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Companies could receive billions from the U.S. Air Force to play the role of enemy aircraft during pilot training. It's lucrative, provided contractors can meet the challenges PAGE 30

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AIAA
Shaping the Future of Aerospace

On the cover: Two Aero L-159E Alca jets

Image credit: Draken International


SPACE FORUM
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IN THIS ISSUE

Henry Canaday

A former energy economist, Henry has written for Air Transport World, Aviation Week and other aviation publications for more than two decades. PAGE 24

Amanda Miller

Amanda is a freelance reporter and editor based near Denver with 20 years of experience at weekly and daily publications. PAGE 38

Joe Stumpe

A freelance reporter based in Wichita, Kansas, Joe has written for The New York Times, Agence France-Presse and The Huffington Post. PAGE 20

DEPARTMENTS

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Hearing directly from the experts

If I had to label this issue of the magazine with a single word I would say: "Brainpower." We always aim for a single Q&A with a prominent aerospace personality, but in this issue we provide three, plus a feature with insights from members of the millennial generation who are involved in groundbreaking aerospace work.

I can't say this coverage was our vision from the start, but we took our opportunities and ran with them. There's something uniquely powerful about hearing from leaders in their own words.

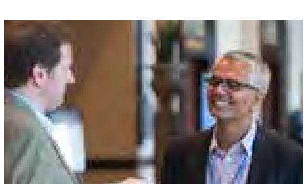
Tom Risen's interview with Boeing CEO Dennis Muilenburg (Page 18) is timely given the company's acquisition last year of Aurora Flight Sciences, its reported interest in regional jet maker Embraer of Brazil, and the industry's growing determination to make personal aerial vehicles and urban air mobility a reality.

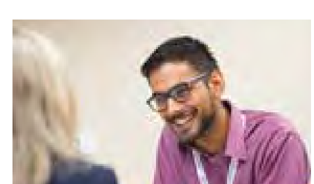
My interview with our new executive director, Dan Dumbacher, was a treat because I knew of Dan mainly from his management roles in the 1990s on the DC-XA and X-33 experimental vehicle projects, when I was writing for Space News. We discussed everything from his management philosophy to the future of AIAA to one of the top issues of the day: the attraction of the moon as an exploration target before heading to Mars. I would encourage readers to also check out the longer verions of our discussion at https://aerospaceamerica.aiaa.org/departments/aiaa-dan-dumbacher/. We present a compressed version in this print edition (Page 6).

For this issue, I also interviewed Dave Bowles, the director of NASA's Langley Research Center in Virginia (Page 16). Our discussion captured the diversity of work at Langley, and touched on some of the big decisions coming up for the center. The interview was unusual, because we conducted it live in the HUB area of the SciTech exposition hall. I appreciate Dave's willingness to help us try something new.

Regarding millennials, we here at Aerospace America are always mindful of the perils of using a single word to describe a generation consisting of millions of people. Single words can sometimes subsume stereotypes. Our feature (Page 38) does a nice job of exploding those stereotypes and putting the remaining grains of truth into context. Millennials are doing serious aerospace work, as demonstrated by this issue's Engineering Notebook article (Page 20) about a computational tool for predicting the performance of aircraft with long, narrow wings. ★

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





A MESSAGE FROM SANDY MAGNUS I will leave AIAA in a few short weeks knowing that you will be in the capable hands of Daniel L. Dumbacher. Dan has extensive experience at NASA, where he was an integral part of the human space flight program. In addition, Dan spent some time as a professor of practice at Purdue University working to inspire and educate the next generation of aerospace professionals. To welcome Dan, we invited him to sit down for an interview with Ben Iannotta, editor-in-chief of Aerospace America.

AIAA Executive Director Dan Dumbacher has decades of experience at NASA and in academia.

AIAA

Welcoming Dan Dumbacher

More online

This interview was compressed for the print edition. For more, see: https://aerospaceamerica.aiaa.org/departments/aiaa-dan-dumbacher/

Ben Iannotta: You've been involved with cutting-edge NASA projects. Why did you choose that line of work?

Dan Dumbacher: I couldn't be an astronaut. I was too tall: 6-foot-4. I always wanted to work at NASA, so I was lucky enough to end up there.

What's satisfying about being in management?

Being able to help facilitate and get the roadblocks out of the way so that the whole team can achieve the mission.

People sometimes poke fun at us here in or near the Beltway in Washington, D.C.

It's a 17-mile-wide logic-free zone, I've been quoted as saying.

[Laughs] Why come back here?

At Purdue, I was working with students in the next generation, and that was very rewarding, but a smaller subset. The AIAA allows influence on a broader scale. Item number two was: In our system of government, the decisions for funding are made by the 536 investors in Washington, D.C., that's the

DAN DUMBACHER

PAST POSITIONS: Professor of engineering practice, specializing in systems and systems of systems, at Purdue University in Indiana, August 2014 to December 2017; NASA's deputy associate administrator for exploration systems development, October 2010 to July 2014; director of engineering, NASA's Marshall Space Flight Center, Alabama, May 2007 to October 2011

NOTABLE: NASA program manager (2003-04) for the X-37, a precursor to the Boeing X-37B design flown today by the U.S. Air Force; assigned by Marshall as deputy program manager in Palmdale, California (1996-99) for the X-33 experimental single-stage spacecraft; assistant manager for the Space Shuttle Main Engine Project (1993-95); program manager (1994-96) for the DC-XA, an experimental vertical takeoff and landing rocket inducted into the International Space Hall of Fame in 2013; began his NASA career in 1979 and 1980 as a summer engineering aide at Marshall while an undergraduate student at Purdue. Hired by Marshall in 1981.

AGE: 59

EDUCATION: Bachelor's degree in mechanical engineering from Purdue University (1981); Master's in business administration from University of Alabama in Huntsville (1984); completed Senior Managers in Government program at Harvard University (2001).

RESIDES: In process of relocating to Washington, D.C., area from Indianapolis.

FAVORITE QUOTE: "The credit belongs to the man who is actually in the arena ... if he fails, at least he fails while daring greatly, so that his place shall never be with those cold and timid souls who knew neither victory nor defeat."
— Theodore Roosevelt
(Source: www.theodoreroosevelt.org)

Congress and the White House. You have to be in the game to affect it.

In terms of AIAA membership, how do we retain members and maybe even grow? How big a priority should that be?

It should be a really big priority. Over the last few years, the AIAA membership has been on a small decline. Whether that's retirements or what not, I'm not smart enough to know yet. I do think growing the membership for the future is important to allow people to build their networks, and also to facilitate the learning and the competition, frankly, as technologies move forward.

What do you see as some of AIAA's recent successes?

The big one is getting the governance structure simplified, and we're going to have to learn what that means and how we implement that, and get our behaviors set up so that we make the best use of that governance improvement. I know Sandy [Magnus] and the team have been working hard on getting more involvement at the section and regional level, and I think we'll continue to work on that and improve that. The Forum 360s and the plenary sessions help provide the context in which those technical discussions need to occur, which provides a more holistic view, a more connected view, so that the technical is connected to the context, and the context is informed by the technical.

Being a 31-year member, what have you gained, either career-wise or just personally?

The personal part was the contacts and the networking that was facilitated through the different conferences and now the forums, along with the ability and the opportunity to go see what other people were doing in other fields. Aerospace America gives more depth that I normally wouldn't go look at, but it puts it in front of me and makes it easier for me to learn. The Daily Launch has been standard reading every morning. I spent all of my career, basically, at NASA, but it gave me the opportunity to look at what's going on in the aviation world.

What do you see as some of the interesting work or trends underway in the aviation area?

Electric propulsion, hypersonics. I'm somewhat motivated for flying cars because one of these days, my kids are going to take my driver's license away 'cause I'm too old, and I need to be able to punch a button and just have it take me wherever I want to go.

How would you describe your management style?

I tend to work in a very collaborative style, very team-oriented. The biggest thing that's important to me is the trust and the integrity among the team. You can't have good teamwork unless you have trust among the team members, and that's built on integrity. So, those are my important points. I'm very open-door, very collaborative, as transparent as I can possibly be, is the way I like to approach things.

How do you deal with the need to move at the speed of the market and the need to work as a team?

You have to have the environment such that the teams are trusted to go work on issues and to be innovative and to try new things. Some will work, some won't. We'll have some failures. But you have to allow the teams to innovate. For example, Google and Apple work in teams, and they are very successful at keeping up and even driving the market. Fundamentally, they allow the teams to innovate with leadership in terms of the direction and the constraints.

So, a team can actually work quickly.

A team can work much more quickly than a highly constrained decision authority chain up and down an org chart.

Are there unique things about working with engineers?

Certainly. We all have our biases and we're subjective to some degree, but engineers in particular want to see the data. So, when you are trying to work through changes and innovation, one of the best things to do with engineers is to run a couple of examples, see what the data tells you. Because I'm an engineer, I'm open to the new ideas. The fail-fast kind of mentality that you hear out of Silicon Valley is somewhat applicable. I don't want to fail too fast on some things, but you also don't want to have analysis paralysis, where you can sit back and make very little progress because you're trying to answer all the questions before you do anything.

How do you see AIAA's relationship evolving with the space startups, the urban mobility people, Silicon Valley?

Our heart and soul is aerospace, and we have to evolve with that industry. Commercial aviation has evolved through key technology enhancements in terms of the turbofan engine and other things that have led us to where we are today. That's a continuing effort to get more efficient, to get safer, to provide more and better services, and quicker services. The space world today is comparable in maturity to commercial aviation in the 1930s and '40s. We are learning how to come out of all government, all the time. How can we accelerate and enhance private enterprise development just like we helped facilitate commercial aviation? One of the reasons we got commercial aviation off and running was because the government funded the initial airmail contracts. Well, that's not a whole lot different than private enterprise delivering cargo and crew to space station.

Do relatively new players like SpaceX or Blue Origin benefit from research that NASA and others have funded?

They have benefited from research in the past, and even recently. For example, the Orion parachute data was provided to private industry for the parachutes that they need to bring their capsules back to Earth. Propulsion investments gave SpaceX the ability to put the Merlin engine together. Vertical-landing capability that was invested in by the government back in the mid-'90s provides some of the heritage for Blue Origin and SpaceX to do vertical landing. That's one of the things that AIAA can help do: Make everyone aware of that linkage.

Right. So, footsteps on the moon or Mars?

We still have the far side of the moon and the poles to deeply explore. The moon will provide us the learning that we need to be able to go out to Mars.

Would that be done robotically or by people?

Both. I don't buy into this "us versus them" between robots and humans or government and private industry. It is a continuum, and all the capabilities are needed for the complexities of space exploration.

Well, I've enjoyed this. Is there any message you want to get through that maybe you haven't gotten to do?

I really should have said right up front that it's an honor and a privilege to be part of this team. I am thrilled to be here. I look forward to being a part of the future. ★

The long wait for Webb

BY ADAM HADHAZY | adamhadhazy@gmail.com

As development of astronomical instruments goes, the James Webb Space Telescope has been decidedly — pun intended — star-crossed. NASA managers are doing their best to make sure the bad luck does not extend into the home stretch. The spacecraft must be shipped from Northrop Grumman in California, through the Panama Canal and to the Ariane 5 launch site in French Guiana for launch sometime between March and June 2019.

NASA is even accounting for "potential threats from pirates" during the shipping, NASA's Mike Menzel, the mission systems engineer for Webb, told an audience at the 2018 AIAA SciTech Forum in January. A U.S. Navy escort is being planned.

Last September, NASA announced that Webb's launch date would slip from October 2018 into 2019. The delay stems from a routine schedule assessment, which identified the need for additional time to wrap up integration and environmental testing of elements of the spacecraft.

The delay is the latest in a string of cost and schedule overruns since Webb's development began in the 1990s, originally slated for a 2007 launch and a $500 million price. Due to underfunding at times and construction snags, the budget has increased to $8.8 billion.

Though unwelcome news, this new delay might not be all that significant given the scale of the project. NASA estimates the costs of keeping Webb's corps of scientists and engineers around an extra five to eight months at less than 2 percent of the project's overall development costs, so around $160 million. Critically, those funds are already available within the existing budget, explains Eric Smith, the Webb program director at NASA Headquarters in Washington, D.C. When crafting Webb's major budget replan in 2011, managers set aside reserve funds to deal with the all-but-inevitable issues that arise whenever large, complex projects near the finish line. "History would say there's going to be something that bites you," says Smith.

In Webb's case, the holdup centers on the spacecraft's bus and sunshield, now undergoing integration and testing at Northrop Grumman in Redondo Beach, California. The sunshield will shade Webb from the heat and light of the sun, Earth and moon, so that infrared light emitted by faint, cold, distant phenomena stand out in its observations. During Webb's launch on an Ariane 5 rocket from French Guiana, the sunshield will be folded up, origami-style, to fit within the fairing — as will the telescope's 6.5-meter-diameter primary mirror, composed of 18 hexagonal segments.

Then comes what NASA's Sandra Irish and others refer to as "14 days of terror," as the telescope is deployed one step at a time, with ground commands rather than through an automated sequence. For the sunshield to unfurl in space to its full tennis-court size, though, 107 membrane release devices will have to actuate. These devices contain a metal wire that melts due to an electrical current, releasing a pin that pulls through the sunshield's five layers and then allows them to expand. Test deployments of the sunshield at Northrop Grumman will require replacement of the actuators and those swap-ins have taken more time than predicted.

▲ **The sunshield for NASA's James Webb Space Telescope** in a cleanroom at Northrop Grumman Aerospace Systems in Redondo Beach, California.

Northrop Grumman

Additional vibration and acoustics tests, mimicking the launch conditions Webb will experience, still loom for when the telescope's science instruments — currently at NASA's Johnson Space Center — are wedded to its bus and sunshield. And with some reserve funds now allocated, there is less wiggle room for problems that could pop up. That said, fears of Webb being derailed are not founded, Smith says. "At this point, you're testing largely workmanship — have things been put together correctly?" he says.

Alan Boss, a staff scientist at the Carnegie Institution of Washington and a longtime follower of Webb's development, sees a bright side in the recent delay. Having plenty of time for I&T to "get it right" ultimately "trumps everything else," says Boss, who is also a member of NASA's Astrophysics Advisory Committee. The Transiting Exoplanet Survey Satellite, or TESS, pegged for a March 2018 launch, will also have additional time to gather promising, nearby, newfound exoplanets for Webb to scrutinize. Webb will have the light-gathering power to identify cocktails of gases in these worlds' atmospheres that might indicate the presence of alien life, an ability largely beyond the current generation of telescopes.

When Webb launches, its backers say the telescope will be worth the extra wait. "Webb is going to teach us things that no other science facility or instrument can," says Smith. For instance, by peering 13.5 billion years back in cosmic time, Webb should also help finally reveal how the first stars and galaxies formed. "We're coming along with this fantastic facility," Smith says. "We're almost there." ★

Ben Iannotta contributed from AIAA SciTech.

NASA report to chart new approach to aircraft design

BY KEITH BUTTON | buttonkeith@gmail.com

PUTTING VISION 2040 TO WORK

This is a list of key technology elements that define the broad areas of future research and development which would be important to achieving NASA's Vision 2040, according to a contributor to the report. The graphic is intended to convey how the key elements need to be integrated to reach the goal.

1. Models and methodologies
2. Multiscale measurement and characterization tools and methods
3. Optimization and optimization methodologies
4. Decision making and uncertainty quantification and management
5. Verification and validation
6. Data, informatics and visualization
7. Workflows and collaboration frameworks
8. Education and training
9. Computational infrastructure

NASA's Aeronautics Research Mission Directorate wants engineers and scientists to design aircraft and the materials for them in a coordinated fashion, and it is putting the finishing touches on a report it expects to release in February to define how that could be done.

The report, called "Vision 2040: A Roadmap for Integrated Modeling of Materials and Systems," describes a future in which experts working at every stage in the development of an aircraft and its materials collaborate with each other, from the very beginning of the supply chain to manufacturing the plane to recycling it. As portrayed in a draft executive summary and by two of its contributors — Steven Arnold, manager of the Vision 2040 project, and Dale Hopkins, acting project manager of NASA's transformational tools and technologies project — the report explains how each development stage would fit seamlessly with the other stages.

In the current environment, experts tend to organize themselves in silos, speak their own technical languages, and work independently as they pick up a project from the previous stage and then pass it off to the next stage. But in the future envisioned by the report, experts would share their knowledge and tools with engineers and nonengineers of all skill levels, even if those experts were not directly involved in the work at hand.

The report also paints a future where engineers and scientists will determine a material's properties from computer models, not empirical data, and regulators will certify aircraft, and their systems and materials, based mainly on computer simulations.

To reach that vision of the future, the NASA report recommends how to overcome technical and cultural hurdles organized into nine categories. In all, the study identifies 118 gaps, including underdeveloped technologies, poor data management practices and workforce skill deficiencies.

Changing attitudes will be tougher than the technical hurdles, says Arnold, who is the senior research engineer leading materials and structures modeling, simulation and validation research at NASA's Glenn Research Center in Cleveland.

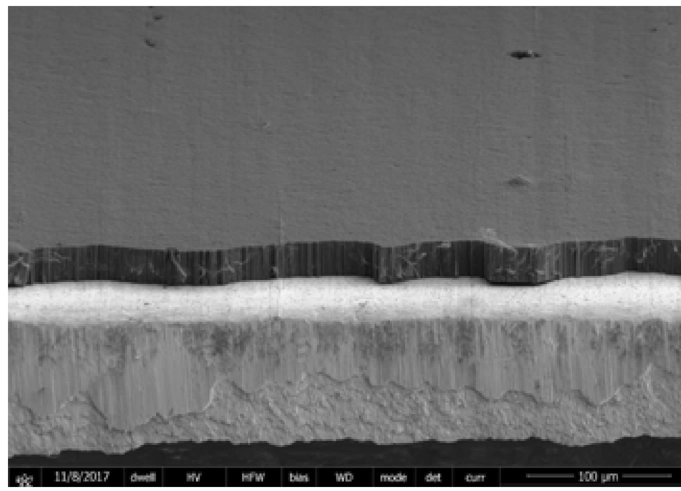
"Technologically, a lot of the things we're talking about building can all be done, technically. It's cultures within organizations that are holding things back," Arnold says. "You can have a great strategy; you can have this great road map. But if your culture won't accept it, if it won't deal with it, you're dead."

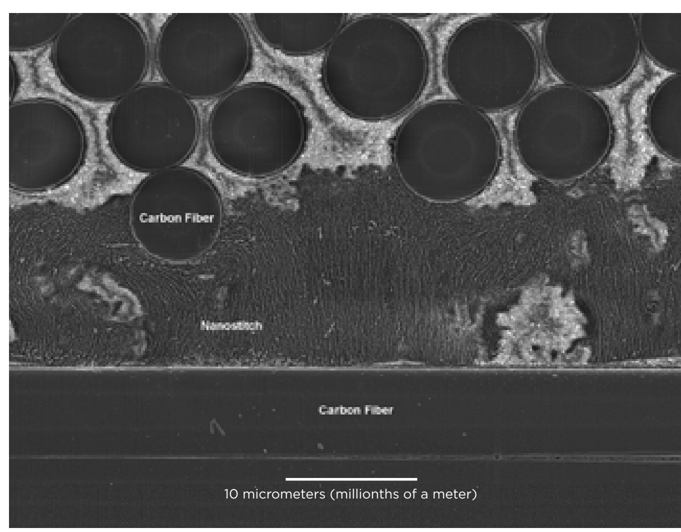
The carrot for engineers and scientists and their organizations to buy into the vision is the promise of a more streamlined, less expensive, faster, more practical aircraft design and build process. "The whole point of having the tools that are going to be involved in the 2040 vision is so I can go off and conceive of something, then I can design it and I can build it, and build it cheaper," Arnold says. "You don't just design some new fancy thing that you could never build."

The report was drafted by NASA and its contractor on the project, Pratt & Whitney, and subcontractors Nexight Group, BlueQuartz Software and ESI Group, based on a two-thirds consensus of nearly 200 volunteer experts in the aerospace and materials science communities in private industry, government and academia. Those experts, organized into panels for each of the nine categories of hurdles and recommendations, winnowed ideas gathered from another 250 participants in surveys and workshops over the last two years. ★

Taking on delamination

BY BEN IANNOTTA | beni@aiaa.org





N12

Carbon composites have a tendency to weaken and delaminate when subjected to repeated cycles of heating and cooling as is common in aerospace applications.

N12 Technologies Inc., a 35-person company formed in 2012 as a spinoff of an MIT project, this year hopes to enter high-volume production with a material called NanoStitch, which would be added during the composite fabrication process to combat delamination.

Today, engineers must either add more carbon fiber layers to compensate for the delamination risk, which adds undesired weight, or find a structural workaround. "NanoStitch specifically addresses and eliminates the delamination failure mode," says materials scientist Ryan Williams, director of science and technology for the company and its first employee. It can achieve the same strength with less material or higher strength with the same amount of material, he says. N12 bills the material as especially suitable for today's consumer electric-VTOL (vertical takeoff and landing) concepts, where weight is a performance hurdle.

Mass production of NanoStitch has been a challenge, but N12 thinks it has solved that. Technicians at the company's Somerville, Massachusetts, factory place a sheet of proprietary metal substrate into a large furnace called a reactor. The gray material in the scanning electron microscope image **(right, top)** is the substrate. Gases are introduced, and trillions of cylindrical, carbon nanotube molecules (the grass looking material) form vertically via this chemical-vapor-deposition process. So far, N12 has scaled up the width of the sheets to 300 millimeters and Williams says one machine has the potential to produce 1,500 mm wide sheets.

From there, an additional roller would be added to the composite production sequence and a NanoStitch sheet would be applied onto a standard sheet of carbon composite pre-impregnated with epoxy. "We just sort of sneak in at the end," Williams says. Rolls of this composite/NanoStitch material would be shipped to component fabricators who would follow their standard process of cutting composite sheets and stacking them to form a composite structure. Heat and pressure would then be applied to harden the polymer into the final part.

How do the nanotubes add strength? As shown in the other image **(bottom)**, the tubes are sandwiched vertically between layers of carbon fibers running in two directions. "Now you really have a material that's reinforced in three directions," Williams says. The whitish material is the epoxy that binds everything together. ★

Forum Highlights

Mainstreaming urban air mobility

Companies are building and testing electric vertical takeoff and landing aircraft, or eVTOLs, to ferry people above car traffic, but they need to be safe, affordable and energy-efficient to become part of a daily commute. Entrepreneurs and engineers detailed how their companies are tackling these challenges during the "Dude, Where's My Flying Car" panel.

To build an urban air mobility ecosystem for these aircraft, vehicle manufacturers will have to coordinate with numerous types of organizations, including real estate providers to create landing pads known as skyports, said Mark Moore, director of engineering at California-based Uber Elevate.

"We will never build a vehicle, but we want to make sure that our partners who are building vehicles are successful and that these aircraft are as community-friendly as possible," Moore said, explaining Uber Elevate's partnership with manufacturers and regulatory agencies to clear the way for Uber to provide on-demand flight through a mobile app. Some of the companies partnering with Uber have not publicly released their aircraft concepts, so Moore unveiled a "common reference model" that illustrates some of the challenges these electric aircraft will face, including battery energy density and noise pollution.

"The batteries are almost there, because the longest distance we need to travel in between skyports is only 45 miles," Moore said.

Noise and expense are two of the major reasons helicopters are not more widely used for urban transport, and eVTOLs will have to improve upon both to gain public acceptance, said Mark Cousin, senior vice president of flight demonstrators at Airbus.

Cousin predicted there would be "a multitude" of aircraft designs for the new generation of urban air mobility, referring to the numerous types of cars on the road. Airbus holds true to that example: A prototype of its CityAirbus air taxi will test fly at the end of 2018, he said. A full-scale demonstrator of the tandem tilt-wing Vahana aircraft by Airbus' Silicon Valley arm, A³ [pronounced "A cubed"], "will fly within the next month," he said.

— Tom Risen | tomr@aiaa.org

"We need to figure out how to learn from all that data."

— Brenchley Boden, chief technology officer of the Digital Manufacturing and Design Innovation Institute and senior industrial engineer at Air Force Research Laboratory

"Capt. [John] Young was an American hero — a true astronaut's astronaut who ... lived a life full of 'firsts' and 'onlys.'"

— Pamela Melroy, former astronaut, retired U.S. Air Force colonel and general chair of the 2018 AIAA SciTech Forum

"George Lucas gave us the best blueprint for a digital assistant back in 1975, and his name was R2-D2."

— Mark Valentine, Microsoft

Human-machine teams need a little trust to work

▲ **Victoria Coleman,** chief technology officer of the Wikimedia Foundation

AIAA

Human-machine teams hold promise in helping with space exploration, training and boosting human performance, panelists said during the "Human-Machine Teaming" session, but the thorny issue of trust is at the heart of successful partnerships.

Our own expectations of what machines can do, the roles machines play on a team, and trust — too much or not enough — can get in the way of teamwork, panelists said.

Trust doesn't come automatically, said Victoria Coleman, chief technology officer of the Wikimedia Foundation. Repetition helps as does how machines arrive at decisions.

"Trust is something you establish ... then it's a cycle," she said.

But, machine intelligence is finding a home at NASA.

NASA's smart machines will work with crew members as the agency plans space stations, said Julia Badger, Robonaut project manager with Autonomous Spacecraft Management Projects at NASA's Johnson Space Center. These complex space stations sometimes will work with crew and other times will be on their own to solve problems, such as leaks, and maintain the station, she said.

Humans and machines don't speak the same language, and nuance is difficult for machines to process, said Eileen Liu, a research scientist with Human Systems and Autonomy at Lockheed Martin Advanced Technology Laboratories.

"I might say something, but I might mean something else," she said.

Liu said humans are good at thinking creatively and solving problems on the fly, but that we fail at repetitive tasks because our minds wander. She said that's where machines excel and can help.

— Michele McDonald | michelem@aiaa.org

SCITECH FORUM

- **4,258** Attendees
- **39** Countries represented
- **1,272** Students

Astronaut John Young onboard Columbia in 1981

NASA

Regulatory and operational challenges of on-demand mobility

Overcoming regulatory and operational barriers to achieve the dream of high-density urban mobility requires close collaboration among industry, government and academia, along with an incremental and methodical approach, said experts during the "On-Demand Mobility — Regulatory and Operational Challenges" panel.

Rapid technological advancements in electric vertical takeoff and landing craft, or eVTOLs, and autonomous systems are making future on-demand urban mobility a certainty, panelists said. But moderator Tom Gunnarson of Zee Aero cautioned: "If we think about the men and women out there who are developing these fantastic machines, there has to be a path set before they can actually realize what they want to do with them."

Gunnarson suggested the technological challenges posed by urban air mobility are unlikely to be as difficult as regulatory and operational ones.

"The really big bar in all of this may not be the development of the aircraft, but being able to operate it," he said.

Gregory Bowles, vice president of global innovation and policy at the General Aviation Manufacturers Association, wondered about FAA certification for new types of personal aerial vehicles and other autonomous eVTOL aircraft when they don't fit in established categories. He said that industry, in collaboration with government, needs to figure out how "we define these vehicles."

Another significant challenge, Bowles said, is how to train future pilots of these aircraft, as well as what they'll be trained to do. He noted it's unlikely these aircraft will be totally autonomous initially.

"Some will have operators; some will have pilots," Bowles said. "We need to look at what the human pilot does, what automation can do today and where's that gap; that's what needs to be trained."

Wes Ryan, the unmanned systems certification lead for the FAA, said industry and academia should work with the FAA and NASA "to create a purposeful and evolutionary path to address the design of, the testing of, the operation of these pilotless aircraft at some point in the future."

— Lawrence Garrett | lawrenceg@aiaa.org

AIAA

◀ **Gregory Bowles,** vice president of global innovation and policy at the General Aviation Manufacturers Association

Remembering John Young

1972 moon walk

NASA

SciTech attendees stood and honored astronaut John Young with a moment of silence, following NASA's announcement that the man who commanded the first space shuttle mission had died of pneumonia on Jan. 5 at his home in Houston. He was 87.

"John was a tireless advocate for the development of the technologies that will allow us to live and work on the moon and Mars, and equally tireless in his insistence that they be as safe as possible," said former astronaut and retired Air Force Col. Pamela Melroy, as she invited the audience to join her for the moment of silence. "His imprint is on both the past and the future of human spaceflight."

NASA's acting Administrator Robert Lightfoot noted in a statement that Young will be remembered as the only NASA astronaut to go into space as part of the Gemini, Apollo and space shuttle programs. Young walked on the moon as commander of Apollo 16 and commanded STS-1, the first space shuttle mission (he's shown above in Columbia's commander's seat during the mission in a photo shot by pilot Robert Crippen). His sixth and final spaceflight was also on Columbia, the 1983 STS-9 Spacelab 1 mission. He retired from NASA in 2004.

According to Lightfoot: "I participated in many Space Shuttle Flight Readiness Reviews with John, and will always remember him as the classic 'hell of an engineer' from Georgia Tech, who had an uncanny ability to cut to the heart of a technical issue by posing the perfect question — followed by his iconic phrase, 'Just asking… .'

Forum Highlights

Big data's power starting to reach potential


Ross Skeegan

▲ **Pamela Kobryn, a principal aerospace engineer** with the Aerospace Systems Directorate at the Air Force Research Laboratory

The aerospace industry can be a leader in how best to apply big data to real-world critical missions, speakers discussed in a series of presentations during the "Data, Data Everywhere … the Power & Potential" session.

The influx of digital data is changing everything from how we buy cars to space exploration. For example, Pamela Kobryn, a principal aerospace engineer with the Aerospace Systems Directorate at the Air Force Research Laboratory, said digital twins — digital counterparts to physical things — could change how we buy and maintain cars.

Your digital twin would know your driving habits, including the routes you take and how often you hit the brakes, she said. The information would be "personalized to how you are going to drive that vehicle."

Kobryn said automakers would have simulations to match driving habits and requirements with vehicles and that you'd know how your new car would handle, how much gas it would use and future maintenance costs.

"Now imagine if that simulation capability was free, easy to use and access, and readily available — it would be pretty cool," she said.

But the journey doesn't stop there. Your new car would continually update its digital counterpart about maintenance needs and could predict possible breakdowns during trips, Kobryn said, adding that when it's time to buy a new car, the digital twin could inform the timing of that decision.

The same concept of digital twins can be applied to aircraft, spacecraft and other complex systems, Kobryn said.

— Michele McDonald | michelem@aiaa.org

"Challenges and prizes work best when you define a problem. Once you ask for a specific solution, then you hinder innovation."

– Chris Frangione, a consultant and former vice president of prize development and execution at the XPRIZE Foundation

"That's the beauty about the aerospace industry. There's no room for error because it is fatal; a plane is not a car."

– Naguib Attia, vice president of Global University Programs at IBM

"It's critical … to have the robot be able to identify, detect and recover from failures."

– Stefanie Tellex, assistant professor of computer science and assistant professor of engineering at Brown University

Design and visualization move into new virtual worlds


Ross Skeegan

▲ **Rachel Narciso,** an immersive technology specialist at Ball Aerospace

Design and visualization environments are changing fast, and digital natives are changing design environments, panelists said during the "Digital Natives Leading the Digital Transformation in Design and Knowledge Environments" session.

Virtual and augmented reality, analysis-based certification processes, and performing simulations with video game engines are a few new technologies panelists discussed.

"Virtual reality and augmented reality are here to stay. It's emerging as an affordable and attainable solution," said Rachel Narciso, an immersive technology specialist at Ball Aerospace. "As a mechanical engineer, I do a lot of my design on a 2-D screen doing CAD with a mouse and a keyboard. I see a lot of benefit from stepping into a VR headset and doing it with my hands."

She said VR could train workers on cleanroom techniques or save time and money on business travel by using it as a means to collaborate. Narciso admitted that VR is still limited but emphasized it could be useful in the space industry.

"If we're coming up with a new, novel idea, we can't test that in its exact environment," she said. "We have to simulate that."

Panelists said aircraft companies are interested in moving to analysis-based certification processes.

"Airplane certification is one of the largest nonrecurring cost-drivers in a commercial airplane development program," said Adam Clark, an aerodynamic engineer at Boeing Commercial Airplanes. Computational fluid dynamics "is going to play an increasing role in the future — using computers instead of having to fly everything. We can move toward simulating a lot of this."

— Hannah Thoreson | hannaht@aiaa.org

AIAA

▲ **Panelists for the popular session "Dude, Where's My Flying Car"** take questions in the HUB, AIAA's new multiuse area built into the heart of the exposition hall.

Digital disruption becomes part of aircraft design

Digital innovation that changed daily life with smartphones and cloud computing is breaking technical barriers in space and aviation, technologists said during the "Digital Transformations Disrupting Aerospace Business Models" panel.

The design process for aircraft is one of the main digital disruptions in the aerospace sector. The CH-53K King Stallion helicopter that Sikorsky is developing for the U.S. Marine Corps is the Lockheed Martin subsidiary's first production aircraft built with a completely digital, paperless design, said Andreas Bernhard, the helicopter's chief engineer at Sikorsky. Looking ahead to the 2020s, Bernhard predicted, "our most profitable product is no longer going to be the Black Hawk, but the CH-53K." New technologies on the CH-53K also include composite rotor blades that he said "generate enough lift to carry an empty Black Hawk," a transmission with improved power density over previous generation Sikorsky helicopters, and digital engine controls in the cockpit.

Digital assistants on smartphones also have great potential to guide aerospace engineers. A "Siri for designers" akin to the Apple digital assistant could give real-time feedback on the effect of different options, including materials, said Jack O'Banion, vice president of strategy and customer requirements with Advanced Development Programs at Lockheed Martin.

"There are optimizing routines out there now, but if you're not careful with the human too far removed from the design loop, you could walk through design choices that you may have preferred to make," O'Banion said.

NASA is also keeping flexibility in mind when designing its autonomous technology. The semi-autonomous, free-flying robot Astrobee that NASA's Ames Research Center is developing to assist International Space Station astronauts in tasks like inventory will free up valuable time on the station. The disruptive feature, however, is that it can be upgraded with code for scientific tests and improvements from people outside of NASA, said LaNetra Tate, program executive with NASA's Space Technology Mission Directorate.

— Tom Risen | tomr@aiaa.org

Immersive technologies capable of revolutionizing aerospace

Advancements in immersive technologies such as virtual and augmented reality will revolutionize and streamline many processes in the aerospace industry, said Elizabeth Baron, virtual reality and visualization specialist for the Ford Motor Co., during the "Welcome to the Holodeck" session.

Baron, principal inventor of the Ford immersive Vehicle Environment process and technology and the first VR technical specialist at the company, said Ford's immersive technologies have similar characteristics to the fictional Holodeck from "Star Trek." In the Holodeck, characters engage with different VR environments.

In Ford's use of replicator technology, Baron said, it mills out simple props representative of the key touch points of a vehicle to allow someone to experience the control of it in the virtual world.

Another benefit of immersive technologies, Baron said, is the ability to take data templates and import them into the virtual world to perform what-if scenarios.

"We have the ability to bring in information that's relevant without having to go into some software and have to click a bunch of things," she said. "And it's simple and understandable, and it's global."

The technology also offers other noteworthy benefits, Baron said.

"It's allowed us to augment a changing process," she explained. "We're not standing still; our processes continue to evolve. But immersion in many cases is really at the heart of how we experience, share and discover new capabilities."

As a result, Baron said, Ford has been able to gain a deeper understanding of what constitutes an enjoyable experience for its customers. She said that at Ford, immersive reviews are now a requirement in the company's product development process.

"We do not produce a vehicle at Ford Motor Co. with any level of change that a customer can see without looking at it in the immersive environment first," she said. "It's so valuable to people that the labs are filled, and we're building extra capacity."

— Lawrence Garrett | lawrenceg@aiaa.org

Ross Skeegan

Dave Bowles says leaders at NASA's Langley Research Center are facing some tough budget choices, including the fate of some wind tunnels.

DAVID E. BOWLES

PREVIOUS POSITIONS: Deputy director and then acting director of NASA's Langley Research Center (2014 to 2015). Directed Langley's Exploration and Space Operations Directorate (2007 to 2012).

NOTABLE: Bowles has worked at Langley for his entire 37-year career, starting in 1980 with research on advanced materials for aerospace vehicles and, later, for spacecraft. He was manager for airframe structures integrity and composites for NASA's Advanced Subsonic Technology Program and was project manager for vehicle systems research and technology under NASA's Next Generation Launch Technology Program.

AGE: 62

EDUCATION: Bachelor's, master's and doctoral degrees in engineering mechanics from Virginia Tech (1978, 1980 and 1990)

RESIDES: Suffolk, Virginia

Leading Langley

Dave Bowles and his team at NASA's Langley Research Center in Virginia are working to put the center on a trajectory to many more years of technical breakthroughs, following its centennial year of 2017 and the notoriety that came with the award-winning film "Hidden Figures." Bowles faces difficult decisions ahead as he charts that course. The Trump administration has proposed deep cuts to Earth science instruments, including some made at Langley. The center's wind tunnels have become expensive to maintain and some might need to be closed. Bowles discussed these and other issues with me in an interview recorded live in "The HUB" in the exposition hall at SciTech.

— *Ben Iannotta*

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IN HIS WORDS

View of NASA administrator nominee Rep. Jim Bridenstine, R-Okla.

I haven't had a chance to talk to him one-on-one, but the people who have talked to him have been very impressed. I've been really impressed with everything I've heard about him, so I'm excited.

Future of Earth science instruments

Science, not just Earth science, but science is really much driven by the science community and what we call the decadal surveys. So every 10 years, the various science communities come out with their list of science priorities for the next 10 years. With Earth science, a survey literally just came out [Jan. 5]. And our new administrator said, hey, we should follow decadal surveys, so I think that's very positive.

Role in urban air mobility

I think it's going be a mix of purely autonomous vehicles and piloted vehicles. We have a very strong competency in systems analysis. We have an autonomy incubator where we're taking skills from across the center, putting them together to work on what we call assured, or trusted autonomy. It's really about the vehicle being self-aware, self-managed. Also, we're kind of that bridge in a lot of areas between fundamental research and certification for the end user. So working with universities and doing some in-house low TRL research, taking that, looking at the applications, looking at the maturation of those technologies to ultimately integrate them into a system. That's a niche Langley plays very well in.

Moon or Mars?

The new administration has just re-stood up the Space Council. So, the vice president chairs that. They came out with a Space Policy Directive 1 a couple months ago. The moon is definitely in our plans, but it doesn't take Mars off the table. It still talks about Mars being the ultimate destination but there's lots to learn and lots to do on the moon. So we're developing those plans right now. To take things down to Langley, we have a rich heritage in human exploration. We were very involved in the Constellation program in the 2000s that was developing a plan to go back to the moon. And I think we're involved now, we weren't very involved in SLS [the Space Launch System rocket] aerodynamics. There has been data base development in understanding the aerodynamic performance.

Possibility of closing some wind tunnels

A lot of wind tunnels across the nation were built in the '50s. Our newest wind tunnel is the National Transonic Facility, and that was being built when I got here in the early 1980s. So all of our tunnels are old. They're expensive to maintain, they're expensive to operate, so you have to be judicious. We don't have enough money to do some key things because they're nice. I've challenged people, at some of our facilities: "Where can we trust CFD?" Those are emotional and hard decisions but you have to be relevant and viable going forward. We have to make tough decisions sometimes. We try to make them with the best data we have. So, that's what I'm all about right now is collecting that data so we can make intelligent decisions going forward.

"The moon is definitely in our plans, but [the Space Council] doesn't take Mars off the table."

Millennials and turnover

We have a lot of people who have stayed a long time. People in my generation, it's not unusual. I'm trying to remember the statistic: People usually stay on average five years past their retirement age and actually further than that. We've heard millennials will come in, work a few years, change careers numerous times; they don't have this vision of a 30-plus career. I don't have a lot of data for millennials, [but] I don't see them leaving. We try to keep it pretty interesting. I think one of the things that allows us to do that, and I'm a little parochial when it comes to Langley, but I think one of the keys there is we do everything that the agency does. We do science, we do space technology, we do exploration, and we do aeronautics.

Attraction of Langley for engineers, scientists

I think [it's] the diversity of work. It's not just space. It's not just aeronautics. We have a very large program in Earth science. We cover the breadth of fundamental research through flight, through technology demonstration flights. So again, it depends. Do you want to become a subject matter expert in a narrow field? If you want to go touch hardware, build hardware, we've got work in that area. So diversity of work is what they get. We have lots of cool problems to solve.

Langley's history

A lot of people don't know the space program started at Langley, before NASA stood up. NASA was stood up in 1958. The Space Task Group actually started at Langley under N-A-C-A. A lot of those people ended up transferring down to JSC [Johnson Space Center], but we were heavily involved in the space program. ... We managed the Viking program in the mid '70s. A lot of people don't know that. So it's not just recently that we've expanded our portfolio. We've pretty much touched aeronautics, science, exploration, across all of this. I think it's important that we continue in all those lines of business.

Effect of budgetary continuing resolutions

Actually, we're kind of used to operating under CRs. I'm trying to remember back in the recent history when we haven't started under a CR. So, there are some restrictions with the CR as far as new starts and things like that, but a lot of our portfolio is within existing portfolios, so we have some flexibility to do that. From an overall budget perspective, I'd say the last several years at an agency, and at the agency level, that flows down to Langley, the budget has been pretty stable. ★

Boeing CEO Dennis Muilenburg meets employees at the company's 787 Dreamliner factory in Charleston, S.C.

Boeing

Boeing's expanding tech ambitions

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Boeing's Dennis Muilenburg describes the 101-year-old aerospace giant as "more innovative than we've ever been in our history." He's definitely been busy in his roles as chairman, president and CEO. The acquisition last year of Virginia-based Aurora Flight Sciences aims to further the company's development of electric vertical takeoff and landing aircraft, or eVTOLs, with the potential for services ranging from cargo delivery to sky taxis. In January, Boeing unveiled a prototype electric autonomous quadcopter aimed at the cargo delivery market. That same week, Boeing at the 2018 AIAA SciTech Forum in Florida unveiled the concept for a hypersonic plane aimed at flying faster than Mach 5. On top of all that, Boeing has mentioned a "potential combination" with Brazil-based Embraer amid a growing demand for regional commercial flights. I spoke with Muilenburg on the phone while he was at Boeing headquarters in Chicago and I was at the AIAA SciTech Forum.

— By Tom Risen

DENNIS MUILENBURG

POSITIONS: CEO at Boeing since July 2015; added chairmanship in March 2016; also president since December 2013

NOTABLE: First worked with Boeing in 1985 as a summer aerodynamics intern. After graduating from Iowa State in 1986, he joined Boeing full time and has worked there ever since. As vice president of Boeing Air Traffic Management from 2001 to 2003, led the engineering program to modernize air traffic management with FAA, including weather information and aircraft positions. Co-authored the 1999 patent for the airframe that became the Boeing X-32, which was the company's entrant in the Joint Strike Fighter competition against Lockheed Martin; he was chief engineer for the X-32 from 2000 to 2001. Muilenburg, by email, describes that chapter as "a period of tremendous learning for me that helped shape how I approach similar programs and tough technical challenges."

AGE: 54

RESIDENCE: Chicago

EDUCATION: Bachelor of Science in aerospace engineering from Iowa State University; master's in aeronautics and astronautics from University of Washington

IN HIS WORDS

Boeing hypersonic concept plane

That's just another example of the advancements we're making there. I think you're familiar with our earlier work on the X-51 hypersonic vehicle, where we're beginning to prove out the ramjet propulsion technology, where we set some new records in terms of performance capability. We're leveraging that propulsion technology for next-generation configurations, including the hypersonic airplane that you saw at [AIAA SciTech]. If we look at the future of flight, we do see an opportunity at some point of having an economically viable supersonic or hypersonic capability with the idea that you could travel anywhere in the world in one to two hours.

Commercial supersonic flight

The key there will be the economic viability for broad participation in that marketplace. With airplanes like the 787 Dreamliner, our ability to basically connect any city pair in the world efficiently provides a lot of great economic options for our customers. Similarly as the 777X comes into the marketplace, it will again provide another 10 to 15 percent operating cost advantage. We're going to need to see a next step in propulsion system efficiency and economic viability to make a supersonic jet more broadly attractive to customers, although in the nearer term, we could see some business traveler interest.

Space transportation

We see an evolving marketplace for low Earth orbit space travel. Right now we're working on our CST-100 Starliner with NASA that will provide transportation to the space station. We anticipate beyond that, we'll see additional low Earth orbit destinations evolve and at some point, an economically viable low Earth orbit space travel network. Our X-37 spaceplane is setting long endurance records for autonomous space operations.

Fully electric flight

The exact timeline around that is difficult to predict, but I would suggest it's going to move faster than any of us might anticipate, given the amount of capital flowing into electrical power technologies. We've made an investment in Zunum [Aero] technology and are working with them today on a hybrid electric-powered and then all-electric-powered regional jet. We anticipate that the entry point for the electrically or hybrid electric-powered airplanes is to start with those smaller-scale airplanes.

Medium-range regional jet ambitions

Passenger traffic [is] globally growing 6 to 7 percent a year. Every year in Asia alone, we have 100 million people who fly for the first time. Less than 20 percent of the world's population has ever taken even a single flight. More than 80 percent of the world still has to fly for the first time. We anticipate you're going to see strong demand for new aircraft, around 41,000 new airplanes for the next 20 years. We do see the single-aisle segment, our 737-class airplane, as the strongest segment within the overall air traffic projections. We see regional airplanes as a strong growth sector. We also see wide-body airplanes as a strong area of growth, and our 787 and 777X [commercial planes] are well positioned for that future market.

Defining "regional" flight

I think that's still a fluid part of the equation. That'll depend on our customer needs and preferences. It's not something that I want to pin down with the particulars today.

Fixed-cost versus cost-plus contracts

We think it's important that the contractual type and structure matches the risk profile of the program. There are some development programs where a fixed-price structure makes sense where you might be using existing technology and the development requirements are very clear. When you look at the ongoing tanker program, the new [KC-46A Pegasus] tanker, that's a fixed-price development program. While that's been challenging, that has made good sense in contract structure. Other programs where the requirements might still be more fluid, next-generation space programs that still require a fair amount of R&D, those might make more sense to have a cost-plus kind of structure.

Upper airspace competition

We're doing a number of things on high-altitude long-endurance vehicles. I think you're familiar with the previous flight testing we've done on the Phantom Eye, which was a high-altitude — 60,000- to 70,000-foot altitude — hydrogen-powered aircraft. Aurora's portfolio also has the Orion high-altitude long-endurance aircraft, which is now part of our Boeing portfolio.

Next-generation, autonomous jet after F-35

Military autonomous vehicles is one of our core investment areas. That spans a range of aircraft from fighter aircraft to unmanned helicopters to spacecraft and pretty much every segment of our portfolio. I think you're going to see a combination of piloted and nonpiloted vehicles in the future. Autonomous vehicle advances with our defense customers have allowed us to reduce risk and begin to build some of the fabric required for eventual commercial application. Just another example of that is right now we're competing for the MQ-25 Stingray, which is the Navy's latest competition to put an unmanned drone aircraft onboard the aircraft carriers that could provide tanking capability. We're also working on an unmanned underwater autonomous vehicle that went into sea trials about three months ago.

Mass produce or own eVTOL tech?

I think it could be a combination. We want to have a strong and vibrant supply chain and having the right balance for that for the future. We have a number of autonomous air vehicles that are either in production or in design. As we contemplate future product lines, it will be a combination of internal Boeing design and production capabilities. The opportunity for urban mobility solutions, both passenger and cargo solutions, is increasing. The drone that we rolled out [in January] is part of the prototyping we're doing to begin innovating in that marketplace.

Human space exploration

One of the big things we're working on right now that certainly has my attention is the first rocket to Mars and the new Space Launch System. I think that's something that's capturing the attention of the future generation of talent. I think it's something that will create a great economic and technology ripple benefit, and I believe the first person that steps foot on Mars will get there on a Boeing rocket. ★

Performance

Designers of next generation airliners are beginning to embrace long, narrow wings as an option for improving fuel efficiency. A hurdle has been lack of an adequate computational tool for predicting their performance when attached to specific fuselage designs. Joe Stumpe spoke to researchers who are working on a possible solution.

BY JOE STUMPE | jstumpe@cox.net

predictor

As the University of Michigan's unmanned X-HALE plane takes off, its composite wings flex upward by about .85 meters, or about 30 percent of the aircraft's half wingspan, before returning to their more horizontal position as the plane gains altitude.

Are longer, more flexible wings like these the way of the future for commercial transport aircraft? Many observers think so because of the fuel efficiency these wings promise, and in fact the trend has begun to a degree. The wings of the Airbus A350 and Boeing 787 are notable for their flexing, but even bolder and more futuristic designs will require exploring "uncharted territory for the industry's methodologies," says University of Michigan professor Carlos Cesnik.

He is among the researchers working to chart this new territory through the fields of flight dynamics and aeroelasticity — the science of how aerodynamic forces distort nonrigid structures and are in turn affected by them. Cesnik isn't a fan of wing flexibility for its own sake. Rather, it's the fact that longer wings could cut fuel consumption in future airplanes because of their superior lift-to-drag ratios. Those wings would need to be flexible to be viable, because stiffening them would add unacceptable weight. Such wings have a high aspect ratio, a reference to their length compared to their width.

Cesnik notes that X-HALE and commercial airliners "are very different configurations. However, the flexibility problem and other issues are very similar."

The trend in airliners is toward higher aspect ratios, but so far those ratios are not as high as that of the X-HALE. NASA has identified high-aspect ratios as a key technology for commercial air transports of the future.

Achieving higher aspect ratios would be a lot more complicated than simply attaching longer wings to a fuselage. Longer wings don't just bend more than traditional ones. They twist and respond to flight conditions and also interact with rigid fuselages in ways that are still are not completely understood. For instance, the up-and-down motion of a plane body during turbulence might be faster than the slow bending of a long, flexible wing — or vice versa. Flexibility "can create an unstable mode that doesn't exist with more rigid wings," says Jessica

▼ **As the X-HALE plane takes off, its composite wings flex upward** by about 30 percent of their half wingspan before returning to their more horizonal position as the plane levels off. This is a series of photos taken during a test flight at the University of Michigan.
Carlos Cesnik

Jones, one of Cesnik's former grad students who now designs aircraft for Aurora Flight Sciences, a subsidiary of Boeing.

Twenty years ago, it was impossible to predict or model such motions because the available computational models relied on linear equations. So Cesnik began developing software called UM-NAST (for the University of Michigan's Nonlinear Simulation Toolbox). Although not finished, UM-NAST is already in the hands of designers in some aerospace companies, Cesnik says.

Traditionally, the movement, or "deflection" in engineering terms, of wings has been so small that it can be analyzed with traditional calculations. "Mathematically, the problem is linear," Cesnik says. "The relationship between the input and output of things, if you double the input, you double the output."

But as the length and flexibility of wings increase, that linear behavior no longer applies.

"This is where the challenges are," Cesnik says. "Computationally, the problem becomes more difficult."

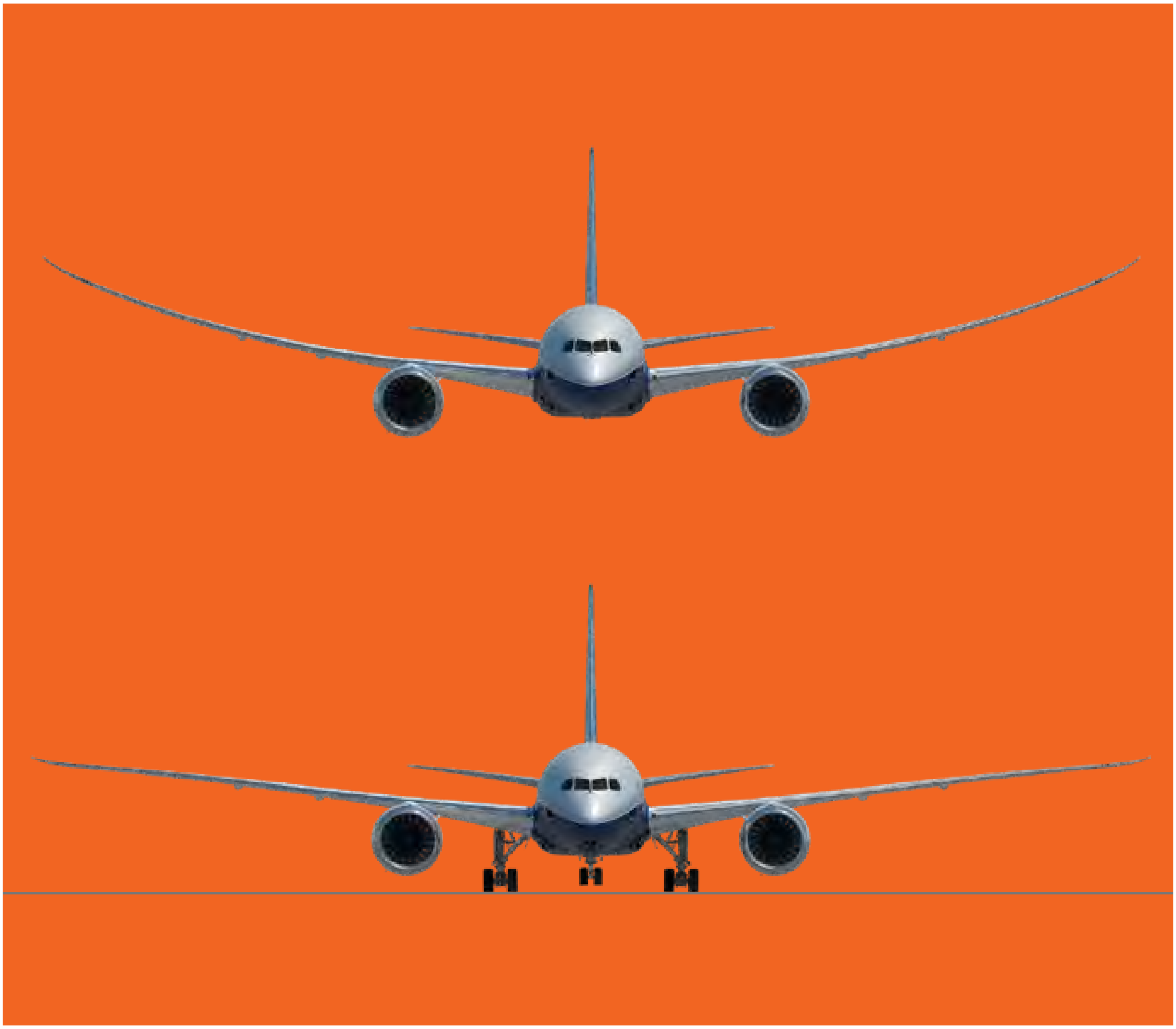
Cesnik works with grad students to explore different vehicle configurations and flight scenarios.

"It is like flying these very flexible aircraft in a virtual world," he says.

Jones says the data needed "is usually fairly detailed — length of wings, weight of wings; the entire aircraft is defined in that way. Then we specify what speed; if there are any external disturbances like turbulence. Then we basically solve a series of equations that tells us how the aircraft system responds to these inputs."

Designers can explore the aircraft's envelope in the safety of this virtual world. "We fly the airplane

▼ **The Boeing 787's wings** can flex up almost 8 meters. In the illustration at top, the bend is about 3.5 meters.



Boeing

at its limits — at very low speeds and very high speeds, subjecting the aircraft to increasingly large disturbances to study how it reacts. This can give us valuable information about vehicle stability and modes of failure before the aircraft ever takes off."

Cesnik says UM-NAST "allows us to be aggressive in the conditions we want to simulate with relatively minor consequences. Also, "since it is a computer, we can just pick it up from where it ends and re-start it and/or figure out what was missing in the [simulated plane] and improve the design."

As powerful as UM-NAST is, it is not yet in final form. That's where X-HALE comes in. Cesnik's team built and designed X-HALE (for "Experimental High-Altitude, Long-Endurance") a decade ago. Its flights from a small runway outside Ann Arbor help UM researchers validate the predictions of their UM-MAST computer simulations, providing missing fundamental data on the stability of long-winged planes; the loads on them as they maneuver and their responses to wind gusts. X-HALE's sensors record the shape of the wing as the aircraft flies at different speeds and trajectories."In order to be accurate, we need experimental data to compare it with," Cesnik says. "We start by taking computational tools and use them to design the experiment. We fly it and we collect the data and we see if the data we collect actually matches with the predictions we have done. When it doesn't, we figure out why so that it will predict accurately next time."

The university flies two X-HALE planes each weighing 12 kilograms with a 6-meter wingspan. A wing-boom-tail type aircraft, X-HALE is powered by five motors and carries four data collection devices.

Despite its name, X-HALE flies at a maximum altitude of about 122 meters due to legal restrictions, for up to 30 minutes at a time. The data it collects is "scaled up" to that of larger, faster, longer-flying aircraft.

X-HALE has the dents to show that it's made hard landings "multiple times, but we never take it lightly," Cesnik says.

"It is costly to fix physical things and takes time. However, our approach is to take 'manageable risk' and be aggressive in our experiments as well. It is a fine balance to keep engineering progressing."

Research on high-aspect-ratio wings and other potential innovations is driven primarily by two factors: the desire for unmanned planes that can fly at a high altitude for a long time, and the realization that growth in commercial airline traffic requires aircraft that burn less fuel and create fewer emissions.

Currently, most commercial aircraft wings have an aspect ratio of about 9, which means the square of the wingspan is nine times larger than its area. Calculations have shown that aspect ratios of 13 to 15 can significantly improve fuel efficiency.

"IT IS LIKE FLYING THESE VERY FLEXIBLE AIRCRAFT IN A VIRTUAL WORLD."

– Carlos Cesnik, AIAA fellow and University of Michigan professor

Increased wing span is already part of new designs, although in much smaller increments than a plane like X-HALE with its aspect ratio of 30.

Unmanned, solar-powered planes with wing lengths on the order of X-HALE have been attempted in the past. In 2015, Google's Solara 50 crashed shortly after takeoff in New Mexico. In 2016, Facebook's Aquila crashed 90 minutes after takeoff in Arizona. Studying the failures of those aircraft is another aspect of the research. In the crashes of both the Google and Facebook airplanes, Cesnik says, it's believed that excessive speed led to structural deformation of the wings and ultimately failure.

Asked when he expects high-aspect-ratio wings to become mainstream, Cesnik notes that it's starting to happen. "We keep moving forward in terms of developing new tools. The level of understanding has grown significantly, but there's still a lot to know."

From his perspective, he says with a laugh, "I think it's a lifelong pursuit." ★

AFFORDABLE MICROGRAVITY

Conducting experiments on the International Space Station is too expensive for some researchers. Luckily, there are commercial options closer to Earth, and those options are about to grow. Henry Canaday looks at the company that started it all.

BY HENRY CANADAY | htcanaday@aol.com

G-Force One, a modified 727, gives tourists willing to pay $4,950 about half a minute of microgravity. Companies are offering the service to scientists wishing to conduct experiments, as well.

Zero-G

This year, just as every year since 2004, a Boeing 727 equipped with an open cabin design and padding over its windows will cruise at 24,000 feet and suddenly ascend at a 45-degree angle to briefly produce 1.8 times the force of gravity. The pilots will throttle back to let momentum carry the plane, and thrilled tourists or often times microgravity scientists will float weightless for about 20 seconds as the plane reaches a peak of 32,000 feet and plunges downward.

Meet G-Force One, an aircraft that in 2004 was a shiny new example of space entrepreneurship. The plane, flown by Virginia-based Zero Gravity Corp., gives tourists willing to pay $4,950, or scientists, a sense that they are in space. The company was the brain child of space entrepreneur Peter Diamandis, former astronaut Byron Lichtenberg, notable as the first space shuttle payload specialist, and former NASA microgravity researcher Ray Cronise. They spent a decade planning the business and winning FAA certification for the flights. The 727, for example, has a modified hydraulic system to prevent dangerous cavitation, or bubbles, from forming.

These days, Zero-G touts itself mainly as a "space entertainment and tourism" company, but it is also a hit with materials scientists, horticulturists and other technologists who crave the experimental mysteries that those few seconds of weightlessness could help them solve.

Today, Zero-G could be called the graybeard of space entrepreneurship. It's about to have some big-name competition in the microgravity business. Blue Origin plans to offer the New Shepard rocket for suborbital flights by both passengers and experiments in 2018 or as soon as tests can be completed. New Shepard would open up the possibility of researchers accompanying their experiments for three to four minutes. Richard Branson's Virgin Galactic with SpaceShip Two is moving in the same direction, but without accompanying researchers.

Zero Gravity's major advantages are capacity and presumably cost. Blue Origin and Virgin Galactic will have longer duration, and slightly "purer" weightlessness. The competition is apparently welcome. "We applaud what they are doing," says Michelle Peters, Zero Gravity's director of research and education.

Zero-G

▲ **University of Florida students experience microgravity** while working on their experiment during a parabolic flight. The team developed a special coating for the inside of a rocket propellant transfer pipe to maximize a spacecraft's fuel system efficiency.

It was NASA that opened the door to this new commercial line of business by stepping out of the way in the same month that Zero-G conducted its first flight. The agency had started a Reduced Gravity Research aircraft program in 1959, and in 2004 it retired the latest iteration of the program's aircraft, a converted KC-135A fuel tanker dubbed the "Vomit Comet" that hosted experiments and introduced numerous astronauts to the feeling of weightlessness.

For scientists, an attraction of these flights — called parabolas for the shape of the arc the plane makes — is price. G-Force One can take a team of five researchers and all their test equipment from Orlando Sanford International Airport, Florida, over the Gulf of Mexico for $38,500. For some experimenters, the International Space Station would be the preferred venue, but it can cost several times the G-Force One fee just to get an experiment to the station. Plus, the scientists don't get to accompany their project.

Zero Gravity pilots throttle back engines to just the level necessary to offset drag, so the aircraft proceeds through the parabola at the same speed as before. Weightlessness occurs because both aircraft and its contents are subject to exactly the same forces, momentum plus gravity. More aggressive flying could prolong weightlessness to 28 seconds on G-Force One, notes Peters, but the aircraft generally stays with 20-21 seconds. Flying larger arcs at the parabola's top can produce lunar or Martian gravity, one-sixth and one-third Earth gravity, respectively.

There are also drop towers. These are inexpensive but the experiment time is brief. The best in the U.S. is at NASA's Glenn Research Center in Ohio, and it offers only five seconds of zero gravity. The Japanese Microgravity Center used an abandoned vertical mine shaft near Hokkaido, Japan, to achieve approximately 10 seconds of drop with gas thrusters and other equipment, but the facility is no longer operational.

Sounding rockets, which reach suborbital altitudes, are another option but these offer opportunities for only unmanned flights and experiments. The size and weight of the experimental equipment are also restricted.

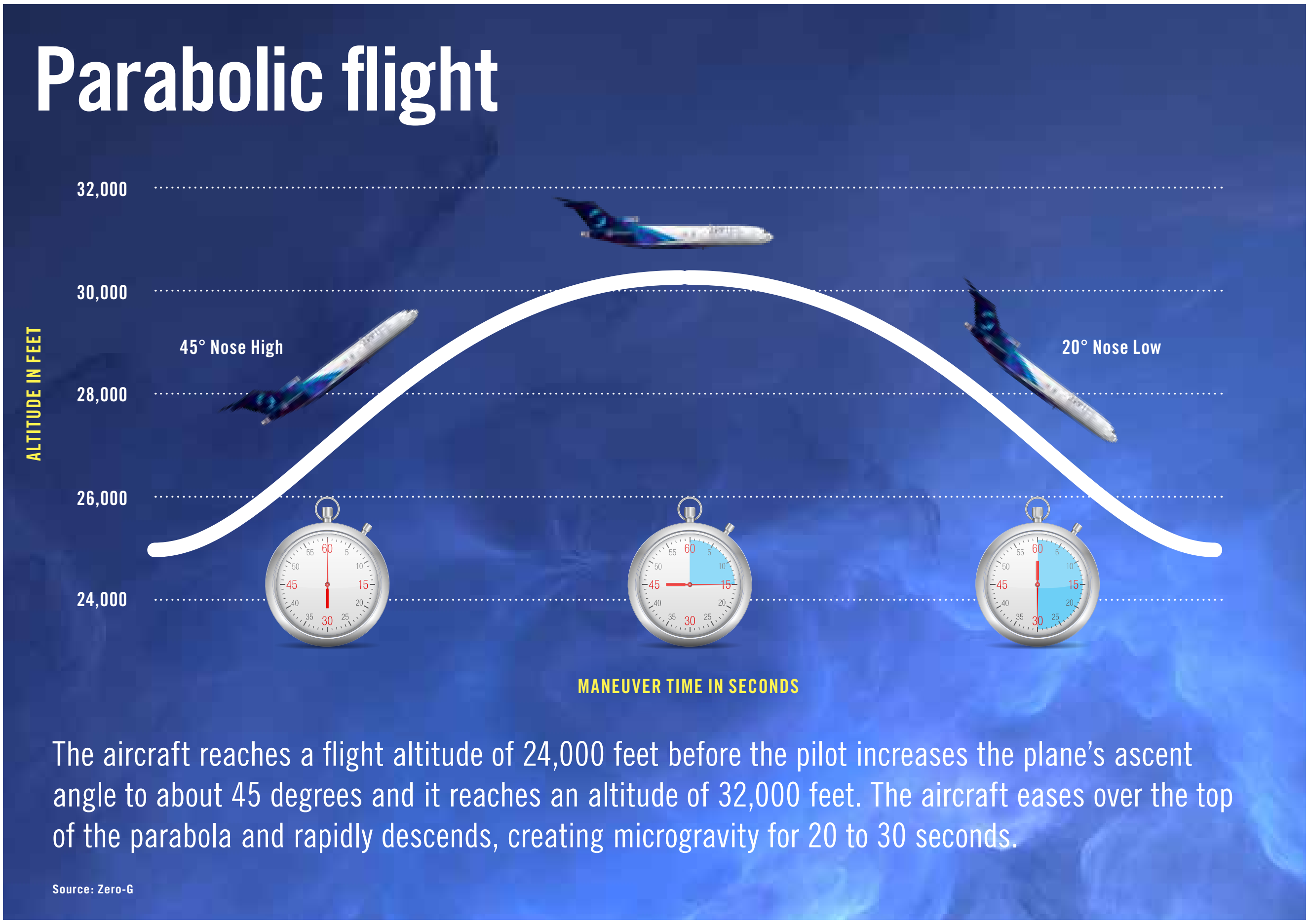
Experiments aboard G-Force One in recent months provide a window into the variety of applications for parabolic flights that have sprouted since Diamandis and his team founded the company. Here are examples:

Soldering

For space explorers or those seeking to set up commercial bases in space, soldering in microgravity could become necessary. Electronic components might at some point fail, and it would be impossible to have a replacement part available for every scenario. Odds are, circuitry, for instance, is going to have to be repaired. Soldering in microgravity could be risky, says John Kuhlman, professor emeritus of mechanical and aerospace engineering at West Virginia University, who has conducted experiments on G-Force One.

The problem, as NASA learned in a KC-135 parabolic experiment, is that in microgravity vapors can remain in the solder as tiny bubbles that weaken joints. Here on Earth, the weight of the solder pushes it downward and vapor bubbles up and out through the surface of the solder, much as gravity pushes bubbles up in carbonated water or soda.

Experiments at Yale University and analysis by



Kuhlman at West Virginia suggested a possible solution: Put tiny iron pieces in solder and draw the iron and solder to the soldered joint with magnets, pushing the bubbles up and out like gravity. "That should improve the longevity of repairs on electronics," Kuhlman says.

Kuhlman chose Zero-G because his prior experience with parabolic flight taught him that 20-21 seconds of weightlessness would be long enough for solder to melt and solidify. West Virginia's own drop tower yields only one or two seconds of zero gravity, hardly long enough, and it would need an automated experiment. NASA's sounding rockets flying suborbital parabolas could yield much longer durations, but would require miniaturized and automated equipment, adding to costs. And use of ISS would dramatically increase cost and delays.

To ensure the experiment did not interfere with the 727's communication and avionics, the West Virginia team used small, rare-Earth permanent magnets placed close to the solder. Their magnetic fields decline rapidly as distance lengthens. Zero-G and experimenters always verify beforehand that equipments and processes will not interfere with safe flights.

The research team went through an orientation program to understand what would happen during flight and how to handle safety equipment like vests. In addition, Zero Gravity assigned a coach to help experimenters with the exercise. The coach was also trained to take over from a team member if one were disabled, for example by sickness.

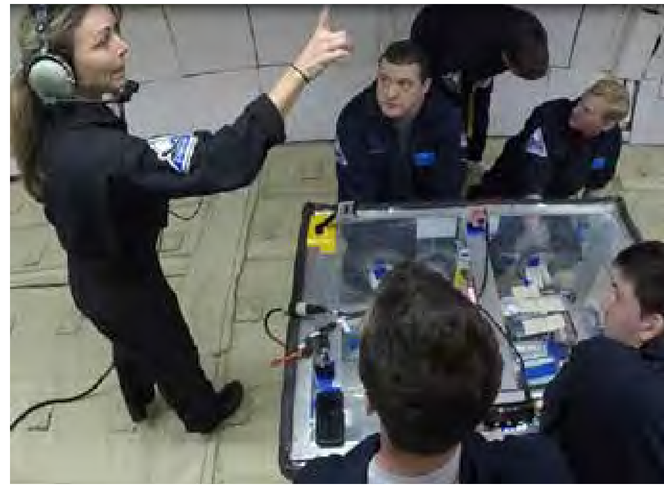
As it happened, one student was disabled and the coach took his place. On Nov. 15, 2017, Kuhlman's team flew 30 parabolas, soldering individual joints and also using reflow ovens to solder components to circuit boards. Another planned experiment, using induction heating, was not done due to safety concerns that the required cooling water might leak.

By January 2018, West Virginia researchers had visually inspected the magnetized solders and prepared them for the instrumental analysis necessary to detect the amount of air space per solder volume. Analysis of results will take months.

Kuhlman plans on more experiments, one with an improved solder that should have stronger magnetic attraction and still another that may not require magnets to prevent bubbles.

Vegetation experiment

Space explorers will surely want to grow their own vegetables, because produce can't be preserved long and transporting it to space would take up scarce and valuable delivery capacity.



Zero-G

◀ From left, student Savona Garrett of Gadsden State Community College; NASA scientist Oscar Monje; NASA engineer Prital Thakrar; and Audrey Webb, student NASA mentor for Gadsden, pose with the Gadsden students' experiment onboard the Zero-G aircraft before the flight.

▶ University of West Virginia students prepare to solder their experiment during a parabolic flight onboard G-Force One. Zero-G's Michelle Peters indicates that they will enter microgravity conditions in about one minute.

But microgravity poses problems, says Audrey Webb, division chair and instructor at Gadsden State Community College in Alabama. There's no force to pull water down to plant roots so it can feed the plants' growth. Different techniques might have to be used to get water to the roots and then tools developed to determine when the system needed more water.

Webb chose Zero-G partly because the space station was too expensive, $80,000 to $90,000 for just the one-way transport of an earlier experiment. Also, her students could perform the tests, rather than turning them over to astronauts. Finally, results would come quicker than the three months to get data back from ISS.

Webb's team went up on a 30-parabola flight. The Zero-G pilots can tailor the amount of gravity during parabola, and the first five parabolas simulated lunar and Martian gravity. Then pairs of researchers each tried five parabolas at a time to observe, with sensors and cameras, where water went. Various techniques were used for watering plants.

Webb's team first tested water flows into Turface, a cat-litter-like material used on athletic fields. Moisture sensors were embedded in Turface and triggered a water pump to maintain constant moisture. The researchers showed that moisture could be distributed by capillary action within the Turface.

Another experiment of Webb's tested aeroponics, which grows plants in mist without soil, to water roots, represented by sponge, Mylar and Teflon. Water colored with green food dye was atomized and sprayed toward plant roots in zero gravity in a closed container for five seconds during each parabola. Unfortunately, the mist blocked cameras recording the experiment, but the green dye showed up on roots, indicating success. Webb says sensor results were generally satisfactory. But cameras had a tendency to fog up and need to be redesigned.

By January 2018, Webb was working on next steps, tweaking the watering and measuring processes to improve results. She says the 20-second zero gravity is sufficient for preliminary experiments, but if she finds an encouraging approach to the problem she might opt to put an experiment on a three-month test on the space station.

Asteroid mining

Government and private organizations are getting closer to exploring and perhaps mining asteroids. For mining, asteroids could someday produce rare elements less expensively than digging into mountains on Earth or yield water embedded in asteroid material. If water can be broken down into its constituent oxygen and hydrogen, asteroids could serve as refueling stations for rockets.

Safety is among many questions posed by asteroid mining, according to Josh Colwell, a physicist at the University of Central Florida. The very slight gravity of asteroids means surface material, called regolith, could be kicked up by just slight impacts from mining activity.

So Colwell has been experimenting with simulated regolith, developed from examining meteorites, which are fragments of asteroids. Tests in November 2017 on Zero Gravity's 727 shot 2-centimeter marbles into the simulated regolith. They revealed that only at impact speeds of less than 20 centimeters per second, extremely slow, is the regolith relatively undisturbed and safe.

Colwell also studied faster impacts and their effects, for operators that might want to collect samples of the asteroid's regolith. And in the course of his experiments, Colwell's team collected data on how an impact might cause a chunk to bounce off the surface, which has implications for scientific questions about the early stages of planet formation.

The Florida researcher has used other microgravity environments, including a drop tower, suborbital parabolas and the space shuttle, to conduct asteroid experiments. He says it is a big advantage to actually be on the Zero Gravity aircraft, and he can do many 10-second experiments on one flight. ★

RED A

For the better part of 50 years, U.S. fighter pilots practiced fighting adversaries by flying against fellow pilots who were steeped in the enemy's tactics and who flew government-owned planes meant to replicate the enemy's. These days, the U.S. Air Force is facing a shortage of "Red Air" aircraft and pilots, and so it is preparing to outsource much of the demand to private companies. The question is whether this trend should be permanent or temporary. Jan Tegler spoke to those with the most at stake.

BY JAN TEGLER | wingsorb@aol.com

IR RESET

A U.S. Air Force F-22 Raptor takes off from Elmendorf Air Force Base, Alaska, while acting as an aggressor aircraft for pilot training. The Air Force is planning to hire contractors to supply aircraft and pilots for such work. U.S. Air Force

When Air Force Lt. Col. Kevin "Flash" Gordon retired from the service two years ago, he walked across the ramp at Nellis Air Force Base in Nevada and joined the Nellis arm of Draken International. The Florida-based company is among a cadre of firms that specialize in equipping and piloting retired fighter planes to mimic the aircraft that U.S. fighter pilots would face in combat against the likes of China or Russia.

Historically, the role of aggressor, or Red Air forces, has been played by active duty Air Force, Navy and Marine Corps squadrons. Gordon used to lead one of those squadrons, specifically the F-16C-equipped 64th Aggressor Squadron at Nellis. He now flies Draken-owned Douglas A-4K Skyhawks and Aerovodochy L-159Es against student pilots at Nellis, which is home to the Air Force Weapons School.

Gordon's new job is emblematic of a shift by commanders toward acceptance of contract adversary services, though sometimes with reservations. Depending on who is speaking, the trend is either an economically driven temporary step or a permanent step toward better training. At stake is just how far the contract adversary industry will grow, and how best to plug the widely observed shortage of adversary aircraft to properly train fighter pilots in the U.S.

"This is a massive opportunity and a huge challenge for our industry says Draken International CEO Jared Isaacman. "We have to deliver quantity and capability while remaining affordable with airplanes modernized appropriately to achieve the perfect balance for the customer."

These days at Nellis, Red Air sorties are created by mixing privately owned and flown aggressor planes with F-16s flown by Gordon's former squadron. Fresh out of the cockpit of an L-159 in late November, Gordon described what it's like to fly in a force made up of A-4s, L-159s and F-16s.

He and his Red Air colleagues were simulating twin-engine Sukhoi SU-30 Mk.2 multirole fighters, a type flown by the Chinese Navy. They carried simulated air-to-air missiles and air-to-ground bombs. On the Blue, or friendly side, trainees flew F-16s, F-15Cs, F-22s and F-35s, and were tasked with defending targets for 50 minutes.

"We were fighting air-to-air and if we got to the target we were dropping bombs," Gordon says. "I had a kill on a Blue guy and another L-159 killed a Blue guy," he adds. "It would be good if none of us ever got a kill, but I'd rather these guys learn from their mistakes here than, god forbid, on a real mission."

Gordon's snapshot illustrates how contractors are now starting to take over a role the military once largely handled alone.

Big dollars

Over the last three decades the U.S. military has closed down most of its aggressor squadrons, devoting dwindling funding to operational aviation units rather than supporting adversary training. Today, two dedicated aggressor squadrons remain in the Air Force, three in the Navy, and one in the Marine Corps. That's roughly a third of the active duty units that flew in the aggressor role as recently as the late 1980s.

In the mid-1990s, contract adversary firms began to form to fill part of the void, offering commercially owned tactical jet aircraft flown by civilian pilots to provide a range of Red Air training. For two decades, military demand for outsourced Red Air remained relatively modest.

That changed dramatically last July when the Air Force released a draft solicitation outlining demand for nearly 40,000 hours of adversary air services annually at 12 bases, including 11,250 hours per year at the Nellis school. This Adversary Air, or ADAIR, business could be worth $400 million spread among multiple companies.

Draken will be among the companies bidding for this work, with awards scheduled to begin in 2019. The U.S Navy is also planning to make greater use of contract adversary support with its own solicitation due midway through 2018.

Highly motivated

To understand the changes and challenges of this contracting trend, I spoke with Air Force officials and three of the major players in contract adversary support, Draken; Airborne Tactical Advantage Company, or ATAC, based in Virginia; and Tactical Air Support Inc., or TacAir, headquartered in Nevada.

What is driving the trend? "We have a decrease in readiness and a fighter pilot shortage," says John Saghera, Air Combat Command's ADAIR Function-

SEEKING MORE ADVANCED CAPABILITIES

The U.S. Air Force told industry in December that it is considering adding "a SECRET addendum" to the unclassified request for proposals for the ADAIR (adversary air) contract, in which private companies would fly aircraft to simulate enemy aircraft during training of U.S. fighter pilots. This "notice to industry" asks companies bidding for ADAIR work to "submit a response that includes your company's plans to obtain a SECRET facility clearance and identifies the personnel within your company holding a U.S. Government security clearance (including clearance levels)."

U.S. Air Force

▲ **A Douglas A-4K Skyhawk** owned by Draken International on the flightline at Nellis Air Force Base in Nevada, where the company was providing crew and aircraft to play the aggressor role in training with the U.S. Air Force.

al Lead. "Contract adversary support is the quickest and most cost effective means to get us bridged to where we can build the Air Force back up to where we can maintain organic aggressor status."

Saghera's comments reflect those of the military's top commanders. In 2017 testimony before the House and Senate Armed Services committees, service chiefs said that a shortage of funding, personnel and equipment has led to a military-wide readiness problem.

The Air Force vice chief of staff, Gen. Stephen Wilson, told the committees the Air Force was "out of balance," adding that "this nonstop combat, paired with budget instability and lower-than-planned top lines made the United States Air Force one of the smallest, oldest-equipped, and least-ready in our history."

An improving economy has also led to an exodus of pilots across the services, often to lucrative careers in commercial aviation "1,500 pilots short and, if we don't find a way to turn this around, our ability to defend the nation is compromised," said Gen. David Goldfein, Air Force chief of staff, speaking in September at an Aircrew Summit at Joint Base Andrews outside Washington, D.C.

Recognizing the problem, President Donald Trump in October signed an executive order that would allow the military services to recall retired military pilots to active duty.

Now a military analyst, retired Marine Corps Lt. Col. David Berke flew F/A-18 Hornets in combat, the F-22 Raptor for the Air Force, and the F-35B for the Marines as commander of the fighter's first operational training squadron, from 2012 to 2014. He was also a Navy Top Gun lead adversary instructor. Now a nonresident senior fellow with the Center for Strategic & Budgetary Assessments, he says the military's lack of adversary training resources amounts to a Red Air crisis and views the adoption of contract adversary support as a positive development.

"It would be catastrophic if our Air Force, Navy and Marine aviators lost the ability to train against Red Air. What the adversary squadrons have provided historically and what contract adversary support firms can offer is absolutely invaluable from a readiness standpoint. Without Red Air we would be woefully unprepared for future warfare."

While the Navy has availed itself of contract adversary support for nearly two decades, the Air Force has been a reluctant and sparing user. According to the commander of Air Combat Command in Virginia, the ADAIR contract will turn the service into a consumer, but temporarily.

An IAI F-21 KFIR fighter, one of the aircraft belonging to the Airborne Tactical Advantage Co., taxis on the flightline at a U.S. Marine Corps base.
U.S. Marine Corps

Aircraft attributes

The contractor jets that would be flown under the U.S. Air Force's $400 million-a-year adversary air, or ADAIR, contract must meet a set of ambitious requirements defined by the service last October. Here are some key attributes for the planes, which are expected to be flown by multiple contractors:

Speed, altitude, duration — Companies must provide a mix of aircraft for a variety of scenarios, from acting as "metal in the sky" for pilots in "Blue Air," or friendly, aircraft, which will try to find and identify them, to engaging in mock air-to-air combat. Speed requirements range from high subsonic (Mach 0.9, approximately 690 mph (1,110 kph) to supersonic velocities typical of advanced fighter aircraft (Mach 1.5, approximately 1,150 mph (1,850 kph). Altitude requirements vary from a minimum ceiling of 30,000 feet up to a minimum ceiling of 50,000 feet. The aircraft also must be able to fly unrefueled (duration) from 1.2 hours (72 minutes) up to 1.5 hours (90 minutes).

Radar — Aircraft must be capable of detecting and tracking other aircraft at ranges varying from 20 nautical miles (37 kilometers) to 90 nautical miles (167 km). They also must be capable of simulating weapons employment – firing various types of air-to-air missiles, for example – against an opposing aircraft. To satisfy requirements at the high end, contractors must procure radars that are among the most advanced available currently. That will be expensive, and it will take time to adapt them to the contractor airplanes.

Link-16 — Link-16 is a military tactical data exchange network operated primarily by the U.S. and NATO member militaries. An aircraft that detects targets in the airspace, on the ground or at sea can pass that information to another aircraft. This data creates a tactical picture for allied pilots in a conflict area. Link-16 and comparable advanced data link networks have until now only been flown by governments/militaries. Their use by civilian contractors would be unprecedented and poses a range of classified information challenges.

Captive air training missiles, or CATM — These come in a variety of versions to simulate airborne missiles for training. As captive missiles, they stay fixed to the adversary airplane, but they can take simulated shots, mimicking the emissions produced by the firing and release of their "live" counterparts. Raytheon's missile unit in Arizona makes a CATM version of its latest Sidewinder air-to-air missile, the AIM-9X, and there are CATM versions of other advanced missiles, such as the Python from Rafael Advanced Defense Systems in Israel. CATMs are expensive and difficult to procure, and contractors will be competing with the military to acquire them.

— Jan Tegler

"In a perfect world we would have the resources to maintain the aggressor squadrons that we used to have, and we'd do our best to work in-house," said Air Force Gen. Mike Holmes, during the annual Air, Space and Cyber conference in September near Washington, D.C.

"In the world we're living in now, I don't want to have to trade an actual fighter squadron for an aggressor squadron because of limits on my budget," he adds. "The next best thing is to see if we can contract some of that Red Air out."

Hiring bandits

With the two organic adversary units left — the 64th Aggressor Squadron at Nellis and the 18th Aggressor Squadron at Eielson Air Force Base, Alaska — the Air Force is thousands of flight hours short of the training it requires for current aviators. In addition, the service must train hundreds of F-35 Joint Strike Fighter pilots as more of the fifth-generation fighters enter operational service over the next decade.

Recognizing its predicament, the Air Force commissioned a feasibility study of contract adversary support in 2014. It also awarded a one-year contract to Draken International in late 2015 to evaluate the real world performance of a commercial Red Air provider. The Air Force thought the trial went well and the service extended its contract with Draken through 2018.

That arrangement addresses short-term requirements. The ADAIR contract will run for a decade with the possibility of an extension.

With the multiaward contract set to commence in about 18 months, contract adversary providers are scrambling to procure the people and equipment necessary to bid for the lucrative work. They're also conversing with the services to learn what level of capability could be required. Will contract adversaries be expected to match the sophistication of high-end aggressor planes flown by military squadrons?

The right mix

To provide the quantity of training the Air Force has asked for annually, the three company leaders I spoke with estimated that 150 to 200 aircraft will be needed. Currently ATAC, now part of Textron, operates 25 airplanes, a mix of supersonic Kfir C2s and subson-

U.S. Air Force

▲ **An Airborne Tactical Advantage Co. pilot** and maintenance technician prepare a Hawker Hunter Mk. 58 for training maneuvers at Kunsan Air Base in South Korea.

ic Hawker Hunters. Draken International actively flies 34 aircraft: 13 subsonic Douglas A-4 Skyhawks and 21 subsonic Aero Vodochody L-159 light attack jets. TacAir has 25 supersonic Northrop F-5 fighters and a small number of subsonic Embraer A-29 Tucano trainer/light attack turboprops.

In total, these three companies offer fewer than 100 aircraft for Red Air. The number of hours the ADAIR contract calls for is just slightly less than the number of hours ATAC has flown over 20 years in the adversary business. Add in the number of hours and additional aircraft that forthcoming Navy or Marine Corps contracts will require and, as ATAC CEO Jeffrey Parker says, "it's clear there will be plenty of business to go around."

The prime question for these companies is how to meet requirements for the ADAIR contract and future Navy/Marine Corps contracts simultaneously. ADAIR requirements were still being defined at this writing, expected to be finalized late in 2017. As the industry understands them currently, the Air Force is looking for a range of performance for its Red Air support aircraft.

At the high end, the Air Force desires supersonic airplanes with sophisticated radar and sensors to present F-22 and F-35 trainees with near-peer challengers, replicating a variety of threats including full-fledged dogfighting.

Currently, none of the providers can simulate America's most sophisticated adversary threats. So how will they equip themselves to represent advanced enemies?

ATAC and Draken International provided a partial answer by buying recently retired foreign fighters. In September, ATAC completed an unprecedented purchase, paying more than 30 million Euros for most of the French Air Force's retired Dassault Mirage F1 fighter fleet, totaling 63 jets.

"It's a huge acquisition," Parker affirms. "And a huge quest to manage, then refurbish, upgrade and operate these aircraft and their over 6 million parts, 150 spare engines and other equipment."

Draken International made a similar buy, purchasing 20 slightly newer Mirage F1s retired from Spanish Air Force service. In December, the company augmented its fleet further with a buy of 12 supersonic ex-South African Air Force Atlas Cheetah fighters. Both companies plan to upgrade the capabilities of these aircraft significantly but there's uncertainty about how much capability the Air Force will ask for from industry.

Could industry airplanes play the role of fifth generation adversaries against the Air Force Blue Air?

"In the spectrum of threats, I think we're going to train up to the 80 to 85 percent level," Parker suggests. "And let the rest be done by 4.5 and fifth generation aircraft in the U.S arsenal as well as advanced, integrated simulator training."

The Air Force agrees but leaves wiggle room, stating that it's asking industry to "progressively provide advanced adversary capabilities" up to "near-peer and peer threats."

"Tying a number to it is tough," Air Combat Command's Saghera says. "It's very fluid but in general the top end is going to require in-house Air Force assets."

Opinions differ, but leaving high-end threat simulation to government squadrons might be wis-

U.S. Marine Corps

▲ **An Airborne Tactical Advantage Co. Hawker Hunter** Mk. 58 takes off during training exercises with the U.S. Marine Corps.

est for contract adversary providers. Draken's Issacman says that the cost of simulating those advanced adversaries may not be affordable for industry.

"If you do a [Freedom of Information Act] request on what flight hour costs are for front-line combat planes, an F-16 costs about $30,000 per hour, an F-15 is about $40,000 per hour and you can imagine it goes up from there."

"So when the ACC chief asks for $400 million for 40,000 hours, quick division gets you to around $10,000 per hour as a rough budget," he explains. "That's where the real challenge begins."

Affordability is central. If the contract providers can offer training at a third to a quarter of what active duty adversaries would cost, the equation makes sense, company leaders say. This notion underpins ATAC and Draken's acquisitions — planes that can provide performance and simulation capability approaching that of fourth generation fighter jets cost effectively.

But TacAir CEO Roland Thompson thinks that his planes can be equipped to match fourth generation capabilities. He believes his company's F-5s, which are already familiar to the Navy and Marines, can be upgraded with electronically scanned array (AESA) radars like those in some fourth generation fighters along with other sensors. He admits this will be more costly but thinks it may be practical.

With such improvements, Thompson feels the systems on his company's planes could be sophisticated enough to significantly challenge F-35s and F-22s. He also thinks it's possible that the military might be open to having active duty pilots fly TacAir's jets to gain familiarity with Red Air. Thompson says TacAir can upgrade the systems in its F-5s to match what's in an F-35 or F-22 and thinks it's possible that the military might be open to having active duty pilots fly TacAir's jets to gain familiarity with Red Air.

The idea of active military pilots flying contractor-supplied aircraft is a step further than the leaders of the other companies I spoke with would go. But all three executives mentioned that they are looking to procure more aircraft, including "more advanced packages."

Perhaps there is a middle ground. "We should embrace contract Red Air," says Berke, the analyst and retired Marine Corps pilot, "and look for all the ways it brings value but I wouldn't support the idea of the military completely extricating itself from adversary air."

In his view, commercial providers offer a "ridiculously good amount of really good training" with current assets that cannot be replicated in the military. Creating a truly high-end threat with contractor aircraft alone would be difficult, he cautions. However, combining commercial and military assets with sophisticated simulation and an advanced training system could work.

"We need to use the synergy of the two to create an ecosystem of threats from every domain available to train our people up to and including fifth-generation training."

The future of Red Air

The trend is expanding globally with companies including ATAC, Draken and TacAir already providing Red Air and other training in Europe. Contracts for even more business are pending in the U.K. and other NATO countries.

Holmes, the ACC commander, has stated that contract adversary support is temporary, a gap filler until active USAF aggressor units will once again provide organic Red Air. But as ATAC's Parker says, if the industry is successful, it will be a trend that is hard to reverse.

"I think the Navy model will persist," he says. "Once these programs are integrated into the way

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Recent workshops by the IEEE and AIAA have identified the need to bring together electrical engineers and aerospace experts as the industry looks to more electric propulsion technologies for future aircraft. For 2018, the AIAA Aircraft Electric Propulsion and Power Working Group, the IEEE Transportation Electrification Community, and the College of Engineering of the University of Illinois at Urbana-Champaign are collaborating to organize a new two-day symposium to address these issues. The event occurs on 12–13 July, following the AIAA Propulsion and Energy Forum.

The symposium will focus on electric aircraft technology across three programmatic tracks: (1) electric-power enabled aircraft configurations and system requirements, (2) enabling technologies for electric aircraft propulsion, and (3) electric aircraft system integration and controls. Abstracts are solicited in specific areas of relevancy including, but not limited to, the following:

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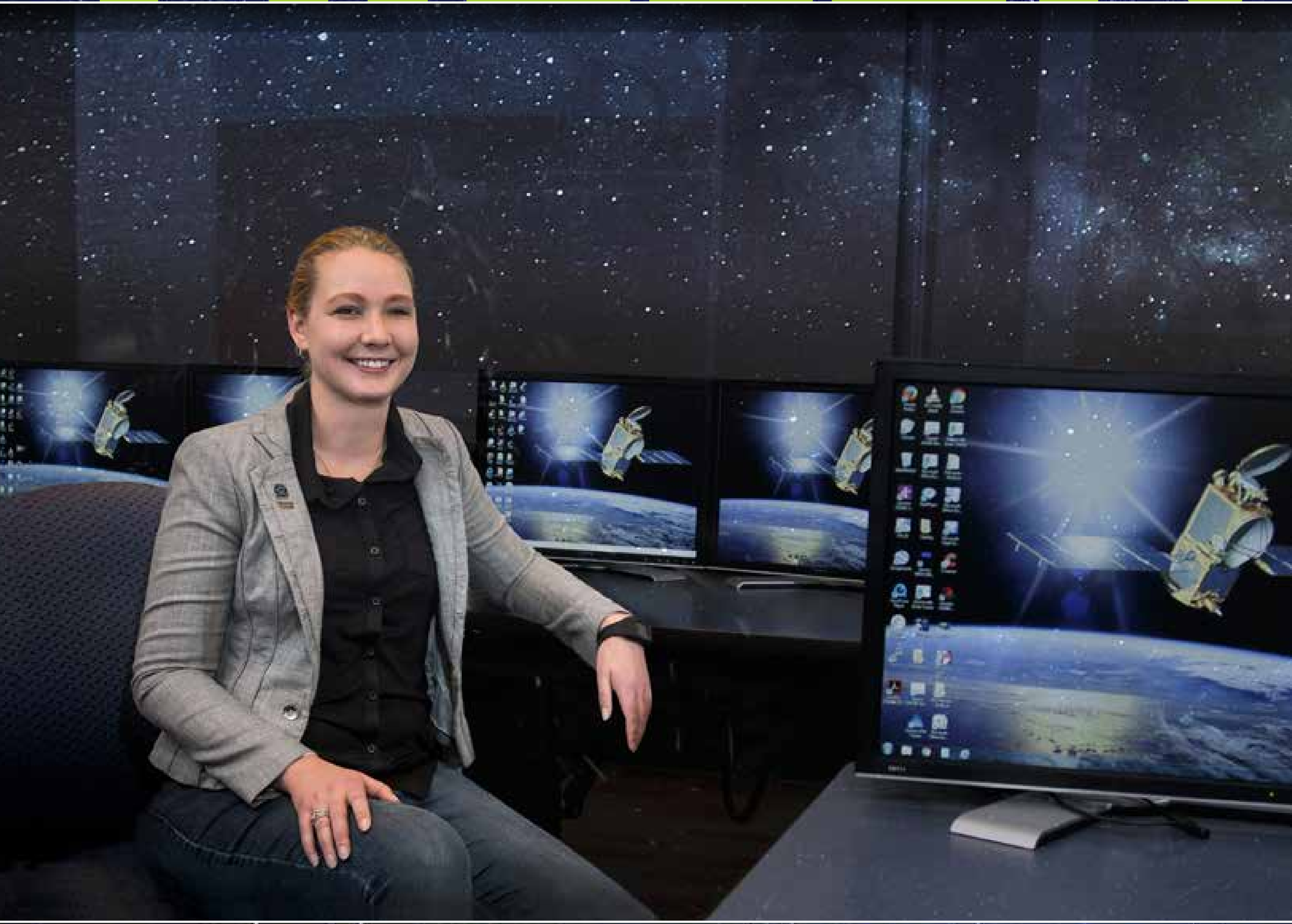
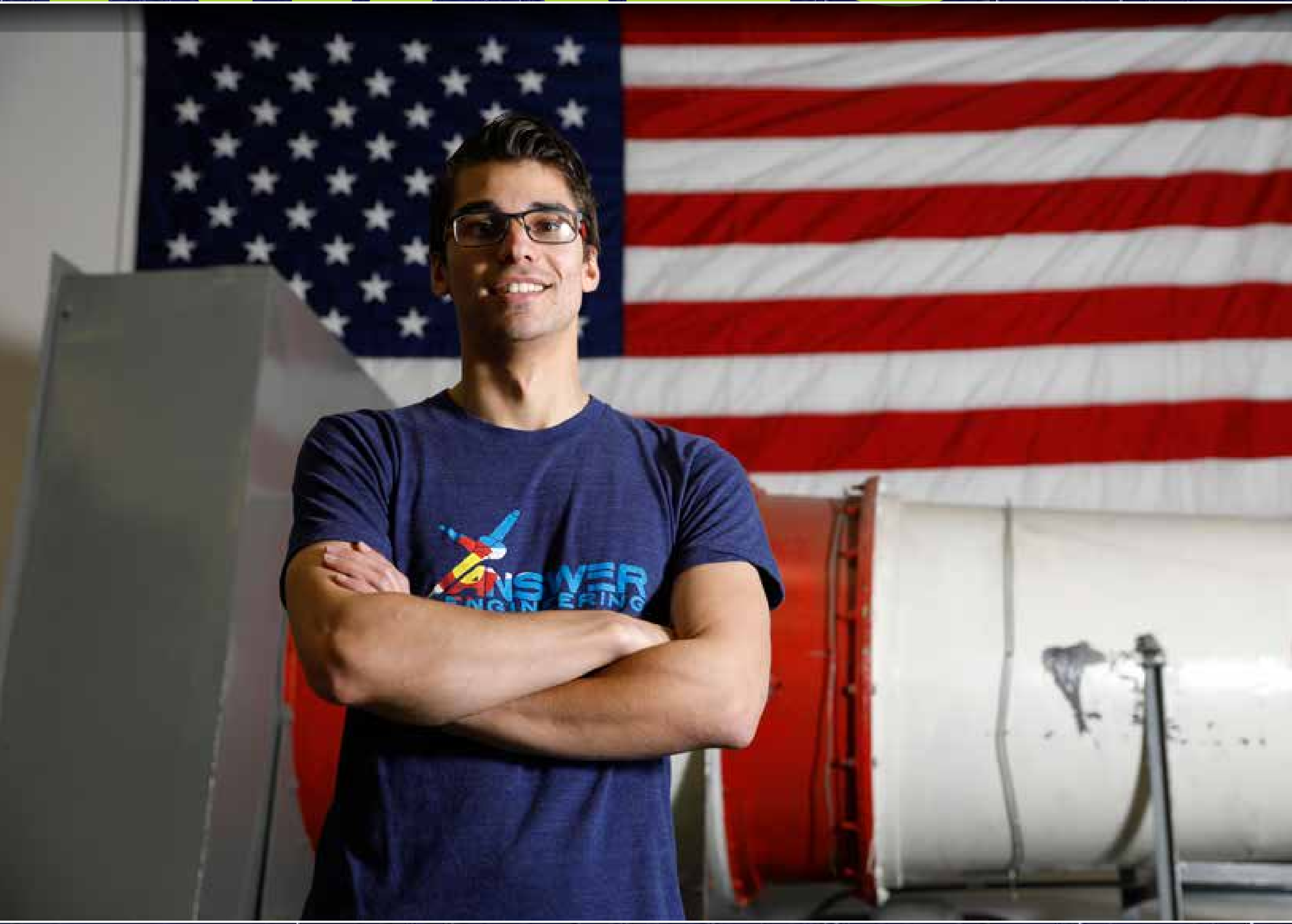


▲ **Sierra Nevada** engineering technician Magens Orman started college as an art major, then got inspired by a space class.

Metropolitan State University of Denver

BY AMANDA MILLER | agmiller@outlook.com

NIALS



Alyson McClarah

▲ **Joe Meyer is new on the staff** at Answer Engineering in Englewood, Colorado.

New college graduates are becoming a larger percentage of aerospace employers' new hires as they look to replenish an aging workforce. Amanda Miller met up with a group of the industry's young professionals to hear about their career inspirations and goals.

Workforce data suggests that, whether they like it or not, aerospace employers who want to succeed will need to rely on the talents of millennials, the generation of people about 20 to 35 years old who grew up with the internet and are sometimes disparaged as easily bored, prone to job hopping and impatient for promotion.

The average age of an aerospace worker was 46 in Aviation Week's 2017 Workforce Study. Workers older than 55 outnumbered those under 35. Employers have no choice but to turn toward millennials, and they are starting to do so. In the 2017 Workforce Study, employers planned to target 28 percent of new hires straight out of college. The year before, new grads amounted to 16 percent of new hires.

The good news for employers is that the common view of millennials appears more than ever to be a stereotype, an oversimplification that does not hold up to scrutiny. Like all human beings, millennials are prone to maturing, and at times they even show signs of settling down. Here are some insights about millennials based on the views of some who attended a November discussion about their generation organized by AIAA's Rocky Mountain section.

Inspiration — and internships — attract college students to the industry

Earlier generations were inspired by the Apollo and space shuttle programs. Millennials sometimes find their passions by circuitous routes.

Magens Orman was an art major at Metropolitan State University of Denver without much direction, and the degree required a science elective.

"I picked the least-miserable-sounding science credit that I could, and that was Intro to Space," Orman says.

"The professor told me that if I wanted to pass the class, I had to put up a balloonsat, and that it was going to have to record data. And that was horrifying to me because 'I don't do science.'

"And we got the thing back, and it took pictures — and it was like getting hit in the face by the universe. It was a moment where my life diverged."

She graduated in 2014 with a bachelor's in aerospace systems design and now works as an engineering technician for Sierra Nevada Corp. She loves that her job includes aspects of NASA's new Mars rover.

"The prospect that this thing is going to another planet, and I built it, is overwhelmingly beautiful to me — that I have the opportunity to expand human reach for the species, for the planet. … And that may be a little bit of an ego trip, but it drives me, and I think it's wonderful."

For Chris Pumford it was a sorority sister at Colorado School of Mines who urged her to apply for an internship at United Launch Alliance.

"My grand plan was to go into automotive engineering because 'Cars — there's always going to be cars.' That was what I was sure I wanted to do," she says. Following "one really uninteresting internship," she took her sorority sister's advice. The ULA internship that came next was at Vandenberg Air Force Base, California.

"I was doing launch operations there, and it was the coolest experience of my life," Pumford says. "I was pretty sold after that."

"Bored" doesn't totally capture this millennial tendency

What may be perceived as boredom, or impatience, could be the opposite if the anecdotes — and the

STALLED

In terms of their numbers, women in the aerospace world haven't made headway over the last 10 years, according to Aviation Week's 2017 Workforce Study. Women made up 24 percent of the total workforce and 15 percent of engineers, down from 26 percent of the workforce and up from 12 percent of engineers a decade earlier.

Metropolitan State University of Denver

▲ **Engineering technician** Magens Orman talks to students at her alma mater's Introduction to Space class.

data — are any indication.

"Millennials are very mission-driven," says Pumford, now a full-time structural engineer at ULA hired in 2017 after graduating with her bachelor's. "We're very passionate about whatever mission we're given."

Keeping her engaged now are the engineering problems that come up day to day.

"I'm a design engineer, so I send a lot of hardware to production, and if they have problems, they'll call me. And it's always something interesting, something new, something really different or weird. … I love the little problems like that. It makes it fun, and it really makes you use your brain. …

"I feel like the millennials I've interacted with in aerospace, they're more inclined to be doing more, to be taking on more projects, to be more interested in what they're doing."

Orman, the former art major who is now at Sierra Nevada, says a feeling of "restlessness" can arise work-

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– Chris Pumford,
structural engineer at
United Launch Alliance

Joe Meyer, a staff engineer at Answer Engineering in Englewood, Colorado, says he thinks "a big hallmark of our generation is everybody wants to feel very unique." Photo by Alyson McClaran

PERSPECTIVE ON THE NEW SPACE (JOB) RACE

Millennials may or may not think "Elon Musk is a god," as one panelist at an AIAA-Rocky Mountain section's event put it. Either way, the SpaceX founder's influence — and that of companies such as Blue Origin and Virgin Group — are undeniable. From the millennial perspective, "They're making space cool again," another said.

The new companies have also acquired a reputation among industry recruits for being less risk-averse — having less "scar tissue" from past failures.

The commercial space boom "has had a huge influence on people coming into the industry," says Will Pomerantz, vice president of special projects at Virgin Orbit. "Space has always had that appeal, but for a long time, it was hard for people to understand that it's an industry you can actually work in."

While that was the case, he suspects it lost talent to the tech industry — the likes of Google, Facebook and Amazon "with a very well-established reputation for what it's like to work there."

He's been involved in his company's campus outreach and has unique insight into the incoming aerospace workforce thanks to his role co-founding a nonprofit fellowship program that places undergraduate interns throughout the industry.

He's learned that young professionals need to keep an open mind about where they apply — that small companies can offer big experience.

"For any given person, some of these companies will be a much better fit than others."

Virgin Orbit is the Virgin Group's new company focusing on small satellites. "We are a smallish company that is well funded and moving quickly. … When there are fewer other people around, it means every individual gets more responsibility."

To fend off restlessness or frustration — owing in no small part to a lifetime of connectivity — it's often about providing that instant challenge.

"They definitely are exposed to a lot more information," Pomerantz says. "They have it all at their fingertips."

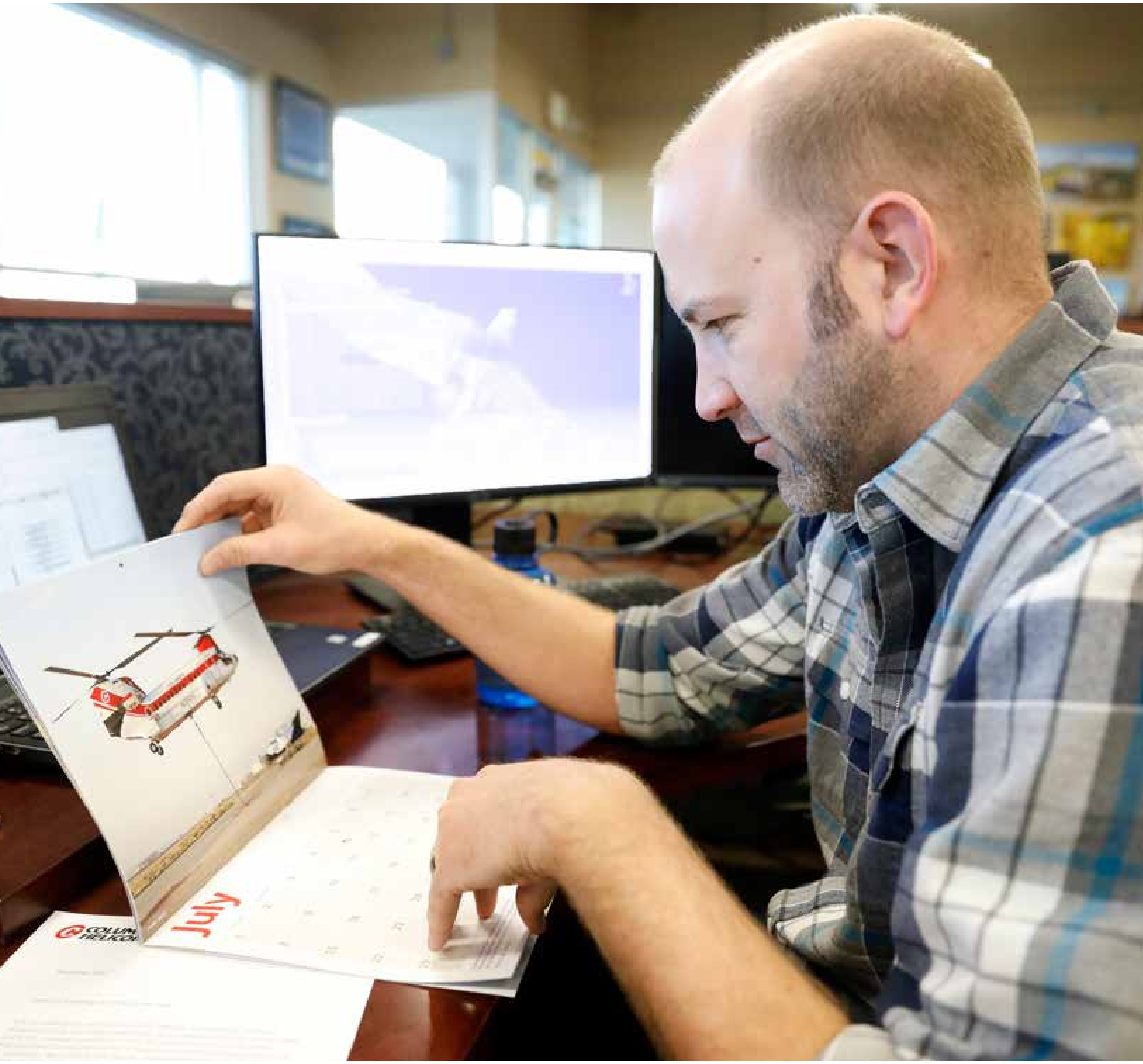
The downside to this instant information gratification is that they may get frustrated when the data is just not there — or when processes seem to hold up progress — and "that frustration needs to be channeled."

However, the defining characteristic he perceives is unquestionably a positive:

"The best students today are better than they've ever been before. By the time they finish school, they know so much more and have done so much more than someone my age ever did."

For more on the Brooke Owens Fellowship Program co-founded by Will Pomerantz — and good advice for students on landing any internship — go to https://goo.gl/Ymkhw2.

— Amanda Miller



▲ **Senior structures engineer Stephen Floyd** has worked at Answer Engineering since 2015.
Photo by Alyson McClaran

ing on one project, in the same role, for several years, after having steadily progressed all throughout school.

"That's, I think, a common millennial theme," Orman says. "Then you get to your job, and you start, and in Year 3, you're still working on the same program. [You feel like] 'Why haven't we moved forward? Why is this taking so long?'"

Desire for a tougher technical challenge can end in a job hunt

Turnover, according to the Workforce Study, was highest in 2017 among the 27- to 34-year-olds, who most often went after new challenges or promotions.

"I feel it, too, after a couple of months," Orman says. "I don't think there's a solution — you have to climb the corporate ladder — but I think it's recognition of what it is that you're feeling toward it" that's called for in those times.

Young professionals surveyed in the 2017 Workforce Study were most attracted to new jobs by technological challenges and placed heavy emphasis, when it came to accepting a job, on "an ongoing challenge" and the "ability to feel valued in contributing to meeting company targets."

To Joe Meyer, a new staff engineer at Answer Engineering in Englewood, Colorado, "being surrounded by total airplane nerds" is good enough for now. As a self-proclaimed guy who just really likes airplanes, so does working on a space plane.

"I think a big hallmark of our generation is everybody wants to feel very unique and feel like they're doing something special," Meyer says.

"And I think a big challenge with the current state of the aerospace industry, especially the space side of it, is that a lot of the things we're doing are not far off from what conventionally has been done."

They're a generation keen to innovate.

"We get restless, especially when we're bogged down by a lot of these heritage requirements where we didn't see it fail. We won't know what went behind it. We don't have that 'scar tissue,' and so to us, it seems really excessive, and it's really frustrating," says ULA's Pumford.

"But I think that companies are really starting to see that, and we're starting to accept more risk. As we do that, we allow for more innovation, and I think that allows for millennials to contribute a lot to the company."

The ability to quickly acquire expertise is another draw.

"Because [today] we have a lot better systems in place, we have a lot better knowledge transfer, and so, it's becoming easier for entering employees to get that expertise in something," Pumford says.

Co-workers who job-hop — switch companies quickly or frequently, chasing titles or a new challenge — seem to foster less confidence among company leaders, "a sense that, 'I'm not going to train you on this really expensive system because there's too much risk that you're going to take that someplace else and I'm going to have to start over with another person,'" says Orman, the technician at Sierra Nevada.

"My first initiative would be to try to move within a company, especially if you like your company."

When helping bring on new engineers at Lockheed Martin, John Marcantonio lets fellow millennials know they probably won't get promoted a lot right out of the gate and tries to give them a sense of the pace of the work — managing the frustration by managing expectations. He graduated with a master's in aerospace, aeronautical and astronautical engineering in 2015 and went to work for Lockheed Martin the same year. Now he's a propulsion engineer.

Newness appeals to the new generation — but they don't want everything virtual

Angel Abbud-Madrid, director of the Colorado School of Mines' Space Resources Program and moderator of the Rocky Mountain panel, challenged the millennials in the audience and on the stage:

"You mentioned video games, being bored, switching fields and careers — these are all things that we associate with millennials," he said. "The idea that you like to work with somebody face-to- face is something we don't usually associate with your generation." The common view is that digital-savvy millennials "don't want to put their hands on any real hardware" and they prefer to work remotely.

Video games? Cue the simultaneous affirmative.

But a disconnect with fellow humans and physical hardware? Not so much.

"I know a number of people across all age groups have really taken advantage of the new technologies such as working virtually. I personally prefer bothering people, like my co-worker … and just going and sitting in his cube until he answers my question," says Marcantonio of Lockheed Martin. "I'd just rather be personal with somebody."

He struck a reverential tone when referring to his colleagues who have been in the industry for decades.

Joe Meyer, who is a student pilot as well as a budding engineer, had his own take on the millennial mindset.

"There's just so much cool stuff going on out there. … Why would you want to do the same thing for 10 years of your realistically 35-, 40-year working career? Why make more than a quarter of your career one program? …

"Just whatever interests you, why not chase all of it?"

Meyer says he just hopes pilots are required in the cockpit long enough that someday he gets to take off from an airport runway in an airplane, fly to space, and land back on a runway. ★

STAYING POWER

Attrition was down by half among workers with five or fewer years on the job, according to Aviation Week's most recent Workforce Study, dropping from 21 percent in 2009 to 10.5 percent in 2017.

Earth's best defense

If a dangerous meteoroid were discovered on a collision course with Earth, there would be no time for political correctness. What's the best defense? Michael J. Dunn makes the case for going nuclear.

I strongly disagree with Aerospace America's characterization of the nuclear option against dangerous near Earth objects as a "Hail Mary" that would have "little chance of averting disaster." The article "Course Correction" [October 2017] states that the kinetic impactor is preferred "because the technology for doing it is the most mature."

Let's subject the nuclear and kinetic impactor options to a comparison based on the history of technology and some back-of-the envelope calculations.

A credible threat: For sake of discussion, let's imagine that a body analogous to the meteoroid that formed the Barringer Crater in Arizona (1.2 kilometer diameter, 0.17 km deep) was detected 2 astronomical units from Earth, and its trajectory showed it to be on a collision course with Earth. That means our notional target would be a hunk of nickel-iron 50 meters in diameter with a volume of 65,450 cubic meters. Let us say that our approaching meteoroid has an average density of 8,400 kg/cubic meters, and therefore a mass of 549,780,000 kilograms, and a linear momentum of 3.421 x 10^{12} kg-m/sec.

Interceptor requirements: Let us first look at the interceptor that would be needed for either the nuclear or kinetic impactor option. Let's postulate that we have the means to intercept this meteoroid when it reaches 1 astronomical unit, a distance equivalent to that from the Earth to the sun or 149,597,870 kilometers. The escape velocity of this interceptor would need to be 11.186 km/sec, and it would need an additional 6.222 km/sec to reach the object at 1 au. This means the interceptor would need a total propulsive delta-velocity of 17.408 km/sec. Time to intercept (calculated by dividing 1 au by 6.222 km/sec) would be 278.3 days.

If the first engagement were a "miss," or some other kind of failure, we would have 139 days of flight time for a second shot. (We now have warning at a distance of 1 au, so an intercept with the same closing velocity would occur at 0.5 A.U., for half the previous flight time.) If that failed, we would have 69 days of flight time for a third shot. This desire for multiple shots is one constraint on such an interceptor launch vehicle, which may strongly influence the practicality of the kinetic technique that I discuss next.

A kinetic impactor: In order to assure that the meteoroid would not hit Earth, it should have its trajectory deflected by at least Earth's radius of 6,378 km; let us say 10,000 km for a round number with some margin. Roughly speaking, this would convert to a transverse, or sideways, velocity perturbation of 0.416 m/sec. The kinetic impactor would, therefore, need to impart a momentum perturbation of 228,661,760 kg-m/sec. Even in the unlikely hope that this could be accomplished by a head-on collision, this would require an impactor (or flock of impactors) massing 36,750 kilograms. This (plus an end-game propulsion system) would need to be launched by a vehicle about the payload capacity of the Apollo-era's Saturn V rockets.

Also, there is no assurance that the kinetic impact would be transmitted to the entire mass of the meteoroid. It is possible that the impactor might simply split the meteoroid instead of perturbing its trajectory. And, if the meteoroid were only an agglomeration of material, the impactor might simply pass through with minor interaction.

A nuclear device: Let us suppose we could deliver a nuclear device like the Soviet-era Tsar Bomba hydrogen bomb of 100 megatons yield, weighing 27,000 kg, at a range of 0.1 to 1.0 km. Approximately half the yield would be available as radiation (X-ray photons) of sufficient energy to ionize the surface material of the meteoroid and form a thin plasma. (The other half of the yield is usually considered to comprise the kinetic energy of the bomb plasma. In space, this would have little effect.) The thin plasma would be inertially confined to a layer of maybe 1 mm thickness. Because of this confinement, the energy deposition would go into heat, temperature, and thus pressure across the surface of the meteoroid exposed to the nuclear blast. The direction of this force is therefore determined by the relative position of the nuclear device at detonation.

The exposed area of the meteoroid would be approximately 1,963.5 square meters, leading to a total force application between 3.229×10^{12} and 3.229×10^{10} newtons for 0.1 msec. This means the nuclear device can accomplish the momentum perturbation if detonated at a distance slightly greater than 0.1 km. In this case, because the "X-ray slap" is a whole body interaction, it would be effective even against an agglomerated meteoroid. The material facing the detonation would be impelled into the material behind.

And, because the Barringer meteorite was vaporized by its impact, it stands as a logical conclusion that a 10-megaton nuclear warhead detonated on impact would likewise vaporize a similar meteoroid. As a reference point, the W53 warhead for the LGM-25C Titan II reportedly had a yield of 9 megatons and a weight of 2,800 kg.

It bears mentioning that we have had experience detonating high-yield warheads in outer space. The U.S. detonated the HARDTACK-Teak and Orange devices in 1958 (3.8 megatons each). In 1962, we detonated Starfish Prime (1.4 megatons). We have also shown the ability to deliver anti-ballistic missile warheads to orbital altitude, as when the LIM-49A Spartan missile in 1975 delivered a W71 nuclear warhead to a 560 km ceiling (though the warhead was not tested operationally).

A reasonable conclusion: Our notional meteoroid threat could, only in theory, be resolved by a massive kinetic impactor, requiring propulsive maneuvers in the end game to achieve the required transverse momentum perturbation, with unknown terminal effects. On the other hand, it could also be solved with a nuclear detonation at close range on a passing trajectory, using technology that is over half a century old. It is fair to say that the nuclear solution is the "most mature."

My overall concern is this: It is starkly apparent that the nuclear detonation approach has the most timely and most powerful prospect of achieving the desired end of repelling a true planetary threat. As an engineer conscious of the lives depending on the technical solution, I find the dismissal of nuclear detonations to be highly negligent. I will say candidly that a "politically correct" approach would invoke the Outer Space Treaty as a barrier to their use. This would be a suicidal denial of what is needed for the human race to survive. The treaty would need to be abandoned or changed to permit this defense. High-yield nuclear devices must be designed, fabricated and tested in space. Launch vehicles must be prepared and placed in readiness. Surveillance systems must be constructed and operating. It is not acceptable to waste time with solutions that have a low prospect of success. ★

As an engineer conscious of the lives depending on the technical solution, I find the dismissal of nuclear detonations to be highly negligent.

Michael J. Dunn
is an AIAA senior member. He retired from Boeing in 2016 after a 40-year career that included engineering work on the Brilliant Pebbles strategic defense concept and kinetic energy weapon concepts.

AIAA Bulletin

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

Calendar

Notes About the Calendar

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2018			
1 Feb	DirectTech Webinar—Introduction to Computational Aerodynamics	Virtual (aiaa.org/onlinelearning)	
22 Feb	DirectTech Webinar—UAV Conceptual Design & Testing Using Computer Simulations	Virtual (aiaa.org/onlinelearning)	
8 Mar	DirectTech Webinar— Introduction to Uncertainty Quantification and Industry Challenges	Virtual (aiaa.org/onlinelearning)	
21 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (aiaa.org/CVD)	
1 May	2018 Fellows Dinner	Crystal City, VA	
2 May	Aerospace Spotlight Awards Gala	Washington, DC	
3–10 Mar †	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	
26 Apr	DirectTech Webinar—Electric Aircraft Design Fundamentals: Enabling Technologies and Analysis Methods for More-, Hybrid-, and All-Electric Aircraft	Virtual (aiaa.org/onlinelearning)	
8–10 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum) Featuring: – AIAA Missile Sciences Conference – AIAA National Forum on Weapon System Effectivenss – AIAA Strategic and Tactical Missile Systems Conference	Laurel, MD	30 Nov 17
28–30 May †	25th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru)	
28 May–1 Jun	SpaceOps 2018: 15th International Conference on Space Operations	Marseille, France (Contact: www.spaceops2018.org)	6 Jul 17
4–8 Jun†	DATT (Defense & Aerospace Test & Telemetry) Summit	Orlando, FL (www.dattsummit.com)	
25–29 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – AIAA/CEAS Aeroacoustics Conference – AIAA Aerodynamic Measurement Technology and Ground Testing Conference – AIAA Applied Aerodynamics Conference – AIAA Atmospheric Flight Mechanics Conference – AIAA Atmospheric and Space Environments Conference – AIAA Aviation Technology, Integration, and Operations Conference – AIAA Flight Testing Conference – AIAA Flow Control Conference – AIAA Fluid Dynamics Conference – AIAA/ASME Joint Thermophysics and Heat Transfer Conference – AIAA Modeling and Simulation Technologies Conference – AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference – AIAA Plasmadynamics and Lasers Conference	Atlanta, GA	9 Nov 17
25–29 Jun†	15th Spacecraft Charging Technology Conference (SCTC)	Kobe, Japan (Contact: http://www.org.kobe-u.ac.jp/15sctc/index.html)	
3–6 Jul†	ICNPAA-2018 - Mathematical Problems in Engineering, Aerospace and Sciences	Yerevan, Armenia (Contact:: www.icnpaa.com)	
9–11 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – AIAA/SAE/ASEE Joint Propulsion Conference – International Energy Conversion Engineering Conference	Cincinnati, OH	4 Jan 18
12–13 Jul	AIAA/IEEE Electric Aircraft Technologies Symposium	Cincinnati, OH (aiaa.org/eats)	15 Feb 18
19–23 Aug†	2018 AAS/AIAA Astrodynamics Specialist Conference	Snowbird, UT (www.space-flight.org)	

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

AIAA Continuing Education offerings

AIAA Symposiums and Workshops

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
17–19 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition) Featuring: – AIAA Complex Aerospace Systems Exchange – AIAA International Space Planes and Hypersonic Systems and Technologies Conference	Orlando, FL	8 Feb 18
1–5 Oct†	69th International Astronautical Congress	Bremen, Germany	
2019			
7–11 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – AIAA/AHS Adaptive Structures Conference – AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Dynamics Specialists Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – AIAA Non-Deterministic Approaches Conference – AAS/AIAA Space Flight Mechanics Meeting – AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – AIAA Spacecraft Structures Conference – Wind Energy Symposium	San Diego, CA	11 Jun 18
3–5 Apr†	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (Contact: www.eurognc19.polimi.it)	
27–29 May†	26th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru/icins2019/en)	

Class of 2018 AIAA Associate Fellows Honored

The Class of 2018 AIAA Associate Fellows were inducted at the AIAA Associate Fellows Recognition Ceremony and Dinner on 8 January at the Gaylord Palms, Kissimmee, FL, in conjunction with the AIAA SciTech Forum.

CLASS OF 2018 AIAA ASSOCIATE FELLOWS

Region I Class of 2018 Associate Fellows

Region II Class of 2018 Associate Fellows

Region III Class of 2018 Associate Fellows

Region IV Class of 2018 Associate Fellows

Region V Class of 2018 Associate Fellows

Region VI Class of 2018 Associate Fellows

Region VII Class of 2018 Associate Fellows

AIAA Announces Its Class of 2018 Fellows And Honorary Fellows

AIAA has selected its Class of 2018 AIAA Fellows and Honorary Fellows. The induction ceremony for the new Fellows and Honorary Fellows will take place at the AIAA Aerospace Spotlight Awards Gala on 2 May 2018 at the Ronald Reagan Building and International Trade Center in Washington, DC.

Honorary Fellow is the highest distinction conferred by AIAA, and recognizes preeminent individuals who have had long and highly contributory careers in aerospace and who embody the highest possible standards in aeronautics and astronautics. The 2018 Honorary Fellows are:

H. Norman Abramson, Southwest Research Institute (retired)

Charles Elachi, Jet Propulsion Laboratory, California Institute of Technology

Antony Jameson, Stanford University

AIAA confers the distinction of Fellow upon individuals in recognition of their notable and valuable contributions to the arts, sciences or technology of aeronautics and astronautics. The 2018 Fellows are:

Nancy F. Andersen, Johns Hopkins University Applied Physics Laboratory

Supriya Banerjee, FAMES

Olivier A. Bauchau, University of Maryland

Marty K. Bradley, The Boeing Company

Edward L. Burnett, Lockheed Martin Corporation

Carissa B. Christensen, Bryce Space and Technology, LLC

Jonathan E. Cooper, University of Bristol

James E. Graf, Jet Propulsion Laboratory

Michael A. Hamel, Lockheed Martin Corporation

Vlad J. Hruby, Busek Co. Inc.

Parimal H. Kopardekar, NASA Ames Research Center

Eugene Lavretsky, The Boeing Company

Sankaran Mahadevan, Vanderbilt University

Mark D. Maughmer, Pennsylvania State University

Robert E. Meyerson, Blue Origin LLC

Dava Newman, Massachusetts Institute of Technology

Robert W. Pitz, Vanderbilt University

Stephen A. Rizzi, NASA Langley Research Center

Hannes G. Ross, IBR Aeronautical Consulting; EADS Military Aircraft (ret.)

Robie I. Samanta Roy, Lockheed Martin Corporation

Steven P. Schneider, Purdue University

Steven D. Young, NASA Langley Research Center

In 1933, Orville Wright became AIAA's first Honorary Fellow. Today, AIAA Honorary Fellows and AIAA Fellows are the most respected names in the aerospace industry. For more information on AIAA's Honors Program, or the AIAA Honorary Fellows or Fellows Program, please contact Patricia A. Carr at 703.264.7523 or triciac@aiaa.org.

2018 AIAA Key Issues and Recommendations

As the world's largest aerospace technical society, serving a diverse range of nearly 30,000 individual members from 85 countries, and 95 corporate members, AIAA urges Congress to enact and sustain policies that will enhance a robust, technologically-proficient aerospace and defense (A&D) sector essential to our continued national competitiveness and security.

The A&D industry is critical to our nation's well-being, providing major contributions to national defense and homeland security, the economy, our quality of life, and education and learning. According to the Aerospace Industries Association, in 2016 the sector:

- Supported more than 2.4 million jobs (845,500 directly employed) and 13 percent of the nation's manufacturing base
- Generated nearly $872 billion in sales revenue and $422 billion more from the industry's supply chain
- Created a total economic contribution of $307 billion, or 1.8 percent of the GDP
- Provided tax revenue of $62.6 billion to federal, state, and local governments
- Exported a record $146 billion in goods, which is 10 percent of all U.S. exports
- Provided a top net-exporting industry with a positive trade balance of $90.3 billion

Each year, AIAA develops a set of key issues that become the focal point of the Institute's engagement with Congress, the administration, and state and local officials. We strongly believe these issues, including associated actionable recommendations, are crucial to the continued health of our industry and of our nation. As we strive to represent our membership and our industry, we also welcome and encourage feedback—our motive is to strengthen our profession and serve as a valued resource for decision makers.

Funding Stability and Competitiveness

The A&D industry is facing one of its greatest challenges in history as Congress and the administration grapple with mounting national debt and balancing the federal budget. At the same time, our adversaries are investing heavily in military modernization, while the United States confronts significant strategic risks due to continuing funding uncertainty and the use of arbitrary budget caps through sequestration.

Moreover, the usage of continuing resolutions, passage of omnibus appropriations packages, and threat of government shutdowns have become commonplace. Congress has not funded the federal government by the start of the new fiscal year in over 20 years. This unpredictable fiscal environment creates short-term perspectives, increasing the risk of delayed aerospace initiatives and the constant threat of important programs being terminated or scaled back to suboptimal levels. A return to a regular appropriations process coupled with a long-term perspective is needed immediately so that the nation, including the A&D industrial base, can begin work on initiatives critical to a secure and economically robust future.

Recommendations:

- Permanently eliminate sequestration.
- Provide the DOD with stable and predictable funding that supports efficient and effective multi-year acquisitions and operations—critical to readiness and results.
- Provide long-term authorization and appropriations with top-line increases in the out years to properly fund all NASA missions in a balanced manner in order to meet short- and long-term program and mission requirements. This will help maintain our nation's leadership in space exploration and scientific discovery, while also making critical advances in aeronautics research and technology development.
- Provide long-term authorization and appropriations with top-line increases in the out years to properly fund the FAA in order to successfully implement the Next Generation Air Transportation System, commercial space transportation operations, safely integrate unmanned aerial vehicles into the National Airspace System, and complete other high-priority FAA modernization initiatives.
- Provide a trade policies and regulatory environment that assures that U.S. companies can effectively compete in the global marketplace.

R&D and Innovation

U.S. leadership in aerospace, as in any other industrial sector, is not a birthright. Since the dawn of aviation, through the advent of the space age, and the most recent rise of new space opportunities, the United States has been the world leader in the aerospace industry. In order to assure U.S. leadership—such as during the Cold War-era Space Race—both government and industry have stepped up to their respective responsibilities to fund and perform research and development (R&D) through which a myriad of aerospace-related innovations have been realized.

Despite the recent uptick in government funding for R&D to support the A&D industry, the overall trend has been downward. While the United States still represents nearly half of global aerospace R&D spending, our foreign competitors—including China, Japan, and some Europe countries—continue to aggressively invest significantly more than the U.S. in technologies critical to aerospace and defense. Sufficient and sustained R&D investments are therefore crucial to maintain our preeminence in this sector. Just as important is moving technologies from the laboratory into the marketplace through innovative new products and services which fuel growth, exports, and expanded employment.

Recommendations:

- Sustain existing funding levels and invest in new experimental (ground and flight testing) and computational infrastructure for military and commercial R&D. This will help ensure improved quality and reduced systems-development costs and timelines by providing the right tools for qualified staff to identify and remove defects early in the development process.
- Provide sufficient and stable funding for federal labs specifically charged with helping industry accelerate innovation and develop products in critical areas, such as advanced materials, robotics, manufacturing processes, and battery and other clean-energy technologies.
- Promote greater interaction and cooperative arrangements between federal labs and research centers, academia, and industry to develop technologies which are needed for innovation and growth. Additionally, adopt a holistic approach to encourage the sharing of ideas, enhanced utilization of capabilities, improved quality from using the right tools, and optimization and cost-control at the national level.
- Offer incentives for corporate research and commercialization of that research into new products and services.
- Increase DOD's R&D budget to provide sufficient funding to ensure the United States maintains long-term technical leadership and qualitative technical superiority.
- Support robust, long-term federal civil aeronautics and space research and technology initiatives funded at a level that will ensure U.S. leadership in aeronautics and space, which includes technology demonstrations.

Workforce Development and Enhancement

The U.S. A&D industry currently enjoys a prominent position in terms of global competitiveness and technical superiority. However, there are justifiable concerns about its future standing as the industry faces impending retirements; a shortage of highly trained technical graduates; an underrepresentation of women and minorities; significant delays in processing security clearances, often exceeding 24 months; and increasingly serious competition from both allies and adversaries.

According to *Aviation Week & Space Technology's* 2017 Aerospace & Defense Workforce Study, nearly 30 percent of the nation's A&D workforce is over the age of 55 and 22 percent are younger than 35. The percentages of ethnic minorities and women working in A&D, at less than 25 percent, have not changed significantly in four decades, despite a major shift in the demographics of the United States. Moreover, only 16 percent of 12th graders are proficient in math and have expressed interest in a STEM-related career.

Recommendations:

- Continue to pass legislation that enhances the pipeline of STEM-competent workers into the U.S. economy, including initiatives aimed at underrepresented demographics.
- Craft legislation that will bolster economic competitiveness and job opportunities in the A&D industry, and encourage education and training programs required for both the existing workforce and new entrants.
- Incentivize industry and the military to be more directly engaged with evaluating and hiring transitioning military personnel, such as creating a standard to process and categorize military skill sets.
- Ensure federal incentives and/or grants are readily available to support industry, government, and academic partnerships that tailor training for high-level skills, professional education opportunities, and provide research-focused collaborations.
- Pass visa legislation that encourages the retention of foreign professional STEM workers in U.S. industry.
- Reform the security review process to expedite clearances, and ensure the implementation of an effective system that protects sensitive information and utilizes advanced technology to appropriately manage risk.

Register Now for CVD 2018

Don't Miss a Chance to Make a Difference for Aerospace!

Registration is open for any AIAA member who would like to attend the 2018 Congressional Visits Day (CVD). Attendees will gather on 21 March in Washington, D.C. to promote the Institute's Key Issues. A training webinar will be held 21 February and a formal, in-person training session will take place 20 March at Boeing's facility in Arlington, Virginia.

Register at **aiaa.org/cvd2018**

For more information about the event, please contact Steve Sidorek, AIAA Public Policy, at steves@aiaa.org or at 703.264.7541.

AIAA Rocky Mountain Section 6th Annual Technical Symposium

by Wesley Kenison

On 17 November, the AIAA Rocky Mountain Section hosted its 6th Annual Technical Symposium (ATS) at Metropolitan State University (MSU) of Denver. This was the first year that the event was held at MSU Denver, and through generous university support, the event went fantastically well.

The symposium broke with tradition and separated its formerly unified technical theme into four tracks, giving attendees the ability to select aeronautics, astronautics, unmanned aircraft systems, or advanced manufacturing as the focus of their day's events. In addition to the separate tracks, plenary sessions, expert panels, and an exhibit hall filled with booths and interactive displays from 17 event sponsors were also available to attendees. In addition to its section website, aiaa-rm.org, the Rocky Mountain Section also added a new website (www.aiaa-rm.tech) dedicated to the symposium.

Some of the highlights of this year's symposium included: a presentation by Congresswoman Diana DeGette (D-CO 1st District), a drone delivery demonstration by the AIAA Colorado School of Mines Student Branch, a 3D fly-through of the Lockheed Martin-designed Deep Space Gateway, and a keynote presentation on the development of the Mars Base Camp by DSSI President Stephen Bailey.

Each track also featured a panel of industry experts giving attendees the chance to ask questions and take a deeper dive into the policies and programs shaping these industries. Panel topics included The Effects of Advanced Additive Manufacturing on Engineering Development Cycles, Airport Mapping and Maintenance using UAS, and a Young Professionals Panel highlighting the challenges and opportunities for young people just starting their aerospace careers. A new feature this year, certification testing for AGI's Systems Tool Kit (STK) software, was also conducted, giving attendees the chance to add an industry certification to their resumes.

One of the things that continues to set this event apart from so many similar events throughout the industry is accessibility to a broad range of industry participants, from Fortune 500 vice presidents and congressional delegates to collegiate students and eager new hires. ATS has a history of strong planning and close ties to the community, which was highlighted this year by the partnership between AIAA and MSU Denver. ATS Committee Chair Wesley Kenison was able to bring together nearly 100 students, faculty, and staff from across the university to help make the event successful. University organizations for Aviation and Aerospace, Hospitality Tourism and Events, Brewing Science, Restaurant Management, Events Management, The Advanced Manufacturing Sciences Institute, Marketing and Communications, and The Center for Advanced Visualization and Experiential Analysis all participated to turn this event into a truly unique experience for attendees and event sponsors.

In addition to the symposium activities, the event organizers held a sponsor recognition dinner the evening prior. This event featured five beers specially crafted for the event to celebrate the partnership between AIAA and MSU as

Figure 1. A boxed lunch arriving via drone. Photo by A. Pickett

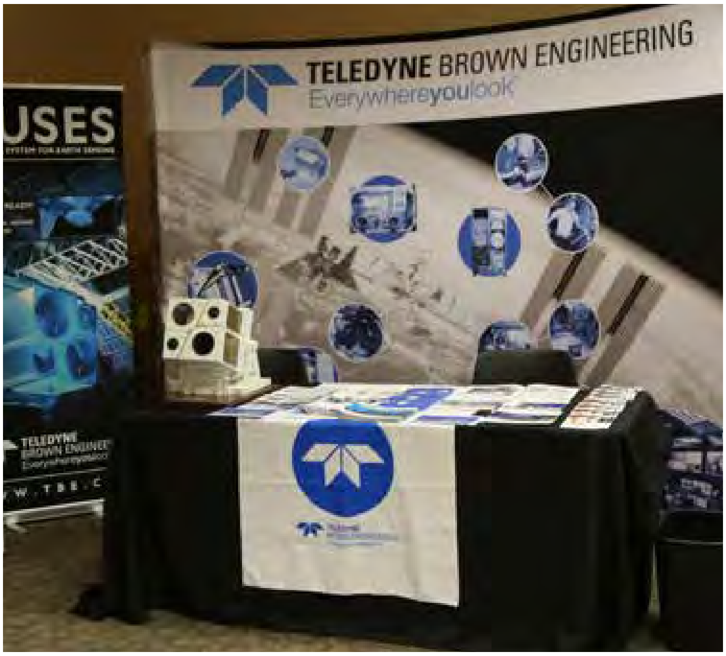

Figure 2. One of the many interactive booths in the Exhibit hall. Photo by A. Pickett

well as their shared love for all things aerospace. The culinary program prepared dozens of amazing treats and paired these to the small batch brews, taking guests on a taste extravaganza demonstrating the university's top-notch programs. "This is the first time in the history of the department that three major programs – brewing science, restaurant management, and event management – came together to plan and produce an event," said Andrea Peterson, affiliate faculty.

The decoration and event management for both days was handled by the Hospitalities, Tourism, and Events Program's Advanced Planning and Risk Management class, who also provided a 50+ page risk management plan to ensure the safety and security of all guests.

Not only did this year's symposium turn out great, MSU Denver is excited to apply the lessons learned this year to making next year's symposium even bigger and better.

Figure 3. MFG panel

2018 Space Systems Technical Committee Essay Contest

AIAA and the AIAA Space Systems Technical Committee invite you to participate in their annual National Essay Contest for students in 7th and 8th grade through AIAA sections.

THEME

In 2017, NASA selected 12 new astronaut candidates. Describe the role of astronauts and their impact on NASA, their impact on the future of the United States, and their impact on international partnerships.

REQUIREMENTS

- Double-spaced, typewritten (size 12 font) essay, in 1,000 words or less
- Student name, teacher name, grade, and school name must be written in the top right-hand corner of the essay
- Include student and teacher name, phone, email, and mailing address for notification and awards

JUDGING CRITERIA

- Originality of ideas presented
- Soundness of logic used to develop ideas
- Realism of ideas presented
- Quality of composition and clarity of expression

  (Note: All decisions by the judges are final)

NATIONAL PRIZES

At each grade level: Certificate of recognition + Essays published by AIAA at a national level

1st place: $100 award + $500 for their science classroom; 2nd place $50 award; 3rd place: $25 award

Each student will receive a one-year free membership with AIAA

ELIGIBILITY

Any seventh or eighth grader (or equivalent). Please contact your local section officers (aiaa.org/RegionSectionMap.aspx) to confirm that they will be running the contest and accepting entries. Entries accepted by "at-large" students through Jeff Puschell, jjpuschell@raytheon.com

DEADLINE

Final submission deadline to local AIAA section officers is 31 March 2018. Local winners and their teachers will be notified in April. National winners and their teachers will be notified in May.

QUESTIONS

Email Anthony Shao and Erica Rodgers (ant.shao@gmail.com, erica.rodgers@nasa.gov)

2018 International Student Conference Winners

The AIAA Foundation International Student Conference takes place annually at the AIAA SciTech Forum. Students who have won first place in the Regional Student Conferences have a chance to present their papers at a professional technical conference. The conference offers the students a chance to showcase their research at an event where they can network with potential employers and colleagues. The 2018 International Student Conference was held on 8 January in conjunction with the AIAA SciTech Forum in Kissimmee, FL. Thank you to The Boeing Company for sponsoring the 2018 International Student Conference.

Ben Linder, The Boeing Company; Shelly Corbets, chair, Student Paper Competition; and AIAA President Jim Maser presented the awards to Rhiannon Kirby, Calvin Buechler, and David A. Coleman.

Undergraduate Division

Rhiannon Kirby, Monash University (Region VII-AU), was awarded the prize for her paper entitled "Tomographic Background-Oriented Schlieren for Three-Dimensional Density Field Reconstruction in Asymmetric Shock-containing Jets."

Undergraduate Team

Calvin Buechler, Kevin Faggiano, Dustin Fishelman, Cody Gondek, Lee Huynh, Aaron McCusker, William Sear, Himanshi Singhal, Craig Wenkheimer, and Nathan Yeo, University of Colorado Boulder (Region V), were awarded the prize for their entry entitled "Project REPTAR: REcoverable ProTection After Re-entry." Calvin Buechler accepted the award.

Graduate — Master's

Carolyn M. Walther and David A. Coleman, Texas A&M University (Region IV), were awarded the prize for their paper entitled "Understanding Unsteady Aerodynamics of Cycloidal Rotors in Hover at Ultra-low Reynolds Numbers."

For more information on the AIAA Foundation International Student Conference, please contact Rachel Dowdy at 703.264.7577 or racheld@aiaa.org.

Dr. Ella M. Atkins Appointed as New Editor-In-Chief of the *Journal of Aerospace Information Systems*

On 11 January, AIAA President James Maser formally appointed Dr. Ella M. Atkins as editor-in-chief of the *Journal of Aerospace Information Systems (JAIS)*. Dr. Atkins is an exceptional educator and researcher who is committed to the study of flight software systems, aerospace information systems, and autonomy. Currently she is a Professor in the Aerospace Engineering Department at the University of Michigan where she has been innovative and influential in moving a traditional aerospace engineering department in new directions. She is also the Associate Director of Graduate Programs at the University's Robotics Institute.

An AIAA Associate Fellow, Dr. Atkins has made significant contributions to the Institute, including serving on the Intelligent Systems Technical Committee and the Software Technical Committee. She also serves as the faculty advisor for the AIAA University of Michigan Student Branch, and was a founding organizer of the AIAA Infotech@Aerospace conference. She holds B.S. and M.S. degrees in Aeronautics and Astronautics from the Massachusetts Institute of Technology, and M.S. and Ph.D. degrees in Computer Science and Engineering from the University of Michigan.

Atkins will be the fourth editor-in-chief of the journal. She has been an advocate for *JAIS* since its inception and has served as an associate editor for the journal. The journal was launched in January 2004 under the title *Journal of Aerospace Computing, Information, and Communication*, reflecting the growing importance of computing and information systems to aerospace engineering. *JAIS* led the way as AIAA's first online-only journal with a goal of rapid publication of all articles. Atkins succeeds Dr. Ashok Srivastava, who has served as editor-in-chief of *JAIS* since 2012. During Srivastava's tenure, the journal scope was revised and the title changed to its current form, further refining the journal's place in the industry.

Looking toward the future, it is clear that Dr. Atkins's unique background in aerospace information systems will serve to enhance the quality, rigor, and reach of *JAIS*.

Obituaries

AIAA Associate Fellow Herty Died in October

Dr. Charles (Chuck) Holmes Herty died on 6 October.

After beginning college at the University of North Carolina, Chapel Hill, Herty entered the U.S. Navy in 1943, rising to the rank of Aviation Radioman on the U.S.S. *Midway*. He returned to college in 1946 and graduated with a B.S. in Chemistry in 1948. Dr. Herty received his M.S. and Ph.D. degrees in Chemistry by 1953 while teaching Freshman Chemistry. He then went to work at Phillips Petroleum on solid rocket propulsion development.

He remained with Phillips for 32 years, with the majority of his time spent in the Research and Development Laboratory. Dr. Herty became the Manager of the R&D Department, and later Technical Director of Tactical Propulsion. While employed he was awarded three patents for solid rocket propulsion technology. The plant went through many ownership changes, and when Dr. Herty retired in 1987, it was called Hercules.

He served over 40 years on the Board of the Central Texas Science and Engineering Fair, retiring as Program Review Team Chair Emeritus. Dr. Herty was a member of several scientific organizations, including the American Chemical Society and AIAA.

Fellow Przemieniecki Died in November

Dr. Janusz (John) S. Przemieniecki died on 29 November, at the age of 90.

Born in Poland, he joined the Warsaw underground at the age of 15 and participated in the Uprising of 1944. He resumed his education in England in 1946, graduating from the University of London (Bsc., Msc., and a 1958 Ph.D. in Aeronautical Engineering), with a specialization in Structural Analysis. He worked at the Bristol Aircraft Corporation with key roles in design of a Mach 3 fighter and the SST, later to become the Concorde.

He emigrated to the United States in 1961, and took a position on the faculty of Mechanics at the Air Force Institute of Technology. He earned recognition as a pioneer in FEA. His text (*Theory of Matrix Structural Analysis*, 1968, McGraw-Hill) became a standard reference in the industry and was used in over 30 universities through 14,000 copies in 11 printings, translation to Japanese, and a paperback reprint in 1985. After several years as the Associate Dean for Research, he was chosen as Dean of the School of Engineering in 1969, and served for 20 years. From 1989 to retirement in 1995, he served as the Institute Senior Dean and Scientific Advisor.

Dr. Przemieniecki was an AIAA Fellow and received the 1992 Pendray Aerospace Literature Award and a 2002 AIAA Sustained Service Award. He was also the Editor-in-Chief of the AIAA Education Series (1984–2001). In addition to editing over 60 books in that series, he authored two: *Mathematical Methods in Defense Analysis* (1990, 1994, 2000) and *Finite Element Structural Analysis: New Concepts* (2009). He also was the volume editor of *Acquisition of Defense Systems* (1993).

His many honors and awards include Presidential Ranks of Distinguished Executive and Meritorious Executive, Commanders Cross of the Polish Order of Polonia Restituta, and Air Force Decoration for Exceptional Civilian Service.

1918

Feb. 16 A Zeppelin-Staaken R.VI biplane drops a 1,000 kilogram bomb on the Royal Hospital in West London. It is the largest bomb dropped so far during the war. David Baker, **Flight and Flying, A Chronology**, p. 106.

Feb. 17 As the Tsarist Russian government collapses, the Imperial Russian authorities burn 30 Sikorsky Ilya Muromets four-engine heavy bombers to prevent their capture by advancing German troops. David Baker, **Flight and Flying, A Chronology**, p. 106.

Feb. 18 The American members of the Lafayette Escadrille are transferred to the U.S. Army Air Services as the 103rd Aero Squadron, bringing their wealth of combat experience to the U.S. war effort. John Morrow Jr., **The Great War in the Air**, p. 336.

1943

Feb. 7 Prime Minister Winston Churchill arrives home after traveling nearly 16,000 kilometers in a specially adapted Consolidated Liberator named the "Commando." The tour included a meeting in Adana, Turkey, with President Franklin Roosevelt, stops in Cyprus and Egypt, and a review of troops in Tripoli. **The Aeroplane**, Feb. 12, 1943, p. 180.

Feb. 9 Malta-based Spitfires bomb Axis targets in Sicily, Italy, and North Africa using bomb racks made out of metal from crashed German bombers. **The Aeroplane**, Feb. 19, 1943, p. 210.

Feb. 11 British Air Marshal Sir Arthur Tedder arrives in North Africa on a Boeing B-17 Fortress from England to lead Allied air forces in the Mediterranean. He will control air strategy in the North African theater, but air operations in Northwest Africa are under the direction of U.S. Gen. Carl Spaatz. Both men report to the new commander of the North Africa Command, U.S. Gen. Dwight Eisenhower. **The Aeroplane**, Feb. 19, 1943, p. 210, and Feb. 26, 1943, p. 240.

Feb. 12 Curtiss-Wright announces delivery of its Curtiss SO3C-1 Seagull long-range scout to the British navy's air arm. Powered by a 520 horsepower Ranger motor, Seagull is renamed Seamew by the British after a local breed of gull. **The Aeroplane**, Feb. 19, 1943, p. 210; **Aviation**, March 1943, p. 277.

Feb. 13 The Vought F4U Corsair fighter makes its combat debut when several of the planes escort U.S. Navy PB4Y Liberator bombers during a raid on Bougainville, Papua New Guinea. Gordon Swanborough and Peter Bowers, **United States Navy Aircraft Since 1911**, p. 450.

Feb. 16 Pan American Airways initiates night flights in Latin America on its Los Angeles-to-Mexico City route. This service enhances the war effort by cutting a day off the flying time between vital war activities on the U.S. West Coast and the strategic Canal Zone. **Aero Digest**, March 1943, p. 481.

Feb. 17 The 10th German A-4 rocket (later known as the V-2) makes a test flight of 20 kilometers from the secret Peenemunde rocket research center. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 44.

Feb. 18 Edmund Allen, called "the greatest test pilot of them all," dies with 10 other people while on a test flight over Seattle in the new Boeing XB-29 Superfortress. Allen was Boeing's director of flight and chief of its research division. He tested other companies' planes, most recently the Lockheed Constellation. He is posthumously awarded the Daniel Guggenheim Medal for "notable achievement in the advances of aeronautics." **Aviation**, March 1943, p. 280.

Feb. 25 Wing Cmdr. Raymond Duke-Wooley becomes the first British Royal Air Force officer to be awarded the American Distinguished Flying Cross. He earned this distinction for the many successful operations he conducted over enemy territory while the commander of a fighter group temporarily assigned to U.S. forces. **The Aeroplane,** March 5, 1943, p. 263.

1968

Feb. 3 A new British Petrel sounding rocket is launched from the South Uist Range, on the second-largest island of the Outer Hebrides, in Scotland. Its experiments gather data about high-speed electrons from space that continually bombard Earth's upper atmosphere. At high latitudes this bombardment becomes so intense that it produces the aurora, or northern lights. **Flight International**, March 14, 1968, p. 387.

Feb. 4 Britain's SR.N4, short for Saunders-Roe Nautical 4, hovercraft makes its first excursion off the English seaport of Cowes on the Isle of Wight. It is the largest hovercraft built to date. Hovercraft are hybrid air-cushion-propelled vessels operated by a pilot as an aircraft rather than a captain as a marine vessel. Built by the British Hovercraft Corp., formed from the merger of the British aero- and marine-engineering Saunders-Roe Limited company and Vickers Supermarine company, the SR.N4 is designed to carry 254 passengers in two cabins and has a four-lane automobile bay that holds up to 30 cars. It is powered by four Rolls-Royce turboprop engines that each drive a set of 6-meter-diameter steerable propellers that are the world's largest. The control cabin of the SR.N4 resembles the flight deck of an aircraft and the flying controls also appear broadly similar to a typical aircraft. The first SR.N4 enters commercial service in August between Dover and Boulogne, France, and remains in service until 2000. In 1971 it is featured in the James Bond movie "Diamonds Are Forever." **Flight International**, Feb. 29 , 1968; Robin Paine and Roger Syms, **On a Cushion of Air: The Story of Hoverlloyd and the Cross-Channel Hovercraft**, pp. 249, 297.

Feb. 15 The British Royal Navy's first Polaris missile firing is made from the HMS Resolution, about 48 kilometers off Cape Kennedy, Florida, and carries a dummy warhead that impacts 2,415 km downrange. **Flight International**, Feb. 23, 1968, p. 249.

During February 1968

- The first production model of the Beech Model 99 is rolled out from Beechcraft's plant at Wichita, Kansas. Powered by two United Aircraft of Canada PT6A-20 turboprop engines, the unpressurized, 15- to 17-passenger aircraft becomes highly popular and upon its introduction, 15 U.S. and 10 foreign airlines order it. **Aviation Week**, Feb. 19, 1968, p. 58.

- Thomas Paine, above center, who was appointed deputy administrator of NASA on Jan. 31, is confirmed by the U.S. Senate. Upon the retirement of NASA Administrator James Webb on Oct. 8, Paine is named acting administrator of NASA and then is nominated as NASA's third administrator on March 5, 1969, and confirmed by the Senate on March 20. **Aviation Week**, Feb. 12, 1968, p. 21.
- The convertible cargo/passenger "Super DC-8" Series 63, DC-8-63CF aircraft makes its first flight, from the Long Beach Municipal Airport in California. The transport carries a maximum 51,165 kilograms of cargo or 259 passengers. During this initial flight, the DC-8 reaches 39,000 feet and a top speed of Mach 0.9. **Aviation Week**, April 1, 1968, p. 27.
- The possible manned Apollo lunar landing sites are narrowed to five by NASA after a study of photographs from the Lunar Orbiter and Surveyor unmanned programs. The top two are both within the Sea of Tranquility and this region is later chosen for the first manned landing for the Apollo 11 mission. Among the selection criteria are that the site be a smooth area, with relatively few craters and large boulders, and provide an approach path without high hills or cliffs that could cause erratic altitude signals for the landing radar. **Aviation Week**, Feb. 12, 1968, p. 26.
- Bunker Hill Air Force Base, Indiana, is renamed Grissom Air Force Base in memory of Air Force Lt. Col. Virgil Grissom, one of the three American astronauts who died in the Apollo AS-204 spacecraft fire during a pre-launch test in January 1967. **Flight International**, Feb. 22, 1968, p. 278.

1993

Feb. 4 The first solar sail, the Znamya space mirror, is deployed by the unmanned Russian Progress 15 tanker after it undocked from the Mir space station. The umbrella-shaped sail is 20 meters in diameter and made of aluminum-coated Kevlar to reflect sunlight. The reflected light is seen on Earth as Progress orbits 482 kilometers overhead. The deployment of the sail is a test only. Its potential includes as a means of space propulsion for interplanetary craft, using the sun's photon energy to provide low but steady thrusts. **Flight International**, Feb. 17-23, 1993, p. 19.

Feb. 9 The Satellite de Coleta de Dados or Data-Collecting Satellite, known as SCD-1, is placed in orbit by an air-launched Pegasus rocket. SCD-1 is a remote sensing satellite to observe air quality and tide levels in Brazil. This is the first international launch for Pegasus and Brazil's first remote-sensing satellite. **NASA, Astronautics and Aeronautics**, 1991-1995, pp. 317, 700.

Feb. 10 McDonnell Douglas delivers its 10,000th military jet aircraft to the U.S. Navy, an F-4 Phantom 2. The company's first jet, the McDonnell FH-1 Phantom, was made in 1945 and was the first American jet to land and take off from an aircraft carrier. **Flight International**, Feb. 3-9, 1993, p. 14.

ERIC JOYCE, 31

Project Manager, Made in Space

Growing up in Ohio, Eric Joyce watched Lockheed Martin C-130 transports fly over his house from a base in western Pennsylvania to a training range in eastern Ohio and wondered what they were doing, where they were going and how they remained airborne. In elementary school, Joyce saw the space shuttle launch from Cape Canaveral, which heightened his interest in all things that flew. After spending his early career as an engineer on military aircraft programs, Joyce joined Made in Space of Mountain View, California, in 2015. The company operates two 3-D printers on the International Space Station and is developing tools for additively manufacturing large structures, like telescopes or antennas, in microgravity.

How did you become an aerospace engineer?

As I worked through school, I studied advanced math and science, I found that was very satisfying to look at those kinds of problems. I also learned about everything that flew. That continued through college at Ohio State University. After I graduated, I went to work as an engineer for Booz Allen Hamilton, Dayton, Ohio, for six years. I was at the Air Force Research Lab, working on a variety of aircraft projects. I heard about what Made in Space was doing and said, “If we are ever going to get people into space, that is the company that is going to help do it.” An opportunity came up for me to take a role here, so I took it.

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

That’s something we talk about all the time around here. At Made in Space, we have a variety of optimists and pessimists. There’s one school of thought that says we’ll basically be doing the same thing we are now. We’ll have a space station that is perhaps run by a commercial consortium, so maybe you have a few more people in space than we have on ISS right now and we will be doing things focused on commercial space. Then you have the other end of the spectrum where you have the pure optimists who think we’ll have people on the moon, people possibly living on Mars and headed toward the asteroids. I’m probably closer to that more optimistic category. I think we’ll have a continued human presence in space. We’ll have some commercial space stations. We’ll have people living in space, conducting experiments and pushing beyond low Earth orbit. ★

By Debra Werner | werner.debra@gmail.com


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Every year, AIAA members—engineers, scientists, researchers, students, educators, and technology executives—travel to Washington, DC, for a day of advocacy and awareness with national decision makers. Spend a day meeting with new and established congressional members and their staff.
Your participation, enthusiasm, and passion remind our lawmakers that aerospace is a key component of an economically strong and secure nation. If you are interested in the future of your profession, the advancement of technology, the furthering of scientific research, and the strengthening of our nation's security, this event is for you!
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