippled vessels on the seabed with their air running out. But following the fatal sinking of Russia's Kursk sub in 2000, NATO set up the International Submarine Escape and Rescue Liaison Office, ISMERLO, to coordinate a global search and rescue response to peacetime submarine sinkings for even non-NATO members. ISMERLO can call on teams of deep-water escape and rescue experts using submarine rescue vehicles with a variety of compatible docking collars.

If space rescue were to have a global organization akin to ISMERLO, it ought to be part of an organization like the U.N.'s International Civil Aviation Organization, says Sgobba. ICAO governs airspace navigation, airplane safety standards and accident investigation — and the IAASS believes a version for space should standardize space safety and rescue, monitor space debris hazards and manage space traffic. IAASS is tentatively exploring how such a space safety body might work in consultation with the European Union.

Cates hopes his paper will at least get the space sector talking. "The primary purpose is to bring this issue closer to the forefront, so that we can have discussions about what the posture should be for in-space rescue. What are the risks? And how do we advance so that we can get more people flying into space and do it as safely as possible?"

In Launius' view: "This paper has done us a real service by pointing out a glaring hole in planning going forward concerning space rescue. There should be a change of philosophy and approach, leading to the creation of appropriate space rescue capabilities."

Launius speculates that rescue might be a role for the U.S. Space Force, working in space akin to the way the uniformed U.S. Coast Guard operates on the ocean. But whatever form it takes, it needs to happen, he says.

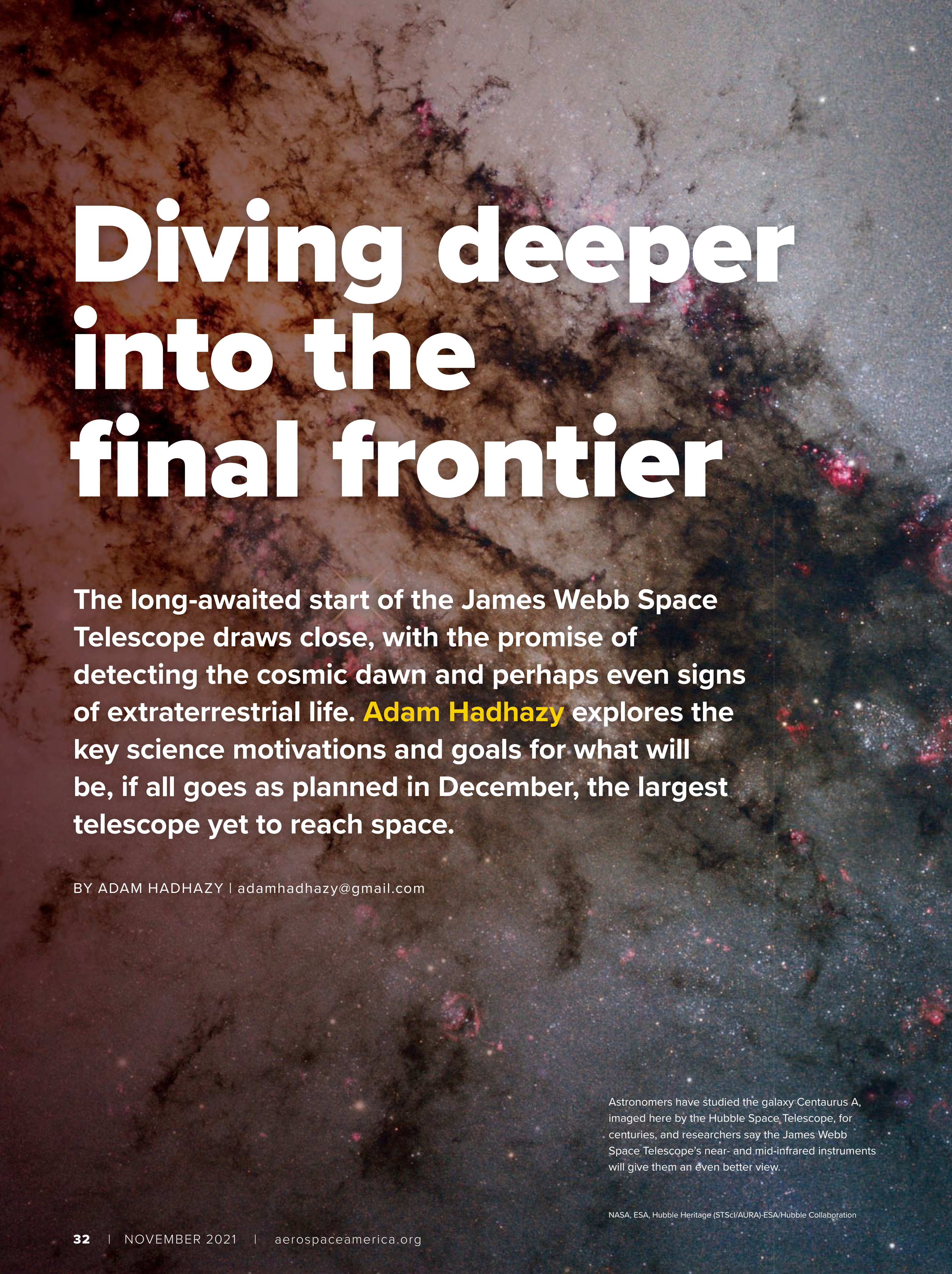
"Space rescue capabilities should become a reality in the future. How soon in the future is the question."★

Staff reporter Cat Hofacker contributed to this report.

Diving deeper into the final frontier

The long-awaited start of the James Webb Space Telescope draws close, with the promise of detecting the cosmic dawn and perhaps even signs of extraterrestrial life. Adam Hadhazy explores the key science motivations and goals for what will be, if all goes as planned in December, the largest telescope yet to reach space.

BY ADAM HADHAZY | adamhadhazy@gmail.com



Astronomers have studied the galaxy Centaurus A, imaged here by the Hubble Space Telescope, for centuries, and researchers say the James Webb Space Telescope's near- and mid-infrared instruments will give them an even better view.

NASA, ESA, Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration

Since Galileo first pointed a telescope skyward in 1608 and saw farther than any human ever had before, astronomers have strived to peer ever deeper into space and, because of what's now known about the speed of light, back in time. Some four centuries later, hopes of continuing this quest by detecting the universe's first light are now vested in the James Webb Space Telescope, the biggest, most powerful, most complicated, most expensive and — not unrelatedly — most delayed space telescope in history.

Motivation for the observatory traces back to astronomers realizing the limits of the Hubble Space Telescope. In the decades since its corrective optics were installed in 1993, Hubble has revolutionized astronomy and cosmology in part due to its deep-field observations involving long exposures that gather up every precious particle of light possible across a range of infrared, visible and the ultraviolet wavelengths. The first revelatory Hubble Deep Field images —gathered over a 10-day span in 1995 — showed that a tiny piece of sky, despite appearing blank and empty to the naked eye and telescopes on Earth, actually held thousands of extremely distant and therefore very young galaxies. These galaxies were primitively smaller and more disordered than modern, mature galaxies, but even so, they were clearly not the first galaxies ever formed.

No amount of observing by Hubble would ever be able to see back to the cosmic dawn, researchers accordingly fathomed. That's because light waves from the earliest galaxies have been stretched so far into the longer infrared wavelengths that Hubble can't detect them. Ground-based telescopes could not capture this severely stretched or redshifted light, either, because Earth's atmosphere blocks out most infrared.

And so, ironically, "the main science goal for Webb arose from something that Hubble did not see," says Eric Smith, NASA's program scientist for Webb at headquarters in Washington, D.C.

As the scope of the redshift problem was becoming clear, astronomers, urged on by then-NASA Administrator Daniel Goldin, began deliberations in 1995 over the instruments and science goals for a next-generation telescope. They realized that detecting the universe's first light, as Goldin challenged astronomers to do, would require gathering much more of the infrared range than Hubble does. Also, some of the primordial features are bound to be faint, so the new telescope's primary mirror would need to be at least several times wider than Hubble's. And the infrared detecting materials behind the primary mirror would need to be chilled, so that the infrared light from the earliest galaxies would stand out.

Now, after a quarter-century of work, including 17 years of construction and testing, the Webb telescope is at last ready to head to space. Careers, reputations and some of humanity's boldest scientific aspirations will be riding with it when it lifts off from French Guiana on Dec. 18 on an Ariane 5 rocket, about a decade later than planned.

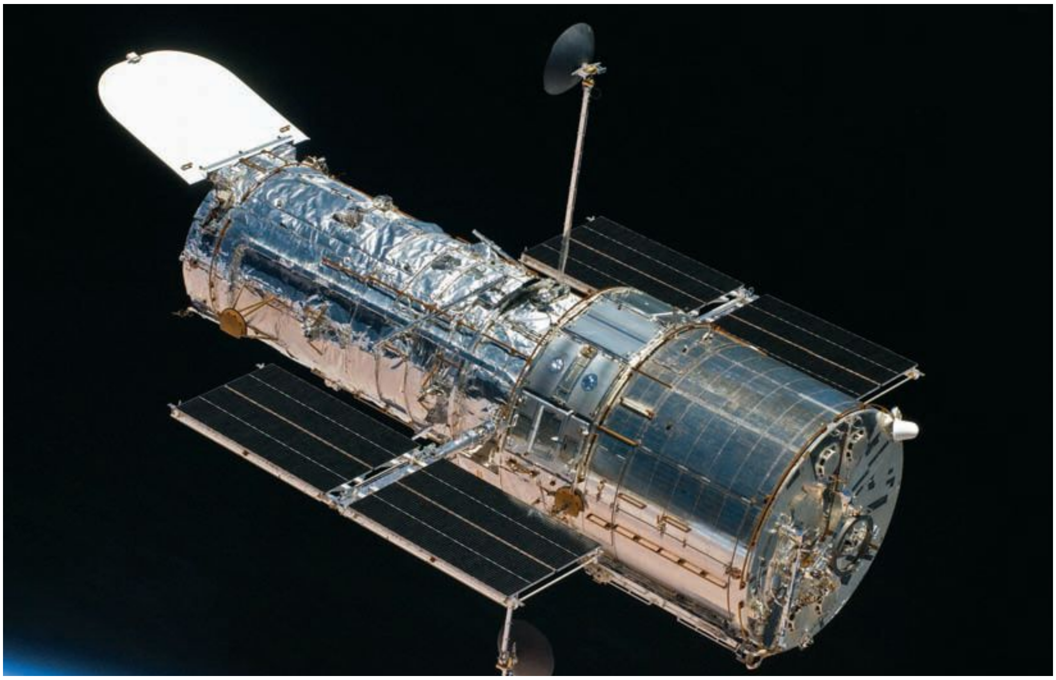
"It's been a very long journey," says Smith, noting that his daughter, who was born shortly after he started working on the concept 25 years ago, recently received her graduate degree.

Once aloft, set up and commissioning will take about six months, and then Webb will begin attacking its top scientific goal of seeing 99.3% of the way back to the Big Bang. Also, its infrared-sensing instruments and large light-collecting mirror are ideal for observing exoplanets and specifically for measuring the compositions of these alien atmospheres. And astronomers will wield Webb to peer inside dusty stellar nurseries to gather new details about star and planet formation, as well as study the moons of the outer planets in our solar system and the faint objects way out in the Kuiper Belt, home to Pluto.

Delving deeper

To date, the most distant object humankind has ever managed to glimpse is the galaxy GN-z11 discovered in 2016 by astronomers poring over Hubble's infrared observations. The observations show GN-z11 as it existed nearly 97% of the way to the Big Bang. This galaxy is a strange beast. It holds only about 1% of the mass of our Milky Way galaxy but furiously forms stars 20 times faster. While the extreme star formation rate fits with theoretical expectations for early galaxies, GN-z11 is unexpectedly large for its era, suggesting that key, unseen, galaxy-building steps preceded its emergence.

Hubble captured just enough light emitted by this galaxy's stars to perform spectroscopy and obtain a redshift reading, which reveals a cosmic object's distance. The spectroscopic process begins with the ridges on a glass surface, called a grating. This device divides the incoming light into spectra and directs the spectra to detectors that convert the photons into electrical signals. The color-coded lines that represent the spectra on an astronomer's computer show a predictable pattern, usually from chemical elements emitting and absorbing particular wavelengths of light. In the special case of extremely distant and faint objects like GN-z11, astronomers see a specific transition in the spectral signature of hydrogen. This pattern shifts toward the infrared the farther away an object is, because the expansion of the universe has stretched the light out as it traveled to us. As a result, what had originally been emitted as ultraviolet light can redshift into longer (redder) visible wavelengths and, for highly distant objects, all the way on into the infrared, leaving no signal at all in the wavelengths of light that the signal originated. In the case of GN-z11, its degree of redshift shows that Hubble saw the



The Hubble Space Telescope, photographed by a shuttle astronaut, has provided decades of data to researchers, but they began planning in 1995 for an even better observatory.

NASA

galaxy as it appeared 13.4 billion years ago, or just 400 million years after the cosmos' origin in the Big Bang.

As faint as it is, GN-z11 is nevertheless likely to be an ultrabright outlier for its era; in general, the farthest Hubble and the best ground-based observatories can strain to see back to is about 500 million years post-Big Bang. With Webb, however, astronomers expect to routinely see objects farther away than GN-z11, and possibly even pierce all the way to a mere 100 million years after the cosmos' genesis.

Those few hundreds of millions of years matter tremendously, Smith points out. Galaxies are theorized to have grown in ways akin to human maturation, starting out small and then enlarging and developing more complexity in terms of their structure. Smith compares the galaxies that Hubble can just barely glimpse to "teenager galaxies," while Webb will snap childhood pics, perhaps even baby pictures, unveiling a fledgling galactic era that's been hidden to astronomers.

"When you think of babies, it's an important time in a human life, where a lot of change is happening," Smith says. "We think the same is true with galaxies."

In keeping with the deep-field approach, Webb will delve deeper into some of the very same fields plumbed by Hubble in search of even more distant, younger galaxies. The project is called JADES for the JWST Advanced Deep Extragalactic Survey. Astronomers in charge of Webb's three main instruments will coordinate with each other to systematically perform deep imaging and spectrometry on thousands of galaxies. Those three instruments are the Near Infrared Camera, or NIRCam; the Near Infrared Spectrograph, or NIRSpec; and the Mid-Infrared Instrument, or MIRI. Together, the instruments cover a wavelength range of 600 nanometers (millionths of a meter) to 28,500 nanometers — spanning the orange portion of the visible spectrum out to the mid-infrared.

To trace early stellar and galactic growth, Webb will see light that was emitted as ultraviolet and visible light, but whose wavelengths have been stretched out into those ranges targeted by Webb's instruments.

Because massive, newborn stars are particularly bright in the ultraviolet and visible ranges, the infrared light detected by Webb will serve as a marker of new star birth and as a tracer of galactic structure. The universe is expected to have undergone an initial surge of stellar birth as the matter formed in the Big Bang at last cooled enough to pool into clumps that then gravitationally collapsed into the nuclear fusion factories that are stars. Webb could see vast collections of stars — perhaps collectively even the first stars, formed almost purely of hydrogen — turning on together as the first galaxies.

Cooking up galaxies

As for galaxies themselves, they are more than just mere collections of billions of hosted stars. Most of a galaxy's constituent material is dark matter, a poorly understood substance whose existence is inferable by the gravity it evidently exerts. All the observable expected matter, plus unobservable expected matter, in a galaxy amounts to a fraction of the cumulative gravitational force needed to keep a galaxy from flying apart; dark matter fills that yawning gap, outnumbering normal matter 6:1. Also playing a major role in galactic evolution are supermassive black holes. Almost every galaxy is thought to have one of these behemoths in its core, and the

energy poured out of the region surrounding a black hole as the object devours matter can disrupt star formation throughout an entire host galaxy.

How and when regular matter, dark matter and black holes all came together as proto-galaxies and evolved into the common, spiral and football-shaped varieties of galaxies we see in the nearer, modern universe is a story whose beginning remains obscured. A program dubbed COSMOS-Webb, which has been awarded the most planned observation time, will help resolve the issue.

The program will take in a huge and representative sample of ultra-distant galaxies across a large swath of sky covering the equivalent of three full moons. This approach is very different from the extreme drilldowns of deep fields, which zero in on a spot "covering the same area of sky as that covered by the head of a pin held at arm's length," says Caitlin Casey, an astronomer at the University of Texas at Austin and the principal investigator for COSMOS-Webb.

Casey says Webb's broader view of the distribution of a few tens of thousands of galaxies will reveal critical details about how the universe took shape.

"We'll see if the galaxies forming shortly after the Big Bang live in the equivalent of cosmic metropolises, with lots of galaxies turning on together, or are galaxies roughly evenly distributed like in small hamlets across the universe," says Casey. "Whether things are highly concentrated or not makes a big difference in our understanding, not just of how galaxies form and evolve, but how the universe came to be in those early days after the Big Bang."

The search for life

As part of its science agenda, Webb will also stare intently at objects formed much later in cosmic chronology: nearby exoplanets. That Webb will be so useful in this regard is serendipitous, as exoplanetary ambitions had not factored into its design. NASA's Smith jokes that in the mid-1990s, "when Webb was conceived, the universe only had two exoplanets." Since that time, the field of exoplane-

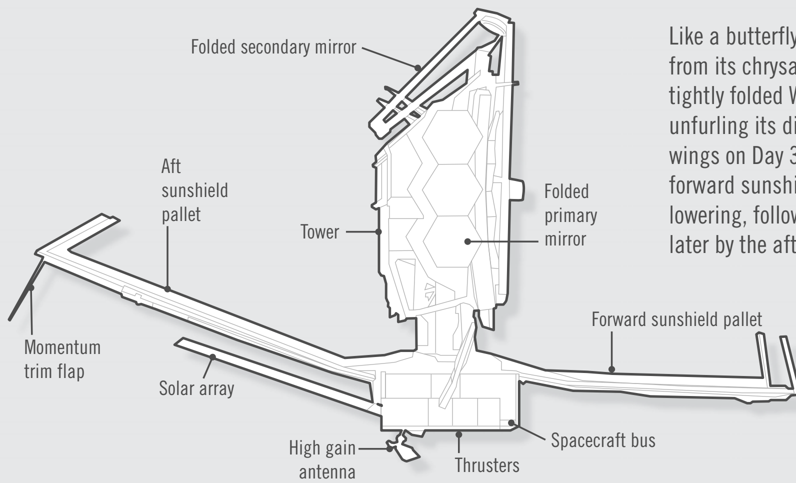
▲ Webb is unpacked at Europe's Spaceport in French Guiana after the complete telescope arrived from California by ship in October.

ESA/CNES/Arianespace

A fortnight of fear...

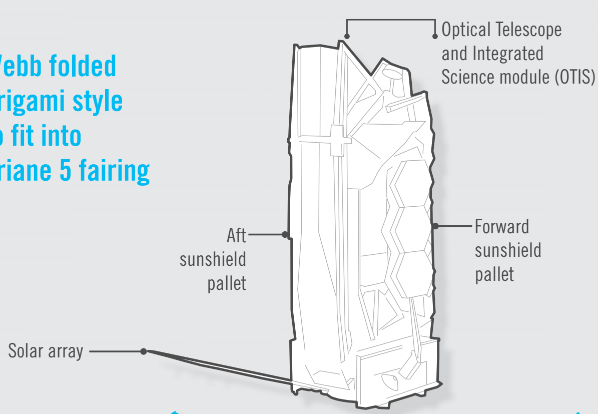
The James Webb Space Telescope's first two weeks in space will be an intense time for mission controllers and legions of scientists. Once dropped off by its Ariane 5 rocket, a series of reverse origami procedures will begin, and if even one of the dozens of steps fails, the $9.7 billion mission will likely fail too. Unlike Hubble, Webb was not designed for servicing by astronauts, even if they could reach it in its deep space orbit.

The sun is both Webb's friend and enemy. Sunlight is the spacecraft's sole electric power source, so Webb's single solar array will be the first component to unfurl after launch. But sunlight and heat would overwhelm Webb's infrared detections, so an impenetrable tennis court-sized sunshield must protect its topside primary mirror, secondary mirror and science instruments, known collectively as OTIS, Optical Telescope and Integrated Science Instrument Module. Another problem: Momentum imparted by photons striking the shield could destabilize Webb as it lines up its cosmic targets. To compensate without wasting station-keeping thruster fuel, Webb will unfurl a momentum trim tab, a flap aft of the sunshield.



Like a butterfly emerging from its chrysalis, the tightly folded Webb begins unfurling its diaphanous wings on Day 3, with the forward sunshield pallet lowering, followed six hours later by the aft assembly.

Webb folded origami style to fit into Ariane 5 fairing



Mission elapsed time

Day 0: Ariane 5 launches Webb, boosting the telescope toward deep space

+33 mins: Webb powers up: solar array deployed

Day 1: Antenna dish fully extends beneath spacecraft

Day 2: +12 hrs: The spacecraft fires its bipropellant thrusters to refine Webb's trajectory into deep space, the midcourse trajectory correction maneuver

Day 3: + 3 hrs: Forward sunshield pallet section lowers

+9 hrs: Aft sunshield pallet section lowers

Day 4: +14 hrs: Extendable tower hoists Optical Telescope and Integrated Science (OTIS) module 2 meters above the sunshield, to boost thermal isolation of the observatory, cooling it to -233° C against 85° C of spacecraft bus below the sunshield

2016, 2 month delay; vibration tests of OTIS optical assembly failed noisily, when faulty closing latch on side wing of primary mirror failed to secure it and shook loose

Day 5: +0 hrs: Momentum management flap unfurls

+2 hrs: Aft sunshield membrane cover release

+7 hrs: Forward sunshield membrane uncovered

+10 hrs: Central part of sunshield exposed

+13 hrs: Robotic sidebooms push membrane foils outward, to full size

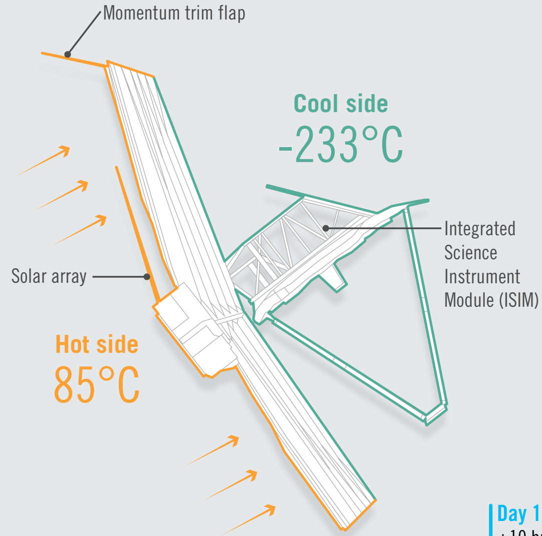
+23 hrs: Sunshield rim tensions the membrane

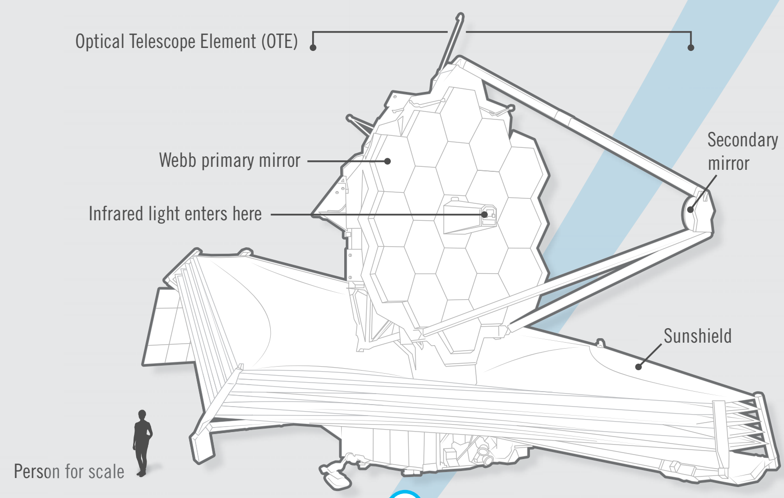
The five-layer, aluminum-coated Kapton foil sunshield has caused numerous program delays. Membranes tore in 2017 at the locations where tensioning cables are attached. Membrane fastening screws were discovered after acoustic testing in 2018, forcing a lengthy redesign

Day 6: +2 hrs: Sunshield membranes shifted into vertical, five-layer passive cooling assembly that reflects solar radiation back into space, away from the infrared observatory's optics

+16 hrs: Vertical radiator shade opens beneath spacecraft

Graphic by Nigel Hawtin, reporting by Paul Marks





Day 11:
+10 hrs: Secondary mirror extends on articulated booms ahead of the primary mirror

+15 hrs: Aft radiator opens, cooling the science payload

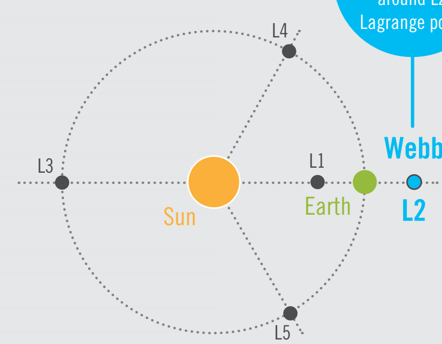
Day 12:
+15 hrs: First side wing of the gold-coated, beryllium primary mirror unfolds. Later, the segments will be aligned

Day 14:
Second side wing of the primary mirror unfolds

Day 29:
Webb begins "halo" orbiting around L2 Lagrange point

Day 9:
+20 hrs: Cryocooler starts up. Helium gas chills the Mid-Infrared Instrument, a camera and spectrograph, to 7 kelvins

Behind Webb's honeycomb of 18 mirror segments, near-infrared detectors must sense the universe's early light, but NASA nearly launched defective detectors. In 2010, the U.S. Defense Department found their sensitivity decayed over time, so Webb's detectors were replaced



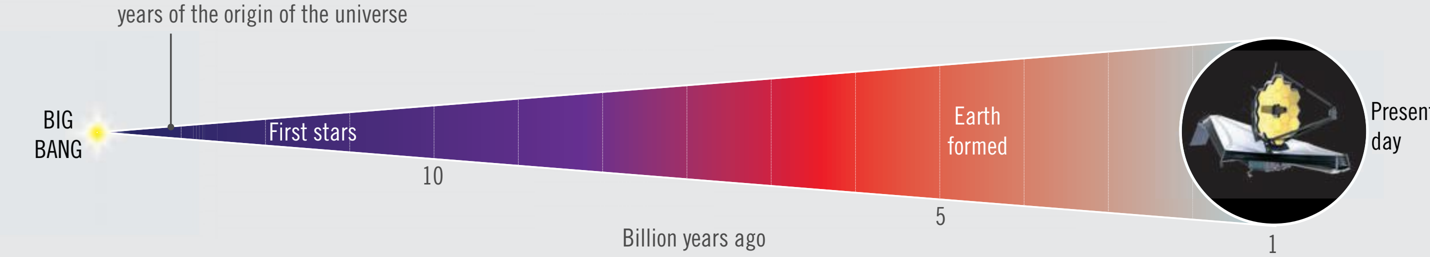
Helium leaks in Webb's refrigerant system have been a recurring problem. In 2010 cryogenic valve leaks prompted a redesign – but the new valve design leaked, too. In 2012 a fix was developed – but the program had been slowed by 18 months

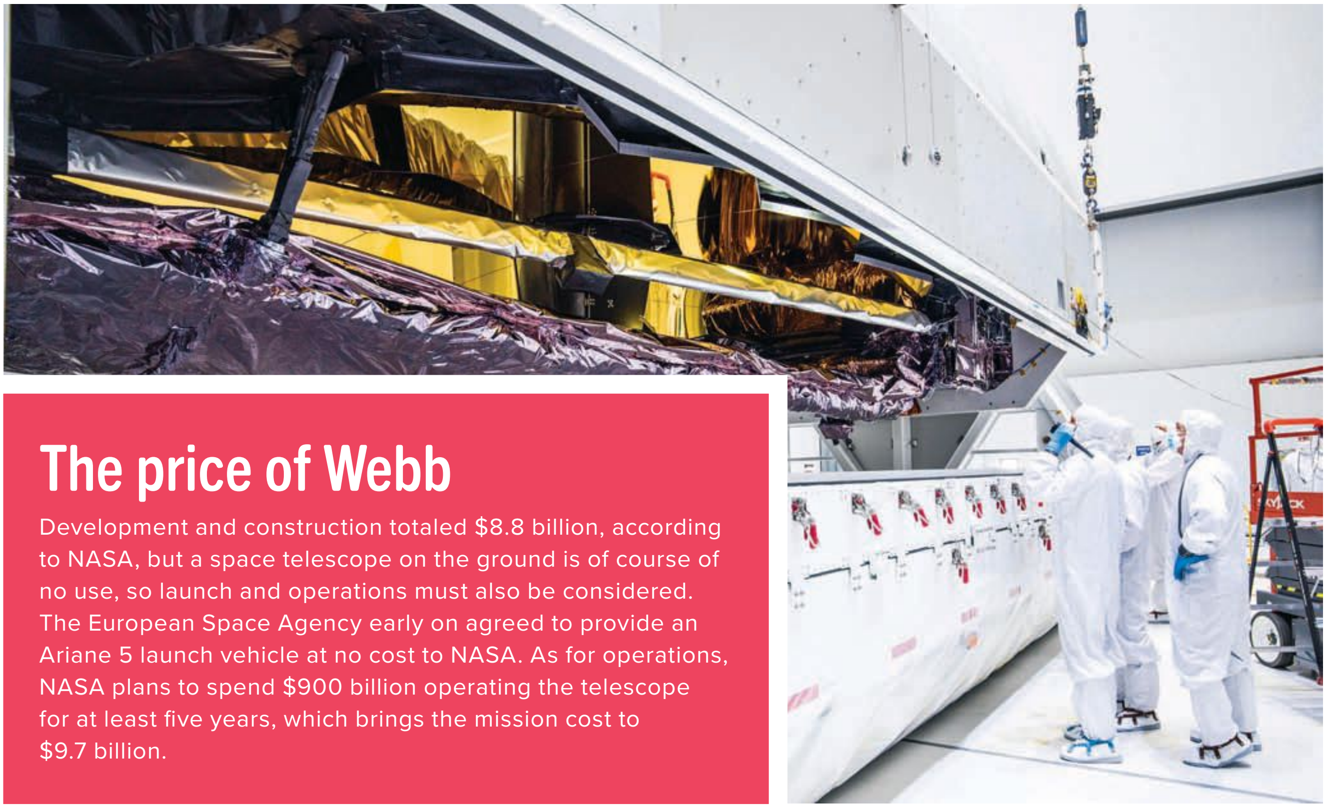
What is L2 and why is Webb going there?

Webb will survey the universe in the infrared, seeking out the faint heat of dim, distant, redshifted objects. So Webb's optics and science instruments must be kept ultracold by flying such that its sunshield always shades them from the heat of the sun, Earth and moon – at a point in space where those celestial bodies appear in roughly the same place.

Due to what NASA calls "a wonderful accident of gravity and orbital mechanics," there is just such a place: L2, the second Lagrange point. Lagrange points (there are five, see above) are places where the gravity of the sun and the Earth/moon system balance out the orbital motion of a spacecraft so the three bodies stay in the same place relative to each other. But L2, 1.5 million km from Earth, is perfect for Webb's shady mission – and so Webb will orbit L2 in a 100,000 km diameter "halo" pattern.

Webb will be the largest telescope ever placed in space (about half the length of a Boeing 737) and will be able to look back 13.5 billion years – to within 200 million to 400 million years of the origin of the universe





The price of Webb

Development and construction totaled $8.8 billion, according to NASA, but a space telescope on the ground is of course of no use, so launch and operations must also be considered. The European Space Agency early on agreed to provide an Ariane 5 launch vehicle at no cost to NASA. As for operations, NASA plans to spend $900 billion operating the telescope for at least five years, which brings the mission cost to $9.7 billion.

▲ Technicians begin removing Webb from the container that protected it during its voyage from California to Europe's Spaceport in French Guiana.

NASA

tology has exploded, with at least 4,400 confirmed worlds known so far and many thousands of candidates awaiting additional verification.

Within this vast catalog of worlds, astronomers will train Webb on a select group of exoplanets around nearby stars. Some of those worlds have bulk properties of mass and size, coupled with temperate orbital distances from their host stars, that collectively indicate the planets could be habitable, even Earth-like. Knowing what these appealingly small worlds are really like is beyond the capabilities of current instruments, which cannot scan atmospheres for so-called biosignatures — mixtures of gases that could plausibly exist only due to biological activity.

Webb, though, with its infrared vision and large light-collecting capabilities, should prove ideal for transmission spectroscopy. This technique involves observing exoplanets as they cross the faces of their stars. During these transits, starlight filters through the planet's atmosphere en route to Webb. Chemicals in the atmosphere absorb some of the starlight, leaving telltale spectral signatures.

Researchers hope Webb serves as the breakthrough tool for strongly inferring the existence of alien life. "The infrared is a good place to look for certain chemicals, like water, carbon dioxide, and methane," says Smith. "Sometime in the not-too-distant future, because of Webb, you might be able to go out and look up at a star in the sky and say there's a planet over there that could be habitable."

Surmounting the technical challenges

None of this groundbreaking science would be possible without engineers having solved the immense problems posed by a large, infrared-optimized space telescope. To achieve their science objectives, planners settled on Webb having a 6.5-meter mirror, or about 2.5 times the diameter of Hubble's 2.4-meter mirror, ultimately bestowing Webb with about six times its predecessor's collecting area. To collect extremely faint, cold infrared light, the infrared-detecting portion of the space-borne facility must be cooled to temperatures on par with the surface of Pluto. To go so low, Webb's mirror and instruments must be shielded from light from the sun, Earth and moon. That will be accomplished with a sunshield, measuring 21 by 14 meters (70 by 47 feet), or about the size of a tennis court, that keeps the infrared-detector side of Webb in shadow.

Given that the largest available rocket fairing was that of the Ariane 5, with a 4.57-meter internal diameter, engineers faced the unenviable task of designing Webb such that it folds up, Transformer-like, to be stowed for launch and subsequent unfolding in space.

"It was this combination of size and cryogenic operation of the telescope that conspired to make [Webb] a monumental engineering challenge," says Paul Geithner, a deputy project manager at NASA for Webb who has worked on the project since 1997.

The mirror accomplishes its downsizing courtesy of two collapsible wing-like side sections. Meanwhile,

▲ Before folding and packing Webb for shipping in April, Northrop Grumman technicians commanded the telescope' 6.5-meter-diameter primary mirror to fully open and lock itself into place, as it must do in space.

Northrop Grumman

the sunshield must pack perfectly, folding onto itself rather like a parachute. All these parts and pieces must then unfold and interlock with precision for Webb to see objects at unprecedented distances and as they existed billions of years ago.

"We're essentially rebuilding and realigning the telescope on orbit," says NASA's Mike Menzel, Webb's mission systems engineer, whose project tenure goes back to 1998 when he was an engineer at Lockheed Martin during the company's early work on Webb; Menzel then joined Northrop Grumman, Webb's prime contractor, in 2001 before coming to NASA in 2004.

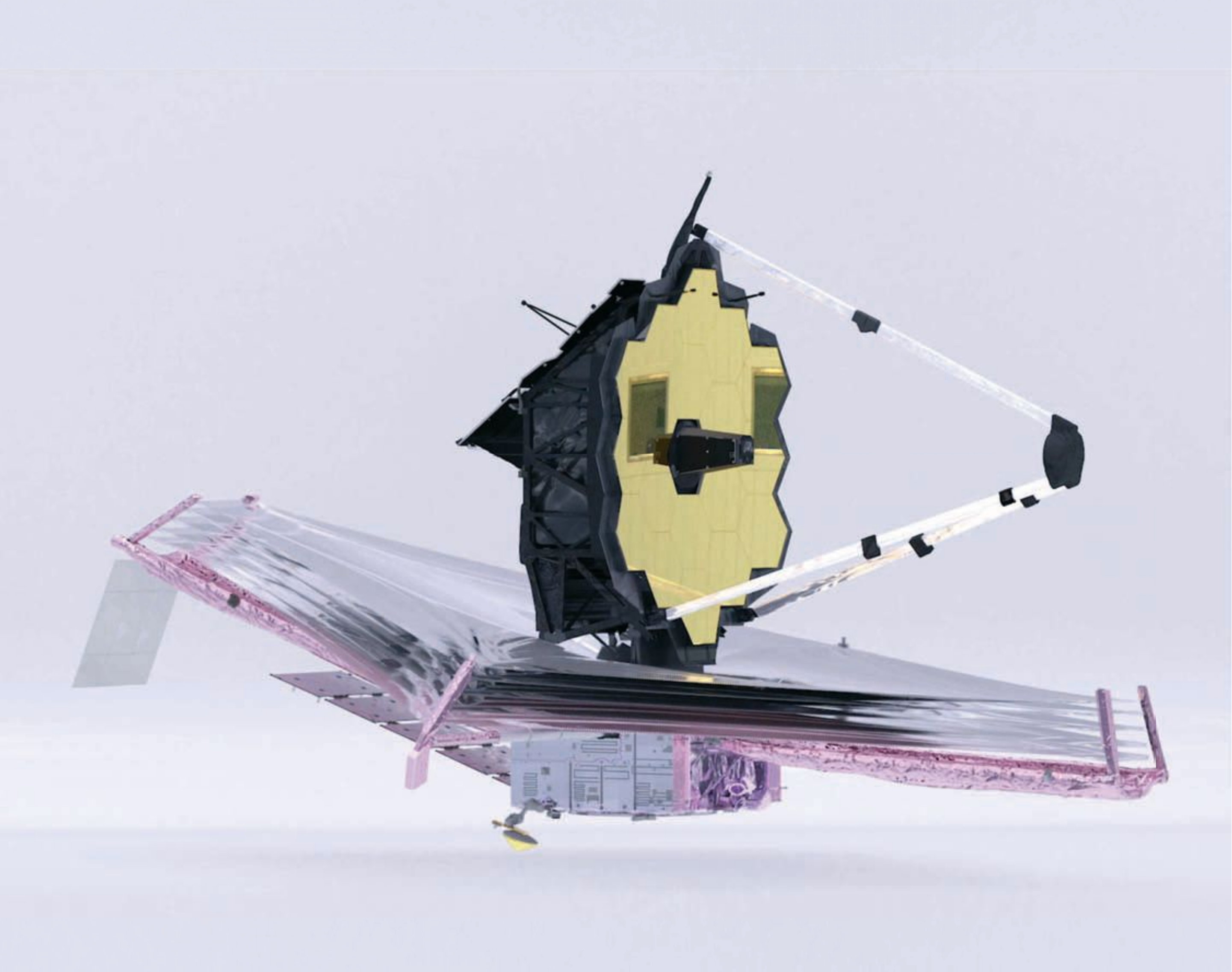
The sunshield proved one of the highest hurdles. Engineers fashioned it as five layers of Kapton, a thermally stable polymer film, with each separated from the other by the vacuum of space. This architecture makes each layer successively cooler than the last by radiating absorbed heat back out into space. The sunshield works so effectively that it reduces a near-boiling temperature of 85 degrees Celsius (185 degrees Fahrenheit) from sunlight at its top layer to minus 233 degrees Celsius (minus 388 degrees Fahrenheit) on its cold, science operations side. To stow the sunshield, engineers placed a total of 107 pins through holes in the five layers; once in space, the pins release, and 90 tensioning cables throughout the sunshield move the heat barrier into its intended shape.

As for the primary mirror, engineers opted for beryllium because of its light weight, sturdiness and thermal stability. The mirror is divided into 18 hexagonal segments, each measuring 1.3 meters across, arranged in a honeycomb-like pattern, and coated with a highly reflective, microscopically thin layer of gold. The mirror has two foldable wings consisting of three vertically aligned segments each. When folded away from the 12-segment core, the wings shave off about 2.6 meters off the mirror's diameter to fit in the Ariane 5. Each mirror segment has seven motors, or actuators, to precisely control the segments' alignment, plus an additional actuator that can fine-tune the curvature of each segment, all working in concert to focus the telescope.

Another design tactic to reduce the temperature on the science side was to place Webb's heat-generating main spacecraft bus, with its solar panel, communications antenna, computer, and reaction wheels and jets all on the hot side of the sunshield.

Compounding the challenge of fashioning all this hardware was having to build Webb's components here on Earth in ambient room temperatures, though portions of the spacecraft operate in deep cryo. Accordingly, engineers had to account for how every material composing Webb would change shape as the mercury plunges. Doing so meant building in tolerances, along with small heaters to allow for a mission controller-guided cooldown.

"We had to build Webb perfectly wrong at room temperature so it's perfectly right at its operating temperature," says Geithner.



▲ An artist's rendering of how Webb will look when fully deployed and operating in space.

NASA

To additionally assist in keeping Webb cold, mission planners chose to place Webb in an orbit about the second Lagrange point, or L2, a waypoint 1.5 million kilometers outward from Earth where the gravitational infuences of our planet and the sun balance the orbital motion of an object. There, Webb will face away from the sun while expending little energy on course corrections.

During the first two weeks in space, a series of complex deployments will take place as Webb makes the monthlong journey to L2. Once there, the actuators will bring the segments into alignment and to their correct curvature, followed by a commissioning phase. Mission planners have taken to calling this tense post-launch period the "six months of terror," an allusion to the well-known seven minutes of terror experienced by Martian probes undergoing entry, descent and landing. Unlike the completely autonomous EDL at Mars, though, necessitated by the communications time delay with Earth, Webb is "never more than a few light-seconds away," says Geithner, meaning mission controllers will be directly implementing and overseeing every phase of the commissioning process. "We have a huge degree of flexibility in executing our plan, depending on if something weird happens," says Geithner. "But we're hoping it's really boring."

The long wait is over

For all the scientists and engineers who have played a role in realizing Webb for a quarter-century now — equal to the bulk of the careers of Smith, Geithner and Menzel — the imminent launch is tantalizing. "It's surreal to be this close to actually doing what we set out to do," says Geithner.

If the science returns can meet expectations, many in the astronomical community might justify Webb's $8.8 billion development price tag and well over a decade of delays. "The wait has been worth it," says Casey.

Smith admits to mixed feelings, having spent so long connected to the observatory here on the ground. Yet he knows the best part, the science, will start soon.

"Webb feels like one of your children when they go off to college," Smith says. "Some part of you hates to see them go, but part of you knows it's where they belong.

"I'm going to miss the observatory. It's bittersweet," adds Smith. "But Webb wants to be in space. I can't wait to see what this amazing instrument can do." ★

AIAA Bulletin

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Other Important Numbers: Aerospace America / Karen Small, ext. 7569 • AIAA Bulletin / Christine Williams, ext. 7575 • AIAA Foundation / Alex D'Imperio, ext. 7536 • Book Sales / 800.682.AIAA or 703.661.1595, Dept. 415 • Communications / Rebecca Gray, 804.397.5270 • Continuing Education / Jason Cole, ext. 7596 • Corporate Programs / Nancy Hilliard, ext. 7509 • Editorial, Books and Journals / Michele Dominiak, ext. 7531 • Exhibits and Sponsorship / Paul doCarmo , ext. 7576 • Honors and Awards / Patricia Carr, ext. 7523 • Integration and Outreach Committees / Angie Lander, ext. 7577 • Journal Subscriptions, Member / 800.639.AIAA • Journal Subscriptions, Institutional / Online Archive Subscriptions / Michele Dominiak, ext. 7531 • K–12 Programs / Sha'Niece Simmons, ext. 7590 • Media Relations / Rebecca Gray, 804.397.5270 • Engage Online Community / Luci Blodgett, ext. 7537 • Public Policy / Steve Sidorek, ext. 7541 • Section Activities / Lindsay Mitchell, ext. 7502 • Standards, International / Nick Tongson, ext. 7515 • Technical Committees / Angie Lander, ext. 7577 • University and Young Professional Programs / Michael Lagana, ext. 7503

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

Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2021			
8–10 & 15–17 Nov	ASCEND Powered by AIAA	Las Vegas, NV, & ONLINE	30 Mar 21
15–17 Nov	AIAA International Space Planes and Hypersonic Systems & Technologies Conference	Las Vegas, NV, & ONLINE	30 Mar 21
29–30 Nov	Australian International Aerospace Congress & Region VII Student Conference	ONLINE	15 Sep 21
2022			
3–7 Jan	AIAA SciTech Forum	San Diego, CA, & ONLINE	1 Jun 21
7 Jan	3rd AIAA Geometry and Mesh Generation Workshop (GMGW-3)	San Diego, CA	
7 Jan	4th AIAA CFD High Lift Prediction Workshop (HLPW-4)	San Diego, CA	
8 Jan	Additive Manufacturing: Structural and Material Optimization Course	San Diego, CA	
8 Jan	Computational Aeroelasticity Course	San Diego, CA	
8 Jan	Hypersonics: Test and Evaluation Course	San Diego, CA	
8 Jan	Technical Writing Essentials for Engineers Course	San Diego, CA	
8–9 Jan	Agile Systems Engineering Course	San Diego, CA	
8–9 Jan	Aircraft and Rotorcraft System Identification Engineering Methods Course	San Diego, CA	
8–9 Jan	Design of Electrified Propulsion Aircraft Course	San Diego, CA	
8–9 Jan	Missile Guidance Course	San Diego, CA	
8–9 Jan	OpenFOAM CFD Foundations Course	San Diego, CA	
8–9 Jan	Spacecraft Design, Development, and Operations Course	San Diego, CA	
8–9 Jan	1st AIAA High Fidelity CFD Workshop	San Diego, CA	
18 Feb–8 Apr	Design of Experiments: Improved Experimental Methods in Aerospace Testing Course	ONLINE (learning.aiaa.org)	
23–25 Feb, 1–3 Mar	UAV Aircraft Design Course by Dan Raymer	ONLINE (learning.aiaa.org)	
28 Feb–11 Mar	Fundamentals of Python Programming with Libraries for Aerospace Engineers Course	ONLINE (learning.aiaa.org)	
3–4 Feb	Region I Mid-Atlantic Section Young Professionals, Students, and Educators (YPSE) Conferenc	ONLINE (www.aiaaypse.com)	
5–12 Mar*	2022 IEEE Aerospace Conference	Big Sky, MT (aeroconf.org)	
8–17 Mar	Trusted Artificial Intelligence Course	ONLINE (learning.aiaa.org)	

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
2022			
25–26 Mar	AIAA Region III Student Conference	West Lafayette, IN	27 Jan 22
25–27 Mar	AIAA Region I Student Conference	Blacksburg, VA	24 Jan 22
29 Mar–7 Apr	Technical Writing Essentials for Engineers Course	ONLINE (learning.aiaa.org)	
1–2 Apr	AIAA Region IV Student Conference	San Antonio, TX	31 Jan 22
1–3 Apr	AIAA Region VI Student Conference	Merced, CA	5 Feb 22
4–6 Apr*	3rd IAA Conference on Space Situational Awareness (ICSSA)	Madrid (http://reg.conferences.dce.ufl.edu/ICSSA)	
19–21 Apr	AIAA DEFENSE Forum	Laurel, MD	19 Oct 21
21–24 Apr	AIAA Design/Build/Fly	Wichita, KS	
26 Apr	AIAA Fellows Induction Ceremony and Dinner	Arlington, VA	
27 Apr	AIAA Aerospace Spotlight Awards Gala	Washington, DC	
3–5 May*	6th CEAS Conference on Guidance, Navigation and Control (EuroGNC)	Berlin, Germany (eurognc2022.dglr.de)	31 Oct 21
4 –27 May	Electrochemical Energy Systems for Electrified Aircraft Propulsion: Batteries and Fuel Cell Systems Course	ONLINE (learning.aiaa.org)	
16–19 May*	26th Aerodynamic Decelerator Systems Technology Conference and Seminar (ADSTCS)	Toulouse, France (https://earthlydynamics.com/adst-2022)	
30 May–1 Jun*	29th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia	
21–24 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
25–26 Jun	7th AIAA Drag Prediction Workshop ("DPW-VII: Expanding the Envelope")	Chicago, IL	
26 Jun	2nd AIAA Workshop for Multifidelity Modeling in Support of Design & Uncertainty Quantification	Chicago, IL	
27 Jun–1 Jul	AIAA AVIATION Forum	Chicago, IL	10 Nov 21
16–24 Jul*	44th Scientific Assembly of the Committee on Space Research and Associate Events (COSPAR)	Athens, Greece (cospar-assembly.org)	11 Feb 22
7–10 Aug*	AAS/AIAA Astrodynamics Specialist Conference	Charlotte, NC	1 Apr 22
4–9 Sep*	33rd Congress of the International Council of the Aeronautical Sciences (ICAS 2022)	Stockholm, Sweden (icas2022.com)	10 Feb 22
18–22 Sep*	73rd International Astronautical Congress	Paris, France (iac2022.org)	
24–26 Oct	ASCEND Powered by AIAA	Las Vegas, NV	

AIAA Continuing Education offerings

Meetings cosponsored by AIAA. Cosponsorship forms can be found at aiaa.org/events-learning/exhibit-sponsorship/co-sponsorship-opportunities.

AIAA Announces its Class of 2022 Associate Fellows

AIAA is pleased to announce its newly elected Class of 2022 Associate Fellows. AIAA will formally honor and induct the class at the AIAA Associate Fellows Induction Ceremony, Monday, 3 January 2022, at the Manchester Grand Hyatt San Diego in San Diego, Calif., during the 2022 AIAA SciTech Forum, 3–7 January.

"Congratulations to each member of the Class of 2022 Associate Fellows," said AIAA President Basil Hassan. "This distinguished group of individuals exemplify passion and dedication to advancing the aerospace profession. Each of them was selected because of their significant and lasting contributions to the field. They are truly shaping the future of aerospace."

The grade of Associate Fellow recognizes individuals "who have accomplished or been in charge of important engineering or scientific work, or who have done original work of outstanding merit, or who have otherwise made outstanding contributions to the arts, sciences, or technology of aeronautics or astronautics." To be selected as an Associate Fellow an individual must be an AIAA Senior Member in good standing, with at least 12 years of professional experience, and be recommended by three current Associate Fellows.

"The AIAA Associate Fellows personify the innovation that drives our industry forward," said Dan Dumbacher, AIAA executive director. "The members of the Class of 2022 Associate Fellows embody the commitment, dedication, and ingenuity that are crucial for devising the best solutions to the complex questions raised across the aerospace community. On behalf of the Institute, we recognize the families, friends, and colleagues who support the Associate Fellows as they contribute in such a meaningful way to the aerospace community."

Class of 2022 AIAA Associate Fellows

Fred F. Afagh, *Carleton University, Ottawa, Canada*

Frederic Alauzet, *French Institute for Research in Computer Science and Automation, France*

Jose S. Alonso Miralles, *Collins Aerospace*

Charles Bersbach, *Raytheon Technologies Missiles and Defense*

William Blackwell, *MIT Lincoln Laboratory*

Edwin Blosch, *Lockheed Martin Aeronautics*

Charles F. Bolden Jr., *The Charles F. Bolden Group LLC*

Iman Borazjani, *Texas A&M University*

Nicholas Borer, *NASA Langley Research Center*

Luis Giovanni Bravo Robles, *U.S. Army Research Laboratory, Weapons and Materials Research Directorate*

Roger Brewer, *Lockheed Martin Aeronautics*

Kevin Brink, *Air Force Research Laboratory*

L. Alberto Cangahuala, *NASA Jet Propulsion Laboratory*

Katya Casper, *Sandia National Laboratories*

William M. Chan, *NASA Ames Research Center*

James Chen, *University at Buffalo, State University of New York*

Isaias Chocron, *Southwest Research Institute*

Jonathan Christensen, *Sandia National Laboratories*

Timothy Cichan, *Lockheed Martin Space*

Douglas Cooke, *Cooke Concepts and Solutions*

Andrew M. Crocker, *Dynetics, A Leidos Company*

Yongdong Cui, *National University of Singapore, Singapore*

Kenneth Davidian, *Federal Aviation Administration, Office of Commercial Space Transportation*

Diane Davis, *a.i. solutions, Inc.*

Roeland De Breuker, *TU Delft, The Netherlands*

Daniel M. Deans, *Axient, LLC*

Timothy Deaver, *Airbus U.S.*

Jorge Delgado, *Astra Inc.*

Cassondra Dellinger, *Dellinger Technologies*

Lian Duan, *Ohio State University*

Sebastien Ducruix, *Laboratoire EM2C-CNRS, France*

Houfei Fang, *Shanghai YS Information Technology Co., Ltd., China*

Antonino Ferrante, *University of Washington*

George Finelli, *NASA Langley Research Center*

Glen Fountain, *Johns Hopkins University*

Roberto Furfaro , *University of Arizona*

Ross Gadient, *Boeing Research & Technology*

Judith Gallman, *Northrop Grumman Aerospace Systems*

Mirko Gamba, *University of Michigan*

Volker Gollnick, *Hamburg University of Technology, Germany*

Nelson W. Green, *NASA Jet Propulsion Laboratory*

Robert E. Harris, *CFD Research Corporation*

David Hash, *NASA Ames Research Center*

Maziar Hemati, *University of Minnesota*

Miguel A. Hernandez Jr., *Bastion Technologies, Inc.*

Jason Hicken, *Rensselaer Polytechnic Institute*

Zekai Hong, *National Research Council Canada*

John M. Horack, *Ohio State University*

Keiichi Hori, *Japan Aerospace Exploration Agency, Japan*

Micah Howard, *Sandia National Laboratories*

Chih-Yung Huang, *National Tsing Hua University, Taiwan*

Tristram Tupper Hyde, *NASA Goddard Space Flight Center*

Eddie Irani, *Spirit Aerosystems, Inc.*

Hrvoje Jasak, *Wikki Ltd, United Kingdom / University of Cambridge, United Kingdom*

Justin Jaworski, *Lehigh University*

Sanjay Jayaram, *Saint Louis University*

Robert J. Jensen, *Sierra Lobo, Inc.*

Sharon Monica Jones, *NASA Langley Research Center*

Thomas Juliano, *University of Notre Dame*

Sergey Karabasov, *Queen Mary University of London, United Kingdom*

John Kelly, *NASA Armstrong Flight Research Center*

Andrew Keys, *Air Force Institute of Technology*

Elad Kivelevitch, *MathWorks, Inc.*

Sudarshan Kumar, *Indian Institute of Technology Bombay, India*

Gregory Laskowski, *Dassault Systemes Company, France*

Stuart Laurence, *University of Maryland*

David E. Lee, *Northrop Grumman Space Systems*

Seongkyu Lee, *University of California, Davis*

Kristina Lemmer, *Western Michigan University*

Charles Lents, *Raytheon Technologies Research Center*

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Hever Moncayo, *Embry-Riddle Aeronautical University*

Jamie Morin, *The Aerospace Corporation*

Michael E. Mueller, *Princeton University*

Karen A. Mulleners, *École Polytechnique Fédérale de Lausanne, Switzerland*

Jeffrey Muss, *Sierra Engineering & Software, Inc.*

Lee Noble, *NASA Headquarters*

Taku Nonomura, *Tohoku University, Japan*

Alison Nordt, *Lockheed Martin Space*

Julie Parish, *Sandia National Laboratories*

Peter Parker, *NASA Langley Research Center*

Olivia Pinon-Fischer, *Georgia Institute of Technology*

George Price, *Crown Consulting, Inc.*

Mark Rennie, *University of Notre Dame*

Jay G. Santee, *The Aerospace Corporation*

Amit K. Sanyal, *Syracuse University*

Benjamin Michael Sarao III, *Primary Image*

Virendra Sarohia, *NASA Jet Propulsion Laboratory*

Walter S. Scott, *Maxar*

Kay Sears, *Lockheed Martin Space*

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Michael Snyder, *Redwire*

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Philippe Spalart, *Boeing Commercial Airplanes (retired)*

S. Alan Stern, *Southwest Research Institute*

George Story, *NASA Marshall Space Flight Center*

Veera Sundararaghavan, *University of Michigan*

Edward Swallow, *The Aerospace Corporation*

James Taiclet, *Lockheed Martin Corporation*

Richard E. Tuggle, *PeopleTec / U.S. Army Reserve*

Krishna Venkatesan, *GE Research*

C.J. (Onno) Verberne, *Nammo Raufoss AS, Norway*

Naveen Vetcha, *Engineering, Research, and Consulting, Inc. (ERC)*

John Vickers, *NASA Marshall Space Flight Center*

Jason Wadley, *Lockheed Martin Aeronautics*

Ross Wagnild, *Sandia National Laboratories*

Harold (Sonny) White, *NASA Johnson Space Center*

Michael E. White, *Office of the Under Secretary of Defense for Research & Engineering*

Robert White, *Tufts University*

Julie Williams-Byrd, *NASA Langley Research Center*

Jay Willis, *Modern Technology Services, Inc. (MTSI)*

Richard G. Winski, *Analytical Mechanics Associates / NASA Langley Research Center*

Andrew Wissink , *U.S. Army DEVCOM AvMC Technology Development Directorate*

Sherry Yang, *The Boeing Company*

Joseph W. Zimmerman, *CU Aerospace, LLC*

AIAA Announces Candidates for 2022 Election

The Council Nominating Committee has selected candidates for next year's openings on the AIAA Council of Directors. Elections will be held 20 January–11 February 2022. Council Nominating Committee Chair John Blanton and AIAA Governance Director Christopher Horton confirmed the names of the candidates who will appear on the 2022 ballot.

Integration and Outreach Activities Division

Director–Aerospace Outreach Group
Kevin Burns, Retired
David Dolling, George Washington University

Director–Integration Group
Thomas Irvine, TBI Aerospace Consulting, LLC
Chandru Mirchandani, Leidos Innovations Corporation

Director-Elect–Young Professionals Group
Bryan Kowalczyk, University of Cincinnati
Dominic Pena, Answer Engineering Inc.

Regional Engagement Activities Division

Director–Region IV
Ellen Gillespie, Retired
Andrew Santangelo, sci_Zone, Inc.

Director–Region V
James Guglielmo, Boeing Research & Technology
Merri Sanchez, The Aerospace Corporation

Technical Activities Division

Director–Information Systems Group
Stephen Blanchette, The Aerospace Corporation
Michel Ingham, NASA Jet Propulsion Laboratory

Director–Propulsion and Energy Group
Steven Gorrell, Brigham Young University
Rusty Powell, Axient

The 2021 Jay Hollingsworth Speas Airport Award was presented to the Jackson Hole Airport Board at the 2021 AAAE National Airport Conference (27–28 September, Savannah, GA).

Left to right: Megan Jenkins, Jackson Hole Airport; Dirk Speas, Speas Award; Jim Elwood, Jackson Hole Airport; Michelle Anderson, Jackson Hole Airport

Nominations Being Accepted for the Class of 2022 NASA Langley and Langley Alumni Association Hall of Honor

The Langley Alumni Association and NASA Langley Research Center partnered to develop the Hall of Honor to provide a way for distinguished Langley Research Center researchers and managers to be honored for their exemplary contributions and careers at NACA, NASA, and the nation at large in the pursuit of revolutionary scientific understanding and technological progress on the frontiers of aerospace sciences. The Hall of Honor also provides a focused opportunity for the local aerospace community to reflect on the contributions of these notable individuals who made enduring impacts on aerospace technologies.

We encourage you to consider nominating a deserving individual for the Hall of Honor Class of 2022. All nominees must satisfy the selection criteria found at **https://larcalumni.org/nomination-form**, and nominations must be received by 14 January 2022. If you have any questions, please email info@larcalumni.org.

Preparing for the 2031 AIAA Centennial

By Kevin Burns, AIAA History Committee Chair

This year the AIAA History Committee started its preparations for the 2031 AIAA Centennial. Our goal is to have papers presented at AIAA SciTech Forums over the next decade on the history of each committee, section, branch, and organization within AIAA. We will kick off with a session on the History of AIAA at the 2022 AIAA SciTech Forum. *Rocketeers and Gentlemen Engineers*, written for AIAA's 75th anniversary in 2006, chronicles the social history of the Institute. The papers and presentations in the coming years will allow a more technical understanding at the grassroots level of how the Institute came together and grew over the last century. The committee encourages our committees and sections to mentor students and young professionals in writing these papers, so that they can get published early in their careers and experience the publication and presentation of a paper. More information about the History Committee and advice for writing history papers for AIAA SciTech Forum can be found on its website at **aiaahistorycommittee.com**, or by contacting the committee chair at kevinrobburns@gmail.com.

AIAA also has joined the Engineering and Technology History Wiki (ETHW) consortium in 2021 (www.ethw.org). The website has thousands of articles, firsthand accounts, oral histories, milestones, archival documents, and lesson plans pertaining to the history of technology. It fosters the creation of narratives that not only document the history of engineering practices but also explain when, how, and why these technologies developed as they did. Over the next year, the History Committee will be working to establish liaisons with other AIAA technical committees to develop content within the aerospace engineering category of the transportation history section of the ETHW. All AIAA members are encouraged to contribute content. Those interested in this project can contact the History Committee chair at kevinrobburns@gmail.com.

MAKING AN IMPACT

AIAA and Challenger Center Launch New Trailblazing STEM Educator Award

The AIAA and Challenger Center have launched the Trailblazing STEM Educator Award. This annual award will celebrate K-12 teachers going above and beyond to inspire the next generation of explorers and innovators.

The award will recognize teachers who connect classroom lessons to the country's current and future plans for exploration and innovation, introduce students to STEM careers, and spark students' imagination about space exploration. Following a year of incredible challenges for educators, this year's award also will celebrate educators who continued to excite their students about STEM throughout the difficult circumstances caused by the COVID-19 pandemic. Nominations are being accepted at **aiaa.org/TrailblazingSTEMEducatorAward** and may be submitted through 30 January 2022.

Five finalists will be selected from the nominations. Each of the finalists and their respective schools will be awarded $5,000; each finalist also will receive free access to Challenger Center's STEM programs, a trip to Washington, DC, to be honored at the AIAA Aerospace Spotlight Awards Gala, and a special presentation ceremony at their school.

"We are excited about our collaboration with Challenger Center supporting those who are invaluable to our communities – educators. We share a commitment to strengthening the aerospace profession by inspiring the future workforce," said Dan Dumbacher, AIAA executive director. "We need a diverse and robust STEM next generation who use what they learn today to innovate and invent tomorrow. We can't wait to recognize these passionate and inspirational trailblazers who spark students' interest in STEM subjects, especially the science and engineering behind aerospace."

Even as the U.S. aerospace and defense industry leads the world in innovation, it faces challenges with the workforce: a skills gap of STEM-literate students entering the industry, a need for greater participation by women and ethnic minorities, and a growing knowledge gap from early retirements. Based on the "2021 AIAA State of the Industry Report," nearly 50% of respondents believe an increased focus on diversity, equity, and inclusion by aerospace industry employers will help increase the pipeline of skilled, competent aerospace professionals.

Uncrewed Aerial Systems in the Australian Military from Today to 2040

By Michael Spencer, AIAA Sydney Section Committee, and Tjasa Boh-Whiteman, Co-Chair, AIAA Sydney Section

To keep their members informed about different areas of the aerospace industry, the AIAA Sydney Section recently invited **Wing Commander Keirin Joyce, Royal Australian Air Force**, as a guest speaker. He is a currently appointed as the Chief Engineer for Remote Piloted Aircraft Systems (RPAS): MQ-4C Triton and MQ-9B SkyGuardian.

On 21 September, he delivered a public lecture on his views of the military Uncrewed Aerial Systems (UAS) that are currently in service or being considered for acquisition out to the year 2040 in the Australian Defence Force. Due to government-mandated COVID-19 lockdown restrictions, this AIAA Sydney Section event was hosted online as a livestreamed presentation.

A graduate of the Australian Defence Force Academy (ADFA) with an Honours Bachelor of Aeronautical Engineering, WGCDR Joyce has spent the last 15 years supporting the Australian Defence Force (ADF) to better understand, utilize, and acquire UAS capabilities, including joining operational deployments to Iraq and Afghanistan. He is a Chartered Professional Engineer with master degrees in Aviation Management (Human Factors), Aerospace Engineering, and Military and Defence Studies, and a part-time Ph.D. research student at UNSW Canberra/ADFA. WGCDR Joyce was responsible for all Australian Army UAS activities, including Army Drone Racing and drone videography, before transitioning to the Royal Australian Air Force as the Remotely Piloted Aircraft Systems (RPAS) Sub-Program Manager, before being appointed the Chief Engineer, RPAS.

During his career as an Army engineer, he supported Army to adopt an incremental capability approach to incorporating drones across the Army organization of its warfighters. The Australian Defence Force (ADF) Drone Racing Team was established as a non-traditional sport that overlaps both work and personal interests with Army, Navy, and Air Force participation, enabling ADF and STEM to be promoted to soldiers, sailors, and aviators and youth interested in becoming the next generation military.

The most recent Defence Strategic Update steers the ADF to adopt remotely operated and autonomous air vehicles that provide increased lethality and survivability, improve battlespace situational awareness, and complement existing aircraft capabilities, including investigating the potential for teaming air vehicles. To aid this transformation and keep the momentum of change, Army has acquired a COTS Multi-Rotor UAS for issue to every Army unit, enabling everyone in Army to improve their drone literacy, supplement counter-UAS awareness, and familiarize soldiers with how UAS pose a new and fast-growing threat to small units, plus support the Army development of better UAS training.

Army has invested in a drone strategy to provide operational drones in capability increments of increasing mass, size and performance, corresponding to the size of the force element. Army drones range from pocket-sized nano-UAS (e.g., Black Hornet) for combat platoons; medium-sized hand-launched Small UAS (e.g., Wasp AE) for every combat team; up to a catapult-launched Tactical UAS (e.g., Shadow 200) to equip a deployable brigade without needing an established runway.

Figure 1. A grateful AIAA Sydney Section discusses the success of the event with Wing Commander Joyce.

Figure 2. Wing Commander Joyce, Chief Engineer for Australian Military RPAS and Army RQ-7 Shadow 200.

The Navy is also investing in an exciting drone program with two different types of drones: catapult-launched ScanEagle fixed-wing drone and Schiebel S-100 vertical lift helicopter drone. These drones provide the Navy with new experiences adapting technologies to conduct flights between the shore and a warship and flights at sea.

Air Force is doctrinally roled to acquire and operate the very large-sized drone capabilities for the ADF. ADF doctrine ensures no unnecessary duplication of combat capabilities within the Army, Navy, and Air Force. Each contributes combat elements to be integrated and work cooperatively within the same ADF deployed Joint Task Force (JTF) to deliver a military effect that meets an operational need jointly. Air Force is currently acquiring two remotely piloted aircraft systems: the MQ-4C Triton high-altitude long-endurance RPAS for conducting intelligence, surveillance, and reconnaissance (ISR) missions and the MQ-9B SkyGuardian medium-altitude long-endurance armed RPAS for ISR and strike missions. These large-sized RPAS UAS are roled for Air Force to provide ISR and strike support to a JTF.

The Triton project is the biggest RPAS project at the moment. Acquired under a cooperative program arrangement with the U.S. Navy, Triton is the most modern iteration of the Global Hawk design but when the two designs are compared side-by-side, they're very different aircraft.

Another cool and exciting experimental ADF project is the Loyal Wingman – a $40 million investment in the Boeing Air Power Teaming System (BATS). This fighter-size aircraft has a similar performance range and speed to match a conventional crewed fighter aircraft, except that the BATS flight controls and mission are planned to be autonomously controlled by artificial intelligence (AI). WGCDR Joyce is excited that about 80% of the Loyal Wingman's development effort has occurred with Australian content. About 70% of the actual aircraft is designed, built, and assembled in Australia. This effort represents the ADF's first step toward developing a concept for air combat teaming between human and AI-controlled aircraft systems.

The AIAA Sydney Section is very grateful for the opportunity to have Wing Commander Joyce share his experiences and insights into the UAS/RPAS capabilities in the Australian military and their impacts on the broader interests and applications for drones and aerospace engineering. A video recording of this AIAA Sydney Section event is available for viewing on the Facebook and YouTube channels for the AIAA Sydney Section at **https://youtu.be/iO0hB1KrdwA**.

Society and Aerospace Technology Outreach Committee (SAT OC) Update

By Amir S. Gohardani, SAT OC Chair

In light of the many activities SAT OC has pursued during the past time period and the committee's ongoing efforts and upcoming plans, the SAT OC is delighted to share details about:

- SAT OC's art activities
- SAT OC's ongoing initiatives
- 2020 Gohardani Presentation Award
- SAT OC's planned contributions

Left: Ceremonial grand opening and book signing of Astronaut Al Travels to the Moon with (left to right) Ed Wilson (Emcee), Michelle Rouch, and Anthony Paustian, Ph.D. (Provost & Publisher).

Middle: Roland A Boucher, winner of the 2020 Gohardani Presentation Award in Aeronautics and Astronautics.

SAT OC Art Activities

The committee prides itself on the contributions of its members to the arts. Michelle Rouch, one of SAT OC's inspiring members, leads many such efforts and recently illustrated a children's book by Al Worden with Francis French, called *Astronaut Al Travels to the Moon*. After the book's release during CiLive, Rouch participated in Dayton's Festival of Flight in September to engage with the public and spark individuals' interest in aeronautics and astronautics while bringing to attention the power of the arts.

SAT OC Activities at AIAA Events

The interest in Society and Aerospace Technology has been substantial. SAT OC will lend support at the 2022 AIAA SciTech Forum and is coordinating the following tracks during 2021 ASCEND: Society and Aerospace Technology: History and Future, Society and Aerospace Technology: Societal Impacts.

2020 Gohardani Presentation Award

The Gohardani Presentation Award in Aeronautics and Astronautics was initially launched by the nonprofit Springs of Dreams Corporation. A key intent of this award is to celebrate presentation skills among those interested in aeronautics and astronautics. In partnership with the AIAA Orange County Section, this award is now presented to the most thought-provoking and exceptional all-around presentations delivered during the Aerospace Systems and Technology (ASAT) Conference. Awardees join a talented pool of presenters, including students, seasoned professionals, and rising stars in the aerospace sector, and are presented with a monetary prize and a certificate of excellence. The 2020 Gohardani Presentation Award was presented to **Roland A. Boucher**. Boucher holds a Bachelor of Science in Engineering with distinction from the University of Connecticut and a Master of Science in Engineering from Yale University. A licensed Professional Engineer with over 50 years of experience, Boucher began his studies of Ancient Measurements in 2013 and has presented his findings in oral presentations at national conferences of the American Association for the Advancement of Science, the History of Science Society, and AIAA.

SAT OC Is Working with History Committee

As we approach the AIAA Centennial in 2031, the History Committee has asked for AIAA groups to document their history, and SAT OC will be contributing a paper to this wonderful effort. The timely AIAA historical records are a valuable resource, and we encourage interested AIAA committees to contact Kevin Burns through the AIAA History Committee's website (aiaahistorycommittee.com) to arrange submission of papers. SAT OC appreciates the support of AIAA History Committee and looks forward to future collaborations.

2021 Best Professional and Student Technical Papers

AIAA technical committees (TCs) and integration and outreach committees (IOCs) have selected the best professional and student technical papers presented at recent AIAA forums. With a standard award criteria and selection process from the respective committees, the following technical papers were selected as the "best," and the authors were presented with a Certificate of Merit. The papers can be found online at the AIAA Aerospace Research Central (**arc.aiaa.org**), marked as "Best Paper."

BEST PROFESSIONAL PAPERS

2020 AIAA Adaptive Structures Best Paper Award
"Phase Transformation Characteristics of High-Temperature Shape Memory Alloy under Tension, Compression, and Bending Actuation Cycling" (AIAA-2020-2231) by Daniel Martin, Lei Xu and Dimitris Lagoudas, Texas A&M University

2020 AIAA Air Transportation Systems Best Paper Award
"Analysis of Fleet Management and Infrastructure Constraints in On-Demand Urban Air Mobility Operations" (AIAA-2020-2907) by Sheng Li, Stanford University; Maxim Egorov, Airbus; and Mykel J. Kochenderfer, Stanford University

2020 AIAA Atmospheric and Space Environments Best Paper Award
"An X-Ray Spectroscopic Approach to Remote Space Object Potential Determination: Experimental Results" (AIAA-2020-0049) by Kieran Wilson and Hans-Peter Schaub, University of Colorado, Boulder

2020 AIAA Atmospheric Flight Mechanics Best Paper Award
"Global Aerodynamic Modeling Using Automated Local Model Networks in Real Time" (AIAA 2020-0762) by Rose Weinstein, NASA Langley Research Center; James E. Hubbard, Texas A&M University

2020 AIAA Electric Aircraft Technology Best Paper Award
"A Study of Large Scale Power Extraction and Insertion on Turbofan Performance and Stability" (AIAA-2020-3547) by Jeffryes W. Chapman, NASA Glenn Research Center

2020 AIAA Electric Propulsion Best Paper
"A Predictive Hall Thruster Model Enabled by Data-Driven Closure" (AIAA-2020-3622) by Benjamin Jorns, Thomas A. Marks, and Ethan T. Dale, University of Michigan, Ann Arbor

2020 AIAA Energetic Components and Systems Best Paper
"New Formulation for Studying of Detonation Of Gaseous Energetic Mixtures II: CH_4/O_2 & CH_4/Air" (AIAA-2020-3653) by Lien C. Yang

2020 AIAA Fluid Dynamics Best Paper Award
"Node Numbering for Stabilizing Preconditioners Based on Incomplete LU Decomposition" (AAIA-2020-3022) by W. Kyle Anderson, Stephen Wood, and Kevin E. Jacobson, NASA Langley Research Center

2020 AIAA Guidance, Navigation and Control Best Paper Award
"Towards a Unified Model-Free Control Architecture for Tailsitter Micro Air Vehicles: Flight Simulation Analysis and Experimental Flights" (AIAA-2020-2075) by Jacson M. Olszanecki Barth, Jean-Philippe Condomines, Murat Bronz, Gautier Hattenberger, French Civil Aviation University; Jean-Marc Moschetta, Higher Institute of Aeronautics and Space; Cédric Join, Université de Lorraine; and Michel Fliess, École Polytechnique

2020 AIAA High Speed Air Breathing Propulsion Best Paper Award
"Adaptive Pressure Profile Method to Locate the Isolator Shock Train Leading Edge Given Limited Pressure Information" (AIAA-2020-3715) by Robin L. Hunt, NASA Langley Research Center; and Gregory J. Hunt, College of William and Mary

2020 AIAA High Speed Air Breathing Propulsion Best Paper Award
"Flow Choking Induced by Combustion and Mass Injection in a Circular Model Scramjet at Mach 4.5" (AIAA-2020-1611) by Damiano Baccarella, University of Tennessee, Knoxville; Qili Liu, Gyu Sub Lee, and Tonghun Lee, University of Illinois, Urbana-Champaign

2020 AIAA Hybrid Rockets Best Paper
"Combustion Efficiency in Single Port Hybrid Rocket Engines" (AIAA-2020-3746) by Greg Zilliac, NASA Ames Research Center; George T. Story, NASA Marshall Space Flight Center, Ashley C. Karp, Elizabeth T. Jens, Jet Propulsion Laboratory, California Institute of Technology; and George Whittinghill, Whittinghill Aerospace

2020 AIAA History Committee Best Paper Award
"Evolution of the Flight Crew and Mission Control Relationship" (AIAA-2020-1361) by Maya Nasr, Massachusetts Institute of Technology

2020 AIAA Intelligent Systems Best Paper Award
"Interactive Explanation of Entry, Descent, and Landing Simulations" (AIAA-2020-2094) by Samalis Santini De León and Daniel Selva, Texas A&M University; David W. Way, NASA Langley Research Center

2020 AIAA Liquid Propulsion Best Paper
"Lightweight Thrust Chamber Assemblies using Multi-Alloy Additive Manufacturing and Composite Overwrap" (AIAA-2020-3787) by Paul R. Gradl, Chris Protz, and John Fikes, NASA Marshall Space Flight Center; David Ellis and Laura Evans, NASA Glenn Research Center; Allison Clark, NASA Marshall Space Flight Center; Sandi Miller, NASA Glenn Research Center; and Tyler Hudson, NASA Langley Research Center

2020 AIAA Modeling and Simulation Best Paper Award
"A Model for Simulating Unsteady Wake Interference Effects in Aerial Refueling" (AIAA-2020-3202) by Peter A. Cavallo, Jeremy D. Shipman, and Michael R. O'Gara, Combustion Research and Flow Technology, Inc.

2020 AIAA Modeling and Simulation-Technologies Best Paper Award
"Retention of Manual Control Skills in Multi-Axis Tracking Tasks" (AIAA 2020-2264) by Rowenna Wijlens, Delft University of Technology; Peter M. T. Zaal, NASA Ames Research Center; Daan M. Pool, Delft University of Technology

2020 AIAA Multidisciplinary Design Optimization Best Paper Award
"Toward Predictive Digital Twins via Component-Based Reduced-Order Models and Interpretable Machine Learning" (AIAA-2020-0418) by Michael G. Kapteyn, Massachusetts Institute of Technology; David J. Knezevic, Akselos, Inc; and Karen E. Willcox, University of Texas, Austin

2020 Nuclear and Future Flight Propulsion Best Paper
"Mars Opposition Missions Using Nuclear Thermal Propulsion" (AIAA-2020-3850) by Christopher B. Reynolds, Claude R. Joyner II, Timothy Kokan, Daniel J.H. Levack, and Brian J. Muzek, Aerojet Rocketdyne

2020 AIAA Plasmadynamics and Lasers Best Paper Award
"Fully-Coupled Simulation of Plasma Discharges, Turbulence, and Combustion in a Scramjet Combustor" (AIAA-2020-3230) by Bernard Parent, Kyle M. Hanquist, and Ajjay Omprakas, University of Arizona, Tuscon

2020 AIAA Power and Energy Forum Best Paper
"Power Generation from Interplanetary and Interstellar Plasma and Magnetic Fields" (AIAA-2020-3537) by Matt Wentzel-Long, University of Missouri St. Louis/NASA Glenn Resarch Center; Geoffrey A. Landis, NASA Glenn Research Center

2020 AIAA Pressure Gain Combustion Best Paper Award
"RDC Operation and Performance with Varying Air Injector Pressure Loss" (AIAA-2020-0199) by Eric Bach, Christian Oliver Paschereit, Panagiotis Stathopoulos, and Myles D. Bohon, Technical University of Berlin

2020 AIAA Propellants and Combustion Best Paper
"High-Performance Data Analytics of Hybrid Rocket Fuel Combustion Data Using Different Machine Learning Approaches" (AIAA-2020-1161) by Charlotte Debus, Alexander Rüttgers, Martin Siggel, Anna Petrarolo, and Mario Kobald, German Aerospace Center (DLR)

2020 AIAA Sensor System and Information Fusion Best Paper Award
"Sensor Fusion with Censoring Limits" (AIAA-2020-0948) by Bethany L. Allik, Army Research Laboratory

2020 AIAA Shahyar Pirzadeh Memorial Award for the Outstanding Paper in Meshing Visualization and Computational Environments
"Comparing Unstructured Adaptive Mesh Solutions for the High Lift Common Research Model Airfoil" (AIAA-2020-3219) by Todd Michal, Joshua Krakos, and Dmitry Kamenetskiy, The Boeing Company; Marshall Galbraith and Carmen-Ioana Ursachi, Massachusetts Institute of Technology; Michael A. Park and W. Kyle Anderson, NASA Langley Research Center; and Frederic Alauzet and Adrien Loseille, National Institute for Research in Computer Science and Control (INRIA)

2020 AIAA Small Satellite Best Paper Award
"Simulating the Dynamics and Control of a Free-Flying Small Satellite with a Robotic Manipulator for 3D Printing" (AIAA 2020-1432) by Randy L. Spicer and Jonathan Black, Virginia Polytechnic Institute and State University

2020 AIAA Space Architecture Best Paper
"Future Space Architecture: Cross-Functional Multidisciplinary Design and Engineering" (AIAA-2020-4067) by Daniel Inocente, Colin Koop, and Georgi Petrov, Skidmore, Owings & Merrill LLP; Piero Messina and Isabelle Duvaux-Bechon, European Space Agency; Advenit Makaya, David Binns, David Brandao, and Robin Biesbroek, ESA, European Space Research & Technology Centre

2020 AIAA Spacecraft Structures Best Paper Award
"Integration, Test, and On-Orbit Operation of a Ka-band Parabolic Deployable Antenna (KaPDA) for CubeSats" (AIAA-2020-0933) by Jonathan Sauder, Nacer Chahat, Brian Hirsch, Richard Hodges, and Eva Peral, Jet Propulsion Laboratory, California Institute of Technology; Yahya Rahmat-Samii, University of California, Los Angeles; and Mark W. Thomson, Northrop Grumman Corporation

2020 AIAA Structures / Collier Research HyperSizer Best Paper Award
"Progressive Damage Failure Analysis of a Multi-Stringer Post-Buckled Panel" (AIAA-2020-1481) by Jason Action, Lockheed Martin Corporation; Frank A. Leone, NASA Langley Research Center; and Nelson Vieira De Carvalho, National Institute of Aerospace

2021 AIAA Aircraft Design Best Paper Award
"A Generalized Energy-Based Vehicle Sizing and Performance Analysis Methodology" (AIAA-2021-1721) by Imon Chakraborty and Aashutosh Aman Mishra, Auburn University

2021 AIAA Applied Aerodynamics Best Paper Award
"Improvements in Simulating a Mach 0.80 Transonic Truss-Braced Wing Configuration using the Spalart-Allmaras and k-ω SST Turbulence Models" (AIAA 2021-1531) by Daniel Maldonado, NASA Ames Research Center; Craig Hunter, NASA Langley Research Center; Jeffrey A. Housman, NASA Ames Research Center; Sally A. Viken, NASA Langley Research Center; Michael G. Piotrowski, NASA Ames Research Center; Susan N. McMillin, NASA Langley Research Center; Cetin C. Kiris, NASA Ames Research Center; and William E. Milholen, NASA Langley Research Center

2021 AIAA Gas Turbine Engines Best Paper
"Unsteady Body Force Methodology for Fan Operability Assessment under Clean and Distorted Inflow Conditions" (AIAA-2021-0388) by Amaury Awes, ISAE-Supaéro; Renaud Daon, Safran Group; Guillaume Dufour, Xavier Carbonneau, ISAE-Supaéro; Julien Marty, Raphaël Barrier, ONERA – The French Aerospace Lab

2021 AIAA Ground Test Best Paper Award
"Infrared Thermography on a Biconic Model in Hypersonic Expansion Tube Flows" (AIAA 2021-0873) by Timothy G. Cullen, Christopher M. James, Ranjith Ravichandran, Matthew Thompson, Michael E. Moran, Ranjini Ramesh, Richard G. Morgan, The University of Queensland; Thirukumaran Nadesan, National University of Singapore

2021 AIAA Inlets Nozzles and Propulsion System Integration Best Paper
"Propulsor Models for Computational Analysis of Aircraft Aerodynamic Performance with Boundary Layer Ingestion" (AIAA-2021-0991) by David K. Hall and Michael K. Lieu, Aurora Flight Sciences

2021 AIAA Survivability Best Paper Award
"Cislunar Debris Propagation Following a Catastrophic Spacecraft Mishap" (AIAA 2021-0102) by Nathan R. Boone and Robert A. Bettinger, Air Force Institute of Technology

2021 AIAA Thermophysics Best Professional Paper Award
"Characterization of Radiative Heating Anomaly in High Enthalpy Shock Tunnels" (AIAA-2021-0103) by Brett A. Cruden, Analytical Mechanics Associates, Inc.; Chun Y. Tang and Joseph Olejniczak, NASA Ames Research Center; Adam J. Amar, NASA Johnson Space Center; and Hideyuki Tanno, Japan Aerospace Exploration Agency (JAXA)

2021 AIAA/CEAS AeroacousticsBest Paper Award
"Supersonic jets with compliant wall nozzles" (AIAA-2021-1524) by Charles E. Tinney and John Valdez, University of Texas, Austin; Nathan Murray, University of Mississippi

BEST STUDENT PAPERS AND STUDENT PAPER COMPETITIONS

2020 AIAA Air Transportation Systems Best Student Paper Award
"Modeling, Assessment, and Flight Demonstration of Delayed Deceleration Approaches for Community Noise Reduction" (AIAA-2020-2874) by Jacqueline L. Thomas and R. John Hansman, Massachusetts Institute of Technology

2020 AIAA Applied Aerodynamics Student Paper Competition
"Experimental Analysis of Passive Bristling in Air to Enable Mako-Shark-Inspired Separation Control" (AIAA-2020-2768) by Sean P. Devey, Amy W. Lang, James P. Hubner, and Jackson A. Morris, University of Alabama, Tuscaloosa; and Maria L. Habegger, University of North Florida

2020 AIAA Atmospheric Flight Mechanics Student Best Paper
"Global Aerodynamic Modeling Using Automated Local Model Networks in Real Time" (AIAA 2020-0762) by Rose Weinstein, NASA Langley Research Center; and James E. Hubbard, Texas A&M University

2020 AIAA Hybrid Rockets Best Student Paper
"Enhancement of Fuel Regression Rate for Hybrid Rockets by Introducing Novel Coaxial Tube Injector" (AIAA-2020-3733) by Mehmet Kahraman and Ibrahim Ozkol, Istanbul Technical University; and Arif Karabeyoglu, Koc University

2020 AIAA Plasmadynamics and Lasers Student Paper Competition
"LIDAR Requirements and Approaches for Transcontinental Supersonic Flight" (AIAA 2020-3241) by Anuj Rekhi, Texas A&M University; Mikhail Shneider, Princeton University; and Richard B. Miles, Texas A&M University

2020 AIAA Power and Energy Forum Best Student Paper
"Development of a Deep Space Nuclear Electric Propulsion (NEP) System - a NuAER Plasma NEP Reactor" (AIAA-2020-3540) by Joseph Kalyan Raj I., Technion—Israel Institute of Technology; Geoff Parks, University of Cambridge

2020 AIAA Power and Energy Forum Best Student Paper
"Elements of an Inductive Electrical Power Conversion System for Fusion-Class Plasmas" (AIAA-2020-3539) by Nathan M. Schilling, Jason T. Cassibry, University of Alabama, Huntsville; Robert B. Adams, NASA Marshall Space Flight Center

2020 AIAA Space Architecture Best Student Paper
"Building with Celestial Bodies" (ICES-2020-508) by Tim Elrick, Wentworth Institute of Technology

2020 AIAA Walter Lempert Best Student Paper
"Electric Field Measurements in Atmospheric Pressure Plasmas By Ns and Ps Electric Field Induced Second Harmonic Generation" (AIAA 2020-0182) by K. Orr, The Ohio State University; Y. Tang, Tsinghua University; M. Simeni Simeni and D. van den Bekerom The Ohio State University; T. Butterworth and T. Orriere, King Abdullah University of Science and Technology; D.Z. Pai, Institut Prime; D.A. Lacoste and M.S. Cha, King Abdullah University of Science and Technology; and I. V. Adamovich, The Ohio State University

2021 AIAA Aeroacoustics Student Paper Competition
"Modelling the Suppression of Rotor-Alone Fan Noise with Over-Tip Rotor Liners and Comparison with Measurements from a High-Bypass Turbofan Rig" (AIAA 2021-2242) by Sergi Palleja-Cabre, Brian J. Tester, and R. Jeremy Astley, University of Southampton

2021 AIAA Applied Aerodynamics Student Paper Competition
"GSA-SOM: A Metaheuristic Optimization Algorithm Guided by Machine Learning and Application to Aerodynamic Design" (AIAA 2021-2563) by Alejandro González Pérez, Christian B. Allen, and Daniel J. Poole, University of Bristol

2021 AIAA David Weaver Thermophysics Best Student Paper Award
"Influence of Chemical Kinetics Models on Plasma Generation in Hypersonic Flight" (AIAA-2021-0057) by Pawel Sawicki, Ross S. Chaudhry, and Iain D. Boyd, University of Colorado, Boulder

2021 AIAA Flight Testing Student Paper Competition
"Performance Characterization of a Modern Gyroplane" (AIAA 2021-2799) by Jacob C. Dewey and Robert J. Niewoehner, U.S. Naval Academy

2021 AIAA Guidance, Navigation and Control Graduate Student Paper Competition Graduate Winners
1st Place: "Information-Based Guidance and Control Architecture for Multi-Spacecraft On-Orbit Inspection" (AIAA 2021-1103) by Yashwanth Kumar Nakka, California Institute of Technology

2nd Place: "Planetary Entry in a Randomly Perturbed Atmosphere" (AIAA 2021-1218) by Jack Ridderhof, Georgia Institute of Technology

3rd Place: "LSTM-Based Spatial Encoding: Explainable Path Planning for Time-Variant Multi-Agent Systems" (AIAA 2021-1860) by Marc Schlichting, University of Stuttgart

2021 AIAA Intelligent Systems Student Paper Competition
"Heterogeneous Fixed-wing Aerial Vehicles for Resilient Coverage of an Area" (AIAA 2021-1004) by Sachin Shriwastav, University of Hawai'i at Manoa

2021 AIAA Multidisciplinary Design Optimization Student Paper Competition
WINNER: "Coupled Aeropropulsive Design Optimization of a Podded Electric Propulsor" (AIAA 2021-3032) by Anil Yildirim, University of Michigan; Justin S. Gray, NASA Glenn Research Center; Charles A. Mader and Joaquim R. Martins, University of Michigan, Ann Arbor

RUNNER-UP: "Dynamic Topology Optimization of Battery Packs for eVTOL Aircraft Under Time-Dependent Loading" (AIAA 2021-3068) by Jiayao Yan, Mark Sperry, David Kamensky, and John T. Hwang, University of California San Diego

2021 AIAA Walter Lempert Best Student Paper Award
"Spatio-Temporal Studies on Laser Induced Plasma Interactions with Micro-Particles Using Stereo-Imaging" (AIAA 2021-1376) by Atulya U. Kumar, Boris S. Leonov, Yue Wu, and Christopher Limbach, Texas A&M University

2021 AIAA V/STOL Student Paper Competition
"Global Trajectory-tracking Control for a Tailsitter Flying Wing in Agile Uncoordinated Flight" (AIAA 2021-3214) by Ezra A. Tal and Sertac Karaman, Massachusetts Institute of Technology

2021 American Society of Composite Student Paper Award
"Effects of Fiber Non-Linearity and Matrix Type on the Realization of Foldable Structures" by (AIAA 2021-0086) by Arthur Schlothauer, Dominik Cueni, Georgios A. Pappas, and Paolo Ermanni, Swiss Federal Institute of Technology

2021 Harry H. and Lois G. Hilton Student Paper Award in Structures
"A Comprehensive Experimental and Computational Study on LVI induced Damage of Laminated Composites" (AIAA 2021-1623) by Shiyao Lin, University of Michigan, Ann Arbor; Vipul Ranatunga, Air Force Research Laboratory; and Anthony M. Waas, University of Michigan

2021 Jefferson Goblet Student Paper Award
"Geometrically Nonlinear High-fidelity Aerostructural Optimization for Highly Flexible Wings" by (AIAA 2021-0283) by Alasdair Christison Gray, University of Michigan, Ann Arbor/The Technical University of Delft, Holland

2021 Lockheed Martin Student Paper Award in Structures
"Folding of Flexible Hinges for Aircraft Wingtips and Wind Turbine Blades" (AIAA 2021-0204) by Aileen G. Bowen Perez, Giovanni Zucco, and Paul Weaver, University of Limerick

2021 Southwest Research Institute Student Paper Award in Non-Deterministic Approaches
"Probability-Damage Approach for Fail-Safe design Optimization under Aleatory Uncertainty (β-PDFSO)" (AIAA 2021-1480) by Clara Cid Bengoa, Aitor Baldomir, and Santiago Hernandez, Universidade da Coruña

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PANEL #1

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COLLEGE OF ENGINEERING

Multiple Open Rank Tenure-Track Faculty Positions

The Department of Aerospace Engineering at Auburn University invites applications for multiple **open rank tenure-track faculty positions (Assistant, Associate or Full Professor)**. Applications are invited in all areas related to aerospace engineering. Candidates are strongly encouraged to apply with expertise in: aerodynamics and propulsion; computational fluid dynamics; flight dynamics; and space systems and payloads. Candidates will be expected to fully contribute to the department's mission through (i) the development of a strong, nationally recognized, funded research program, (ii) teaching aerospace engineering related courses at both the undergraduate and graduate level, and (iii) professional service. Successful candidates will have a demonstrated track record of scholarship, a creative vision for research, an active interest in engineering education, and strong communication skills. For applications at the rank of Associate or Full Professor, an emphasis will be placed on the strength and caliber of the candidate's existing research program and the candidate's ability and desire to provide mentorship and leadership to a young, enthusiastic, and rapidly growing department. Candidates must have an earned Ph.D. in aerospace, mechanical engineering, or a closely related field at the time of employment.

Candidates should log in and submit a cover letter, CV, research vision, teaching philosophy, statement on diversity, equity and inclusion, and three references at **http://www.auemployment.com/postings/25090**. Cover letters may be addressed to: Dr. Brian Thurow, Search Committee Chair, 211 Davis Hall, Auburn University, AL 36849. To ensure full consideration, candidates are encouraged to apply before December 1, 2021 although applications will be accepted until the positions are filled. The successful candidate must meet eligibility requirements to work in the U.S. at the time the appointment begins and continue working legally for the proposed term of employment.

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JAHNIVERSE

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Surveillance Systems complex, where I was astrodynamics lead, and then to the Satellite Guidance, Navigation, and Control program at Kirtland Air Force Base in New Mexico, where I was a technical advisor. Instead of embracing debate like at JPL, debating was equated with making ad hominem attacks. To be sure, I met some excellent folks in the DoD and worked with quite a few of them whom I am proud to call peers and friends. But overall, I had difficulty achieving excellence in that culture.

One reason is that only someone other than yourself can bestow the mantle of technical excellence upon you, and that someone must have the freedom and even encouragement to challenge and refute your work. Some might call this academic or intellectual freedom, a required and healthy necessity for scientific and technical excellence. Another reason excellence was hard to attain was that some took advantage of security classification to shield themselves from full peer review. Classification became a way to hide their mediocrity or technical incompetence. Of course, I'm not the only one to recognize the problem of over classification. People with stars on their shoulders have bemoaned the problem too. I also know there is a real and substantiated need to protect and safeguard certain information and activities in the interests of national security. However, I lost count of the number of times meetings required a security clearance to attend when no need for classification actually existed. There was a knee-jerk response to simply classify everything just because this was easier than doing the work needed to properly evaluate what required the classification and what didn't. Also, I perceived a tendency to cloak things in a security classification because doing so gave a perception of relevance. To wit, there remains a sense within the DoD that if it isn't classified it's not relevant to the war fighter, which is not only wrong but has the negative consequences I describe here.

The United States is at a scientific and technological disadvantage because of over- or misclassification. Most of our smartest citizens don't have security clearances and never will. Just because something is unclassified doesn't make it irrelevant to our most dire national security needs. We must become allergic to this nonsensical perception. There are many non-military problems and use-cases that share analogous security needs and can be used to drive unclassified research, which can eventually be absorbed into rooms with no windows. Our country also needs to hire the required staff in order to evaluate information and resources more surgically instead of issuing blanket rulings for classifying things. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1921

1 **Nov. 3** A Curtiss CR biplane, designed and built for the U.S. Navy to compete for the Pulitzer Trophy, sets an absolute speed record of 176.7 mph (109.8 kph). The aircraft is flown by Curtiss test pilot Bert Acosta. David Baker, **Flight and Flying: A Chronology**, p. 141.

2 **Nov. 12** The first air-to-air refueling is accomplished when Wesley May steps from the wing of his Curtiss Jenny on to the wing of another plane and fuels this plane from a 5-gallon (19 liter) can of gasoline strapped to his back. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 14.

Nov. 15 The Italian airship Roma makes its first U.S. flight at Langley, Virginia. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 14.

Nov. 21 The D1, the first aircraft produced by Dewoitine, a French aircraft manufacturer that will produce a long line of military and civilian aircraft, completes its inaugural flight. Designed by Emile Dewoitine and built in Toulouse, the aircraft is a parasol monoplane powered by a Hispano-Suiza engine with a top speed of 250 kph. David Baker, **Flight and Flying: A Chronology**, p. 141.

Nov. 28 The National Advisory Committee for Aeronautics publishes Report No. 116, "Applications of Modern Hydrodynamics," by aerodynamicist Ludwig Prandtl of Germany who will become known as the father of modern aerodynamics. Another important contribution is his 1904 paper on boundary layers that will be translated into English and published in 1928 by NACA as Report No. 452. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 14.

1946

Nov. 9 The prototype of the Lockheed R6O Constitution, the world's largest transport airplane, completes its first flight, from its factory in Burbank, California. Built for the U.S. Navy and Pan American Airways, the double-decker aircraft is powered by Pratt & Whitney Wasp Major radial engines. The Constitution can carry 72 passengers in sleepers across the Atlantic, and double that number if the airplane stops at Bermuda for refueling or travels direct by day. While big and graceful, only two Constitutions will be built as service tests reveal it is underpowered and too large for existing commercial markets. **The Aeroplane**, Nov. 15, 1946, p. 562.

3 **Nov. 10** Stanford Moss, a pioneer turbine engineer, dies. His supercharger experiments, which were conducted at the end of World War I on Pike's Peak at 4,300 meters, led to the development of practical engine superchargers that enabled high-speed, high-altitude flight for fighters, bombers and airliners. **The Aeroplane**, Nov. 22, 1946, p. 611.

Nov. 18 British European Airways introduces former Luftwaffe Junkers Ju-52 3/m trimotor transports on its London-Liverpool-Belfast route. Operated for BEA by Railway Air Services, 11 Ju-52s were converted to carry passengers by Short & Harland of Belfast. The aircraft will fly until 1948. David Baker, **Flight and Flying: A Chronology**, p. 312.

4 **During November** The two-seat Sikorsky S-52 helicopter is unveiled. It is the first production helicopter equipped with all-metal blades. A Franklin air-cooled engine drives the three-bladed main rotor. **The Aircraft Year Book, 1946**, p. 266.

1971

Nov. 1 Robert Gilruth, director of NASA's Marshall Spaceflight Center, suggests that the Apollo 18 mission scheduled for April 1974 be used to map the moon from polar orbit and that the Lunar Module be converted into a "massive scientific experiments bay." However, NASA will cancel Apollo 18, mainly due to budget cuts, and the Apollo program will conclude with the Apollo 17 mission of Dec. 7-19, 1972. **Aviation Week**, Nov. 1, 1971, p. 15.

Nov. 3 Fairchild Industries agrees to purchase Swearingen Aircraft, manufacturer of the Metro turboprop commuter airliner. Fairchild will provide $3 million of working capital to Swearingen until a subsidiary is formed. **Wall Street Journal**, Nov. 3, 1971, p. 17.

Nov. 4 Despite commenting that the design is too "industrial," the National Capital Planning Commission approves plans for the new National Air and Space Museum in Washington, D.C. Museum director and former astronaut Michael Collins, noted for his role as the command module pilot in the Apollo 11 mission, counters that the design reflects the "flavor of air and space." **Washington Post**, Nov. 5, 1971, p. A14.

Nov. 4 The U.S. Navy completes the first launch of its new two-stage solid-fuel Poseidon submarine-launched ballistic missile from a surfaced submarine. The Poseidon is the United States' second SLBM after Polaris. The test is conducted from the submarine Nathanael Greene, stationed 16 kilometers east of Cocoa Beach, Florida, and is observed by a Soviet fishing trawler nearby. **Washington Post**, Nov. 5, 1971, p. A5.

5 **Nov. 7** Hughes Aircraft announces the start of production of its Maverick air-to-surface missile under a $69.9 million U.S. Air Force contract. The missile is designed to destroy tanks and other armored equipment. **New York Times**, Nov. 7, 1971, p. 57.

Nov. 8 The first Lockheed S-3A Viking is rolled out at the company's Burbank, California, factory. Powered by two General Electric TF34 turbofan engines, it is designed for ship-based antisubmarine warfare. The Viking is slated to replace the Grumman S-2 Tracker operated by the U.S. Navy. R. Francillon, **Lockheed Aircraft Since 1913**, pp. 455-460.

Nov. 12 The discovery of diamonds in a 1.4-kilogram meteorite that fell through a storehouse roof on the Finnish island of Havro on Aug. 2 is announced by the Smithsonian Center for Short-Lived Phenomena. This is the sixth such meteorite to be found. **Washington Post**, Nov. 12, 1971, p. A36.

6 **Nov. 13-15** NASA's Mariner-9 spacecraft, launched on May 30, enters orbit around Mars, becoming the first human-made object to orbit another planet. The spacecraft immediately begins to transmit photographs of the Martian surface, although a violent dust storm temporarily obscures the images. Mariner 9 will orbit Mars twice daily for three months and photograph 70% of the planet. It will also send back the first detailed photographs of Deimos and Phobos, the two Martian moons. **New York Times**, Nov. 14-16, 1971.

Nov. 15 An Italian team launches NASA's Explorer 45 from the San Marco platform off the Kenyan coast. The spacecraft, designed to study the Earth's ring current, is placed into orbit by a four-stage solid-propellant Scout booster. **NASA Release 71-212**.

Nov. 15 Intersputnik, the international space communications organization, is formed under an agreement signed in Moscow by the Soviet Union, Bulgaria, Hungary, East Germany, Cuba, Mongolia, Poland, Romania and Czechoslovakia. **New York Times**, Nov. 17, 1971, p. 9.

Nov. 23 Commercial pilot Elgin Long becomes the first person to fly solo over the North and South poles during one journey. Having flown over the North Pole earlier in the month in his twin-turbo prop Piper Navaho, Long then flew 5,632 kilometers in 19 hours from Puntas Arenas, Chile, over the South Pole and landed at a U.S. Navy station at McMurdo Sound in Antarctica. **New York Times**, Nov. 23, 1971, p. 48; **Washington Post**, Nov. 23, 1971, p. B3.

Nov. 27 A capsule ejected by Soviet probe Mars 2 into the atmosphere of Mars becomes the first human-made object to reach the Martian surface. However, the capsule crashes on Mars when the lander descent module malfunctions and the parachute fails. **New York Times**, Dec. 1, 1971, p. 20.

1996

Nov. 7 The Mars Global Surveyor is launched on a Delta 2 rocket from Cape Canaveral, Florida. It is the first spacecraft in an international program to establish a permanently orbiting observatory of Mars. The spacecraft is designed to map the minerals and climate of the planet. It also will relay data from the Russian Mars 98 landers and other spacecraft. **Aviation Week**, Nov. 11, 1996, pp. 22-24.

Nov. 19 After significant delays, NASA launches STS-80, the last space shuttle mission for 1996, from the Kennedy Space Center. The crew of space shuttle Columbia releases the Orbiting Retrievable Far and Extreme Ultraviolet Spectrometer to make up to 300 astronomical observations. NASA, **Astronautics and Aeronautics, 1996-2000**, pp. 43-44.

Nov. 27 Agila 1 (Eagle 1, also known as Palapa B2P), the first Filipino satellite, is launched on a U.S. Thor Delta. **Filipino Today**, December 1996.

Nov. 29 A refurbished Russian Tupolev Tu-144LL supersonic transport takes off from Zhukovsky Airfield. The jet, which had been taken out of commercial service in 1978, was modified by Tupolev and U.S. companies including Boeing, Lockheed and General Electric to participate in NASA's High-Speed Research Program. The Tu-144LL is intended to study the effects of high-speed flight on airframes and engines as well as the potential commercial market for supersonic jets. NASA, **Astronautics and Aeronautics, 1996-2000**, pp. 43-44.


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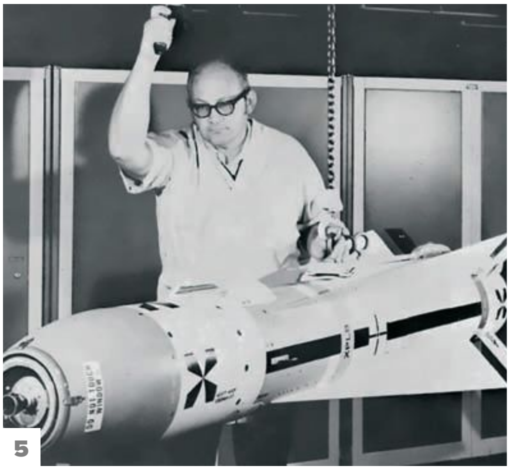
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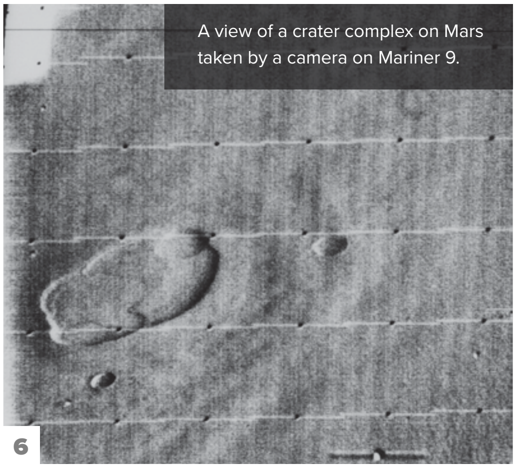
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A view of a crater complex on Mars taken by a camera on Mariner 9.

Hiding behind classification

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If you are a scientist or technologist, you are only as good as someone's ability to refute your work. That should be a motto echoed and embraced the world over. The outcome of peer-review must be excellence derived by welcoming scrutiny. Otherwise, peer review risks devolving into a method for cleverly disguising mediocre scientific work, a risk that's especially high in the U.S. national security community with its classification requirements.

My first encounter with the right kind of peer review was at NASA's Jet Propulsion Laboratory, arguably humanity's leader in robotic space exploration. I began my career there as a spacecraft navigator in 1999, the year when the loss of the Mars Climate Orbiter and Mars Polar Lander showed a need for improved peer review. I recall many times when my own work in understanding and predicting orbital trajectories to Mars was spiritedly debated and argued against by my peers and fellow navigators. Standing by a whiteboard or projection screen, I would be challenged about my assumptions, whether there were any caveats, about the validity of this or that, why I did not account for certain factors and why I did things the way I did.

The experience was never one of comfort, and I've since learned that growth requires us to sit in our discomfort. In fact, doing so is a sign that growth is possible. The conclusion of my technical immolation was always positive bias and measured progress toward excellence as a navigator. JPL demanded excellence from me, and I never knew I had it in me to be so. I still get emotional when I think on this, because I was that kid who marveled at the work and papers of those whom I later worked alongside and got to earn the right to call my peers. Peer review made this possible.

My time at JPL gave me confidence. While working full time there, I performed doctoral research centered on exploiting in-situ inertial measurement unit data as a means to automate aerobraking operations. I knew I would need to defend the resulting dissertation back at the University of Colorado in Boulder, and I came to realize I was ready to earn the three letters that today trail my name. I went back to Boulder and defended my dissertation.

In my next career adventure, starting in 2006, I encountered a marked cultural difference that reminded me of oil and water. Having learned how excellence was achieved at JPL, I brought this perspective and methodology with me to the Air Force Research Laboratory's Maui Space

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