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AEROSPACE

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WELCOME ABOARD

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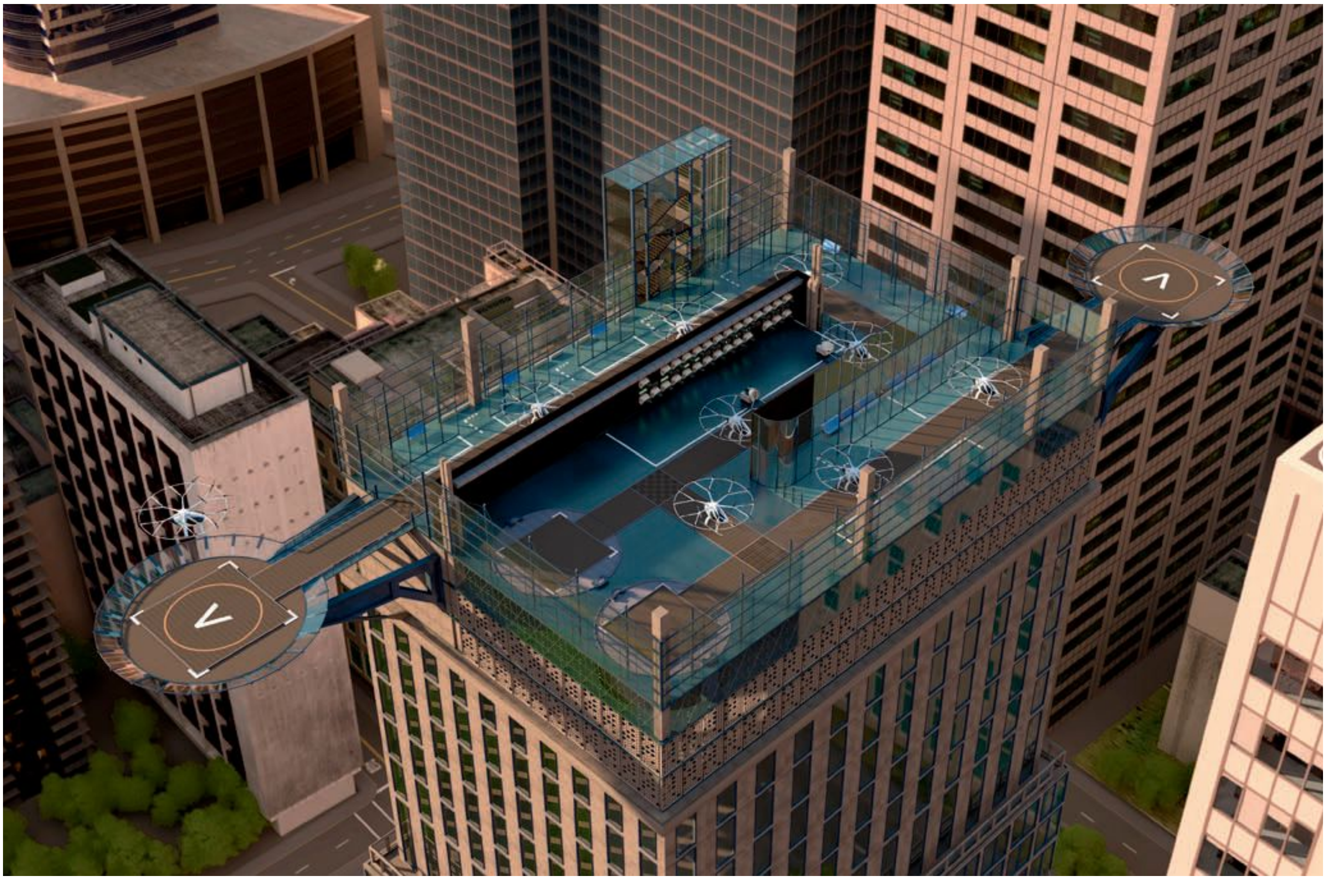

On the cover: Alpha 2 Vahana demonstrator

Image credit: Vahana/Airbus

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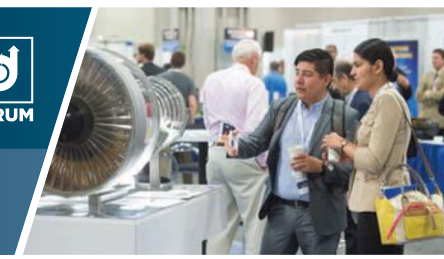

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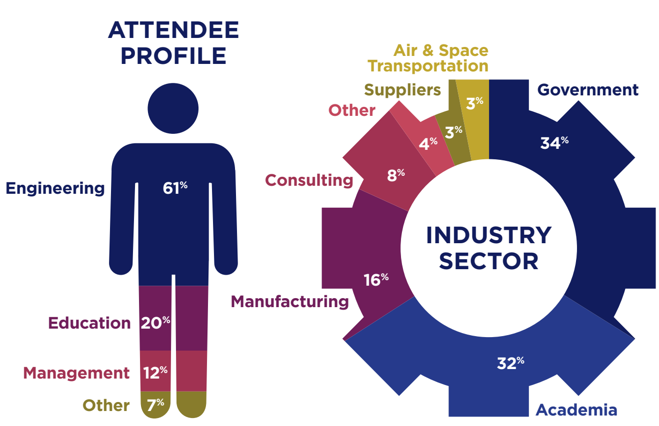

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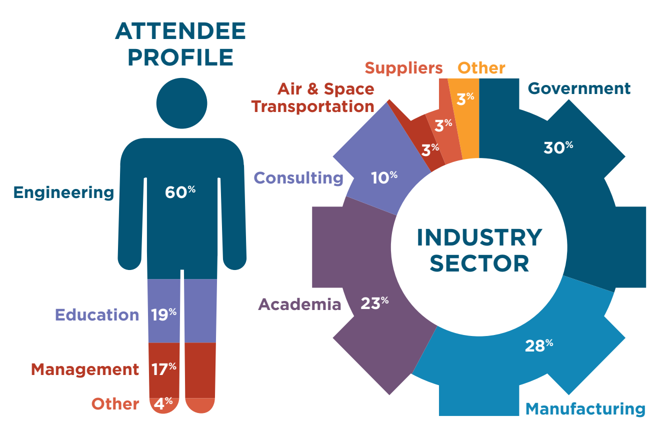

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IN THIS ISSUE

Keith Button

Keith has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns scandal that kicked off the global credit crisis.

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Tom Jones

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

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Amanda Miller

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Marc Selinger

A former congressional reporter and Pentagon correspondent, Marc has written for more than 20 aerospace and defense publications.

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Debra Werner

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

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DEPARTMENTS

Looking beyond rockets and airframes

▲ **The Mission Operations** Control Room at NASA's Johnson Space Center in Houston for the Apollo 11 mission.
NASA

The Apollo 11 anniversary is bringing out the TV marketers in the U.S., and most of the material is fairly thought-provoking.

In an ad by the wireless company Verizon, the massive Saturn 5 lifts off, and in a grainy film, spectators in Bermuda shorts and oversized sunglasses look skyward in total awe. Cut to a film of people working in front of old-fashioned computer displays. The narrator, identified as a Verizon engineer, says — and I paraphrase — sure, the big rocket was cool, but if you're an engineer, you should be looking "in awe at those men and women in the room."

Setting aside the question of whether women, plural, were in the room, my knee-jerk reaction was: Well, the gall of a networking and cable TV company to seize the aerospace industry's greatest achievement to lure talent away from aerospace.

The commercial stuck with me, so I looked it up on YouTube. I realized I missed the spot's bigger point, which is a fair one. This mission was humanity's greatest achievement, not just the aerospace industry's. In terms of technology, rockets were not the whole story in 1969, and they are not the whole story now. The same goes for aircraft and satellites. These vehicles can't do much without a network. On the other hand, not much of a network would be needed were it not for the vehicles. Breakthroughs are going to take a big, wide community of talented people, and there will be lots of ways to contribute while making a living.

This message comes through in Aerospace America's coverage. Our April story, "Waiting in the wings," about the lack of a firm plan in the U.S. for managing commercial drone traffic, points out that these aircraft probably will need to share information over commercial cellular networks to quickly deconflict their routes.

In the Verizon commercial, with Earth emerging from the curve of the moon, the narrator closes with a pitch for the company's version of 5G, the standard that's being rolled out for higher-bandwidth wireless: "When I think of it, I think of what people might do with it. I think of where people might go with it."

OK, so the ad is not exactly theft. When a rocket lifts off, or a Falcon's stages land, I will remember the bits, radio waves and those who crafted them.

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

EDITOR'S NOTEBOOK | PUBLIC POLICY

Leading in aerospace

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

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

I sense this aerospace leadership beginning to slip away.

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

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

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

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

▲ Boeing 737 MAX
Boeing

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

4 | APRIL 2019 | aerospaceamerica.aiaa.org

Imagining great things

Thank you for your very straightforward "Leading in aerospace" editorial [April Editor's Notebook]. After nearly 40 years of working in the defense sector of aerospace, I know much of your audience needs to hear it but will not like it. Past glories do not define us today — only current performance can. We need to stop being in denial of the realities of the present and do great things again. More imagination would help. Ask, "What's the worst that can happen and how do we prevent it?" and "What's the absolute best we can achieve?"

Thomas R. Woodford
AIAA senior member
woodfordtr@gmail.com

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

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

TOPIC AREA 1

Aircraft Configurations and Systems Requirements

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

TOPIC AREA 2

Enabling Technologies and Components

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

TOPIC AREA 3

System Integration and Controls

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

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The Summer of '69

Where were you on July 20, 1969? About half of today's AIAA membership was not even born then, but if you were around I'm sure you remember how you spent that Sunday afternoon. I was in 6th grade. My friends and I used to lie on our backs on the floor, three abreast, feet up against a sofa in an imaginary Apollo capsule, running checklists. I think it was my first all-nighter, watching Walter Cronkite and Wally Schirra co-anchor the CBS News coverage as Neil Armstrong and Buzz Aldrin landed, and then — too excited to sleep themselves — suited up and accelerated their moonwalk.

Where will you be on July 20, 2019? Hopefully somewhere involved in some sort of STEM activity, sharing the excitement of our industry today with the next generation or two. In Huntsville they plan to launch 5,000 model rockets simultaneously. These sorts of outreach activities will be happening across the country and would be perfect for AIAA sections and members to sponsor or join in. Now is the time to be making your plans!

At a recent MIT celebration of the Apollo moon landing's 50th anniversary, I took part in a panel discussing "The New Space Industrial Ecosystem." The panelists were asked if the space enterprise was changing from one that has traditionally depended on large government contracts alone. "Can we look forward to a self-sustaining industrial ecosystem, like aviation is today, or is that an illusion?" It's a great question, with important implications for AIAA.

Since World War II, the United States has led the world in research and development, largely through a triumvirate of government, academic, and industry R&D collaborations. What Vannevar Bush called "The Endless Frontier" has been the most effective and powerful force for technical progress ever assembled by mankind.

Is this paradigm now changing in a meaningful way? The goal has always been for the government to provide the R&D needed to meet urgent national priorities, such as defense, and to stimulate private sector investment wherever possible. The ideal is for government-funded initiatives to transition to private enterprise as quickly and as completely as possible. The Internet, mapping the human genome, and the GPS system are three recent examples of this system working as intended. In space, we have seen a whole new wave of start-ups create new vehicles, using some combination of private funding and public funding. At its best, the use of private funding allows product development to proceed outside the complexities of government procurement systems. This sometimes results in development programs that are faster and more efficient. But not necessarily: NASA accomplished Freedom 7 in three years. Winning the Ansari X Prize, which

Let's make the summer of 2019 a celebration of the past, but with a strong and central focus on building for the future.

had essentially the same mission except to be quickly reusable, took eight. The prize was won in 2004 — and as of this writing, some fifteen years later — we still do not see the much-vaunted commercial tickets to space. Getting into space is hard, getting humans there and back is harder, and doing it safely harder still.

What we can say is that the new wave of space entrepreneurship has injected a new measure of competition in the nation's space enterprise, something largely lacking since the end of the Cold War. The Apollo program was driven by the great-power competition that used space rivalries as a surrogate for more destructive conflicts on Earth. The new wave of space entrepreneurship has increased economic competition and has vastly raised the level of excitement, enthusiasm, and diversity in the U.S. space enterprise.

AIAA has a critical role to play in all of this. First and foremost, we support the professional workforce that makes this all possible. Our forums, publications, and activities bring together scientists, engineers, and program leaders from across the enterprise. Second, we enlighten and inform the public discourse and debate. AIAA has an important role to play in providing the information, viewpoints, and forums needed to facilitate the development of sound public policy. Finally, we are building the future workforce. Our efforts in STEM education, in developing a vigorous student and young professional constituency, and increasing the diversity of our industry is central to our mission.

The 50th anniversary of the Apollo 11 mission is the ideal time for us to bring all this together. Let's make the summer of 2019 a celebration of the past, but with a strong and central focus on building for the future. Where will you be on July 20, 2019? Hopefully with people not old enough to have experienced the event first hand, paying it forward and lighting the fires of innovation and imagination that will be the fuel for our next 50 years in space. ★

John Langford, AIAA President

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

Call for help

Q. A small plane has crash-landed on a remote tropical island. The plane's emergency beacon and radio were shattered, and no one filed a flight plan. Luckily, a sailor among the passengers has a VHF radio with just enough power left for a mayday call. The pilot tells him to make the call, but an engineer in the group yells, "Stop!" She explains that the weather forecast calls for calm winds and a strong temperature inversion tomorrow. What phenomenon does she hope to tap into?

FROM THE APRIL ISSUE

HOME RUNS AND WEATHER: We asked you what would be the best atmosphere for a home-run hitter: a 59-degree night in Phoenix in April (with the roof open) or a 97-degree day in Atlanta in June.

Barton Smith, professor of mechanical and aerospace engineering at Utah State University and self-described baseball missionary, picked this month's top submission.

WINNING RESPONSE: You would rather bat on a 97-degree day in Atlanta in June for a few reasons. First, let's think about what factors influence home run distance: local humidity, stadium elevation, temperature, wind and park dimensions. Higher humidity is a good thing for drag reduction, because water molecules are lighter than gases they displace, lowering air density. Elevation is similar, with higher elevations being equated to lower air densities. Higher temperatures are a good thing for flight, because the air molecules are expanded and, thus, less dense. Finally, park dimensions give the distance that a baseball needs to travel to get out. The first factor we can negate is elevation: Phoenix and Atlanta have negligibly different elevations, ~<30 feet [9 meters]. Next, the park dimensions of Chase Field (Arizona) and SunTrust Park (Georgia) are also roughly the same, within 5 feet [1.5 meters] on every outfield wall. This leaves humidity, temperature and wind. Arizona in April has 0% humidity compared to Georgia in June's ~60% on average, giving Atlanta the advantage. The temperature is warmer on a Georgia day in June, giving Atlanta the advantage. And finally, wind is negligible in Chase Field but relevant in SunTrust Park. There is no way to know for sure whether the wind will help or hurt in Atlanta. Therefore, the Atlanta day in June, with its high humidity and temperature, will be the on-average better place to hit for distance, such as a home run.

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

For advocates of this tiltrotor, a picture is worth 1,000 words

BY KEITH BUTTON | buttonkeith@gmail.com

▲ This illustration of Bell's V-247 design is in the "2019 Marine Corps Aviation Plan."
Bell

Aficionados of U.S. military aviation might have noticed that the very real-looking rotorcraft pictured over an amphibious assault ship in the "2019 Marine Corps Aviation Plan" does not yet exist. It's a drone design called the V-247 that Bell of Texas would like to sell to the Corps. In an unusual step, the Corps plans to pay on its own to develop the V-247 or a competing design without help from other service branches.

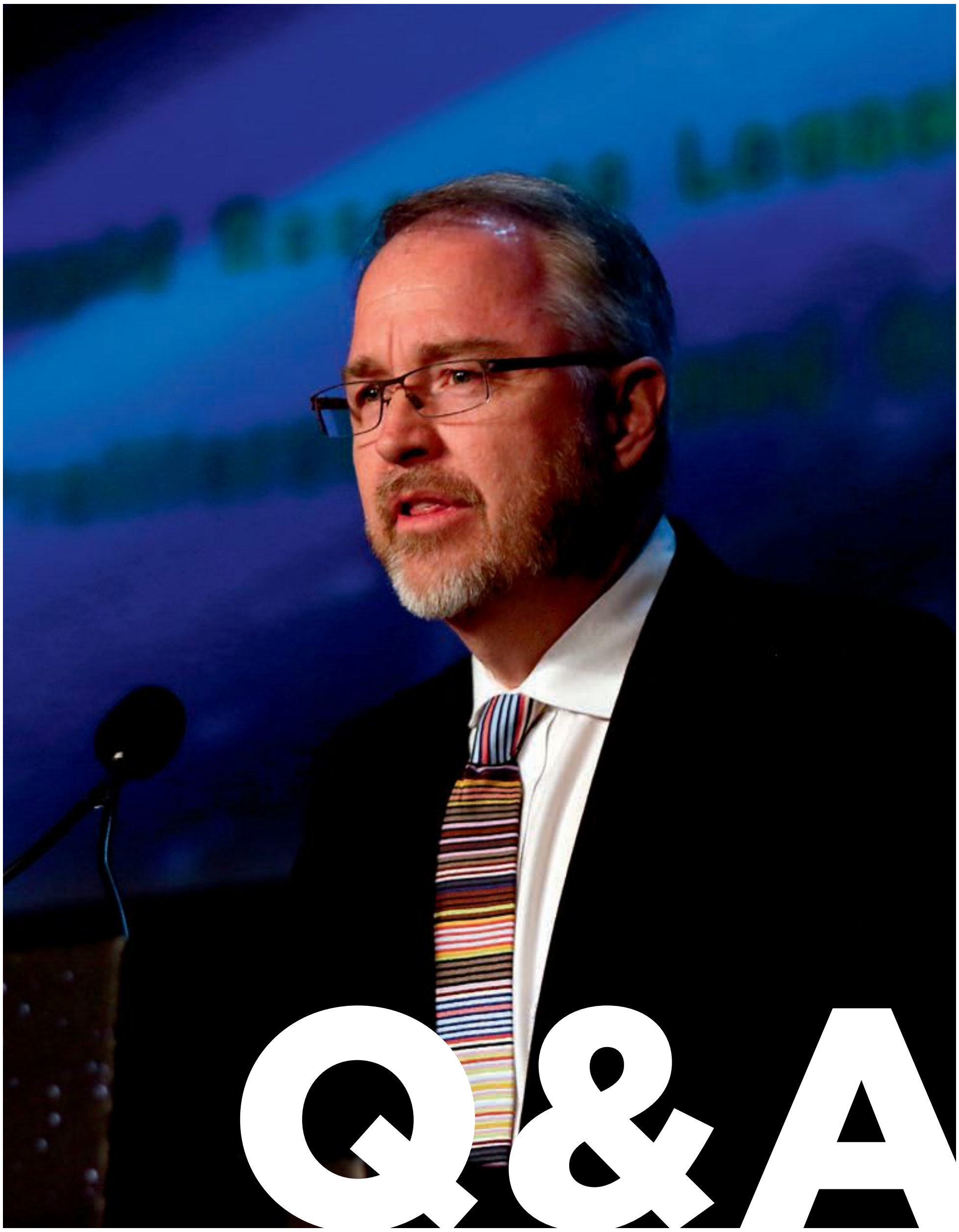
A Marine spokesman cautions that publishing Bell's illustration of the V-247 in the aviation plan last month does not indicate that the Corps has chosen a design for its MUX fleet, short for MAGTF (Marine Air-Ground Task Force) Unmanned Expeditionary aircraft. Bell presented the V-247 concept to the Marine Corps in response to a 2018 request for information about drones that would take off from and land on ships while carrying thousands of kilograms of cameras, weapons or cargo slung beneath them. The Corps has asked for $21 million in its fiscal 2020 budget request to study technical concepts that could lead to developing and fielding the aircraft by fiscal 2026.

The Marine Corps, which is organized under the Department of the Navy, typically does not have the money or clout to acquire a fleet of aircraft on its own. As the smallest service branch, it frequently joins with the Navy or — in the case of "light attack" turboprop planes — the Air Force in purchasing aircraft. In this case, the Corps plans to develop and buy the ship-based drones on its own, the spokesman says.

Bell started designing the V-247 in 2015 as an unmanned, smaller version of its conventionally piloted V-280 Valor tiltrotor demonstrator. The V-247, like its V-280 cousin, would take off vertically and then tilt its rotors and gearboxes to transition to horizontal flight. By contrast, today's V-22 Ospreys tilt their entire engines. For fuel economy, the V-247 would have one engine mounted internally that turns the rotors through an interconnect shaft. The V-280 has two external engines on the wing ends. The "247" refers to its long-endurance capabilities, as in 24 hours a day and seven days a week, whereas the V-280 is named for its cruise speed of 280 knots. Bell says the V-247 could stay aloft for at least eight hours after flying 650 kilometers from a ship and that it could refuel in the air to extend its flight time. Bell unveiled a subscale model in 2016 and a full-scale model in 2018 after refining the design through wind-tunnel testing and analyses of how the hydraulics, the electrical and cooling systems, and other components will affect the aircraft.

"What you see today is an aircraft that actually looks real. It's not a cartoon aircraft anymore. You can actually see that this aircraft is being designed as an actual, producible aircraft," says Todd Worden, manager of sales and strategy for unmanned aircraft at Bell.

The V-247 is not related to the Future Vertical Lift program, although Bell envisions the V-247 accompanying V-280s on missions and as a candidate to fit yet-to-be-requested drone needs of the other service branches. ★



Space Foundation

Accelerating innovation

Combining the military might of the Pentagon with the innovation of the commercial space industry: That's the task for Fred Kennedy as the first director of the U.S. Space Development Agency, an organization created in March to develop the country's "next-generation military space capabilities," as SDA's founding memo puts it. Kennedy plans to do this by streamlining the development process for new satellites, equipment and other capabilities yet to be specified. He has between now and Sept. 30 to put together a proposal for this new space architecture and he has some big plans. For details, I sat down with Kennedy at the Space Symposium last month to talk about SDA.

— Cat Hofacker

FRED KENNEDY

POSITIONS: Inaugural director of the Space Development Agency; director of DARPA's Tactical Technology Office, 2017-February 2019; assigned to DARPA in 2005 as an Air Force major; retired from the Air Force in 2016 as a colonel.

NOTABLE: While at DARPA, was assigned to the White House Office of Science and Technology Policy in 2016 as the senior policy adviser for national security space and aviation, where he led the Obama administration's "Harnessing the Small Satellite Revolution" initiative that promoted their use in the government and private sectors. At DARPA, he was program manager for Orbital Express, a 2007 space experiment in which service satellites transferred fuel and batteries to another spacecraft.

AGE: 50

RESIDENCE: Arlington, Virginia

EDUCATION: Bachelor of Science and Master of Science, both in aeronautics and astronautics, from MIT; Master of Arts in organizational management from George Washington University; Master of Arts in strategic studies from the U.S. Army War College; doctorate in electronics and physical sciences from the University of Surrey, United Kingdom.

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IN HIS WORDS

Rapid response

For many years we've known that peer competitors like Russia and China were building capabilities to deny or degrade our ability to operate in space. Well, that's ramped up. And furthermore, they're building capabilities to indirectly get after our space assets, which means that they're building out systems in other domains that evade our space sensors, or attempt to at least. This is a troubling trend, and it's one that we should attempt to stop. What I would tell you, though, is that we have a culture in the space community which is not well-postured to solve this problem. We've been living in sanctuary for so long, even though we know it's possible to build space weapons and other things. We've been driven by a desire for what I would call hyper-reliability and ultimate performance. And we do that at the expense of cost and schedule.

Changing the game

We want to put up capability early, as early as 2022. We want to go up in two-year upgrades after that. Boom. Boom. Boom. Boom. I'm going to be less concerned about hitting a performance target and more concerned about hitting the schedule. So more minimum viable product to start, and then showing how we can improve on that in successive iterations. Really trying to innovate over and over and over again. Our innovation cycle now is measured in decades. We're flying focal planes on SBIRS [missile warning satellites] that were basically designed in the '80s and '90s. That's not right. We shouldn't be doing that. We need to get out of that mode and figure out how to put our best technology forward quickly. I think this is the right way to go forward with that.

Being proactive

I'm not going to be requirements-based; I'm going to be threat-based. I'm not going to wait for someone to validate the need for the capability; I'm going to get in front of that. I'm going to talk to the intel community; I'm going to talk to the war fighters in a combatant command and say, "What are you faced with right now, and then how can I respond to that now?" As opposed to giving you capability a decade hence. I don't want to do that, or even five years hence. I want to put up capability in a couple of years and see how it works, and do it again, and then do it again. In the same way that we managed to make it work with these things, right, with these phones, with computers, I think the space community is ripe to go solve this problem. We have the tech; we now have a sense that we can do mass production. We can apply mass production to spacecraft and theoretically to payloads and other things. Why not try that? That's what SDA's about.

Not just the Space Force runner-up

I think the bottom line for Space Force is: In the same way we need "air mindedness" to stand up an air force, you need people who understand air power, I think now you need people who understand space power to go stand up a separate entity to go work that problem. In terms of what SDA's going to do, we're trying to step back and say, "All right, we've been building systems for the Air Force, the Army, Navy, IC — everybody — a certain way for a long time." Whether or not the Space Force is inaugurated soon, the idea that we need to go fix this front end of development is still there. That problem set remains.

"We want to put up capability early, as early as 2022. We want to go up in two-year upgrades after that. Boom. Boom. Boom. Boom. I'm going to be less concerned about hitting a performance target and more concerned about hitting the schedule."

Filling in the gaps

We're going after every piece of the mission space you would expect, maybe even a few more, and we're trying to go after gap areas that are not being addressed by legacy systems. So, for example, we're looking at tracking missile threats, which current systems have a hard time doing today. We're going after hypersonic systems and other things [for which] detection and track is a bear.

The megaconstellation

But we all agree that the key element of all this is to have a global low-latency communications capability. We're calling it the "space transport layer," but it's a comms and data transport layer that would reside in LEO, that would be proliferated, that may leverage a significant amount of commercial input to get there. I'm not saying it's necessarily somebody's megaconstellation. It might be a government constellation. But we would really try to leverage as much of the investment and work that's going into new space right now as we can.

Inspired by commercial innovation

If I can lock, stock and barrel take something off the shelf and use it, I would be crazy not to. If it's just sitting there and it meets my need, let's go. Let's just go do it. But if it requires a little bit of ruggedization, or if we're looking at a band that's not quite what we had hoped for, then yeah, let's go fix that and move on. But we want to do it in a way that allows us to mass produce capability.

Pushing forward

Yeah, we are going to make mistakes. I'm not even going to try to tell you that we're not. We are going to make mistakes, and we're going to fall short on certain aspects, but the whole point of this is to say, "All right, let's take a look at what we did in 2022." Who else is putting up capability that quickly? No one. So, we'll take what we learned in 2022, and within two years, we're going to put up a different suite of capabilities that will do better. ★

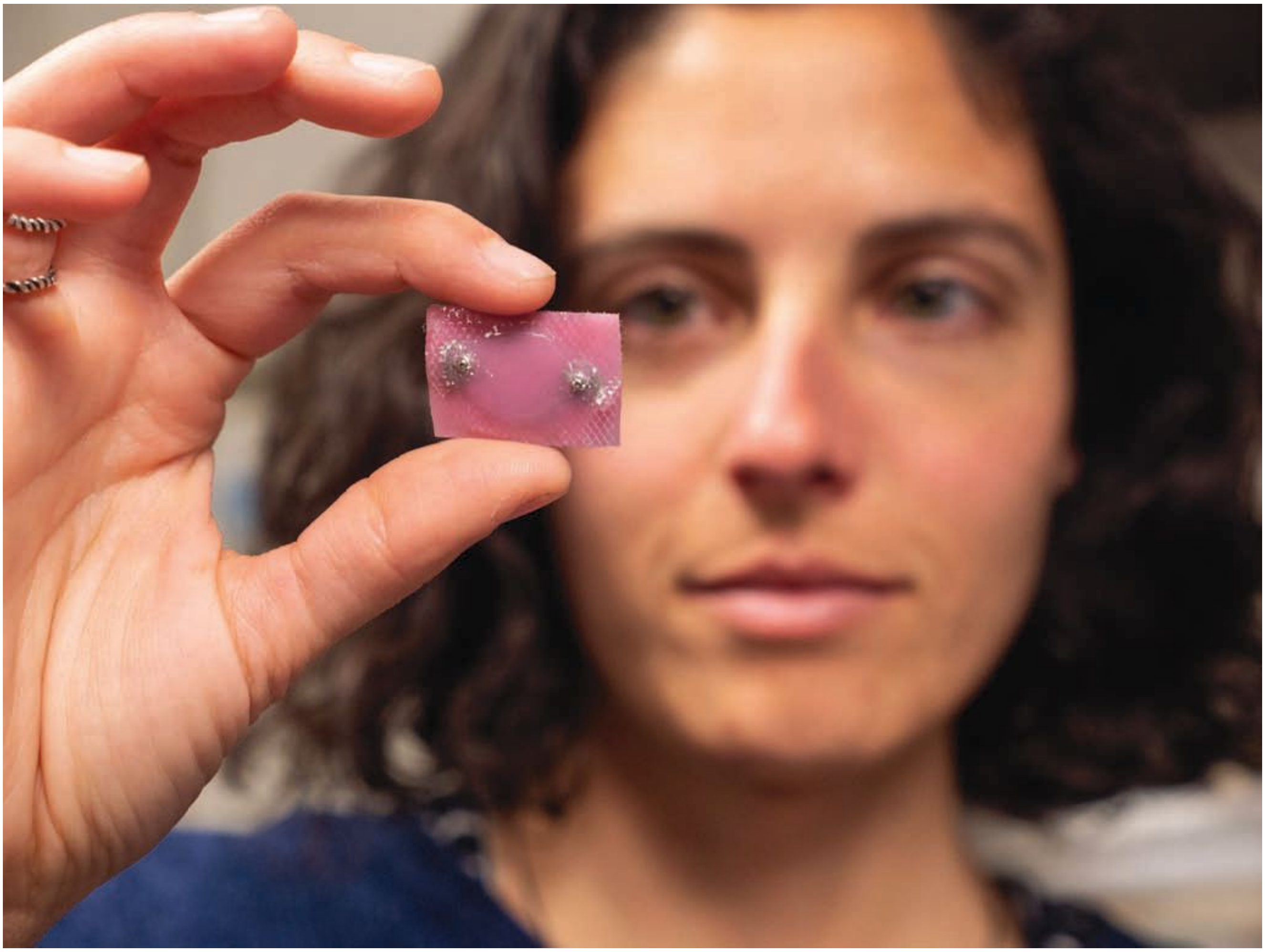
A safer s

◀ **NASA astronaut Peggy Whitson** works outside the International Space Station in 2017. Whitson has said NASA's spacesuits are sized bigger than the average woman.
NASA

U.S. astronauts on the moon or Mars will need a spacesuit that won't injure or exhaust them. One hurdle is that no one knows exactly what goes on in a physical sense when an astronaut inside one of today's spacesuits moves his or her limbs. Amanda Miller visited with student researchers in Colorado who think they know how to find the sore spots in today's suits, a breakthrough that could point the way to better designs, perhaps including one of their own.

BY AMANDA MILLER
agmiller@outlook.com

pacesuit



Glenn Asakawa/University of Colorado

In a windowless, subterranean lab at the University of Colorado in Boulder, doctoral candidate Katya Arquilla takes what looks like the sleeve of a shirt down from a shelf and shows it to me. It's black and made from a stretchy fabric, with fine copper wire connecting patches of pink plastic. This is just a mock-up, but ultimately, she and fellow students plan to create an entire skin-tight body suit with these pink pressure sensors arrayed over it. When the wearer rubs or bumps against something, or something rubs or bumps against the wearer, the resulting pressure increases electrical resistance in the copper wires, and the suit detects the contact.

The team plans to create a second suit and equip it with smartphone-inspired inertial sensors to track the wearer's limb movements.

If all goes as planned, test subjects will don these suits separately, each a skin-tight layer under a conventional spacesuit. The researchers will begin to diagnose where and why today's spacesuits are rubbing astronauts the wrong way. The suit with the inertial sensors should be ready first, in about a year.

Taken together, the findings could help the Colorado team or others design a less bulky spacesuit that won't injure or unduly tire astronauts working on the surface of Mars, where astronauts will endure long shifts. The students don't think they could have a suit ready for NASA's return to the moon, planned for 2024.

▲ **Aerospace engineering** doctoral candidate Katya Arquilla and a fellow student are working on a suit wired with these sensors to map the parts of a conventional spacesuit that most irritate the wearer.

To understand the problem, consider that conventional spacesuits are pressurized with filtered oxygen that the wearer breathes, including the gas that flows through his or her gloves. This results in a suit that's hard to move around in. Improvements to the suits over the years haven't solved a major problem: "The astronauts are getting injured," says Allison Anderson, who oversees the spacesuit research as an aerospace biomedical engineer and bioastronautics assistant professor.

Some astronauts have lost fingernails from squeezing their gloves so much. Others have suffered shoulder injuries. There are also aggravations, such as pressure "hot spots" and fatigue.

Work will be especially difficult on Mars, where the astronauts could be expected to go outside once a week for eight-hour shifts: "That's a huge increase in the amount of EVA [extravehicular activity] compared to what we're doing now, where it's a relatively infrequent event," Anderson says. She thinks

Some astronauts have lost fingernails from squeezing their gloves so much. Others have suffered shoulder injuries. There are also aggravations, such as pressure "hot spots" and fatigue.

suit-induced strain and injuries will rise with the added demands.

The root of the problem is that today's suits require astronauts to struggle against appendages that become rigid under pressurization. Once manipulated, these parts naturally want to revert to their original shapes.

As experts in the emerging field of bioastronautics, Anderson and her students set out to measure the strain on the wearers and conceive of a less cumbersome spacesuit design. They think the answer could lie in a hybrid that will combine a stretchy, skin-squeezing layer (probably neoprene) under a slimmer version of today's gas-pressurized suits.

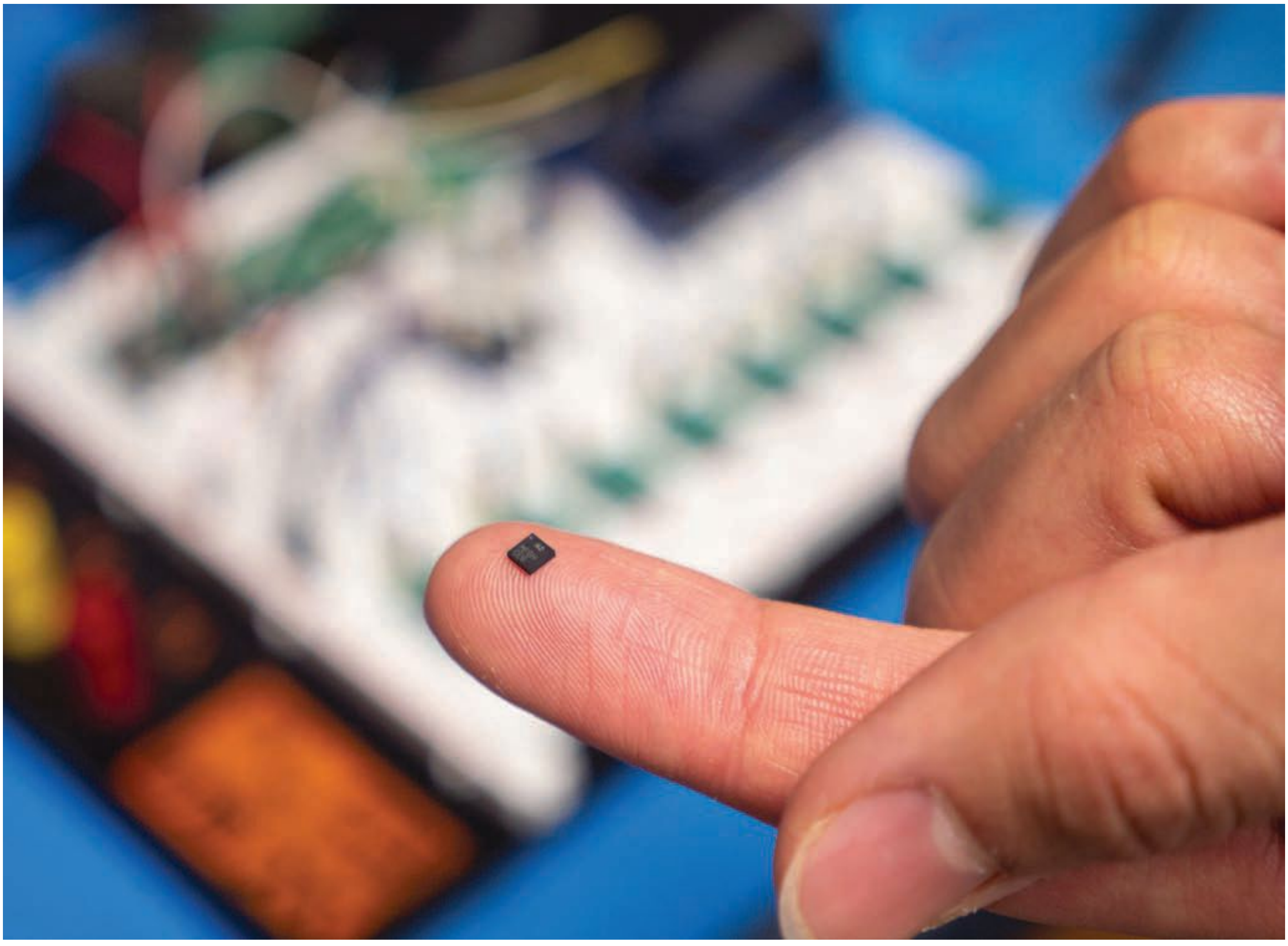
Together, the layers must impart sufficient, even pressure across the wearer's body, just as today's suits do. That's crucial for functions like blood flow and to avoid outright calamity.

"You need to be above the vaporization pressure of water to make sure the water in the surface layer of your skin doesn't boil," Anderson explains. "Even above that, you need a level of pressure to allow oxygen to dissolve into your bloodstream. Above that, we like to have higher pressures because it preserves us from getting decompression sickness."

Anderson thinks aspects of the research have a chance of being incorporated into a future suit that would be made by a commercial manufacturer. Her team's dream come true, of course, would be to make an entirely new suit. At the moment, the students are working on the suit to meet academic requirements, with funds from the university.

Gas-pressurized layer

Today, an astronaut taking a spacewalk outside the International Space Station does so within a double-walled, gas-inflated suit. An inner bladder holds the gas that's imparting the pressure on the body — while a tough, outer fabric layer, called a restraint layer, stops the bladder from expanding



▼ **Inertial sensors** like this will track the angles of a test subject's limbs inside a conventional spacesuit.

Glenn Asakawa/University of Colorado

Glenn Asakawa/University of Colorado

▲ **Design mock-ups** of a mechanical counterpressure spacesuit glove leading up to the latest iteration, bottom right.

too big from the gas' pressure and helps protect the occupant from the cold, radiation and debris of space.

But no one really knows how the wearer's limbs move relative to the wall of the suit. That's the first thing the students want to know before they design a suit.

The schedule is not firm, but in about a year, a test subject will wear the inertial suit under a conventional spacesuit. Doctoral candidate Young-Young Shen will track the movements of the subject's limbs compared to the movements of the spacesuit.

Shen likens the sensing process partly to what happens inside a smartphone. "It knows which way the phone is tilted," he says. Likewise, "you can figure out which way a certain limb segment is tilted," says Shen, who leads the work on a set of inertia sensors with a particular emphasis on tracking joint angles.

While the sensors track the subject's movements on the inside, cameras will simultaneously record the suit's movements from the outside.

"That gives us an idea of how they're positioned relative to the suit, how they're moving relative to the suit, what parts of the suit they're coming into contact with," Shen says.

The students suspect that a test subject's movements and the movements of the suit will look nothing alike.

Meanwhile, Arquilla is working on the pressure sensors that will measure the force of astronauts bumping into the sidewalls of the suit, and in that way, quantify likelihood of injury.

A conventional spacesuit "is like this big bubble around your arm, and because it doesn't fit you perfectly, and it's bigger than your arm actually is, to move, say, something over here, you have to get the suit to move, and then move over to where you want to do something," Arquilla says.

Arquilla and fellow doctoral candidate Abhishektha Boppana have built a partial prototype of wearable contact sensors — the copper-sewn sleeve. They molded channels in thumbprint-sized dabs of flexible plastic — soft, to conform with body contours — and filled the channels with liquid metal, feeding an electric current through the wire stitching to the metal.

"When we press down on those channels, the liquid changes shape, and that creates a change in [electrical] resistance that we can measure," Boppana says. "We correlated that to a change in the amount of force that's being applied over that area."

Glenn Asakawa/University of Colorado

▲ **Student Roger Huerta's** idea for a spacesuit glove has a plastic insert to help exert even pressure over a person's concave palm. Huerta is working on a master's degree in aerospace engineering.

Mechanical-counterpressure layer

The gas in today's oxygen-filled spacesuits must be cranked up to a pressure equivalent of about a third of Earth's atmosphere. Adding the skin-tight inside layer — a suit concept called mechanical counter-pressure — means the hybrid suit would require less gas pressure, so the suit could be less bulky.

Having stretched out several fabrics on a materials strength testing machine, Anderson and her team think that with the stretchy fabric neoprene, which wet suits are made from, they can get to about half the required one-third of the atmosphere.

There is another challenge, though. A conventional suit, despite its shortcomings, does a good job of spreading pressure evenly with its layer of oxygen. The Colorado team needs to impart pressure evenly, too, with their suit. "A mechanical-counter-pressure suit needs to fit exactly to the contours of your body," says aerospace engineering master's student Roger Huerta.

An astronaut's hands posed a big issue for the team. Huerta has made a prototype of plastic inserts that would be tucked inside the wearer's gloves to fit an individual's concave palm. The whole thing is snugged on with a gauntlet that can be tightened.

The boot

Boppana, who took part in the sensor research, is also studying how to make a snug enough boot, taking cues from researchers at NASA's Johnson Space Center in Texas who started studying ideas for a Mars spacesuit and ran into trouble on the march.

"They realized that when they were starting to walk, the boot would sort of just stay on the ground, and their heel would lift up out of it," Boppana says. "And that's due to the suit just being so heavy that the boot is supporting a good portion of that weight."

He's now making a 3D model of how a person's foot changes shape throughout a walking gait to engineer a boot — complete with both mechanical-counterpressure and gas-pressurized layers — from the inside out.

A boot for walking on another world, with significant gravity, will be a first.

"On the moon, you're not really walking, you're loping," Boppana says. "As long as you can push off a little bit, you have locomotion. But when we go to a higher-gravity environment such as Mars, you really need the same type of locomotion we have here on Earth." ★

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A bridge to Mars

Beyond the moon, sending astronaut explorers to near Earth asteroids in the 2030s would open intriguing, resource-rich objects to in-depth inspection and exploitation, smoothing the daunting path to Mars. Former astronaut Tom Jones makes the case.

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

▲ **The OSIRIS-REx** spacecraft is close to grabbing a sample from the asteroid Bennu in an artist's concept.
NASA

So, America is going to the moon in five years, to the threshold of deep space. Administration plans call for a landing near the lunar south pole by 2024, with an outpost to follow. NASA's lunar return is to build the experience and skills needed to reach Mars sometime in the 2030s.

Mars is a tall order: more than six months in deep space each way, long exposure to radiation and other human health hazards, and the still-unsolved problem of landing people and cargo there. One of the biggest technical challenges NASA and its partners face is building a spacecraft reliable enough to support astronauts during a two- to three-year voyage, beyond resupply and physical assistance from Earth. Mars flight will pit our best technology against the unpredictable hazards of interplanetary travel, a true leap into the unknown.

Achieving Mars readiness

Our machinery and skills, even after a return to the moon, will not be sufficiently mature for multiyear Mars expeditions. One idea for proving the readiness of a Mars cruise vehicle is to put a crew aboard and have them orbit the moon for a year. Such a mission would present few Mars-relevant operational tasks and deliver almost no new science return. Yawn. "Houston, this is Infinity 1. Please shoot me now."

The right way to test our Mars readiness is to launch explorers on a daring yet measured step into deep space, to a nearby asteroid. New discoveries at near Earth asteroids show these ancient objects are worthy targets for astronauts and their craft. An NEA mission would toughen us for Mars voyages by wringing out nearly every system of a Mars cruiser in deep space. Such an expedition would gather a shipload of scientific discoveries, assess asteroid resources and give us the exploration experience we'll need to light out for Mars.

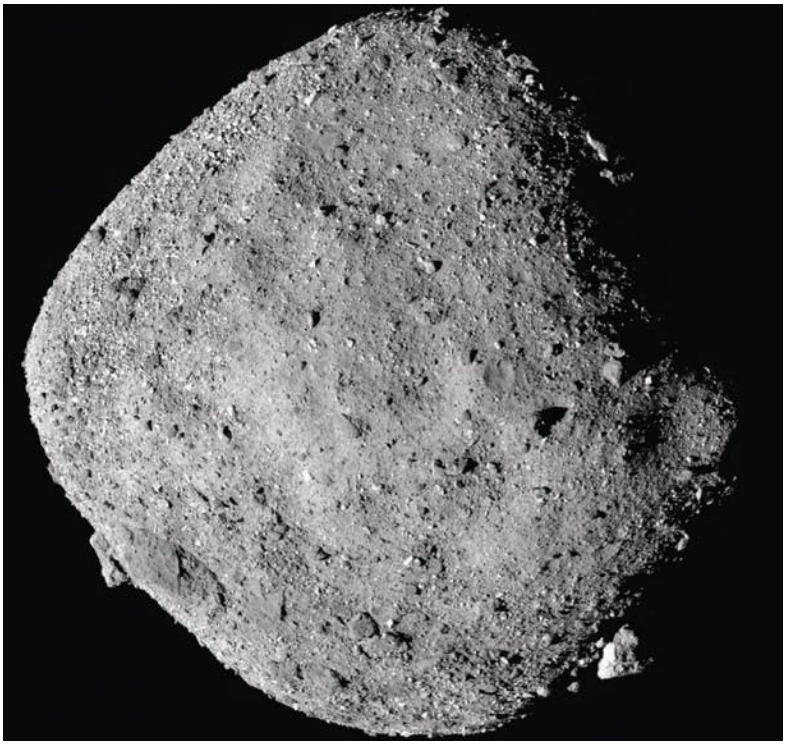
NEA missions, for example, allow us to test the reliability of life support systems, countermeasures against radiation and free-fall debilitation, deep-space communications, and radiation-hardened computers. On a crewed NEA expedition lasting up to a year, we'll get those reliability answers, while putting human explorers in direct contact with these ancient, resource-rich objects.

Mars-relevant challenges

Near Earth asteroids are not easy to visit. A crew would depart the Earth-moon system into orbit around the sun, rendezvous with an NEA in its heliocentric orbit, conduct a couple of weeks of intense exploration, then return to Earth. Of the roughly 20,000 known NEAs, only a fraction offer round-trip mission durations of less than a year. But that's exactly the point — the trip times are longer than International Space Station expeditions and lunar sorties but far shorter (and less hazardous) than multiyear trips to Mars.

We know much more about the challenges of operating around and on asteroids thanks to recent results from two robot spacecraft now visiting a pair of different, subkilometer-sized asteroids. Japan's Hayabusa 2 is at 162173 Ryugu, and the U.S. probe OSIRIS-REx arrived at 101955 Bennu in late 2018. Both objects are rubble piles: impact-shattered pebbles, rocks and boulders held loosely together by the object's very weak gravity (10 micro-Gs at Bennu's surface).

The weak, irregular gravity fields of these top-shaped objects make orbiting them difficult:



▲ **This mosaic image** of 490-meter-diameter asteroid Bennu is composed of 12 images collected by the OSIRIS-REx spacecraft from a range of 24 kilometers.
NASA/University of Arizona

gravitational variations will perturb a craft into an eventual collision with the asteroid. Rather than executing a stream of fuel-intensive maneuvers to compensate, trajectory planners for a human mission might choose to fly in loose formation in near-parallel heliocentric orbit, as demonstrated by OSIRIS-REx.

Ryugu and Bennu are rougher than expected: no smooth, dusty plains but instead jumbled rock fields ranging in size from pebbles to office-building-size boulders. Several massive Bennu boulders are perched on crater rims or on slopes and may be composed of crumbly, low-strength clays. The rapid spin and Bennu's low gravity mean that those rocks are tenuously bound, especially around the equator. If a spacecraft or suited astronaut tips one from its delicate balance, they may trigger a slow-moving but still-dangerous avalanche.

The OSIRIS-REx team had hoped to find a smooth, 25-meter touchdown zone for next year's sample collection attempts, but such obstacle-free spots on Bennu are nonexistent. The team is now refining the probe's navigation and sensor software to hit a landing ellipse just 10 meters across.

Assuming a suitable touchdown target can be found, anchoring a spacecraft on such a rubble pile will require some clever harpoon or auger engineering. In February, when Hayabusa-2 touched down momentarily on Ryugu to collect a sample, the projectile fired to liberate surface material launched a blizzard of asteroid shards that tumbled chaotically alongside the rising craft. Imagine trying to anchor a multiton crewed craft amid a shower of debris, hoping to find purchase on an unstable surface. It's a design challenge that we'll face again on the martian moons, Phobos and Deimos.

OSIRIS-REx has detected small particles leaving the surface — an asteroid shower — perhaps liberated by thermal fracturing or flash evaporation of water in hydrated minerals. Some of this debris rains back onto the surface, while some escapes entirely. However, these slow-moving particles pose little hazard to spacecraft.

Now the good news

NEAs harbor a wealth of scientific rewards and valuable resources. Bennu and Ryugu, for example, are weird but fascinating places. They pose enough mysteries and puzzles to challenge a crew of deep space explorers for weeks.

Current NEA accessibility tables list nearly two dozen NEAs that will be reachable from Earth between 2030 and 2035. They offer round-trip mission durations of less than a year and stay times of at least eight days and require a total velocity change from low Earth orbit of less than 6 kilometers a second — about the same as a one-way trip to the moon's surface. Many initial NEA targets will be discovered by powerful new search telescopes by the time NASA and partners prepare to shift aim from the moon to Mars.

▶ **Near Earth asteroid Bennu is actively ejecting** particles from its surface in this composite image from January. The source and cause of the debris shedding would be one of many scientific mysteries to be explored at nearby asteroids.
NASA/University of Arizona/Lockheed Martin

Smithsonian National Museum of Natural History

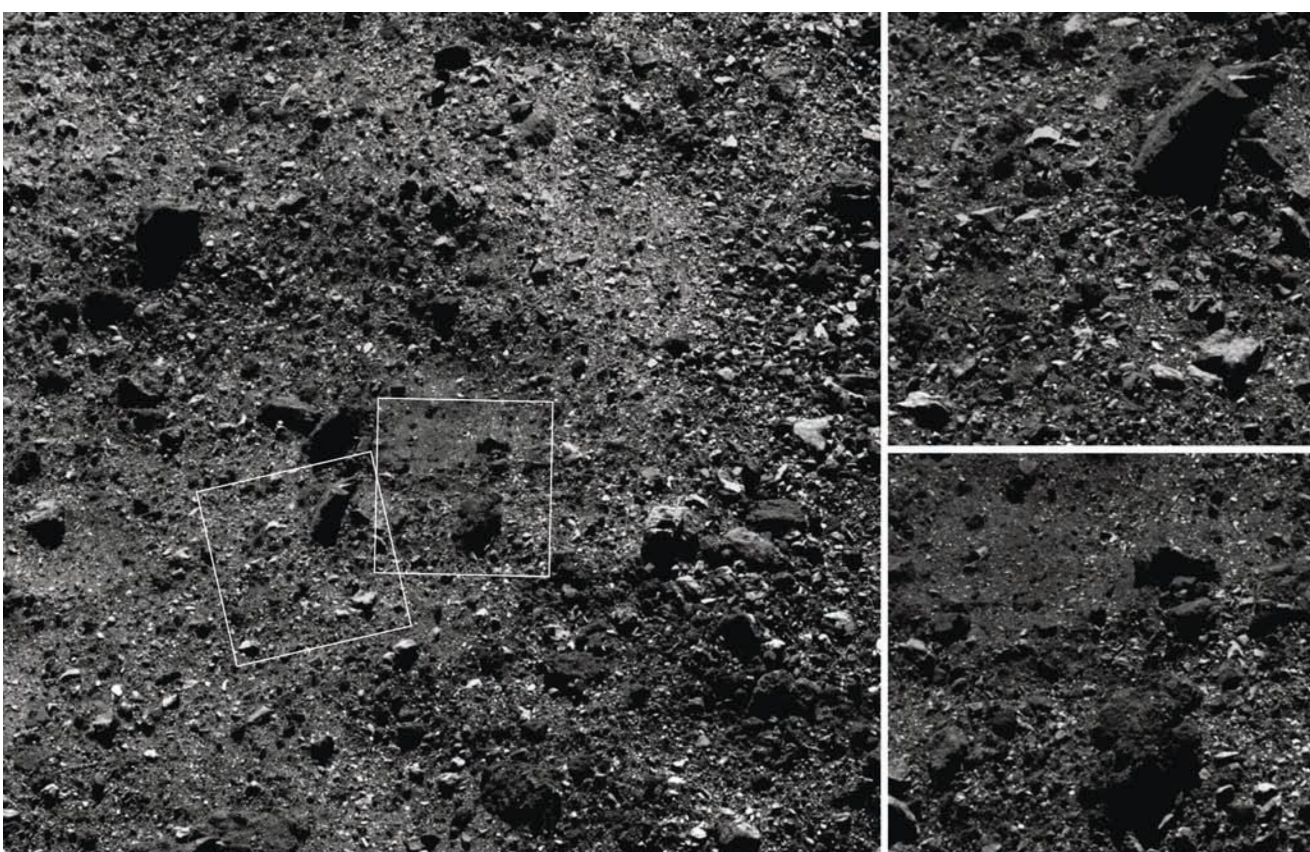
◀ **Asteroids like Bennu and Ryugu** are believed to be composed of minerals similar to those in carbonaceous chondrite meteorites, like Murchison, shown here.

▼ **The wide-angle image** of a region in Bennu's northern hemisphere shows a 180-meter-wide area with some large boulders and a "pond" of regolith. The two closer images show details of part of the region, a 15-meter boulder, top, and the regolith pond, bottom. Cameras on NASA's OSIRIS-REx spacecraft shot the images when it was about 1.8 kilometers from Bennu's surface.

NEAs represent a windfall of scientific discovery as we reach for Mars. Objects like Bennu and Ryugu likely contain materials that date to the very formation of the solar system. Mineralogical analysis of such asteroids, thought to resemble carbonaceous chondrite meteorites, will tell us in detail about the raw materials and thermal conditions that gave rise to the terrestrial planets like Earth. These primordial asteroids likely delivered water and complex organic compounds to our young planet, perhaps kick-starting the complex chemistry that gave rise to life.

OSIRIS-REx has discovered water-bearing clay minerals across Bennu's rocky surface. Can we invent a way to liberate that water and distill it for practical use? If the answer is yes, then this near Earth water can be transferred to tanks and launched from low-gravity NEAs. It may even compete economically with lunar water that must be launched from a substantial gravity well. Asteroidal water could be the propellant in a simple steam rocket, or if separated into hydrogen and oxygen, could fuel high-thrust chemical — and even nuclear — rocket engines.

Asteroid exploration promises to test a variety of Mars-relevant exploration technologies. Astronauts can wring out the kinks in exploration-class spacesuits in the gritty, low-G asteroid environment, one they will surely encounter again on the Martian



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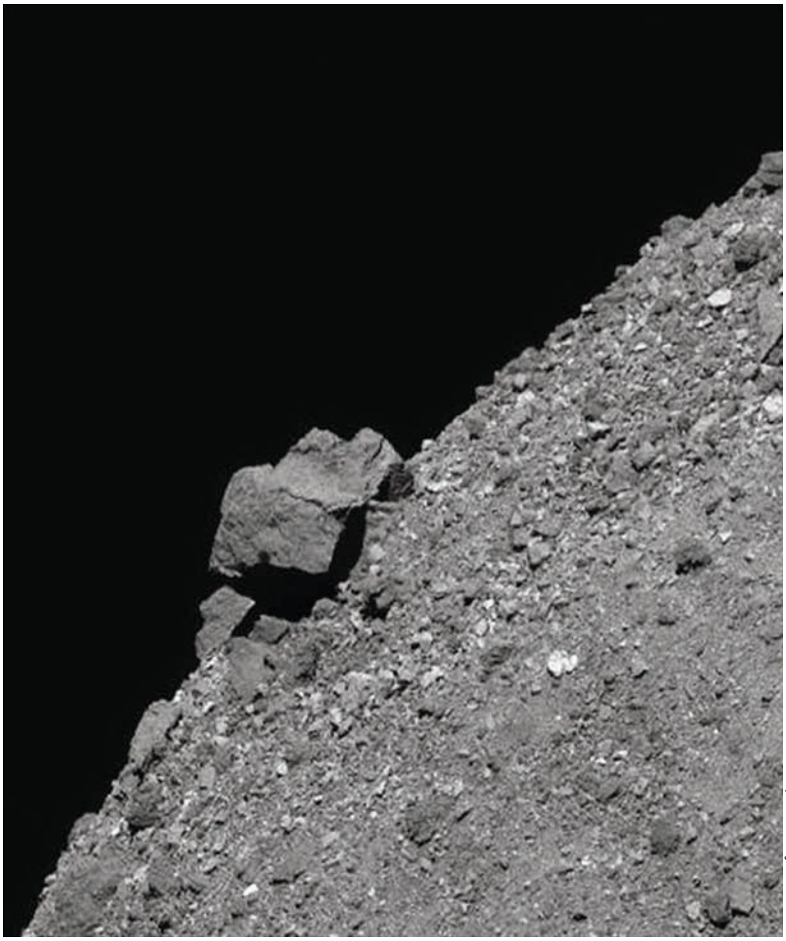
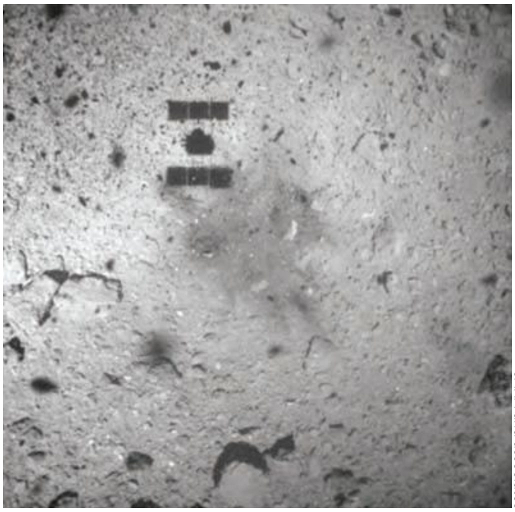


NASA/University of Arizona

▲ **NASA's OSIRIS-REx** spacecraft imaged this 52-meter boulder jutting from asteroid Bennu's southern hemisphere and the rocky slopes that surround it. This target could also be hazardous to astronaut explorers, as Bennu's rotation and weak gravity field could cause the boulder, once dislodged, to slide inexorably "downslope" toward the equator.



JAXA and associates

▲ **This image of Ryugu's rocky, rough surface** was captured by Japan's Hayabusa 2 probe on ascent at an altitude of about 25 meters. Adjacent to the spacecraft's shadow is an area discolored by the spacecraft thrusters or projectiles.

moons. Alternatively, astronauts can work inside small, personal spacecraft with manipulators and anchoring systems to avoid bringing their cruise vehicle down to a hazardous, uneven surface.

In another promising exploration strategy, these same small spacecraft could be teleoperated from the cruise vehicle to explore the asteroid surface. Their strange surfaces, hazardous to space-suited astronauts, are attractive candidates for near-real-time telepresence. Astronaut-directed, low-latency telepresence could move from early trials at the lunar gateway and surface, to asteroid expeditions, to the moons of Mars, and finally to its surface.

Such an expedition would gather a shipload of scientific discoveries, assess asteroid resources and give us the exploration experience we'll need to light out for Mars.

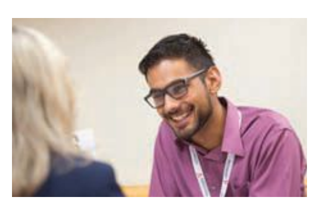
Finally, a 2030s NEA expedition is the perfect scenario for proving the deep-space reliability and performance of a nuclear thermal propulsion system. Tested initially around the moon, a nuclear thermal engine could shorten trip times to an asteroid and reduce the expedition's propellant requirements. If NASA is serious about getting humans to Mars, nuclear propulsion must be part of the picture.

A road map to Mars

The startling results from robotic explorers Hayabusa 2 and OSIRIS-REx have surprised asteroid scientists and spacecraft designers alike. They are peeling back the veil of ignorance cloaking the solar system's early history. Following robotic reconnaissance, crewed NEA expeditions offer logical, well-timed steps toward human Mars exploration. Dispatching a prototype Mars cruiser first to an NEA or two would test critical deep-space systems and open intriguing, small worlds to sophisticated science. These expeditions would help NASA build a strong, reduced-risk bridge to Mars.

Yes, asteroids present difficult, and different, exploration problems from those waiting for us on the Martian surface. But if we plan to send humans into deep space, we should look to master its challenges, not merely survive them. Building on our lunar experience from Apollo and the coming decade, NEA expeditions will explore new terrain and tap new resources. When we do reach for Mars, near Earth asteroids will have made us smarter, safer and more successful. ★





An illustration of Volocopter's concept for an urban air taxi.
Volocopter

ALL ABOARD

It's a dream shared by everyone who's ever been stuck in a traffic jam, from the bored child in the back seat to the late-to-work-again commuter: If only I could fly. That day could be coming. Keith Button spoke to experts in the urban air mobility field about how this might work.

BY KEITH BUTTON | buttonkeith@gmail.com

For Davis Hackenberg, NASA's urban air mobility strategic adviser, rolling on wheels is oh so primitive. "You've got to build a road that goes from A to B, and everybody sits on it," he laments.

Hackenberg is one of those working to grow urban air mobility, or UAM, from today's collection of experimental conceptual aircraft into a U.S. economy of 130 million passenger trips a year, in one estimation.

Entrepreneurs, from airplane builders to ride-sharing companies, are working on at least 100 UAM vehicle designs, and NASA has organized a series of demonstrations of UAM technologies scheduled to start in 2020 to inspire public interest and display everything from aircraft designs to airspace management software.

Let's assume that the market takes off as Hackenberg and many others hope. What will the commute look like? No one knows for certain, of course, but based on my discussions with experts, here are some possibilities for how things could work in a decade or so when UAM reaches an advanced stage:

1. There won't be a human pilot aboard.

Two reasons: Cost and safety, says Ella Atkins, an aerospace engineering professor at the University of Michigan. On the cost side, UAM will have to win over a large number of riders who will pay for regularly scheduled flights — 130 million trips per year, industrywide, before the market becomes profitable, according to an analysis by the New York-based McKinsey & Co. management consulting firm. The study is included in the 2018 "Urban Air Mobility (UAM) Market Study" commissioned by NASA from a team led by Crown Consulting Inc., an engineering and analytics consulting firm in Arlington, Virginia. To attract that many riders, the cost per ride will have to be low. Paying skilled pilots would make the rides too expensive, and finding skilled pilots to fly so many flights would be too difficult, Atkins says. Preliminary results from a Georgia Tech survey show that commuters with annual incomes of more than $100,000 generally would be willing to pay $25 per ride in a piloted UAM vehicle.

On the safety side, riders will demand safer flights than today's mode of urban air travel, human-piloted helicopters. Otherwise, UAM won't become popular enough for millions of scheduled flights per year.

"The average passenger who wants to live to a nice old age is not going to feel really happy climbing onboard a helicopter every day if they know that the risk is greater than if they drove in a car or flew in a commercial [passenger] airplane," Atkins says.

UAM will likely go through a transition period from today's human-piloted aircraft "to gradually get to the point where we are comfortable treating [urban air mobility] like a train at the airport that talks to us in a computerized voice," Atkins says.

◀ **Embraer's electric vertical takeoff and landing** aircraft in an illustration.

Embraer

▲ **The hybrid-electric Bell Nexus**, in an artist's concept.
Bell

UAM aircraft may employ "safety pilots," or human pilots who fly with the aircraft even after technology has advanced to the point where the vehicles are capable of autonomous flight, to help build consumer buy-in, says Scott Winter, an assistant professor and consumer perceptions researcher at Embry-Riddle Aeronautical University in Daytona Beach, Florida. Research shows that people are less willing to fly when a human pilot is absent, because they are more comfortable with what they know. Over time, as consumer confidence increases in autonomous flight, the safety pilots could be phased out, Winter says.

2. Passengers will fly between "vertiports" on scheduled flights, like passenger trains running between stations.

UAM commuters will probably fly between vertiports, which would be airports specifically built for vertical-takeoff-and-landing aircraft. The high cost per ride for on-demand air taxis will make them impractical, outside of areas with high concentrations of potential riders who are extremely wealthy. The Crown Consulting UAM market study for NASA found that UAM flights organized like passenger train systems, with scheduled routes among 100 to 300 vertiports in a metropolitan region, might become profitable after 11 years of operating at a loss. At that point — the study marked the first profitable year at 2028 — the price per trip would be $50. But the study found that an air taxi system with on-demand single-passenger rides for "door-to-door" service, in which a passenger would walk 2.5 minutes or less for single-passenger rides, would likely cost nearly $2,000 per ride. Uber, which started holding annual "Elevate Summits" about UAM in 2017, says it plans to offer an "Uber Air" service starting in 2023 in Dallas and Los Angeles. Passengers would order shared rides by air, taking off from vertiports and not, initially at least, with door-to-door flights. Uber Air service would cost riders $1.85 per mile "within a few years of launch," according to Uber's website.

Vertiports could be built on train or bus stations, or at highway interchanges, so a passenger could access ground transportation for the next leg of their journey, Hackenberg says. Positioning a vertiport at a ground transportation hub would also ensure that people could move out of the area efficiently. In downtown areas, vertiports could be located on top of tall buildings.

3. Their aircraft will need to be quieter than today's helicopters.

Aircraft noise will be a critical issue in determining whether UAM succeeds or fails. If UAM aircraft are too noisy, then local communities could oppose flights over their neighborhoods or the construction of vertiports in their neighborhoods.

If UAM aircraft designers don't fix "the noise problem," then UAM flights will generate a lot of complaints early on, which will make it tough for UAM to gain traction, Hackenberg says. This is one factor that has prevented urban helicopter flights from growing more popular.

Noise levels will also help determine where and when the UAM aircraft will fly. One idea is to mix the noise of the aircraft in with ambient noise sources that already exist. For example, UAM operators could fly them above highways so the ground traffic covers up the aircraft noise.

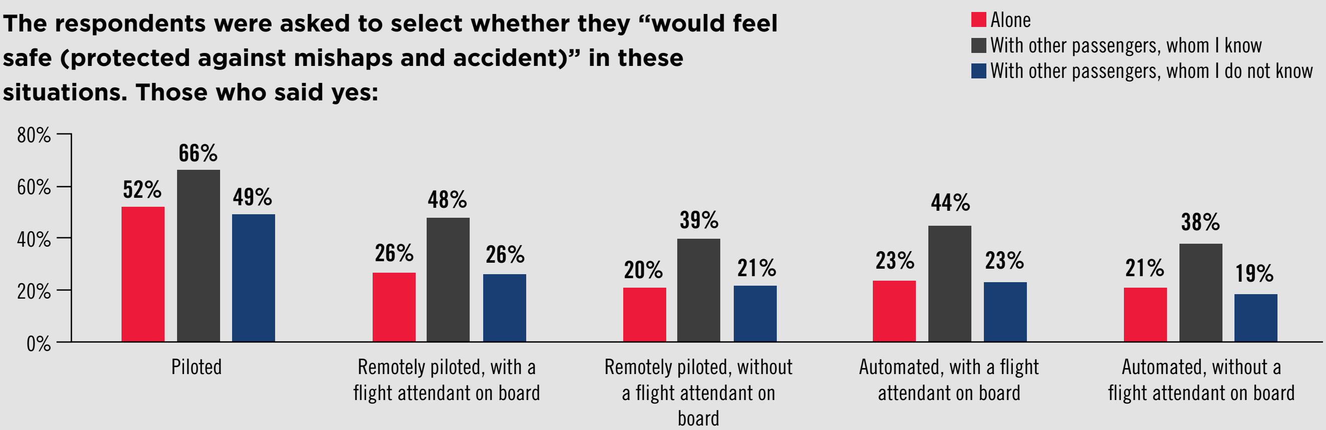
Communities will be more likely to buy into the concept of UAM serving their neighborhoods if the flight paths are planned to stay as far as possible from schools, hospitals, parks and residential areas, says Raymond Bea, a noise analyst for ATAC Corp., a Santa Clara, California, consultant on air traffic

▼ **Vahana,** an all-electric vertical takeoff and landing aircraft by A^3 by Airbus, flew in 2018 for the first time.
Vahana/Airbus

Must a pilot be aboard?

A majority said "Yes" in a 2018 survey of perceptions about urban air mobility. The 1,700 people who responded were from five U.S. cities that were selected based on a variety of issues, including demography, geography, weather and availability of past or present taxi services.

The respondents were asked to select whether they "would feel safe (protected against mishaps and accident)" in these situations. Those who said yes:



Source: NASA Urban Air Mobility (UAM) Market Study

issues. In general, the main factor determining how noise will propagate is distance, he says.

In addition to the cost, noise levels could also discourage UAM concepts in which individuals catch flights from their homes, instead of vertiports, says Winter of Embry-Riddle. "If you think it's bad when somebody fires up their Mustang in the morning to leave your neighborhood, just imagine if he fires up the helicopter."

But aerospace engineers will probably solve the noise problem with good designs, says Brian German, an aerospace engineering associate professor at Georgia Tech. Propellers could be positioned on the airframe to limit noise; rotor blades could be widened or more blades added so tip speeds could be lowered; long ducts could be added to reduce noise at certain frequencies, German says.

4. Their aircraft will be battery powered.

Electric propulsion with its energy and aerodynamic lift efficiencies will be a key to UAM success. With electric propulsion, designers can create aircraft with propellers placed where they are most aerodynamically effective for maximum lift and fuel efficiency. Today's electric aircraft are divided between battery-powered concepts and hybrid-electric versions, in which a gas-powered turbine generates the electricity.

Eventually, the hybrid-electric designs likely will be abandoned in favor of the battery-powered propulsion, says German of Georgia Tech. The reason is cost: Hybrid-electric propulsion will be more expensive to maintain. "A gas turbine in general is a high-maintenance-cost piece of equipment, and if you now have a gas turbine plus a whole bunch of electric motors and generators and batteries, you actually have a potentially higher level of system complexity than you do with current aircraft," he says. Battery-powered propulsion has fewer moving parts, so less wear and tear, and it can draw its charging electricity from renewable energy sources, with no need to maintain combustible fuel supplies for the aircraft.

In five to 10 years, advances in battery technology could produce batteries with enough energy density, or energy stored per unit of space, for the length of flights that UAM would require — up to 80 kilometers, German says.

But even when battery technology has matured, there still could be a role for hybrid-electric aircraft with longer UAM flights, says Parimal Kopardekar, acting director of the NASA Aeronautics Research Institute. Even when battery-powered aircraft are reaching 130-kilometer flights, hybrid-electric aircraft will be capable of flying 450 kilometers, he says.

5. Their aircraft may still need a wing.

UAM aircraft designs will probably include a wing, which will make the aircraft more aerodynamically efficient in forward flight and faster, to reduce travel time, German says. For flights of 50 to 60 kilometers, a winged aircraft has a big speed advantage. The exception might be when flying only over

“If you think it’s bad when somebody fires up their Mustang in the morning to leave your neighborhood, just imagine if he fires up the helicopter.”

— Scott Winter, Embry-Riddle Aeronautical University, on UAM’s potential noise problem

highly congested space for short distances — 8 to 16 kilometers, for example. A wing might not be necessary, he says.

6. Passengers will share their ride with three to five other passengers.

The vertical-takeoff-and-landing aircraft typically envisioned for UAM would carry four to six passengers. UAM operators will want to fly as many passengers as possible per flight to make the flights less expensive, but the amount of energy and power required for taking off and hovering limits the size of the aircraft, German says. Also, as the aircraft gets heavier relative to its combined rotor size, the noise produced by the rotors increases dramatically. And, it increases the downwash field, or the intensity of the wind kicked up to the rotors.

To accommodate more passengers per vehicle, aircraft designers would have to create aircraft with larger rotors, which would require larger landing pads. “There’s many operational advantages to having a greater number of people in the aircraft, but in my opinion that puts some more technical challenges on the vehicle design up against some fundamental physics,” he says.

7. Their flight routes may not follow any predictable pattern.

When UAM operations and technology reach their most advanced stage, the software and data links that control where the aircraft fly and keep them from crashing into each other will be autonomous. Human air traffic controllers will not be required, so

Ehang 184 is a one-seat autonomous aerial vehicle. The company describes it as a low-altitude aircraft for medium and short distances.
Ehang

◀ **Uber Air** says it is working to start commercial flights in 2023 in Dallas-Fort Worth and Los Angeles.
Uber

there will be no need to maintain air traffic in prescribed corridors in the sky, Atkins of the University of Michigan says. Other than avoiding obstacles and not flying over sensitive areas, the software-controlled flight paths may appear random to humans.

"If you imagine standing on a city street and looking up into the sky, the efficient urban air mobility set of operations is going to be like taking a pencil and drawing a whole bunch of lines, but they're not all going to be in the same direction," she says. "I don't think it's going to be as orderly as a human mind would like it to be, unless we really dial back the availability of those operations and never have them be very dense or very varied."

Because conserving energy will be key for battery-powered aircraft, traffic control will also ensure that the aircraft won't be held in holding patterns waiting to land, Kopardekar says. "You don't want to hover around and waste the energy. You want to schedule them so that everybody gets a slot, so to speak." ★


MEO
LEO
GEO

MATCH OF THE CENTURY

The past few years have been rough for builders of geosynchronous communications satellites as they square off in the marketplace against demands for low Earth and medium Earth orbit constellations. Debra Werner spoke to some of the leaders in the satellite industry about the future of GEOs and came away with some surprising revelations.

BY DEBRA WERNER | werner.debra@gmail.com

With World War II grinding to its conclusion, Arthur C. Clarke, then a radar instructor in the British Royal Air Force, turned his mind to outer space. He sent a letter and then a paper to the British trade magazine Wireless World in which he explained the possibility of sending an "artificial satellite" high over the equator at a precise speed and altitude so that "it would remain fixed in the sky of a whole hemisphere and unlike all other heavenly bodies would neither rise nor set."

Clarke called his satellites extra-terrestrial relays, but today we know them as geosynchronous satellites. For some government agencies and those in the satellite communications business, these truck-size GEO satellites are no longer where the future lies. They can cost upward of $1 billion, presenting enormous liabilities in the event of a launch accident or technical issue, and to at least one Air Force general, they are at best "juicy targets." Stock traders live in fear that prices will drop precipitously in the quarter of a second it can take for a "sell" command to bounce 36,000 kilometers into space and back on its way to a stock market half a world away.

For these and other reasons, much of the entrepreneurial action today in the satellite world centers on erecting constellations of small, often mass-produced spacecraft in low or medium Earth orbit for voice communications, broadband internet and Earth imaging.

Given all the hubbub about nongeosynchronous satellites, as they are known in the industry, no one could be blamed for wondering if the sun is about to set on Clarke's great vision. Many experts I spoke with don't think so, and the reasons often come down to dollars and cents and memories of the 1990s, when LEO satellites also seemed destined to rule the skies.

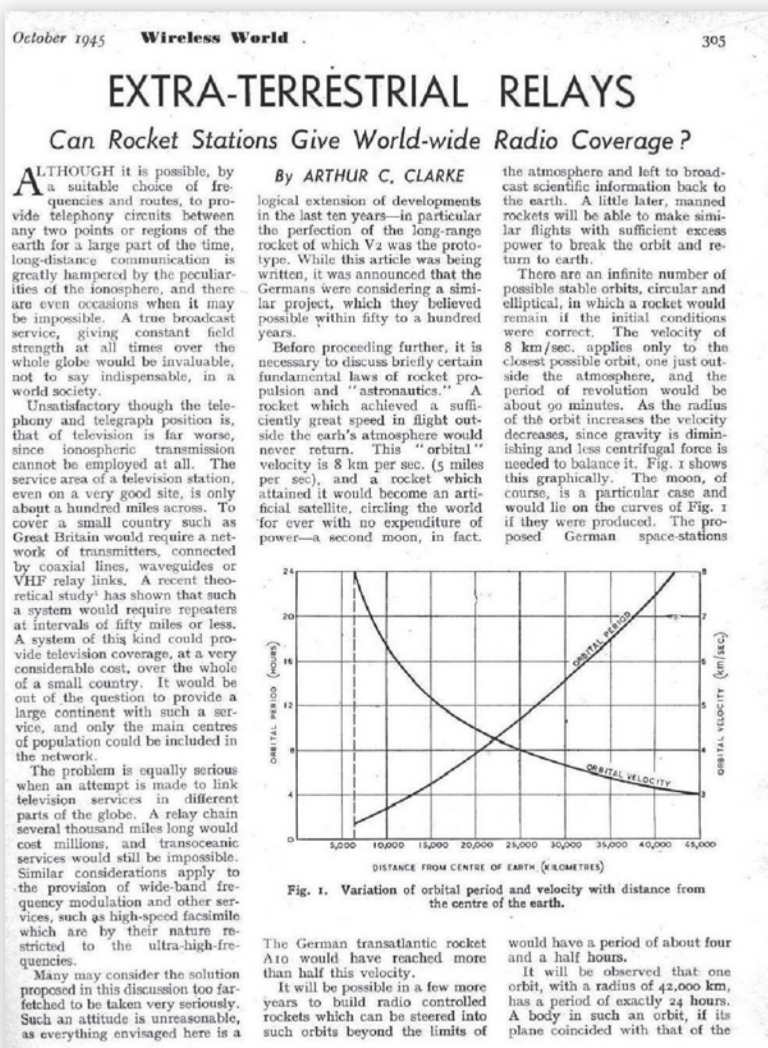
First, the money question. Satellite customers typically push their needs and budgets through "the affordability equation," says Harris Corp.'s Bill Gattle, president of the company's Space and Intelligence Systems segment.

Does the business plan dictate global or regional coverage? If only regional coverage is needed, that could argue for a single GEO satellite. Are advances in materials, power and computing coming so quickly that it makes sense to launch new satellites every five years instead of 15? If so, that would suggest smaller, less-expensive satellites in low Earth orbit. How much latency can be accepted? If, like a stock trader, the answer is not much, then lower latency of nonGEO satellites might be a necessity.

AIAA fellow Daniel Hastings, who leads the aeronautics and astronautics department at MIT, summarizes the tradeoffs like this: "The GEOs will continue to be good for applications which do not require low latency. The obvious example is DirecTV. It would be hard to deliver the quality signals from a moving set of LEOS which are only overhead for 10-20 minutes," he said in an email. "On the other hand, the low latency with cross links that the LEOS give enable voice and internet communications in a way that the GEOS have a hard time doing."

The budget aspects of the affordability equation can be trickier to assess. Customers must anticipate the cost of building, launching and operating a constellation of small satellites, including ground equipment, and compare that cost to the price of building and launching just one or a few GEO satellites.

"The costs required for a LEO system are a big unknown right now, and the devil is in the details," says engineering consultant and AIAA fellow Chris Hoeber, a former senior vice president at SSL, a longtime manufacturer of truck-size GEO satellites that now also produces minifridge-size satellites for



October 1945 **Wireless World** 305

EXTRA-TERRESTRIAL RELAYS

Can Rocket Stations Give World-wide Radio Coverage?

By ARTHUR C. CLARKE

ALTHOUGH it is possible, by a suitable choice of frequencies and routes, to provide telephony circuits between any two points or regions of the earth for a large part of the time, long-distance communication is greatly hampered by the peculiarities of the ionosphere, and there are even occasions when it may be impossible. A true broadcast service, giving constant field strength at all times over the whole globe would be invaluable, not to say indispensable, in a world society.

Unsatisfactory though the telephony and telegraph position is, that of television is far worse, since ionospheric transmission cannot be employed at all. The service area of a television station, even on a very good site, is only about a hundred miles across. To cover a small country such as Great Britain would require a network of transmitters, connected by coaxial lines, waveguides or VHF relay links. A recent theoretical study[1] has shown that such a system would require repeaters at intervals of fifty miles or less. A system of this kind could provide television coverage, at a very considerable cost, over the whole of a small country. It would be out of the question to provide a large continent with such a service, and only the main centres of population could be included in the network.

The problem is equally serious when an attempt is made to link television services in different parts of the globe. A relay chain several thousand miles long would cost millions, and transoceanic services would still be impossible. Similar considerations apply to the provision of wide-band frequency modulation and other services, such as high-speed facsimile which are by their nature restricted to the ultra-high-frequencies.

Many may consider the solution proposed in this discussion too far-fetched to be taken very seriously. Such an attitude is unreasonable, as everything envisaged here is a logical extension of developments in the last ten years—in particular the perfection of the long-range rocket of which V2 was the prototype. While this article was being written, it was announced that the Germans were considering a similar project, which they believed possible within fifty to a hundred years.

Before proceeding further, it is necessary to discuss briefly certain fundamental laws of rocket propulsion and "astronautics." A rocket which achieved a sufficiently great speed in flight outside the earh's atmosphere would never return. This "orbital" velocity is 8 km per sec. (5 miles per sec), and a rocket which attained it would become an artificial satellite, circling the world for ever with no expenditure of power—a second moon, in fact.

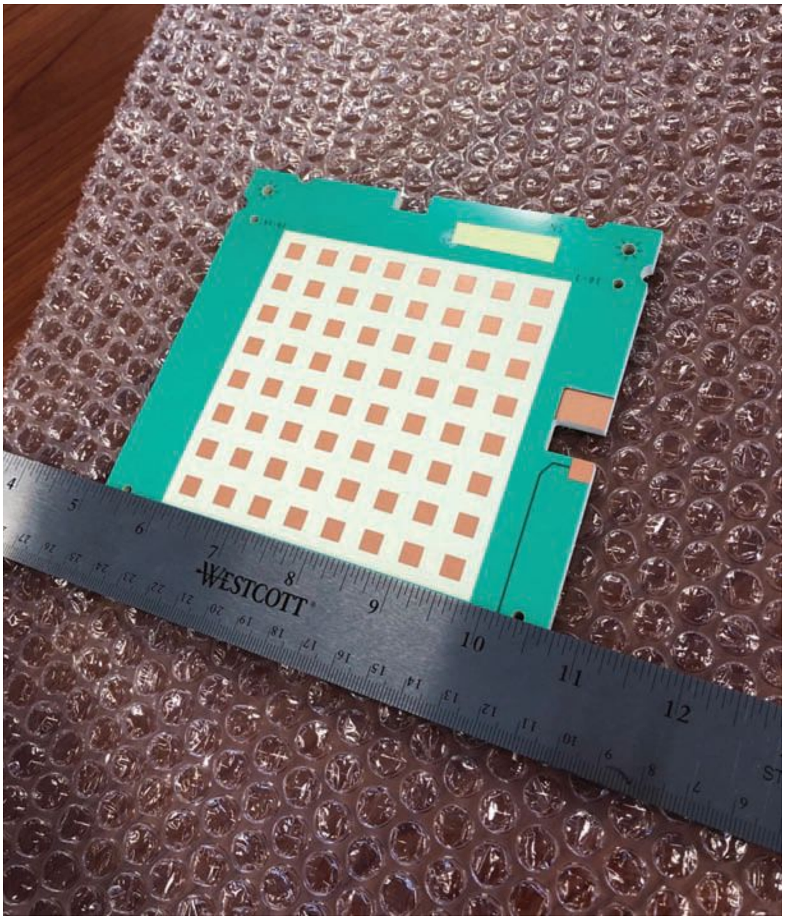
The German transatlantic rocket A10 would have reached more than half this velocity.

It will be possible in a few more years to build radio controlled rockets which can be steered into such orbits beyond the limits of the atmosphere and left to broadcast scientific information back to the earth. A little later, manned rockets will be able to make similar flights with sufficient excess power to break the orbit and return to earth.

There are an infinite number of possible stable orbits, circular and elliptical, in which a rocket would remain if the initial conditions were correct. The velocity of 8 km/sec. applies only to the closest possible orbit, one just outside the atmosphere, and the period of revolution would be about 90 minutes. As the radius of the orbit increases the velocity decreases, since gravity is diminishing and less centrifugal force is needed to balance it. Fig. 1 shows this graphically. The moon, of course, is a particular case and would lie on the curves of Fig. 1 if they were produced. The proposed German space-stations would have a period of about four and a half hours.

It will be observed that one orbit, with a radius of 42,000 km, has a period of exactly 24 hours. A body in such an orbit, if its plane coincided with that of the

Fig. 1. Variation of orbital period and velocity with distance from the centre of the earth.



▲ OneWeb founder Greg Wyler tweeted that this antenna prototype can transmit data at 20 megabits per second. Analysts say that antennas tracking low Earth satellites need to become cheaper before consumers will buy them.
@greg_wyler/Twitter

"The costs required for a LEO system are a big unknown right now, and the devil is in the details."

— Chris Hoeber, an engineering consultant

low Earth orbit. By contrast, the costs of GEO satellites for commercial communications are well understood, because a commodity market has developed over several decades, he explains.

Consider OneWeb, a startup based in Arlington, Virginia, that's starting to launch satellites to LEO for global internet access. The company used to say that its entire planned constellation of 648 satellites would cost $2.5 billion to $3.5 billion. Now, the company does not provide a figure, although industry observers suspect the cost could be twice that.

Hype vs. reality

It's impossible to ignore the buzz around the megaconstellations announced by OneWeb, SpaceX and about a dozen others. Even the term for these constellations comes with a bit of hype: Sticklers for metric prefixes like to note that mega means million and that no one anticipates launching that many satellites. They prefer to say "proliferated" constellations. Regardless, the new constellations have attracted lots of media attention, including here in Aerospace America, but more importantly, billion-dollar investments. Although just beginning to launch, they've already hurt GEO satellite sales by disrupting the market. Orders for GEO satellites have fallen precipitously in recent years, as the world's top satellite customers watched the new constellations begin to take shape and wondered what impact the upstarts would have on the market for satellite services.

"During this period of transition, everyone has a wait-and-see attitude," says Lluc Palerm-Serra, a senior analyst at Northern Sky Research, a consulting firm based in Cambridge, Massachusetts.

Analysts suspect it will be years before we know which of the budding satellite internet constellations will survive, since companies have barely begun to launch their spacecraft. SpaceX of California and Telesat of Ottawa launched the first prototypes for competing proliferated satellite internet constellations in 2018. OneWeb sent its first six operational satellites into orbit in February.

The GEO-focused service providers are taking the megaconstellations seriously. One of the GEO providers is Hughes Communications, which links 1.3 million residential and business customers in North America with internet access through 24 GEO satellites operated by its parent company, EchoStar Corp. Hughes chose to be an early investor in OneWeb and is building gateways, modems and power amplifiers for the constellation. Hughes sees OneWeb as complementary to its GEO business for this reason: GEO satellites tend to focus on regions, like North America, Europe or Africa. They're good at moving a lot of data, such as beaming video, to customers in their region, says Paul Gaske, executive vice president and general manager of Hughes Network Systems North America Division. "The beauty of LEO is coverage of the entire planet" and low latency, which means quicker responses for games and web pages, he says.

Stock traders or business customers who can't wait for signals to travel 36,000 kilometers to satellites in GEO and back, could access the internet through OneWeb's satellites, which at 150 kilograms are 30 to 40 times lighter than GEO communications satellites.

A harbinger of demand for nonGEO constellations is O3b Networks, the medium Earth orbit constellation purchased in 2016 by SES of Luxembourg, one of the world's largest satellite fleet operators. Like the new constellations, O3b satellites in 8,000-kilometer orbits offer lower latency than GEO satellites. As a result, web pages load and transactions conclude more quickly. Each O3b satellite has 12 steerable Ka-band spot beams supplying broadband to remote towns, companies, schools and ships. For Royal Caribbean Cruise Lines, for instance, O3b spot beams follow ships, supplying passengers and crew with continuous Wi-Fi.

OneWeb and O3b captured global attention with promises of extending internet access to underserved communities around the world. But faced with the enormous cost of building nonGEO constellations,

each has redirected their initial focus to first bringing in revenue from wealthier customers.

The ultimate goal of the LEO constellations is to ensure people rich and poor can remain connected to high-speed networks in remote regions and aboard trains, ships and airplanes. For that to happen, the new networks will need more bandwidth and new user terminals.

▼ Geosynchronous satellites like the GOES weather series are still necessary because they collect simultaneous readings that low Earth orbit satellites cannot.

Lockheed Martin

Communications satellite developers are looking beyond Ka-band to Q- and V-bands, a treasure trove of available bandwidth. They also are working with antenna developers because LEO constellations will never serve mass markets until the terminals to access them become more affordable.

Today, terminals sophisticated enough to track one satellite darting across the sky for a few minutes and then acquire the next satellite in the series are installed on some aircraft, yachts and emergency response vehicles, but they cost anywhere from a couple of thousand to a couple of hundred thousand dollars. Government agencies and corporations can afford them, but terminal prices, including the tracking antennas, need to fall to the $200 to $300 range before consumers embrace them, says Tom Butash, an AIAA fellow who leads Innovative Aerospace Information Systems, a consulting firm in Virginia.

Greg Wyler, who founded O3b before starting OneWeb, announced in January that his company has prototyped an inexpensive electronically steered antenna it hopes to begin selling in 2020. Antenna experts are dubious. These billion-dollar constellations are betting on technology that remains to be fully demonstrated, Butash says.

Rough patch for GEOS

Communicating with GEO satellites is much easier. Antennas selling for less than $100 can bring TV and internet access into homes and schools. From their positions over the equator, they can't cover the poles but can reach latitudes between 70 degrees north and 70 degrees south. Manufacturers are quick to point out that's where the vast majority of human activity and communications traffic occurs.

Demand for GEO service remains strong because consumers want perpetual access to high-speed broadband, says Dave Ryan, president of GEO satellite operator Viasat Space and Commercial Networks of Carlsbad, California, which delivers internet access and secure networks for commercial and government customers.

To keep up, Viasat plans to add three Viasat-3 satellites to its constellation. Each will deliver about a terabit per second of network capacity for high-speed, high-quality internet surfing and video streaming by customers throughout the Americas, Europe, the Middle East, Africa and Asia. Slated to launch between 2021 and 2022 and designed to last at least 15 years, the 6,400-kilogram satellites demonstrate the company's conviction in the long-term future of its GEO satellite business, Ryan says.

Despite rising demand for bandwidth, sales of GEO satellites have slowed. From 2005 to 2010, companies around the world annually bought a total of 20 to 25 large geosynchronous satellites. In recent years, they've announced roughly half that

"I can move a [GEO] satellite that's been sitting over one region to another region for a short period of time, for something like the Olympics or the World Cup, and then move it to a different market. This is the place where GEO has a dramatic advantage over LEO."

— Erik Daehler, Lockheed Martin Space Systems

number, as high-throughput satellites produced a surge in available bandwidth, lowering the price of leased capacity. That trend made some customers hesitant to commit hundreds of millions of dollars for new satellites.

Even with weak sales, satellite manufacturers are spending heavily on high-power solar arrays, solid state power amplifiers and digital signal processors. In the past, satellite service providers spent hundreds of millions of dollars to customize satellites to serve specific markets over their lifespans of 15 years or more. While that still occurs in some markets, flexibility is becoming increasingly important. Lockheed Martin, Boeing and SSL are designing satellites that can change the shape of communications beams to adapt to new markets and hop frequencies if they encounter interference or jamming.

"I can move a satellite that's been sitting over one region to another region for a short period of time, for something like the Olympics or the World Cup, and then move it to a different market," says Erik Daehler, who leads business development for commercial communications and remote sensing for Lockheed Martin Space Systems. "This is the place where GEO has a dramatic advantage over LEO. You can't really move a satellite in LEO from

▼ A U.S. soldier works on a portable satellite terminal during an exercise. The military and intelligence agencies are expected to continue to need geosynchronous satellites.

U.S. Army

NOAA

▲ Weather satellite controllers at NOAA's Satellite Operations Control Center.

one market to another because the orbital dynamics don't let you do that. In GEO, you can very easily walk around the globe and change the position of your satellite over the life of the vehicle."

In the next decade, GEO satellites could complement service provided by the LEO constellations. "LEO constellations spread the capacity evenly around the world. But maybe you would like to have an extra layer of capacity in Africa, Latin America or North Atlantic airplane routes," says Palerm-Serra, the Northern Sky Research analyst. If so, GEO satellites could point spot beams toward the region to offer additional coverage.

In spite of turbulence in commercial satellite markets, government customers in the U.S. are likely to keep buying GEO satellites. "The Air Force and intelligence agencies are not abandoning that orbit," says Brett Loubert, a former Lockheed Martin program manager who leads information technology strategy for Deloitte.

NOAA also will need GEO sentinels for the foreseeable future. Numerical weather models benefit from simultaneous global observation of winds and other atmospheric conditions. "That's something you're never going to get from LEO unless you have 1,000 satellites," says Stephen Volz, who leads NOAA's Satellite and Information Services branch. "People say they can fly that many. But the cross-calibration of 1,000 satellites is a lot harder than it is with five. GEO is going to be around for a while."

Déjà vu?

For some people, the new LEO constellations trigger memories of the LEO constellations of the 1990s. Globalstar, Iridium and Teledesic promised to bring communications to the masses equipped with satellite phones. What they didn't anticipate was the rapid spread of terrestrial cellular networks offering customers inexpensive alternatives to satellite links. All three constellations declared bankruptcy, although Iridium and Globalstar emerged from bankruptcy to build successful businesses.

Will terrestrial networks once again overtake satellites? Network providers are spending tens of billions of dollars on 5G, the fifth-generation standard for cellular mobile communications. Satellites are part of 5G, which promises higher-speed communications and additional capacity. Networks will send traffic over satellites to reach places fiber and sea-floor cables do not. In fact, some call 5G a network of networks.

Experts agree 5G networks will boost satellite communications traffic. They disagree about whether fiber and sea-floor cables will ultimately spread to the point where satellites play a minor role in communications networks.

Mobile terrestrial network operators rely on optical fiber or satellites for backhaul and trunking, connecting remote sites to the core communications network. If 5G boosts network traffic, that means more work for satellites.

"We believe GEO satellites will be part of the solution as will constellations in low Earth orbit and medium Earth orbit and even high-altitude platforms," says Paul Estey, chief operating officer for satellite manufacturer SSL, a Maxar Technologies company.

Linking all the satellites, airships and unpiloted aerial vehicles into a series of seamless nodes won't be easy, but it's necessary for 5G. "When you go to the mountains away from all the cellphone towers, your 5G service will go seamlessly from cell towers to some sort of airborne or spaceborne delivery system," Estey says.

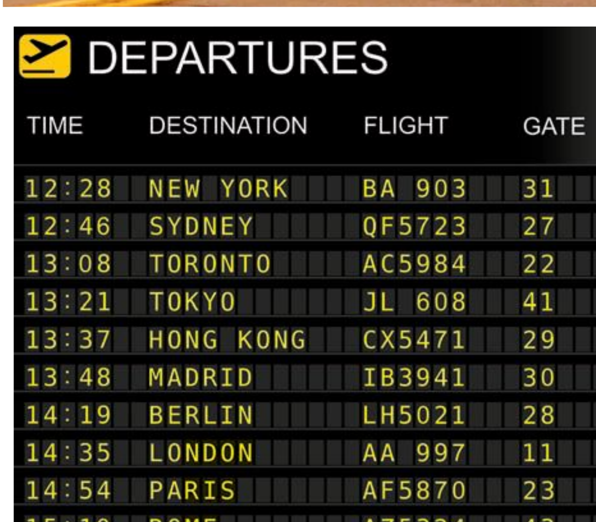
As fiber and undersea cables continue spreading in a global communications web, some think they eventually will diminish the role for satellites of any kind.

"The explosive, exponential growth of fixed and mobile fifth-generation solutions over the next few years will decimate the satellite broadband markets, which have been pretty healthy in developed countries like [those in] North America, Europe and developed parts of Asia," says consultant Butash. That would mean trouble for both GEO satellite manufacturers and the new nonGEO orbit constellations.

Even if that scenario plays out, satellites in GEO and nonGEO orbits will continue to serve customers on the move and in remote communities.

"It will be nearly impossible for the landlines to reach everybody," Gattle says. "It's such a huge infrastructure cost." ★

COUNTERDRONE



CHALLENGES

Airport authorities know that they can't let wayward consumer drones paralyze airports. Companies in the U.S. and abroad have demonstrated a range of technologies for detecting and neutralizing drones, but a consensus has yet to emerge on the best solutions, writes Marc Selinger.

BY MARC SELINGER | marc2255@yahoo.com

A consumer drone under a Christmas tree is good. The same drone flying near an airport frequented by holiday travelers is bad. The point was proved at London's Gatwick Airport last December, when a series of drone spottings disrupted 1,000 flights and delayed 140,000 travelers, according to The Times of London. A month later, flights out of New Jersey's Newark Liberty International Airport were briefly halted when two pilots reported seeing a drone flying at 3,500 feet, according to The New York Times.

Did it take a flock of drones, sometimes called unmanned aircraft systems, to paralyze air travel? No, just one or two perhaps flown over and over again, based on witness accounts in news reports.

In the U.S. and abroad, the incidents at Gatwick and Newark have heightened efforts to try out and select technologies that can detect, track and stop drones that accidentally or intentionally fly too close to civilian or military sites.

Even before the headline-grabbing cases at Gatwick and Newark, academics who study these matters were sounding the alarm and urging faster action. Arthur Holland Michel, co-director of Bard College's Center for the Study of the Drone in upstate New York, wrote in a report last year that "near misses between drones and manned aircraft have become a common occurrence in every crowded airspace system in the world, and many worry that a collision between a manned aircraft and an unmanned aircraft could result in a catastrophic accident."

The United Kingdom incident underscored the impacts of disruptions short of calamity.

"It cannot be right that drones can close a vital part of our national infrastructure in this way," Gatwick CEO Stewart Wingate said in a statement at the time. The intrusions highlighted "a wider strategic challenge for aviation" in the U.K., "which we need to address together with speed — the aviation industry, government and all the other relevant authorities."

"New hot topic"

In the U.S., 160 companies have devised 300 products, with participants representing "a good mixture" of startups and well-established firms, says Tim Bennett, who oversees counterdrone efforts at the U.S. Department of Homeland Security's Science and Technology Directorate.

"It's the new hot topic that everybody wants to get involved with," says Bennett.

Through a pilot program, the FAA tested a variety of drone detection systems at four airports from February 2016 to December 2017. Spurred by a provision in the 2018 FAA Reauthorization Act, the FAA is formulating plans "to conduct additional pilot program activity related to evaluation of detection and mitigation systems at airports," the agency said in a statement.

In addition, the Utah Department of Transportation's Division of Aeronautics has given Fortem Technologies permission to evaluate drone-detecting radar at two runways at Salt Lake City International Airport. The department has access to the data that Fortem collects and might eventually buy the company's radar for its own use, a spokesman says.

Despite the various counterdrone efforts by government and industry, experts say no consensus has emerged on the best way to address the problem.

Michel of Bard College says that all detection systems have drawbacks. Radar can struggle to see small, low-flying drones. Electro-optical and infrared systems must have direct line of sight with a drone. Systems

SCI Technology's AeroGuard, left, fires a tethered net at a drone in a demonstration.
SCI Technology

"There's no one good system that will do it. It's going to have to be a collection of different sensors and systems to go together to make it operate."

— Tim Bennett, U.S. Department of Homeland Security

that detect a drone's sound or radio links rely on libraries that must be updated regularly.

"There's no one good system that will do it," Bennett says. "It's going to have to be a collection of different sensors and systems to go together to make it operate."

Stopping a drone is considered an even bigger problem than detecting and tracking it. The U.S. military can often shoot drones out of the sky when it encounters them on barren battlefields overseas. But that is more problematic at, say, civilian airports because flaming debris could fall on and injure people.

Another way to down drones would be to jam their communications links or GPS signals. But those tools will become less effective as drones increasingly fly autonomously, with no communications links, and become more reliant on other forms of navigation, such as mapping software.

Within a few years, drones will be "all-silent aircraft" that require "other means" to stop them, Bennett explains.

Fighting drones with drones

Some of the newer interdiction systems would capture drones with nets, drawing comparisons to the spiderwebs that Spider-Man fires from his wrist to trap villains.

Denver-based Liteye Systems, for example, offers two ground-launched net guns: the hand-held SkyWall 100 and the larger, longer-range SkyWall 300, which can be mounted on a turret. Both systems fire a projectile that releases a net to entangle the drone. A parachute gently lands the intruder.

Several firms also offer drone-mounted net capture systems.

▲ **Skysec's Sentinel** Catch & Carry, top, and Sentinel Catch drone interceptors.
Skysec

Utah-based Fortem Technologies, which counts Boeing among its financial backers, has developed DroneHunter. Fortem says that once it installs DroneHunter on a host drone, the aircraft can autonomously patrol an airspace with a radar that can detect and track a drone. It fires a tethered net to capture the intruder drone and tow it to a safe spot on the ground.

SCI Technology of Huntsville, Alabama, has AeroGuard, an octocopter that is launched when a hostile drone is detected. Like DroneHunter, AeroGuard fires a tethered net at a drone and tows the captured device to a safe landing zone.

"This disposal location is typically away from the protected area to prevent exposure to a potentially dangerous payload," such as a bomb, said Max Klein, SCI's chief technology officer.

Switzerland's Skysec is developing Sentinel Catch, a four-winged drone, and Sentinel Catch & Carry, a fixed-wing/quadcopter hybrid. Each interceptor, or "effector," has a seeker in its nose to help it zero in on a target. After snagging a drone with a towed net, Sentinel Catch deploys a parachute to bring itself and the intruding drone to the ground, while Sentinel Catch & Carry carries the target to a landing zone.

Bennett says he prefers drone-mounted nets over ground-launched ones, which require the shooter to be close to the target.

"I like the idea of using other UAS with the systems on them that can actually net the aircraft and then tow it away somewhere else," Bennett says. "I think that's going to be a very promising one."

But Michel cautioned that drone-mounted nets need to undergo more rigorous testing to prove they perform as advertised.

"It's such a new technology; we don't have a lot of data from real-world use," Michel says. "It's hard to say at this point to what extent it would or would not work or whether there are unexpected variables that could influence how well it works or how safe it is."

Kenneth Geyer, Liteye's CEO and co-founder, offers a similar assessment.

"Liteye will continue to evaluate all the different technologies out there, including UAS-mounted net solutions," Geyer says. "Only when we have seen a technology tested under live fire, unscripted testing will we consider recommending its deployment." ★

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

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

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

Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2019			
2–3 May*	Improving Space Operations Workshop	Santa Clara, CA (info.aiaa.org/tac/SMG/SOSTC)	
7–9 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum)	Laurel, MD	20 Nov 18
10 May	75 Years of Hypersonics Development: History, Resources, References, and Insights	Laurel, MD	
14 May	AIAA Fellows Dinner	Crystal City, VA	
15 May	AIAA Aerospace Spotlight Awards Gala	Washington, DC	
20–23 May*	25th AIAA/CEAS Aeroacoustics Conference (Aeroacoustics 2019)	Delft, The Netherlands	15 Oct 18
27–29 May*	26th Saint Petersburg International Conference on Integrated Navigation Systems	St. Petersburg, Russia (elektropribor.spb.ru/icins2019/en)	
10–13 Jun*	18th International Forum on Aeroelasticity and Structural Dynamics	Savannah, GA (http://ifasd2019.utcdayton.com)	
12–14 Jun*	The Sixth International Conference on Tethers in Space (TiS2019)	Madrid Spain (http://eventos.uc3m.es/go/TiS2019)	
15–16 Jun	Practical Design Methods for Aircraft and Rotorcraft Flight Control for Manned and UAV Applications with Hands-On Training Using CONDUIT®	Dallas, TX	
15–16 Jun	Designing Unmanned Aircraft Systems	Dallas, TX	
15–16 Jun	Hypersonic Flight: Propulsion Requirements and Vehicle Design	Dallas, TX	
15–16 Jun	OpenFOAM Foundations: The Open Source CFD Toolbox	Dallas, TX	
16 Jun	Principles of Electric VTOL	Dallas, TX	
16 Jun	Workshop for Integrated Propeller Prediction (WIPP)	Dallas, TX	
16 Jun	Workshop for Multifidelity Modeling in Support of Design and Uncertainty Quantification	Dallas, TX	
17–21 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition)	Dallas, TX	7 Nov 18
17–21 Jun*	International Conference on Icing of Aircraft, Engines, and Structures	Minneapolis, MN	
25–27 Jun*	2nd Cognitive Communications for Aerospace Applications (CCAA) Workshop	Cleveland, OH (ieee.org/CCAA)	
11–15 Aug*	2019 AAS/AIAA Astrodynamics Specialist Conference	Portland, ME (space-flight.org)	5 Apr 19
16–18 Aug	Rocket Testing Workshop at Purdue Zucrow Labs	Indianapolis, IN	
17–18 Aug	Applied Model-Based Systems Engineering Course	Indianapolis, IN	
17–18 Aug	Hypersonic Air-Breathing Propulsion: Emerging Technologies and Cycles Course	Indianapolis, IN	

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
17–18 Aug	Integrated Performance Assessment of Boundary Layer Ingesting Aircraft and Highly Integrated Propulsion Concepts Course	Indianapolis, IN	
17–18 Aug	Missile Propulsion Course	Indianapolis, IN	
19–22 Aug	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition)	Indianapolis, IN	31 Jan 19
21 Aug	Aircraft Electrified Propulsion Systems and Component Design Course	Indianapolis, IN	
22–24 Aug	AIAA/IEEE Electric Aircraft Technologies Symposium (EATS)	Indianapolis, IN	31 Jan 19
21–22 Sep*	Amelia Earhart Aerospace Summit	West Layfayette, IN (earhartsummit.org)	
26–27 Sep*	CEAS-ASC Workshop 2019 on Advanced Materials for Aeroacoustics	Rome, Italy (https://www.win.tue.nl/ceas-asc)	
21–25 Oct*	70th International Astronautical Congress	Washington, DC	28 Feb 19
2020			
6 Jan	Class of 2020 AIAA Associate Fellows Induction Ceremony	Orlando, FL	
6–10 Jan	AIAA SciTech Forum	Orlando, FL	11 Jun 19
14–16 Jan*	2nd IAA Conference on Space Situational Awareness	Washington, DC (icssa2020.com)	
25–28 Jan*	Aircraft Noise and Emissions Reduction Symposium (ANERS)	Bordeaux, France	31 May 19
27–30 Jan*	66th Annual Reliability & Maintainability Symposium (RAMS®)	Palm Springs, CA (www.rams.org)	
7–14 Mar*	2020 IEEE Aerospace Conference	Big Sky, MT (aeroconf.org)	
5–7 May	AIAA DEFENSE Forum	Laurel, MD	
25–27 May*	27th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (elektropribor.spb.ru/en/conferences/142)	
15–19 Jun	AIAA AVIATION Forum	Reno, NV	
23–26 Jun*	ICNPAA 2020: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
14–18 Sep*	32nd Congress of the International Council of the Aeronautical Sciences	Shanghai, China (icas.org)	15 Jul 19
26–27 Sep*	CEAS-ASC Workshop 2019 on “Advanced Materials for Aeroacoustics”	Rome, Italy	
12–16 Oct*	71st International Astronautical Congress	Dubai, UAE (mbrsc.ae/iac2020)	
29 Oct–1 Nov*	37th International Communications Satellite Systems Conference (ICSSC 2019)	Okinawa, Japan (kaconf.org)	15 May 19

● AIAA Continuing Education offerings

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

AIAA Outreach on Capitol Hill

AIAA's 22nd annual Congressional Visits Day (CVD) program took place on 20 March and approximately 175 members representing 36 states and 37 sections took part. State teams visited about 275 offices to help promote the Institute's 2019 key issues and raise awareness of the long-term value that science, engineering, and technology bring to the nation. Over 60 percent of this year's participants were students!

Our members' participation in CVD reminds our lawmakers that aerospace is a key component of an economically strong and secure nation. And there's more that can be done to address the profession's public policy needs throughout the year. Reach out to your elected officials to communicate the importance of the aerospace community to our economy, national security, and as an inspiration to the future STEM workforce. Invite lawmakers to participate in your AIAA section's events and activities or tour a local facility. Be a vocal advocate for aerospace!


THANK YOU,
PURDUE AAE!


SENATOR
Pat Roberts
Kansas
SH109

(From l to r): Robert Ramsey, chief operating officer, Metropolitan Nashville Airport Authority; Caitlin Dillon, project manager, Design, Metropolitan Nashville Airport Authority; and Dirk Speas.

News

Nashville International Airport Wins 2019 Speas Airport Award

On 21 February, the 2019 AIAA/AAAE/ACC Jay Hollingsworth Speas Airport Award was presented to the **Nashville International Airport** during an awards luncheon at the 2019 ACC/AAAE Airport Planning, Design and Construction Symposium. The airport was recognized for creatively transforming a nearby quarry into the largest geothermal lake plate cooling system in North America to provide a sustainable source of water for the airport's terminal cooling and irrigation needs."

The Speas award was established in 1983 and is presented annually to the nominee(s) judged to have contributed most significantly in recent years to the enhancement of relationships between airports and/or heliports and their surrounding environments via exemplary innovation that might be replicated elsewhere.

MAKING AN IMPACT

FIRST® LEGO® League

Looking for ways to show students how much fun STEM can be? AIAA is supporting FIRST® LEGO® League teams. Through this program, new teams can receive up to $500 and existing teams can receive up to $250 to offset costs associated with FIRST® LEGO® League activities. There are no restrictions on how teams may use their grant funds. It can go toward covering the costs of challenge materials, travel expenses, team t-shirts, or anything else the team may need.

Going on its third year, this partnership has generated 493 applications and awarded 480 grants to deserving teams! FIRST® LEGO® League (FLL) team registration and AIAA Foundation grant application opens May 2019 (**aiaa.org/firstgrants**).

Coached by Dr. Supriya Banerjee, the **FAMES® FLL Program at the Boys and Girls Club of Greater Washington** sought to inspire students to pursue STEM education. "Support from the AIAA Foundation helps us prepare the next generation of aerospace leaders," Banerjee said. As one student wrote: "…when I grow up, I want to be an engineer and build something for NASA."

Coached by Mark Gullickson, the **Albany FFL Robotics Team** #27006, the Fin-tastic Fish, won First Place Championship Honors at the 2018-2019 State Robotics Championship Tournament. "Our NASA - Into Orbit season was such an amazing experience for us all!" Gullickson said. "Because of our AIAA Foundation FLL Grant, our team discovered how a FLL team from Albany can impact the lives of students just like us all over the world.

Top: FAMES® FLL Program.
Bottom: Albany FFL Robotics Team #27006

"[Inspired by our FLL grant, we had a] … clothing donation drive in which we collected 500+ pairs of new socks for homeless people in our community, [helped] … start an aquaculture fish farm program for girls in rural Vietnam, [and honored] our Veterans by celebrating their service as we marched in the largest Veterans Day parade west of the Mississippi. [The] … AIAA Foundation Grant made it possible for our team to truly put into practice so many ways to honor diversity in our community and all over the world."

The AIAA Foundation Grant also made it possible for the Fin-tastic Fish to purchase blue colored LEGO parts from different countries all over the world because this LEGO color is nonexistent in large quantities in the USA, Gullickson explained.

"Our robot, Blue Bob, is truly an international robot designed with LEGO pieces from as far away as St. Petersburg, Russia, Holland, Sweden, and Germany," he said. "Through our involvement with FIRST, and the support our team received from the AIAA Foundation, we have shared our research project and CORE Values successes with more than 35,000 FIRST teams all over the world."

For more information about the AIAA Foundation and the impact it makes, please visit **aiaafoundation.org**.

Professor Scott Wins Hargrave Award

Professor Murray Scott, an AIAA Associate Fellow, is the 2019 winner of the Lawrence Hargrave Award of the Royal Aeronautical Society Australian Division, which recognizes significant contributions to Australian aviation. Professor Scott has been honored for his major contributions to the development of advanced composite materials and structures.

Professor Murray Scott has made an outstanding contribution to the design and manufacturing of advanced fiber-composite aerospace structures, primarily as CEO of the Cooperative Research Centre [CRC] for Advanced Composite Structures. He has also played pivotal leadership roles in establishing other high-value R&D programs such as CRCACS Helicopter Composite Structures, Defence Materials Technology Centre, CRC-ACS Extension Program, and Innovative Manufacturing CRC.

In 1992, Professor Scott founded the Australian Composite Structures Society, which has been instrumental in fostering expertise in advanced composites in Australia. He coedited the book *Composite Materials for Aircraft Structures*, and has brought a considerable international focus to Australia's capabilities in aeronautics and composites through attracting major international conferences to the southern hemisphere. Professor Scott is an Honorary Fellow of the International Council of the Aeronautical Sciences and served a two-year term as President. He is also a World Fellow of the International Committee on Composite Materials (ICCM) and has served a term as President.

Australian Division Past President Air Vice Marshal Noel Schmidt (left) presents Professor Scott with his award at the 18th Australian International Aerospace Congress Dinner on 25 February in Melbourne.

2019 Sperry Winner Casper Providing New Insights into Hypersonic Boundary-Layer Transition

By Michele McDonald, AIAA Communications

While flying in an ultralight one summer day in Eastern Tennessee when she was 17, **Katya M. Casper** realized a career in aerospace was for her.

"I was in the air and it was so quiet," recalled Casper, who was working then at the front desk of a flight school so she could afford to take flying lessons.

Casper is now principal member of technical staff at Sandia National Laboratories in Albuquerque, NM, and is the 2019 winner of the AIAA Lawrence Sperry Award, which is given for a notable contribution made by a young person, age 35 or under, to the advancement of aeronautics or astronautics. Casper won the prestigious award "For highly significant contributions to the fundamental understanding of boundary layer transition and fluid-structure interactions in hypersonic flows through novel diagnostics with national program impact."

The award was created in 1936 to honor Lawrence B. Sperry, pioneer aviator and inventor, who died in 1923 in a forced landing while attempting a flight across the English Channel. Past recipients of the award include Michael West, Karen Berger, Sally Ride, Eugene Kranz, and Clarence L. "Kelly" Johnson.

Casper joined Sandia full time in 2012 after completing her Ph.D. from Purdue University where she also earned her M.S. in 2009. She received her B.S. in Aerospace Engineering from North Carolina State University in 2007, joining AIAA in her sophomore year.

"Dr. Katya Casper is one of the brightest young engineers I know," wrote Basil Hassan, AIAA President-Elect and senior manager and program deputy for the Engineering, Stockpile Assessments, and Responsiveness Program at Sandia, when he nominated Casper for the Sperry Award.

Casper's interest in science started early, encouraged by her father's love of astronomy. When she was 10 years old, Casper wanted to build the first rover to land on Pluto, drawn to the icy planet because it was so far away. Learning to fly shifted her focus from computer engineering to aerospace. Today, she's about speed, hypersonic to be exact.

"I like being hands-on and hypersonics is the next frontier," she said.

Casper develops, conducts, and manages wind tunnel experiments in support of Sandia's programs. Her work centers on high-speed experimental fluid dynamics, with a focus in hypersonic boundary-layer transition and hypersonic fluid-structure interactions, as well as fluid-structure interactions in subsonic/supersonic cavity flows. She also works to apply traditional wind-tunnel diagnostics to novel applications and testing environments at Sandia.

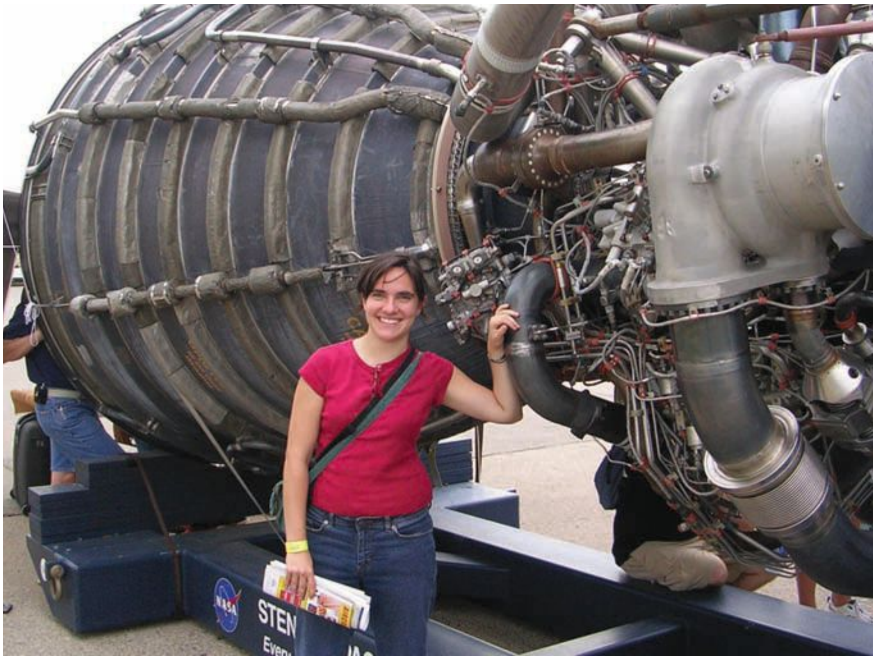
Simply put, Casper studies how air shakes a vehicle. And no one wants to be shaken at hypersonic speeds. Most of the experiments on boundary-layer transitions have been conducted at low speeds. Casper's work turns it up a notch and examines how the load on a particular shape—in this case a simple cone—changes in real time the faster it goes.

"We've taken a big step forward in the research," she said.

She's also applying advanced diagnostics in wind tunnels by using high-frequency pressure sensitive paint to register how a vehicle reacts in a real-world environment.

"We push it to the edge of where the paint can be applied," she said. "We've been applying it in a blast tube facility at Sandia. It's an outdoor environment where you have sunlight and dust—it's not a pretty lab environment."

While you can't dance to it, she's also testing how acoustics impact vehicles in flight. Soundwaves, from simple sine waves to more complex sounds found



during flight, also receive the paint test. Casper points a bunch of speakers at a structure that's been coated in the pressure-sensitive paint, turns up the volume, and records the results.

And the results from all her research is impressive.

Casper's research has provided new insights into hypersonic boundary-layer transitions, noted AIAA Fellow Steven Schneider, a professor in Purdue's School of Aeronautics and Astronautics. In some cases, revealing that past interpretations were wrong, while in other areas, illuminating problems that have eluded controlled studies for decades.

"Over the last decade, Katya has made major contributions to hypersonic transition," Schneider wrote in a letter supporting her nomination for the Sperry award. "She is a trusted collaborator who is helping to build a coordinated national team that works well together to meet national goals, both unclassified and classified."

Casper has been very involved in certain areas of AIAA and was the AIAA International Traffic in Arms Regulation (ITAR) chair in 2015 and 2016 and has been an associate organizer for two technical conferences. She also routinely serves as a journal and fellowship reviewer.

She co-founded a fluid-structure interactions (FSI) discussion group as part of the AIAA Fluid Dynamics Technical Committee. Seven years ago, the group started with three people and has grown to 60 members, who are from academia and the U.S. Air Force. Increased collaboration is the goal for the twice-yearly meetings at AIAA SciTech Forum and AIAA AVIATION Forum.

"We have a vibrant community that's talking about what we should do in the future," she said.

For students who want to pursue aerospace or other STEM careers, Casper strongly recommends internships because they offer a chance to try out fields for a short time, unlike regular jobs where it's usually more difficult to change areas.

Internships helped Casper fine-tune the direction of where she wanted to go in her work. "Internships were absolutely key to my career," she said.

At NASA she learned about the computational side of aerospace and decided she wanted to conduct experiments. And it was an internship at Boeing where she realized she had to go to graduate school. Working as a Summer Undergraduate Research Fellow in Purdue's Aerospace Sciences Lab in 2006, she decided where she wanted to study and what she wanted to do.

Casper recommends that students talk to their professors and apply at many places.

"The first internship is the hardest one to get," she said.

Three K–12 Educators Win AIAA Foundation Educator Achievement Awards

Three K–12 educators have won the 2019 AIAA Foundation Educator Achievement Awards, honoring their efforts to promote STEM education.

This year's honorees each received $5,000 for themselves as well as $5,000 for their respective schools. The winners are:

Charlotte Cook, Young Astronaut specialist at Carver Magnet School in Little Rock, AR, for "bringing STEM practices to our school, district, and community by utilizing AIAA and other resources that open students' eyes to endless possibilities."

Patricia Palazzolo, Gifted Education Coordinator at Upper St. Clair High School in Upper St. Clair, PA, for "encouraging students to pursue space- and STEM-related careers through hands-on projects and mentorship."

Megan L. Tucker, Lead Teacher, STEAM Specialist/Gifted & Instructional Facilitator, Technology at Hillsboro Charter Academy in Hillsboro, VA, for "inspiring a love of STEAM nationally for scholars and colleagues alike using aerospace education, Megan has a passionate mission for creating an 'Aviation Fascination'!"

The AIAA Foundation Educator Achievement Award recognizes K–12 educators for outstanding contributions to the continued study of STEM subjects among America's youth. Each of these teachers has had a significant impact on creating the next generation of aerospace professionals who will shape our community's future. Since 1997, the award has honored more than 65 educators from the United States.

Northern Ohio Section Judged and Sponsored Special Awards at Area Science Fairs

By Jonathan Kratz

In March, the AIAA Northern Ohio Section (NOS) continued its support of the Northern Ohio regional science fairs by again offering $400 in prizes for aerospace-related projects, which are judged by volunteer members of the section.

The Northwest District Science Day (NWDSD) science fair was held at the University of Toledo on 2 March. Jonathan Kratz and Aaron Hensley of NASA Glenn Research Center (GRC) were on hand to judge the projects, which were grouped into two categories: 5th – 8th grade and 9th – 12th grade— with over 140 total science projects on display. AIAA NOS judges evaluated a number of these science projects broadly related to aerospace engineering and associated sciences. One 1st place and two 2nd place prizes were awarded in each category for a total of six prizes.

Many students put together impressive projects and exhibited a great deal of knowledge and passion toward their topic. Particularly worthy of highlighting is **Adley McNeal's** (Grade 11) assembly, programming, and testing of a self-navigating robot with a vision toward potential application to autonomous exploration and mining on Mars; **Travis Burnard's** (Grade 7) analysis of strength and deflection in 3D printed parts when considering different infill patterns and their density; and **Nipun Jayatissa's** (Grade 12) design and testing of a novel biosensor for detecting heart disease.

The Northeastern Ohio Science and Engineering Fair (NEOSEF) took place at Cleveland State University on 12 March. There were over 450 projects in a wide range of categories covering grades 7–12. The judges were given time to look at the displays, before interviewing around 15 students to select two 1st place winners and four runners up. The judges, who were from NASA GRC, were Jonathan Kratz, Jonathan Litt, Al Juhasz, Yu Hin Hau, and David Sagerser (retired GRC).

A great deal of work was put into these projects and the high level of enthusiasm and extensive knowledge should be acknowledged. Particularly worthy of spotlighting was **Michelle Park's** analysis of the modulation of the light curves of stars as a result of their Fe/H values; **Brendan Smith's** carefully thought out, sound, and resourceful approach to evaluating the impact of winglets on aircraft range and efficiency; **Antonio Linek's** showcase of work and knowledge concerning the use of a vaccum to create a propulsive force; and **Jaden Stainforth's** engineering of a track and vehicle for testing a maglev system with application to aircraft take-off.

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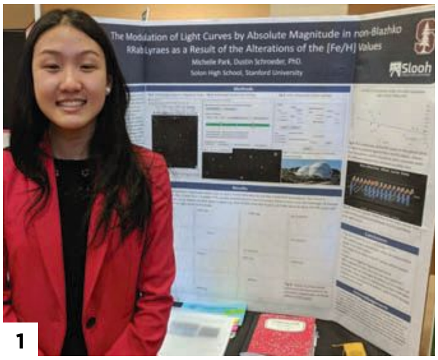

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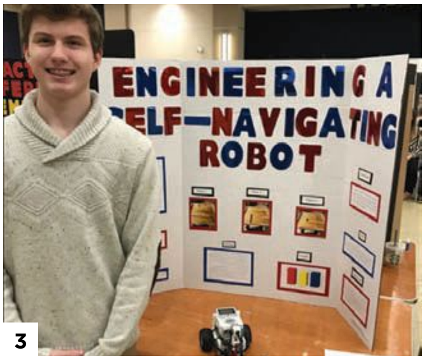

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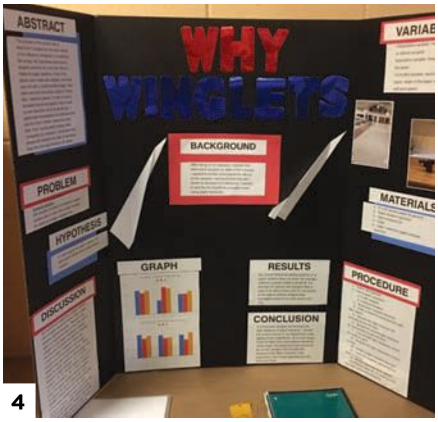

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1 Michelle Park 2 Travis Burnard
3 Adley McNeal 4 Brendan Smith's display
5 NEOSEF projects, students, and judges at the Cleveland State University recreation center.

National Capital Section Presents Future City 2019 Special Award

By Bruce Cranford

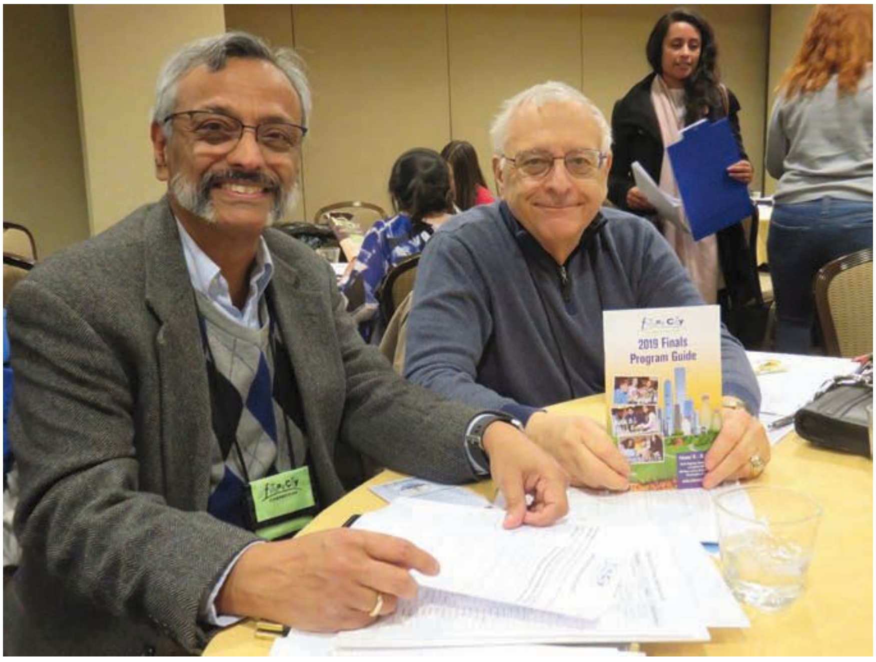
From 16 to 20 February, regional Future City winners from 43 middle schools, after-school organizations (e.g., scouts, 4H, boys/girls clubs) nationwide, Canada, and China participated in the Future City National Finals in Washington, DC. Regional winning teams received an all-expense-paid trip to the National Finals. In its 27th year, this year's Future City theme was "The Power of the Future," and middle school students were asked to create cities of the future, first on a computer and then as large tabletop models. Working in teams with a teacher and volunteer engineer mentor, students create their cities using the SimCity 3000 TM video game donated to all participating schools by Electronic Arts, Inc., of Redwood City, CA. Students wrote an abstract and an essay on using engineering to solve an important social issue. Then they presented and defended their cities before engineer judges at the competition. Over 40,000 students from more than 1,350 schools participated in 2018–2019.

The students created detailed — often fantastic — cities of tomorrow that give intriguing insight to how young minds envision their future. At the same time, their bold designs and innovative concepts provide a refreshingly optimistic appreciation of how our nation can realistically deal with the many challenges facing its cities, including the power of public spaces.

As part of the Future City's program, the AIAA National Capital Section (NCS) presented the 17th annual Special Award for the Best Use of Aerospace Technology to the city named **Jotunheim** (Team members: Paige Wiethoff, Ian Robinson, Aubrey Morton, William Feeney, Annie Talbot, Carter Fulk. Educator: Dorothy Bleakley, Mentor: Russel Talbott, School: Liberty Classical Academy, Colorado). The AIAA NCS congratulates the team for their outstanding efforts in winning this award. David Brandt, NCS chair, presented the award on 19 February 2019. The award consisted of a savings bond for each student team member, and a plaque highlighting the award for each member of the team.

Thea Sahr (director of Programs and DiscoverE) related the following story about a 2014 Future City student. The student's mother, Dorothy Bleakley, indicated her son became very interested in aviation and space as a result of his participation in the Future City competition. He will be a freshman in the fall of 2019 at Embry-Riddle Aeronautical University, Daytona Beach, FL, majoring in aeronautical technology. And it just so happens that the school that he helped mentor with his mother this year is the team that won NCS's Best Use of Aerospace Technology in 2019.

The AIAA NCS wishes to thank the NCS judges for the Best Use of Aerospace Technology: Dr. Ananthakrishna Sarma, Technical Fellow at Leidos, and Bruce Cranford, NCS Social Media Chair. For more information and a list of all the winners, visit **futurecity.org**.



ABOVE: Liberty Classical Academy Future City Team with David Brandt, NCS Chair.

LEFT: NCS judges Dr. Sarma and Mr. Cranford.

Photographs by Bruce Cranford

Obituaries

AIAA Fellow Kulpa Died in March 2018

Major General John E. Kulpa Jr. passed away on 12 March 2018 at 88 years of age. General Kulpa graduated from West Point Military Academy in 1950 with a B.S. in military engineering and went on to complete an M.S. in aeronautical engineering at the Air Force Institute of Technology. After serving in the Korean War, he returned home to play a vital role at Air Force Systems Command before joining Space Systems Division at Los Angeles Air Force Station as a project manager.

Following graduation from the National War College in 1969, some of his notable assignments included: commander of the Air Force Avionics Laboratory; director for programs in the Office of Space Systems, and principal deputy for plans at the CIA from 1974 to 1975. After retiring from the Air Force in 1983, he worked with several organizations, including as vice-president at McDonnell Douglas, CEO of the Scorpius Space Launch Corporation, and L.A. County Commissioner, in addition to serving on the boards of a number of companies and universities.

His military decorations and awards include the Distinguished Service Medal with oak leaf cluster, Legion of Merit with oak leaf cluster, Distinguished Flying Cross, Air Medal, Air Force Commendation Medal with oak leaf cluster, and Distinguished Unit Citation emblem. He was the recipient of the prestigious General Thomas D. White Space Trophy in 1980.

AIAA Associate Fellow Palmer Died in November 2018

George M. Palmer, a longtime Purdue professor and alumnus, passed away on 13 November. He was 97.

After receiving his bachelor's in aeronautical engineering from Purdue University in 1945 and working in industry until the end of WWII and getting a graduate degree from Caltech, Palmer joined Purdue as an instructor in the Mechanical Engineering School in 1947. In 1948, Palmer transferred to the School of Aeronautics as it was then called and later was promoted to assistant professor and associate professor.

During his tenure at Purdue, Palmer taught Stability and Control, Airplane Aerodynamics, Jet Propulsion and Rocketry, Space Propulsion, and 490, 590 and 690 Special Individual Projects, all of which invariably used the wind tunnel he designed and built. He retired after 41 years of dedicated service in 1987.

Palmer is best known for his work and tireless efforts in developing Purdue's wind tunnel program, including designing and constructing The Boeing Wind Tunnel, which was completed in 1950. He later modified it, to provide an open test section for wind engineering studies. That change allowed Purdue to become one of few universities that could test building designs and post mortems that occur due to heavy wind.

AIAA Associate Fellow Lewin Died in January

Norman "Norm" Lewin, an aeronautical engineer and executive who helped develop the Lunar Module and avert a calamity on Apollo 13 during his 37-year career at Grumman Corp., died on 14 January. He was 90.

Lewin earned a bachelor's degree in aeronautical engineering from New York University and a master's in applied mathematics from Adelphi University. He joined Grumman in 1953, holding numerous positions, including director of engineering and vice president and chief engineer. As chief of guidance and control for the Grumman-built Lunar Module in 1970, Lewin was part of the brainstorming team of engineers that advised NASA on actions to take when an oxygen tank exploded during the Apollo 13 mission, forcing the crew to use the Lunar Module as a lifeboat.

When Grumman was developing the F-14 Tomcat fighter, Lewin worked on aerodynamics, thermodynamics and propulsion. His duties took him aboard the aircraft carrier USS Forrestal to ensure the jets were meetingn performance goals.

AIAA Associate Fellow Kastner Died in January

Carl E. Kastner Jr., 87 passed away on 15 January 2019.

After earning a B.S. degree in Engineering from Stevens Institute in 1953, he joined the Army, achieving the rank of SP5.

He returned to New Jersey to pursue his passion for rocket engineering and aeronautics with Reaction Motors, Inc. He was one of 3 patent holders for the Steam Generator for Rocket Engines in 1961 and was involved in the development of engines for the X-15 supersonic rocket powered airplane. He later spent over 20 years travelling globally to build energy plants with Foster Wheeler Corporation.

AIAA Associate Fellow Mason Died in March

William H. Mason, professor emeritus of aerospace and ocean engineering in the College of Engineering at Virginia Tech, died on 27 March. He was 72.

Mason was an expert in aerodynamic and hydrodynamic design and a steadfast member of the Virginia Tech community. He received his bachelor's degree in 1971, a master's degree in 1972, and a doctoral degree in 1975, all in aerospace engineering at Virginia Tech.

As an undergraduate student, he gained experience during summers working at McDonnell Douglas in St. Louis, MO, on various F-4 aircraft projects, including the "swing wing" F-4, and for the U.S. Army at Edwards

Air Force Base, CA, working on the Huey Cobra helicopter.

After graduating from Virginia Tech, Mason went on to work at Grumman Aerospace in Bethpage, NY, from 1974 to 1989. At Grumman, he served in the structural mechanics section and later in aerodynamics and worked on a number of high-profile projects, including the Grumman X-29, an experimental aircraft that tested a forward-swept wing and canard control surfaces; the NASA/Grumman Research Fighter Configuration, a program to study a super cruiser with low-speed, hi-alpha transonic maneuver, supersonic cruise and supersonic maneuver; and the NASA/Grumman SC3 Wing Concept, which featured an attached flow maneuver wing with controlled supercritical crossflow and set a record at NASA Langley Research Center for low drag at high lift supersonic performance.

He returned to Virginia Tech in 1989, where he educated and advised numerous undergraduate and graduate students in the aerospace engineering degree program over the course of 21 years. He served as graduate advisor for 23 master's thesis students and nine doctoral students.

His love of aircraft design led him to serve as faculty advisor for many of the department's undergraduate design teams, most notably the Design/Build/Fly team. In addition, Mason served as the student branch advisor for AIAA for many years.

Mason also acted as assistant director of the Stability Wind Tunnel in the 1990s and 2000s, alongside colleague William Devenport, current director of the Stability Wind Tunnel. During the 2007-2008 academic year, Mason served as a Distinguished Visiting Professor at the U.S. Air Force Academy. During this time, he taught, wrote, and collaborated with Russell M. Cummings, Scott A. Morton, and David R. McDaniel on *Applied Computational Aerodynamics: A Modern Engineering Approach*.

He was named professor emeritus in 2010. Upon retirement, he continued to teach classes — including his "famous" Configuration Aerodynamics course — and continued to assist with design review and critique for the aircraft design teams.

Throughout his career, Mason authored more than 100 publications and was contributing editor to various book chapters. He was an AIAA Associate Fellow and served on a number of committees, such as the Applied Aerodynamics Technical Committee and the Aircraft Design Technical Committee.

In his memory contributions can be made to the AIAA student branch at Virginia Tech. Checks* made payable to The Virginia Tech Foundation, Inc. can be mailed to: Virginia Tech Advancement (0336), Office of Gift Accounting, 902 Prices Fork Road, Blacksburg, VA 24061. *Note on your check that this gift is "In memory of Bill Mason."

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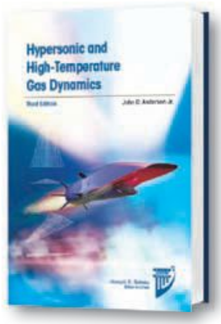

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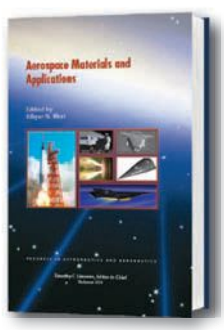

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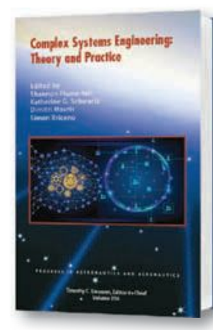

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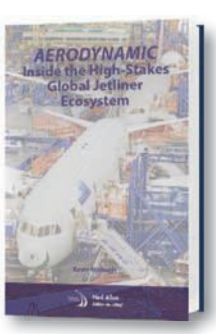

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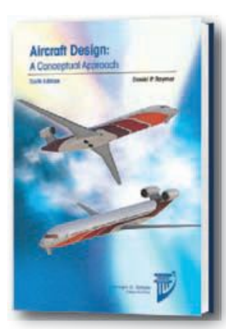

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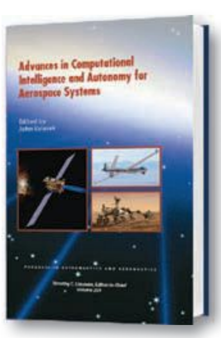

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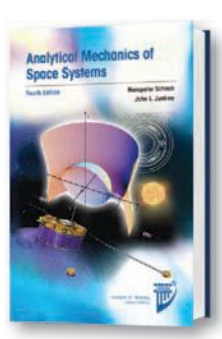

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1919

May 10 The first regularly scheduled airline service in Great Britain commences when A.V. Roe and Co. begins flying three-seat AVRO biplanes from Manchester to Southport and Blackpool. The service lasts until September 1919 with 194 of the scheduled 222 flights completed. R.E.G. Davies, **A History of the World's Airlines**, p. 16.

May 16-27 U.S. Navy Lt. Cmdr. Albert C. Read and his crew are the first to fly across the Atlantic, which they do in stages in their Curtiss NC-4 flying boat, from New York to Plymouth, England. Three identical planes begin the journey, but Read's is the only one that completes it, flying from Trepassey, Newfoundland, to Lisbon with a stop in the Azores. Charles H. Gibbs-Smith, **Aviation**, p. 180; Roy A. Grossnick, **United States Naval Aviation, 1910-1995**, pp. 39-40.

1944

Ricardo Reis

May 6 The Portuguese military's air forces hold an air display of their equipment at Portugal's Ota Air Base. In addition to Supermarine Spitfires, Consolidated Liberators, and Junker Ju 52s and Ju 86s aircraft, there are anti-aircraft guns, searchlights, and barrage and observation balloons on display. **The Aeroplane**, May 19, 1944, p. 554.

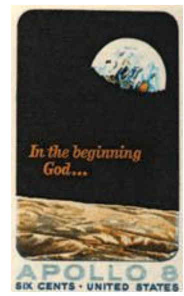
May 10 A Bell Model 30 helicopter piloted by Floyd Carlson flies a demonstration indoors at Bell's Buffalo, New York, plant, marking the second time a helicopter is flown indoors. The first was on Feb. 14, 1938, when Hanna Reitsch flew the Focke-Wulf Fw 61. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 47; **The Aeroplane**, May 19, 1944, p. 554.

May 15 The U.S. Navy discloses details of its new Budd RB-1 Conestoga cargo-transport plane, the first plane made from stainless steel. The 68-foot-long (20-meter), 100-foot-span (30-meter) Conestoga is a high-winged, twin-motor monoplane with a maximum speed of 265 kph and an operating range of 2,735 kilometers. With a 4,700-kilogram cargo capacity, it can operate as an ambulance carrying 24 stretchers or as a transport carrying two jeeps. However, the plane fails to live up to such expectations and is not placed into serial production. **The Aeroplane**, May 26, 1944, p. 582.

May 31 The VB-7 vertical bomb, which incorporates television in its guidance system, is launched for the first time. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 47.

During May 1944 Wing Cmdr. J. Wooldridge sets a new record for Atlantic air crossings by flying a de Havilland Mosquito from Montreal to Goose Bay, Labrador, in 3.5 hours, and then from Labrador to Great Britain in five hours, 46 minutes, at an average speed of 525 kph. The previous Atlantic crossing record was eight hours, 56 minutes, held by Capt. W.L. Stewart of British Overseas Airways Corp., flying a Consolidated B-24 Liberator. **The Aeroplane**, May 19, 1944, p. 546.

1969



May 5 Postmaster General Winton M. Blount introduces the Apollo 8 postage stamp in a dedication ceremony. It is the fifth U.S. stamp honoring an event in spaceflight. Blount says that the flight of Apollo 8 around the moon and back was "perhaps the greatest technological achievement of man to date." **NASA, Aeronautics and Astronautics, 1969**, pp. 129-130.

May 7 The Collier Trophy for 1968 is presented to astronauts Frank Borman, James A. Lovell Jr. and William A. Anders by NASA Administrator Thomas O. Paine for the greatest achievement in aeronautics or astronautics for the year. **Washington Star**, May 8, 1969, p. A3.

May 9 The first supersonic flight in an HL-10 Lifting Body is made and is piloted by John A. Manke after an air-launch from a B-52 aircraft at 45,000 feet. The HL-10 reaches an altitude of 164 kilometers and a speed of 1,165 kmh, or Mach 1.1. The purpose of the flight is to obtain stability and control data. **NASA, Aeronautics and Astronautics, 1969**, p. 183.

May 17 The Soviet Union's Venus 6 planetary probe, also designated Venera 6, launched on Jan. 10, lands on the night side of the planet Venus. During the 51-minute descent of the probe's capsule by parachute to slow its speed, instruments measure the chemical composition, pressure, density and temperature of the planet's atmosphere. Venera 6's improved chemical analysis instruments provide more precise measurements of the atmosphere's components than its predecessors. However, due to the planet's extreme temperature and pressures, the capsule ceases operation at roughly 10- to 12-kilometer altitude from the surface. **Washington Post**, May 18, 1969.

The Apollo 10 command module is seen from the lunar module after it separated in lunar orbit.

May 18 A Saturn 5 rocket lifts off from the Kennedy Space Center in Florida with Apollo 10, the fourth crewed mission in the U.S. Apollo program and the second (after Apollo 8) to orbit the moon. Thomas Stafford is commander, John Young command module pilot and Eugene Cernan the lunar module pilot. Apollo 10 will produce the first live color TV images from space and set a record for the highest speed attained by a crewed vehicle: 39,897 kmh on May 26 during the return from the moon. During the mission, the lunar module is flown to a descent orbit within 15.6 kilometers of the lunar surface, at the point where powered descent for landing would normally begin. **Aviation Week**, May 16, 1969, pp. 18-19; **Flight International**, May 22, 1969, pp. 846-847.

May 19 The Robert Hutchings Goddard Library at Clark University in Worcester, Massachusetts, is dedicated by Sen. Edward Kennedy. It is named after the American rocket pioneer who, in 1926, launched the world's first liquid-propellant rocket, besides other accomplishments in rocketry. Esther Goddard, his widow, is among those present. **NASA, Aeronautics and Astronautics, 1969**, p. 147.

May 21 The Air Force's Lockheed C-5A Galaxy transport becomes the heaviest aircraft flown in a test flight from Dobbins Air Force Base, Georgia, with a weight of 330,266 kilograms at takeoff. The previous record was 319,255 kg. **Washington Star**, May 22, 1969, p. A5.

May 26 Allan Holmes Lockheed, the co-founder with his late brother Malcolm of the Lockheed Aircraft Corp., dies at 80 in Tucson, Arizona. They established Lockheed Aircraft in 1926. The brothers built their first aircraft in 1912 and established a previous firm in 1916 under their original name, the Lougheed Aircraft Manufacturing Co. (The spelling of their name was legally changed in 1934 to avoid mispronunciation.) **Aviation Week**, June 2, 1969, p. 8.

May 27 The German aviation firm Dornier claims five flight records in a new category for its Do. 31 vertical-takeoff-and-landing transport aircraft following its flight from Munich to Paris for the Paris Air Show. The new records are: rate to climb for a VTOL using jet lift, 19.2 meters per second; a speed of Mach 0.6; an altitude of 30,000 feet, a time in the air of one hour, 19 minutes and 30 seconds, and distance covered at 750 kilometers. **Aviation Week**, June 9, 1969, p. 32.

May 29 A formal agreement to go ahead with the development of the A-300B European Airbus aircraft is signed by French and German government representatives at the Paris Air Show. Subsequently, the wide-body twin-engine Airbus is first flown in 1972 and becomes the world's first twin-engined wide-body airliner and the first product of Airbus Industrie, a consortium of European aerospace manufacturers afterward known as Airbus. The original A-300, which is smaller, lighter and more economical than its three-engine American rivals like the Douglas DC-10, becomes popular and a competitor to the large American aircraft manufacturers. Several later models and variants are also produced. **Flight International**, June 5, 1969, p. 914.

May 29 Wendell Moore, assistant chief engineer at Bell Aerosystems and developer of the Bell rocket belt that could lift a man and carry him the length of a football field, dies in Niagara Falls, New York, at 51. Moore won the John Price Wetherill Medal of the Franklin Institute in 1964 for his invention that was first test flown in 1961. **New York Times**, May 30, 1969, p. 69.

During May 1969
The gold medal James Martin Award is established by Britain's Martin-Baker Aircraft Co. to be bestowed annually, together with a small cash prize, to a citizen of the British Commonwealth or NATO countries who has made "an outstanding and practical contribution leading to the safety of military aircraft." The award is named after the Northern Ireland-born Sir James Martin, the inventor and developer of widely used ejection seats. **Flight International**, May 22, 1969, p. 814.

1994

May 8 The last Scout all-solid-fuel vehicle is launched from Vandenberg Air Force Base, California, to orbit the Miniature Sensor Technology Integration-2 satellite. This is the 118th launch of Scout, which first flew on July 1, 1960. **NASA, Astronautics and Aeronautics, 1991-1995**, pp. 511, 715; **Spaceflight**, November 1979, pp. 446-459.

May 20 Russia launches a Gorizont communications satellite into a 36,000-kilometer-high orbit on behalf of the U.S. company Rimsat. It is the second such launch for Rimsat from the Baikonur Cosmodrome in Kazakhstan. **NASA, Astronautics and Aeronautics, 1991-1995**, p. 522.

ALEX DAUENHAUER, 32

Systems engineer, Collins Aerospace

Alex Dauenhauer had no career aspirations before attending high school in Tualatin, Oregon. There, he found a career path that carried him through college. After graduating into a historically dismal job market in 2010, Dauenhauer worked as a laboratory technician before landing a job with Rockwell Collins, which became Collins Aerospace. Now, Dauenhauer works on helmet mounted displays for Lockheed Martin's F-35 stealth fighter, fine-tuning the luminosity of images produced with organic light-emitting diodes, carbon-based materials that turn electricity into light.

How did you become an engineer?

My high school physics teacher sparked my interest in math and problem-solving. Not only did I enjoy solving problems with math, I realized I was good at it. In 2010, I graduated from Oregon State University with a Bachelor of Science in physics. After the financial collapse in 2008, it was very difficult to find a job in the field of physics. I worked as a lab technician for Nike Golf, then moved to a company called Williams Controls, which was purchased by Curtiss-Wright. Eventually, I was offered a position as an optical technician at Rockwell Collins (now Collins Aerospace). After working on the F-35 helmet mounted display sustaining team, which handles production issues, I was hired as an engineer in the optical engineering department. After a few years there, I moved into my current position working on the F-35 helmet-mounted display, a product that gives pilots unparalleled situational awareness. I spend most of my time ensuring displays offer pilots consistent video presentation at desirable brightness levels. This allows them to be more successful during night missions, such as aircraft carrier landings under overcast night skies, without display symbols such as altitude and horizon line obstructing their field of view.

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

Speaking for myself and not for Collins Aerospace, I believe artificial intelligence will have likely superseded human intelligence by 2050. I imagine we will see autonomous flight as the norm rather than the exception. Camera systems will become more tightly integrated into aircraft design, and computer vision techniques will be trained to allow for the many difficult situational decisions that pilots currently are required to make. I would think we will see advances in electric motor technology as well, and the aviation industry will be forced to move to renewable fuel sources by this time.

BY DEBRA WERNER | werner.debra@gmail.com

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