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AEROSPACE
★ ★ ★ AMERICA ★ ★ ★

Space traffic at a crossroads

The U.S. Commerce Department wants its plan for preventing smashups in space to unfold in a step-by-step fashion. Is there time for that? PAGE 32

NOVEMBER 2023 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

AIAA
SHAPING THE FUTURE OF AEROSPACE

NASA's X-59 demonstrator was moved from the hangar at the Lockheed Martin Skunk Works' facility in Palmdale, California, in June for the next phase of ground testing. The agency now plans to fly X-59 in 2024, about three years behind the original target.

Lockheed Martin

ON THE COVER: An artist's rendering of the night sky and two orbiting objects crossing paths.

AEROSPACE AMERICA

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IN THIS ISSUE

Keith Button

Keith has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns hedge fund blowup that kicked off the global credit crisis. He is based in New York.
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Jonathan Coopersmith

Jonathan is an historian of technology and former professor at Texas A&M University in College Station who has written about the failures of 20th century space commercialization. He has a doctorate in history from the University of Oxford. PAGE 10

Moriba Jah

Moriba is a space environmentalist, associate professor at the University of Texas at Austin and chief scientist at Privateer. He helped navigate spacecraft at NASA's Jet Propulsion Lab and researched space situational awareness issues at the U.S. Air Force Research Laboratory. PAGE 64

Pat Host

Pat is an award-winning Washington, D.C.-based journalist covering the aerospace and defense industries. He has written about fixed-wing piloted aircraft, helicopters, uncrewed aircraft and space for Janes and Inside Defense Defense Daily. PAGE 40

Aaron Karp

Aaron has covered the aviation business for 20 years, including as managing editor of Air Cargo World and editor-in-chief of Aviation Daily. He remains a contributing editor to the Aviation Week Network.
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Jon Kelvey

Jon previously covered space for The Independent in the U.K. His work has appeared in Air and Space Smithsonian, Slate and The Washington Post. He is based in Maryland.
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Paul Marks

Paul is an award-winning journalist in London focused on technology, cybersecurity, aviation and spaceflight. A regular contributor to the BBC, New Scientist and The Economist, his current interests include electric aviation and innovation in new space.
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DEPARTMENTS

AD INDEX

In this issue: space traffic to net-zero, with lunar paving in between

Our cover story, "Mastering space traffic management," (page 32) shows just how complicated it's going to be to commercialize space traffic management through the U.S. Office of Space Commerce. The article gives insight into the thorough planning that's going into making this transition from what is today a Space Force responsibility to a mainly civilian responsibility. As you'll see in the story, the industry is not entirely united around every aspect of the transition plan, but that's not a weakness. Speaking up is likely to make the transition stronger. On a related topic, this month's Jahniverse column, "Orbital occupation: a colonialist behavior needing reversal," (page 64) draws on current organizational mission statements and history to make the case that Earth orbit should not be available only to the strongest nations and corporations.

On the topic of cleaner air travel, a signal emerging through our reporting, including in this issue, is that achieving a net-zero carbon footprint by 2050 is going to be difficult given the development and certification timelines for new aircraft and the need to vastly increase the supply of sustainable aviation fuels derived from renewable bio products. What is the best shot for achieving net-zero by that date? Well, the world's two leading airliner manufacturers, Airbus and Boeing, have diametrically opposed views about that. In this issue, we take you "Inside Boeing's net-zero vision," which centers on aerodynamic innovations, more fuel-efficient engines and a transition to sustainable aviation fuels. Those following along will recall that in the September issue, "A Manhattan Project for the Climate," (page 26) we dug into the technical and resource challenges of developing hydrogen-powered aircraft, a strategy that's at the heart of Airbus's vision. We are going to stay tuned on this one and the feasibility of the 2050 goal.

Speaking of aerodynamic and propulsion innovations, we also set out to learn whether there is any softening of NASA's faith in X-planes and demonstration aircraft, given that it has yet to fly any since announcing in 2016 what was then known as the New Aviation Horizons Initiative. In "NASA stands by its X-planes" (page 40), I think you'll see a transparent NASA articulating the value it still sees in such efforts and explaining why it's been challenging to get flying.

On military matters, this month's Engineering Notebook article, "Up next in commercialization: Hypersonic testing," (page 16) takes us inside Stratolaunch's planning to become a testing service provider. I do mean "inside" literally. Our staff writer, Paul Brinkmann, visited Mojave while in the area to cover an air taxi event, and our contributor Keith Button dove into the technology side remotely.

Let's not forget about the moon. We came up with our "R&D" mini-feature page to look at far-reaching ideas for which hands-on research is underway. "Paving the moon" (page 9) is a good example.

Overall, this issue of the magazine represents a breadth of coverage we strive to achieve each month. ★

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

More on the "Manhattan Project" analogy

Excellent article in the September issue by Paul Marks on "A Manhattan Project for the climate." Being both an aerospace and history "geek," I must point out the Manhattan Project was eclipsed in cost by another vital wartime project, the Boeing B-29. Quoting the National WWII Museum website: "The B-29 would not only require a significant amount of American aviation production capacity but would eventually become the nation's single largest military expenditure of the war: With the Manhattan Engineer District (MED) costing the American taxpayer $2 billion, the B-29 program far surpassed that figure with a price tag of $3 billion."

The two programs were linked in that the Manhattan Project would not have been militarily successful without the B-29 to serve as the aerial delivery system.

In relation to the article, the Manhattan Project developed the "energy source," while the B-29 program developed the aircraft. To keep that analogy, the "Manhattan Project" part of building a hydrogen aviation ecosystem would be to develop the energy infrastructure that would supply the fuel with the "B-29 Program" part to be the development of aircraft to utilize hydrogen. In this case, unlike World War II, the green hydrogen energy infrastructure development will far outstrip the cost and time to market of new aircraft.

Keep the insightful articles coming!

R. Steven Justice, AIAA Fellow
Tyrone, Georgia

LET US HEAR FROM YOU

Send letters of no more than 250 words to letters@aerospaceamerica.org. Your letter must refer to a specific article and include your name, address and phone number (Your address and phone number won't be published).

A Launching Pad for Emerging Aerospace Professionals

AIAA is the place where emerging aerospace professionals can get their start. Whether a student in grade school, high school, or university, or pursuing advanced degrees, AIAA can enable a meaningful career journey. The AIAA Foundation is an inspiring and invaluable part of a student's experience.

The work of the Foundation over the past 25+ years has inspired a new generation of aerospace professionals. Every day we strive to impact students where their aspirations begin and to reach educators where their inspiration begins. Through the Foundation we make funding available for STEM education programs, providing hands-on experiences that spark students' curiosity about space, nurture their passions around STEM topics, and move them along a journey from the classroom into their career.

Understanding the impact of the Foundation through stories is powerful. My own AIAA story began almost 40 years ago at the AIAA Student Branch at North Carolina State University. Since then, I've been honored to lead the Institute as its president (2020–2022) and serve as the chair of the AIAA Foundation today. My career has been enabled by AIAA. I also have been pleased to support the Foundation, along with my late father, by establishing a graduate scholarship in the aerospace program he helped start at North Carolina State University, the Dr. Hassan A. Hassan Graduate Award in Aerospace Engineering. After his death, I doubled the impact of his scholarship by making a donation to add an extra recipient.

The story of the AIAA Foundation this year is best told by major impacts made through outreach, student and educator involvement, and investment:

- 644 university students attended the seven annual AIAA Regional Student Conferences
- 58 university students participated in the Diversity Scholars Program at 2022 ASCEND, 2023 AIAA SciTech Forum, and 2023 AVIATION Forum
- 2,565 university students participated in hands-on competitions: AIAA Design/Build/Fly and Design Competitions
- $100,000 was awarded to university students in scholarships and graduate awards
- $75,000 was awarded to K-12 educators as grants and awards

In addition, the Foundation has made an impact through its partnerships this year:

- The ExGen program – in partnership with AIAA Corporate Member Estes Rockets and the National Science Teaching Association (NSTA) – provides K-12 educators with free, engaging classroom-ready lessons and curriculum storylines to help immerse students in real-life applications of STEM while exploring various concepts in aerospace, engineering, and rocketry and has impacted 540,000 K-12 students.
- Students To Launch (S2L) – in partnership with First Light, Griffin Communications Group, and Oregon State University – inspires middle and high school students with the wonders of space. With a focus on those in underrepresented and underserved communities, S2L invites students from across the country to engage in NASA mission-inspired events – from hands-on afterschool activities to attending rocket launches at NASA Kennedy Space Center and has impacted 21,888 middle school students.

The Foundation Board is looking at additional opportunities and partnerships to help broaden the reach of our mission. I invite you to read more stories about the impact of the AIAA Foundation at **aiaa.org/foundation**.

An Invitation to the 2023 AIAA Foundation Day of Giving

We each have a special opportunity this year to write the next chapter of the story of the Foundation by making a financial contribution.

The Foundation will participate in the nationally recognized Day of Giving on 28 November. Our goal is to inspire the possibilities of the future. Please consider how you might make your mark on our profession. I hope each of you will join me in contributing toward our goal of raising $75,000 to develop the next generation of aerospace leaders. The AIAA community includes more than 30,000 members. Just think what we could accomplish if each of us made some contribution, even a small one. If you do the math, with a majority of us making a $10 investment, we can blow past our goal and make a massive impact!

More now than ever, I believe that AIAA's future is bright. With your generosity, the AIAA Foundation will continue supporting students and teachers, inspiring more young people to launch an aerospace career with the support of AIAA. ★

Basil Hassan
AIAA Foundation Chair
Connect with me on LinkedIn

AERO PUZZLER

Email us at aeropuzzler@aerospaceamerica.org

Coaxial conundrum

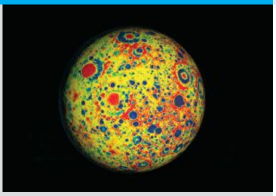
Q: True or false and why? The top and bottom rotor blades of a coaxial helicopter are separated vertically by a good distance for one simple reason: Designers can't risk the blades contacting each other when they flex.

SEND A RESPONSE OF UP TO 250 WORDS that someone in any field could understand to aeropuzzler@aerospaceamerica.org by noon Eastern Nov. 10 for a chance to have it published in the next issue.

Scan to get a head start on the December AeroPuzzler

FROM THE OCTOBER ISSUE

DOES MASS MATTER TO MEASURE MASS?



We asked you whether the spacecraft of the Gravity Recovery and Interior Laboratory mission had to have the same mass to do their job of measuring variations in lunar gravity. There was no winner this month, so we asked scientist Michael Watkins, who co-conceived the concept behind GRAIL and similar gravity-mapping missions, to explain:

"From the perspective of gravity alone, the satellites actually didn't have to match in mass. Here's why: When the mass of a satellite is very small compared to the mass of the central body like the moon, then the effect of gravity on them is essentially the same regardless of their mass. This idea was proposed by Galileo, but beautifully shown by Apollo 15 Commander David Scott when he dropped a hammer and feather on the moon and they landed at the same time.

Therefore, when the lead GRAIL spacecraft passed over an unusually massive interior feature, it was affected the same way as the trailing spacecraft even if the masses were different.

Aside from gravity, though, the satellite's motions were also affected by non-gravitational forces like solar radiation pressure, which are sensitive to the area to mass ratio, and of course, it is generally less expensive to build two nearly identical spacecraft than two very different ones. So, in the end, the spacecraft were close in mass, but not really due to gravitational effects."

Paving the moon

BY PAUL MARKS | paulmarksnews@protonmail.com

▲ Researchers melted simulated lunar regolith via a laser to form triangular tiles (upper left). The work at the Technical University of Clausthal in Germany was part of a European Space Agency project that aims to determine whether such tiles could be interlocked to form pads for launching and landing lunar spacecraft, as well as roads on the lunar surface, shown in this rendering.

Federal Institute of Materials Research and Testing and Liquifer Systems Group

Lunar colonists in the 2030s could witness a rover traversing the surface and pausing to hold a large lens close over the moonscape, a beam of hot light emanating straight downward. The sight would mean that early experimentation at a lab in Germany last year, described in an October scientific article, ended up paying off.

The goal of the European Space Agency-funded experimentation, done by 13 researchers, was to take the first small steps toward someday assembling a solar concentrator on the moon to melt regolith into two kinds of infrastructure: landing-launch pads and roads.

With the moon potentially becoming a busy construction site, the researchers aim to prevent landers and rovers from kicking up clouds of pestiferous lunar dust. In low g, the abrasive, electrostatically charged particles would become suspended above the surface and get into everything — potentially causing mechanical clogging, electrical hazards and spacesuit degradation.

Melting regolith into tiles might prevent such dust-ups. The work so far has been led by materials engineers Juan Carlos Ginés Palomares and Miranda Fateri at Aalen University near Stuttgart, and Jens Günster of the Federal Institute of Materials Research and Testing in Berlin.

In mid-October, the trio published early results in the journal Nature Scientific Reports. To develop the technique, the team needed to determine which light intensity and beam width best melts regolith, then formulate rules for what kind of shapes could be created. In early 2022, they began eight months of experimentation at a lab at the Technical University of Clausthal, south of Hanover, Germany. An ESA-developed lunar regolith simulant was poured into a tray-shaped crucible. The researchers did not have a rover, lens or access to atmosphere-free sunlight, so they elected to move the crucible beneath a carbon dioxide laser fired at different power levels and beam widths.

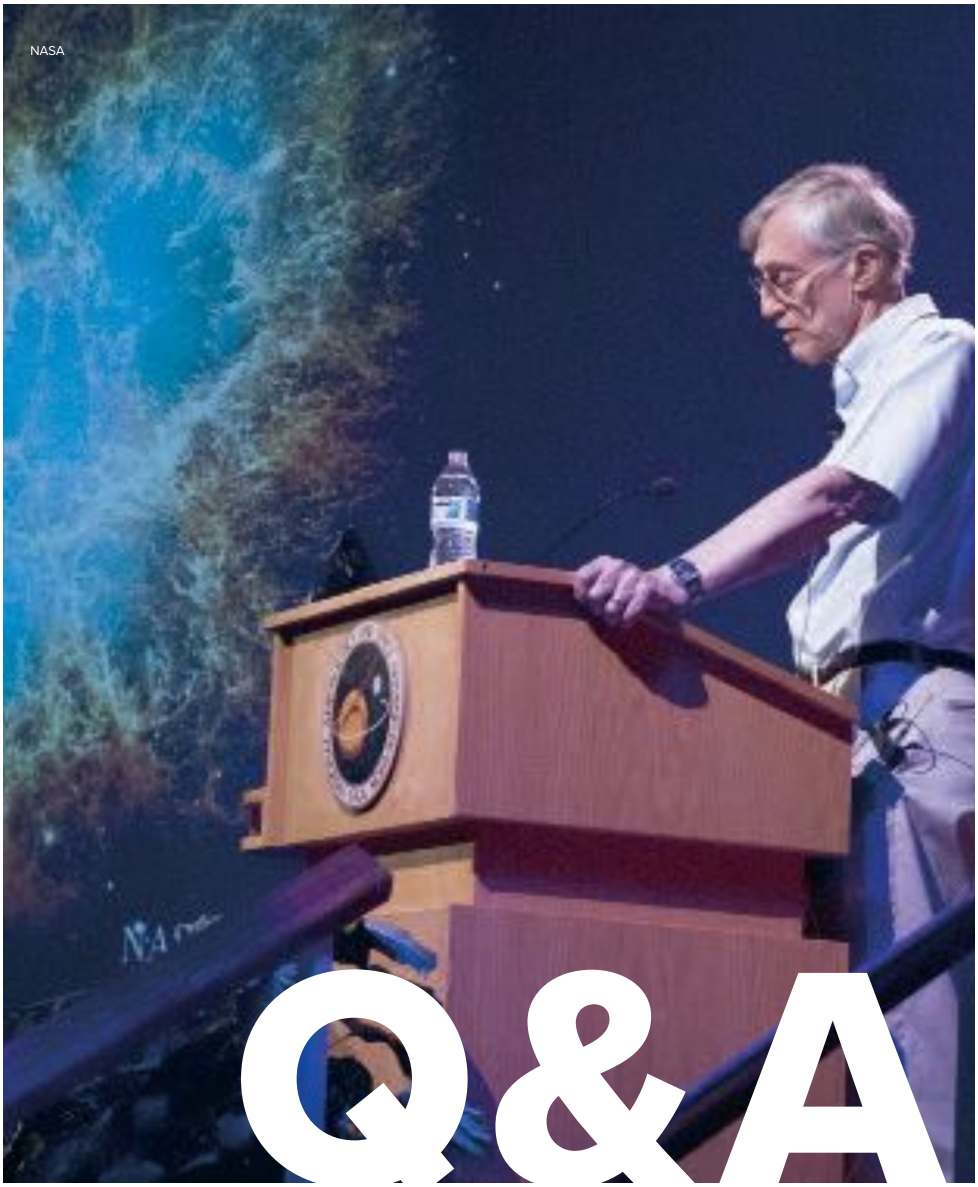
At first, they tried overlapping a fresh laser track slightly with the edge of a previous one, but that resulted in the older track cracking. Eventually, they concluded that a triangular shape, holed in the middle, evaded cracking while permitting dense interlocking.

The best melting performance was achieved at a laser power level of 3 kilowatts with a beam width of 45 millimeters. They calculated that a 2.4-meter-surface-area Fresnel (pronounced fruh-NEL) lens would be best, given its thin, concentric, annular sections can focus light with less material than a conventional lens.

"We propose the use of our simple lens system on the moon, with fewer components that can fail, and for the direct use of solar energy with no need to convert it into electricity with all its associated losses," says Ginés Palomares.

More work lies ahead, particularly on the topic of tile resiliency, following the decimation of a launch pad in Texas by a Starship-Super Heavy rocket earlier this year. "The launch pad is a very sensitive structure, and the structural requirements must be properly calculated," says Ginés Palomares.

Of course, Earth is not the moon, so there is reason for optimism. "On the moon, we have the advantage of its lower gravity, which facilitates launches from there," he adds. ★



Instrument maker for the stars

When John Mather stepped down as top scientist for NASA's James Webb Space Telescope in June, one might have assumed it was to enjoy a well-deserved retirement. The agency that month celebrated one year of observations with Webb, whose development Mather oversaw for nearly 30 years at Goddard Space Flight Center in Maryland. It wasn't always smooth going: Originally slated to be launched in 2010 at a cost of just under a billion dollars, Webb's projected cost rose to $9.7 billion by the time of its launch on Christmas Day 2021, including the first five years of operations. Mather has no regrets. Not only was the extra cost and development time "absolutely worth it," he says, he will spend the next phase of his career conceiving of future, cutting-edge telescope designs with which NASA might plumb the other secrets of the universe. I visited him outside Washington, D.C., to discuss some of these ideas and the projects that have defined his career. Here is our conversation, compressed and lightly edited for clarity. — *Jonathan Coopersmith*

JOHN MATHER

POSITIONS: Since 1974, astrophysicist at NASA's Goddard Space Flight Center in Maryland. In June, he stepped down as senior project scientist for the James Webb Space Telescope, a role he'd held since 1995, to study designs for future Earth-space hybrid observatories that NASA could pursue. 1976-1998, study scientist and then project scientist for NASA's Cosmic Background Explorer, or COBE, satellite. 1974-1976, led the scientific proposals for COBE.

NOTABLE: Co-author of "The Very First Light," a 1996 history of cosmology written with science writer John Boslough. For 25 years starting in the mid-1990s, led the NASA and industry teams that defined the Webb telescope's science objectives and chose the instruments that receive light from its mirrors, among other tasks. In 2006, received the Nobel Prize in physics with George Smoot for confirming the Big Bang theory via their measurements of cosmic microwave background radiation with the COBE satellite. With his Nobel prize money, established the John and Jane Mather Foundation for Science, which since 2008 has provided funds to ballet students (in honor of his wife, Jane), and also about 200 summer interns at NASA Goddard to attend professional conferences and present papers.

AGE: 77

RESIDENCE: Hyattsville, Maryland

EDUCATION: Bachelor's degree in physics, Swarthmore College, 1968; doctorate in physics, University of California at Berkeley, 1974.

Q: How did growing up in rural New Jersey with parents who had science and teaching backgrounds shape you?

A: I grew up on a research farm of Rutgers University, a mile from the Appalachian Trail. There wasn't much to do except think and play with science toys.

The research farm he refers to was a plot of land owned by Rutgers as part of its Agricultural Experiment Station. Mather's father, an agricultural science statistics professor, conducted studies about milk production and other aspects of the dairy industry. — JC

I read Scientific American about projects you could do. I grew up thinking that the great adventure of science was to think of a way to measure something or build some equipment that could measure something. Now, looking back on it, I call myself a theoretical instrument builder.

"I grew up thinking that the great adventure of science was to think of a way to measure something or build some equipment that could measure something."

Q: A couple years into studying physics in grad school, you switched focus. How did you choose a new subject?

A: I got kind of tired of thinking; I needed to be more social. I needed to be in a laboratory building something with my hands with people, because it is lonely just sitting in a library writing into the night. So when it was time to look for a thesis project, I ran around and talked to faculty. Paul Richards, Charles Townes and Michael Werner were looking to measure the cosmic microwave background radiation. The cosmic background had just been discovered in 1965, and this was 1970. It's the beginning of the subject: Only a few measurements had ever been done. So I joined their group, and my thesis project was an attempt to measure the cosmic background radiation spectrum with a balloon-borne payload that my thesis adviser had conceived. I and two other graduate students and some engineers in the faculty built this apparatus, and we took it to Texas and launched it. It didn't work properly, so we didn't get to write a thesis about a working project, but it was clearly a breakthrough concept.

Q: That led to a job offer at NASA. How did you go from a postdoc to the chief scientist for the Cosmic Background Explorer satellite?

A: At the Goddard Institute for Space Studies, I was happy to get to work with Patrick Thaddeus, a quite famous molecular radio astronomer but also quite familiar with cosmic background radiation studies. In 1974, NASA put out a call for proposals asking for new satellite mission ideas. I said, "Hey boss, my thesis project failed. We should try it in space." You could measure the spectrum of the radiation much better because we could have a perfect calibrator — a blackbody object — that would radiate exactly the same way the cosmos is supposed to radiate. This was something you could never do with a balloon-borne payload. We were also after the map of the anisotropy, the hot and cold spots. If you could measure that from space, you could do it without interference from the atmosphere and get the entire sky. Then we said, "We should also add an experiment to measure the infrared from the most distant galaxies, because we don't know how bright they are." I thought our proposal would never go anywhere, but a few months later, NASA gave us some money to study this. The idea was to make a small spectrometer that would fit in the top of the IRAS [Infrared Astronomical Survey] satellite. After a while, it was clear that wasn't a good fit, but we thought maybe NASA would really be interested in the whole mission that we'd proposed. So in 1976, I came to Goddard Space Flight Center with a hope that the project would actually go. Since it was sort of my idea, people said, "OK, run with it." I spent every day talking to engineers and thinking, "How can we possibly do this?" We were pushing far beyond the state of the art. For the cryogenic instruments, we had to learn how to build equipment that would work at a temperature of

▲ John Mather shown in 2016 in front of the primary mirror for the James Webb Space Telescope. The 6.5-meter-diameter mirror comprises 18 hexagonal segments, made of beryllium and coated in a microscopic layer of gold to reflect incoming infrared light toward the telescope's scientific instruments.

David Friedlander/NASA

1.4 Kelvin, surrounded by liquid helium in its own tank. Everything changes when it gets cold: Metals change a little bit; some of them disintegrate. You cannot lubricate with oil because it will become solid, and controlling the temperature of something is very tricky in a vacuum. Electronic parts do not work. You have to invent detectors that have to be the very best. We got lucky because the Hubble telescope was behind schedule and over budget. NASA headquarters said, "We're going to slow down COBE. What would you do if you have longer time?" We found new technology: more sensitive microwave radiometers.

Two concepts were key for COBE: For the spectrometer experiment, we must have a calibrator that simulates the sky as the universe would have done it. It's called a blackbody and is shaped like a trumpet mute. You move it into the antenna to substitute for the incoming sky radiation. If they match, then you have confirmed the expanding universe story. You had to be in space to do that. Second, for the radiometers to measure the microwave hot and cold spots, we do it with a differential device. A single receiver has two antennas and a little switch that goes back and forth a hundred times a second. The upshot is there's a signal at 100 hertz, which represents the difference in brightness between the two antennas. We're going to spin the spacecraft in all possible orientations and end up with a list of hundreds of millions of measurements of differences of brightness between two spots on the sky. A computer program reassembles a map of the sky based on hundreds of millions of differences. It's easy to explain, hard to implement.

Q: How did COBE shape later projects you worked on, like Webb?

A: Goddard learned how to do big projects, but also how hard it was. For instance, almost every cold test of a part for COBE had to be done over. We learned how tedious it is because you can only do these cold tests inside giant vacuum tanks, which have their own procedures and cycle time. It might take you months to repeat a test that has failed, so I have to plan for that. We learn how to do it at the technical basis. We developed our knowledge base and also developed the people. So when we got the chance to work on other missions that required low temperatures, we say, "That's hard, but we're not intimidated."

Q: It's not impossible any longer.

A: That's a phrase I often say nowadays: "It's not impossible." That's my job, to pursue what is not impossible.

Q: When you began Webb in 1995, how would you have responded if you knew it wouldn't launch until 2021 and cost not $800 million but nearly $10 billion?

A: I would have said it's absolutely worth it. There's no other way to get this information. If you want to know how those galaxies grew, you have to build this equipment. NASA Administrator Dan Goldin was a reason we were able to pursue the segmented telescope design. He knew it was possible to have a telescope with a bigger diameter than your rocket fairing because he'd been working on those things for TRW in the black [classified] area. They knew they needed them — and not for astronomy. Although astronomers might wish to think that we are pure of heart, we are using the equipment we couldn't have if not for the military. So when Goldin urged us to find a way to do something "faster, better and cheaper," we worked on it. The upshot from my perspective was that we would need organizations that combined all of the parts in one place as much as possible to streamline the activities. In actuality, you can't accomplish that, so we negotiated contributions from Europe and Canada and the United States. Coordinating all that is a massive challenge, but you can't streamline something that's got so many moving parts. Also, you can't easily say, "That's too hard, let's cut back." If you want something faster, it's not going to be as good. And with a project of this scale, it's very difficult to make changes without affecting the science objectives. You cannot. You're going to need four wheels on your car. You cannot just say, "We'll skip that."

Q: If you really want to do major science, you need to take that big step.

A: Clearly, if we had started off from the beginning to build a 4-meter-diameter telescope that could have fit inside a rocket without unfolding the telescope itself, we would have aimed at that, and it would have been cheaper.

Mather is referring to the original proposal for what became the Webb telescope, published by astronomers in the 1995 report "HST and Beyond." — JC

The instrument package might have still cost several billion dollars. It wouldn't have suddenly become an easy project; it would have just become a weaker project. So in the end, I think we decided well to do what we did. One of the big discussions early on was the wavelength range Webb should cover, and that was challenging because we weren't sure what this telescope was going to see when it peered back toward the cosmic dawn. One point of view said, "We know the early universe doesn't have any dust in it, so you don't need the cryogenic detectors to see the early universe." Other people said, "Well, actually you don't know that. Maybe the early universe is dusty." And sure enough, Webb has found that it's pretty dusty. You need what we now call the mid-infrared channels from 5 to 28 microns to tell what are those little fuzzy dots going and doing. So we started 25 years ago designing something that would be launched far in the future, and now we have a predicted life of something like 25 years. Are you planning for 50 years of operation when you know what you're going to look for? Maybe not. Maybe it's better to have a general-purpose toolkit. That is what we have: a general-purpose collection of instruments that can basically take images and spectra from 0.6 microns up to 28. It's ready for anything. We didn't include things we thought you could possibly do from the ground or were just too hard. That has to be put off to another generation.

Q: What was too hard?

A: When we started designing Webb, planets had just been detected around other stars. We certainly want to see them, but we did not have and still do not have the coronagraphic technology ready so you could see an Earthlike planet around a star like the sun. We said, "We'll do a best effort, an elementary version and hope for the best." We do see some planets with Webb, but only big, bright ones. We are doing transit spectroscopy — that is, waiting for the moment when a planet goes in front of its star and blocks the starlight. If the planet has an atmosphere, then some starlight goes through the atmosphere of the planet on its way to the telescope, and we look for that part. There's not very much of a signal there, but there's some. I think we had about 60 planets to examine during Webb's first year of operation. The big bright ones do have atmospheres, and you can tell what's in them. We're still working on the coronagraph technology, and there's an immense payoff for getting it right. We have no idea whether our solar system history is representative or unique. The current thinking is that solar systems like ours are unusual. Most stars have small planets. That doesn't tell us what we need.

▲ In its first year of observations, the James Webb Space Telescope has shown astronomers that the early universe was "pretty dusty," Mather says. In this composite released in June to commemorate Webb's one-year anniversary, pale yellow dust and interstellar gas partially obscures the Rho Ophiuchi cloud complex, a star-forming region near Earth. The dark red is molecular hydrogen, which shoots out in jets when young stars burst through the dust.

NASA, ESA, CSA, STScI, Klaus Pontoppidan (STScI)

Q: We're living by Enrico Fermi's paradox.

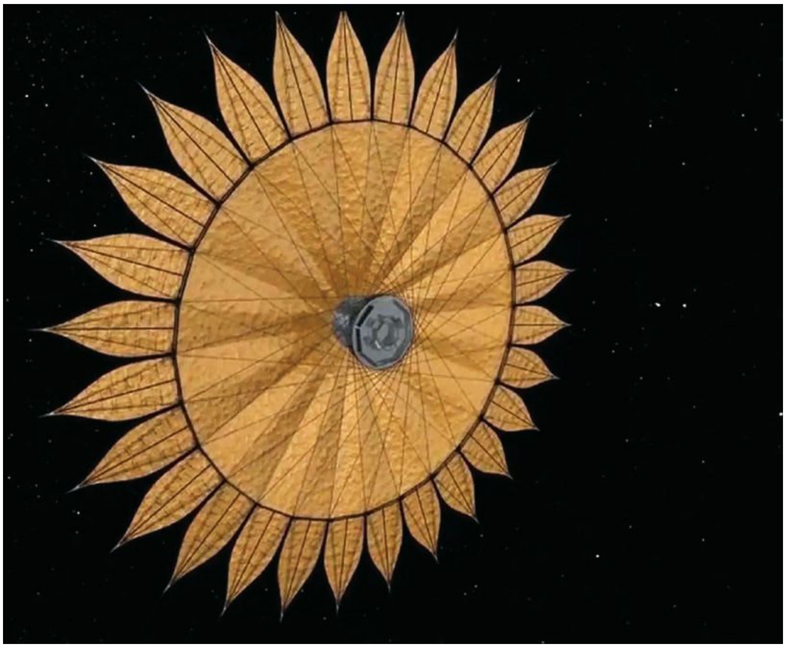
A: I don't actually think it's a paradox. If they're out there, why aren't they here? And I think the answer is pretty simple: It's too damn far, and there is no such thing as warp drive. Therefore, they're not here. Even if they want to be here, they can't be here.

Q: So you're not a member of the UFO fan clubs and secret government cover-ups?

A: Being a member of the government, I can't imagine keeping a secret that big that long. That's not our job to keep secrets. Our job is to find things and publish them. That's my perspective anyway.

Q: Switching gears, your projects have been the subjects of multiple independent review boards that often made blunt assessments. In hindsight, were those valuable?

A: They're a kind of reality check. It's good to have them, even if they're unpleasant for the participants. The people sending the money need to know they can trust us, and the people doing the project need to know we didn't make any mistakes that are big. It's quite unusual for a panel to discover something not already known to the participants, but once in a while, you need the review panel to explain this to the boss. It's a way of insulating against the mentality, "Well, why don't you just try it? It might work." My history



▲ Mather's current endeavor involves studying hybrid observatories, one form of which would combine a ground telescope with a starshade like the one in this artist's concept. These massive structures would be deployed in orbit to block light from host stars. Telescopes would then observe the planets revealed by blocking the light to see if the atmospheric composition suggests habitability.

NASA/JPL-Caltech

with projects is if you do not test it, it will not work. It's not a matter of chance. One of the interesting questions, though, is "How much testing is enough?" There are few things where you cannot test them the way that they're going to be operated. But you can't do everything; you can't do zero-gravity here [on Earth]. That's a good time to get your experts together and have them imagine all the things that could go wrong. It leads to our discussion of risk management. If we didn't have a formal risk management process, it would be hopeless because my fellow human beings and me especially are pretty ready to take a chance when we shouldn't be. When you're building a space mission and spending the public money, it's not just risk to yourself. It's a matter of risk to a whole agency or a whole nation or a whole future of science. So we have to go have a discussion and make sure that we fully understand all of those risks and what we might do to ameliorate them.

Q: How can future missions balance generating wild ideas that do important science while not exceeding budgets and timelines?

A: Picture a sort of idea factory with tens or hundreds of brilliant things coming up, people working on them, and gradually the ideas get more mature until you can tell which one might win. Sometimes it's a formal process where you ask prospective contractors to tell you how they would do it, and you select the best one. As to how we decide which wild ideas get picked, it's not exactly a democratic process, but it's not "We did this because the old guy wanted us to." It's "We did it because the community put in their best effort to write good proposals, and they were evaluated carefully and fairly." We always are cranky when we lose, and most of us lose most of the time. But once in a while we win, and it's worth it because the whole community of science and the whole world gets to see what we do.

Q: For big projects like Webb, NASA relies heavily on Decadal Surveys to recommend the top priority at a given time. Does this approach still work, even when the big flagships take more than 10 years to develop?

A: The decadal has demonstrated its value very well. The virtue of having a giant National Academies report is it shows the people that have money we know what we need to do. If you're a legislator on Capitol Hill, you do not want seven different astronomy projects saying, "Me, me, me." It's one of the ways astronomy has made so much progress, not only for space stuff, but on the ground as well. Ten years seems to be about a right cadence to me, even though big projects like giant telescopes take more than 10 years to build — some of them 20 to 30 years.

Q: Now that you've stepped back from Webb's day-to-day operations, tell me what you'll be working on.

A: I'm working on hybrid observatories, which combine something like a telescope on the ground with something orbiting in space. I started with a 2018 idea I had for an orbiting starshade that cast a shadow of a star onto a telescope on the ground. We are getting a 39-meter-diameter ground telescope in Chile built by Europe.

He's referring to the Extremely Large Telescope under construction at the European Southern Observatory on top of the Cerro Armazones mountain. — JC

If you could get a starshade to work with it, you could get a snapshot of a solar system in a minute. It has not yet gotten far beyond the "it's not impossible" stage, but I'm still working on it with NASA. We have some ideas to make it much lighter and cheaper, which would be essential. Then, we spun off the orbiting guide star, which would enable adaptive optics for telescopes on the ground to get images as sharp as in space. That's the ORCAS concept, proposed in 2019 that had as part of it a calibrator body.

Short for Orbiting Configurable Artificial Star, the ORCAS concept was submitted by Mather and colleagues for consideration in the 2020 astronomy and astrophysics decadal. The National Academies did not select it as a priority for development in the 2020s. — JC

◀ The Cosmic Background Explorer, or COBE, satellite is assembled in a clean room at NASA's Goddard Space Flight Center in preparation for its 1989 launch. Mather is the co-recipient of the 2006 Nobel Prize in Physics for his observations with COBE, whose measurements of cosmic background radiation confirmed the Big Bang.

NASA/COBE science team

"That's a phrase I often say nowadays: 'It's not impossible.' That's my job, to pursue what is not impossible."

We spun that calibrator off as a separate idea and got some support from NASA to build a standard light bulb for measuring how bright the stars really are. Another idea is extending the Event Horizon Telescope and measuring the spin of black holes, which you can do if you get an orbiting antenna to work with the EHT. They're all pretty cool ideas.

The Event Horizon Telescope is an array of eight radio telescopes located around the world to study black holes and other astronomical phenomena. Linked together to create an Earth-sized interferometer, EHT began operations in 2009, and in 2019, EHT researchers published the first picture of a black hole. — JC

Q: On a personal note: As a lifelong scientist, what are your thoughts on the future of education?

A: People want to know what to teach the kids and how to teach the kids. Clearly, it's a major challenge for us to get good science in front of the kids. I worked on a National Academies committee to outline "A Framework for K-12 Science Education," which was published in 2012. The report did a couple of interesting things. It said, "Evolution should be taught as science. Climate change should be taught as science." I wanted to make sure that we say, "And you can do something about it." They also included for the first time engineering as something that students should learn, so people who like to build things also get some attention in school. Although I love pure science, maybe many or most people will not. But being able to say you can build something, that's much more tangible. I want kids to be curious. So please, let us have students learn from touch, learn from coaching, learn from doing. Let's play these as sports, as they are really team sports. The fact that we now include something about engineering and constructing things is a reminder that it's not always about the principles of things. Engineers and scientists are building things that are going to solve problems. ★

UP NEXT IN COMMERCIALIZATION:
HYPERSONIC TESTING

Stratolaunch, owner of the world's largest aircraft, plans to start flying a reusable hypersonic testbed from this plane in a bid to remake itself as a provider of services to the U.S. Defense Department and others. After a brush with insolvency and four years of development, the first test flight is at hand. Keith Button and Paul Brinkmann tell us about the technology.

BY KEITH BUTTON | buttonkeith@gmail.com
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Stratolaunch's "Talon-A 0" flew for the first time in October 2022. In this captive carry flight, TA-0 was flown over the Mojave Desert attached to the company's massive Roc carrier aircraft. During an operational flight, a Talon would fire its engine after being released from Roc's center pylon, then glide back autonomously to make a runway landing. Stratolaunch

Under a blue sky and the treeless expanse of the Southern California high desert, a massive carrier plane sits on a tarmac. Even without the bright sun glinting off its white exterior and dual fuselages, the aircraft easily draws the eye due to its wingspan of 117 meters. On this September day, various panels in the plane's airframe were open for ground checks, but most of the surrounding engineers and technicians were focused on something else: a smaller vehicle attached to the center pylon. It's the first in a series of test vehicles that Stratolaunch LLC is counting on to prove the technical side of its new business model of selling hypersonic flight-testing services.

Four years ago, the approach of such a test flight appeared unlikely. Originally conceived as a launcher of small satellites, Stratolaunch was left rudderless by the death of founder Paul Allen of Microsoft fame in 2018, six months before the carrier plane flew for the first time. This aircraft was built at nearby Scaled Composites to carry up to three satellite launch vehicles between those fuselages — hence its name, Roc, a mythical bird in Arabian fairy tales that carried an elephant in its talons. Releasing the rockets and their payloads in the stratosphere meant that a smaller, less expensive rocket could do the job of getting them to orbit, and this was supposed to give Stratolaunch an edge in the competition for launch contracts.

Instead, by mid-2019 the company was on the brink of shutting down, which would have relegated its giant, twin-fuselage aircraft to a curiosity of history as the largest aircraft by wingspan ever to fly. At this time, Stratolaunch started pondering a shift toward hypersonic testing services, a decision that was finalized months later when the company was acquired by billionaire Steve Feinberg's private equity firm, Cerberus Capital Management, well known for resurrecting distressed companies. Under Cerberus, one of the first steps Stratolaunch took was to hire Aaron Cassebeer, a longtime engineer at Scaled Composites. Cassebeer was tasked with building a team of engineers, now about 75, and a reusable, rocket-powered flying testbed that would make those testing services possible: Talon-A.

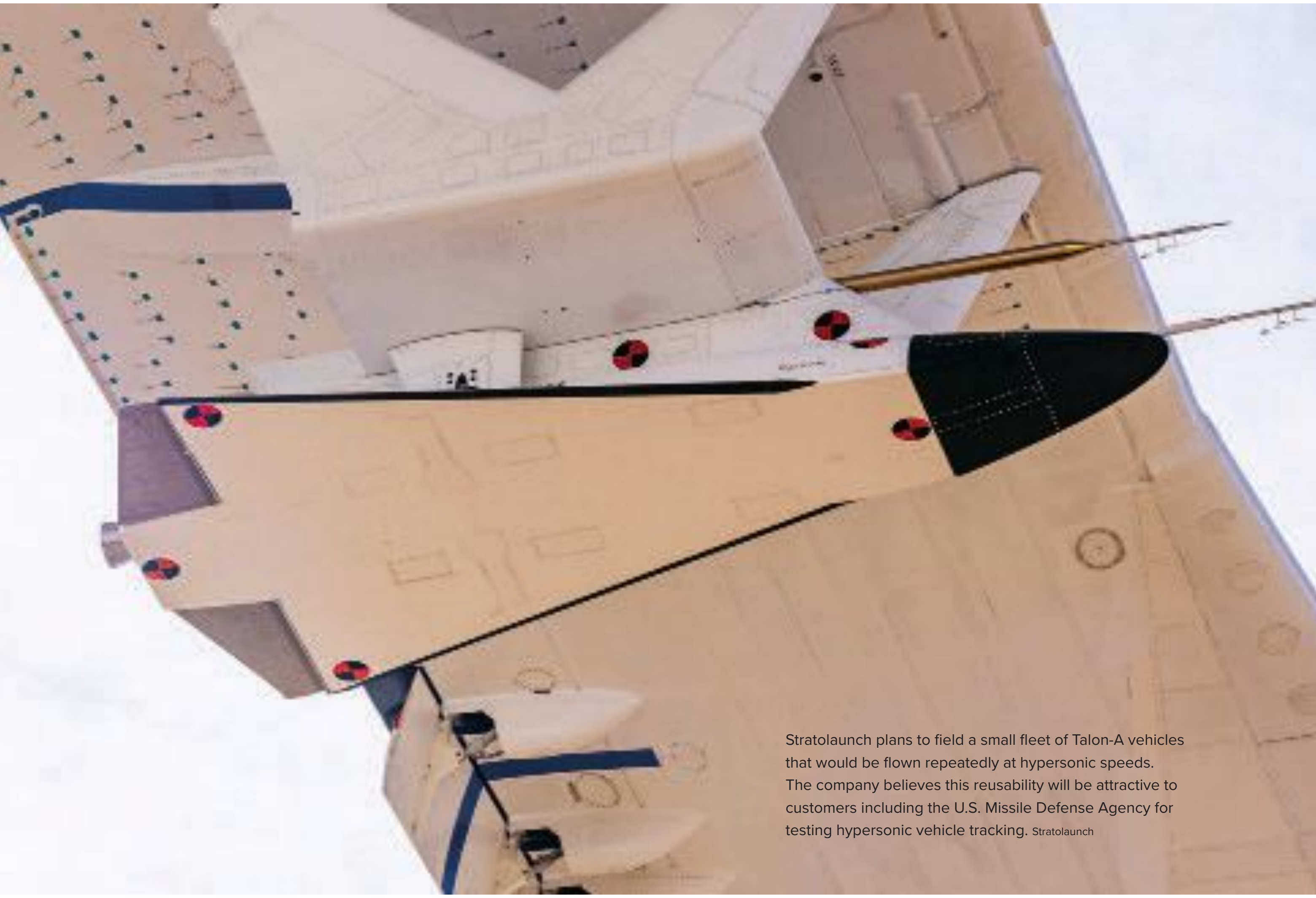
While Stratolaunch isn't saying exactly when, plans call for releasing the first test vehicle, TA-1, from Roc over the Pacific Ocean before year-end to prove that the design can achieve hypersonic speeds. Another prototype, TA-2, is scheduled to be launched in early 2024 to prove that the design will be able to autonomously navigate and land at Vandenberg Air Force Base on three wheels.

It took an accelerated development program that drew lessons from hypersonic craft throughout history to get to this test period on schedule.

Cassebeer, who at Scaled Composites specialized

▲ Stratolaunch has four Talon test vehicles in various stages of production at its facility in Mojave, California. At front is the "Talon-A 0" vehicle with which the company completed captive carry flights and a separation test. Behind it is TA-1, which will be used for the first powered flight, and TA-2. In the back is the Talon-A System Mockup, a test article used for verification and training. The TA-3 craft is not pictured here.

Stratolaunch



Stratolaunch plans to field a small fleet of Talon-A vehicles that would be flown repeatedly at hypersonic speeds. The company believes this reusability will be attractive to customers including the U.S. Missile Defense Agency for testing hypersonic vehicle tracking. Stratolaunch

FACT

STRATOLAUNCH IS ACQUIRING the modified Boeing 747 that Virgin Orbit, which filed for bankruptcy in April, had planned to launch rockets from. This second carrier plane would allow Stratolaunch to fly Talon-As simultaneously in two locations, such as over the Pacific test range and on an East Coast range, or potentially in Australia, says CEO Zachary Krevor.

in rapidly designing prototype planes, was given one year to design and start building the Talon-A prototypes. There were at least two interrelated reasons for the big rush. One was demand for hypersonic testing by the U.S. government and its contractors; the second was China's and Russia's purported hypersonic weapon capabilities, which was driving U.S. demand. In 2018, Michael Griffin, then under secretary of defense for research engineering, testified to the U.S. Senate Armed Services Committee that China was conducting 20 times as many hypersonic flight tests vehicle tests as the U.S. and had fielded or was close to fielding hypersonic missiles that could strike U.S. aircraft carriers thousands of kilometers away. The U.S. had no hypersonic weapons that could counteract them.

"It is among my very highest priorities to erase that disadvantage," he told the committee.

Stratolaunch believes a small fleet of Talon-As can help the U.S. catch up.

"Our country is able to fly on the order of a handful of hypersonic flights a year successfully, and where the government would like to go is: They would like to be flying a flight every week; every seven days they'd like to have a hypersonic flight occurring in this country," Cassebeer says. "The last vehicle that flew hypersonically often with a major flight test campaign — we're talking hundreds of flights — was the X-15" in the 1950s and 1960s.

Reusing Talon-As could also reduce the costs of individual flights. A single hypersonic test flight by the U.S. government can cost between $60 million and $100 million, says Zachary Krevor, Stratolaunch CEO, while Stratolaunch expects to offer test flights for "single-digit millions" of dollars. The company also anticipates demand from companies developing civilian hypersonic aircraft for crew and cargo transportation.

"We can go Mach 3 to Mach 6, so we can fly a lot of different and operationally relevant trajectories and flight paths," Krevor says. "Flying a variety of different Mach numbers and dynamic pressures is what the hypersonic community cares about."

Among the first orders of business was to figure out what materials to build their aircraft from and how to protect it from heat. Cassebeer dreamed of becoming a Formula One race-car engineer before choosing a career in prototype aircraft design. He also honed an ability to assess risk in his aerospace decision-making through his pastime of technical rock climbing, which has included ascents of El Capitan and Half Dome in Yosemite National Park, California. As with other engineering decisions for Talon-A, the top priority in making the material decisions was the schedule — designing and building the aircraft quickly to get customers quickly.

"While they may prefer that we can fly faster and for a longer durations, they will take flying in the first place," Cassebeer says. Cost and technical performance were priorities Nos. 2 and 3.

Thermal protection materials for Talon-A would need to hold up for as many as 20 flights without melting at hypersonic velocities, meaning greater than Mach 5 and faster than any bullet. Even for a short flight, the friction of an aircraft moving through the air at hypersonic speeds can generate temperatures of 500 to 1,100 degrees Celsius, hot enough to eliminate common metals in aviation from consideration.

"If you were to put a stainless steel material or a steel material into that environment, it's going to be glowing orange and yellow. If you were to put an aluminum material in that flight environment, it's going to melt; it won't even exist," Cassebeer says. "It really puts you into a situation as an engineer where you have to go to higher- and higher-performing materials."

They considered thermal materials flown in hypersonic programs dating to the late 1950s. "Ideally, we wanted to choose materials that had already been developed in the past. We never wanted this vehicle to be the experiment itself," Cassebeer says.

Three X-15s, the piloted rocket-powered aircraft that were flown 199 times by the U.S. Air Force and NASA from 1959 to 1968, were covered with a skin of Inconel, a nickel-chrome superalloy. NASA's two unpiloted, expendable X-43As, the first hypersonic aircraft powered by airbreathing engines, each flew once in 2004 and were protected by a covering of composite carbon-carbon ceramic tiles; they dropped into the Pacific Ocean after their flights and were not recovered. The Air Force's X-51As, also unpiloted with air-breathing engines, collected nine minutes of data during hypersonic flights from 2010 to 2013 while employing a silica-based material for thermal protection and ceramic tiles similar to those on NASA's space shuttle orbiters. Flight controllers destroyed one X-51A after it stopped transmitting during a test flight; another was lost because of faulty control fin; the other two flew into the Pacific Ocean.

For Stratolaunch, the best option proved to be the thermal protection materials from the shuttle program, along with decades of engineering, manufacturing, and research and development data that NASA shared with the company via a Space Act Agreement. By early 2020, Cassebeer had chosen the "latest and greatest" of the thermal protection material installed on the shuttles over the years: the black ceramic tiles that were visible on the underbellies of orbiters coming in for landing; and a blanket material with a white surface coating, Felt Reusable Surface Insulation, which is the white covering on the shuttles.

For the Talon-A airframe — the internal structure — Cassebeer had to choose a material that could hold up for repeated flights under the aerodynamic loads of hypersonic speeds, provide a mounting structure for components carried inside the vehicle, and also adhere to the heat-protection materials on the surface. Metals employed in previous hypersonic and general aviation aircraft were considered, such as aluminum,

FACT

TALON-A'S DELTA-WING SHAPE was created in 2019, before the Cerberus acquisition of Stratolaunch, by staff engineers who thought it could be a business opportunity for the company.

▲ In preparation for the first powered flight of a Talon, Stratolaunch in May tested the Roc carrier plane's release mechanism by dropping the propulsionless "Talon-A 0" test vehicle over the Pacific Ocean. Telemetry was gathered and, as intended, TA-0 crashed into the sea and was not recovered.

Stratolaunch/Ethan Wagner

Inconel alloys, stainless steel and steel options, and titanium. But Cassebeer decided early in 2020 to build the airframe from carbon fiber composite — not for its superior strength relative to the metal options, but for speed.

"It was the fastest possible way for our team to rapidly design and manufacture an airframe to go do these flights," he says. Metal airframes, on the other hand, require longer lead times for tooling and setting up their assembly, plus they're more difficult to modify once that assembly process has been set. On the plus side, it's easier to mass produce airframes from metal. "If we had been designing a system that we expected to build 100 or 1,000 of the Talon-A, it's very possible that we would have chosen a different path," he says.

The airframe was built in Mojave from layers of resin-impregnated carbon fiber textiles that were hand-laid into forms, bagged and vacuum pumped, and hardened in an oven. Acquiring the composite materials and tools for a single prototype and designing it took weeks, compared to months or years that would have been required to set up production for a metal airframe and then fabricate it.

Talon-A's carbon fiber composite airframe can be easily modified or repaired — to add reinforcement to a specific part of the structure, for example. Stratolaunch took a "concurrent design-build" approach, Cassebeer says, meaning that engineers started building parts of the aircraft while still making adjustments to its design. By continuously evaluating the airframe design, they made changes as it was being built.

Even with NASA's voluminous data about the shuttle's thermal protection materials, Stratolaunch was missing a key piece of information: How would those materials be attached to Talon-A's carbon composite airframe? On the shuttle orbiters, the thermal protection materials were glued to their aluminum airframes, but Talon A's airframe would be carbon composite. The bond would need to hold up over dozens of flights, Cassebeer says.

The engineers tested potential adhesives. They glued pieces of ceramic tile to fist-sized samples of the carbon composite airframe material, then set each glued sample in a load frame to pull from both sides of the bond and measure how much force it took to pull it apart. They also repeated the test across a range of temperatures, up to 175 Celsius — the maximum temperature that the carbon composite airframe was expected to be exposed to. If the ceramic tile broke before the adhesive bond did, the bond was a success.

> **“IDEALLY, WE WANTED TO CHOOSE MATERIALS THAT HAD ALREADY BEEN DEVELOPED IN THE PAST. WE NEVER WANTED THIS VEHICLE TO BE THE EXPERIMENT ITSELF.”**
>
> **— Aaron Cassebeer, Stratolaunch**

The adhesive that won out was unexpected (a common material that Cassebeer declined to identify for proprietary reasons). Meanwhile, an adhesive that the engineers thought would be their choice “ended up falling on its face” for a different reason: It was strong enough but dried too fast.

“Imagine building a model aircraft or car, and the glue dries two seconds after application, and you have almost no time to put two pieces together,” he says.

Flash forward to present day: The challenging hypersonic test flights are still to come, but Cassebeer and company are getting closer. In late 2022, they flew their first hardware, TA-0, a propulsionless version of Talon-A that was clasped in Roc’s center pylon during a series of captive carry flights. And in May, Roc carried and released TA-0 to fall into the Pacific Ocean. This “separation release test,” as Stratolaunch calls it, was the first test toward the business plan that calls for flying versions of Talon-A repeatedly on a variety of missions for customers. Currently, the company has four Talon-As built or partially built, including one ready for flight. Stratolaunch also plans to modify the aircraft if needed between flights or build a new version with a design change if that’s necessary to accommodate a customer’s in-flight experiment.

Some customers will test electronics carried inside Talon-A — either as payloads or as avionics controlling its flight; others will want their test items on the aircraft’s surface to experience the hypersonic flight conditions there. “Think about materials, instrumentation, windows, optical seekers, things of that nature,” Krevor says. That could require engineers to modify the Talon-A fuselage or nose cone, for example, or make other changes that weren’t considered in the original design.

“We can make modifications to our thermal protection system or even the underlying airframe structure,” Cassebeer says, “and we can integrate new technologies of payload into the vehicle in very interesting ways, which sometimes require some surgery.”

Potential customers have already expressed interest in testing modified versions of Talon-A, says Krevor. Some may want to try alternate nose shapes, or an airflow experiment on the bottom surface of the aircraft, or alternate rudder shapes. Other potential customers, such as the U.S. Missile Defense Agency and Space Development Agency, may want to test their hypersonic missile or space vehicle tracking capabilities with Talon-A.

As for speed and endurance, Stratolaunch expects Talon-A to eventually fly at Mach 6, remaining in hypersonic flight for at least two minutes. A launch could be done every week.

In the nearer term, Stratolaunch has booked customers to fly their tests aboard TA-1 — the first hypersonic flight targeted for later this year. That Talon is to crash into the Pacific Ocean after being released from Roc, and none of the hardware onboard will be recovered.

“That highlights the real demand and need in this country for hypersonic flight testing,” Krevor says, and also, perhaps, hypersonic bargain-hunting: He notes that the first-flight customers will get a “screaming deal.” ★

INSIDE BOEING'S NET-ZERO VISION

BY AARON KARP | aaronkarp74@gmail.com

The two companies that manufacture the vast majority of the world's airliners, Airbus and Boeing, have diametrically opposed visions about the kind of aircraft and fuels that will be required if the air transport industry is to achieve net-zero carbon emissions by 2050. In our September issue, we took a close look at Airbus' vision, "A Manhattan Project for the climate." Now, Aaron Karp looks at Boeing's thinking.

Joe Sutter, Boeing's lead engineer for designing and developing the 747 in the 1960s, had some advice regarding new aircraft programs: "Take stock before charging out of the gate."

Boeing appears to be heeding the late engineer's suggestion — relayed in Sutter's 2006 book "747" — as the company explores concepts for a next-generation commercial aircraft. Some 19 years after Boeing launched the 787 program, the manufacturer's last clean-sheet airliner, it is taking its time studying potential new technologies for an aircraft that will not enter service until the mid-2030s at the earliest and, according to Boeing, needs to have a 25-30% fuel efficiency gain over currently operating aircraft such as the 737 MAX and 787.

That aircraft will also have to be environmentally sustainable, enabling airlines to meet the global industry's 2050 net-zero emissions goal, which hangs over all considerations of a new airliner design.

"This is bigger than just a business decision," Ryan Faucett, Boeing's director of environmental sustainability, told me. "This is the future of our industry and relies on us really being ambitious" with a new design.

While Boeing has made no commitments about the shape of the new aircraft — CEO Dave Calhoun has preached patience to those who are curious — the company has offered clues. In particular, Boeing is eager to test the Transonic Truss-Braced Wing airframe configuration in conjunction with NASA on a modified MD-90 aircraft. This X-66A Sustainable Flight Demonstrator is targeted for flight tests starting in 2028 that are scheduled to last one year. [See related coverage page 40]

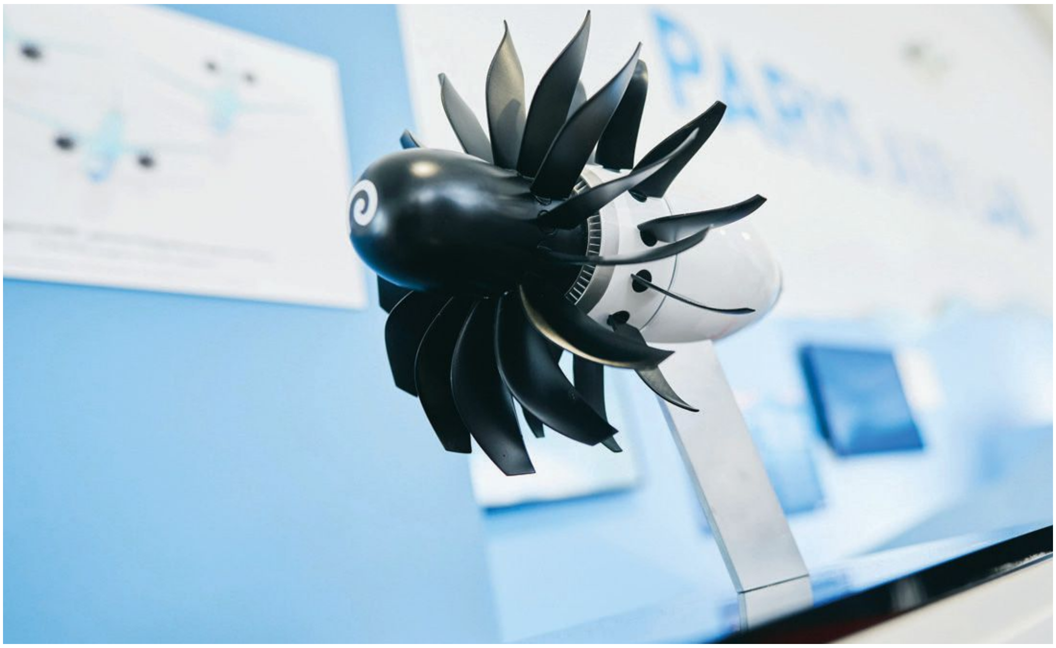
Boeing is "heavily invested" in testing the TTBW design, Calhoun said in July on the company's second-quarter earnings call with analysts and reporters. "We like what it could potentially deliver to this market: a level of performance that the industry is used to seeing with brand new programs."

He went on: "Suffice to say, we are intent on proving this technology. We are hopeful, and if it matures the way we think it will and that NASA frankly thinks it will, I do think it'll see service."

Brent Cobleigh, NASA's X-66A project manager, told me by email that the TTBW design "by itself" could deliver a 10% fuel efficiency gain over "today's best-in-class aircraft." He said a TTBW aircraft would produce "less drag due to its longer, thinner wings" and "when combined with other advancements in propulsion systems, materials and systems architecture, the X-66 could result in up to 30% less fuel consumption."

Cobleigh added: "TTBW also offers other advantages, including its high-wing design, which would allow for potentially larger-diameter, more efficient engines to be mounted underneath it."

As for that propulsion, CFM International, the GE



▲ CFM International displayed multiple mockups of a planned open rotor engine at the Paris Air Show in June, a design that eliminates the front casing to draw in more air around the engine core. Boeing hasn't chosen an engine for its next-generation airliner, but CEO Dave Calhoun has said the company "would prefer" one with a larger rotor diameter.

CFM International

Aerospace/Safran Aircraft Engines joint venture, is researching an open rotor engine architecture to power potential commercial aircraft entering service in the 2030s. This design is part of CFM's Revolutionary Innovation for Sustainable Engines program. The idea is to eliminate the case around the front fan of the engine, which GE Aerospace says would allow for a larger fan size and higher bypass ratio, meaning a larger portion of air flows around the engine core to generate thrust more efficiently. CFM envisions a 20% fuel efficiency gain from this open rotor design compared to current jet engines.

With its thinner wings set higher off the ground, a TTBW aircraft could accommodate such larger-diameter rotors. Pratt and Whitney is providing two of its geared turbofans for X-66A, but Calhoun has been noncommittal on an engine for Boeing's next airliner.

"For me to pick and choose the power plants at this stage is probably not smart," he said on the

earnings call. "We can use existing power, but we would prefer frankly to have a bigger fan diameter ultimately, and maybe even open rotor someday." But he added that "I don't want to make choices too early."

Current jet engine designs deliver about as much fuel efficiency as can be wrung from their enclosed cores and front fans, according to Pat Anderson, a professor of aerospace engineering at Embry-Riddle Aeronautical University and director of the Eagle Flight Research Center, Embry-Riddle's aerospace research and design facility.

"Unfortunately, we're in the incrementalism phase of improving jet engines," he explains. "Jet engines are pretty amazing devices that have been around for 80 years, but we're just tweaking them now for a possible 1% or 2% efficiency gain."

He says the TTBW is "one of the more effective methods of reducing drag in an airplane that we have the ability to design."

Regardless, whatever the design and engine type, Boeing has largely ruled out relying on the development of a new power source for this next-generation aircraft. Battery-electric and hydrogen-electric power, as promising as these technologies may be for smaller aircraft such as electric vertical takeoff and landing vehicles and even regional commercial aircraft, are unlikely to be viable for a 737- or 787-sized aircraft for the foreseeable future, according to Faucett.

"When it comes to hydrogen as a direct propulsion source, physics becomes a limiter," he says. "Liquid hydrogen takes up a lot of space on an aircraft from a volume perspective. It's also difficult to move around safely and requires a lot of infrastructure. We believe there's a future in which you do have larger-sized hydrogen aircraft, but it's just not likely in the 30-year window to get to net-zero."

Faucett notes that "Most of the carbon emissions in commercial aviation, around 73%, come from flights over 1,000 nautical miles. It's the longer routes, the larger aircraft where most of your emissions come from. Hydrogen is going to be a reality first on smaller aircraft, but it becomes very difficult to scale that into the larger aircraft where most of the emissions are coming from."

Anderson, the Embry-Riddle professor, says hydrogen on a large aircraft must "be stored at high pressure or cryogenically, which goes to a weight problem." He continues: "That's problematic, and the other part is if you're using a fuel cell, there's actually cooling drag associated with it."

Boeing earlier this year acquired electric aircraft designer Wisk, which is developing an autonomous air taxi, but Boeing's interest in the startup is largely

▲ Boeing plans to modify this retired MD-90 into the X-66A demonstrator. The aircraft was flown in August from a storage site in Southern California to Boeing's Palmdale facility, where the work will be done in preparation for flight tests in 2028.

Boeing

"WE BELIEVE THERE'S A FUTURE IN WHICH YOU DO HAVE LARGER-SIZED HYDROGEN AIRCRAFT, BUT IT'S JUST NOT LIKELY IN THE 30-YEAR WINDOW TO GET TO NET-ZERO."

— Ryan Faucett, Boeing

related to exploring autonomous flight, not battery-electric power.

Electrically charged batteries are "really, really terrific for road transport," Faucett says. But with a large aircraft, "you run into real issues on the energy density contained in a battery compared to its weight." Battery-electric airliners are "certainly not coming in the next 30 years."

Anderson adds: "We would literally need Nobel Prize-winning battery chemistry development to see, anytime in the near future, a large-scale battery-electric airplane."

So, Boeing believes a future aircraft will need to run on 100% sustainable aviation fuel — with potential feedstock sources, including nonedible plants, agricultural and forest waste, and municipal waste — and incorporate aerodynamic design changes that create significant fuel efficiency gains. But even if the company is able to achieve a 25-30% improvement in efficiency, SAF will be necessary to take care of most of the remainder of the carbon dioxide emissions produced by airliners, Faucett says.

"We're very transparent about how big of a deal SAF is to the industry's effort to decarbonize," he explains. "Our industry is going to grow. Specifically regarding SAF, our industry lacks a lot of the options that other industries have for decarbonizing easily. So, we need alternative liquid fuels under almost any scenario to decarbonize in large volumes."

Anderson says it is "nearly impossible to beat the storage of energy as a liquid from a weight standpoint. So, if we can make that liquid in a life-cycle that's carbon neutral, then that meets our needs. With SAF, it means that however many billions of billions of dollars of airplanes we have out there, those airplanes really don't have to change. Whereas the other two options of battery-electric or hydrogen require changes in the airframe, the engines, fundamentally everything."

Boeing projects that, because SAF comes from renewable sources, it can reduce carbon contributions from air travel by 80% on a lifecycle basis versus standard jet fuel.

The manufacturer has committed to producing all aircraft from 2030 with capability to run on 100% SAF, and it is planning for any new aircraft to use only SAF.

Today, regulations in the U.S. and elsewhere limit SAF to 50% of an aircraft's fuel for passenger flights, with airlines including United using 50% SAF blends on a small percentage of flights.

From a technical standpoint, Anderson says he sees "no barrier toward getting to 100%" SAF usage for passenger flights. "But if it's something new in aviation, you're obviously going to do a controlled entry into service. So, until you get lots of experience

NASA and Boeing released this illustration of the X-66A Sustainable Flight Demonstrator in June. Under the terms of a Funded Space Act Agreement, Boeing will supplement NASA's $425 million contribution with $725 million of its own funds and retain ownership of the aircraft after flight testing concludes. Boeing

with it, it would be prudent to slowly increase the use of that fuel by mixing it with classic Jet A until you actually see if it affects engines long term or anything else in the system: any of the logistics, the fuel tanks, the tank cars, and so forth. I don't think anybody's seeing that, but obviously it would be prudent to go slow."

Also, "there's simply not enough" SAF being produced today to power the thousands of flights conducted every day, he says, "so mixing it with Jet A makes economic sense and also makes sense from a safety standpoint. As more of it comes online, that percentage will inevitably go up."

United did operate an in-service flight between Chicago O'Hare and Washington National airports in 2021 with 100% SAF in one of the 737 MAX's two CFM engines. The other engine had 100% Jet A fuel, so the 50% standard was met. The in-service demonstration was intended to show that operating an engine on 100% SAF is already technologically feasible. United uses a 50/50 SAF blend produced by Finland-based Neste Worldwide for flights departing from Amsterdam, San Francisco and London Heathrow airports. The fuel is sourced from used cooking oil and animal fat waste. In the future, the airline plans to purchase SAF from feedstocks that could include household trash, forest waste and algae.

United plans to use around 10 million gallons of

> **"WE WOULD LITERALLY NEED NOBEL PRIZE-WINNING BATTERY CHEMISTRY DEVELOPMENT TO SEE, ANYTIME IN THE NEAR FUTURE,** A LARGE-SCALE BATTERY-ELECTRIC AIRPLANE."
>
> **— Pat Anderson, Embry-Riddle**

SAF in 2023. But technological feasibility does not mean enough supply will be available for Boeing's new aircraft to run on 100% SAF, even if standards change to allow for it. United has made a strong and very public push on SAF, investing in research and using the alternative fuel on a small number of in-service flights starting in 2016, but only 0.1% of its 2023 fuel consumption will come from SAF.

"It's going to take the whole value chain," including aircraft manufacturers, airlines, airports, governments and fuel suppliers to develop the infrastructure to produce the high levels of SAF that will be needed at airports worldwide, Faucett says. "That takes a collaboration between us and fuel producers, and then we also are working with governments. Policy is the big unlock here for scaling SAF."

Boeing is encouraging governments to provide tax incentives and other inducements for producing and using SAF. "We don't currently have a level playing field with road transport fuel incentives," Faucett says.

Beyond fuels, Boeing is also testing 19 technologies this year on its latest ecoDemonstrator aircraft, a 777-200ER. Among them are wall panels in the cargo hold consisting of 40% recycled carbon fiber and 60% bio-based feedstock resin.

Some 230 technologies have been tested across nine ecoDemonstrators flown since 2012.

"We get to test the technologies on the ecoDemonstrator to see what works, what doesn't work, see what makes sense for our production airplanes," Faucett says.

Additionally, this year for the first time, the company is operating a series of "Explorer ecoDemonstrators." In June, a 787-10 without passengers was flown from Seattle to Bangkok, Singapore and Tokyo to test "more efficient air traffic management" in conjunction with air traffic control providers.

The flights demonstrated that "if you can manage that airspace better, you can actually gain efficiency," Faucett says. Boeing believes such improved air traffic management can improve fuel efficiency by up to 10%.

With demanding net-zero goals that need to be met, the company is indeed looking for every efficiency gain it can find, so a potential new aircraft can operate in an environmentally sustainable way well into the second half of this century.

The 747 program — initially believed to be a temporary solution for long-haul air travel before fleets of supersonic jets were expected to take over — lasted for more than 50 years and produced more than 1,500 aircraft. To achieve a similar lifespan and success for its next airliner, Boeing is aiming for a sustainable solution that will have staying power in a decarbonized world. ★

▲ Boeing has pledged that its next-generation passenger aircraft will run on 100% sustainable aviation fuel, which today is only permitted in demonstration flights. During the March flight of this Airbus A321neo on 100% SAF, a Falcon 20E from the German Aerospace Center followed, collecting samples of the exhaust plumes via inlets on its fuselage.

Airbus

Mastering space traffic management

The U.S. Office of Space Commerce is facing a deadline of late 2024 to have in place the initial software and people to take over tracking of debris and civilian spacecraft from the military. Is OSC moving fast enough? Jon Kelvey tells the story.

BY JON KELVEY | jonkelvey@gmail.com

The window of the Soyuz spacecraft afforded a view of the dark of space. Somewhere out there was the reason the three crew members of the International Space Station had hastily floated into their docked lifeboat and sealed the hatch. The space station and a piece of debris — possibly from a 1993 rocket launch — were closing in on each other, and NASA mission control had declared a red conjunction to the crew, meaning there was no time to move ISS out of danger. They would need to take shelter.

Back in Houston months later, "I learned that the orbital path of an old payload assist motor had been incorrectly calculated, and it was much closer to ISS than indicated by data from the catalog maintained by the U.S. Air Force," recalled Sandy Magnus, then a NASA astronaut and one of the crew, in an article last year in Aerospace America. If the debris pierced ISS badly enough, the station would depressurize, suffocating all aboard. So the trio in the Soyuz waited to learn whether they would need to jettison away from the orbiting lab whose construction NASA contributed $60 billion to. Luckily, the fragment passed ISS by 4 kilometers.

This 2009 incident was not a one-off event. A similar case of a red conjunction unfolded in 2021 when debris from a Russian anti-satellite weapon test sent the crew of seven rushing to their lifeboats. Again, the debris passed by harmlessly. In cases where there is enough warning, ISS is maneuvered to keep the debris out of a safe zone around it. That's because astrodynamicists can't predict with absolute certainty whether two objects will collide or miss each other. For this reason, ISS has been maneuvered upwards of 30 times since 1999.

While space is a big place, it could be just a matter of time before luck runs out not only for astronauts and cosmonauts, but also for operators of satellites and the millions of us who rely on satellites for communications, weather data, scientific readings, navigation photos and other services.

"There's a real question in my mind about how much time we really have," says space entrepreneur Kevin O'Connell.

O'Connell hasn't been the only one worried. In 2018, then-President Donald Trump signed Space Policy Directive-3, instructing the U.S. Department of Commerce with setting up a civilian space object tracking program for commercial satellites, while the military focuses on its own.

For a while longer, the job of tracking civilian objects and sending conjunction alerts will remain in the hands of Space Force personnel (formerly Air Force) in operations centers at Vandenberg Space Force Base and the Naval Support Facility in Dahlgren, Virginia. The Commerce Department's Office of Space Commerce, though, is preparing to take on the civilian role.

For OSC, the year has been an active one of outreach to industry and planning to meet a goal of having the initial version of new tracking software and operations centers in place by September 2024. Former astronaut Magnus is the acting program manager and chief engineer for creation of this Traffic Coordination System for Space, or TraCSS. Needed will be a suite of software to display numerical and graphical representations of trajectories on computer screens for civil servants. They will take over the job of warning commercial and civilian government organizations of potential collisions. At first, tracking the civilian objects will continue to be done mainly with ground telescopes and radars operated by the military, but plans call for OSC to gradually wrap in commercially operated services.

"What we've planned is a very slow change from the commercial industry receiving data from the DoD over to TraCSS in a way that does not disturb current operations and allows everyone to get comfortable," Magnus said in a July video update posted on the OSC website.

Space, especially low-Earth orbit, has become a complicated place since 1957, and it is becoming more so at an accelerating pace. Some 8,900 active satellites orbit Earth, most of them in LEO, where ISS and China's space station orbit. They do so among an estimated 35,000 pieces of tracked debris ranging in size from 10-centimeter-long metal fragments to entire satellites, old rocket motors and discarded rocket stages and fuel tanks. Satellite operators regularly have to decide whether to expend precious propellant to maneuver out of the way. And the numbers are only projected to grow as megaconstellation operators add more satellites. SpaceX's Starlink constellation alone numbers some 4,800 satellites and is growing, with near-weekly launches of between 20 and 50 satellites.

▲ The International Space Station has been maneuvered nearly three dozen times since 1999 to avoid space debris, though the station has not avoided small impacts. The photo at right of a window in the Zvezda Service Module was taken in 2007.

NASA

This year, OSC has done the following: issued a request for information from the commercial space industry on what services TraCSS should offer; held industry days and workshops; posted the explanatory video on the OSC website; and awarded one contract for cloud computing hosting for TraCSS. So far, no software code has been written nor figurative metal bent. And while Magnus and OSC Director Richard DalBello have said they are taking a "crawl, walk, run," approach to developing TraCSS, moving in deliberate phases to avoid causing any space traffic accidents, not all are convinced there's time to crawl and walk.

"Why are you crawl, walk, running when you already proved through [a pilot program] that you have something that works?" says Paul Graziani, the founder of space and military software company Analytical Graphics and now the CEO of the Commercial Operations Center, or COMSPOC, a Pennsylvania company that tracks satellites and debris.

He's referring to an OSC pilot program in late 2022, in which commercial companies including COMSPOC demonstrated that they could perform aspects of the

> “There’s a real question in my mind about how much time we really have.”
>
> — **Kevin O’Connell, former director of the Office of Space Commerce**

TraCSS mission. So in his view, OSC’s approach to developing TraCSS amounts to “spending more money delaying the capability.” Whereas if the office contracted with companies like COMSPOC, “you could turn it on and go and have the function immediately.”

Another expert concerned about the pace is O’Connell, who directed OSC from 2018 to 2021 and began conceptualizing what’s now called TraCSS.

“My worry is we’ll have a major crash in space,” he says.

After all, it’s happened before.

A month before Magnus and her crewmates had to take shelter, an operational Iridium communications satellite was crossing over Siberia in LEO, as was Cosmos 2251, a defunct Russian military communications satellite. The two collided, generating 2,000 pieces of debris larger than 10 centimeters, at least some of which won’t naturally deorbit before the end of the century, according to a NASA analysis. Magnus’ close call had nothing to do with debris from that collision, but two years later, ISS maneuvered to avoid a piece of the Cosmos-Iridium debris. Iridium said it received no alert in 2009 before the collision.

Both satellites were spotted and tracked by the U.S. Space Surveillance Network, consisting mainly of ground radars and telescopes, plus some satellites. They were in the Air Force’s catalog, but reportedly no human at the Vandenberg operations center responsible for monitoring the network had conducted a conjunction assessment, an analysis of the satellites’ orbits, to see if they were at risk of colliding.

"They were only screening a smaller list of critical government payloads at that time," says Brian Weeden, director of program planning for the Secure World Foundation and who from 2004 to 2007 tracked space objects as a U.S. Air Force officer.

Following the collision, the Defense Department expanded its conjunction assessment screenings to include all operational satellites, publishing their ephemerides (position coordinates and velocities over time) on its existing space-track.org website.

Currently, there are about 47,000 objects in the catalog, now overseen by U.S. Space Command, and conjunction assessments are made by the Space Force's 18th Space Defense Squadron at Vandenberg and its sibling squadron, the 19th Space Defense Squadron, at Dahlgren. Conjunction alerts are sent automatically.

"Today, if you are a company that operates a satellite or you're a foreign government operating a satellite, you will occasionally get an email from the U.S. government that says, 'Hey, your satellite X is predicted to come close to another space object in let's say, three days from now,'" Weeden says. "There's a one in 8,000 chance it's going to collide."

Back in 2011, the Secure World Foundation published an analysis highlighting some possible drawbacks and limitations to this approach. For instance, the position and velocity information for objects available on space-track.org was not as accurate as it could be. In the case of the Iridium and Cosmos satellites, they were predicted to pass within 600 meters of each other instead of colliding.

"The DoD computer systems and software to do

▲ A U.S. Air Force technical sergeant monitors space objects at Vandenberg Air Force Base in 2009. At the time, the Air Force was tracking some 19,000 pieces of space debris. Today, this task is done from Vandenberg and a Virginia base by U.S. Space Force personnel, and they are tracking some 35,000 pieces of debris.

U.S. Air Force/Staff Sgt. Vanessa Valentine this are ancient, and they are struggling to upgrade them," Weeden says. It's also not ideal, he adds, for the military to share space object tracking data collected with the same sensors with which it keeps tabs on classified military satellites and potential nuclear missile launches. "They have all this classification, all this national security stuff; they're not the right entity to be doing this."

The Obama administration seemed to agree. An interagency policy committee discussed moving the responsibility for tracking civilian and commercial space objects to a civilian agency within the Department of Transportation, and this idea was picked up by the Trump administration in 2017. The result was SPD-3, which states that as the number of objects in space increases, the "limited traffic management activity and architecture" of the military's space tracking facilities will "become inadequate."

"To maintain U.S. leadership in space," SPD-3 states, "we must develop a new approach to space traffic management (STM) that addresses current and future operational risks."

No one believes it will be easy.

"Commerce is being asked and tasked to do a lot of stuff, and they are starting from scratch," Weeden says. "And then, how do they enhance it? Because the whole point of this exercise was not just to replicate what the DoD is already doing, because we know that's already not good enough."

OSC won't be building its own surveillance network. Instead, TraCSS will begin operations with unclassified tracking data from the Space Surveillance Network, with the goal of relying more and more on commercial tracking companies over time. OSC will also hire its own civil servants to conduct the conjunction assessments for TraCSS based out of two operations centers, one primary and one backup, according to a presentation DalBello made in September at the Advanced Maui Optical and Space Surveillance Technologies, AMOS, conference.

"We haven't chosen those locations yet, but we're starting that staffing process," he said. "It's a complicated process, but our goal is next year, in 2024, to have a staff of about 50."

One of those roles will be a permanent program manager for TraCSS, with Magnus continuing to serve as chief engineer, DalBello added. The hiring process was helped along by OSC receiving a $70 million budget for fiscal year 2023, up from $16 million the year prior.

OSC will eventually take over space-track.org, though what changes will be made to how the website looks and what information is displayed is not yet clear. According to remarks by Magnus in the July OSC video, the TraCSS operation centers will screen for conjunctions twice as often as the military — every four hours instead of every eight. Eventually, commercial users will be able to pull whatever alerts or notifications they need directly from the TraCSS software into their own computers, rather than looking out for warning emails.

▲ U.S. President Donald Trump signed Space Policy Directive 3 in 2018, directing the Commerce Department to take over satellite tracking and notifying commercial operators if their spacecraft were projected to collide with another satellite or a piece of debris. This would allow the Defense Department to "focus on protecting and defending U.S. space assets and interests," the directive reads.

NASA/Bill Ingalls

Software, in addition to OSC staff, will be the heart of TraCSS, divided into three main components: The TraCSS-OASIS database will ingest and hold all the space tracking data, whether from the military or private contractors. TraCSS-SKYLINE will host the user interface and any commercial third-party software OSC purchases to provide services for users. Lastly, TraCSS-HORIZON will serve as a mirror of the operational TraCSS software, a sandbox for testing new capabilities before integrating them into operations.

In mid-August, OSC contracted with Amazon Web Services to provide hosting for all the TraCSS software, DalBello said at AMOS. Plans call for OSC to select a systems integrator to connect the different pieces of the TraCSS software and hardware, and later a contractor to build the user interface, though the office declined to say when those requests for proposals will be published.

The plan is to roll out TraCSS in three phases, with phase one beginning in late 2024. The first TraCSS conjunction assessments and other information about the orbits of space objects will be posted to space-track.org as conjunction data messages. OSC will fix any bugs and build out the user interface through the end of 2025.

"Then we'll move on to phase two, which will be the launch COLA [collision avoidance] phase," DalBello said at AMOS, which will require coordination with FAA. "And then phase three will follow that, where we'll look at the issue of reentry and management." He did not give a timeline for the completion of these phases.

That is the TraCSS plan, but the actual action, so far, has been mostly planning. There was the RFI published in January, and multiple industry workshops held since then, but the only procurement has been the cloud computing services contract in August.

"The workshops are good for engagement, but at some point, there's enough talking and there's got to be doing," says space environmentalist Moriba Jah, an associate professor of aerospace engineering and engineering mechanics at the University of Texas at Austin and chief scientist at the space sustainability company Privateer. "To me, a signal of change, of real change, is when space-track.org closes its doors, and it's space-commerce.org," he says, suggesting a potential domain name for an OSC-run space tracing website.

They needn't wait to get the TraCSS operations centers going but could simply port the existing space-track.org information to a new website, Jah adds, because "that shift alone, going from the military to something civil, already sends a positive signal to the globe."

Meanwhile, Graziani of COMSPOC worries that reliance on legacy military software could bog TraCSS down. TraCSS will start off using a software called Astrodynamic Support Workstation, but "that's late '80s and early '90s technology," Graziani says. "The DOS operating system, essentially, is what they're trying to use in today's world."

When asked, OSC Special Adviser Christine Joseph said the plan is to use ASW temporarily in order to decompress military file formats and port that information into TraCSS Oasis.

Graziani and Weeden also point out that in developing OASIS, SKYLINE and HORIZON, the office will need to show it can do better than the Defense Department has in the multiple attempts to develop replacements for its own software like Astro Standards Workstation: An April report published by the U.S. Government Accountability Office calculated that the military spent $1.7 billion between 2000 and 2022 on attempts to replace out-of-date software. Weeden rattled off a long list of these failed attempts:

There was the Cheyenne Mountain Upgrade attempt from 1981 to 1998, and the Combatant Commanders' Integrated Command and Control System attempted from 2000 through 2008.

From 2009 to 2012, there was the new Joint Space Operations Mission System, JMS, and 2012 to 2018 an attempted reboot of JMS.

JMS was terminated in 2018, and the military launched Space C2. In 2019, Space C2 was joined by the Enterprise Battle Management Command and Control program and another "agile software development program."

In 2022, a contract was awarded for the Advanced Tracking and Launch Analysis System, which appears to be a replacement for SpaceC2.

The problem, Graziani says, is that the government procurement process simply moves too slowly to keep up with the changing requirements of sophisticated software. "Moore's Law turns over every 18 months," he says, referring to the doubling of the computer power of microprocessors. Therefore, by the time contracts roll three to seven years after the start of a program, the end product is already obsolete.

The solution, in Graziani's opinion, is to better harness the private sector. He argues that companies like his own COMSPOC, Slingshot Aerospace and ExoAnalytic Solutions already demonstrated the ability to meet the requirements of TraCSS during the 2022 pilot program.

At the very least, OSC could do more pilots and experimentation with private companies now, says former OSC director O'Connell, before taking full responsibility for civilian and commercial space tracking from the military.

"Why are we not taking advantage of that as a great opportunity to experiment very much with what is going on in industry, to try different things, to aggressively experiment as opposed to relying on traditional processes for acquiring capabilities?" O'Connell said during a panel at the AMOS conference. "I worry that we're still being too cautious in our bureaucratic processes, given the demand."

Asked about Graziani's argument that OSC could simply contract with commercial space companies to begin offering space traffic and situational awareness services through TraCSS sooner, OSC provided a statement by email: The pilot program in geostationary orbit "did highlight that, in the GEO regime, commercial SSA companies can play a key role in the implementation of TraCSS," but that "the findings also emphasized the need for transparent metrics around evaluating SSA data and services."

The statement also noted that OSC, which was created in 1988 to foster the commercialization of space activities, has always been "a primary proponent of the policy that the government should not compete with industry, and should buy commercially available goods and services to the maximum extent practicable. In the TraCSS program, we are going to practice what we preach."

O'Connell understands the task before the current OSC civil servants and hopes they succeed. But he still suggests time may be one of the more limited resources in the whole enterprise. Too much delay not only could lead to tragedy in space but could also be a blow to the future of the commercial space economy.

"I really worry about a day when there's a terrible crash in space, at which point everyone will come out of the woodwork with their own well-intended idea about what to do about it," O'Connell said at AMOS. "And if this community does not have the loudest voice, and that is based on scientific data, best practices, etc., we're going to be in trouble." ★

NASA STANDS BY ITS X-PLANES

A substantial portion of the agency's aviation budget over the next four fiscal years will be dedicated to building and flying demonstration aircraft, including some with X-plane designations. NASA is staying with that plan, despite setbacks since the initiative was announced in 2016. Why is the agency so determined to continue, and when will the first of the experimental planes fly? Pat Host and Ben Iannotta set out to find out.

BY PAT HOST | patrick.host@gmail.com and BEN IANNOTTA | beni@aiaa.org

NASA has not flown an experimental aircraft in the seven years since it pledged to build and fly five of them to deliver "revolutionary levels of aircraft performance improvements." The goal was to give the U.S. an edge in the "international competition" to build aircraft capable of satisfying an anticipated doubling in passenger trips by the 2030s, according to a 2016 NASA brochure announcing what was then known as the New Aviation Horizons Initiative. That demand portended an "economic potential of trillions of dollars in the fields of manufacturing, operations and maintenance, and the high-quality jobs they support," the brochure reads.

While the name "New Aviation Horizons Initiative" was abandoned in 2018, and the number and kind of X-planes and demonstrators has shrunk, what has not changed is NASA's belief that getting new technologies and configurations airborne is among the most important things it can do to support the U.S. air transportation industry and a new global aspiration to achieve net-zero carbon emissions by 2050, a goal set by the International Air Traffic Association in 2021.

"The changes that you've seen from the snapshot in 2016 until now are really just reflective of making sure that these really high-value flight demonstrations — that are also high cost — really are bringing the maximum benefit," says Lee Noble, director of the Integrated Aviation Systems Program within NASA's Aeronautics Research Mission Directorate. "If we strictly adhered to the plan from 2016, we would be doing the U.S. taxpayer a great disservice, because we really wouldn't be flexing with how we see the market developing."

The agency proposes to spend $1.4 billion through 2028 — a quarter of the total for aeronautics — for these flight demonstrations, including development of two aircraft that have X-plane designations: the X-59 that aims to demonstrate quieter supersonic flight, and the X-66A Sustainable Flight Demonstrator to be built by NASA and Boeing to test a novel wing configuration for fuel efficiency. That's a switch in scope from 2016, when NASA said it would "build a series of five mostly large-scale experimental aircraft — X-planes." Also in the conceptual phase this time is a yet-to-be defined Future Flight Demonstrator that might or might not someday receive an X-plane designation, something that must come through a request from NASA to the U.S. Air Force.

In Noble's view, no one should get hung up about such labels. "We don't formulate a project and say, 'Oh, this is an X-plane.' We formulate a flight demonstration," he says. "But sometimes we stare at it and go, 'Wow, this is kind of novel, let's go ask for an X-plane designation.'"

Noble does not sugarcoat the fact that nothing has been flown since 2016. NASA last month bumped the first flight of the piloted X-59 to sometime in 2024, after the aircraft had to be moved back indoors into the assembly area in Palmdale, California, earlier this year to address airworthiness issues.

"We've paused a time or two to make sure that we work through technical issues and really have an aircraft that's safe," Noble says. Plans call for a pilot to fly the aircraft over populated areas so that residents can be surveyed about the sonic thump, rather than a boom, that the plane is supposed to produce.

As for the all-electric X-57, Noble says it was wise to shift the project into a closeout phase without ever flying the modified Tecnam P2006T prop plane. It was to have been flown with various electrification technology and wing configurations under a series of "mods." A potentially dangerous issue with its motors was discovered earlier this year, and solving the problem would have spilled into fiscal 2024, Noble says.

"When we looked at the benefits of how X-57 has already contributed, they've already punched their ticket in terms of being a pathfinder," he says, referring in part to a potentially dangerous battery issue resolved during its development.

Will Congress be willing to continue to fund NASA's flight demonstrations, given that none have flown? Noble does not offer a prediction, but he says NASA has been open with Congress, and the White House for that matter, about the issues it has faced. "I think we've been really transparent with our stakeholders, both at OMB [the White House office that creates the president's budget request] and Congress about the progress we've made on all of these. And thus far, they seem to acknowledge that we're working through these things credibly," he says.

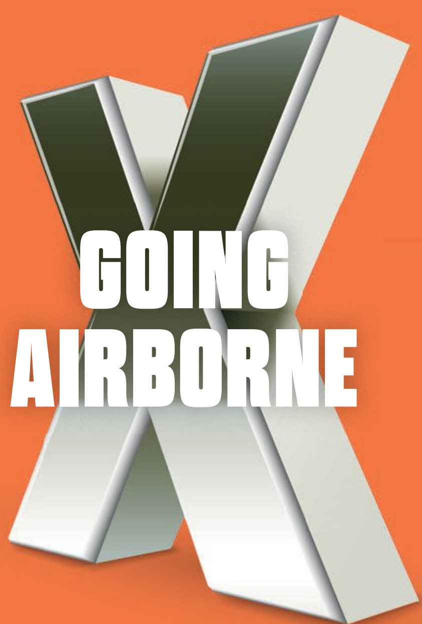
None of which means that flying isn't preferable. "Unless we bring [technologies] to a readiness level of six or seven," — demonstration in a relevant environment, meaning in flight in the case of an aircraft — "industry really has a hard time picking those up and transitioning them into products."

Noble is, after all, in the business of making sure flight technologies work together properly. "Sometimes you want to understand how technology A, B, C and D actually behave together as a system on the aircraft," he says. "And again, we can do all of that when we go to fly."

Robert Kraus, dean of aerospace at the University of North Dakota, says NASA's demonstration projects are particularly valuable to newcomers to the field. "If you are a startup company making a new business, you are not going to have the time to get to a viable product that is profitable" without help, Kraus says. "The only way to get to that point is to have the government partner with businesses, labs and companies."

Startups, however, aren't the only beneficiary — a case in point being the X-66A, whose approach of improving fuel efficiency by shifting to thin wings supported by trusses was just one of several non-tube-and-wing designs vying for demonstration back in 2016. Boeing will own the aircraft, with NASA playing a supporting role under an arrangement that will have an aircraft being developed under a Funded Space Act Agreement. "It's different than anything we've ever done," Noble says.

While X-66A is novel in terms of contracting, not all are convinced the aircraft will earn the stature of other X-planes throughout history. In the view of Dan Patt, who holds a Ph.D. in aerospace engineering and is a former DARPA manager, the development will no



GOING AIRBORNE

NASA's 10-year X-plane initiative announced in 2016 has morphed into four projects. Though none of the aircraft have been flown yet, the X-59 supersonic demonstrator is poised for its inaugural flight in 2024, NASA announced last month.

The X-59 in June was moved from the hangar at Palmdale to the flight line for the next phase of ground testing, including vibration tests. Lockheed Martin

X-59

This demonstrator, which NASA now plans to fly for the first time in 2024, remains in the final stages of development by Lockheed Martin Skunk Works in Palmdale, California. Plans call for a pilot to fly X-59 over various populated areas in the U.S. to see if the sonic thump from its sleek shape will be acceptable to residents. The thinking is that the results of these community overflights could prompt regulators to lift the prohibition on civilian supersonic flights over land in the U.S. and elsewhere. Workers have encountered multiple technical problems during construction, however. Last year, it took several attempts to fit the General Electric F414-GE-100 engine into the aircraft without interference, although NASA says this was not a significant issue.

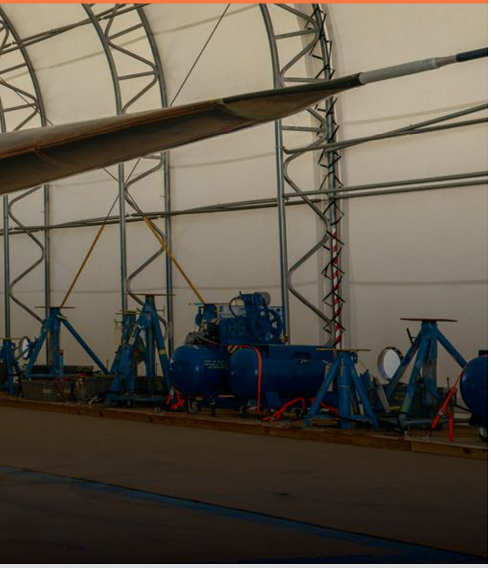
"When we installed the engine, we did our best to take blue light scans of the engine bay and the engine to make sure there wouldn't be any interferences," says Lee Noble, director of NASA's Integrated Aviation Systems Program. "But we found a couple minor ones," he adds, and that required taking the engine out and reinstalling it doubt present engineering and integration challenges. From his vantage point at the Hudson Institute think tank, he sees the project as more of an industrial policy effort to help Boeing compete against Airbus than an effort to break untrodden aerodynamics ground. He noted that the industry has known about truss-braced wings for decades.

On the technology front, Noble describes the X-66A as worthy of its experimental designation given the potential shift away from the conventional tube-and-wing designs that have dominated air travel for decades. “That’ll just be huge,” he says. “We specifically said, ‘Let’s focus this one on airframe technologies. Let’s not bring new propulsion systems onto the aircraft.’ That’s kind of too many miracles in one place.”

So, at the end of the day, NASA stands by its X-planes, or its demonstrators, viewing them as a linchpin in the race toward cleaner, partially electrified air travel. “In the current environment, we really want to make sure that these technologies that we develop really do have a big impact on U.S. competitiveness, on sustainability of the commercial aviation fleet,” Noble says.

FACT

EMISSION REDUCTIONS: NASA is pursuing a 50% cut in aircraft emissions via a hybrid-electric concept known by the shorthand SUSAN, or formally the Subsonic Single Aft Engine Electrofan. Work is centered at Glenn Research Center in Ohio. “We haven’t approved [SUSAN] to actually become a flight vehicle,” says NASA’s Lee Noble, who manages flight experiments.



“probably two or three times” until the right fit was achieved.

In August, after a stint on the flight line, “we did move [X-59] back indoors to the assembly area because there were some components that we realized either needed some upgrade or some kind of replacement,” Noble says. Those details are now being worked.

In 2016, NASA said it expected X-59 to fly for the first time “in the 2020 timeframe depending on funding.”

NASA has selected two teams to fly modified aircraft under its Electrified Powertrain Flight Demonstration. The Saab 340B, bottom in this illustration, will be powered partly by a motor-generator developed by GE Aerospace. A De Havilland Dash 7 will be equipped with magniX electric motors.

NASA/GE Aerospace/magniX

Electrified Powertrain Flight Demonstration Project

By mid-decade, two teams are to fly different versions of megawatt-class hybrid-electric powertrains. The goal is to produce enough electricity to someday power a hybrid passenger aircraft — either a regional aircraft or the equivalent of today’s single-aisle Airbus A320s or Boeing 737s.

NASA’s Lee Noble says the idea was born in a 2018 strategy discussion. “The thing that bubbled up to the top was: If we could bring megawatt-class electric motors — machines — to flight, that’s the sweet spot that impacts all the way from small general aviation aircraft up to single aisle transports,” he says. “This is really an enabler for turbine engines of the future, where maybe it’s a hybrid engine system where it’s not just running on jet fuel, but it also has electric augmentation.”

GE Aerospace of Cincinnati will test its version on a Saab 340B turboprop, although the company’s goal is a single-aisle, hybrid jet. Boeing’s Aurora Flight Sciences company in Virginia is assisting GE with the Saab modifications. Meanwhile, magniX of Washington plans to demonstrate its version on a Dash 7 turboprop. “We have two different approaches because GE is of course an established OEM [original equipment manufacturer]. MagniX is a newer entrant to the community but very nimble and very focused and has already flown electric aircraft,” Noble says. **GRAPHIC CONTINUES ON FOLLOWING PAGES ▶**

X-66A Sustainable Flight Demonstrator

▲ NASA in January selected Boeing to build a transonic truss-braced wing demonstrator, later designated the X-66A. This illustration shows the configuration that will undertake a yearlong flight campaign in 2028.

Boeing

The aircraft will be built on the frame of an MD-90 airliner at Boeing's facility in Palmdale, California. The aircraft's wings will be removed and replaced with longer, ultra-thin wings and carbon fiber support beams. This truss-braced wing design is supposed to deliver 10% better fuel efficiency if paired with conventional jet engines and up to 30% better efficiency when paired with an advanced jet engine. Boeing last month announced it had selected Pratt and Whitney's geared turbofans, but neither company nor NASA has specified the fuel efficiency these engines will yield. Plans call for a one-year flight campaign starting in 2028. Boeing is developing the aircraft under a Funded Space Act Agreement with NASA. The agency plans to spend $425 million, and Boeing will spend $725 million, says NASA's Lee Noble.

While Boeing will own the aircraft, and NASA must be careful not reveal its partner's proprietary information, Noble anticipates sharing enough details to inspire innovation elsewhere. "As we go to conferences, we'll be careful to report things in a way that doesn't kind of give up the proprietary nature of their design but still shows the benefits of performance and really how the X-66 behaved in flight," he says.

He also notes that NASA selected Boeing as a result of a competition: "I couldn't comment on the number of proposals we got, but it was multiple, and Boeing just really rose to the top in terms of their vision for the future and how novel their concept was," he says.

Future Flight Demonstrator Project

This is a proposed new start for 2027 shown in the out years of NASA's fiscal 2024 budget request. The nature of the aircraft is to be decided. So far, NASA has been fielding ideas internally, but at some point a request for information will be issued to invite the industry to make suggestions.

"We're envisioning it to be of a scope of a large flight demonstrator, but we're thinking about lots of different possibilities," says NASA's Lee Noble. One option, he says, "would be to integrate a novel propulsion system." Another possibility could be to test technologies for self-flying aircraft: "Would we try to bring some autonomous systems on board, and is that something we want to demonstrate?"

There is plenty of time to think it through and decide, he says.

▲ NASA's X-57 Maxwell undergoes high-voltage ground testing in 2021. At the time, plans called for a first flight in 2022, but the target was continuously pushed back. In June, NASA announced it would begin winding down the X-57 program without flying the aircraft to avoid expending funds beyond September, the end of the 2023 fiscal year. NASA

AND IN THE PROCESS OF BEING SHUT DOWN:

X-57 Maxwell

NASA plans to hold a public "technical closeout meeting" sometime between January and March for this project under which an electrified Tecnam P2006T would have been flown to demonstrate distributed electric propulsion. The agency decided earlier this year that it would begin shutting the project down to meet a fiscal 2023 deadline that was set in 2021. In theory, the agency could have extended the project to begin flying a series of planned "mod" flights that would have tried out a range of electrification technologies and configurations.

Development at Armstrong Flight Research Center in California had been slowed by the pandemic: "X-57 was all about being around the aircraft and integrating things. So unless you could show up at the center and work, you couldn't do any of that remotely. So, they were impacted by covid in a unique way," says NASA's Lee Noble. But over the winter at Armstrong, "design deficiencies" related to the aircraft's motors were discovered, and these would have put the pilot at risk, NASA said in an email statement. The discovery sparked multiple "Tiger Team" meetings between NASA officials and ESAero, the X-57 prime contractor in California, which proposed modifications to the motors.

"ESAero believes that these simple fixes along with successful ground testing and frequent inspection would have been sufficient to accept the risk and go to flight by September," said Andrew Gibson, CEO of ESAero, in an email. NASA nevertheless decided to begin the closeout process, noting in its statement that "the NASA Armstrong airworthiness review board concurred with the project's safety and risk assessment." ★

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

Calendar

FEATURED EVENT

8–12 JANUARY 2024

Orlando, FL

AIAA SciTech Forum is the world's largest event for aerospace research, development, and technology. Thousands come to witness breakthrough science, revolutionary technologies, and next-generation capabilities that are redefining what is possible in aerospace. Immerse yourself in a wealth of information and leave with fresh ideas and new perspectives to elevate your work.

aiaa.org/scitech

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2023			
7–16 Nov	Business Development for Aerospace Professionals Course	ONLINE (learning.aiaa.org)	
17 Nov	Fundamentals of Space Domain Awareness Course	ONLINE (learning.aiaa.org)	
17–18 Nov	AIAA Young Professionals, Students, and Educators (YPSE) Conference	Laurel, MD (www.aiaaypse.com)	
27–28 Nov	AIAA Region VII Student Conference	Canberra, Australia, & Online	13 Sep 23
4–7 Dec	Aircraft and Rotorcraft System Identification Engineering Methods Course	ONLINE (learning.aiaa.org)	
2024			
6–7 Jan	2nd AIAA High-Fidelity CFD Verification Workshop	Orlando, FL (aiaa.org/scitech)	
6–7 Jan	Design of Experiments Course	Orlando, FL (aiaa.org/scitech)	
6–7 Jan	Propeller Aerodynamics for Advanced Air Mobility Course	Orlando, FL (aiaa.org/scitech)	
6–7 Jan	Spacecraft Design, Development, and Operations Course	Orlando, FL (aiaa.org/scitech)	
7 Jan	Hypersonics: Test and Evaluation Course	Orlando, FL (aiaa.org/scitech)	
8–12 Jan	AIAA SciTech Forum	Orlando, FL	25 May 23
10 Jan	AIAA Associate Fellows Induction Ceremony and Dinner	Orlando, FL	
16–25 Jan	Aircraft Maintenance Management Course	ONLINE (learning.aiaa.org)	
29 Jan–7 Feb	Mission-Based Vehicle Design Course	ONLINE (learning.aiaa.org)	
30 Jan–8 Feb	Cryogenic Fluid Management for Storage & Transfer of Liquid Propellants in Space 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
2024			
6 Feb–14 Mar	Vibration of Periodic StructuresCourse	ONLINE (learning.aiaa.org)	
13 Feb–7 Mar	Fundamentals of Aeroelasticity: From Basics to Application Course	ONLINE (learning.aiaa.org)	
14–15 Feb	ASCENDxTexas	Houston, TX	
21–22 Feb	Principles of Success in Spaceflight from Andrew Chaikin Course	ONLINE (learning.aiaa.org)	
26 Feb–3 Apr	Design of Space Launch Vehicles Course	ONLINE (learning.aiaa.org)	
2–9 Mar*	IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
23–24 Mar	AIAA Region VI Student Conference	Santa Clara, CA	26 Jan 24
4–5 Apr	AIAA Region II Student Conference	Cocoa Beach, FL	4 Feb 24
5–6 Apr	AIAA Region III Student Conference	Akron, OH	9 Feb 24
5–6 Apr	AIAA Region IV Student Conference	Stillwater, OK	9 Feb 24
5–6 Apr	AIAA Region V Student Conference	St. Louis, MO	2 Feb 24
12-13 Apr	AIAA Region I Student Conference	Morgantown, WV	29 Jan 24
16–18 Apr	AIAA DEFENSE Forum	Laurel, MD	17 Aug 23
18–21 Apr	AIAA Design/Build/Fly	Wichita, KS (aiaa.org/dbf)	
8–10 May*	4th IAA Conference on Space Situational Awareness (ICSSA)	Daytona Beach, FL (http://reg.conferences.dce.ufl.edu/ICSSA)	
8–10 May*	Dayton Digital Transformation Summit	Dayton, OH	
14 May	AIAA Fellows Induction Ceremony and Dinner		
15 May	AIAA Awards Gala	Washington, DC	
4–7 Jun	30th AIAA/CEAS Aeroacoustics Conference	Rome, Italy (aidaa.it/aeroacoustics/)	8 Dec 23
12–14 Jun*	CEAS EuroGNC 2024	Bristol, UK (https://eurognc.ceas.org)	
29 Jul–2 Aug	AIAA AVIATION Forum	Las Vegas, NV	12 Dec 23
30 Jul–1 Aug	ASCEND Powered by AIAA	Las Vegas, NV	12 Dec 23
9–13 Sep*	34th Congress of the International Council of the Aeronautical Sciences	Florence, Italy (icas2024.com)	
14–18 Oct*	75th International Astronautical Congress	Milan, Italy (iac2024.org)	

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

● AIAA Continuing Education offerings (highlighted in green)

AIAA Announces Candidates for 2024 Election

The Council Nominating Committee has selected candidates for next year's openings on the AIAA Council of Directors. Elections will be held January/February 2024. Council Nominating Committee Chair Laura Richard and AIAA Governance and Executive Operations Administrator Susan Silva confirmed the names of the candidates who will appear on the 2024 ballot.

Integration and Outreach Activities Division

Director–Elect Young Professional Group
Taylor Fazzini, Northrop Grumman Aeronautics Systems

Regional Engagement Activities Division

Director–Region III
Peggy Cornell, NASA Glenn Research Center

Director–Region VI
Cristian Calugarita, BijuSoft
Oleg Yakimenko, Naval Postgraduate School

Technical Activities Division

Director– Aerospace Design and Structures Group
Dawn Phillips, NASA Marshall Space Flight Center
Masoud Rais-Rohani, University of Maine

Director– Aerospace Sciences Group
Christopher Cotting, EpiSys Science, Inc.
Martiqua Post, NASA

MAKING AN IMPACT

Invest in the Future of Aerospace

Join the AIAA Foundation on Giving Tuesday, 28 November 2023, and support the future of aerospace.


Students To Launch Hub event


AIAA Kahn Scholarship recipients


AIAA SciTech Diversity Scholars


AIAA Design/Build/Fly

The AIAA Foundation has been igniting students' interest in aerospace for over 25 years. Educator awards and grants provide K-12 educators with the resources they need to foster enthusiasm for aerospace in their classrooms. At the university level, the Foundation provides real-world experience through student conferences, the Diversity Scholars Program, design competitions, and Design/Build/Fly, as well as awarding over $100,000 in scholarships and graduate awards.

In 2023 the AIAA Foundation proudly supported:

- 644 university students at seven Regional Student Conferences
- 58 university students through the Diversity Scholars Program at 2022 ASCEND, AIAA SciTech Forum, and AIAA AVIATION Forum
- 2,565 university students through Design/Build/Fly and Design Competitions
- $100,000 in scholarships and graduate awards
- $75,000 in K-12 educator grants and awards

Our new K-12 partnerships are having a significant impact.

- The ExGen program, a partnership with Estes Rockets and the National Science Teaching Association (NSTA), provides K-12 educators with free, engaging classroom-ready lessons and curriculum storylines to immerse students in real-life applications of STEM while exploring various concepts in aerospace, engineering, and rocketry and has **influenced 540,000 K-12 students.**
- Students To Launch (S2L), a partnership with First Light, Griffin Communications Group, and Oregon State University, inspires middle and high school students with the wonders of space. S2L invites students from underrepresented and underserved communities to engage in NASA mission-inspired events – from hands-on afterschool activities to attending rocket launches at NASA Kennedy Space Center – and has **influenced 21,888 middle school students.**

On Giving Tuesday, please consider helping us reach our goal of raising $75,000 to develop the next generation of aerospace leaders. With your support, we are looking forward to making an even bigger impact next year! Donate at **aiaa.org/foundation**.

The Many Paths to Aerospace


Volunteers and School of Mines AIAA Faculty Advisor Dr. Madrid.


Panelists.

The AIAA Colorado School of Mines Student Branch hosted the Pathfinder Conference on 16 September. This free event was conceived to enlighten students from diverse backgrounds about the myriad career opportunities in the aerospace sector. About 100 students from community colleges and high schools throughout Colorado attended.

A highlight of the conference was a panel discussion titled "The Many Paths to Aerospace," including Robin Bruce, president of the Colorado Council of Black Nurses; Anthony Clark, assistant director of Scholarship Programs at the Organization of Black Aerospace Professionals; Zyola Mix, an opto-mechanical engineering technical specialist at Ball Aerospace; and Brian Ysasaga, a special programs systems integration and test engineer at Lockheed Martin. These professionals provided invaluable insights into their unique experiences as individuals from underrepresented communities in the aerospace domain and imparted advice to the attendees.

The day also featured an enlightening lecture by Abbud Madrid from the Colorado School of Mines' Space Resources Center. He provided an overview of the center's work and passionately encouraged the students to chase their dreams.

The Exhibit Hall featured a diverse range of industry stakeholders, academic institutions, and student organizations, all poised to share knowledge and opportunities in the aerospace industry. Among the exhibitors were Ursa Major Technologies, ULA, UCCS admissions, Spartan College, the Department of Electrical Engineering at the Colorado School of Mines, and the Colorado School of Mines chapter of NSBE. To foster engagement, students were provided with bingo cards, prompting them to interact with exhibitors and partake in various activities. The completed cards were eligible for entry into a raffle.

Feedback from the conference was overwhelmingly positive. We would like to extend our gratitude to the AIAA Rocky Mountain Section for awarding us the Diversity Grant, which played a significant role in making this event possible. We hope the section will continue to support such initiatives and spearhead the planning of this conference annually, enabling it to rotate among different campuses.

Diversity Corner

Daniel Perez

NAME: Daniel Perez (AIAA Young Professional Member)

NOTABLE CONTRIBUTIONS: Perez is a Senior Principal Test Engineer at Northrop Grumman. Before coming to Northrop, he worked as a flight test engineer at NAVAIR. Perez holds a B.S. in Mechanical Engineering from Rochester Institute of Technology and an M.S. in Aeronautics and Astronautics from Purdue University.

POTENTIAL SOCIETAL IMPACT OF CONTRIBUTIONS: Perez is working on different assignments that span the entire lifecycle of AARGM-ER missile program and other derivatives. Prior to this assignment, he worked at Northrop's Palmdale facility as a System Test Engineer on all the different High Altitude Long Endurance UAV platforms, such as Global Hawk, Triton, and NATO AGS. At NAVAIR, he worked on F-35B, F-35C, and P8A. Perez has a strong background in flight test along with broad development and manufacturing experience in military aviation. He currently serves as the Defense Systems Sector Chair for the Adelante Employee Resource Group (ERG) (2021–2023) and participated in the company's Mentoring Technical Protégé (MTP) program for the 2023 class.

*In collaboration with the AIAA Diversity and Inclusion Working Group and Claudine Phaire, the AIAA Society and Aerospace Technology Outreach Committee is highlighting prominent members of the wider aerospace community in the Diversity Corner.

SAT OC and the U.S. Aerospace Workforce

By: Amir S. Gohardani, SAT OC Chair

In addition to exploring the use of aerospace technology for the benefit of society, the AIAA Society and Aerospace Technology Outreach Committee (SAT OC) is also examining the relationship and influence that society, culture, and the arts have on aerospace technology. In a new event on 16 November, AIAA and SAT OC will collaborate to host a free webinar on the U.S. aerospace workforce. The global workforce has changed significantly over the past few years, and we'll explore some of the challenges and opportunities. Against a COVID-19 pandemic backdrop and changes in the aerospace sector, conversations about the aerospace workforce are more important than ever. Moderated by Amir Gohardani, vice president and Space Thought Leader, Deloitte, the session features Digna Carballosa, Talent Services Director, NASA; Mike French, vice president for Space Systems, Aerospace Industries Association (AIA); and Janet W. Grondin, chief executive officer, Stellar Solutions.

More information can be found at: aiaa.org/SciTech/program under What's New on the dropdown menu.

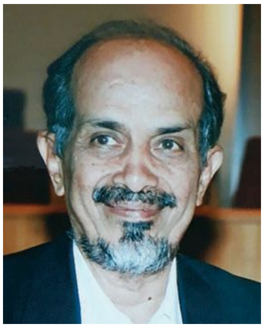
Amir Gohardani

Digna Carballosa

Mike French

Janet W. Grondin

Obituaries



Roddam Narasimha. Credit: AIP Emilio Segrè Visual Archives, Physics Today Collection, Courtesy of Maithreyi Narasimha.

Correction: Indian aerospace and fluid dynamics scientist Roddam Narasimha's AIAA membership level was incorrect in his obituary in the September issue of the *AIAA Bulletin*. He was elevated to AIAA Fellow in 1993. AIAA regrets the error and has updated the *Aerospace America* website with the correction information.

AIAA Associate Fellow Englar Died in March 2021

Robert (Bob) J. Englar, 76, died on 29 March 2021.

Englar earned a B.S. in Aerospace Engineering in 1967 from Virginia Polytechnic Institute. He served in the Virginia Polytechnic Institute ROTC guard and completed a co-opt internship with the U.S. Navy. In 1973, he earned an M.S. in Aerospace Engineering from the University of Maryland.

Englar worked for the Department of Navy, followed by the David Taylor Naval Ship Research and Development Center in Carderock, Maryland. He then worked at Lockheed Martin in Marietta, GA, and Georgia Institute of Technology Research Institute (GTRI). He had over 44+ years of experience in aerodynamic research, much of it was circulation control related, advanced concept development, and experimental techniques.

Englar was a Principal Research Engineer at GTRI and was responsible for research project direction and development of advanced technologies in aerodynamics. He had originated, conducted, and/or directed over 134 such sponsored research programs at GTRI since January 1989. He was Principal Investigator leading a NASA program on circulation control aerodynamics for subsonic fixed-wing aircraft and a co-investigator on a NASA program on pneumatic powered lift aircraft. He held 11 patents and 19 invention disclosures on these advanced concepts and published 209 papers and technical reports. He also taught senior design courses in the Georgia Tech Aerospace Engineering and Mechanical Engineering Schools.

An AIAA Associate Fellow, Englar was a founding member of the AIAA Applied Aerodynamics Technical Committee. He was elected AIAA Young Engineer/Scientist of the Year for his work on circulation control wing (CCW), received numerous professional awards, and lectured on the subject of powered lift and advanced concepts to government agencies, technical societies, private industry, and universities.

He was elected as a GTRI Technical Fellow because of his involvement with advanced aerodynamics and related advanced concepts. He led the development of advanced CCW airfoils and other pneumatic concepts, including full-scale flight testing of the A-6/CCW STOL Demonstrator aircraft. After retiring in 2013, Englar continued to act as Advanced Aerodynamics Consultant, particularly in the development of advanced pneumatic aerodynamic technologies for ground and water-based vehicles as well as advanced STOL and high-performance aircraft.

He led the revival of the Willard Custer Channel Wing for wind tunnel experiments directing airflow, a study that was funded by NASA and for which he was featured in *Air & Space Magazine*, and recently co-authored the book *History of the Channel Wing* with Joel Custer, the grandson of the original developer, Willard Custer. He also worked as a consultant on the X-plane project DARPA – CRANE (Control of Revolutionary Aircraft with Novel Effectors).

AIAA Associate Fellow Chang Died in October

Ming Chang, AIAA Aeronautics Domain Lead, died 1 October. He was 69 years old.

After spending most of his childhood in Hong Kong and Brazil, Chang immigrated to the United States, and attended college at the Polytechnic Institute of New York, where he received his bachelor's degree in aerospace engineering. Chang worked for Boeing for a short period of time before pursuing his master's degree in aerospace engineering at Cornell University, graduating in 1981. Chang then accepted a job as an aerospace engineer at Lockheed Corporation.

Between 1991 and 1994, he worked for Martin Marietta and Northrop Grumman before returning to work at Lockheed Martin in 1994. Chang excelled within Lockheed Martin where he assumed various roles, starting as an aerospace engineer associate and later managing the Aero, Acoustics and CFD group. He also was the Flight Sciences IPT lead for the JASSM (Joint Air-to-Surface Standoff Missile) and Nano UAV program. He was a Lockheed Martin Fellow specializing in Aeronautics. In that capacity he managed flow control programs for drag reduction such as plasma flow control and the Air Force Research Laboratory engineered surfaces, materials, and coatings (ESMC) program.

In December 2017, Chang started a position as a senior director at General Atomics in San Diego. His responsibilities included working on the Predator product line, developing real time pilot-in-the-loop simulations for handling qualities assessment, assembling the company's first remote flight test control room for Predator flight test monitoring and participation, and developing capture strategies for CRADS such as ASAPTR and SkyBorg programs. He retired in 2021 as Senior Director of Flight Technologies, overseeing aero, propulsion, CFD, and flight controls/GNC activities.

After he retired in 2021, he became the inaugural AIAA Aeronautics Domain Lead, where he set Advanced Air Mobility, Carbon Emissions and Sustainability, Certification, and High-Speed Flight as key topics for the engagement of volunteer-led domain task forces and external programming opportunities.

An AIAA Associate Fellow, Chang was also a member of the AIAA Applied Aerodynamics Technical Committee for six years. In his position as Aeronautics Domain Lead, he was the chair of the 2023 AIAA AVIATION Forum Guiding Coalition.

Regional and Section Officers, 2023–2024

Jane Hansen
Regional Engagement Activities Division Chief

Jeffrey Marchetta
Student Branch Committee Chair

Region I - North East Officers

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Vanessa Aubuchon
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Kenneth Visser
Deputy Director, Education

Colin Britcher
Deputy Director, Education

Alaa Elmiligui
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Raymond Trohanowsky
Deputy Director, Membership

Megan Tucker
Deputy Director, STEM K-12

Joseph Burns
Deputy Director, STEM K-12

Vanessa Aubuchon
Deputy Director, Technical

Jessica Evans
Deputy Director, Young Professionals

Region II - South East Officers

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Ashley Scharfenberg
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Brittani Searcy
Assistant Deputy Director, Education

Alan Lowry
Assistant Deputy Director, Finance

Cassondra Dellinger
Deputy Director, Education

Matthew Zuk
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Terri Tramel
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Trevor Moeller
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Bruce Morris
Deputy Director, Public Policy

John Fay
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Joseph Majdalani
Co-Deputy Director, Technical

Andrew Keys
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Region III - Central Officers

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Director

Christopher Pestak
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Darius Sanders
Deputy Director, Finance

Sivaram Gogineni
Deputy Director, Honors & Awards

James Gilland
Deputy Director, Membership

Patrick McNally
Deputy Director, Public Policy

Robert Bruckner
Deputy Director, Technical

Janice Gong
Deputy Director, Young Professionals

Region IV - South Central Officers

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Director

Humberto Silva
Deputy Director, Education

Edward Laverdure
Deputy Director, Education

James Walker
Deputy Director, Finance

Alicia Baker
Deputy Director, Honors & Awards

Douglas Yazell
Deputy Director, International

Svetlana Hanson
Deputy Director, Membership

Wayne Rast
Deputy Director, Public Policy

Edgar Bering
Deputy Director, STEM K-12

Sidney Chocron
Deputy Director, Technical

Joshua Kivijarv
Deputy Director, Young Professionals

Region V - Mid West Officers

Jim Guglielomo
Director

Sam Stanton
Deputy Director, Education

Kristen Gerzina
Deputy Director, Finance

Michael Martin
Deputy Director, Honors & Awards

Alexandra Dukes
Deputy Director, Membership

Colin Campbell
Deputy Director, Public Policy

Karolyn Evans
Deputy Director, STEM K-12

John Schaefer
Deputy Director, Technical

Christopher Stevens
Deputy Director, Young Professionals

Region VI - Western Officers

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Director

Jeffery Puschell
Deputy Director, Education

Marilyn McPoland
Deputy Director, Finance

Joel Perez
Deputy Director, Membership

Arianna Sanchez
Deputy Director, Public Policy

Elana Slagle
Deputy Director, STEM K-12

Catherine Beck
Deputy Director, Technical

Region VII - International Officers

Cees Bil
Director

Roelof Vos
Deputy Director, Europe

João Luiz Azevedo
Deputy Director, South America

AIAA Section Chairs

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Adelaide

Kyle Lynch
Albuquerque

Jason Lechniak
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Cameron Coates
Atlanta

David Fleming
Cape Canaveral

John Blanton
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Central Coast of California

Walter Hammond
Central Florida

Puneet Singla
Central Pennsylvania

Michael Peterson
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Daniel Nice
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Robert Tramel
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David Brandt
National Capital

Shreyas Hegde
New England

Walter Gordon
Niagara Frontier

James Sergeant
North Texas

Raymond Trohanowsky
Northern New Jersey

Joseph Connolly
Northern Ohio

John Fay
Northwest Florida

Michael Frey
Oklahoma

Dino Roman
Orange County

Quinn Kupec
Pacific Northwest

Randy Parsley
Palm Beach

Aiden Bramer
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Giovanni Minelli
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William Gastelum
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Eric Wahl
San Francisco

Hemali Vyas
San Gabriel Valley

Cameron Carson
Savannah

Angela Campbell
Southern New Jersey

Pablo Bueno
Southwest Texas

Stephen Clark
St. Louis

Tjasa Boh Whiteman
Sydney

Phil Kreth
Tennessee

Teresa Clement
Tucson

Kristen Gerzina
Twin Cities

Jessica Reust
Utah

Stephen McDougle
White Sands

Edward Feltrop
Wichita

Todd Treichel
Wisconsin

2023 Best Professional and Student 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 by 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

2021 AIAA Hybrid Rockets Best Paper
"Machine Learning Techniques for Flight Performance Prediction of Hybrid Rocket Engines" (AIAA 2021-3506) by Alessandro Zavoli, Paolo Maria Zolla, Lorenzo Federici, Mario Tindaro Migliorino, and Daniele Bianchi, Sapienza University of Rome

2021 AIAA International Space Planes and Hypersonic Systems & Technologies Best Paper
"Preliminary Study of Shock / Boundary-Layer Interactions Generated by a Sharp Fin Mounted Above a Flat Plate" (AIAA 2021-4118) by Dustin L. Otten, Lockheed Martin; and Frank K. Lu, University of Texas at Arlington

2021 AIAA Pressure Gain Combustion Best Paper
"Effects of Inlet Area Ratio on Operability of an Axial Air Inlet Rotating Detonation Combustor" (AIAA 2021-3676) by Joshua Shepard, Alexander Feleo, and Mirko Gamba, University of Michigan, Ann Arbor

2021 AIAA Propellants and Combustion Best Paper
"Modeling of Layered Ammonium Perchlorate Composite Propellant with Different Burning Rates" (AIAA 2021-1970) by Monique S. McClain, Purdue University; Brian T. Bojko, Naval Air Warfare Center Weapons Division; Simon Ray and Steven F. Son, Purdue University

2022 AIAA Aircraft Design Best Paper Award
"Comparison of Future Aviation Fuels to Minimize the Climate Impact of Commercial Aircraft" (AIAA 2022-3288) by P. Proesmans and R. Vos, Delft University of Technology

2022 AIAA Aircraft Operations Best Paper Award
"Identifying Common Coordination Procedures across Extensible Traffic Management (xTM) to Integrate xTM Operations into the National Airspace System" (AIAA 2022-3910) by Paul U. Lee, NASA Ames Research Center; Connie L. Brasil, Deborah L. Bakowski, Conrad Gabriel, San Jose State University; Mark Evans, ASRC Federal Data Solutions; and Ryan Chartrand, NASA Langley Research Center

2022 AIAA Electric Propulsion Best Paper
"Experimental Characterization of Wave-Induced Azimuthal Ion Velocities in a Hollow Cathode Plume" (AIAA 2022-1561) by Parker J. Roberts and Benjamin Jorns, University of Michigan, Ann Arbor; and Vernon Chaplin, Jet Propulsion Laboratory

2022 AIAA Electrified Aircraft Technology Best Paper
"Sizing and Analysis of a Lift-Plus-Cruise VTOL Aircraft with Electrified Propulsion Systems" (AIAA 2022-3513) by Imon Chakraborty and Aashutosh Aman Mishra, Auburn University

2022 AIAA Gas Turbine Engine Best Paper
"An Experimental Study on the Dynamic Ice Accretion Process over the Surfaces of the Rotating Fan Blades of an Aero-Engine Model" (AIAA 2022-2435) by Linchuan Tian, Linkai Li, Haiyang Hu, and Hui Hu, Iowa State University

2022 AIAA Guidance, Navigation and Control Best Paper
"On A Higher Order Method for Anonymous Feature Processing" (AIAA 2022-0606) by James S. McCabe, NASA Johnson Space Center

2022 AIAA High Speed Air Breathing Propulsion Best Paper
"From Thermal Choking to Inlet Buzz of Circular Scramjets in High-Enthalpy Flows" (AIAA 2022-0202) by Qili Liu and Li Qiao, Purdue University; and Kyungrae Kang and Hyungrok Do, Seoul National University

2022 AIAA Inlets Nozzles and Propulsion System Integration Best Paper
"Summary of the 5th Propulsion Aerodynamics Workshop Nozzle Test Case: Heated Nozzle Exhaust Passing Over a Flim-cooled Plate" (AIAA 2022-0086) by Nicholas J. Georgiadis and Mark P. Wernet, NASA Glenn Research Center; Darrell S. Crowe, Air Force Research Laboratory; Carolyn D. Woeber and Kristen Karman-Shoemake, Cadence Design Systems; and Chad M. Winkler, The Boeing Company

2022 AIAA Intelligent Systems Best Paper
"Deep Reinforcement Learning for Autonomous Aerobraking Maneuver Planning" (AIAA 2022-2497) by Giusy Falcone and Zachary R. Putnam, University of Illinois Urbana-Champaign

2022 AIAA Joint Liquid Propulsion and Propellants and Combustion Best Paper Award
"Simultaneous OH, CH2O and flow field imaging of near blowoff dynamics" (AIAA 2022-2348) by Raghul Manosh Kumar, Subodh Adhikari, Benjamin L. Emerson, and Timothy C. Lieuwen, Georgia Institute of Technology; and Christopher A. Fugger, Special Energies, LLC

2022 AIAA Meshing, Visualization, and Computational Environments Best Paper Award
"Overlap Preservation Using Loosely-Coupled Boundary Conditions for Body-Fitted Structured Overset Grids" (AIAA 2022-0216) by Andrew M. Chuen, University of California Davis; and William M. Chan, NASA Ames Research Center

2022 AIAA Modeling and Simulation Best Paper Award
"Estimating Aircraft State from Surveillance Data Using Statistical Learning" (AIAA 2022-3424) by Cody Nichols, Federal Aviation Administration; and Tyler Cook, University of Central Oklahoma

2022 AIAA Modeling and Simulation Best Paper
"Just Noticeable Differences for Variations in Quasi-Steady Stall Buffet Model Parameters" (AIAA 2022-0510) by Arne Imbrechts, Coen C. de Visser, and Daan M. Pool, Technische Universiteit Delft Faculteit Luchtvaarten Ruimtevaarttechniek

2022 AIAA Multidisciplinary Design Optimization Best Paper
"Multidisciplinary design optimization with mixed categorical variables for aircraft design" (AIAA 2022-0082) by Paul Saves, Eric Nguyen Van, Nathalie Bartoli, Thierry Lefebvre, Chrostophe David, and Sébastien Defoort, ONERA, DTIS, Université de Toulouse; and Youssef Diouane and Joseph Morlier, ISAE-Supaero ONERA, DTIS, Université de Toulouse

2022 AIAA Pressure Gain Combustion Best Paper
"Flight Demonstration of Detonation Engine System Using Sounding Rocket S-520-31: Performance of Rotating Detonation Engine" (AIAA 2022-0232) by Keisuke Goto, Nagoya University; Ken Matsuoka, Koichi Matsuyama, Akira Kawasaki,

Hiroaki Watanabe, Noboru Itouyama, Kazuki Ishihara, Valentin Buyakofu, Tomoyuki Noda, and Jiro Kasahara, Nagoya University; Akiko Matsuo, Keo University; Daisuke Nakata and Masaharu Uchiumi, Muroran Institute

2022 AIAA Sensor Systems and Information Fusion Best Paper
"Using Drone Swarms as Countermeasure of Radar Detection" (AIAA 2022-0855) by Claudia Conte, University of Naples Federico II; Sofia Verini Supplizi and Antonio Mele, Italian Air Force Academy; Giorgio de Alteriis, Giancarlo Rufino, and Domenico Accardo, University of Naples Federico II

2022 AIAA Small Satellite Best Paper Award
"On-orbit Rule-Based and Deep Learning Image Segmentation Strategies" (AIAA 2022-0646) by Shreeyam Kacker, Alex Meredith, Violet Felt, Joe Kusters, Hannah Tomio, and Kerri Cahoy, Massachusetts Institute of Technology

2022 AIAA Software Best Paper
"Automated Test Case Generation for the Verification of System and High-Level Software Requirements for Fly-by-Wire Platforms" (AIAA 2022-0254) by Reinhard Reichel, Christian Block, and Serkan Dikmen, University of Stuttgart

2022 AIAA Spacecraft Structures Best Paper
"Compressive Behavior of Isogrid Columns Fabricated with Bend-Forming" (AIAA 2022-2263) by Harsh Bhundiya, Fabien Royer, and Zack Cordero, Massachusetts Institute of Technology

2022 AIAA Systems Engineering Best Paper
"A Formal Approach to Identify Inconsistencies in Stakeholder Needs in the Context of Systems Engineering" (AIAA 2022-1469) by Hanumanthrao Kannan and Benajmin C. Jantzen, Virginia Polytechnic Institute and State University; and Bryan L. Mesmer, The University of Alabama in Huntsville

2022 Collier Aerospace HyperX Software Structures Best Paper Award
"A Study of Airframe Thermal Stresses for Hybrid Composite-Metallic Structure" (AIAA-2022-2605) by D. Scott Norwood, Scott Malaznik, Brandon M. Schneberger, Kevin M. Fuller, Jason A. Grant, Matthew T. Gill, and Jesse C. Long, Lockheed Martin Aeronautics Company; and Kevin S. Brown, Air Force Research Laboratory

2023 AIAA Applied Aerodynamics Best Paper Award
"GPU-accelerated simulations for eVTOL aerodynamic analysis" (AIAA 2023-2107) by Vito Pasquariello, Yannick Bunk, Sebastian Eberhardt, Pei-Hsuan Huang, Jan Matheis, and Matteo Ugolotti, Lilium GmbH; and Stefan Hickel, Delft University of Technology

2023 AIAA Fluid Dynamics Best Paper Award
"Rational Boolean Stabilization of Subgrid Models for Large Eddy Simulations" (AIAA 2023-2485) by Emilio E. Torres and Werner J. A. Dahm, Arizona State University

2023 AIAA Plasmadynamics and Lasers Best Paper Award
"Modeling Flame Speed Modification by Nanosecond Pulsed Discharges to Inform Experimental Design" (AIAA 2023-2056) by Colin A. Pavan and Carmen Guerra-Garcia, Massachusetts Institute of Technology

2023 AIAA Thermophysics Best Professional Paper Award
"Arc-jet Testing of Continuously Woven Aeroshells –Spiderweave– for Adaptable Deployable Entry Placement Technology" (AIAA 2022-3503) by Jonathan Morgan, Tahir Gökçen, and Paul Wercinski, NASA Ames Research Center

2023 AIAA/CEAS Aeroacoustics Best Paper Award
"Near-field measurements of stationary and rotating in-duct sound sources with pressure-sensitive paint" (AIAA-2022-3056) by Michael Hilfer, Maximilian Behn, Christian Klein, Thomas Ahlefeldt, and Ulf Tapken, German Aerospace Center; Lukas Katzenmeier, Airbus Defence and Space; Lars Koop and Lars Enghardt, German Aerospace Center

BEST STUDENT PAPERS AND STUDENT PAPER COMPETITIONS

2021 AIAA Hybrid Rockets Best Student Paper
"Swirl injection in hybrid PMMA combustion assessed by thermochemical imaging" (AIAA 2021-3513) by R. Mitchell Spearrin, Isabelle C. Sanders, Fabio A. Bendana, Nora G. Stacy, Kevin K. Schwarm, Fabio A. Bendana, Nora G. Stacy, and Kevin K. Schwarm, University of California, Los Angeles

2021 AIAA International Space Planes and Hypersonic Systems & Technologies Best Student Paper
"Aerothermal Uncertainty Quantification of Deployable Entry Technologies Using Multi-Fidelity Modeling" (AIAA 2021-4228) by Mario Santos and Serhat Hosder, Missouri University of Science and Technology; and Thomas K. West, NASA Langley Research Center

2022 AIAA Structural Dynamics Best Paper
"Hypersonic Fluid-Structure Interactions on a Compliant Clamped-Free Clamped-Free Panel Under the Influence of Static Shock Impingement" (AIAA 2022-0241) by Paulo B. Vasconcelos, Liam P. McQuellin, Krishna M. Talluru, and Andrew J. Neely, University of New South Wales

2022 AIAA Walter Lempert Best Student Paper
"Thomson and Collisional Regimes of In-Phase Coherent Microwave Scattering Off Small Plasma Objects" (AIAA 2022-1748) by Adam Patel, Apoorv Ranjan, Xingxing Wang, Mikhail Slipchenko, and Alexey Shashurin, Purdue University; and Mikhail N. Shneider, Princeton University

2022 AIAA Walter Lempert Best Student Paper, Honorable Mention
"Analysis of Screech Phenomena in a Mach 1.0 Jet with Linear Array Focused Laser Differential Interferometry" (AIAA 2022-1798) by Theron J. Price, Mark Gragston, and Phillip A. Kreth, University of Tennessee Space Institute

2022 AIAA Walter Lempert Best Student Paper, Honorable Mention
"Measurements of NH3 in a Shock Tube for Investigating the Chemical Kinetics of Rocket Propellants" (AIAA 2022-1875) by Sulaiman Alturaifi and Eric L. Petersen, Texas A&M University

2023 AIAA David Weaver Thermophysics Best Student Paper Award
"Assessment of Detailed Thermochemistry and Excitation Models for Shock-Heated Oxygen Mixtures" (AIAA 2022-3500) by Timothy T. Aiken and Iain D. Boyd, University of Colorado

2023 AIAA Guidance, Navigation and Control Graduate Student Paper Competition Winner
"Bayesian Active Sensing for Fault Estimation with Belief Space Tree Search" (AIAA 2023-0874) by James F. Ragan and Benjamin P. Riviere, California Institute of Technology

2023 AIAA Air Transportation Systems Best Student Paper Award – 1st Place
"Noise- and Fuel-Minimal Departure Trajectory Optimization with Reinforcement Learning" (AIAA 2023-4215) by Chris Nguyen, James M. Shihua, Ka Yiu Hui, and Rhea P. Liem, Hong Kong University of Science and Technology

2023 AIAA Air Transportation Systems Best Student Paper Award – Runner Up
"Urban Air Mobility Network Distribution in Chicago Metropolitan Area" (AIAA 2023-3262) by Qilei Zhang and John H. Mott, Purdue University

2023 AIAA Computational Fluid Dynamics Student Paper Competition – 1st Place
"Nonlinear Nonmodal Analysis Of Hypersonic Flow Over Blunt Cones" (AIAA 2023-3420) by Anton Scholten, North Carolina State University; Pedro Paredes, National Institute of Aerospace; Meelan M. Choudhari, Fei Li, and Mark Carpenter, NASA Langley Research Center; and Michelle Bailey, The University of Arizona

2023 AIAA Computational Fluid Dynamics Student Paper Competition – 2nd Place
"A Hybrid Lattice Boltzmann - Navier-Stokes Method On Overset Grids" (AIAA 2023-3433) by Alexandre Suss, Ivan Mary, and Thomas Le Garrec, ONERA, Université Paris Saclay; and Simon Marié, Laboratoire DynFluid

2023 AIAA Computational Fluid Dynamics Student Paper Competition – 3rd Place
"Eigenvalue Sensitivity Computations For Linear Stability Theory" by Connor Klauss, University of Maryland; Pedro Paredes, National Institute of Aerospace; Meelan M. Choudhari, NASA Langley Research Center; Boris Diskin, National Institute of Aerospace; and James Baeder, University of Maryland

2023 AIAA Multidisciplinary Design Optimization Student Paper Competition Award – 1st Place
"High-dimensional uncertainty quantification usinggraph-accelerated non-intrusive polynomial chaos and activesubspace methods" (AIAA 2023-4264) by Bingran Wang, Nicholas C. Orndorff, Mark Sperry, and John T. Hwang, University of California, San Diego

2023 AIAA Multidisciplinary Design Optimization Student Paper Competition Award – Runner Up
"Model Reduction of Isogeometric Shell Structures For Large-Scale Design Optimization" (AIAA 2023-3720) by Sebastiaan P. van Schie and John T. Hwang, University of California, San Diego

2023 AIAA/CEAS Aeroacoustics Student Paper Competition
"Estimation of the relative balance between the rotor and the OGV broadband noise" (AIAA 2023-3208) by Ram Kumar Venkateswaran, Phillip Joseph, and Chaitanya C. Paruchuri, University of Southampton

2023 American Society for Composites Student Paper Award
"A Novel Anisotropic Hyper-viscoelastic Model for Predicting Fabric Draping Responses" (AIAA 2023-0522) by Qingxuann Wei, Purdue University

2023 Harry H. and Lois G. Hilton Student Paper Award in Structures
"Dynamic performance of hygro-thermal-mechanically preloaded variable stiffness composite fairing structures" (AIAA 2023-1322) by Giuseppe Sciascia, University of Limerick, Ireland

2023 Jefferson Goblet Student Paper Award
"Feature-Mapping Topology Optimization of a Wing-box with Geometric Constraints" (AIAA 2023-1271) by Hollis Smith, University of Connecticut

2023 Lockheed Martin Student Paper Award in Structures
"A Discontinuous-Galerkin, Lagrangian Thermo-chemo-mechanical Material Response Solver for the Analysis of Ablative Thermal Protection Systems" (AIAA 2023-0197) by Christopher Quinn and Daniel Pickard, Massachusetts Institute of Technology

2023 SwRI Student Paper Award in Non-Deterministic Approaches
"Optimally tensor-structured quadrature rule for uncertainty quantification" (AIAA 2023-0741) by Bingran Wang, University of California, San Diego

AEROSPACE ENGINEERING POSITION – The Aerospace Engineering Department at Cal Poly, San Luis Obispo, invites applicants with an earned Ph.D. in Aerospace Engineering, or closely-related field, to apply for a full-time, academic-year Tenure¬-Track faculty position at the Assistant or Associate Professor rank. The projected start date is September 16, 2024. Duties include teaching Aerospace Engineering courses; building a vibrant and innovative research program which integrates undergraduate students; and supporting and developing students into engineers ready to thrive in the modern aerospace industry. Candidates are sought with experience or interest in the areas of aerospace structures, spacecraft design, and spacecraft communications to support of the department's unique and innovative curriculum. Candidates with research, industry, or experimental experience are especially encouraged to apply.

The Cal Poly College of Engineering strongly values diversity, equity, and inclusion (DEI), as part of our focus on equitable student success. This position is one of several open across the college. Successful applicants will show evidence of, or demonstrate, the potential to implement inclusive and equity-minded teaching strategies as well as increase curricular coverage of the intersection of engineering and computing with societal challenges, particularly around DEI issues. Successful candidates will be expected to contribute to the college's goals in these areas.

In addition to the standard new faculty support, candidates with DEI focused scholarship and/or pedagogy may be awarded additional start-up funds to support their DEI work. Once hired, candidates will collaborate with their dean and others to develop a plan for utilizing these funds.

REQUIRED QUALIFICATIONS
Applicants with an earned Ph.D. in Aerospace Engineering, or a closely related field. Demonstrated experience and commitment to student-centered learning and teaching, as well as the ability to collaboratively work in multidisciplinary settings is required. Demonstrated proficiency in written and oral use of the English language is required.

Demonstrated experience and commitment to student-centered learning and teaching, as well as the ability to collaboratively work in multidisciplinary settings is required. Demonstrated proficiency in written and oral use of the English language is required.

The ideal candidate will show evidence of attention to and/or the potential to contribute on issues of diversity, equity, and inclusion across their teaching, scholarship, and service.

Applicants must submit a diversity statement which demonstrates the candidate's experience or potential with respect to supporting the college of engineering's goals related to diversity, equity, and inclusion. In particular, our vision statement is: "The Cal Poly College of Engineering will be nationally recognized for its rapidly diversifying student population and unique, inclusive Learn by Doing educational and applied research experiences. "Candidate's diversity statement should convey how their teaching, research, and/or service at Cal Poly will contribute to this vision. Examples include highlighting the candidate's experience and/or intentions with respect to: implementing inclusive classroom environments, the intersection of DEI in your research/scholarship, mentoring students with diverse backgrounds, outreach to under-represented student populations, and previous professional development in diversity and inclusion topics.

PREFERED QUALIFICATIONS
Preference will be given to those who can show evidence of working with diverse populations and fostering a collaborative, supportive and inclusive environment. Preference will also be given to those with relevant work experience and those who bring professional capabilities.

ABOUT THE DEPARTMENT
Cal Poly's Aerospace Engineering Department offers a B.S. and M.S. in Aerospace Engineering. Cal Poly focuses on undergraduate and graduate education. Our "learn-by-doing" approach involves extensive lab work and projects in support of theoretical knowledge, with extensive interaction and collaboration between students and faculty. U.S. News & World Report ranked the Aerospace Engineering Department top among primarily undergraduate public programs in the nation. For further information about the department, see **www.aero.calpoly.edu**

HOW TO APPLY
Please apply at **https://jobs.calpoly.edu/en-us/listing/-** Requisition # 531204. Rank and salary are commensurate with qualifications and experience. Review of applications will begin December 4th, 2023 and will continue until the position is filled.

Interested candidates must attach a cover letter, resume/curriculum vitae, transcripts (please note proof of a Ph.D. is required by the start date); statement of goals and plans for teaching and research; qualification summary and teaching preferences; and a diversity and inclusion statement. Please be prepared to provide three professional references with names and email addresses when completing the online faculty application.

For further questions please contact Kira Abercromby (**kabercro@calpoly.edu**)

Department of Aerospace Engineering - Open Rank Faculty Search

The Grainger College of Engineering

University of Illinois Urbana-Champaign

The Department of Aerospace Engineering at the University of Illinois Urbana-Champaign seeks highly qualified candidates for two full-time faculty positions (with a focus on qualified senior candidates to be considered for tenured Associate Professor and Full Professor positions). Primary target areas of interest are: (1) Controls and Dynamical Systems, including control theory, robotics, autonomy, remote sensing, optimization, data science, and machine learning; and (2) All other areas relevant to Aerospace Engineering that will reinforce the department's current strengths, such as aerospace mechanics and materials, fluid mechanics and propulsion, and space systems. Senior and mid-career faculty are particularly encouraged to apply, though all qualified candidates will be considered. Candidates from underrepresented racial, ethnic, gender, or other backgrounds across the aerospace engineering field are encouraged to apply.

Please visit https://jobs.illinois.edu to view the complete position announcement and application instructions. Full consideration will be given to applications received by January 15, 2024. Applications received after that date may be considered until the positions are filled.

We have an active and successful dual-career partner placement program and a strong commitment to work-life balance and family-friendly programs for faculty and staff (https://provost.illinois.edu/faculty-affairs/work-life-balance/).

The University of Illinois System is an equal opportunity employer, including but not limited to disability and/or veteran status, and complies with all applicable state and federal employment mandates. Please visit Required Employment Notices and Posters to view our non-discrimination statement and find additional information about required background checks, sexual harassment/misconduct disclosures, COVID-19 vaccination requirement, and employment eligibility review through E-Verify.

Applicants with disabilities are encouraged to apply and may request a reasonable accommodation under the Americans with Disabilities Act (2008) to complete the application and/or interview process. Requests may be submitted through the reasonable accommodations portal, or by contacting the Accessibility & Accommodations Division of the Office for Access and Equity at 217-333-0885, or by emailing accessibility@illinois.edu.

EMBRY-RIDDLE
Aeronautical University
DAYTONA BEACH, FLORIDA
COLLEGE OF ENGINEERING

Department Chair, Aerospace Engineering Department

The Opportunity
The Aerospace Engineering (AE) Department at Embry-Riddle Aeronautical University (ERAU) in Daytona Beach, Florida, invites applications and nominations for Department Chair. ERAU is seeking a department chair who is collaborative, student-focused, creative, and a research leader. The ideal candidate will be a team player who knows how to build consensus in a large and complex department, with a diverse and growing faculty. The Department Chair will successfully maintain ERAU's emphasis on student success, while also leading forward the continued growth in research stature of the department.

The AE Department is the largest in the nation with an enrollment of over 2,300 full-time students. It offers Bachelors, Masters, and Ph.D. degrees. The undergraduate program is currently ranked #4 by U.S. News and World Report, while the graduate program is ranked #25. The department's research expenditures have more than tripled over the last five years, with a continued growth trend. To achieve national prominence, the AE Department has launched an ambitious agenda focused on expanding graduate programs, recruiting talented faculty, and investing in research infrastructure and capabilities. In support of this agenda, ERAU has invested in a new 50,000-sqft engineering building, the John Mica Engineering and Aerospace Innovation Complex (MicaPlex), housing research laboratories, a state-of-the-art subsonic wind tunnel, the Eagle Flight Research Center facility, and tech startup incubator space. Building on this existing capability, the new $50M Cici and Hyatt Brown Center for Aerospace Technology is currently being constructed, creating a growing academic/industry ecosystem to support innovation and entrepreneurship.

ERAU is an independent, culturally diverse institution providing quality education and research in aviation, aerospace, engineering, and other related fields with residential campuses located in Daytona Beach, Florida; Prescott, Arizona; and Singapore – as well as a Worldwide campus that provides educational opportunities online and at approximately 130 locations throughout the United States, Asia, Europe, and Central/South America.

ERAU is the world's largest, fully accredited university specializing in aviation and aerospace, with more than 70 Bachelors, Masters, and Ph.D. programs in Arts and Sciences, Aviation, Business, and Engineering. The Daytona Beach Campus serves a diverse student body of approximately 8,300 students. The research focus areas at ERAU are strategic and continue to incrementally evolve as technology and the world around us changes. Some of our engineering focus areas include: Modeling and Simulation of Complex Multiphysics Systems, Aircraft Design, Flight Test Engineering, Advanced Flight Control Systems, Autonomous Systems, Robotic Systems, Sense & Avoid Technology, Hybrid Propulsion Systems, Cybersecurity, High-Assurance Software and Systems, and others. To further support aviation and aerospace convergent research, the University has established Centers of Excellence such as the Boeing Center for Aviation and Aerospace Safety (https://erau.edu/research/industry-collaboration/center-for-aviation-and-aerospace-safety) and the Center for Aerospace Resilience (https://erau.edu/research/industry-collaboration/center-for-aerospace-resilience).

Qualifications
Candidates must hold a doctoral degree in AE or other related fields, have an outstanding record of securing external funding from a diverse set of agencies and industry, and be committed to teaching excellence with experience in a broad range of innovative methods of instruction and assessment. Candidates must have excellent leadership and communication skills in written and spoken English, as well as experience with development of personnel, project management, strategic planning, and budget management. The position requires an ability to work collaboratively with internal and external constituents as a team member of the department, college, and university. The ideal candidate will have a clear vision for supporting the growth of the AE Department. Candidates must have the necessary qualifications at the time of employment to be appointed as a tenured full professor in the AE Department.

Diversity
ERAU values diversity: we respect the rights and property of all individuals, regardless of gender, race, ethnicity, national origin, age, physical disability, economic background, sexual orientation, or religious belief. We believe in a community where all members are welcome, and individuals or groups are free from harassment. We strongly encourage individuals from populations traditionally underrepresented and underserved in STEM – women, Black, Latinx, Native Americans, persons of all gender identities and/or sexual orientation – to apply.

Equal Opportunity
ERAU is an affirmative action/equal opportunity employer and does not discriminate on the basis on race, color, religion, gender, age, national origin, handicap, veteran status, or sexual orientation.

Application process
Visit **https://careers.erau.edu**, and search to find requisition R306652. Consideration of applications will begin November 2023 and will continue until the position is filled. The anticipated start date is August 2024.

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collisions and the space debris problem are growing, with an assured path toward making specific orbital highways unusable.

To avert a potential crisis in outer space, we must confront this issue with determination. A promising solution can be found in the principles and tenets of traditional ecological knowledge, or TEK, which I've written about in a previous column. TEK emphasizes sharing finite resources in harmony and attunement with the environment and embracing stewardship. I'm not proposing that we turn away from regulation, but to the contrary: that we embrace regulation that is informed by tenets of environmentalism and sustainability as demonstrated by TEK.

TEK provides a framework to address the problem of orbital colonialism by encouraging the notion that passive or tacit occupation is a form of ownership instead of stewardship. Those already engaged in orbital occupation openly state that they should have an operational priority for the space they occupy, in a sense claiming rights. In the absence of legal deeds, this occupation of orbital space implicitly asserts a claim to these spaces, akin to a silent assertion of ownership. The coming generation of leaders recognize what is happening. I spent time in September with native Hawaiian kids at Molokai High School and at Aka'ula School, a private school with an enrollment of a few dozen middle and high school students. The consensus was that we, humanity, do not have a space community but rather space groups and individuals because we don't practice equitable sharing of space.

The native Hawaiians I shared time with said that our collective behavior should be one of stewardship — a responsibility to manage and protect this finite orbital resource equitably through a shared framework or roles and responsibilities. TEK also inspires us to foster a common knowledge of space operations that can lead to shared practices. In this approach, nations and entities engaged in space activities would collaborate to build a collective understanding of responsible satellite deployment, space debris mitigation and equitable access to orbital space. This is a process of developing so-called norms of behavior, which isn't a replacement of regulation but agreed practices that inform the creation of effective regulations.

Capacity building would involve sharing effective practices, jointly developing standards and collaborating on space debris monitoring and removal efforts. This approach would not only promote responsible behavior in space but also foster a sense of stewardship of the orbital environment. In the beginning, seat belts were highly encouraged and eventually became the law. So too with common practices and norms of behavior.

Additionally, TEK principles encourage a long-term view of space resource management, prioritizing sustainability over the myopic pursuit of orbital dominance. By working together and sharing knowledge, we can ensure that outer space remains a realm of peaceful cooperation and equitable access for all nations.

History teaches us that unchecked colonialism leads to division and conflict. We must not allow the race to space to follow this perilous path. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1923

Nov. 1 Robert H. Goddard operates a liquid-propellant rocket motor on a test stand, with onboard pumps supplying gasoline fuel and liquid oxygen oxidizer. In two test runs, Goddard's motor generates 25 pounds of thrust (53.38 newtons) for 12 seconds and 50 pounds (222.42 N) for 15 seconds. NASA, **Aeronautics and Astronautics, 1915-1960**, p. 17; Esther C. Goddard and G. Edward Pendray, eds., **The Papers of Robert H. Goddard**, Vol. I, p. 518 and Vol. III, p. 1662.

1 **Nov. 4** U.S. Navy Lt. Alford J. Williams establishes a world's speed record of 266.5 mph (428.9 kph) while piloting a Curtiss R2C-1 Racer over Mitchell Field, Long Island. The feat earns Alford the Pulitzer Trophy and remains the U.S. record until 1930. NASA, **Aeronautics & Astronautics, 1915-1960**, p. 17; **The Aeroplane**, Nov. 7, 1923, p. 458.

Nov. 5 The U.S. Navy completes tests that demonstrate the feasibility of stowing, assembling and launching a seaplane from a submarine. Conducted at the Hampton Roads Naval Base in Virginia, the tests involve the S-1 submarine, a Martin MS-1 seaplane and the assistance of the crew on the USS Langley. **United States Naval Aviation 1910-60**, p. 46.

Nov. 6 Days after setting his speed record, U.S. Navy Lt. Alford J. Williams climbs to an altitude of 5,000 feet in his Curtiss R2C-1 Racer in one minute. He bests the previous record of reaching an altitude of 2,000 feet in the same amount of time. **United States Naval Aviation 1910-60**, p.46; **Aircraft Yearbook 1924**, p. 227.

Nov. 30 M. F. Laporte reaches an altitude of 19,024 feet in a Schreck F.B.A. seaplane, a world record for flying boats. The previous record was 13,898 feet, set in June by U.S. Navy Lt. C. F. Harper flying a David-Douglas seaplane in San Diego. **The Aeroplane**, Dec. 19, 1923, p. 584.

Also during November New York University inaugurates courses in aeronautical engineering and industrial aviation. **Aeronautical Digest**, December 1923, p. 417.

Also during November Raúl Pateras Pescara of Spain flies his helicopter for 5 minutes and 44 seconds in trials in France. In the course of these, he flies horizontally for 245 meters, lands and, after half an hour, flies back to his starting point. Later, he makes a flight of 347.5 meters. **The Aeroplane**, Dec. 5, 1923, p. 544.

1948

Nov. 4 The U.S. Air Force announces the formation of the RAND Corp. for gathering advanced scientific, technical and military knowledge that the service can apply to policy decision-making. RAND Corp. succeeds Project RAND, the nonprofit formed by Douglas Aircraft Co. in 1946 at the behest of the Air Force. NASA, **Aeronautics and Astronautics, 1915-1960**, p. 60.

Nov. 9 U.S. Navy transport squadrons VR-6 and VR-8 begin flying cargo to western Germany as part of the Berlin Airlift. In October, the U.S. Military Air Transport Service had ordered the squadrons to leave Pacific bases and participate in these flights, also called Operation Vittles. **United States Naval Aviation, 1910-1970**, p. 168.

Nov. 10-12 The first symposium on aeromedical problems of space travel is held at the Air Force School of Aviation Medicine in San Antonio. NASA, **Aeronautics and Astronautics, 1915-1960**, p. 60.

Nov. 22 The 1903 Wright Flyer arrives at the Smithsonian Institution's National Air Museum in Washington, D.C., from London, where the aircraft had been on display since 1928. Smithsonian curators Paul Garber and Stanley Potter supervise its installation in the Arts and Industries Building in preparation for a public unveiling on Dec. 17, the 45th anniversary of the Wright brothers' first flight. The return of the flyer to the U.S. follows years of negotiations with Orville Wright before his death in January, which ended in 1942 when the Smithsonian officially acknowledged the flyer as the first successful heavier-than-air craft to perform controlled sustained flight. Aviation Week, Nov. 29, 1948, p. 15; Geoffrey T. Hellman, The Smithsonian, pp. 154-158; NASA, **Aeronautics and Astronautics 1915-1960**, p. 60.

1973

Nov. 1 A variable sweep-wing General Dynamics F-111 Aardvark with a NASA supercritical wing makes its first test flight at Edwards Air Force Base in California. The joint U.S. Air Force-NASA Transonic Aircraft Technology, or TACT, program is studying whether the supercritical design could reduce drag and increase efficiency at transonic speeds, as indicated by wind tunnel tests. **NASA Release** 73-215.

2 **Nov. 3** NASA's Mariner 10 Venus-Mercury probe is launched into a parking orbit by an Atlas-Centaur D1 rocket. After a 25-minute coast, the rocket's Centaur upper stage fires its engines to inject the spacecraft into a heliocentric orbit, putting Mariner 10 on a trajectory to pass within 5,800 kilometers of Venus in February. The spacecraft measures Venus' atmosphere, surface and body characteristics, then departs toward Mercury to make similar observations during a series of flybys. **NASA Release** 673.

Nov. 3 Mission controllers and scientists at NASA's Ames Research Center in California begin "encounter operations" in preparation for the Pioneer 10 probe's flyby of Jupiter in early December. Shortly after, the spacecraft begins transmitting images of the planet's Great Red Spot from a distance of 8.3 million kilometers. Among the findings is that Jupiter's mass is greater than previously estimated. **JPL release** 673; **New York Times**, Nov. 25, 1973, p. A1 and other issues.

Nov. 6 The NOAA-3 meteorological satellite is launched by a two-stage Thor-Delta rocket. From its sun-synchronous orbit, the satellite provides dependable daytime and nighttime meteorological observations of the entire globe. It is the fourth in NOAA's Improved TIROS Operational Satellite series of second-generation weather satellites. NASA, **Astronautics and Aeronautics, 1973**, p. 312.

Nov. 7 The first direct TV transmission from the Soviet Union to Cuba is made when the Soviet Molniya communications satellite transmits the telecast of the Soviet Red Square parade in Moscow to a ground station in eastern Cuba. Regular TV and communications traffic are scheduled to begin in 1974. **Aviation Week**, Nov. 12, 1973, p. 9.

Nov. 12 NASA announces that Ames Research Center biologists, Paul Deal and Kenneth Souza, have discovered an Earth organism that could survive and grow in an environment resembling that of the outer planets of the solar system. The red-shaped bacteria are swimming, growing and reproducing in a solution of sodium hydroxide. Scientists theorize that the atmospheres of Jupiter, Saturn and Uranus may also be highly alkaline. **NASA Release** 73-238.

3 **Nov. 15** NASA test pilot John Manke conducts the first powered flight of the X-24B Lifting Body. After the craft is released from a B-52, the three thrust chambers of the XLR-11 rocket engine propel the X-24B to Mach 0.85 and an altitude of 16,000 meters. The experimental X-24B is being flown in a joint U.S. Air Force-NASA research program. NASA, **Astronautics and Aeronautics, 1973**, p. 319.

4 **Nov. 16** The Skylab 4 spacecraft carrying three astronauts is launched from NASA's Kennedy Space Center in Florida on a Saturn

1B. Astronauts Gerald Carr, Edward Gibson and William Pogue are the third and final crew to visit Skylab, the first U.S. space station. During their three-month mission, the astronauts conduct zero-g medical experiments, make 121 observations of Comet Kohoutek and complete Earth resources. They depart Skylab in February and splash down in the Pacific Ocean. **New York Times**, Nov. 17, 1973, p. 1 and other issues.

Nov. 20 NASA announces that Thiokol Chemical Corp. will receive a $106 million contract for the design, development, testing and evaluation of solid-fueled rocket boosters for the planned space shuttle orbiters. Lockheed Martin, which also bid for the contract, files a protest in December, which is later overturned by the U.S. Government Accounting Office. **NASA Release** 73-258.

Nov. 24 Soviet helicopter pioneer Nikolai Kamov dies at 71. He was designated a Hero of Socialist Labor by the Soviet Union for accomplishments that include founding the Kamov Design Bureau. He was a co-designer of the Ka-Skr-1, the first Soviet-built rotorcraft that made its inaugural flight in 1929, and is credited with coining the Russian word for helicopter, "vertolyot." NASA, **Astronautics and Aeronautics, 1973**, p. 329.

1998

5 **Nov. 4** Lockheed Martin and NASA test fire a Russian RD-180 rocket engine at NASA's Marshall Space Flight Center in Alabama. This is the third such test in which an RD-180 is attached to a prototype of an Atlas IIIA booster and ignited. Lockheed Martin plans to install one RD-180 on each of the Atlas III boosters, a shift from previous Atlas variants, which each had three U.S.-made engines. **Flight International**, Nov. 18-24, 1998, p. 30; **Aviation Week**, Nov. 22, 1999, pp. 52-55.

Nov. 19 Japan Airlines receives its 100th Boeing 747 airliner. The delivery is celebrated by ceremonies in Seattle, to commemorate JAL becoming the operator of the largest 747 fleet in the world. **Flight International**, 2-8 Dec. 1998, p. 13.

6 **Nov. 20** A Russian Proton rocket boosts the Zarya module into orbit, the first step toward the construction of the International Space Station. In December, the U.S. space shuttle Endeavour launches the Unity module and joins it to Zarya, which provides electrical power, propulsion and other functions for the growing station. Some 80 launches through 2011 are conducted to complete ISS assembly. **Flight International**, Nov. 25- Dec. 1, 1998, p. 7 and Dec. 2-8, 1998, pp. 30, 45.

Nov. 22 The Russian communications satellite Bonum-1 is placed into orbit by a Boeing Delta II rocket that launches from Cape Canaveral, Florida. The satellite, built by Hughes Space and Communications for a private Russian television network, provides television coverage for most of Russia and eastern Europe. NASA, **Astronautics and Aeronautics: A Chronology, 1996-2000**, pp. 173-174.

Nov. 30 The French minister for Education, Research and Technology announces his country will join the U.S. in a proposed Mars sample return mission. The five-year mission is to begin in 2005, but NASA later delays planning after the 1999 failures of its Mars Climate Orbiter and Mars Polar Lander. **Flight International**, Dec. 9-15, 1998, p. 28.

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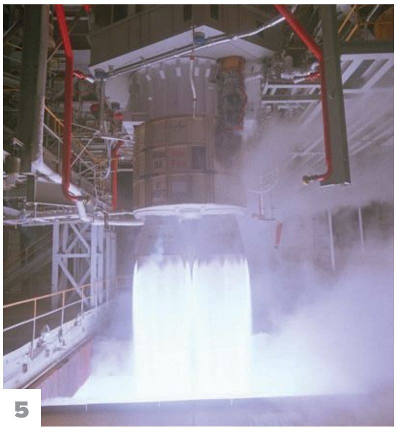
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6

Occupation, even in orbit, is colonialism

BY MORIBA JAH | moriba@utexas.edu

Putting to use the vast expanses of outer space ought to be a unifying endeavor for humanity, a shared quest for discovery and cooperation. Right now, our race to space bears an unsettling resemblance to our history on terra firma. The relentless drive for orbital dominance, fueled by nations and corporations, harkens back to a colonial-era land grab.

Consider the United States. Our Space Force states that its mission is to "secure our Nation's interests in, from, and to space." Notice the difference between those words and the mission of the U.S. Navy, which is, in part, to "keep the seas open and free" — providing not just freedom of navigation for U.S. ships but to all in the name of preserving "economic prosperity." In space, matters are playing out much differently than at sea. In 2010, there were about 1,200 working satellites in orbit. Today, there are a little under 9,000, and about half of them are Starlink internet satellites operated by Elon Musk's SpaceX. Five years ago, about one satellite per month was launched, and today upwards of 60 satellites reach space every few weeks, and most are Starlinks. SpaceX intends to continue to launch its satellites at this rate until it reaches about 12,000 total, with regulatory approval for an additional 30,000 pending. Eutelsat OneWeb, the newly formed French-British conglomerate, plans on having several hundred satellites for its internet services, and Amazon's Project Kuiper plans to launch thousands of satellites too, also for internet. Thus far, the U.S. is winning the race for orbital occupation.

What makes this contemporary form of colonialism especially insidious is its passive assertion of ownership. You won't find a document that declares that these companies own their orbital shells. These de facto claims of ownership thrive in the ambiguity of space laws and the absence of enforcement mechanisms. This behavior is breeding resentment among nations that have yet to participate in the saturation of space with hundreds to thousands of satellites. China, for instance, has complained to the United Nations that the Starlink satellites pose a growing hazard to its own satellite and space station operations and has gone as far as stating that it is considering developing countermeasures for the Starlink satellites. Russia threatened to retaliate against the Starlink communications satellites due to Ukraine's use of them on the front line.

These rising tensions will likely escalate into diplomatic disputes, growing geopolitical friction and, in the worst-case scenario, open conflict.

The Outer Space Treaty of 1967, while a landmark in space governance, did not comprehensively address the issue of orbital occupation. While it explicitly prevented the national appropriation of outer space and celestial bodies, it did not foresee or prohibit the unchecked deployment of satellites, which has resulted in the de facto occupation of orbital space.

Furthermore, the unchecked proliferation of satellites has led to a dramatic increase in space traffic, posing significant risks to all space activities, from satellite communications to scientific research. Potential

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