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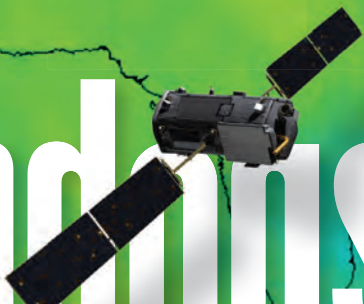
CO_2 Watchdogs



Monitoring carbon dioxide emissions from orbit could someday hold polluters accountable. Will the US participate?

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AIAA
Shaping the Future of Aerospace

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This is Volume 55, No. 1.

AIAA
Shaping the Future of Aerospace

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Tom Risen
is a journalist and researcher whose reporting on policy, science, and tech business has appeared in US News & World Report, Slate, and The Atlantic.
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Joe Stumpe
is a freelance writer based in Wichita, Kansas. He wrote about the AAIA's Design/Build/Fly contest for college students in the June issue of Aerospace America.
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DEPARTMENTS

***Editor's Note:** These articles were accidentaly omitted from the December Year-in-Review issue.

Lockheed Martin

▲ **Lockheed Martin's** Quiet Supersonic Transport (QueSST) concept

The other 4 percent

Here's something worth remembering during any presidential transition: The first A in NASA stands for aeronautics. Research in that area accounts for only 4 percent of NASA's budget, but those dollars have an outsized impact on the daily lives of taxpayers.

Many of us would love to fly from point A to B faster (See "Flying fast, flying quiet" on page 8), on the most efficient route possible, with fewer delays, propelled by engines that won't choke on ice and that fly with the least possible environmental impact. NASA is working with the aviation industry and in some cases the FAA to achieve all those objectives.

Some of what's been accomplished so far is visible when looking out the terminal window. Many airliners now have drag-reducing winglets. Damage-tolerant fan casings protect fuselages in the unlikely event an engine's blades fly apart. NASA's Aeronautics Research Mission Directorate has assembled a diagram depicting "decades of contributions to commercial aviation."

Depending on how one measures fuel efficiency, a Boeing 787 or Airbus A350 today is 50 to 70 percent more efficient than a Boeing 707, according to the forward to the forthcoming book, "Green Aviation: Reduction of Environmental Impact Through Aircraft Technology and Alternative Fuels."

My purpose in pointing this out is not to cry poor on behalf of aeronautics. My fear is that there is a risk of forgetting about this kind of work amid all the exhilaration that will come from peering back toward the origins of the universe with the James Webb Space Telescope; or making a space station near the moon; or mining asteroids for commerce; or walking on Mars or maybe even looking out a spacecraft's window someday and seeing Jupiter's Great Red Spot or the icy surface of Europa.

We are becoming extraterrestrials, and it is exciting. But it is also resource intensive. Forty-four percent of NASA's budget goes to Human Exploration Operations, including the International Space Station, Orion and the Space Launch System rocket; 29 percent goes to a long list of science projects, from assembly of Webb to developing the Mars 2020 rover to planning a robotic mission to Europa.

What is the right balance between aeronautics and space? Opinions will no doubt vary, but here's an argument for why today's balance might be about right. NASA maintains a separate Space Technology research category, and it makes up 4.3 percent of the budget. That's not much more than the 4 percent that goes to aeronautics research. In that sense, there is parity and perhaps one that should be maintained. ★

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

The Section of the Future

The role of associations has changed enormously in the 21st century, and AIAA is one of many societies that need to make sure that we continue to support our members in the most effective ways possible. Over the past 18 months, the Region and Section Activities Committee (RSAC), which governs Section activities, has worked with the AIAA's Sections to define the Section of the Future. In this way, Sections will continue to support you, our members, right in your neighborhood.

The work, which I presented to the Board of Directors in September, resulted in nine important attributes that all Sections should strive for, with actions to help in fulfilling each attribute.

Sections enjoy support from local corporate members and industry

Support may involve providing financial support, use of facilities, publicity, and overhead hours for employees to support the Section's operation. (Sample Actions: Map the Corporate Member locations to Regions and Sections; create a tip sheet of how companies can help Sections.)

Sections are closely linked to Student Branches in the same geographic area, with active involvement of university students in Section council and Section activities

The Section of the Future should offer channels of communication and means of collaboration to the students in their Section. (Sample Actions: Establish means of collaboration at Section activities as well as Student Branch events; visit students at their schools for a presentation/demonstration.)

Recognize and honor members for service and technical innovations, and put them forward for regional or national recognition

Sample Actions: Provide an easily accessible list of awards and see that the information is disseminated; provide a clear understanding of the awards.

Sections have a reliable set of IT tools for all Section activities

Tools should enable the Section complete management anytime, anywhere to help the Section function more efficiently. (Sample Actions: Survey Sections' needs for IT tools, and create a functional requirements list; demonstrate the benefits of the IT tools for Sections.)

Members see clear value in AIAA membership and can state the value proposition

Different members perceive different types of value from their membership based on varying ways of engagement, and all are important. (Sample Actions: Mentor members active in the local Sections and Regions on the value of membership at the Institute level AND vice versa; continue to evolve the Institute-level activities to include events in which Section members will find value.)

Diverse, well-rounded, well-organized programs

Programs should allow for the entire membership to participate in Section events, including a variety of topics such as arts in aeronautics/aerospace, history, financial planning, and related technical areas in other industries. (Sample Actions: Survey Section members for their interests to make them part of the decision process; find energized leadership to organize activities and have a solid succession plan.)

Diverse, inclusive, growing membership

Aim for a diverse representation of technical fields, interests, businesses and affiliations, gender, generations and ethnicity. (Sample Actions: Enlist local aerospace companies to encourage employees to join AIAA; empower young members and students by including them in Section activities and leadership.)

Sections are financially stable

A financially stable Section has the majority of resources, financial and non-financial, needed to accomplish its activities and programs. (Sample Actions: Define criteria and guidelines for acceptable financially stable conditions; create and disseminate guidelines on financial best practices and positive financial controls.

Section leadership rotates frequently, giving new volunteers new leadership opportunities

Members should be aware of new leadership and volunteer opportunities; volunteers should reflect various experiences, skill sets, interests, ages, genders, and employers. (Sample Actions: Announce open volunteer and leadership positions to all Section members and provide a list of current filled and vacant positions monthly to the membership; make personal contact to identify and encourage candidates.)

Many Sections already are successful in these areas—among others—and their members and volunteer leaders have been crucial in suggesting actions. Incoming RSAC Chair Laura Richard and committee members will continue this important work with headquarters staff, Institute leadership, and within the new governance structure, to modify these attributes and actions as member and Section needs evolve. But most of all Sections need your support and participation! We encourage you to attend an event, network with colleagues, exchange ideas, hear a great lecture, or join a Student Branch. The Section of the Future depends on all of us! Participation is power! ★

NASA/ESA

A year of milestones and changes in aerospace

BY P.J. BLOUNT AND CHRISTOPHER M. HEARSEY

The **Legal Aspects Technical Committee** fosters an understanding of legal areas unique to aerospace.

▲ **The crew of the** International Space Station poses in the Bigelow Expandable Activity Module, or BEAM, after it was filled with air in May.

Editor's Note:
These articles were accidentally omitted from the December Year-in-Review issue.

Calendar year 2016 proved to be another eventful one for the aerospace industry. The **Commercial Space Launch Competitiveness Act,** signed by President Barack Obama in late 2015, energized and provided much-needed legal clarity for the commercial space industry. The act provides for statutory rights to obtain space resources for exploration and utilization, adds a new category, "government astronauts," for future commercial launches of NASA crew; establishes exclusive federal jurisdiction for third-party and spaceflight-participant lawsuits for injuries; and mandates a dozen reports and studies on a variety of topics in advance of future policy discussions, including space traffic management, voluntary consensus standards and the status of remote-sensing licenses.

After a difficult period in the launch sector, a SpaceX Falcon 9 launched a Dragon cargo capsule to the International Space Station in April. The mission, Commercial Resupply Services-8, was an important milestone for SpaceX, which for the first time landed a Falcon 9 first stage on a drone ship, the **Of Course I Love You** stationed off Florida, and also for Bigelow Aerospace, whose unique cargo was secured in the trunk of the Dragon. The capsule delivered the Bigelow Expandable Activity Module, or BEAM, the first privately owned, commercial expandable habitat designed for human use. On May 28, NASA astronaut Jeff Williams managed the expansion of BEAM from its original packed configuration. BEAM will stay berthed to the aft port of the Tranquility module for approximately two years, during which time NASA will collect data from internal sensors monitoring radiation, temperature and micrometeorite impacts.

In September, the **House Committee on Science, Space, and Technology** held hearings with experts to discuss the issues with NOAA's licensing of proposed remote-sensing satellites. Reports of licensing denials, unprocessed license applications and licensing changes due to national security concerns in contravention to current law and policy have frustrated the commercial remote-sensing industry. Witnesses noted the need for reduced regulatory burden, adherence to current law and reform of the interagency process that governs NOAA licensing decisions. NOAA is expected to release its mandated study on its licensing processes soon, and some type of policy or statutory reform is anticipated in the near future.

It was also an interesting year for law and policy at the international level. The **United Nations Committee on the Peaceful Uses of Outer Space**, or UNCOPUOS, took two significant steps. In June, the committee reached consensus on 12 guidelines for the long-term sustainability of space. These broad guidelines are intended to give states a framework for engaging in space activities while ensuring the space environment is protected. These initial guidelines are the first of many and are slated to be presented to the U.N. General Assembly in 2018. Then, complementing the U.S. Commercial Space Launch Competitiveness Act, the Legal Subcommittee of UNCOPUOS adopted an agenda item on space resources. This means that in 2017, discussions will begin to heat up on what the U.S. act means at the international level.

Drones remained a hot topic in aerospace law in 2016, specifically the FAA's adoption of small drone rules for non-hobbyists. This rule requires drone operators to obtain a remote pilot certificate before operating a small drone. In addition to showing aeronautical knowledge, potential drone operators must also pass a background check administered by the **Transportation Security Administration**. While these rules will lead to safer drone operations, privacy questions still swirl around drones, which were highlighted by numerous incidents where individuals shot down drones over their property or in public places. In April, the FAA issued a statement that it was a federal crime to shoot any aircraft, including drones.

In both space and aviation, the **Brexit** vote has caused lots of consternation. As the United Kingdom removes itself from the European Union, governments and private industry will need to untangle how Brexit will affect international coordination of aerospace activities. Specifically, the effects of the U.K. leaving the single EU market is likely to have ripple effects across regulatory issues and bilateral cooperation. Going into 2017, the implications of Brexit will become clearer for the aerospace industry. ★

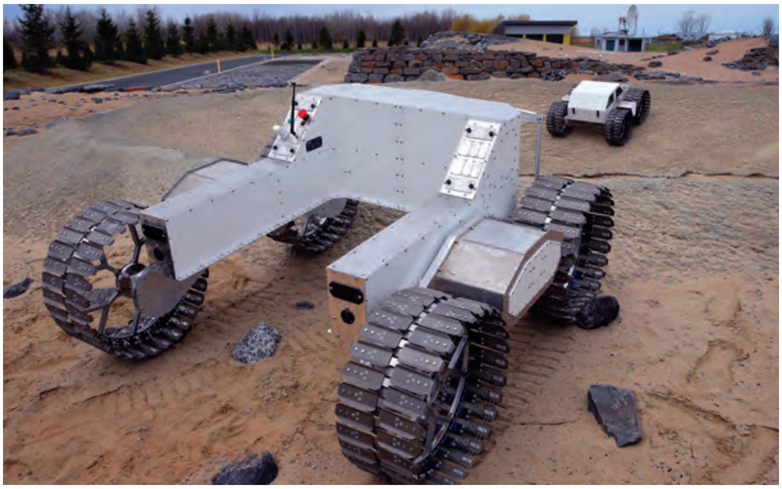
Testing resource utilization

BY JULIE KLEINHENZ

The **Space Resources Technical Committee** advocates affordable, sustainable human space exploration using non-terrestrial natural and discarded resources to supply propulsion, power, life-support consumables and manufacturing materials.

Growing interest in **in-situ resource utilization**, spurred activity in the space resources community in 2016. Lunar and Martian resources are of continued interest for human missions and outposts, and there is a growing focus on asteroid resources.

On the moon, the target resource is the water-ice that has been detected in permanently shadowed craters at the polar regions. Characterizing these resources is the focus of **NASA's Resource Prospector**, RP, rover mission and the European Space **Prospect drilling and sampling package** Technology development continues for these potential missions. In May, RP was put through its fourth thermal vacuum test at the NASA Glenn Research Center's Planetary Surface Simulation Facility. The drill (from Honeybee Robotics), the spectrometer (NASA's Ames Research Center), and sample crucibles (NASA's Kennedy Space Center) were tested with water-doped, frozen, lunar regolith simulant. These tests continue to refine hardware development, concepts of operations, and volatiles-detection methods. Meanwhile, the Canadian Space Agency accepted delivery of two lunar rover prototypes from contractor Ontario Drive and Gear. The larger one measures 1.6 meters X 1.6 m, has a mass of 112 kilograms, and a 1G payload of 160 kg, while the smaller 90 kg rover has a footprint of 1.2 m X 1.2 m and a 50 kg payload. Both platforms have a drivetrain that was subjected to dusty thermal vacuum testing at NASA's Glenn Research Center to achieve **Technology Readiness Level-6**.



▼ **The Canadian Space** Agency's Lunar Rover Drivetrain Prototype, foreground, and Small Planetary Rover Platform were driven across the agency's Mars yard near Montreal in 2016 to simulate conditions on the moon. Ontario Drive and Gear delivered the vehicles in April.

NASA's exploration plans are increasingly including ISRU. **NASA's Human Architecture Team** conducted system level studies to examine the impact of incorporating full-scale ISRU systems into human missions (namely the Evolvable Mars Campaign) using atmospheric and ground water resources. Likewise, the **Mars Water In-Situ Resource Utilization Planning** study led by NASA's Science Mission Directorate leveraged university, NASA, and commercial partners to identify potential Mars resources and the instruments and data still needed to fully characterize them for ISRU use. The NASA Capability Leadership Team continues to assess and plan for facilities and resources needed for future ISRU efforts, and a potential ISRU technology development program is in formulation under NASA's Advanced Exploration Systems.

NASA's Mars 2020 mission will include the **Mars Oxygen ISRU Experiment**, or MOXIE, payload that will demonstrate ISRU technologies to convert Mars atmospheric carbon dioxide into oxygen. Led by MIT, MOXIE completed instrument preliminary design review in January and is now working toward delivery in May 2018. Mars 2020 is the first mission that will fly an ISRU payload.

Asteroid resources are the focus of three university-led projects under NASA Early Stage Initiative awards, now in their second year. The **Robotic In-situ Surface Exploration System** (RISES) project at the University of West Virginia is looking at robotic systems and non-destructive tests for the strength of asteroid materials. At Missouri University of Science and Technology and the Colorado School of Mines, work is focused on volatiles extraction and capture, while Stanford University is examining characterization of asteroids using impact plasma detection.

On the commercial side, several companies are pursuing asteroid resources. Planetary Resources, Inc., PRI, has shipped their **A6 satellite**, a 6-unit cubesat that will demonstrate technologies to measure resources on water-rich asteroids, to Vandenberg Air Force Base with a scheduled launch date of late 2016. PRI also announced a partnership with the government of Luxembourg to advance technologies and businesses related to exploration and utilization of asteroid resources. Honeybee Robotics and the University of Central Florida developed a concept for a 6-unit cubesat that could extract water from hydrated asteroid regolith and use it to "hop" between asteroids via steam propulsion. In 2016, the extraction hardware for this cubesat recovered water from asteroid simulants during laboratory tests under a Small Business Technology Transfer project with Kennedy Space Center. ★

Flying fast, flying quiet

The curves and features of Lockheed Martin's supersonic X-plane model have specific purposes in the quest to show the feasibility of Mach 1-plus passenger jets. Keith Button spoke to the engineers who hope to fly this, or a similar X-plane, by 2020.

By Keith Button
buttonkeith@gmail.com

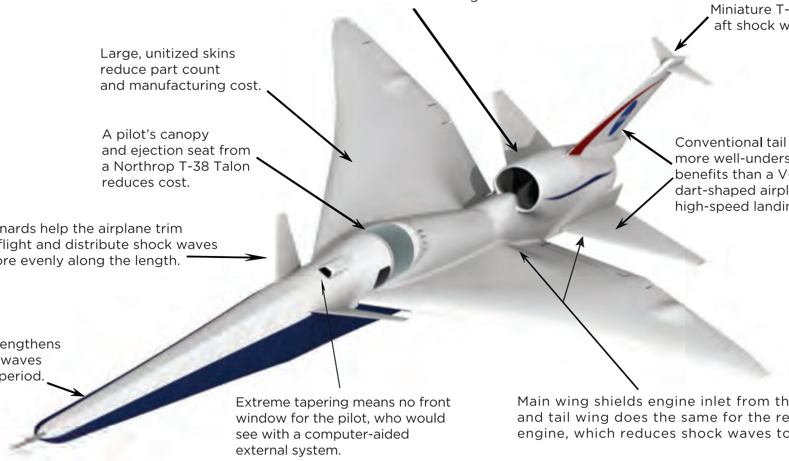
The path to the potential return of supersonic passenger flights travels through an artificial living room, specifically the Interior Effects Room at NASA's Langley Research Center in Virginia, better known as the boom room. It's furnished like a typical suburban American living room, with bookshelves, a flat screen TV and stereo, curtains, paintings on the wall, a coffee table, and a chair and couch. Here, starting in 2011, NASA engineers sat down test subjects to listen to and rate their annoyance from recorded and simulated airplane noise. Speakers pointed at the walls from the outside emitted a range of sounds based on recordings of supersonic F/A-18s, from muted thumps to sonic booms that rattled the fake windows.

This testing and other experiments dating to the 1980s helped engineers from NASA's Commercial Supersonic Technology Program decide just how quiet a future supersonic jet would probably need to fly to be accepted by the public and the FAA.

The FAA banned supersonic flights over land even before the supersonic Concordes began

▲ **Lockheed Martin's Quiet Supersonic Transport (QueSST)** concept seeks to produce a distant supersonic thump rather than a disruptive boom.

DAMPENING SHOCK WAVES



Innovations are evident from tip to tail in Lockheed Martin's wind tunnel model for a proposed X-plane to demonstrate quieter supersonic flight.

(Not shown: Landing gear from an F-16 to reduce cost)

their trans-Atlantic flights to the U.S. in the 1970s. The planes were not permitted to fly supersonically over the U.S. Most other countries also prohibit commercial supersonic flight over their territories. What's changed is that modern computational fluid dynamics and computing are providing confidence that engineers can shape an aircraft to deliver a vastly softer supersonic footprint. To prove it, NASA plans to hire a contractor to build a supersonic X-plane for a series of flights starting in 2020.

Wind tunnel tests are slated in February on a preliminary design crafted by Lockheed Martin Skunk Works, called QueSST, for Quiet Supersonic Transport. Engineers will install a 9-percent-scale model in a high-speed wind tunnel at NASA's Glenn Research Center in Ohio to see if the shape delivers the desired result. A preliminary design review will follow in June, and in August Lockheed Martin will deliver a flight simulator and additional QueSST models to NASA. After that, NASA plans to share the design and test data with the industry and hold a competition in 2018 for the right to build the single-pilot X-plane. It would be one of five X-planes NASA wants to fund under its New Aviation Horizons initiative.

The hope is that the flight tests will provide justification for lifting the ban on supersonic commercial flights over land, if the Trump administration has not already done so, as the transition team was reportedly considering. Airplane makers might then choose to make passenger jets that would cut current flight times in half. The first of the new class would be corporate jets or 100-passenger versions, but large airliners could follow if additional innovations are made.

Noise reduction

Supersonic airplanes typically produce a double-cracking noise of at least 95 A-weighted decibels, or dBA — a measure of loudness in the frequency range detected by the human ear. On the dBA scale, a pin dropping would be 10 dbA; whispering 25 to 30 dBA; normal human speech 60 to 70 dBA; a lawnmower 90 to 100 dBA; and a jackhammer 110 dBA.

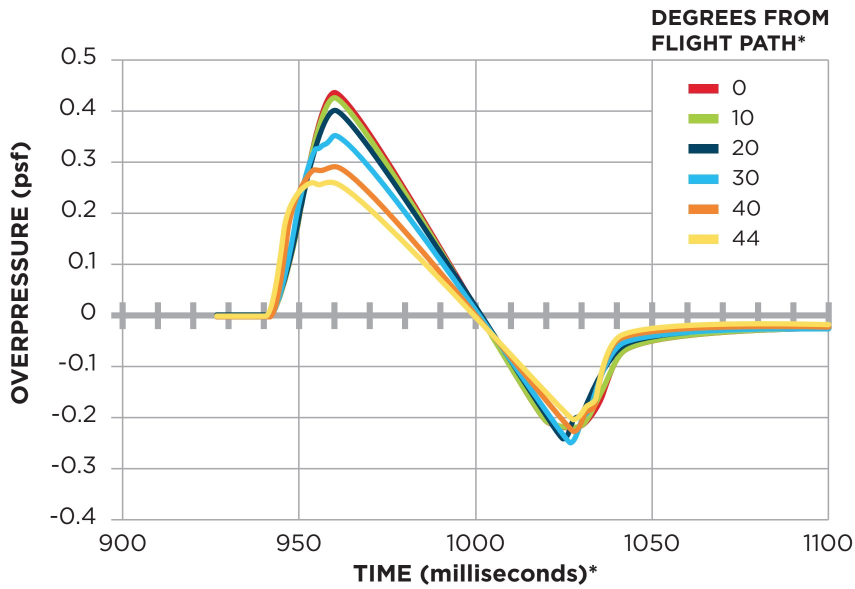
The audible portion of the X-plane shock wave would sound about like riding in a luxury car on a highway. The sound would not be noticeable above the noise of people conversing or a stereo at a low volume, engineers say.

"You get a thump, equivalent to if you get out of your car and your neighbor a few doors down gets out of his car and slams the door, you hear a thump. But it's not really a disturbing sound," says Peter Coen, who manages the Commercial Supersonic Technology Program at NASA Langle.

Lockheed Martin Skunk Works finished building the wind-tunnel scale model of its QueSST concept in December and planned to ship it to NASA Glenn. The Skunk Works designers in Palmdale, California, ran 9,000 potential solutions on the design to optimize it, says the company's Peter Iosifidis, program manager for the QueSST aircraft preliminary design.

Computer simulations show that the X-plane

SONIC HEARTBEAT



*Position of person on ground relative to aircraft

When air pressure beyond normal ambient is charted over time for Lockheed Martin's proposed supersonic X-plane, the result is a sine curve rather than the sharp N expected from a war plane. For someone on the ground, that means hearing a distant thump rather than a loud boom, engineers say.

would be a "low boom" aircraft peaking at far less than the 95 dBA sonic booms produced by the Concorde jets that stopped flying in 2003.

Lockheed Martin engineers demonstrated in 2011 that they could accurately predict the acoustic signature of a supersonic airplane, as designed on paper and proven by the actual noise produced by a different 9-percent model in a high-speed wind tunnel. That demonstration opened the door to computational fluid dynamics designing and optimizing without having to wind-tunnel test each iteration.

It's all in the shape

Any disturbance in the air flowing over a supersonic airplane creates a shockwave. Typically the nose, canopy, antennas, wings, tail and other protuberances create mini-shockwaves at different strengths moving at different speeds, and these small shockwaves pile up as they travel to the ground, combining into two large shockwaves, from the front and rear of the aircraft.

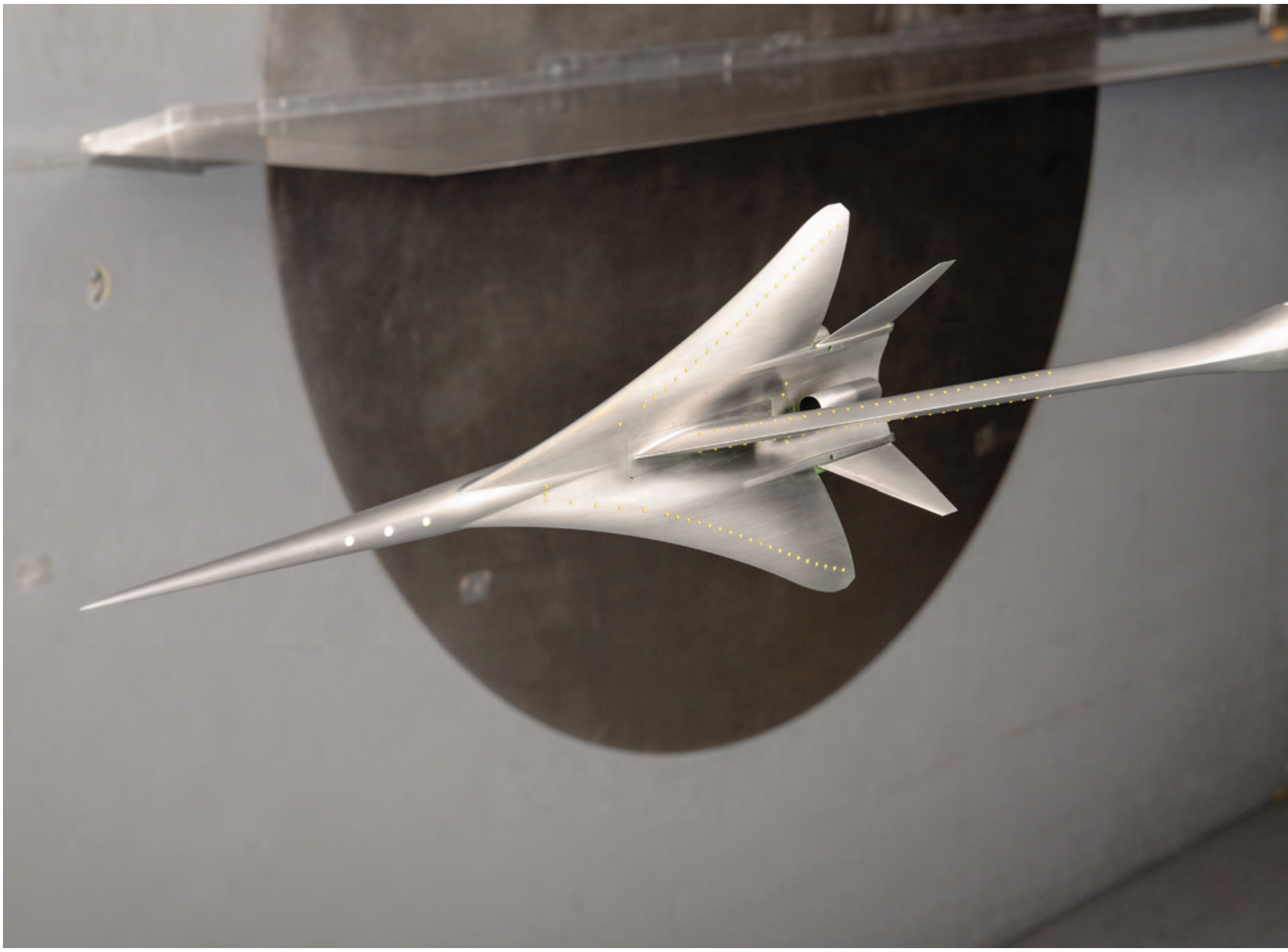
By shaping a plane to control the strength and position of the many small shock waves emanating from the body of a supersonic plane, designers can create shock waves that are relatively evenly spaced and equal in strength, so the waves don't coalesce and are more easily dispersed by the atmosphere as they travel to the ground, says NASA's Coen. Instead of the two sharp increases in air pressure and sound that mark a typical sonic boom for a listener on the ground, an airplane designed to control its sonic boom will create more gradual changes in air pressure that are less noticeable and therefore less annoying.

If one were to chart the pressure changes over time as heard on the ground beneath a conventional supersonic jet, the line would be shaped like an N. It would start at ambient level and rise sharply, then decrease to below ambient, followed by another sharp increase. The line for a controlled sonic boom would look more like an irregularly shaped sine wave than an "N," rising and falling more gradually. It would peak at 65 dBA or less, Coen says.

Lockheed Martin's designers drew up a plan for a plane whose noise signature, if charted, would be an irregular sine wave. The air pressure of individual supersonic shock waves weakens, and the waves spread over time. The plane's long pointy nose creates a weak bow shock, or initial shock. Lengthening the fuselage spreads the acoustic signature. The dart-like shape of the airplane and its extreme fuselage tapering eliminates the forward-facing window for the pilot, who views the front-facing scene through a computer-aided external vision system.

Small canards, or tiny wings, project from the fuselage in front of the main wings to help the airplane trim during flight. They also distribute shock waves more evenly along the length of the plane. The main wing shields the jet engine's inlet from the ground, reducing the shock wave emanating to people on the ground. A horizontal tail wing shields the exhaust end of engine for the same purpose. The airplane has a conventional tail wing arrangement, but also has a small T-wing that designers added not for airplane control, but to reduce the aft shock wave.

The 28.7-meter-long, 10,886-kilogram QueSST


NASA

would fly at Mach 1.4 at up to 55,000 feet. Future designers would draw on data from the computational modeling backed by wind-tunnel testing of the design. This data establishes how each feature of the design contributes to the plane's shock waves, Iosifidis says. Those designers could apply the same methods to design larger aircraft with the same noise level as QueSST, but the QueSST design won't simply scale up to a commercial passenger plane.

Beyond the shaping in the design, every component of the Lockheed Martin would be commercially available off-the-shelf or from salvage, Iosifidis says — a T-38 pilot's canopy and ejection seat; a modified Boeing F/A-18E/F Super Hornet jet engine; and the landing gear from an F-16. "There's no other technology, other than shaping, to actually achieve the noise signature."

Coen says that airplane designers could design, with shaping and currently available technology, a low-noise supersonic corporate business jet, or even a 100-passenger, 136,000-kilogram airplane.

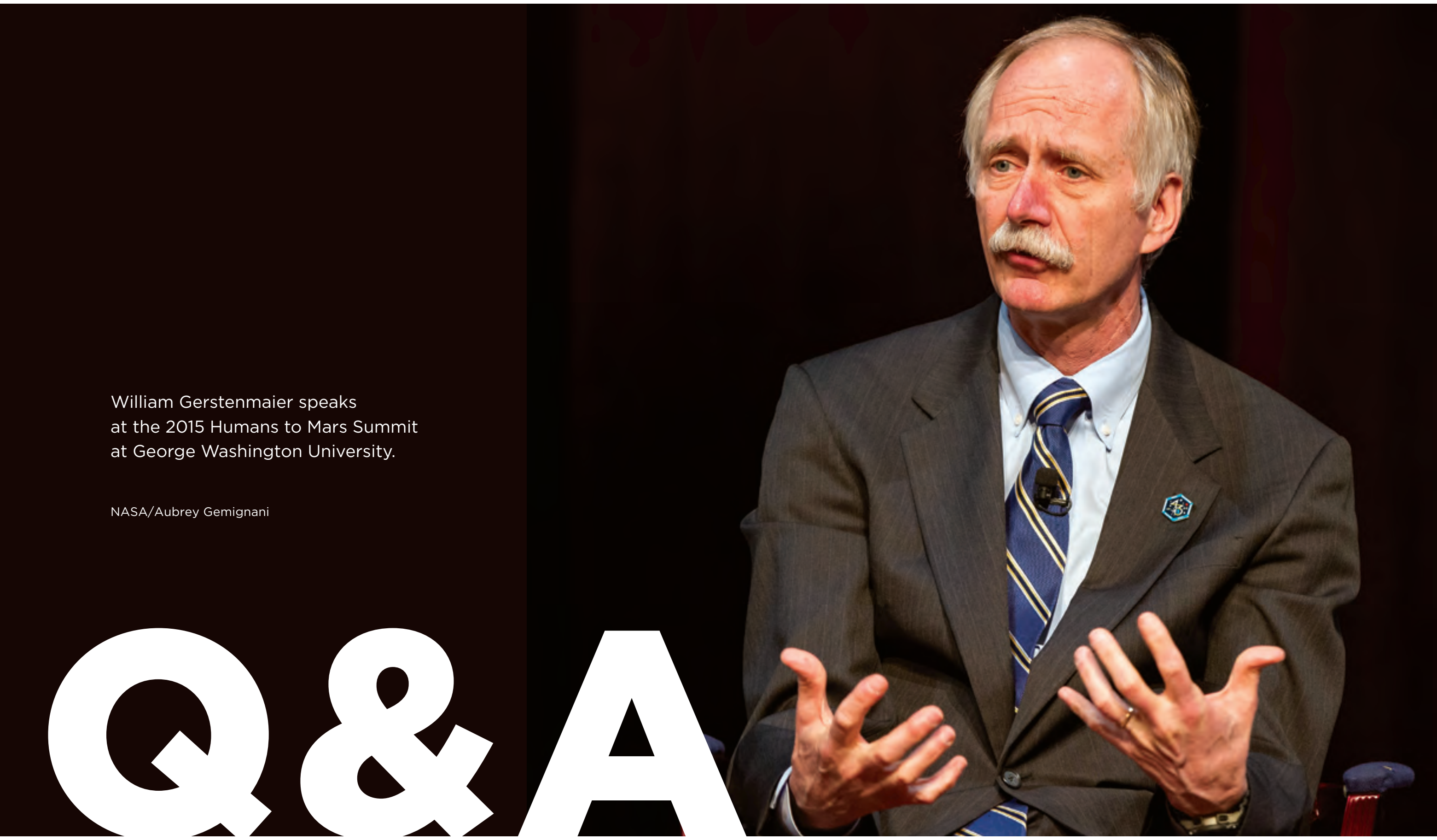
For a 200-passenger supersonic plane, shaping might not be enough. The weight of an airplane is an important component of its supersonic shock wave, because the larger the airplane, the larger the lifting surfaces, and the stronger the shock waves and the more difficult they are to manage. NASA's vision is that airplane makers will innovate once the supersonic market is re-opened, with the X plane as the starting point for technology that will evolve into supersonic airliners.

"If you solve the sonic boom problem, the market will open for supersonic business aircraft, some companies will enter that market," Coen says. "That will help further prove the technology and also open a market and develop an appetite for supersonic flight."

If airplane designers are to create a low-boom supersonic airliner capable of carrying 200-plus passengers, perhaps in 25 years, today's researchers will have to develop new ideas for modifying air flows around supersonic planes, Coen says.

"Could [shaping techniques] improve in 20 years? Maybe. But from my perspective, if we're eventually going to have an airliner, we need all of the technology," Coen says. Flow modification, along with other developing technologies, "needs to be explored at the fundamental level now, so 25 years from now it's ready for application in a practical product." ★

▲ **NASA windtunnel tests on a Lockheed Martin** model in 2011 gave confidence in the accuracy of noise predictions from computational fluid dynamics. The yellow dots on the model protrude from the surface slightly to produce turbulent flow when desired.



William Gerstenmaier speaks at the 2015 Humans to Mars Summit at George Washington University.

NASA/Aubrey Gemignani

Managing NASA's "special task"

More online aerospaceamerica.org

See the extended transcript for more about NASA's space exploration plans.

It's often said that those who don't know history are doomed to repeat it. That shouldn't be a problem for those in NASA's Human Exploration and Operations Directorate, given that the man in charge has been directly involved with decades of NASA's human space flight history.

What about the space shuttle-Mir negotiations and operations in the 1990s? Gerstenmaier managed them. Construction and assembly of the International Space Station? Gerstenmaier managed much of it. The phase out of the space shuttle? Gerstenmaier directed the final 21 shuttle missions.

These days, Gerstenmaier spends much of his time planning and defending NASA's future human exploration endeavors and the hardware necessary for them. A special concern is how to wring the most value out of the International Space Station while simultaneously, it is hoped, inspiring the private sector to build and operate a successor to it.

Gerstenmaier spoke to Ben Iannotta by phone during a layover on one of his many work trips.

WILLIAM H. GERSTENMAIER

POSITION: Associate administrator for human exploration and operations

NOTABLE: Spent much of his career in Houston. Was operations manager for the space shuttle-Mir program during the 1990s. In 1998, became program integration manager for space shuttle, then managed the International Space Station program during its critical construction and assembly period in the early 2000s. Moved to Washington, D.C., in 2005 to direct the final 21 space shuttle missions as associate administrator for space operations.

AGE: 62

RESIDES: Alexandria, Virginia

EDUCATION: Bachelor of science in aeronautical engineering from Purdue University; master of science in mechanical engineering from University of Toledo in 1981

Robotics versus human exploration

It's not that one is better than the other. We absolutely need both, but taking humans and actually placing them in this severe environment is a special task and it's a special role. It gives our population a chance to have an aspirational goal, or an inspirational goal. There's a special character that comes with human space flight. It's present in robotics, but I think it's more personal when you actually see human lives on the line and you're actually, you know, launching your friends and colleagues on rockets into space.

For the U.S., perseverance and soft power

What we've done by keeping our international crews on orbit for 16 years is pretty amazing. That's through the Columbia tragedy, through all those other activities. We've been able to keep this human presence in space. Two countries have done that really – Russia and the U.S. – and that also sets apart kind of a leadership or soft power role for human space flight. It differentiates us from other countries that have space programs but they don't really have a human space flight program and they don't have a human space program of depth and breadth. It's really important for our character as a nation.

Inspiring innovation

You hear many, many times, "If we can land on the moon we can do: Fill in the blank." The lunar landings really differentiated us as a nation, and said: There's nothing that's impossible. There's nothing that we can't do if we all work together internationally, and nationally too, to accomplish these tasks.

Team requirement: Total honesty

The thing I really like about human space flight is the fact that it's really a team effort. We can't say that it's really one individual. It takes the absolute best of all the team players. It takes everyone describing what they know and more importantly what they don't know, and being totally honest with each other and working together. If you look at what we're doing on space station, it is truly an international team activity.

Lifespan of International Space Station

From a pure engineering standpoint, we've done studies that show the physical hardware has a life at least until 2028. Current policy has us ramping down station operations in 2024. We're busy at looking at how we transition from this space station to other space activity.

Moving toward a privately run space station

The station that comes after the International Space Station may not be permanently crewed. It may be smaller, it might be a permanent space station, it may be transient. We'll let the private sector determine what best meets their needs and then they're free to go acquire that and build that on their own

There's nothing that we can't do if we all work together internationally, and nationally too, to accomplish these tasks.

For ISS, "precious" final years

It's 2017 now. We have roughly seven years until this end of mission for the space station as currently planned. Those seven years are pretty precious, so we're trying to expose a broad community of terrestrial researchers to the benefits of research on board the space station. Many physical properties change when they get exposed to microgravity. We see combustion in a different way. We see materials properties in a different way. We see genomics changing. We're trying to take terrestrial industry and terrestrial companies and expose them to these unique properties that occur in space and let them discover and be innovative. Trying to deal with combustion or genetics, they can look at this in the microgravity lens, which is different than the 1G lens to gain competitive advantage or a research advantage over others that are not engaging in this activity. Then hopefully they can use that knowledge to turn revenue around and actually make a profit from space activity. We're using the space station as a catalyst or an innovation engine to get other folks excited about what we've seen as interesting phenomena in space and then turn it over to the imagination of individual companies. Then ultimately they may want to have their own space station or facilities in the future.

Relationship with space station researchers

We're trying to expose an industry that doesn't have any exposure to space to this facility. So the fact that we help them with transportation to space station, the time that crew members spend and the data, I think that's really important, but we're also asking them to invest dollars in building the equipment that's going to fly on station. We don't pay for that equipment. We're asking also them to invest in putting intellectual property and imagination and creativity into these unique properties in space to figure out how they can generate revenue. That's not a trivial ask that we're asking them to go do.

Trending: commercial business in space

We're starting to see some interest from many companies [for example] pharmaceuticals. There's a commercial 3-D printing facility aboard station that they can use to investigate the properties of 3-D printing in space. Little pieces are starting. What's encouraging to me is that I'm starting to see these flickers of interest from other companies saying, "Hey, there is something here that's special. Maybe we can use this in a new way." ★

Correcting NASA's course

Ron Dantowitz/Clay Center Observatory

While we should expect a hard look at NASA from his administration, President-elect Donald Trump should resist the temptation to overturn the agency's human exploration initiatives. Instead, he should give NASA the tools and resources it needs to open space to explorers and commerce. Former astronaut Tom Jones makes the case for continuity, acceleration and a shift toward cislunar space.

By Tom Jones
Skywalking1@gmail.com
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Come Jan. 20, the Trump administration should resist the urge to discard the human space-flight progress of the past eight years. Instead, it should look hard at NASA's priorities and give NASA a course correction, refocusing the agency on achieving concrete exploration and economic goals in cislunar space, the region between Earth and the moon.

In reviewing NASA's goals and programs, the new administration should assess whether those serve the nation's economic, scientific and national security priorities. It should avoid the mistake of starting over, which the Obama administration made seven years ago when it tossed the Bush-initiated Constellation lunar-return program

◀ **Caption to come**

and bypassed the moon for an underfunded Journey to Mars preparation initiative. Instead, the president and Congress should keep the promising elements of NASA's human space-flight portfolio and use those to establish the U.S. as the leader in exploring and exploiting cislunar space. With a properly funded course correction, within two presidential terms, NASA could be poised to exploit the moon's resources, establish an ability for astronauts to visit there and build a partnership to explore Mars.

Where NASA stands

NASA is slowly moving forward on its Journey to Mars, a technology path that aims to put humans on the red planet in the 2030s. So far, progress has been limited mostly to robotic exploration of Mars. For human exploration, the Obama administration has pushed for development of the Orion Multi-Purpose Crew Vehicle and the Space Launch System rocket but has shown little interest in setting calendar milestones beyond those for testing Orion and SLS. It will be up to future administrations to fund the bulk of the technology needed to get human explorers to Mars. Orion is still five years from flying a crew. After an uncrewed test flight to lunar orbit in late 2018, the only future exploration on the books for Orion is the Asteroid Redirect Mission, or ARM, in which an astronaut crew will be sent to lunar orbit to examine a captured asteroid fragment. ARM faces stiff opposition in Congress and may not survive 2017.

Orion's heavy lift booster, the SLS, has yet to fly. In development as the Ares 5 when the Obama White House took charge in 2009, the SLS was first canceled, then revived by congressional direction. Its first flight is now targeted for late 2018 for the uncrewed Orion flight to and from lunar orbit. After Constellation's cancellation, the White House directed NASA's immediate focus not toward the moon or deep space, but to replacing the shuttle with commercially built transports to launch astronauts to the International Space Station. Those ships, from Boeing and SpaceX, are well behind schedule and won't fly for another two years, forcing NASA to extend its reliance on Russia's Soyuz crew transport. That arrangement, in place since 2011, is vulnerable to the whims of Vladimir Putin. The slow progress of restoring U.S. human launch capability is due at least in part to NASA's budget — $19.3 billion in 2016 — which has lost buying power since 2009.

Defining the goal

The most important element of the course correction is to clearly inform NASA of its goal: Establish this nation as the leading technical, scientific and economic power in cislunar space. Everything else — including Mars — should be secondary. In pursuing

NASA

▼ **The liquid hydrogen tank is part of the core** stage for the Space Launch System. The rocket's first flight is set for late 2018, but NASA would need to accelerate its launch pace to sustain astronauts in cislunar space.

NASA

▲ **The Resource Prospector prototype** searches for a buried sample tube at NASA's Johnson Space Center in Texas in 2015. Intensive robotic exploration of the moon could locate water ice and supply propellant for an astronaut return.

that goal, the administration should follow these general principles:

- Expand and repurpose existing programs; don't wastefully cancel them and start over.
- Provide technology and skills to U.S. companies to help expand their reach into cislunar space, in return contracting for essential, more affordable services.
- Enlist international and commercial partners to provide critical human space-flight elements, e.g., lunar orbit habitats, a lunar lander, propulsion, nuclear power and logistics.
- Provide NASA with the resources it needs; increase NASA's budget by 10 percent immediately and let it pace inflation thereafter.
- Use the capabilities and skills gained in cislunar space to reach Mars. We should take that exciting step when the nation and our partners are ready. Exploiting the resources of the moon and near-by asteroids will get us ready sooner.

Within the decade, NASA should do the following:

- Re-establish humans around and on the moon. Start with intensive, robotic lunar surface exploration. Put a U.S. rover down at the lunar poles by 2020, prospecting for water ice. Demonstrate small-scale extraction of oxygen, hydrogen and useful metals like iron.
- Contract for lunar landing services with private firms competing to reliably deliver robotic payloads to the moon. These commercial missions would begin commercial-scale extraction of water, oxygen and rocket propellant.
- Accelerate the Orion and SLS booster flight schedule. By the early 2020s, fly Orion astronauts to a lunar-orbiting habitat for a monthlong stay. From orbit, control a surface rover on the lunar far side.
- Carry out the Asteroid Redirect Mission, extending our astronauts' lunar orbit expertise to asteroid resource exploitation. Open the asteroid fragment to follow-up commercial prospecting and processing experiments, using the returned asteroid boulder to demonstrate extraction of water from hydrated silicate minerals.
- Extend the ISS partnership to the moon. If lunar resources prove attractive, NASA with its willing partners should develop a lunar lander, planning a return to the moon by the mid-2020s. Astronauts would help establish a propellant plant and conduct scientific exploration. The lunar partnership would build momentum toward reaching Mars together.

On course for deep space

By the mid-2020s, NASA should be poised to return astronauts to the lunar surface, for jobs beyond the skills of robots alone. The same spacecraft elements tested in lunar orbit — habitat, propulsion, energy systems and heavy lift booster — could also be combined in a piloted voyage to a near-Earth asteroid, expanding humanity's reach millions of kilometers from Earth and extending our deep-space endurance to six months or more. By 2030, NASA should contract with commercial ventures for the first return of water and rocket propellant from a near-Earth asteroid. Lunar-generated propellants and/or asteroids will be key in designing an affordable human campaign to reach Mars orbit; visit its two small moons, Phobos and Deimos; and eventually, land on Mars itself.

20 years out

Establishing humans on Mars should remain NASA's "horizon goal," but it should not be a near-term or exclusive NASA priority. Instead, the agency should focus on the technical and economic development of cislunar space. By the mid-2030s, NASA should have laid the groundwork to make the Earth-moon system a thriving economic zone, hosting everything from low Earth orbit tourism to space-based solar power stations to commercial research labs or production facilities, to commercially run propellant tank farms. These activities would help support the ongoing scientific exploration of the moon.

Confidence gained in systems tested at the moon and at near-Earth asteroids would put the U.S. in position by the late 2030s to plan an international expedition toward Mars. Even if NASA still lacked the technology by then for landing a crew on Mars, a NASA-led crew could enter Mars orbit and establish a habitat on Phobos (about 22 kilometers in diameter) or Deimos (about 12 km in diameter). From this close-in outpost, geologists could establish a scientific telepresence on the surface, guiding surface rovers with no appreciable time delay.

Under astronaut control, these robots could search for life and the best site for a human landing. Robots could also assemble the elements of that surface outpost: landing aids, habitat, propellant plant, solar or nuclear energy station, and machines for extracting subsurface ice or water. We would cross the final approximate 9,400 kilometers from Phobos to Mars when technology, budget, risk assessments and international partnerships align.

Advantages of changing course

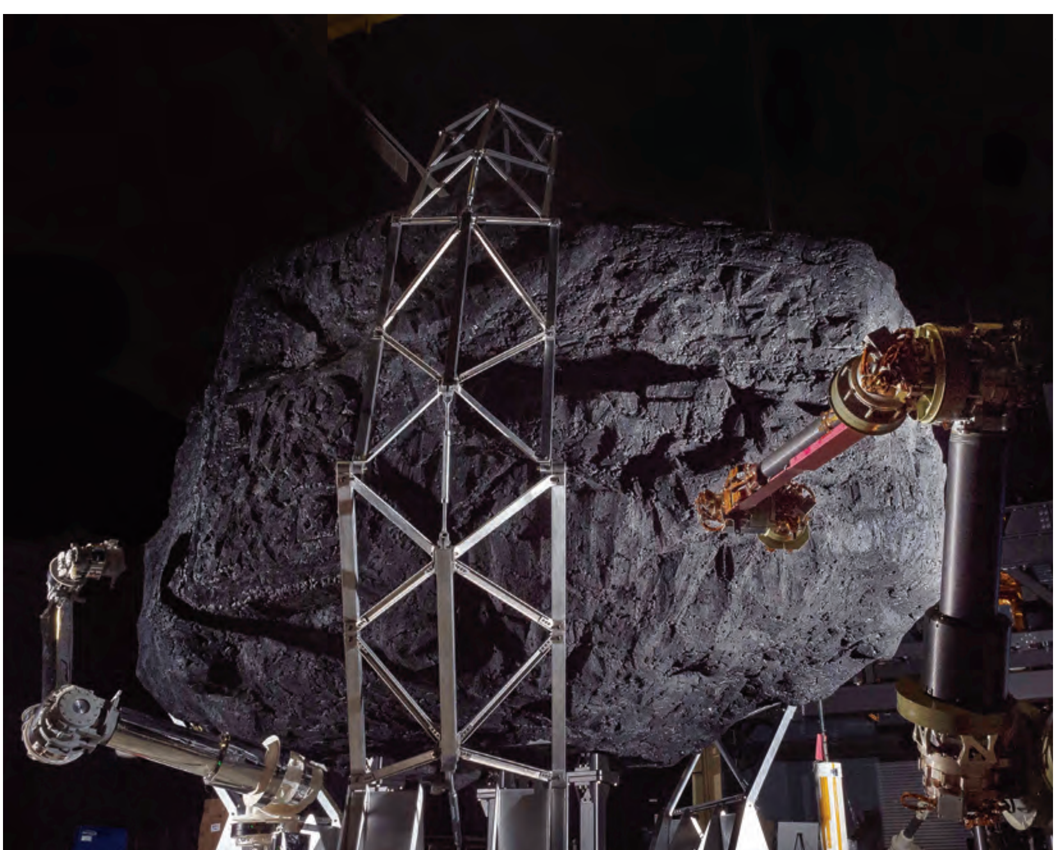
Within two presidential terms, a NASA focus on cislunar space would produce highly visible progress, namely the following:

- Commercial robots busily exploiting the moon, extracting water and metals from the lunar regolith;
- Astronauts regularly visiting a lunar orbit habitat, tele-operating robots and readying for a return to the moon's surface;
- An international lunar exploration consortium for science and resource production, an achievement readily adapted for reaching Mars;
- Private companies under NASA contract shipping supplies to the lunar orbit outpost and extracting tons of oxygen and rocket fuel from the moon;
- And astronauts training for their first deep-space encounter with a resource-rich asteroid.

By contrast, under current NASA direction and projected budgets, the U.S. couldn't achieve a human mission to the moon — even if it decided to join its ISS partners in the effort — let alone Mars. By 2025, for example, NASA astronauts will have flown Orion perhaps twice, repeating what America first accomplished on 1968's Apollo 8 mission. ARM is unlikely to make the new Congress's list of space priorities. And on our current course, by 2025, the ISS will be just a few years from a fiery re-entry into the Pacific, leaving China with the only space station in low Earth orbit. Soon after, these learners in space and up-and-comers will stamp their footprints on the moon.

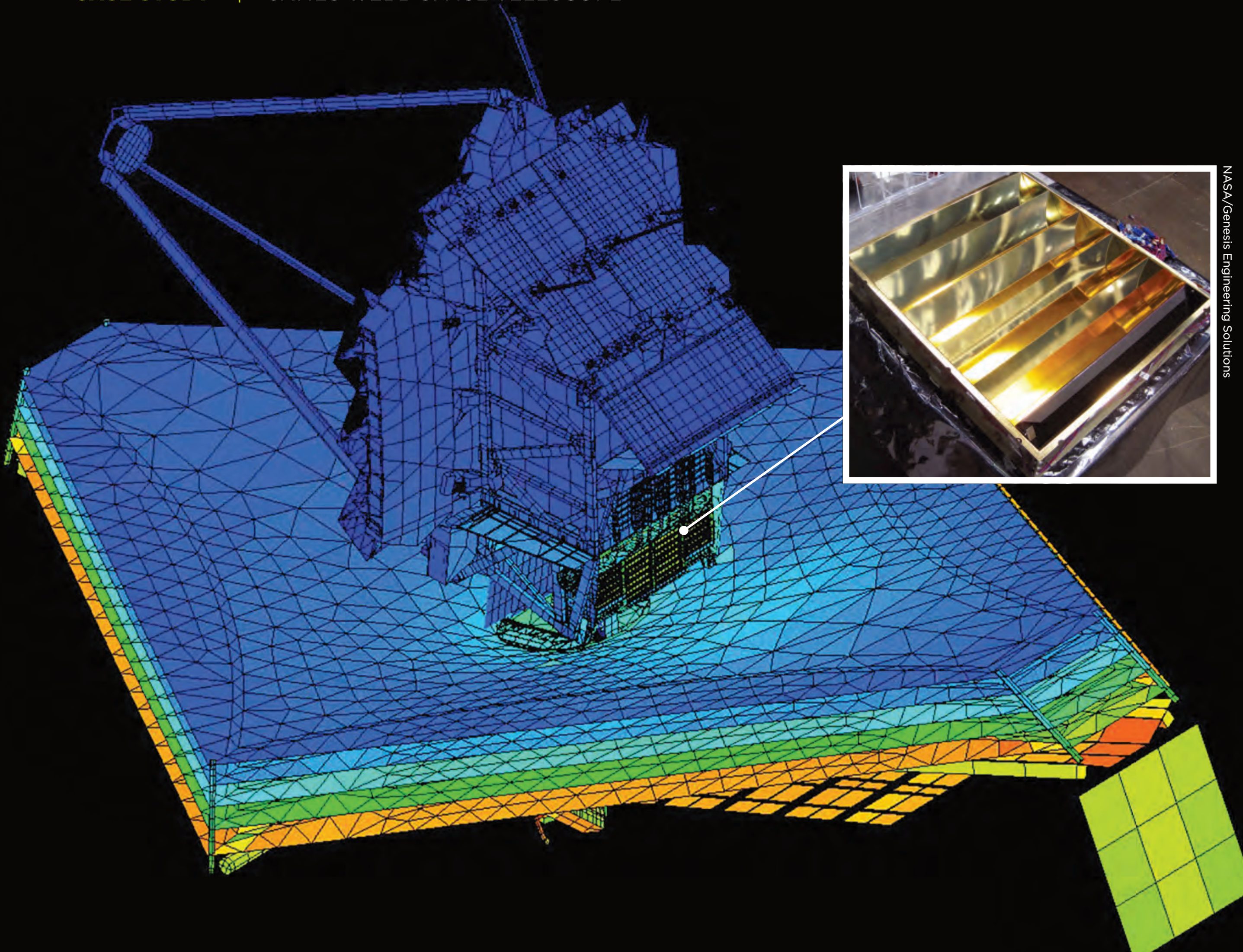
Executing this course correction — preserving and accelerating NASA's promising programs — would restore bipartisan support to the agency, so lacking for eight long years. The U.S. will use cislunar space to train for Mars while tapping the economic potential of the Earth-moon system. Near-term success would bring renewed confidence in NASA's abilities and its hopes for leading a partnership to the asteroids and Mars.

In 1801, President Thomas Jefferson delivered his first inaugural address and predicted a "rising nation, spread over a wide and fruitful land ... advancing rapidly to destinies beyond the reach of mortal eye." Today, that frontier is not the West, but space and its resources. A wise course change for NASA's exploration plans would invigorate our nation's fortunes once again. ★



NASA

An Asteroid Redirect Mission robotic prototype is tested with a mock asteroid boulder at NASA's Goddard Space Flight Center in Maryland. The robotic portion of ARM is targeted for launch in 2021, but the mission's fate is in the hands of the new Congress.



NASA/Genesis Engineering Solutions

Ultimate hands-on experience

One day in 2008, Rick Krontz, then an aircraft-structures instructor at Middle Georgia College, stopped by Neptune Precision Composites in Jacksonville, Florida. It was a routine check-in about a technical student the company hired. Krontz struck up a conversation with Frank Huber, a composites engineer at Neptune. Huber had an inspiration when he heard about the school's fabrication facility and students. He introduced Krontz to Robert Rashford, whose company Genesis Engineering Solutions was known for making flight hardware for the Hubble Space Telescope. Aerospace America invited Krontz and Rashford to describe how they assembled a team of students and professionals to make components for NASA's $8 billion James Webb Space Telescope.

In 2008, composites engineer Frank Huber suggested to us that the missions of Middle Georgia College (now Middle Georgia State University) and Genesis Engineering Solutions might mesh well. At the time, Middle Georgia trained aircraft structural technicians and Genesis made tools and parts for NASA's Hubble Space Telescope servicing missions. Huber was right.

What emerged was a partnership that helped each of our organizations grow while giving hands-on manufacturing experience to dozens of students. This was not just any experience, but experience building critical components of the James Webb Space Telescope scheduled for launch in 2018.

We realized quickly that Middle Georgia State had manufacturing resources capable of accommodating complex structures, and Genesis had experience with space structures, having helped NASA with Hubble. By teaming with Genesis, we won a contract from NASA's Goddard Space Flight Center to build the telescope's Integrated Science Instruments Module Electronics Compartment, or IEC for short, and also a backplane support fixture, the structure that holds the primary mirror. This

The IEC is a composite structure that houses 13 electronics boxes,including those that will control the mechanisms that must unfurl, unfold and erect the Webb telescope in space after its launch; plus the computer that will align the mirror's segments and steer the secondary mirrors to direct photons into an optical path leading to the four science instruments; and the electronics that will convert those photons into signals that will be read by computers on Earth.

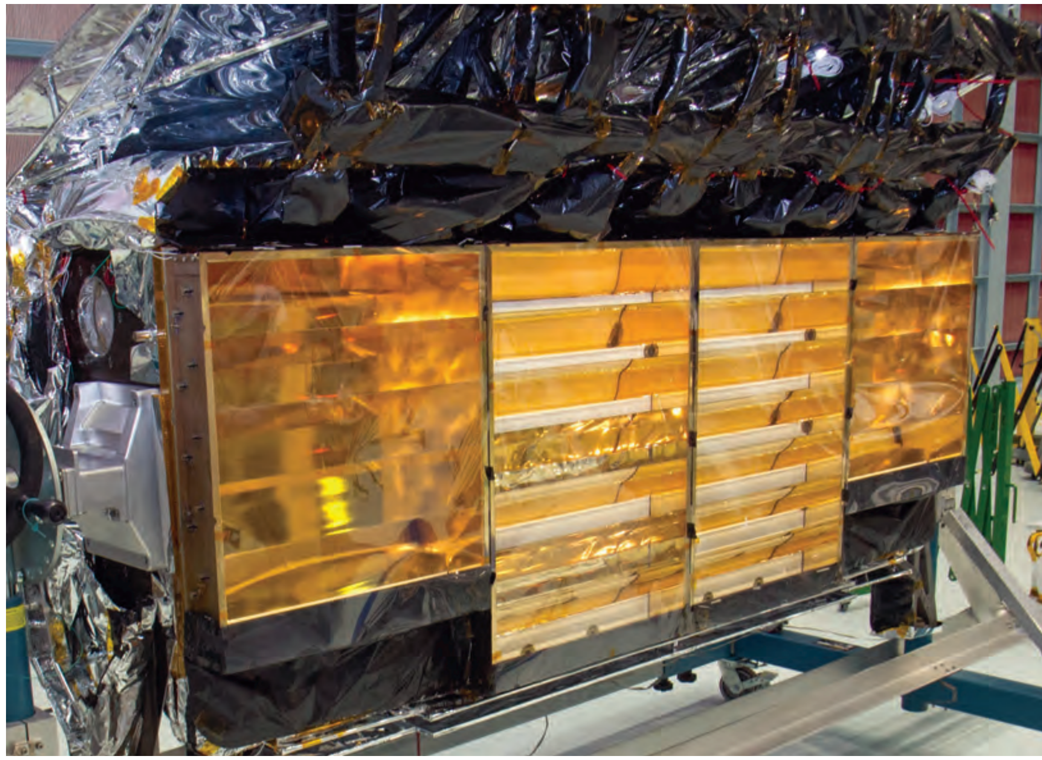
The design of the IEC was complex because of the thermal challenges aboard Webb. The electronics in the IEC must be kept at 80 degrees Fahrenheit (300 kelvins) to operate properly, but the equipment outside the enclosure must stay at minus 400 degrees Fahrenheit (33 kelvins) to maximize the telescope's sensitivity to infrared radiation. The thermal task was akin to putting a freshly roasted chicken into a freezer, and keeping the chicken warm without letting it melt the surrounding ice. To do that, you would have to put the chicken, or the electronics in our case, inside a protective enclosure, but one that lets excess heat escape the freezer without reaching the ice.

◀ **Student contributions:** Gold-coated composite louvers in four baffles, like this one built with the aid of students, will steer heat out of the James Webb Space Telescope's electronics compartment.

▶ **Student technicians** work on composite tubes that will form a backplane support fixture for the Webb telescope. The backplane holds the primary mirror and compartments for Webb's instruments and electronics. This backplane was used in thermal testing.

backplane was for the second round of thermal testing, called Core 2. To orient you, the IEC is located in Region 2 of Webb's blueprint, an area on the shaded cryogenic side of the telescope's sunshield. From this side, the telescope's segmented mirror will look out to the cold of space to gather infrared radiation from the early universe, our galaxy and planets beyond our solar system. Additional mirrors will direct that radiation into the Integrated Science Instruments Module, or ISIM, which houses the four scientific instruments. Mounted to this module is the ISIM Electronics Compartment, or IEC, which our team built.

That's the IEC. Inside, sets of electronics are attached to four composite panels whose job is to capture heat from the electronics. This heat must be steered out of the IEC and away from the instruments, so on one wall we installed four baffles consisting of graphite composite louvers covered with vapor-deposited 14-karat gold. Graphite lay-up material was chosen because of its low coefficient of thermal expansion, which means it's very stable. The gold coating has the desired thermal emissivity for removing heat quickly. Each baffle is attached to a 2.5-centimeter-thick radiator panel. Together, the radiators and baffles direct heat out to space safely.



These four louvered baffles will steer heat out of the electronics compartment of the James Webb Space Telescope. Students helped build them.

To build the IEC and the Core 2 backplane support fixture, Middle Georgia established a student internship program under which participants worked up to 20 hours a week. Other students at times participated from their classrooms. Specifically, students helped build the louvers and the primary ICE structure using computer-aided-design data and approved written work instructions and guidance from Genesis staff. The students interpreted the CAD data; created two-dimensional cut programs to trim the carbon and fiberglass materials on a computer-numerical-control, or CNC, cutting table. They also operated CNC routers and milling machines to make small molds and tooling aids. They helped create written instructions and quality control programs. Students kept track of pertinent information such as batch and lot numbers, expiration dates and quantity. They were required to work within high tolerances and an aggressive schedule. They prepared composite lay-up molds; hand-laid materials; vacuum bagged, leak checked, cured, cut and trimmed composite parts.

NASA accepted the idea of students participating in the manufacturing because of the precautions each of us took. Genesis ultimately is responsible for our contract and the hardware that gets delivered. NASA trusted Genesis, because of our record of on-time and on-budget delivery for Hubble. Our team also walked NASA's quality control and assurance expert through the process of how we were going to manufacture the components.

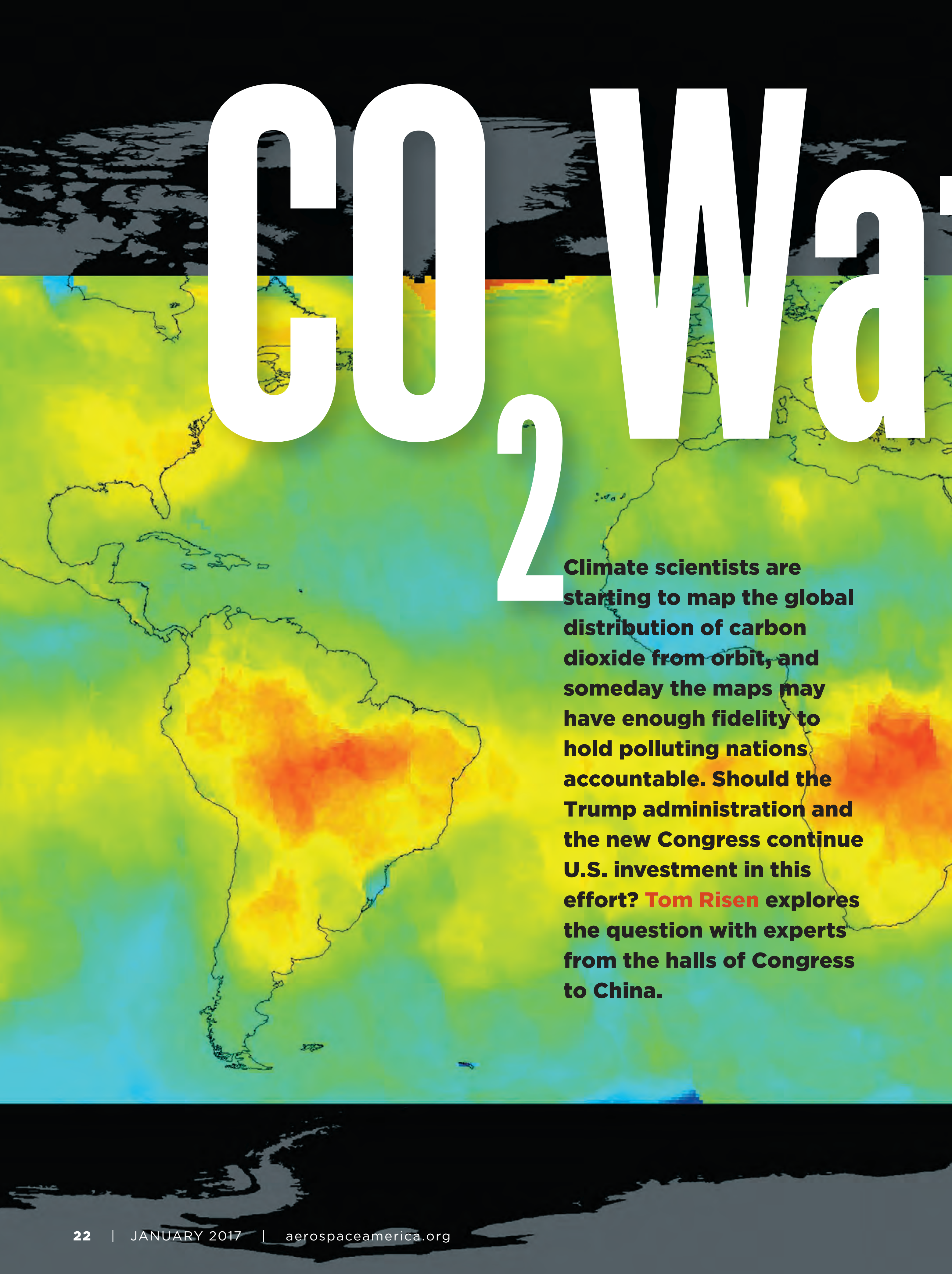
For Middle Georgia, the program was a great way to stay proficient and current in aerospace technologies. The work also caught the eye of Georgia's Center of Innovation for Aerospace, which helped the school forge a partnership with Area I, a drone startup in Kennesaw. For students, the program was an invaluable opportunity to work in real-world, intense, hands-on project. Some students decided to pursue engineering degrees because of their experiences. Others decided to become entrepreneurs. All went on to be employed in some fashion in the aerospace industry, applying a multitude of skills for major aviation or space employers.

When the IEC was completed, we packed the components into an air-cushioned truck and drove the parts to our facility in Lanham, Maryland, for assembly. We delivered the IEC in 2014 on time and within budget. For that reason, NASA asked our team to build two more IECs to support system level testing. Today, we have one flight replica at NASA's Johnson Space Center in Texas and one at NASA's Goddard Space Flight Center in Maryland. They are used for quantifying the rate at which heat is radiated out of the IEC. Maintaining the right temperature is critical for the health of the electronics. Unlike Hubble, Webb will be too far from Earth for NASA to send astronauts to service it.

Today, technicians and engineers in a variety of organizations acquired critical skills because of this program. They will be watching as closely as anyone in 2018 when the telescope lifts off aboard its Ariane 5 rocket. ★

Robert Rashford is an aerospace engineer and founder of Genesis Engineering Solutions of Lanham, Maryland.

Rick Krontz retired in October as director of the Institute for Applied Aerospace Research at Middle Georgia State University's Eastman Campus. Krontz retired from the U.S. Air Force in 1998 as a master sergeant with a specialty in aircraft structures and advanced composites.



CO_2 Wa

Climate scientists are starting to map the global distribution of carbon dioxide from orbit, and someday the maps may have enough fidelity to hold polluting nations accountable. Should the Trump administration and the new Congress continue U.S. investment in this effort? Tom Risen explores the question with experts from the halls of Congress to China.

tchdogs

The tropical rainforests of South America, Africa and Indonesia glow orange on this map, indicating high emissions of carbon dioxide from burning vegetation to create farmland. The orange over China comes mainly from the burning of coal. The map was created from infrared readings gathered by NASA's Orbiting Carbon Observatory-2 between Oct. 1, 2014, and Nov. 11, 2014.

NASA/JPL-CalTech

NASA's Orbiting Carbon Observatory-2 has been circling the globe from pole to pole every 100 minutes for more than two years, gathering sunlight reflected by Earth and bouncing it across reflective surfaces covered with ridges to diffract the light into spectra. Nearly a million daily recordings are downloaded from OCO-2's three near-infrared spectrometers to show the absorption footprints of gases, including carbon dioxide and oxygen.

These recordings once seemed the next step toward an international response to climate change in which the world's worst carbon dioxide emitters would be outed, with their emissions showing up as big orange globs on a global map that would be shared among countries. So far, China and Europe plan to launch carbon-dioxide monitoring satellites; Japan has had one in orbit since 2009; and the International Space Station is even slated to carry one. These readings will be combined with those from spectrometers at ground stations around the globe to gauge the world's progress in curbing emissions of carbon from burning fossil fuels, forests and crops.

"Over time, remote-sensing data is expected to play an important role in compliance monitoring of commitments made in the Paris Agreement," says Paul Wennberg, the American scientist who chairs the Total Carbon Column Observing Network, the international scientific partnership that manages the ground sites. The Paris climate accord, supported strongly by Democratic presidential candidate Hillary Clinton, went into force several days before the U.S. presidential election, when an international ratification threshold was met. The agreement aims to reduce greenhouse gas emissions enough to keep the planet from warming more than 2 degrees Celsius over pre-industrial era levels.

Then came the surprise election of Republican Donald Trump. This outcome is raising new questions about whether the U.S. will continue funding climate change research and more satellites like OCO-2 or whether scientists from Europe, Japan and China will have to proceed without the U.S. in their plans to monitor carbon dioxide from space.

Trump's transition team did not respond to requests for comment, but he has given mixed signals about his views on climate change. In 2012, Trump tweeted that the "concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive." During the heat of the Re-

▼ NASA's Orbiting Carbon Observatory-2 measures carbon dioxide levels across the world to improve understanding of the natural and human-induced sources of the gas as well as how emissions cycle through the Earth's oceans, land and atmosphere. OCO-2 underwent environmental tests in December 2013 at Orbital Sciences Corp. (now Orbital ATK) in Gilbert, Arizona.

Orbital ATK

publican primary in South Carolina, he denounced global warming as a "hoax." In May, he told a North Dakota crowd that he would "cancel the Paris Agreement." Trump then seemed to reverse himself after the election, telling reporters and editors from the New York Times that "there is some connectivity" between humans and climate change, that "clean air is vitally important" and that he would keep an "open mind" on the international emissions agreement. Advocates of the multinational agreement are far from certain, however, about the incoming administration's final stance on policies to address climate change.

International effort

What is certain is that multiple satellites are needed for a more comprehensive map of carbon dioxide in the atmosphere, and that is starting to happen. China was planning to launch its TanSat last month to measure carbon dioxide with a near-infrared spectrometer, says Liu Yi, who is the team leader of the satellite project. Liu says the Chinese Academy of Sciences "plans to sign cooperation agreements soon" to share the TanSat's maps of carbon dioxide sinks and emissions with Wennberg's Total Carbon Column Observing Network. This year, scientists expect the European Commission to ask the European Space Agency to build a carbon-dioxide monitoring satellite likely to be called Sentinel-7. It would be constructed under Europe's Copernicus climate data initiative for launch in 2024 or 2025. Japan led the way on carbon-dioxide monitoring when it launched its Greenhouse Gases Observing Satellite, or GOSAT, in 2009. The Japan Aerospace Exploration Agency plans to launch GOSAT-2 between April 2018 and March 2019 to measure carbon dioxide, methane and carbon monoxide.

One satellite can't do it all. To get its high-resolution readings, OCO-2 measures a swath that is about 10 kilometers wide for each orbit, which means it covers only about 7 percent of the atmosphere each month. Only 10 percent of the nearly 1 million measurements it captures each day are free of disturbances that interfere with its data collection, including clouds that prevent sunlight from reaching the surface. More satellites like OCO-2 would close those gaps and improve the odds of collecting cloud-free data at a specific location. It would then be possible to pinpoint which factories, cities and coal mines in different countries spew the most carbon dioxide, says David Crisp, an atmospheric physicist at the NASA-funded Jet Propulsion Laboratory in California, who led the design of the OCO-2 spectrometer.

The ground spectrometers operated by Wennberg's group don't have to collect data while rapidly orbiting the planet, so they can collect more sensitive measurements than those on existing satellites. The drawback of ground-based spectrometers is that they provide soda-straw views of the atmosphere from fixed locations. Scientists want to expand this coverage by adding the view from multiple satellites like OCO-2. Even with the OCO-2 data, today's carbon dioxide maps are rudimentary.

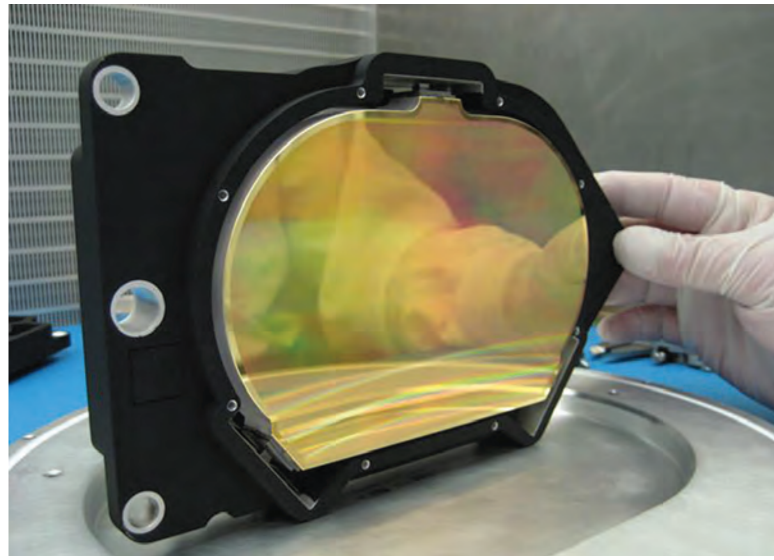
"These maps do not yet have the precision, accuracy, resolution or coverage needed by policymakers," Crisp says. "We are a long way from that goal."

Advocates say the idea can work without the U.S. but that it would be much harder.

"Many hands make for lighter work," Crisp says.

Scientists want to measure carbon dioxide more frequently because the emissions dissipate from their original source or become corrupted by the presence of aerosol, water vapor or other gases.

"Monitoring is knowing. As such, it is in the interest of any modern society and [should] not be seen as a partisan issue," says Guido Levrini, the Italian program manager with ESA's Copernicus initiative. "Space is the only way to get real global coverage and a uniform, calibrated way of measuring air pollution. It will establish the facts of how much pollution is coming from different nations."



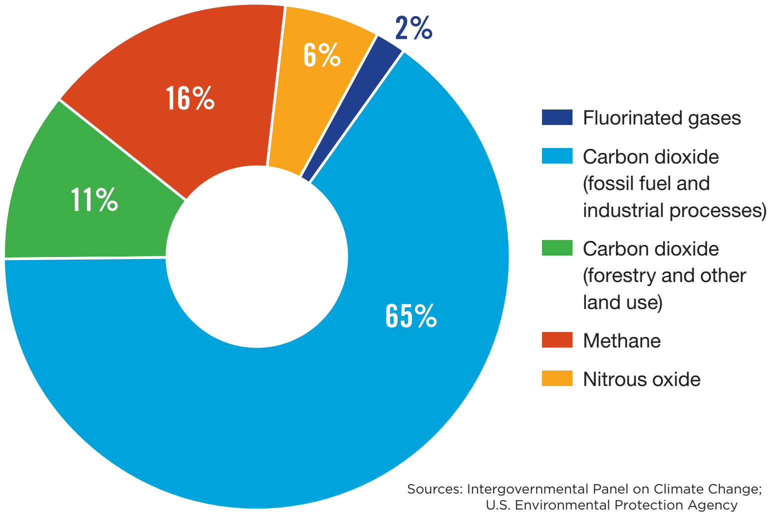
NASA/JPL-CalTech

▲ **A diffraction grating** has ridges spaced a fraction of a millimeter apart to splay light into spectra. This one was destroyed when the first Orbiting Carbon Observatory crashed in 2009.

"I am not aware that the dinosaurs had any problems with industrial pollution."

— U.S. Rep. John Culberson, R-Texas, suggesting that natural factors may play a major role in warming the climate

Global Greenhouse Gases



▲ **Among the naturally** occurring and human-produced gases that are warming Earth, carbon dioxide from human activities is most prevalent. This data was published by the U.S. Environmental Protection Agency based on findings reported in 2014 by the U.N.'s Intergovernmental Panel on Climate Change.

Aside from pinpointing emissions, mapping carbon dioxide could help scientists identify the species of trees and characteristics of the oceans that do the best job of cleansing the atmosphere of carbon. These areas are called carbon sinks because they absorb more carbon dioxide than is emitted from naturally decaying or burning organic matter. Many questions have yet to be answered by research into carbon sinks. Oceans are a special concern, given that two-thirds of Earth is covered by them. Scientists don't fully understand how oceans absorb carbon dioxide, and the effectiveness of forests and biospheres around the equator is a particular unknown because of lack of research in those regions.

"We don't know how long the natural process will continue to absorb carbon dioxide as the oceans warm," Crisp says. "This information is critical to help manage carbon dioxide in the future."

"Monitoring is knowing. As such, it is in the interest of any modern society and [should] not be seen as a partisan issue."

— Guido Levrini of the European Space Agency

The view in Congress

Even before the presidential election, advocates of satellites like OCO-2 hoped for bipartisan support. Even some in Congress who doubt that human activities are responsible for the bulk of the warming have argued that continued studies of the climate were necessary before reaching policy conclusions.

Among the doubters is Republican Rep. John Culberson of Texas, chairman of the House subcommittee responsible for science appropriations. He says that naturally occurring variables in addition to humans could be warming the planet, including ocean currents that he says have shifted and affected the climate numerous times. Culberson notes that carbon dioxide levels in the atmosphere were higher during other eras of history, including the Cretaceous Period nearly 66 million years ago.

"I am not aware that the dinosaurs had any problems with industrial pollution," he says.

Despite Culberson's reservations about humanity's role in the warming, he wants to fund NASA "at record levels to ensure they can do everything on their plate without sacrificing any part of its essential mission." Culberson isn't saying whether that should include a new satellite like OCO-2, but he says he recognizes the value of the data it collects. "We need to understand the effectiveness of carbon sinks that are a natural part of the carbon cycle on Earth," he says, especially ocean plankton and rainforests.

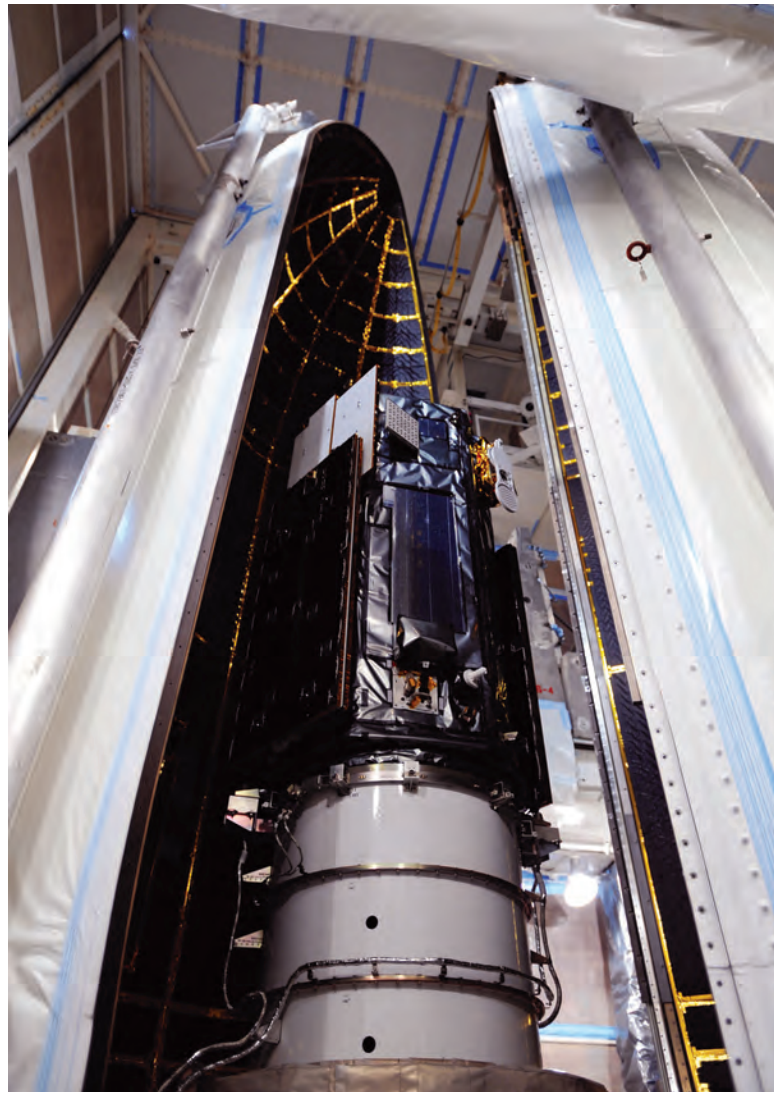
Other Republicans have already made up their minds. One of them is Rep. Dana Rohrabacher, R-California, vice chairman of the House committee responsible for authorizing science expenditures. His chief of staff, Rick Dykema, says in an email that the congressman would not support a new generation of NASA satellites to track greenhouse gas emissions.

"He does not believe that such a function is within the proper role of our space exploration agency," Dykema says. "Congressman Rohrabacher does not support the Paris Agreement. He does not believe that it is legally binding on the U.S."

If the incoming Trump administration and Congress follow tradition, they are likely to shape their position on carbon-dioxide monitoring satellites based on whether the next decadal survey of the National Academies of Sciences, Engineering, and Medicine recommends launching new ones to continue the mission started by OCO-2. The academy expects to release the "Decadal Survey for Earth Science and Applications From Space" in late 2017.

Congress "leans heavily" toward these recommendations but must do so with a budgeteer's eye, says Republican Rep. Lamar Smith of Texas, a climate change doubter and chairman of the House science committee for which Rohrabacher is vice chairman. Smith says he would review any proposal to fund a

▶ The Trump administration and Congress must decide whether to build more satellites like the Orbiting Carbon Observatory-2, which maps carbon dioxide. OCO-2 is shown inside the payload fairing of its Delta 2 rocket before its July 2014 launch from Vandenberg Air Force Base in California.



U.S. Air Force

new satellite based on whether NASA could instead rely on data collected by other nations.

"Members would have to conduct a cost-benefit analysis for the incremental capability derived from that data," Smith says.

Commenting on the election results, Smith says he looks forward to working with the Trump administration on environmental and energy policies "to ensure that decisions are based on sound science and transparency for the American people." Smith had criticized the Obama administration's support for the Paris Agreement as based on "science fiction."

The chairman has in recent years supported budgets for NASA's Earth Science Division that were smaller than those sought by the White House, with the aim of moderating its growth compared with the agency's other divisions. Smith is among Republicans who have said measuring carbon dioxide emissions raises questions about the appropriate role of NASA and whether NOAA should manage that Earth science data instead.

Crisp says it is "business as usual" for NASA to collect environmental data from space to help inform policymakers. Bill Townsend, former deputy director at NASA's Goddard Space Flight Center in Maryland, also says shifting that responsibility from NASA to NOAA would be a bad idea because the atmospheric research agency "already has a full plate" and would likewise have a difficult time securing funds for climate change research.

Rep. Eddie Bernice Johnson of Texas, the ranking Democrat on the House science committee, stresses the value of carbon dioxide monitoring and the Paris Agreement and says she cannot predict how the incoming administration will approach these initiatives.

"I sincerely hope that we can continue to work to better understand our planet, the role that climate plays and how to mitigate the harmful effects of climate change," Johnson says.

Townsend, an industry consultant since leaving NASA in 2004, predicts difficulty ahead for those who advocate more missions like OCO-2. "Anything closely tied to climate change is likely to have a very hard time of it for the next four years in terms of sustaining funding for what's already being built and especially for starting anything new," he says. That said, "International collaboration, where the U.S. cost is substantially reduced, seems to frequently carry the day," he adds. "Climate change is a global problem that needs a global solution."

The OCO satellite team has overcome challenges before. NASA, facing a funding crunch, was forced to temporarily halt planning toward affixing OCO-2's spare science instrument onto the outside of the International Space Station. This mission, called OCO-3, was revived at the end of 2015 because of expanded funds approved by Congress for fiscal 2016, and the instrument is now due for installation in 2018. Then there was the fate of OCO-2's predecessor. It crashed into the ocean near Antarctica in 2009 before reaching orbit, because the fairing shell that protected it during its launch on a Taurus XL rocket failed to jettison.

Today's political situation will be a challenge of a different sort. ★

INFAMOUS RECORD

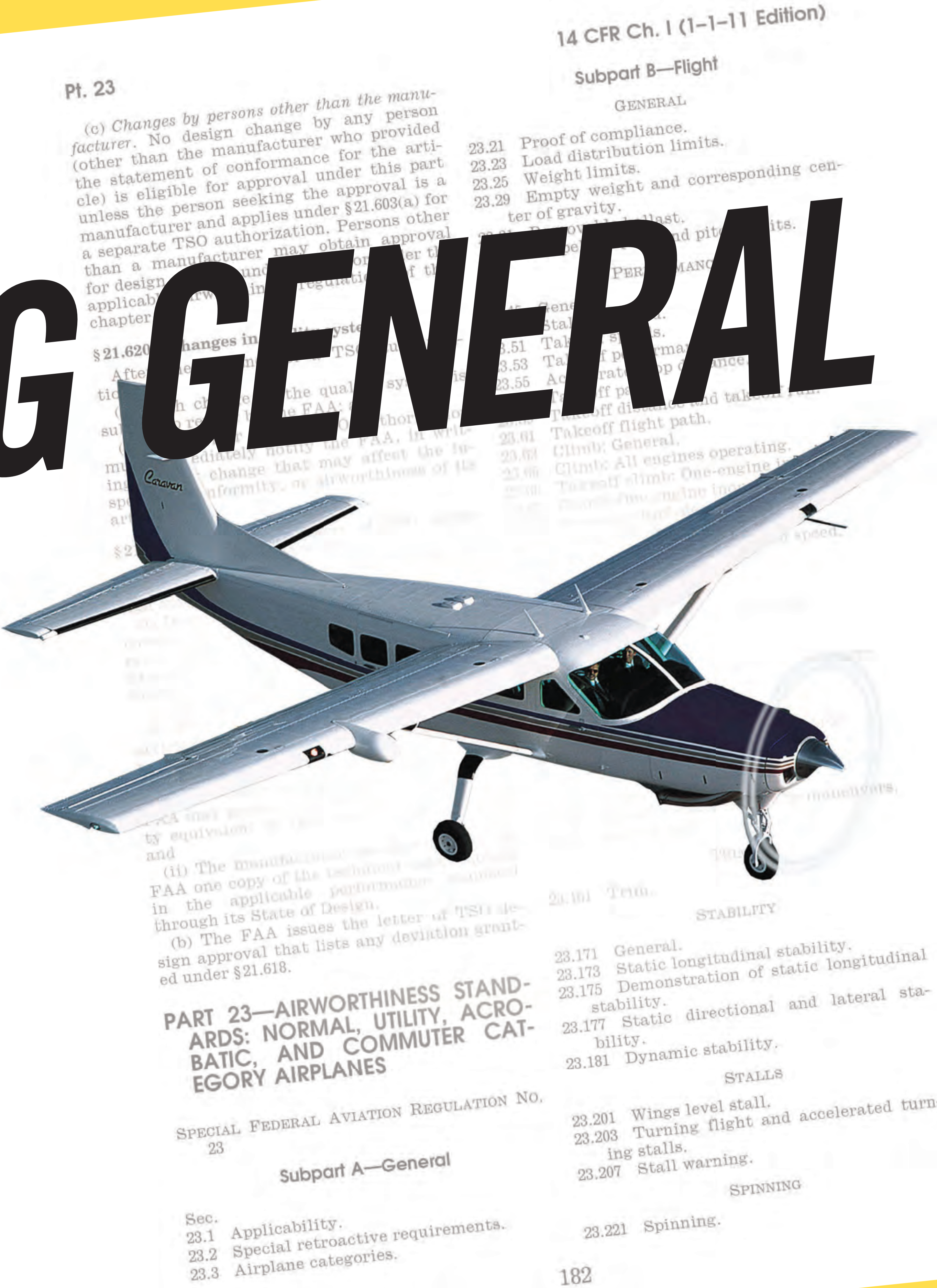
The World Meteorological Organization announced in October that the global average concentration of carbon dioxide in the atmosphere in 2015 reached 400 parts per million, which is the highest in recorded history.

Tom Risen is a journalist and researcher whose reporting on policy, science, and tech business has appeared in US News & World Report, Slate, and The Atlantic.

REVITALIZIN AVIATION

Sales of small aircraft have been sluggish for years. Just as significantly, technical improvements to make it easier for weekend pilots to fly safely have been stalled. Why? One reason has been Part 23 of the FAA regulations for certifying the airworthiness of aircraft and equipment. Even the FAA didn't like Part 23, and so a major revision was approved in December and will go into effect later this year. Joe Stumpe spoke to industry experts and found lots of enthusiasm for the changes.

G GENERAL



Pt. 23

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(c) *Changes by persons other than the manufacturer*. No design change by any person (other than the manufacturer who provided the statement of conformance for the article) is eligible for approval under this part unless the person seeking the approval is a manufacturer and applies under §21.603(a) for a separate TSO authorization. Persons other than a manufacturer may obtain approval for design

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(b) The FAA issues the letter of TSO design approval that lists any deviation granted under §21.618.

PART 23—AIRWORTHINESS STANDARDS: NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

SPECIAL FEDERAL AVIATION REGULATION NO. 23

Subpart A—General

Sec.
23.1 Applicability.
23.2 Special retroactive requirements.
23.3 Airplane categories.

Subpart B—Flight

GENERAL

23.21 Proof of compliance.
23.23 Load distribution limits.
23.25 Weight limits.
23.29 Empty weight and corresponding center of gravity.

Takeoff flight path.
23.61 Takeoff flight path.

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STABILITY

23.171 General.
23.173 Static longitudinal stability.
23.175 Demonstration of static longitudinal stability.
23.177 Static directional and lateral stability.
23.181 Dynamic stability.

STALLS

23.201 Wings level stall.
23.203 Turning flight and accelerated turning stalls.
23.207 Stall warning.

SPINNING

23.221 Spinning.

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For years, Glasair Aviation, a kit-plane manufacturer in northwestern Washington, thought about getting its four-person Sportsman aircraft certified for airworthiness by the FAA. Nigel Mott, Glasair's president of operations, says of the aircraft, "We think it would be very appealing to the general aviation market." The company never went forward, because it felt the certification process would be too onerous.

New FAA regulations released Dec. 16 have given hope to Glasair and many others in general aviation. The changes to Part 23 of the Federal Aviation Regulations will shift the industry to a streamlined and less prescriptive process for certifying newly designed small planes and new avionics for existing aircraft. They go into effect in August.

General aviation executives were still reviewing the 550-page document when Aerospace America went to press, but they seemed pleased. They are counting on these rewritten rules to improve safety and give a jolt to an industry in which the average plane is almost 37 years old and total new general aviation airplane shipments worldwide sit at just over half of what they were before the 2007-2009 recession, according to the General Aviation Manufacturers Association, or GAMA. New avionics, upgrades to existing aircraft and eventually new aircraft designs could result.

"Instead of the unhealthy spiral general aviation has been in, this has the potential to put us in a healthy spiral," says Greg Bowles, vice president of GAMA.

One backer of the regulatory overhaul, U.S. Rep. Mike Pompeo, a Kansas Republican and President-elect Donald Trump's nominee to direct the CIA, had said the certification process "needlessly" increased the cost of safety and technology updates "by up to 10 times."

David Oord, the regulatory affairs director for the Aircraft Owners and Pilots Association, or AOPA, says that while aviation "is never going to be a cheap activity," he hopes to see "not only new, innovative products that are exciting, but also products that are probably a lot more affordable than they are today." He says the language released in December appears to be "very much exactly what we hoped for."

The FAA recognized that its rules were discouraging innovation.

"The old regulations were getting to the point where they were added onto and added onto, creating a very prescriptive process" that was "really adding on a lot of expense on the manufacturing side," an FAA spokeswoman says.

The industry side couldn't have agreed more. Bowles co-chaired the FAA committee that looked at Part 23 and came up with recommendations the FAA incorporated into draft regulations in 2013. The committee included U.S. and international manufacturers, organizations and civil aviation authorities.

The push for change can be traced to at least 2008, when the FAA first reviewed Part 23. The rules were made based on airplane designs from the 1950s and '60s. The agency has made numerous amendments to Part 23 and granted waivers for new designs and technology on a case-by-case basis, resulting in a complex web of regulations.

Compliance levels

The changes are part of the FAA's embrace of the safety continuum concept in which "one level of safety may not be appropriate for all aviation," in the agency's words. That is, the agency is willing to accept a higher level of risk for aircraft that are for personal rather than commercial transportation. This way, the regulations allow a more flexible process of certification for aircraft governed by Part 23 — planes carrying fewer than 20 passengers and weighing 19,000 pounds (8,618 kilograms) on takeoff. Within that general aviation category, simple planes carrying few passengers are to be treated differently than larger, more complex planes carrying more passengers. And it may be easier for those small airplanes to get supplemental safety equipment, since the equipment's potential failure poses little additional risk.

The safety-continuum approach allows the FAA to accept more risk, but industry members believe the revisions will actually mean less danger because safety-enhancing technology and other innovations will reach the market faster.

Bowles describes the new regulations concerning certification as profound. In effect, with the changes, FAA is moving from a prescriptive, process-oriented approach to one based on goals and performance — the chief goal being safety.

"Instead of telling how a technology should apply, it says what the aircraft must do," Bowles explains.

One of the new regulations states that an aircraft cabin exit design "must provide for evacuation of the airplane within 90 seconds in conditions likely to occur following an emergency landing" but does not specify how that is to be achieved. Another addresses fuel systems, and those passages are written broadly enough to permit electric propulsion systems in which batteries and fuel cells provide power. Until the new rules, electric propulsion required special exemptions by the FAA, and crashworthiness of an aircraft was demonstrated by the traditional method of putting seats and restraints onto a sled and rapidly accelerating and decelerating them. Under the new regulations, manufacturers can devise tests that would assess the ability of the aircraft as a whole to protect occupants.

"There is technology that can help us, but it's been far too difficult to develop because of the process."

– **GREG BOWLES**, GENERAL AVIATION MANUFACTURERS ASSOCIATION

Just as big a shift is the FAA's decision to allow applicants to use consensus standards developed by organizations such as ASTM International — a voluntary, nonprofit group with members in more than 140 countries. The standards process that is being replaced made development of standards has been so complicated and costly that there has been little incentive to innovate, says AOPA's Oord.

"That's why you see aircraft that are produced new today are essentially the same aircraft that were produced in the 1960s," he says. "Now if you can develop an industry consensus standard, once that gets accepted by the agency, you can have other manufacturers follow suit. The speed at which technology and innovation will follow increases."

The ASTM F44 General Aviation Committee headed by Bowles, is in the process of writing standards for propulsion systems, design construction

and 18 other areas. Applicants would still have the option to use existing prescriptive Part 23 regulations or to propose their own method of showing compliance, as they can do now.

The proposed regulations treat new airplanes according to performance and complexity, replacing existing weight and propulsion divisions (normal, utility, acrobatic and commuter) with categories based on the maximum number of passengers and performance of airplanes. The FAA embraced the need for change, because as high-performance, complex lightweight planes have been introduced, the standards appropriate to them have been needlessly applied to simple, entry-level planes. The FAA says making it easier for the simplest planes — those with room for a pilot and one passenger — to become certified was one of the chief topics of public feedback during the process of rewriting the regulations.

Reducing causes of crashes

The proposed Part 23 changes are mainly a reorganization of the certification process, but they also would add standards for new planes designed to reduce two of the biggest causes of crashes: loss of control and severe icing conditions. Since crashes frequently result from inadvertent stalls at low altitudes, where pilots don't have time to recover, new designs could improve aircraft performance and pilot awareness in those circumstances.

"Forty percent of fatal accidents are [caused by] loss of control," Bowles says. "We are fully confident the new approach can more than cut that in half."

The FAA counts 74 fatal general aviation accidents between 2008 and 2013 that were caused by stall or loss of control, and it describes these as "of a type that could be prevented" by the proposed regulations.

To deal with severe icing — including supercooled large drops, mixed phase and ice crystals — the proposed regulations give manufacturers two options. One is to certify that their aircraft can operate safely in those conditions. The other is to demonstrate the aircraft's ability to detect and safely exit them.

The regulations would also require new twin-engine planes to be designed so that the loss of one engine would prompt a pilot to make a controlled

▲ **Changes to Part 23** of the Federal Aviation Regulations may make it easier for newer general aviation aircraft, such as the Glasair Aviation Sportsman, to get certified.

Glasair Aviation

"I want to see brand new shiny airplanes with glass cockpits that really inspire that next generation of aviation."

– **DAVID OORD,** AIRPLANE OWNERS AND PILOTS ASSOCIATION

descent rather than maintain climb and lose control, as has happened in some accidents.

The committee co-chaired by Bowles also found that the FAA's current certification process was slowing the installation of safety-enhancing technology in existing planes. Bowles says the new regulations will make it easier for owners of existing airplanes to modify them with, for instance, the installation of low-cost weather displays in the cockpit that alert pilots to avoid bad weather along their flight paths. Such a display would be optional and present little risk in case of failure, the FAA says.

Bowles cites angle of attack indicators as another example of the kind of relatively inexpensive technology that should become more available. The FAA last year announced that it was streamlining the approval process for the devices by allowing them to be built to ASTM standards. The agency said the indicators, which cost as little as $250, could serve as a prototype "for other add-on aircraft systems in the future."

"There is technology that can help us, but it's been far too difficult to develop because of the process," Bowles says.

Oord notes that the use of iPads with apps for moving maps, approach charts, flight-planning filing and more has "spread through general aviation like wildfire" because they're inexpensive, useful and not regulated by the FAA.

The FAA says the cost of implementing the new regulations will be far outweighed by cost savings and safety benefits.

Bowles notes that, while technology has helped so many other segments of society move forward, the Part 23 had "frozen us into place." According to the FAA, because of the international nature of aviation, it has coordinated its Part 23 regulation updates with similar efforts underway in Europe, Canada, Brazil, China and New Zealand. The agency says this process should reduce the cost of both exports and imports in the aviation industry.

Ric Peri, who is in charge of government and industry affairs at the Aircraft Electronics Association, says that when he started in aviation 40 years ago, technology tended to get introduced at the military, space or airline level, then "drift downward" into general aviation. But with the growth of experimental aircraft, electronics and technology, the process may start going the other way.

Peri is adamant that regulators are not "lowering the bar on safety. The regulation of safety is the same. It's the method of showing compliance" that's changed.

Bowles agrees, saying a streamlined, less expensive certification process is necessary.

"Unless that goes hand in hand, you don't get the safety outcome," he says. "If I have a great safety device and nobody can afford to put it on the airplane, it will never produce safety."

Oord says the economics of scale in general aviation mean new products are never going to be developed as quickly as they would be in, say, the automobile industry. There will still be costs associated with certification and litigation. But he notes that manufacturers worldwide have been watching the Part 23 process and similar efforts underway in other countries, ready to rush in with innovations.

He sees it as a new beginning for general aviation. "Today, if somebody got the spark to fly like I did when I was a wee little kid in Southern California, they're going to see a Cessna or Piper built in 1960 or 1970. It's not very new or novel. I want to see brand new shiny airplanes with glass cockpits that really inspire that next generation of aviation. It's also going to be safer."

Glasair's Mott says the new regulations may come as a pleasant surprise to many members of the general aviation community. To this point, relatively few have probably paid attention to the rules-making process because "it's kind of boring stuff that most people don't spend a lot of time on."★

Joe Stumpe is a freelance writer based in Wichita, Kansas. He wrote about the AAIA's Design/Build/Fly contest for college students in the June issue of Aerospace America.

DECISION TIME FOR TRUMP

5 Aviation Decisions

Henry Canaday sees an aviation industry that wants Trump's help to grow, but safely and cleanly.


CANADAY

1. Should air traffic management be separated from FAA safety regulation to speed up the NextGen air traffic modernization?

ANALYSIS – The Trump team may know that NextGen, with its GPS-based navigation approach, offers dramatic reductions in time, cost, fuel burn and emissions for air travel, along with increasing the capacity of the airspace and improving safety. The president-elect's administration will need to decide whether these gains could be achieved faster outside the FAA.

So far, new navigation and communications equipment has been installed on the ground and on aircraft under the array of programs within NextGen. But changes in flight paths and rules that represent the real aim of this vast initiative have taken longer to implement. Most U.S. and international airlines want to spin off traffic management from the FAA into a nonprofit corporation controlled by a board of public and private stakeholders to expedite NextGen. The body could raise funds on capital markets, charge for services and set priorities without political pressures. On the other hand, transitioning traffic controllers to a new organization might interrupt NextGen activities. And some worry that airlines would dominate the new entity's decisions, disadvantaging non-commercial aviation, labor or other interests.

2. Should the U.S. preserve and expand Open Skies agreements?

ANALYSIS – The U.S. and the European Union countries are among those that favor free-market competition among passenger and cargo carriers in both the domestic and international passenger markets, rather than setting ticket prices or limiting airlines to particular routes. The chief mechanism for ensuring international competition has been the Open Skies policy, agreements the U.S. has negotiated with 120 foreign partners, representing 70 percent of America's international departures. These allow unlimited flights between agreeing nations.

▸▸ CONTINUED ON PAGE 36

With President-elect Donald Trump promising big, but still-evolving, policy changes, we asked two leading aerospace journalists to analyze the most important decisions facing the incoming administration.

Associated Press

5 Space Decisions

Warren Ferster says Trump is arriving at a pivotal era for those involved in space, whether for exploration, business or science.

FERSTER

1. Should NASA operate the International Space Station beyond 2024?

ANALYSIS – This is a linchpin decision for president-elect Trump and his team. NASA has pledged to fly the orbiting lab for seven more years, and its international partners have followed suit or are expected to do so. The question is whether to extend operations even longer, to at least 2028, or whether to steer the more than 400,000-kilogram behemoth into the atmosphere, where it would break apart with surviving pieces splashing down in the Pacific Ocean.

A decision to abandon the station in 2024 would surprise many observers, given that assembly was not completed until 2011.

"I can't imagine that, in 2028, you're going to dump a $100 billion asset into the ocean," Robert Walker, a former U.S. congressman who began advising the Trump campaign in October, told the FAA's Commercial Space Transportation Advisory Committee before the election.

If the Trump administration decides to extend the station, it must weigh whether more responsibilities can be handed off to the private sector to reduce today's approximately $4 billion annual expenditure on space station operations and support. Currently, SpaceX and Orbital ATK are under contract to deliver cargo to the station, while Sierra Nevada is developing its Dream Chaser spacecraft for station logistics, too. SpaceX and Boeing have contracts for commercial crew launches, which could start in 2018.

NASA officials are looking at three broad operating schemes: limiting NASA dollars to those space station activities that further the agency's deep space exploration goals; investing in activities that support exploration and also commercialization goals; and investing NASA dollars more aggressively in commercialization

▸▸ CONTINUED ON PAGE 37

NASA

▲ **Robert Walker, a Trump administration** adviser and former U.S. congressman, sees the International Space Station continuing beyond 2024 but with operations shifted more toward the private sector.

▸▸ **AVIATION DECISIONS** Continued from page 34

To keep this competitive momentum going, many free-marketers would like Open Skies agreements with the countries that account for the remaining 30 percent of international departures. The U.S. also would need to renegotiate its Open Skies agreement with the United Kingdom, because the U.K. is leaving the European Union and will no longer be covered by the U.S.-EU agreement.

But Open Skies, like other free-trade policies, has its critics. Major U.S. passenger carriers complain that Persian Gulf carriers have used oil revenue to subsidize rapid growth in world markets under Open Skies. Then again, challenging this behavior could endanger the Open Skies approach. The Trump administration faces the challenge of preserving competition and ensuring that it is fair competition.

3. How far should the U.S. go on reducing aviation emissions?

ANALYSIS – The president-elect's team will quickly learn that advocates of cleaner flight see 2016 as a turning-point year. A committee of the International Civil Aviation Organization in February agreed on carbon dioxide emission limits for new aircraft to be applied in the early 2020s. In October, the U.S. joined 190 other nations in agreeing to an ICAO program in which carbon dioxide offsets could be applied to limit carbon emissions. An airline might, for instance, pay another entity or project outside aviation to reduce carbon dioxide emissions in order for the airline to continue emitting CO_2 at more than the level of 2000.

The U.S. signed up for a voluntary offset program, which starts in 2021. ICAO plans on mandatory offsets from 2027 to 2035. If the Trump administration and Congress accept the offsets, many implementation questions will need to be answered by 2020. Which government department will ensure U.S. compliance? How will carbon dioxide emissions be measured? Will the year 2000 base levels apply to airlines individually or as a whole? Which entities and projects will be eligible for offsets, and how will double counting of offsets be avoided?

4. How can flights of drones be expanded safely in the years ahead?

ANALYSIS – The FAA's new regulations for unmanned aircraft that went into effect in August are unlikely to be the last word on the topic of drones in the national airspace. The regulations allow flights of small drones in many areas but also limit their operating altitudes and create no-drone zones around airports. FAA is working on a system to protect descent and takeoff paths around airports. Many more decisions lie ahead if the Trump administration wants to set the conditions for this market to grow safely. When should geofencing — software that keeps drones from entering certain airspace or forces wayward drones to land — be applied? What rules can best ensure safety, and how can they be enforced? How does drone size affect safety? How should regulation of small, hobbyist drones differ from rules for larger business drones?

5. Should the Ex-Im Bank assist U.S. exports with loan guarantees?

ANALYSIS – The U.S. Export-Import Bank has financed foreign purchases of U.S. aircraft and serves as a counterweight to the export assistance given by other nations to their aerospace industries. But free-market purists in the U.S. consider Ex-Im loan guarantees to be subsidies. Opponents were successful in suspending Ex-Im programs for a while and have limited recent guarantees to $10 million. Aerospace manufacturers want the $10 million limit lifted and a regular Ex-Im appropriation bill passed, rather than another continuing resolution.★

Henry Canaday is a former energy economist who has written for Air Transport World, Aviation Week and other aviation publications for more than two decades.

▸▸ **SPACE DECISIONS** Continued from page 35

initiatives, even if they don't support classic exploration goals. NASA Chief of Staff Mike French described these options at the same advisory committee meeting where Walker spoke.

Walker — a longtime supporter of commercial space "before it was cool," as one industry executive put it — envisions the station as a beehive of private sector activity. Companies and an expanded set of international partners, potentially including China, would chip in for operations and upkeep.

2. Should new military satellites be "disaggregated"?

ANALYSIS – U.S. planners will surely brief the Trump team about proposals to make military satellite constellations less vulnerable to any antisatellite weapons that China or Russia might wield, either launched from the ground or maneuvering in space. The Pentagon wants to decide very soon what the replacement systems will look like for today's missile warning and nuclear command-and-control satellites. That way, work can begin toward fielding them a decade or two from now. One strategy under discussion, called disaggregation, calls for dispersing communication payloads and sensors across lots of smaller satellites, rather than concentrating them on large, vulnerable platforms.

3. Which agency should study Earth's climate, land and oceans?

ANALYSIS – It's no secret that many Republicans in Congress don't see the wisdom of NASA spending between $1.5 billion and $2 billion per year studying Earth when there is a whole solar system and beyond to explore.

The question is whether the Trump administration should try to move NASA's Earth sciences mission portfolio to NOAA, which operates weather satellites and is viewed by some lawmakers as a more appropriate home for that activity.

Moving those programs to NOAA would be complicated and messy and likely require congressional authorization. Advocates for Earth sciences worry the dollars might not be transferred with the portfolio. The move also could encounter fierce institutional resistance from NASA.

Politically, the powerful U.S. Sen. Barbara Mikulski, D-Maryland, is set to retire in January, so this could be a tempting time to try. Mikulski has been a longtime patron of NASA's Earth sciences work, much of which is performed in her state at the Goddard Space Flight Center.

4. Should the U.S. team with China on space projects?

ANALYSIS – Working with China in space has long been a political taboo for NASA and the Pentagon because of China's growing military power, antisatellite testing, military and industrial espionage, and suppression of dissident groups. But if Robert Walker, a Trump adviser and former U.S. congressman, has his druthers, the president-elect's administration would usher in a thaw in Sino-U.S. civil space relations, similar to that with Russia. He doesn't think U.S. know-how would be at risk:

"The fact is, I think we're probably in a position now where we can learn from China as much as they would potentially learn from us, and there's no doubt that they have some fairly expansive views of utilizing space," Walker said at a meeting of the FAA's Commercial Space Transportation Advisory Committee before the election.

Perhaps, but whether Capitol Hill's current denizens feel the same remains to be seen.

5. Should FAA manage space traffic?

ANALYSIS – The world's spacefaring nations have long leaned on the Pentagon as their de facto space traffic cop, but military leaders increasingly see this role as a burden and distraction. Commercial satellites are about to explode in numbers, which will make tracking them more challenging. The U.S. military would rather focus on China and Russia, which have maneuvered spacecraft in manners that suggest work toward antisatellite weapons in space. In 2007, China destroyed one of its weather satellites with an antisatellite rocket. Given that trend, the Pentagon wants the FAA to take on the job of providing standard collision avoidance warnings to government and commercial operators, since it already has a commercial space regulatory role. The FAA's Office of Commercial Space Transportation says such a transition could work. It could fall on the Trump administration to give this novel idea an official thumbs-up — or down. ★

Warren Ferster is a senior analyst with the space consulting practice of The Tauri Group in Alexandria, Virginia. He was editor-in-chief of Space News, where he worked for 21 years, starting as the national affairs and policy reporter.

▼ **The FAA implemented new regulations** for unmanned aircraft in August, but questions remain on how rules for larger business drones should differ from hobbyist drones, such as Parrot's Bebop 2.

Parrot


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DETERRING NORTH KOREA

The U.S. Missile Defense Agency wants 2017 to be a turning-point year for an anti-missile system the Pentagon knowingly deployed before it was fully developed. **Michael Peck** examines the technology and history of the Ground-based Midcourse Defense system.

BY MICHAEL PECK | michael.peck1@gmail.com

Should North Korea's leaders ever consider launching a nuclear-tipped missile at the United States, there are two considerations that might give them pause: First, there is the certainty that North Korea would be committing national suicide. Second, there is the uncertainty that the missile's warheads would ever reach Honolulu or Los Angeles.

That's because the U.S. plans to body-slam any warheads headed this way with darts that would be launched atop boosters sprung from among dozens of silos in Alaska and California.

Ground-Based Interceptors like this one are deployed in Fort Greely, Alaska, and Vandenberg Air Force Base, California, to defend against missile attacks on the U.S. homeland. The Missile Defense Agency plans to raise the number deployed to 44 and improve their Exoatmospheric Kill Vehicles.

Missile Defense Agency/Defense Department

The task for the $28 billion Ground-based Midcourse Defense system, or GMD, is often compared to hitting a bullet with a bullet, but that's probably an understatement. First, the interceptor must spot the bullet in the vast expanse of space. Then it must intercept it at a combined closing velocity at least 10 times higher than that of two bullets fired at each other.

No one can credibly promise that the GMD system will work as planned in an emergency, but with North Korea exploding nuclear bombs underground and testing long-range missiles, the U.S. plans to spend hundreds of millions of dollars in 2017 to continue improving a system that was rushed into service in 2004 to meet then-U.S. President George W. Bush's deadline for deploying a missile defense system.

Intercepting a warhead arcing through space requires fast detection of the missile launch followed by the firing of an interceptor missile armed with an Exoatmospheric Kill Vehicle, plus accurately discriminating the real warhead from what's likely to be decoys and a cloud of debris left by a warhead or warheads separating from a missile.

Norm Tew, the program director for prime contractor Boeing, notes that the GMD system must link seven kinds of sensors spanning 15 time zones. The sensing needed to detect and knock down warheads comes from the Space-Based Infrared System satellites; Cobra Dane upgraded early warning radars; the Ballistic Missile Early Warning System radars in Greenland and England; Precision Acquisition Vehicle Entry Phased Array Warning System radars in the U.S.; a floating Sea-Based X-band radar; land-based mobile X-band radars; and Aegis ship-based radars. Tew, who has been working in missile defense since 1983, describes GMD as such a vast conglomeration of sensors that it is "the missile system for which you can't stand in one place and see everything required to commence an engagement."

As vast an undertaking as it is, it's clear what GMD is not: an impervious "Star Wars"-esque shield meant to eliminate the specter of total nuclear annihilation. If hundreds of Russian intercontinental ballistic missiles were to streak in over the North Pole, GMD won't stop them. GMD is strictly aimed at blocking a missile strike from a rogue nation, in particular North Korea, but the system could also defend against Iran, should the international nuclear agreement fail.

Why it's the focus

Currently, the U.S. has at the ready 30 ground-based interceptors: 26 at Fort Greely, Alaska, and four at Vandenberg Air Force Base, California. By 2017, 44 are scheduled to be primed for launch from their underground silos. In an attack, a volley of them would rise from their silos. Once in space, each booster would release a rocket-propelled metal cylinder. Each cylinder, guided by its own optical and infrared sensors plus targeting data fed from ground- and space-based sensors, would slam into an incoming warhead, the sheer kinetic impact of the collision destroying or disabling the warhead.

The goal is to destroy a warhead in the middle of its approximately 30-minute flight, when the launch vehicle has ascended through the atmosphere and

▼ **A Ground-based Interceptor roars** from Vandenberg Air Force Base last January to test a redesign of the Exoatmospheric Kill Vehicle.

Raytheon

NASA

▲ **In the dark:** North Korea and South Korea as photographed from the International Space Station. In 2004, then-President George W. Bush accused North Korea of "arming with missiles and weapons of mass destruction, while starving its citizens."

into space and the engines have burned out.

To understand why the Pentagon has made such a focus of going after warheads in space, instead of only when they are conveniently closer to the ground, consider the three stages of an ICBM's trajectory: boost, midcourse and terminal. All things being equal, experts say the best time to shoot down a ballistic missile would be during the boost phase, when it is ascending slowly on a pillar of fire that makes a lovely beacon for optical and infrared sensors and weapons. In addition, the warheads and decoys are still nestled in the nose cone, so there is only one target. The trade-off is that boost phase is geographically and technically challenging. As a 2004 American Physical Society report pointed out, the boost phase only lasts two minutes for solid-fueled missiles and three minutes for liquid-fueled, which leaves little time for interception. An interceptor, or perhaps someday a laser, would need to be positioned or flown close to the enemy's launch site.

Then there is the terminal phase, when the warhead is falling through the atmosphere toward its target. Terminal interceptors would have an easier time picking out targets from decoys, because real warheads fall through the atmosphere more slowly and heat up more quickly than heavier warheads sheathed in protective materials. The downside is that the terminal phase might last only 30 seconds, and the warheads could potentially take evasive action or detonate above their targets.

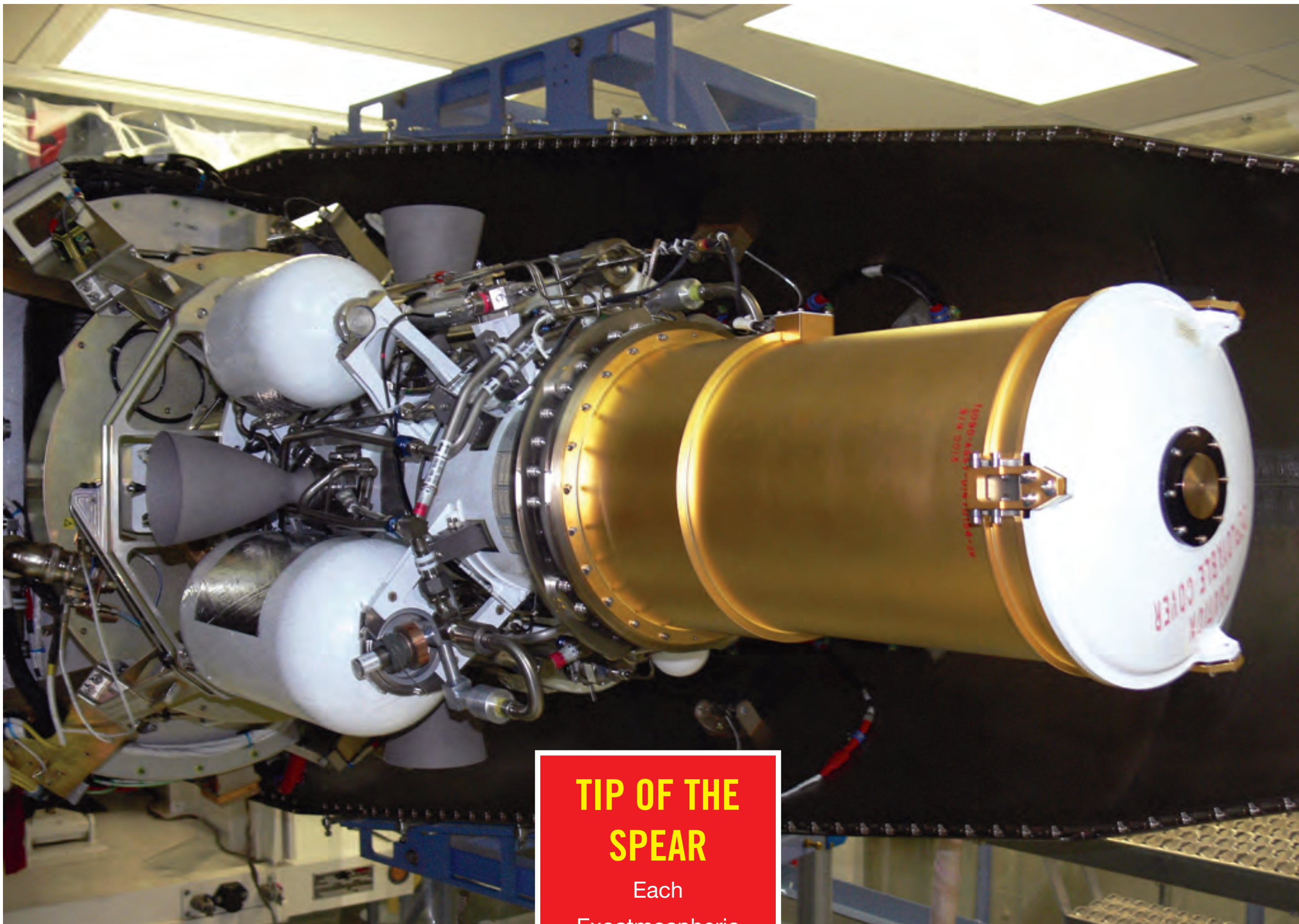
Experts hope that defending the homeland will never come down to a shot in the terminal phase alone, which is why the midcourse is the main focus, at least for now. In the long term, the U.S. Missile Defense Agency wants to put lasers on high-altitude, long-endurance unmanned planes and destroy missiles in the boost phase from standoff ranges. U.S. Navy Vice Adm. James Syring, head of the MDA, said in August 2016 that the agency plans to test lasers aboard MQ-9 Reaper unmanned aircraft. Last year, five prime contractors — Boeing, General Atomics Aeronautical Systems, Lockheed Martin, Northrop Grumman and Raytheon — completed MDA-funded studies to assess the feasibility of an airborne laser demonstrator. In fiscal 2017, MDA plans to award two contracts for preliminary design of a multi-kilowatt laser to be mounted on a high-altitude manned or unmanned aircraft. The goal is to flight test a prototype in 2020.

THE DREAM TEAM

For the Ground-based Midcourse Defense program, Boeing is prime contractor, with Orbital ATK building the booster, Raytheon building the kill vehicle and Northrop Grumman building the fire control and communications systems.

Why it's hard

Development of GMD has been technically challenging, especially the Exoatmospheric Kill Vehicle, or EKV. An MDA fact sheet on GMD lists 17 tests between 1999 and 2014, of which nine were deemed successful: Three of the eight failures were caused



Raytheon

TIP OF THE SPEAR

Each Exoatmospheric Kill Vehicle, or EKV, is a cylinder with four thrusters encircling its midsection. The kill vehicle's three sensors — two infrared and one that detects visible light — must pick out a nuclear warhead or warheads from amid a cloud of decoys and debris from its booster. Once the sensors pick out the warheads, its thrusters line it up to intercept the target.

by the kill vehicle not separating from the booster; two involved sensor issues on the kill vehicle; two involved failure to launch due to problems with launch software or silo hardware; and one was scrubbed because the target vehicle malfunctioned.

Ted Postol, a professor emeritus of science and international security at the Massachusetts Institute of Technology, argues that the basic science behind GMD is flawed.

Postol believes that while the kill vehicle's sensors can detect objects in space, they can't discern warheads from decoys until it is too late to intercept. Assume the warheads and decoys are traveling at around 7 kilometers per second, and the kill vehicle at around 8 kilometers per second, for a combined closing speed of 15 kilometers per second, Postol postulates. If the kill vehicle's sensors only register indeterminate points until the targets are about 10 kilometers away — his best guess based on likely fields of view and sensor dimensions — then once the true target is discriminated, there would be less than one second to adjust course and strike it.

Postol compares the task to a street-corner shell game: You can see the hustler whirl his three cups over the table, but you can't be sure which cup has the little ball. Picking out the warhead from among a cloud of decoys and debris can't be done quickly enough, he says. The only way to find the real warhead would be to have advance knowledge of the characteristics of the warhead, such as its shape, temperature and color.

MDA and the companies that build GMD have a hard time blunting such arguments with specifics, because they fear that disclosing technical details could enable an adversary to spoof or evade a kill vehicle.

Still, Air Force Brig. Gen. Bill Cooley, GMD program director at MDA, expresses confidence about the GMD system. "Objects have different [sensor] signatures," he tells Aerospace America. "We use all phenomenology to perform discrimination."

Tew points out that GMD uses a combination of technologies, including infrared and visible-light sensors on the EKV, plus ground- and space-based sensors that feed updated targeting information to the booster and kill vehicle in flight.

"With any one type of technology, you can figure out how to confuse" a kill vehicle, Tew adds. "So the key is you want to use all the types to make it really difficult for anything to get past it."

Even if the EKV's sensors work as designed, hitting a fast-moving warhead will require the kill vehicle to maneuver extremely rapidly. Which is where

EVEN IF THE EKV'S SENSORS WORK AS DESIGNED, HITTING A FAST-MOVING WARHEAD WILL REQUIRE THE KILL VEHICLE TO MANEUVER EXTREMELY RAPIDLY. WHICH IS WHERE THE GMD STORY GETS ESPECIALLY COMPLICATED.

the GMD story gets especially complicated. A persistent problem with GMD has been rough combustion of the EKV's thrusters. This shakes the kill vehicle's initial measurement unit, which must determine the kill vehicle's position relative to the target. In at least one test, the shaking caused the kill vehicle to miss its target.

That problem affected the first generation of the EKV fielded in 2004, called the Capability Enhanced, or CE-1. New interceptors are equipped with the CE-2 models whose inertial measurement units are cocooned against vibrations caused by rough-firing thrusters. Engineers also improved the sensors, electronics and communication components. MDA declines to specify the exact mix of CE-1s and CE-2s in the field. However, the agency says Redesigned Kill Vehicles currently under development will replace all existing CE-1s by fiscal year 2022. The CE-2 was tested Jan. 28, 2016, in what MDA called a non-intercept test. The kill vehicle wasn't supposed to hit the target but rather get close enough to show that its sensors and thrusters worked. MDA proclaimed the test a success, but in July, the Los Angeles Times reported the kill vehicle had not homed in anywhere near the target. MDA maintains that the test was not meant to be an intercept and that it was successful.

The January launch is not listed on the MDA fact sheet describing test results, and MDA says this is because the sheet lists only intercept tests. The agency provided a list of 11 non-intercept tests between June 1997 and January 2016, all of which were described as "achieving test objectives."

Early deployment

President George W. Bush in 2002 ordered the Pentagon to put a GMD defense in place by 2004. In his January State of the Union address, Bush had accused North Korea of "arming with missiles and weapons of mass destruction, while starving its citizens," and he placed its government in what he called an "axis of evil" with Iraq and Iran. For acquisition officials, Bush's decision meant that GMD had to be developed at the same time as it was being fielded. Bush's predecessor, Bill Clinton, had started the GMD program by signing the National Missile Defense Act of 1999, but Clinton had deferred a deployment decision to his successor.

Raytheon

▲ **A Raytheon engineer** conducts final inspections during assembly of an Exoatmospherc Kill Vehicle.

◀ **An Exoatmospheric** Kill Vehicle is shown in the shroud of a Ground-based Interceptor.

In subsequent years, Government Accountability Office reports criticized the Pentagon for deploying equipment before it was fully tested. As a 2012 GAO study noted, while "some concurrency is understandable, committing to product development before requirements are understood and technologies mature or committing to production and fielding before development is complete is a high-risk strategy that often results in performance shortfalls, unexpected cost increases, schedule delays and test problems."

MDA continues to work toward improving the system. The agency wants $274 million in fiscal 2017 for the Redesigned Kill Vehicle. Another $72 million would go for development of a Multi-Object Kill Vehicle. Just as ICBMs can carry multiple warheads, a single interceptor would carry multiple kill vehicles. The agency also wants an upgraded interceptor that could be launched as a two- or three-stage booster depending on the range to the target.

As program director Cooley sees it, the GMD program has reached a turning point. The focus has shifted from basic development to making the system reliable and sustainable. A CE-1 built in 2004 is now 12 years old, raising issues of obsolescence and maintaining an industrial base for spare parts. Cooley wants to see a kill vehicle "that can last for decades." ★


AIAA Congressional Visits Day
Raise the Image of Aerospace in Washington
Congressional Visits Day
Wednesday, 29 March 2017
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!
Travel subsidies are available
"I continue to participate every year because it's important to me to keep learning more about these pertinent issues and to dedicate my time to help our community develop and grow."
—Kayleigh Gordon, Aerospace Engineering graduate student, Ohio State University
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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.

Notes About the Calendar

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2017			
7–8 Jan	Introduction to Shock-Wave/Boundary-Layer Interactions Course	Grapevine, TX	
7–8 Jan	Liquid Atomization, Spray, and Fuel Injection in Aircraft Gas Turbine Engines Course	Grapevine, TX	
7–8 Jan	Six-Degrees-of-Freedom Modeling of Missile and Aircraft Simulations Course	Grapevine, TX	
7–8 Jan	2nd AIAA Sonic Boom Prediction Workshop	Grapevine, TX	
8 Jan	Hypersonics Test Course	Grapevine, TX	
9 Jan	2017 Associate Fellows Recognition Ceremony and Dinner	Grapevine, TX	
9–13 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – 25th AIAA/AHS Adaptive Structures Conference – 55th AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – 19th AIAA Non-Deterministic Approaches Conference – 58th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – 10th Symposium on Space Resource Utilization – 4th AIAA Spacecraft Structures Conference – 35th Wind Energy Symposium	Grapevine, TX	6 Jun 16
22–26 Jan†	97th American Meteorological Society Annual Meeting	Seattle, WA (Contact: https://annual.ametsoc.org/2017/)	
23–26 Jan†	63rd Annual Reliabiltiy & Maintainability Symposium (RAMS 2017)	Orlando, FL (http://rams.org/)	
5–9 Feb†	27th AAS/AIAA Space Flight Mechanics Meeting	San Antonio, TX (Contact: www.space-flight.org/docs/2017_winter/2017_winter.html)	7 Oct 16
4–11 Mar†	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	
6–9 Mar†	21st AIAA International Space Planes and Hypersonic Systems and Technology Conference (Hypersonics 2017)	Xiamen, China	22 Sep 16
29 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (http://www.aiaa.org/CVD/)	
18–20 Apr†	17th Integrated Communications and Surveillance (ICNS) Conference	Herndon, VA (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, http://i-cns.org)	
25–27 Apr	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	4 Oct 16
25–27 Apr†	EuroGNC 2017, 4th CEAS Specialist Conference on Guidance, Navigation, and Control	Warsaw, Poland (Contact: robert.glebocki@mel.pw.edu.pl; http://www.ceas-gnc.eu/)	
2 May	2017 Fellows Dinner	Crystal City, VA	
3 May	Aerospace Spotlight Awards Gala	Washington, DC	
8–11 May†	AUVSI/AIAA Workshop on Civilian Applications of Unmanned Aircraft Systems	Dallas, TX (www.xponential.org/auvsi2016/public/enter.aspx)	
15–19 May†	2017 IAA Planetary Defense Conference	Tokyo, Japan (Contact: http://pdc.iaaweb.org)	
25–29 May†	International Space Development Conference	St. Louis, MO (Contact: ISDC.nss.org/2017)	
29–31 May†	24th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: Ms. M. V. Grishina, icins@eprib.ru, www.elektropribor.spb.ru)	
3–4 Jun	3rd AIAA CFD High Lift Prediction Workshop	Denver, CO	

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

AIAA Continuing Education offerings

AIAA Symposiums and Workshops

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
3–4 Jun	1st AIAA Geometry and Mesh Generation Workshop	Denver, CO	
5–9 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – 24th AIAA Aerodynamic Decelerator Systems Technology Conference – 33rd AIAA Aerodynamic Measurement Technology and Ground Testing Conference – 35th AIAA Applied Aerodynamics Conference – AIAA Atmospheric Flight Mechanics Conference – 9th AIAA Atmospheric and Space Environments Conference – 17th AIAA Aviation Technology, Integration, and Operations Conference – AIAA Flight Testing Conference – 47th AIAA Fluid Dynamics Conference – 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference – AIAA Modeling and Simulation Technologies Conference – 48th Plasmadynamics and Lasers Conference – AIAA Balloon Systems Conference – 23rd AIAA Lighter-Than-Air Systems Technology Conference – 23rd AIAA/CEAS Aeroacoustics Conference – 8th AIAA Theoretical Fluid Mechanics Conference – AIAA Complex Aerospace Systems Exchange – 23rd AIAA Computational Fluid Dynamics Conference – 47th Thermophysics Conference	Denver, CO	27 Oct 16
5–6 Jun	Cybersecurity Symposium at AIAA AVIATION Forum	Denver, CO	
6–7 Jun	DEMAND for UNMANNED at AIAA AVIATION Forum	Denver, CO	
6–9 Jun†	8th International Conference on Recent Advances in Space Technologies (RAST 2017)	Istanbul, Turkey (Contact: www.rast.org.tr)	
7–9 Jun	Electric Flight Workshop at AIAA AVIATION Forum	Denver, CO	
19–21 Jun†	9th International Workshop on Satellite Constellations and Formation Flying	Boulder, CO (Contact: http://ccar.colorado.edu/iwscff2017)	
10–12 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – 53rd AIAA/SAE/ASEE Joint Propulsion Conference – 15th International Energy Conversion Engineering Conference	Atlanta, GA	4 Jan 17
20–24 Aug†	2017 AAS/AIAA Astrodynamics Specialist Conference	Stevenson, WA	24 Apr 17
12–14 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition)	Orlando, FL	21 Feb 17
13–16 Sept†	21st Workshop of the Aeroacoustics Specialists Committee of the Council of European Aerospace Societies (CEAS)	Dublin, Ireland	
25–29 Sept†	68th International Astronautical Congress	Adelaide, Australia	28 Feb 17
2018			
8–12 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – 26th AIAA/AHS Adaptive Structures Conference – 56th AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – 20th AIAA Non-Deterministic Approaches Conference – 28th AAS/AIAA Space Flight Mechanics Meeting – 59th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – 11th Symposium on Space Resource Utilization – 5th AIAA Spacecraft Structures Conference – 36th Wind Energy Symposium	Orlando, FL	

News

AIAA Rocky Mountain Section 5th Annual Technical Symposium

by Pamela A. Burke

On 21 October, the AIAA Rocky Mountain Section (RMS) gathered to celebrate aerospace/aviation technologies and interests important to the RMS community — from additive manufacturing, unmanned aerial vehicles/systems (UAV/UAS), SmallSats, and Mars exploration to international collaboration and political implications to the industry. For the fifth year in a row, the Annual Technical Symposium (ATS) attendees represented the full range of the Rocky Mountain aerospace community, including representatives from academia, government, and industry.

This year's event was hosted at the Colorado School of Mines (CSM) in the beautiful foothills town of Golden, CO. ATS participants found their day abundantly full with four parallel presentation tracks, a host of plenary presentations, as well as four panel discussions. Ample time was scheduled for networking and perusing the participant poster presentations, sponsor tables and displays, and static exhibits from several local UAV/UAS companies.

Mars emerged as a major topic for ATS 2016. The keynote speaker (Jim Crocker), both Diamond Sponsor (Lockheed Martin and Deep Space Systems) speakers, and multiple session presented on aspects of the history, current technologies, and future for exploring our nearest planetary neighbor. Capping this exciting symposium, Deep Space Systems provided a platform for participants to experience the Lockheed Martin "Mars Base Camp Experience" virtual reality system.

The day started with RMS Chair Brian Gulliver and ATS Chair Scott Tuttle welcoming the participants and sponsors. Scott then introduced the program kickoff speaker Dr. Kevin Moore, dean of the College of Engineering and Computational Sciences at Colorado School of Mines, who addressed the role of CSM and its graduates in aerospace technologies and applications. Rob Chambers, representing Diamond Sponsor Lockheed Martin, gave an invigorating presentation on the Lockheed Martin Mars Base Camp concept and provided convincing arguments about an evolutionary series of missions to viably achieve Mars Base Camp in orbit around Mars by 2028 – "MBC 28".

Photos above: UAV/UAS from Reference Technologies, Leptron, and Black Swift Technologies

After a morning of panels and presentations, the symposium attendees listened to keynote speaker Jim Crocker, former vice president and general manager of Lockheed Martin Space Systems Company (LMSSC) International, give a presentation entitled "The Once and Future Mars," which educated the participants on the history of human investigation of Mars stretching back 4,000 years — from ancient Egypt through the technical revolutions for the study of Mars to the future technologies that will make humans a spacefaring species and inhabitants of Mars. Later in the day, Steve Bailey, of Diamond Sponsor Deep Space Systems, presented a detailed technical assessment of the Lockheed Martin Mars Base Camp, supporting missions, and technologies in his presentation "The Case for Lockheed Martin's Mars Base Camp."

The morning panel, "Political Influences on the Colorado Aerospace Economy," addressed both space and aviation issues. Tracy Copp, from Ball Aerospace and RMS Public Policy Chair, moderated this energetic panel that included Stacey DeFore from Teledyne Brown Engineering, the Colorado Aerospace and Defense Industry Champion Jay Lindell, LMSSC's Government Relations Director Joe Rice, David Ruppel from Front Range Airport (Spaceport Colorado), and Scott Palo from University of Colorado (UC) Boulder.

Later, attendees could choose between the two mid-day panels – UAVs and smallsats. "The Future of Unmanned Aerial Systems" addressed the environment and applications of the growing UAV/UAS industry and was moderated by Allen Bishop, president and CEO of Reference Technologies, the developer of the Hummingbird UAS. Panel members included Constantin Diehl of UAS Colorado, Emanuel Anton from the law firm Polsinelli, LLC, Stephen Meer from the Boulder County Sheriff's Office, Tom McKinnon of Agribotix, Professor Brian Argrow of CU Boulder, and Bill Dunn from the FAA Flight Standards District Office.

"The Big Value of SmallSats," moderated by Erik Eliasen, AIAA RMS Montana Chair and vice president for National Security Space Programs at SSC Space US, investigated different aspects of "value": business value, mission value, enterprise value, and human value (STEM). Panel members included Mike Gazarik from Ball Aerospace, Rick Sanford from Surrey Satellite Technology, Rick Kohnert of the University of Colorado's Laboratory of Atmospheric and Space Physics (LASP), and Debbie Rose of Southwest Research Institute (SwRI). This panel held an engaging exchange with the audience that continued through the rest of the day.

The closing panel, "International Collaboration in Aerospace," was moderated by Kay Sears, vice president of Strategy and Business Development


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for LMSSC. Joining her was an impressive panel that included the NASA Orion Program Assistant Program Manager Paul Marshall, Vice President of Business Development at Sierra Nevada Corp.


3

1 ATS Chair Scott Tuttle

2 Dr. Kevin Moore

3 SmallSat Panel

John Roth, Vice President of Business Development at Teledyne Brown Engineering Scott Alexander, and Director of Engineering at LASP Michael McGrath.

As the day came to an end, ATS Chair Scott Tuttle closed the symposium and thanked all participants and sponsors. ATS 2016 was honored to have several returning sponsors whose support of this event demonstrates their continued interest in supporting the local community and their influence on its future. In addition to the Diamond Sponsors (Lockheed Martin and Deep Space Systems), there were three Platinum sponsors – Red Canyon Engineering and Software, Advanced Solutions Inc., and Ball Aerospace; and seven Gold sponsors - Surrey Satellite Technology US, Sierra Nevada Corp., ISYS Technologies, Teledyne Brown Engineering, SEAKR Engineering, Colorado Space Business Roundtable (CSBR), and Bristol Brewing Company.

There were 247 registered attendees at ATS 2016, of which 23% were students. ATS again was able to offer a discount for new professional members resulting in nine new members (2 professional, 3 young professional, and 4 students) signing up at symposium and several more taking applications. The success of ATS 2016 helps support several RMS events and initiatives including the new RMS Scholarship within the AIAA Foundation.

The 6th Rocky Mountain Section ATS will be hosted by Metropolitan State University of Denver in October 2017. For additional information and photos about RMS ATS 2016 and other RMS events, please visit the RMS website www.aiaa-rm.org.

Atlanta Warbird Weekend

by Ken Philippart

Images courtesy of Arloe Mayne and Lisa Philippart

Members of the AIAA Greater Huntsville Section (Alan and Suzanne Minga, Mike Pessin, Arloe Mayne, Sean Wang, Jennifer Shu-Wang, Zoe Wang, and Ken and Lisa Philippart) headed to Atlanta, GA, the last weekend in September to attend the third annual Atlanta Warbird Weekend. Warbird Weekend commemorates the aircraft and more importantly, the brave men and women, who participated in World War II. This year marked the 75th anniversary of the American Volunteer Group (AVG), better known as the Flying Tigers. Almost 40 aircraft lined the ramp with close to 20 World War II veterans attending. Throughout the day, veterans talked about their experiences while historians provided summaries of operations and other perspective on the China-Burma-India (CBI) theater. Two surviving members of the AVG were on hand to discuss their experiences with a backdrop of the Flying Tigers' steeds, five P40 pursuits.

Warbird rides were available throughout the day and the sight of Mustangs, Texans, and other WWII aircraft regularly taking off and landing was a sight to behold. Two AIAA members took to the skies to experience WWII-era aviation firsthand. Arloe Mayne flew in a Fairchild PT-19A trainer and Ken Philippart hopped aboard a DC-3 to see what passenger travel was like 70 years ago. The DC-3 is unpressurized and with the day's 96-degree temperatures, passenger comfort left a lot to be desired. Dr. Mayne commented that his flight was very comfortable; he flew with the canopy pushed back the entire time and the 100-knot wind kept things cool.

A Curtiss C-46 Commando and Douglas C-47 Skytrain were also on static display and open for tours. Re-enactors in authentic WWII uniforms conducted a simulated mission briefing in front of the aircraft followed by a question-and answer-session with veterans who had flown the Hump route during the war to make history come alive. Lt. Col. Dick Cole, U.S. Air Force (retired), the last surviving member of the Doolittle Tokyo Raiders, was on hand signing autographs and meeting visitors. Lt. Col. Cole, at 100 years old, shared his experiences as Jimmy Doolittle's co-pilot during the 1942 raid and subsequent experiences flying the Hump in the CBI theater. The day concluded with the contingent of five P-40s performing several formation flybys in front of the crowd.

On Sunday, the group went on a tour of the Delta Flight Museum. Ms. Jolie Elder of the AIAA Atlanta Section joined Greater Huntsville for the museum tour, tracing Delta Air Lines' history from its beginnings as a crop dusting service to the major American carrier that it is today. Interior tours of historic aircraft and interactive displays were highlights. The members hatched preliminary ideas for future collaboration between the Atlanta and Greater Huntsville Sections.

The Atlanta Warbird weekend trip was a great way to meet fellow AIAA members, share our love of flying machines, and learn about WWII aviation from the legendary pilots who flew them and the patriot maintainers who kept them in the air.

Fleet Scholarships Awarded by AIAA San Diego Section

The AIAA San Diego Section awarded the Reuben H. Fleet Scholarships at the AIAA San Diego Honors and Awards Banquet on 25 April 2016. Since 1983, 184 students have received the scholarship, made possible by the Reuben H. Fleet Foundation at The San Diego Foundation.

The 2016 Reuben H. Fleet Scholarship recipients (left to right): Greg Marien (Scholarship Coordinator), Nicholas Johnson (Westview High School), Michael Maher (Westview High School), Bryan Martin (Otay Ranch High School), Benjamin Martin (UCSD), Graham Root (SDSU), Enrico Santarpia (SDSU), Man-Yeung Tsay (UCSD), and Alex Fleet (Grandson of Reuben H. Fleet). Not pictured: Rachel Rybarczyk (UCSD/SDSU).

Albuquerque Section Participates in Local Middle School Career Fair

by Robert Malseed, AIAA Albuquerque Section Treasurer

In November, members of the AIAA Albuquerque Section presented a booth at the Lincoln Middle School Career Fair in Rio Rancho. Elfego Pinon, Robert Malseed, and Linda Malseed talked with students to encourage them to consider careers in STEM. A multitude of students came by with questions about careers. Members handed out brochures about aerospace engineering as well as some fun toys that had been provided by AIAA Headquarters. A major item of interest was the Microsoft Flight Simulator software, as dozens of students tried their hand at flying.

Elfego Pinon (far right) shows videos of drones programmed to fly synchronized formations through obstacles.

AIAA Sustained Service Award Winners Announced

Congratulations to the following members who will receive an AIAA Sustained Service Award during 2017. Without their passion for aerospace engineering and science as well as their dedicated efforts, AIAA could not fulfill our mission to inspire and advance the future of aerospace.

REGION 1: Richard Wahls, AIAA Hampton Roads Section
For sustained, significant service at the national level through Technical and Program Committees with emphasis on conference/forum leadership and content development.

REGION 3: Marc Polanka, AIAA Dayton-Cincinnati Section
For service to the Dayton-Cincinnati Section as past chair of the section, past chair of the DCASS conference, and continued service as Honors and Awards Chair and the AFIT Student Section faculty advisor.

REGION 5: Dale Pitt, AIAA St. Louis Section
For over 40 years of significant and lasting service to AIAA at the local, regional, and technical levels.

The Sustained Service Award recognizes an AIAA member who has shown continuing dedication to the interests of the Institute by making significant and sustained contributions over a period of time, typically 10 years or more. Visit http://www.aiaa.org/OpenNominations/ to download the nomination form. The nomination and scoresheet are due to AIAA by 1 July 2017.

Women in Aeronautics and Astronautics Hosts First "WIAA Night"

WIAA members and keynote speaker: (from left to right)
Lauren Trollinger, Rosemary Davidson, Kim Westbrook, Catherine Steele (keynote speaker), Elaine Petro, Sam Howard, Brandi Churchwell, and Paige Pruce.

In November, Women in Aeronautics and Astronautics (WIAA), with the support of the University of Maryland's (UMD) Aerospace Engineering Department, AIAA Diversity Working Group, The Aerospace Corporation and The Boeing Company, hosted the first-ever WIAA Night. This night was a celebration of the organization's accomplishments since its founding in 2015 and an opportunity to thank our sponsors and supporters.

WIAA President Kim Westbrook welcomed the 30-plus attendees and explained the purpose of WIAA and provided an overview of the accomplishments from the past two years. Dr. Norman Wereley, UMD Aerospace Department Chair and AIAA Fellow, welcomed everyone to the university and commended WIAA for their commitment. Merrie Scott, development director of the AIAA Foundation, and Mary Snitch, senior staff of Industry Organizations at Lockheed Martin Space Systems Company and AIAA Fellow, both spoke on behalf of the AIAA Foundation and the AIAA Diversity Working Group.

The highlight of WIAA Night was the keynote address from Catherine J. Steele, senior vice president of The Aerospace Corporation's National Systems Group and AIAA Associate Fellow. Ms. Steele, using her personal experiences, provided tips for young professionals entering the workforce. The talk was impactful and inspiring.

AIAA Student Branches, 2016–2017

AIAA has over 215 Student Branches around the world. Each branch has a Student Branch chair elected each year, and a faculty advisor who serves long term to support their branch's activities. Like the professional Sections, the Student Branches invite speakers, take field trips, promote career development, and participate in projects that introduce students to membership with AIAA and their professional futures. The branches, and their officers in particular, organize their activities in addition to their full-time schoolwork, and their advisors clearly care deeply about their students' futures. Please join us in acknowledging the time and effort that all of them take to make their programs successful.

FA = Faculty Advisor
SBC = Student Branch Chair

REGION I — NORTH EAST

Boston University, FA, Sheryl Grace; SBC, Scott Nickelsberg (New England Section)

Brown University, FA, TBD; SBC, TBD (New England Section)

Carnegie Mellon University, FA, Satbir Singh; SBC, Aaron Tian (Mid-Atlantic Section)

Catholic University of America, FA, Masataka Okutsu; SBC, Danielle Caruccio (National Capital Section)

City College-New York, FA, Ali Sadegh; SBC, Alaa Barakat (Long Island Section)

Clarkson University, FA, Kenneth Visser; SBC, Steven Latimer (Northeastern New York)

Columbia University, FA, Bob Stark; SBC, TBD (Long Island Section)

Cornell University, FA, Perrine Pepiot; SBC, Ming-Wei Wang; SBC, Connor Dempsey (Niagara Frontier Section)

Daniel Webster College, FA, Xinyun Guo; SBC, Jamie Davidson (New England Section)

Dartmouth College, FA, TBD; SBC, TBD (New England Section)

Drexel University, FA, Ajmal Yousuff; SBC, Aryaman Sinha (Greater Philadelphia Section)

George Washington University, FA, Adam Wickenheiser; SBC, David Palumbo (National Capital Section)

Hofstra University, FA, John Vaccaro; SBC, TBD (Long Island Section)

Howard University, FA, TBD; SBC, TBD (National Capital Section)

Johns Hopkins University, FA, Kerri Phillips; SBC, Jalen Doherty (Mid-Atlantic Section)

Lehigh University, FA, Terry Hart; SBC, Ara Parseghian (Greater Philadelphia Section)

Manhattan College, FA, John Leylegian; SBC, Tyler McCloskey (Long Island Section)

Massachusetts Institute of Technology, FA, David Darmofal; SBC, Martina Stadler (New England Section)

National Institute of Aerospace, FA, TBD; SBC, TBD (Hampton Roads Section)

New York Institute of Technology, FA, ZhiYun Lu; SBC, TBD (Long Island Section)

NJIT-New Jersey Institute of Technology, FA, Edward Dreizin; SBC, TBD (Northern New Jersey Section)

Northeastern University, FA, Andrew Gouldstone; SBC, Jennifer Morin (New England Section)

Old Dominion University, FA, Colin Britcher; SBC, Adam Horn (Hampton Roads Section)

Pennsylvania State University, FA, Robert Melton; SBC, Christopher Axten (Central Pennsylvania Section)

Polytechnic Inst. of Brooklyn, FA, Iraj Kalkhoran; SBC, TBD (Long Island Section)

Princeton University, FA, Michael Mueller; SBC, William Guiraroche (Northern New Jersey Section)

Rensselaer Polytechnic Institute, FA, Farhan Gandhi; SBC, Alexander Kocher (Northeastern New York Section)

Rochester Institute of Technology, FA, Agamemnon Crassidis; SBC, TBD (Niagara Frontier Section)

Rowan University, FA, John Schmalzel; SBC, Tyler Harlow (Southern New Jersey Section)

Rutgers University, FA, Francisco Diez; SBC, Kevin Leiton (Northern New Jersey Section)

State University of New York-Buffalo, FA, Paul Schifferle; SBC, Asad Esa (Niagara Frontier Section)

Stevens Institute of Technology, FA, Siva Thangam; FA, TBD (Northern New Jersey Section)

Stony Brook University, FA, Sotirios Mamalis; SBC, Matthew Lee (Long Island Section)

Syracuse University, FA, John Dannenhoffer; SBC, Dalya Omar (Northeastern New York Section)

United States Naval Academy, FA, Scott Drayton; SBC, Samuel Williams (Mid-Atlantic Section)

University of Connecticut, FA, Chih-Jen Sung; SBC, Meagan Ferreira (Connecticut Section)

University of Delaware, FA, TBD; SBC, TBD (Delaware Section)

University of Maine, FA, Alexander Friess; SBC, John Seekins (New England Section)

University of Maryland, FA, Christine Hartzell; SBC, Evelyn Flint (National Capital Section)

University of Massachusetts - Lowell, FA, David Willis; SBC, Evan Brown (New England Section)

University of Pittsburgh, FA, Peyman Givi; SBC, Caren Dieglio, Mid-Atlantic Section)

University of Vermont, FA, Darren Hitt; SBC, Greg Castaldi (New England Section)

University of Virginia, FA, Christopher Goyne; SBC, Matthew Asper National Capital Section)

U.S. Military Academy\West Point, FA, Drew Curriston; SBC, TBD (Long Island Section)

Vaughn College of Aeronautics and Technology, FA, Amir Elzawawy; SBC, Andrew Aquino (Long Island Section)

Villanova University, FA, Kenneth Kroos; SBC, John Coppa (Greater Philadelphia Section)

Virginia Polytechnic Institute and State University, FA, Mayuresh Patil; SBC, Vidya Vishwanathan (Hampton Roads Section)

Wentworth Institute of Technology, FA, Haifa El-Sadi; SBC, Jared Parker (New England Section)

West Virginia University, FA, Wade Huebsch; SBC, Walker McCord (Mid-Atlantic Section)

Worcester Polytechnic Institute, FA, Anthony Linn; SBC, Keith Rockwood (New England Section)

REGION II — SOUTH EAST

Alabama A&M University, FA, Zhengtao Deng; SBC, TBD (Greater Huntsville Section)

Athens State University, FA, J. Wayne McCain; SBC, TBD (Greater Huntsville Section)

Auburn University, FA, Dudley Nichols; SBC, Colin Stelly (Greater Huntsville Section)

Duke University, FA, Kenneth Hall; SBC, Matthew Tobin (Carolina Section)

East Carolina University, FA, Tarek Abdel-Salam; SBC, Chance Killpack (Carolina Section)

Embry-Riddle Aeronautical University-Daytona Beach, FA, Luis Gonzalez-Linero; SBC, Nathan Crane (Central Florida Section)

Florida A&M University, FA, Chiang Shih; SBC, Shared with Florida State University (Northwest Florida Section

Florida Institute of Technology, FA, David Fleming; SBC, Noemi Redak, Cape Canaveral Section)

Florida International University, FA, George Dulikravich; SBC, TBD (Palm Beach Section)

Florida State University, FA, Chiang Shih; SBC, Tariq Grant (Northwest Florida Section)

Georgia Institute of Technology, FA, Dimitri Mavris; SBC, Elizabeth Balga (Atlanta Section)

Kennesaw State University, FA, Adeel Khalid; SBC, Divanny Pena (Atlanta Section)

Louisiana State University, FA, Keith Gonthier; SBC, Jake Roblez (Greater New Orleans Section)

Mississippi State University, FA, Thomas Hannigan; FA, Gregory Olsen; SBC, Briana Holton (Greater Huntsville Section)

North Carolina State University, FA, Jack Edwards; SBC, Andrew Cox (Carolina Section)

Tuskegee University, FA, Mohammad Khan; SBC, Nathan Martin (Greater Huntsville Section)

University of Alabama-Huntsville, FA, D. Brian Landrum; SBC, Ashley Scharfenberg (Greater Huntsville Section)

University of Alabama-Tuscaloosa, FA, James Hubner; SBC, William Sumner (Greater Huntsville Section)

University of Central Florida, FA, Seetha Raghavan; SBC, Justin Kanarick (Central Florida Section)

University of Florida, FA, Richard Lind; SBC, Aston Steele (Central Florida Section)

University of Memphis, FA, Jeff Marchetta; SBC, Ken Mitchell (Tennessee Section)

University of Miami, FA, Ryan Karkkainen; SBC, Shayna Hume (Palm Beach Section)

University of Mississippi, FA, Nathan Murray; SBC, TBD (Greater Huntsville Section)

University of Puerto Rico, FA, Pedro Quintero; SBC, Guillermo Colom (No Section Assigned)

University of South Alabama, FA, Carlos Montalvo; SBC, Alicia Ratcliffe (Greater Huntsville Section)

University of South Carolina, FA, Michael Van Tooren; SBC, TBD (Carolina Section)

University of South Florida, FA, TBD; SBC, TBD (Central Florida Section)

University of Tennessee, FA, Hans Desmidt; SBC, TBD (Tennessee Section)

University of Tennessee Space Institute, FA, Trevor Moeller; SBC, TBD (Tennessee Section)

Vanderbilt University, FA, Amrutur Anilkumar; SBC, Derek Phillips (Tennessee Section)

REGION III — CENTRAL

Air Force Institute of Technology, FA, Marc Polanka; SBC, Brian Bohan (Dayton/Cincinnati Section)

Case Western Reserve University, FA, Joseph Prahl; SBC, TBD (Northern Ohio Section)

Cleveland State University, FA, Wei Zhang; SBC, Erin Tesny (Northern Ohio Section)

Illinois Institute of Technology, FA, Boris Pervan (Illinois Section)

Indiana University-Purdue University Indianapolis (IUPUI), FA, Tamer Wasfy; SBC, Cameron Hedrick (Indiana Section)

Kettering University, FA, TBD; SBC, TBD (Michigan Section)

Lawrence Technical University, FA, Andrew Gerhart; SBC, Cody Hoeffel (Michigan Section)

Miami University, FA, James Van Kuren; SBC, Michael Gunderman (Dayton/Cincinnati Section)

Michigan State University, FA, Dahsin Liu; SBC, Wu Zhou (Michigan Section)

Milwaukee School of Engineering, FA, William Farrow; SBC, Henry Moroder (Wisconsin Section)

Ohio Northern University, FA, Jed Marquart; SBC, Jordan Reeves (Dayton/Cincinnati Section)

Ohio State University, FA, Clifford Whitfield; SBC, Zachary Strimbu (Dayton/Cincinnati Section)

Purdue University, FA, Li Qiao; SBC, Benjamin Vernhes (Indiana Section)

Rose-Hulman Institute of Technology, FA, Calvin Lui; SBC, James Broughton (Indiana Section)

Trine University, FA, James Canino; SBC, Adam Schaaf (Indiana Section)

University of Akron, FA, TBD; SBC, TBD (Northern Ohio Section)

University of Dayton, FA, Sidaard Gunasekaran; SBC, Samuel Barnhart (Dayton/Cincinnati Section)

University of Illinois at Urbana-Champaign, FA, Kai James; SBC, Clayton Summers (Illinois Section)

University of Illinois-Chicago, FA, Kenneth Brezinsky; SBC, Tania Wilson (Illinois Section)

University of Kentucky, FA, Alexandre Martin; SBC, Ajin Sunny (Dayton/Cincinnati Section)

University of Kentucky-Paducah, FA, Sergiy Markutsya; SBC, Christopher Barrow (Dayton/Cincinnati Section)

University of Michigan, FA, Ella Atkins; SBC, Theau Heral (Michigan Section)

University of Notre Dame, FA, Thomas Juliano; SBC, Tory King (Indiana Section)

University of Wisconsin at Madison, FA, Daniel Kammer; SBC, Tashi Atruktsang (Wisconsin Section)

University of Wisconsin at Milwaukee, FA, TBD; SBC, TBD (Wisconsin Section)

Western Michigan University, FA, Peter Gustafson; SBC, TBD (Michigan Section)

Wright State Univ, FA, Rory Roberts; SBC, TBD (Dayton/Cincinnati Section)

REGION IV —SOUTH CENTRAL

New Mexico State University, FA, Andreas Gross; SBC, Phoenix Carter (White Sands Space Harbor Section)

Oklahoma State University, FA, Andrew Arena; SBC, Logan Thomas (Oklahoma Section

Rice University, FA, Andrew Meade; SBC, Christian Renovato (Houston Section)

Texas A&M University-College Station, FA, Gregory Chamitoff; SBC, Jay Evans (Houston Section)

Texas Christian University, FA, Walton Williamson; SBC, TBD (North Texas Section)

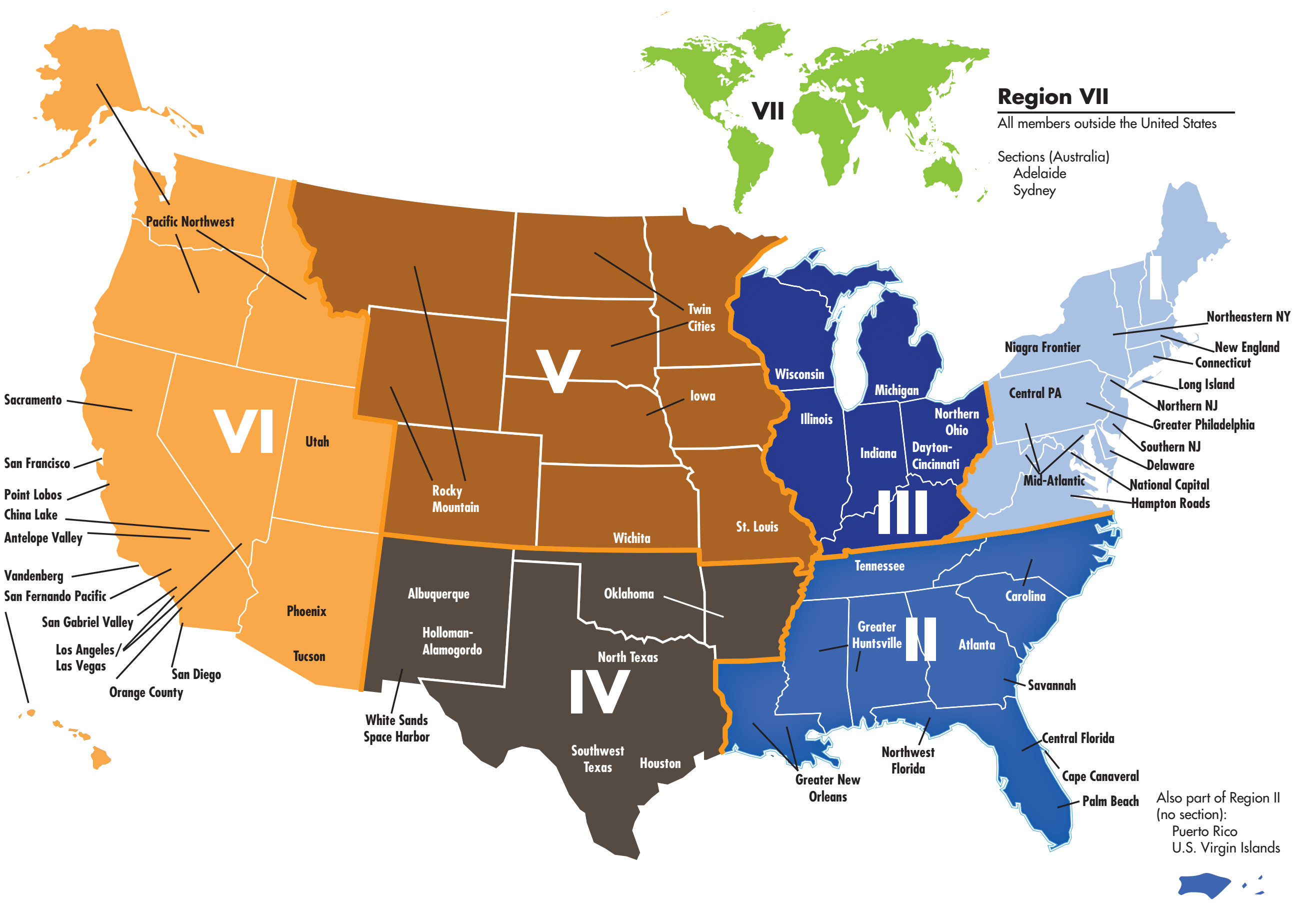
University of Arkansas-Fayetteville, FA, Po-Hao Huang; SBC, Austin Briscoe (Oklahoma Section)

University of Houston, FA, Edgar Bering; SBC, Samar Mathur (Houston Section)

University of New Mexico, FA, Randy Truman; SBC, Benjamin Zamora Urioste (Albuquerque Section)

University of Oklahoma, FA, Thomas Hays; SBC, Olivia Blount (Oklahoma Section)

AIAA SECTIONS AND GEOGRAPHICAL REGIONS



University of Texas at Arlington, FA, Zhen-Xue Han; SBC, Amber Zuehl (North Texas Section)

University of Texas at Austin, FA, Todd Humphreys; SBC, Wesley Yu (Southwest Texas Section)

University of Texas at Dallas, FA, Turaj Ashuri; SBC, Tarang Brahme (North Texas Section)

University of Texas at El Paso, FA, Evgeny Shafirovich; SBC, Christian Rivera (White Sands Space Harbor Section)

REGION V —MID WEST

Colorado School of Mines, FA, Angel Abbud-Madrid; SBC, Jacqueline Loerincs (Rocky Mountain Section)

Colorado State University-Fort Collins, FA, Xinfeng Gao; SBC, Taylor, Morton (Rocky Mountain Section)

Iowa State University, FA, Anupam Sharma; SBC, Layne Droppers (Iowa Section)

Kansas State University, FA, TBD; SBC, TBD (Wichita Section)

Metropolitan State University of Denver, FA, Jose Lopez; SBC, Wesley Kenison (Rocky Mountain Section)

Missouri University of Science and Technology, FA, Joshua Rovey; SBC, Kyle Segobiano (St. Louis Section)

North Dakota State University, FA, Yildirim Suzen; SBC, Noah Gruber (Twin Cities Section)

Saint Louis University, FA, Larry Boyer; SBC, Kevin Mitchell (St. Louis Section)

United States Air Force Academy, FA, Matthew Satchell; SBC, Jeffrey Layng (Rocky Mountain Section)

University of Colorado-Boulder, FA, Donna Gerren; SBC, Tyler Roth (Rocky Mountain Section)

University of Colorado-Colorado Springs, FA, TBD; SBC, TBD (Rocky Mountain Section)

University of Iowa, FA, Albert Ratner; SBC, Andrew Opyd, (Iowa Section)

University of Kansas, FA, Ronald Barrett-Gonzalez; SBC, Madison Sargent (Wichita Section)

University of Minnesota, FA, Yohannes Ketema; SBC, Bryce Doerr (Twin Cities Section)

University of Missouri, FA, Craig Kluever; SBC, James Gentles (St. Louis Section)

University of North Dakota, FA, TBD; SBC, TBD (Twin Cities Section)

University of Wyoming, FA, TBD; SBC, TBD (Rocky Mountain Section)

Washington University in St Louis, FA, Swami Karunamoorthy; SBC, Noah Rowe (St. Louis Section)

Wichita State Univ, FA, L. Scott Miller; SBC, Wee Jun Siow (Wichita Section)

REGION VI — WEST

Arizona State University, FA, Timothy Takahashi; SBC, Huong Ngo (Phoenix Section)

Arizona State University Polytechnic Campus, FA, John Rajadas; SBC, TBD (Phoenix Section)

Boise State University, FA, Inanc Senocak; SBC, Alexander Holt (Pacific Northwest Section)

Brigham Young University-Utah, FA, Andrew Ning; SBC, Alexander Newell (Utah Section)

California Institute of Technology, FA, TBD; SBC, TBD (San Gabriel Valley Section)

California Polytechnic State University–San Luis Obispo, FA, Amelia Greig; SBC, Christopher Barta (Vandenberg Section)

California Polytechnic State University–Pomona, FA, Subodh Bhandari; SBC, Nicole Curtis-Brown (San Gabriel Valley Section)

California State University–Fullerton, FA, Salvador Mayoral; SBC, Luis Robles (Orange County Section)

California State University–Long Beach, FA, Praveen Shankar; SBC, Erwin Joel King (Los Angeles-Las Vegas Section)

California State University–Northridge, FA, Peter Bishay; SBC, Ryan Green (San Fernando Pacific Section)

California State University–Sacramento, FA, Ilhan Tuzcu; SBC, William Gastelum (Sacramento Section)

Embry-Riddle Aeronautical University-Prescott (AZ), FA, David Lannin; SBC, Evan Estep (Phoenix Section)

Northern Arizona University, FA, Thomas Acker; SBC, TBD (Phoenix Section)

Oregon State University, FA, Roberto Albertani; SBC, Karen Kuhlman (Pacific Northwest Section)

San Diego State University, FA, Ping Lu; SBC, Pedro Escobar (San Diego Section)

San Jose State University, FA, Periklis Papadopoulos; SBC, Jeremiah Montemayor (San Francisco Section)

Santa Clara University, FA, Christopher Kitts; SBC, Jacob Ososke (San Francisco Section)

Stanford University, FA, Stephen Rock; SBC, Brian Munguia (San Francisco Section)

University of Alaska Fairbanks, FA, Michael Hatfield; SBC, Clayton Auld (Pacific Northwest Section)

University of Arizona, FA, David Gaylor; SBC, Arek Rembelski (Tucson Section)

University of California-Berkeley, FA, George Anwar; FA, Mitch Oleson (San Francisco Section)

University of California-Davis, FA, Ronald Hess; SBC, Keyur Makwana (Sacramento Section)

University of California-Irvine, FA, Haitham Taha (Orange County Section)

University of California-Los Angeles, FA, Jeff Eldredge; SBC, Tara Kawai-Daniels (Los Angeles-Las Vegas Section)

University of California-Merced, FA, YangQuan Chen; SBC, Bryed Billerbeck (Sacramento Section)

University of California-San Diego, FA, Mark Anderson; SBC, Shraddha Gharmalkar (San Diego Section)

University of Idaho, FA, TBD; SBC, TBD (Pacific Northwest Section)

University of Nevada–Las Vegas, FA, Darrell Pepper; SBC, Reza Faraji (Los Angeles-Las Vegas Section)

University of Nevada–Reno, FA, Eric Wang; SBC, John Hladky (Sacramento Section)

University of Southern California, FA, Geoffrey Spedding; SBC, Naish Gaubatz (Los Angeles-Las Vegas Section)

University of Utah, FA, Kuan Chen; SBC, Donovan Chipman (Utah Section)

University of Washington, FA, James Hermanson; SBC, Alexis Harroun (Pacific Northwest Section)

Utah State University, FA, Stephen Whitmore; SBC, Britany Chamberlain (Utah Section)

Washington State University, FA, Jacob Leachman; SBC, TBD (Pacific Northwest Section)

Weber State University, FA, John Sohl; SBC, TBD (Utah Section)

REGION VII — INTERNATIONAL

Beihang University, FA, Zhiqiang Wan; SBC, Jing Pu (International)

British University in Egypt, FA, TBD; SBC, TBD (International)

Cairo University, FA, Ayman Hamdy Kasem; SBC, Osama Mohammady (International)

Carleton University, FA, Steve Ulrich; SBC, Nicholas Proulx (International)

Chulalongkorn University, FA, Asi Bunyajitradulya; SBC, TBD (International)

Concordia University, FA, TBD; SBC, TBD (International)

Ecole Polytechnique de Montréal, FA, TBD; SBC, TBD (International)

Emirates Aviation College, FA, Ahmed Obaide; SBC, TBD (International)

Ghulam Ishaq Khan Institute of Science & Technology-Pakistan, FA, Javed Chattha; SBC, TBD (International)

Hindustan University, FA, TBD; SBC, TBD (International)

Hong Kong University of Science & Technology, FA, Larry Li; FA, Wei Shyy (International)

Indian Institute of Technology-Kanpur, FA, TBD; SBC, TBD (International)

Institute of Space Technology-Pakistan, FA, Abid Khan; SBC, TBD (International)

Istanbul Technical University, FA, TBD; SBC, TBD (International)

Khalifa University of Science, Technology and Research, FA, Ahmad, Bani Younes; SBC, TBD (International)

Korea Advanced Institute of Science and Technology, FA, Jiyun Leeq; SBC, TBD (International)

McGill University, FA, TBD; SBC, TBD (International)

Middle East Technical University, FA, TBD; SBC, TBD (International)

MLR Institute of Technology, FA, TBD; SBC, TBD (International)

Monash University, FA, Julio Soria; SBC, TBD (International)

Moscow Aviation Institute, FA, TBD; SBC, TBD (International)

Nagoya University, FA, TBD; SBC, TBD (International)

Nanjing University of Aeronautics and Astronautics, FA, Ning Zhao; SBC, TBD (International)

Northwestern Polytechnic University, FA, TBD; SBC, TBD (International)

Queen's University Belfast, FA, Theresa Robinson; SBC, TBD (International)

Royal Melbourne Institute of Technology, FA, Cees Bil; SBC TBD (International)

Royal Military College of Canada, FA, Ruben Perez; SBC, TBD (International)

Ryerson Polytechnic University, FA, Seyed Hashemi; SBC, TBD (International)

Technion-Israel Institute of Technology, FA, Omri Rand; SBC, TBD (International)

United Arab Emirates University, FA, Emad Elnajjar; SBC, TBD (International)

Universidad Autonoma de Chihuahua, FA, Eloy Normando Marquez Gonzalez; SBC, Samuel, Anchondo (International)

Universidad de San Buenaventura, FA, Ruben Salazar; SBC, Catalina Zuluaga (International)

Universidad Pontificia Bolivariana, FA, TBD; SBC, TBD (International)

Università degli Studi di Roma "La Sapienza", FA, Giuliano Coppotelli; SBC, TBD (International)

University of Adelaide, FA, Matthew Tetlow; SBC, Rachelle Ferber (Adelaide Section)

University of Naples Federico II, FA, TBD; SBC, TBD (Adelaide Section)

University of Palermo, FA, TBD; SBC, TBD (Adelaide Section)

University of Queensland, FA, TBD; SBC, TBD (International)

University of Stuttgart, FA, TBD; FA, TBD (International)

University of Sydney, FA, Gareth Vio; SBC, Karolina Leszczynski (Sydney Section)

University of Toronto, FA, TBD; SBC, TBD (International)

Von Karman Institute of Fluid Dynamics, FA, TBD; SBC, TBD (International)

THE OHIO STATE UNIVERSITY

COLLEGE OF ENGINEERING

Faculty Position in Aeroacoustics

DESCRIPTION

The Ohio State University Department of Mechanical and Aerospace Engineering seeks an outstanding scholar for an endowed chair position (Honda Chair) in aeroacoustics and aerodynamics. We welcome applicants with a strong background in aeroacoustics, but the particular requirement for this position is expertise and experience in both fundamental and applied experimental aeroacoustics and aerodynamics in external flows. The position is at full professor level. However, an associate professor level appointment will also be considered for rapidly rising candidates with strong credentials if warranted. The position will be affiliated with OSU's Aerospace Research Center (ARC), Transportation Research Center (TRC), and Center for Automotive Research (CAR).The Ohio State University already has significant activities in aeroacoustics and the candidate is expected to develop a robust fundamental research portfolio to further enhance our stature. Strong partnership with Honda will provide opportunities to also spur activities on the development of advanced emerging technologies in a multidisciplinary environment.

QUALIFICATIONS

We seek individuals who are ardent discoverers and passionate teachers and mentors, with demonstrated excellence in scholarship, collaboration, mentoring, interdisciplinary leadership and teaching in an academic and/or R&D environment. A doctoral degree is required in Mechanical or Aerospace Engineering or in a related field appropriate to the scope of the position. The successful candidate will be expected to develop and sustain active sponsored research programs, teach core undergraduate and/or graduate courses, and develop new graduate courses related to their research expertise. The candidate should have experience developing or working in diverse research teams and experience mentoring members of underrepresented groups. The anticipated start date is August 2017. Screening of applicants will begin immediately and will continue until the position is filled.

ABOUT OHIO STATE

To build a diverse workforce, Ohio State encourages applications from individuals with disabilities, minorities, veterans, and women. Ohio State is an EEO/AA Employer. The Ohio State University is committed to establishing a culturally and intellectually diverse environment, encouraging all members of our learning community to reach their full potential. Columbus is a thriving highly rated metropolitan community and we are responsive to dual-career families and strongly promote work-life balance to support our community members through a suite of institutionalized policies. We are an NSF ADVANCE Institution and a member of the Ohio/Western Pennsylvania/West Virginia Higher Education Recruitment Consortium. For more information about the Department of Mechanical and Aerospace Engineering at OSU, please visit http://mae.osu.edu/.

HOW TO APPLY

Interested candidates should upload a single PDF file containing a complete curriculum vitae, 2-3 pages (each) statements of research and teaching goals, and contact information of four references to: https://mae.osu.edu/jobs/faculty-position-Honda-Chair. Inquiries about the position may be addressed to Professor Mo Samimy, Chairperson of the Search Committee (samimy.1@osu.edu, 614-292-5012).

EMBRY-RIDDLE Aeronautical University

DAYTONA BEACH, FLORIDA

Department of Aerospace Engineering Faculty Position

The Department of Aerospace Engineering at Embry-Riddle Aeronautical University in Daytona Beach, Florida has an ambitious agenda focused on expanding graduate programs, research capabilities, facilities, and recruiting highly talented faculty. A new state-of-the-art engineering building housing several research laboratories including a new wind tunnel and supporting facilities is under construction and will be completed by the spring of 2017 in support of this agenda.

The Department invites applications for a tenure-track faculty position at the Assistant or Associate rank to start in August 2017. The preferred area of expertise is Aerospace Structures and Materials. However, applicants in all areas of Aerospace Engineering will be considered. Current research thrust areas of the Department include: computational fluid dynamics, aeroacoustic modeling, rotorcraft aerodynamics, flow control, air-breathing hypersonic and rocket propulsion, autonomous unmanned air and ground vehicles, aircraft and spacecraft guidance, navigation and control, aeroelasticity, composites, nanomaterials, smart materials, structural health monitoring, computational structural mechanics, and design optimization.

The Department offers bachelors, masters, and Ph.D. degrees. The undergraduate program is the nation's largest with about 1,350 full-time students and has been ranked # 1 by *U.S. News and World Report* for the past sixteen years. In 2016 our Department moved to the PhD-granting category and its undergraduate program was ranked # 16 (tied with Penn State) and its graduate Program (that includes 29 PhD students) was ranked #36 (tied with Rutgers and Syracuse). Embry-Riddle Aeronautical University, the world's largest, fully accredited university specializing in aviation and aerospace, is a nonprofit, independent institution offering more than 70 baccalaure-ate, master's and Ph.D. degree programs.

Candidates must have, by start date, an earned doctorate in Aerospace Engineering or a closely related field. You may apply at http://eraucareers.erau.edu, #160397. For full consideration, please apply before 2/1/17.

Stanford | ENGINEERING

Faculty Opening

STANFORD UNIVERSITY

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

The Department of Aeronautics and Astronautics at Stanford University invites applications for a tenure track faculty position at the Assistant or untenured Associate Professor level. We will also consider senior candidates with outstanding research and teaching track records.

Research advances in the fundamental areas of aerospace engineering are critical for future air and space transportation systems that will provide efficiency, safety, and security, while protecting the environment. We are seeking exceptional applicants who will develop a program of high-impact research, contribute to an innovative undergraduate curriculum, and develop graduate courses at the frontier of areas such as aerospace system design, autonomous vehicle technologies, and breakthroughs in aerospace propulsion concepts. We will place higher priority on the impact, originality, and promise of the candidate's work than on the particular sub-area of specialization within Aeronautics and Astronautics.

Evidence of the ability to pursue a program of innovative research and a strong commitment to graduate and undergraduate teaching is required.

Candidates whose research programs in Aeronautics and Astronautics will involve the development of sophisticated computational and/or mathematical methods may be considered for an appointment with an affiliation with the Institute for Computational and Mathematical Engineering (http://icme.stanford.edu/).

All candidates should apply online at https://aa.stanford.edu/job-openings. Applications should include a brief research and teaching plan, a detailed resume including a publications list, and the names and addresses of at least five references. Applications will be accepted until the position is filled. However, the review process will begin on January 1, 2017.

Stanford University is an equal opportunity employer and is committed to increasing the diversity of its faculty. It welcomes nominations of and applications from women, members of minority groups, protected veterans and individuals with disabilities, as well as from others who would bring additional dimensions to the university's research, teaching and clinical missions.

Aerospace Spotlight Awards Gala

Please celebrate with esteemed guests and colleagues when the American Institute of Aeronautics and Astronautics (AIAA) recognizes individuals and teams for outstanding contributions that make the world safer, more connected, and more prosperous.

Wednesday, 3 May 2017

Reception: 1830 hrs
Dinner and Awards: 1930 hrs
Black-Tie Attire

Ronald Reagan Building and International Trade Center Washington, D.C.

Presentation of Awards

- AIAA Foundation Award for Excellence
- AIAA Foundation Educator Achievement Awards
- Goddard Astronautics Award
- Reed Aeronautics Award
- International Cooperation Award
- Public Service Award
- Distinguished Service Award
- Daniel Guggenheim Medal
- 2017 AIAA Fellows and Honorary Fellows

This event is organized according to government directives. Government guest selection, invitation, and seating will be administered solely by AIAA in accordance with government policy.

Visit **www.aiaa.org/gala2017** to reserve your table or seat.

AIAA
Shaping the Future of Aerospace

PennState

Astronautics Faculty Position

The Department of Aerospace Engineering at The Pennsylvania State University invites nominations and applications for a full-time, tenure-track or tenured open-rank faculty position starting in Fall 2017. Expertise is sought in the general subject of astronautics, with particular interest in spacecraft dynamics and control, space propulsion, the space environment, rarefied flows and plasmas, and space systems engineering. Applicants must have an earned doctorate in aerospace engineering or a related field; at least one degree in aerospace engineering or related aerospace experience is preferred. Responses received before January 6, 2017 are assured full consideration, but the search will remain open until the position is filled. Applicants should submit electronically a single pdf file that contains a cover letter, a CV, a statement of research and teaching interests, and the names and contact information for at least three references to job #66927 at **http://apptrkr.com/899293**. The Department of Aerospace Engineering enjoys an excellent international reputation in aeronautics and astronautics. The Department currently has 16 full-time faculty members, with more than 225 juniors and seniors and more than 120 graduate students. Annual research expenditures exceed $6 million. Penn State at University Park is a land-grant institution located within the beautiful Appalachian mountains of central Pennsylvania. State College and nearby communities within Centre County are home to roughly 100,000 people, including over 40,000 students, and offer a rich variety of cultural, recreational, educational, and athletic activities. State College is a wonderful community in which to raise a family and has an excellent public school system. We encourage applications from individuals of diverse backgrounds.

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Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

1917

Jan. 12 German fighter pilot Captain Manfred von Richthofen, aka the "Red Baron," is awarded the Pour Le Merite — the "Blue Max" — for his leadership of the Jasta 11 squadron, during which time he downed 16 British combat aircraft in less than five months of fighting. David Baker, Flight and Flying: A Chronology, p. 92.

1942

Jan. 6 In his message to Congress, U.S. President Franklin Roosevelt calls for a greatly expanded air force. His goal is 60,000 planes by the end of 1942, including 45,000 combat types, and 125,000 by 1943, 100,000 of them combat aircraft. Aircraft Year Book, 1942, p. 22.

Jan. 14 The two-man Sikorsky XR-4, a single-rotary wing helicopter, achieves its first flight at the company's plant in Stratford, Connecticut. This is an improved military version of the VS-300. The flight leads to the official U.S. Army Air Corps' acceptance of the XR-4 on May 30, 1942, for reconnaissance and rescue work, and of the standard Sikorsky R-4, the first mass-produced helicopter. D. Cochrane, V. Hardesty and R. Lee, The Aviation Careers of Igor Sikorsky, pp. 132, 135.

Jan. 16 For the first time, British Prime Minister Winston Churchill crosses the Atlantic by aircraft. He flies from Norfolk, Virginia, to Bermuda and on to Plymouth, England, in a Boeing 314 "Berwick" flown by the British Overseas Airways Corp., the predecessor to British Airways. A. van Hoorebeeck, La Conquete de L'Air, Vol. 2, p. 19.

Jan. 24 The Special Court of Inquiry on Pearl Harbor, headed by Supreme Court Justice Owen Roberts, places the main responsibility for the disaster on U.S. Navy Rear Adm. Husband Kimmel and Army Maj. Gen. Walter Short for inadequately preparing Navy and Army forces for a possible attack. Short was accused of being more concerned about sabotage, and therefore ordered his planes to be closely parked on airfields rather than dispersed. Liaison between the naval and air forces in Hawaii was also poor, and the Navy disregarded signs that a possible Japanese attack was imminent. K. Carter and R. Mueller, compilers, The Army Air Forces in World War II, pp. 6-7.

Jan. 27 A Philippine Air Lines Beech Model 18 airplane is shot down by the Japanese over Malabang, Lanao del Sur, in the Philippines. The plane was part of a small collection of aircraft called the Bamboo Fleet used for inter-island air transport after most of the country's civilian and military aircraft were either destroyed by the Japanese or used for evacuations to Australia. E.B. Santos, Trails in Philippine Skies, pp. 289, 320; W.F. Craven and J.L. Cates, eds., The Army Air Forces in World War II, Vol. I, pp. 405-406.

Jan. 30 Canadian Pacific Air Lines is created from a merger of carriers including Yukon Southern Airlines, United Aircraft Services and Canadian Airways. R.E.G. Davies, A History of the World's Airlines, pp. 210-211.

1967

Jan. 2 The Tupolev Tu-104, Russia's first jet transport and the world's first successful jet airliner that began service in 1956, will be retired at the end of the year, it is announced. The Tu-104, of which some 200 were built, is a twin-engined, medium-range aircraft. During its lifetime, the Tu-104 carried over 90 million passengers with Aeroflot, then the world's largest airline. Other jet transports were built and flown earlier in other countries, but for various reasons their services were not sustained. Among the successors to the Tu-104 is the Tu-124, one of the first turbofan-powered airliners. Aviation Week, Jan. 2, 1967, p. 26.

Jan. 3 A team of NASA officials headed by Marshall Space Flight Center Director Wernher von Braun arrives at McMurdo Station in the Antarctic to start a 10-day expedition to observe environmental conditions. Those conditions include extreme temperatures, isolation factors and survival techniques for comparisons and possible applications to future problems of manned space flights. The New York Times, Jan. 4, 1967, p. A21.

Jan. 11 The Communication Satellite Corp. Intelsat 2-B spacecraft is launched by a three-stage, Thrust Augmented Improved Delta rocket and is later placed into a geostationary orbit above the Pacific Ocean to provide TV and other communications services between the U.S. and Earth stations in Hawaii, Japan and Australia. The 87-kilogram satellite, the second in this series, is also used for military communications. The first satellite, Intelsat 2-A, was launched in October 1966 but failed to achieve its full mission capabilities. The New York Times, Jan. 8, 1967, p. 18; Aviation Week, Jan. 16, 1967, p. 34.

Jan. 11 The initial test flight of the U.S. Air Force Scramjet (supersonic combustion ramjet) is partly successful. The Scramjet test version is launched by a Scout solid-propellant booster from Vandenberg Air Force Base, California, and the vehicle demonstrates it can separate properly from the booster but fails to perform some secondary missions. The New York Times, Jan. 14, 1967, p. 4; Technology Week, Jan. 23, 1967, p. 3.

Jan. 27 During a launch rehearsal for the first crewed Apollo spaceflight mission scheduled for Sept. 21, 1967, the Apollo Command Module AS-204, mated to an uprated Saturn 1 booster 66 meters above the ground at Launch Complex 34 at the Kennedy Space Center in Florida, experiences a sudden flash fire. The fire kills astronauts Edward White, Virgil "Gus" Grissom and Roger Chaffee. NASA quickly appoints a board of inquiry. Unmanned Apollo flights continue on schedule, but manned flights are postponed until the Apollo 204 Review Board's inquiry is completed and necessary technical revisions introduced. The New York Times, Jan. 28, 1967, pp. 1, 18.

1992

Jan. 22 The space shuttle Discovery is launched from Cape Canaveral, Florida. For the first time, an experiment from China is carried aboard a U.S. space shuttle as one of the "Get Away Special" payloads of smaller experiments on the Discovery's STS-42 mission. Five other countries also have Get Away Special experiments. Ulf Merbold of Germany, who represents the European Space Agency, also serves on this mission. NASA, Astronautics and Aeronautics, 1991-1995, p. 687.

Jan. 25 Noted aircraft designer L. Eugene Root dies at age 87. He was an executive at the Lockheed Missiles and Space Co. and also was a member of the Rand Corp. As president of the Institute of Aeronautical Sciences, Root in 1962 helped merge the IAS with the American Rocket Society to form the American Institute of Aeronautics and Astronautics. NASA, Astronautics and Aeronautics, 1991-1995, p. 687.

NADIA ZERELLI, 33

Senior Manager, Heat Transfer and Secondary Air System Methods, Computational Fluid Dynamics and Coupling at MTU Aero Engines

When Lufthansa began transporting passengers in fuel-efficient Airbus A320neo airliners in 2016, the flights marked a milestone for engine maker Pratt & Whitney and its partner, MTU Aero Engines of Munich. Each plane was powered by two Pratt & Whitney PW1100G-JM geared turbofan engines, which are a culmination of work Pratt & Whitney began in the 1990s and continued with MTU in 2005. Engineers installed a gearbox that freed the turbine to turn at speeds the blades of the engine's unusually large, quiet front fan could not tolerate. The companies have taken orders for more than 8,400 of these quieter, more fuel-efficient engines for at least 80 airlines. MTU developed the engine's low-pressure turbine and high-pressure compressor and now assembles and tests production engines in its Munich factory. That's where German aerospace engineer Nadia Zerelli leads a team of nine engineers who continue optimizing the designs of components with safety in mind.

How did you become an aerospace engineer?

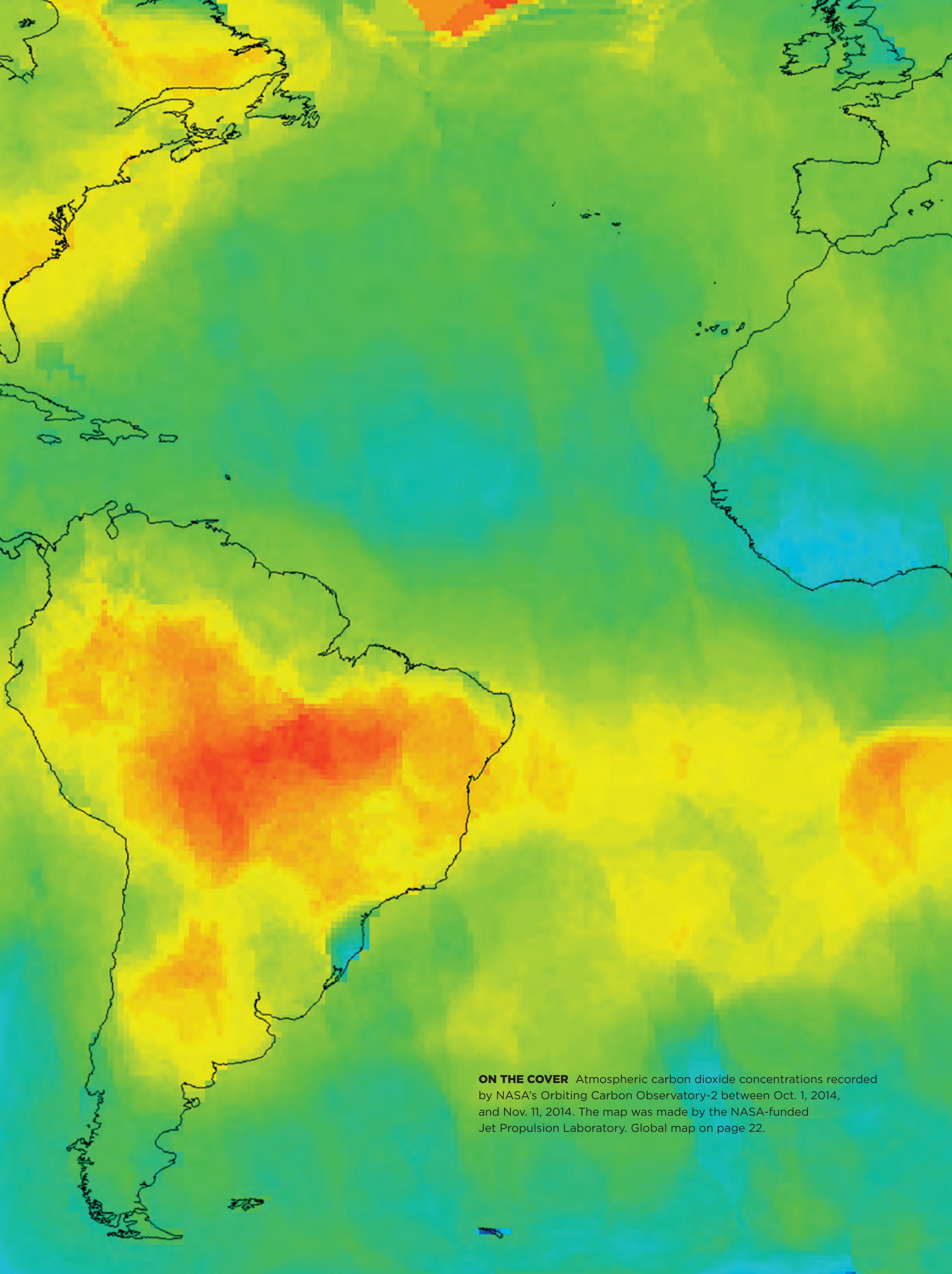
From an early age I was fascinated by aviation. While still in school, I was a summer intern at Contact Air Technik, an aircraft maintenance company at my hometown's airport, Flughafen Saarbrücken, an experience which reinforced my enthusiasm. While studying aerospace engineering at ISAE, France's national university for aeronautics and astronautics engineering, I began to focus on propulsion systems because I appreciated their tremendous complexity. I then interned at the von Karman Institute for Fluid Dynamics near Brussels, where I worked on advanced measurement techniques for aircraft engines. That's when I knew I wanted to become part of the professional turbomachinery community. I was thrilled to later be granted a position in 2008 at MTU Aero Engines, Germany's leading engine manufacturer with a cutting-edge portfolio and strong international connections to scientific and industrial partners. I started my career at MTU in the heat transfer department of the technology and development division. Since then, I have been involved in analytical assessments for compressors and turbines of commercial engines as well as long-term research projects. I lead the secondary air system and thermal analytical integration of MTU's high-speed, low-pressure turbine into Pratt & Whitney's whole engine architecture for the joint PW1000G geared turbofan engine development.

Imagine the world in 2050. What do you expect to see in aviation?

Even conservative estimates tell us that world population will have grown to roughly 9 billion people. Whether on land or in the sky, the focus on resource efficiency will become much more urgent than is already the case today. Among other challenges, increased population density certainly calls for smart infrastructural organization with a strong emphasis on compatibility with environmental and human life. Modern city planning will probably be based on autonomous on-demand mobility, made possible through the successful blend of information and communication technology with classical engineering.

In this future society, I expect aviation to be even more prevalent since it remains a very efficient means of transporting goods and connecting people across the world through a seemingly endless, maintenance-free and cost-free medium. Current projections assume that air traffic worldwide will keep growing at a rate of around 5 percent a year. In order to mitigate and reduce environmental impacts, tomorrow's aircraft must be fuel-thriftier, quieter and cleaner. The geared turbofan engine addresses all of these stringent constraints and therefore deserves its current and future place in 21st century aviation.

Jumping ahead to 2050s innovations, we might start seeing the transition from research phase to technology readiness with regards to hybrid-electric powered propulsion systems for commercial aviation applications. Let's look up! ★



ON THE COVER Atmospheric carbon dioxide concentrations recorded by NASA's Orbiting Carbon Observatory-2 between Oct. 1, 2014, and Nov. 11, 2014. The map was made by the NASA-funded Jet Propulsion Laboratory. Global map on page 22.