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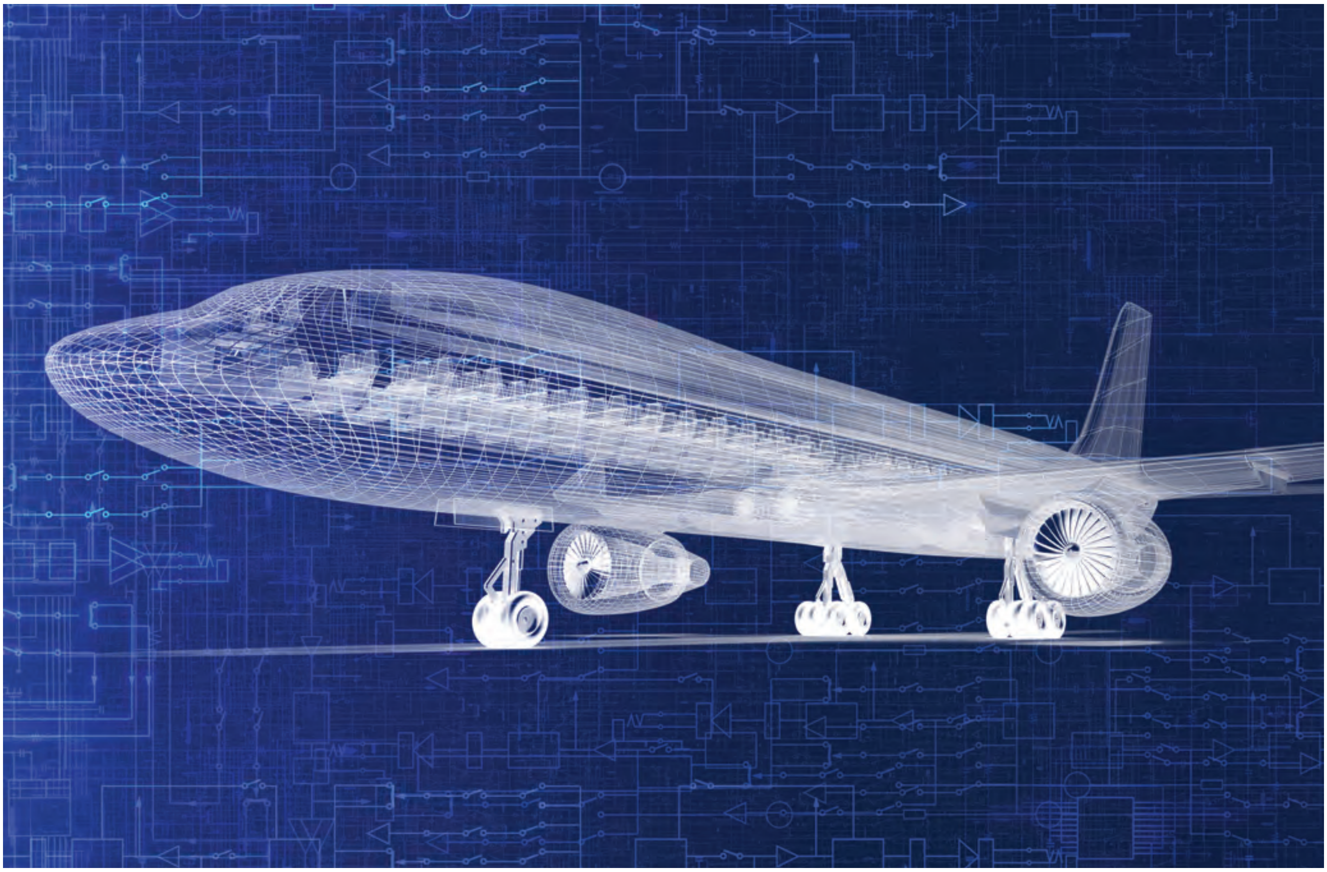

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LETTERS AND CORRESPONDENCE
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Tom Risen
As our staff reporter, Tom covers breaking news and writes features. He has reported for U.S. News & World Report, Slate and Atlantic Media.
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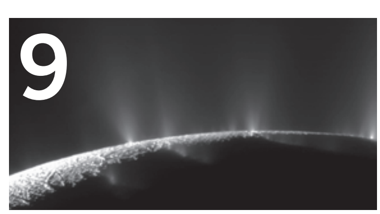

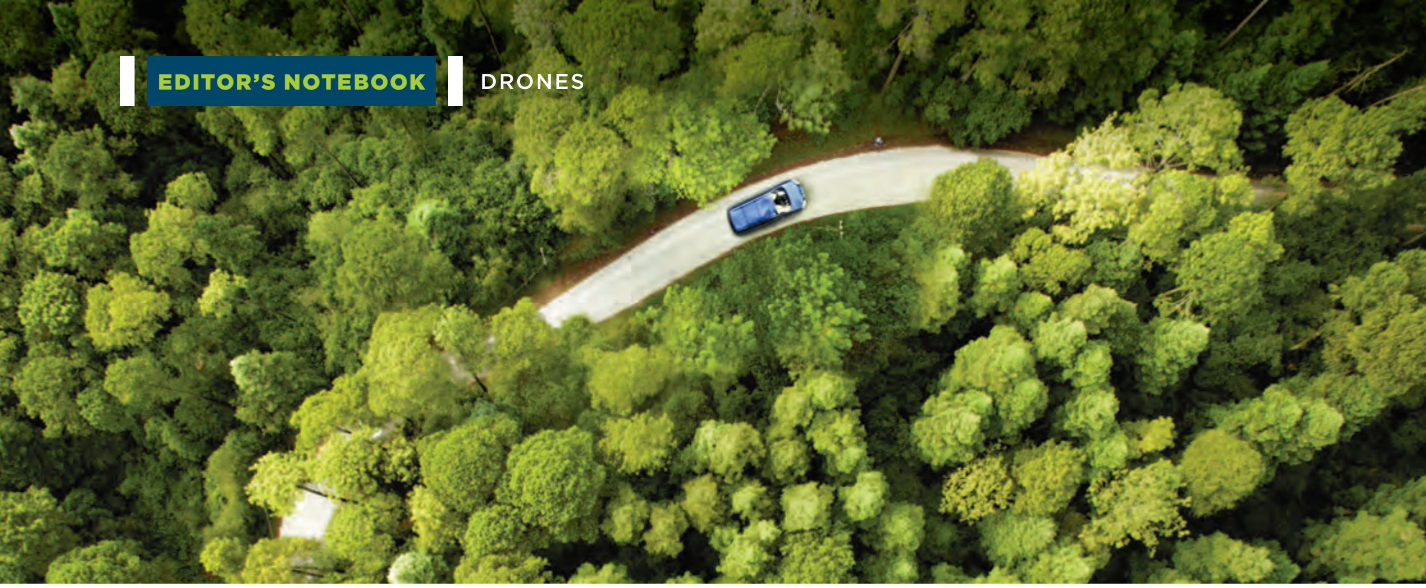

In defense of "drones"

Aerospace America, like other publications, has wrestled with what to call the variety of aircraft that are today giving hobbyists, consumers, filmmakers, farmers, troops and many others their first direct control over a bird's-eye view of the terrain, along with many more applications to come.

Words matter in the magazine business and Aerospace America is no exception. When telling a story or presenting a headline, our most important job is to be understood by all readers. The considerations don't end there, however. We need to do our best to avoid favoring one camp in the semantic wars over another. We can't be euphemistic or overly concerned about offending, but we can't sensationalize or distract readers by being intentionally provocative with our word choice.

So, what should we call this new breed of aircraft?

I've come to the conclusion that there is no single word or phrase that perfectly encapsulates them. The word that comes closest is drone, and you will start to see it in headlines and in the text of articles when warranted to refer to the broad range of designs in the breed.

There was a time when drone was applied only as shorthand for military or CIA aircraft equipped with cameras or missiles and cameras. People in the business of building highly networked aircraft took offense because the word incorrectly conveyed an unsophisticated flying machine "droning" away up there. Troops and commanders who take the Law of Armed Conflict seriously objected to the incorrect implication that no one was in control or held responsible. Anti-war activists branded drone to mean robotic death from the skies.

Those connotations and usages still exist but they are no longer predominant.

For starters, the word "drone" now also refers to the smallest aircraft in the breed. That's a relief, because arguing that a 3-kilogram quadcopter should be called an "unmanned" system or vehicle was always a non sequitur. No one needs to be told that something that small is unmanned. Drone is losing its universally negative connotations too. At last year's AUVSI Xponential conference, the FAA announced the formation of a "Drone Advisory Committee." Thousands of consumers regularly buy drones at websites with that word in the name. Even NASA is assisting with software and technologies for "drone traffic management."

So, we believe we are on solid ground to move drone off the nearly forbidden list. As a story unfolds, we will, of course, specify whether we are referring to hobbyist quadcopters equipped with cameras or the large, fixed wing variety, including Predators, Reapers or Global Hawks. At times, it will be clearer to say unmanned aircraft or plane, and so we'll do that in those cases.

Of course, one thing I can say for sure is that this market is so dynamic that there will never be a last word on this matter of semantics.

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

Countering microgravity

Adam Hadhazy's article on artificial gravity ["Artificial gravity's attraction," April] was right on target: We have learned that long-term habitation in microgravity has health effects that are not easily avoided, and using centrifugal gravity may be required for human missions to the planets. However, while the article discussed centrifuges and "wheel" type solutions, it failed to mention an even better, and far simpler, solution: the use of tethers. By attaching the human habitat to a counterweight (perhaps an empty fuel tank) using a kilometer or more length of high-strength cable, the assembly can be rotated around the common center of mass, providing the required centrifugal force to give the effect of gravity. The advantage is that such cables can easily be kilometers long, thus avoiding the high rotation rates required for a centrifuge or a wheel.

Tethers were investigated by NASA back in the 1990s, but have been out of fashion at NASA in the last 20 years. But the history of spaceflight shows that the simplest solutions are often the best, and it's time we gave the idea of tether-based artificial gravity a second look.

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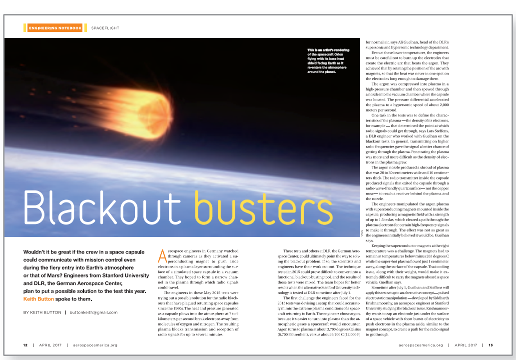
CORRECTION

In the "Blame game" sidebar to the "Disaggregation" article in the April issue, we incorrectly reported that Operation Burnt Frost in 2008 shot down an old U.S. reconnaissance satellite. AIAA senior member John McDonnell correctly notes that the "satellite was actually brand new, stranded in a useless orbit with a completely full hydrazine tank."

Argon arc plasma testing



The "Blackout busters" article [April] is very interesting to me as it involves an electric arc argon gas plasma for testing of manned space vehicle re-entry problems. The described test concept and facility are very sophisticated and should help solve the current re-entry communications blackout problem.

Why is this of special interest to me, retired from a rather long Lockheed "aviation" career? Before aviation (while at the U.S. Army's Redstone Arsenal in Huntsville, Alabama, in 1957, just before Sputnik, Explorer, NASA Marshall, ICBMs, etc.), I was materially involved in the design, construction and test of a similar, smaller, but less sophisticated argon arc-jet plasma test facility for unmanned space vehicle re-entry heating problems. "Arc-Jet" was our descriptive word for the test concept. Our main purpose was to help develop heat resistant materials for ballistic missile nose cones. We got the argon arc-jet plasma prototype operational before my two years of Army duty were up. In those days, I was a research project officer (with a recent physics/math degree and an ROTC second lieutenant's commission), working with civilian and military scientists and engineers at the Army Rocket and Guided Missile Agency Research Laboratory at Redstone.

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CORRECTION

We mistakenly published an early draft of "Green propellant" (March) and consequently the article contained several errors. The corrected article can be found online.

FROM THE CORNER OFFICE

A Community Effort To Address Aerospace Workforce Development

While the U.S. aerospace and defense (A&D) industry currently enjoys a prominent position with respect to global competitiveness and technical superiority—and plays a vital role in maintaining national security and sustaining global innovation—a number of observable trends indicate that its standing may be in jeopardy. Of greatest concern is that only 16 percent of America's 12th graders are proficient in math and interested in a STEM career. In addition, the United States ranks well behind other advanced countries in the percentage of students earning their first university degree in these disciplines. In fact, a May 2016 Aerospace Industries Association report cites that, of the students who declare a STEM major at accredited four-year institutions, less than 40 percent graduate with a STEM degree. A healthy pipeline is vital to ensure the continued success of the aerospace industry.

Addressing these workforce challenges is a top priority of the Institute, and AIAA offers several programs and activities designed to both promote STEM education and stimulate our young professionals' interests in various aerospace fields. At the K-12 level, the AIAA Foundation supports educators through our AIAA Foundation Classroom Grants Program, which awards teachers up to $250 to promote aerospace through classroom-based STEM activities. Likewise, the Foundation's Generation STEM program, held in conjunction with annual forums, engages middle school students in exciting educational activities facilitated by industry professionals.

At the collegiate level, the AIAA Foundation offers over $50,000 annually in undergraduate and graduate scholarships to defray the costs of pursuing aerospace engineering degrees. In addition to financial support, students are able to join AIAA student branches and benefit from their programming, including the Student Regional Conferences, which allow students to present their own research to panels of practicing aerospace professionals. Moreover, undergraduate and graduate students can take part in competitions, such as AIAA's annual Design/Build/Fly Competition, showcasing the practical aircraft design talents of collegiate teams from around the world. AIAA's Rising Leaders in Aerospace program, with events held at several of the Institute's annual forums, offers a variety of networking, mentoring, and educational opportunities to graduate-level students and young professionals. Young professionals are also encouraged to take part in AIAA's technical and standing committees, providing insight into a wide range of topics of relevance to the Institute.

These efforts alone are not enough. They have to be part of a larger strategy and we all need to be aware and involved. We, as a nation and as an aerospace community, must act to address the critical workforce development issues that face us today. Recognizing this responsibility, AIAA teamed with the Aerospace Industries Association to hold a National A&D Workforce Summit last September. The two-day meeting convened nearly 150 leaders from across academia, government, industry, and nongovernment organizations to, among other things, assess how to make our A&D workforce more robust, future-focused and prepared for the ever-evolving global economy.

One conclusion drawn from the summit is that STEM education must begin before a student reaches fifth grade. While several aerospace companies and government agencies have STEM-related partnerships with school districts across the country, we must continue to establish programs at the local, regional, and national levels; ones that reach out to students of all backgrounds. As these students grow older, it is important that they have abundant, available, and affordable opportunities to participate in industry-sponsored competitions, internships, mentorships, and co-ops to foster their love of STEM and gain valuable real-world experience.

Summit participants also addressed workforce retention, noting that industry must place more emphasis on issues of significance to today's young professionals for the United States to retain its competitive superiority; these issues include career advancement, salary levels, and student debt. In addition to these factors, it is critical to create and maintain a workplace environment that not only emphasizes the importance of diversity but creates an environment that thrives on it.

The obligation falls on the every member of the aerospace community—and AIAA—together with federal and state governments, to stimulate workforce interest and encourage students to select technical fields. Only ongoing dialogue, commitment, and support at the highest levels of both the public and private sectors can ensure that STEM workforce development and retention remains a top priority for our community and the nation as a whole. AIAA members are contributing to this effort, financially and through volunteer opportunities, and your continued support of the AIAA Foundation is critical to sustaining its education programs. Let's all actively encourage the next generation of aerospace professionals to follow the path we did—for the good of our country and the world. ★

Sandra H. Magnus, AIAA Executive Director

DARPA

▲ DARPA's Gremlins program calls for releasing groups of drones from larger conventional airplanes and, once the smaller planes have flown their missions, a piloted C-130 transport would collect them and bring them back to base.

Wanted: "Aircraft carrier in the sky"

BY KEITH BUTTON | buttonkeith@gmail.com

It's easy to imagine conventional military planes releasing swarms of drones. It's a lot harder to imagine a C-130 recovering them in midair so they can be flown again. By next February, DARPA should have in its hands two competing preliminary designs for an apparatus to do just that.

Dynetics Inc. of Alabama and General Atomics Aeronautical Systems of California are working on competing designs under $21 million contracts awarded by DARPA earlier this year. The program is called Gremlins, and under it the contractors get to decide the kinds of drones that they will retrieve if the program proceeds to a demonstration phase two years from now. The biggest technical challenge will be controlling and lining up the drones just before they are picked up by the C-130s, which are typically flying at 370 to 560 kilometers per hour.

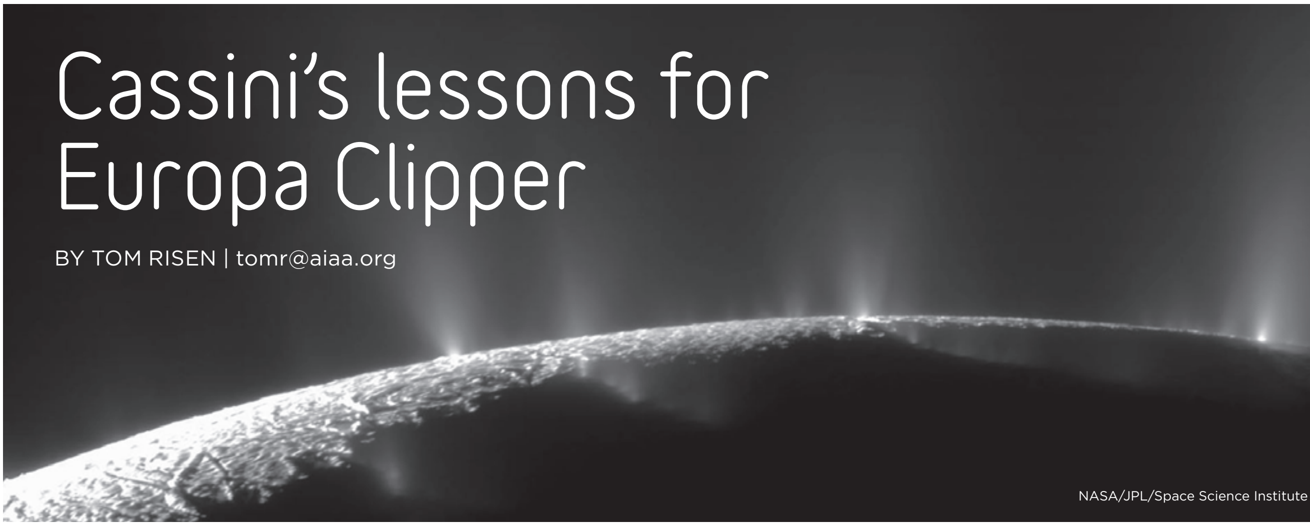
"The glory or the interest in these technology programs tends to focus on the innovative nature of the air vehicles," says Mark Miller, the Gremlins program manager at Dynetics. "The DARPA-hard part, in our opinion, is in the recovery of an unmanned system aboard a manned aircraft," he says. Typically, aircraft "drop bombs, and drop missiles — they don't recover them in the air," he notes dryly. The safety concerns of flying unmanned aircraft so close to manned aircraft, and not keeping what is normally considered the "safe distance" between the two, is amplified by the buffeting created by the wind flows around the cargo aircraft, says Tim Keeter, chief engineer at Dynetics.

The drones will be designed as "trucks" — capable of carrying either weapons or sensors. DARPA is allowing the contractors to choose a launch and recovery method from either outside or inside the larger manned aircraft.

Dynetics isn't divulging its concept for how to do that; General Atomics said in 2016 that it was considering a mechanical arm that would move the planes in and out of the C-130's cargo bay.

According to DARPA, the agency's vision for the program is to show how groups of drones could be launched from many types of military aircraft, including bombers, transport planes, fighters and other unmanned airplanes. They would be picked up later by a C-130, returned to the ground and be ready for launch again in 24 hours. Disposable drones and decoys are a trend in the U.S. military, but DARPA says reusing such planes about 20 times each would save money compared to expendable operation.

In March 2016, Composite Engineering of California, Dynetics, General Atomics and Lockheed Martin won initial contracts for the Gremlins program to develop feasible ideas for launching and recovering unmanned aircraft with minimum modifications to the C-130s. Dynetics and General Atomics were chosen for the second phase. In a third phase, DARPA plans to choose one or perhaps both of the competitors to build a demonstration system for flight testing in 2019. ★



Cassini's lessons for Europa Clipper

BY TOM RISEN | tomr@aiaa.org

NASA/JPL/Space Science Institute

▲ The Cassini spacecraft flew through these plumes of water ice and vapor spouting from the southern hemisphere of Saturn's moon Enceladus, measuring signs that its subsurface oceans could support life.

While NASA scientists were growing excited that the ocean under Saturn's ice-covered moon Enceladus probably harbors conditions hospitable for microbes, technologists at the Southwest Research Institute in Texas were busy applying technical lessons from the mission that collected the tantalizing data.

The story begins in 2005 when the Cassini Saturn probe discovered that Enceladus spouts geysers through cracks in its icy surface. Scientists decided to send Cassini and its spectrometer dashing through those plumes to analyze them. A dive in 2015 provided the strongest evidence yet for the conclusion announced at NASA headquarters in April that the geysers of water and vapor also contain methane that could have been created by methanogenesis, a process that supplies energy to microbes in Earth's deep oceans in the absence of sunlight.

Enter the team at the Southwest Research Institute designing the spectrometer for what is now officially called the Europa Clipper, a probe tentatively targeted for launch in 2022 whose orbit around Jupiter will fly it repeatedly by the moon Europa. Like Enceladus, Europa is thought to consist of an ocean covered with ice. At least one geyser could spout from Europa too, specifically just south of its equator, as the Hubble Space Telescope indicates. It's unclear, for now, if this plume comes from the subsurface ocean or if it is even safe for a probe to fly through.

Nevertheless, the team at Southwest Research Institute realized that the Clipper's spectrometer, a next generation version called the Mass Spectrometer for Planetary Exploration, might need to make similar dives and dashes through Europa's geyser or geysers. Planetary scientist Hunter Waite, who is one of the co-authors of the Enceladus paper, "Cassini Finds Molecular Hydrogen in Enceladus Plume" in Science magazine, says his team is learning from the shortcomings uncovered during Cassini's geyser passes. Detecting the molecular conditions that could support life in the ocean of Enceladus required some improvisation by the Cassini team because the spectrometer was not designed to collect samples from a geyser. The mass spectrometer can measure ions, so it detected the molecules in the vapor, but the oxide layer of its titanium antechamber can react with ice grain specimens from the plume to accidentally create water and make it difficult to make precise readings, Waite says. To collect more accurate readings, Waite and his team took the Cassini measurements in open source mode, which sent samples directly into the spectrometer and minimized contact with the reactive titanium. For Europa Clipper, they are designing a spectrometer that will not include titanium, but rather a composite that will likely include ceramics. Waite says the blueprint will be ready for a preliminary design review in 2018.

Scientists see the geysers as a shortcut in the search for life in the subsurface oceans of Europa and Enceladus. This finding comes as the NASA-funded Jet Propulsion Laboratory is testing political waters to propose new missions to explore the "ocean worlds" of the outer planets. The Trump administration's proposed budget for 2018 does not include funds for a Europa lander that some scientists and lawmakers had favored, for instance. If a geyser spouting from a subsurface ocean is confirmed on Europa it could make the source of the plume an attractive site for a lander mission, says William Sparks, an astronomer with the Space Telescope Science Institute in Baltimore.

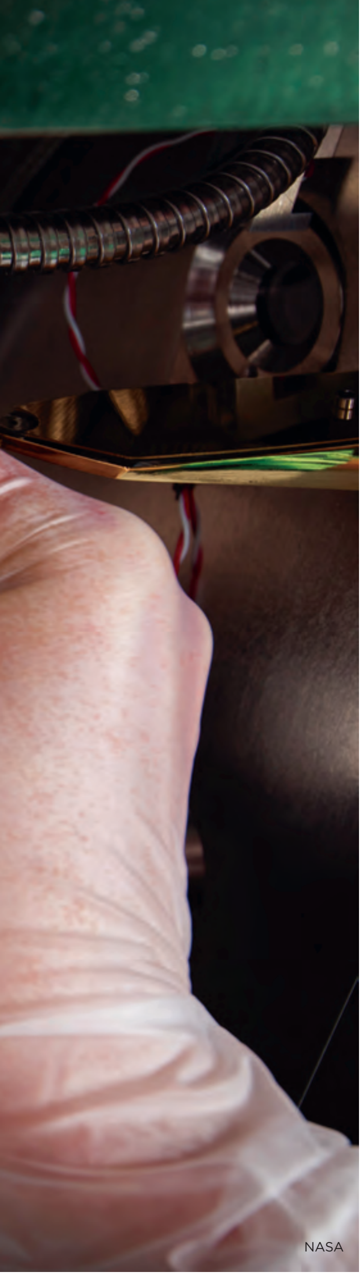
"The Europa Clipper is sure as heck going to want to look at this region," predicts Sparks.★

> **"We did not find inhabitants, but we have pretty much nailed the case that its oceans have habitable conditions."**
>
> — planetary scientist **Hunter Waite** on the Enceladus research

Focused on the small things

Scanning electron microscopy has long been the go-to technology for materials engineers. These experts need to see the nanostructures of alloys or exotic materials, such as aerogels, to be confident of their suitability for specific applications. All scanning electron microscopes have their limits and at some point the images become distorted. In March, NASA scientists acquired a scanning electron microscope that depicts structures at much greater magnifications without such distortion. Keith Button explains the innovations and what they mean.

BY KEITH BUTTON | buttonkeith@gmail.com



▲ **NASA Glenn Research Center's new MAIA3 scanning electron microscope** will give researchers clear views for the first time of critical structures in aerogels.

Today, if a component of a jet or rocket engine calls for the alloy Inconel 718, technicians typically cast the shape of the part from this blend of mostly nickel and iron. They then machine it to create the precise size and shape required. Inconel 718 is exciting for engineers, because it is a "superalloy," meaning it is notably strong and stable at high temperatures. Tim Smith, a materials research engineer at NASA's Glenn Research Center in Ohio, wants to show how the highest grades of Inconel 718 might soon be 3-D printed, also called additively manufactured. Rocket engine parts manufacturers could then build on those specifications, designing and printing parts more quickly, cheaply and accurately. Smith wants to create specifications defining the optimal size and distribution of the strength-enhancing nanoparticles that a component made from additively manufactured Inconel 718 must have. The trouble is, he can't see the nanoparticles well enough.

"It's been really difficult to figure out what size these particles are, and how much of the volume of the metal is made up of those little particles, because of how small they are," Smith says.

All that could soon change for Smith and other NASA materials researchers who face similar dilemmas. In March NASA Glenn took ownership of a new $500,000 microscope built by Tescan Orsay Holding of the Czech Republic.

The innovations inside the microscope, a model called MAIA3, deliver twice the resolution of any of the other seven microscopes at NASA Glenn, some of which are 20 years old. That should open the door to all sorts of possible new applications ranging from 3-D printing of Inconel 718 parts potentially for NASA's Space Launch System rocket to surprising uses for aerogels, a class of lightweight materials typically made from silica and alumina. Scientists have yet to see the porous nanoscale structures of aerogels in clear detail.

Variable pressure

All scanning electron microscopes, including the Tescan MAIA3, work fundamentally the same way: They scan the viewed sample with an accelerated beam of electrons, focused by electromagnetic lenses, much like the optical lenses on a light microscope. The sample emits secondary electrons, which the microscope detects and turns into an image that the viewer sees on a computer screen. The new microscope's resolution ranges down to 0.7 nanometers at 15 kiloelectron volts, a measure of the strength of the electron beam.

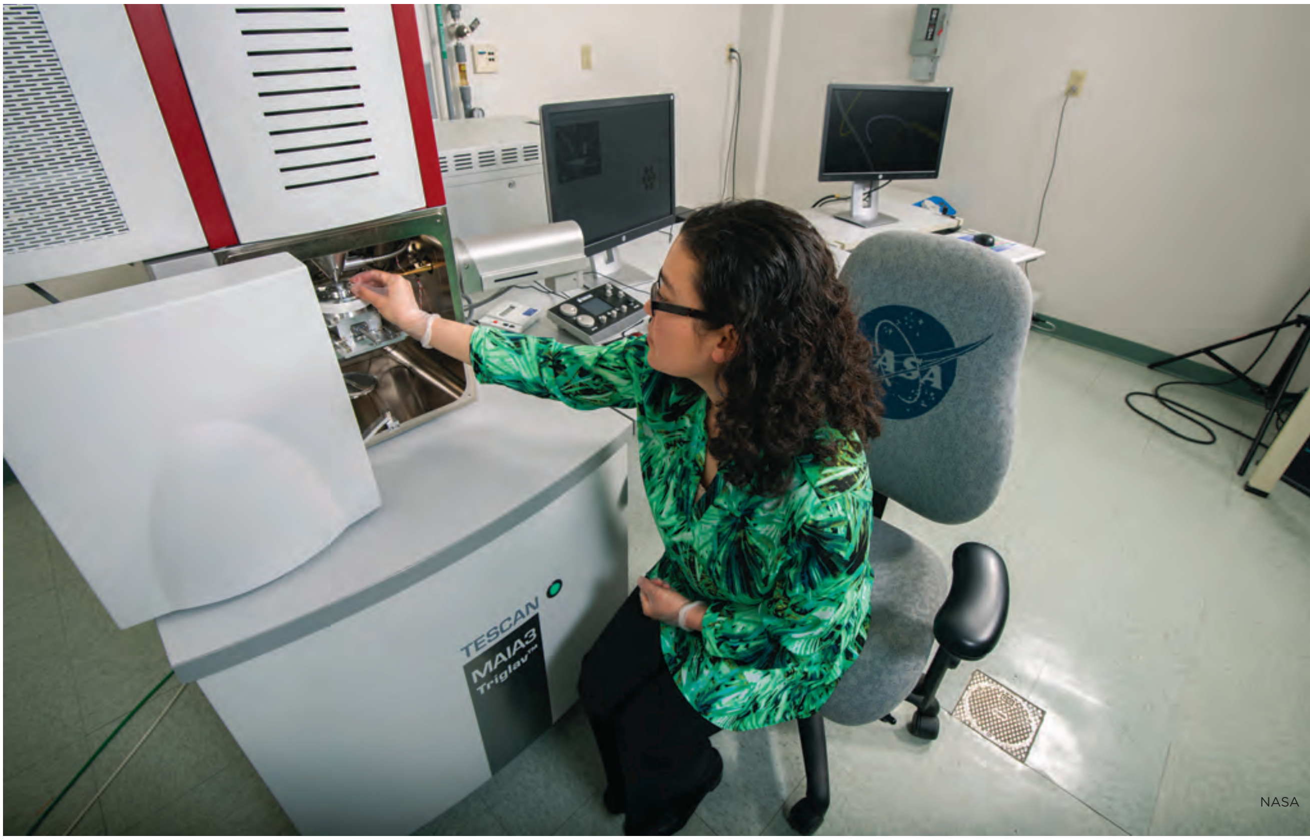
Here's the challenge: Materials with low-conducting qualities will hold a charge from the electrons in the scanning beam. The electrons creating that charge in the material can then deflect other electrons from that incoming beam. This phenomenon deflects electron emissions and distorts the image. Designers of the MAIA3 solved that issue by empowering the user to choose a partial vacuum mode. Normally an electron microscope will create a vacuum in the viewing chamber so gas molecules don't interfere with the incoming electrons' path, making the electrons easier to focus. But for low-conducting materials, that vacuum condition encourages them to hold a charge. With the MAIA3, a user can elect to leave some gas in the chamber and these molecules carry some of the charge away from the material.

The new microscope's software can also create high-resolution images at a lower electron beam strength, which is another way to improve viewing for low-conducting materials. This is done by decelerating the beam and decreasing the energy of the electrons so they don't interact as much with the surface of the sample. This way the microscope can more tightly focus the beam. The new microscope's designers promise a resolution of 1 nanometer at 1 kiloelectron volts for non-conductive materials, which is one of the main reasons NASA purchased it, says Laura Evans, NASA Glenn's electron optics lab lead.

Fran Hurwitz, a senior materials research engineer at NASA, expects the new microscope to give her clear views for the first time of the critical structures in certain aerogels made of silica and alumina. Hurwitz is working on aerogels with a spongelike structure consisting of 94 percent or more air. If you could take a gram of this aerogel and spread its sponge structure flat, it would cover 400 square meters. The pores within the structure are just 10 to 50 nanometers wide and must be viewed at a magnification of 60,000 to 100,000 times. These aerogels tend to hold the charge from the microscope, masking the view of their structures.

Usually, to view a low-conducting material under an electron microscope, the sample is coated with gold or palladium, which becomes the electrical conductor. But for an aerogel, under 100,000 magnification, the viewer starts seeing the structure of the gold metal, which masks the structure of the aerogel, Hurwitz says.

When she views an aerogel under an older electron scanning microscope, she can't slow the scan to get a high resolution image because doing so would cause a charge to build up in the material, which distorts the view so the structure looks solid, she says. So she directs the microscope in a rapid scan, which shows the pores, but she can only view the structure through screen shots.



▲ **Laura Evans,** electron optics lead at NASA's Glenn Research Center's analytical science group, loads a sample into Glenn's new MAIA3 microscope. The sample is a nickel standard, used for calibration.

"Right now, we're playing a balancing game on a scope that's maybe 17 years old," Hurwitz says. "With the older microscopes, we're using very low emission currents, and very low accelerating voltages and very short working distances, so we do all the things you're not supposed to do to image a sample."

Aerogels have physical and thermal properties based on their pore size and pore distribution, so the imaging helps the materials engineers to compare different aerogel formulations and their pore structures to the specific properties they are screening for. In some applications aerogels function as insulators by making it difficult for gas molecules to pass through their pores. Examples are seals or gaskets around cargo doors or engines, or heat insulation, or insulation for thermal electric devices, or protecting structures from fires. Aerogels are potentially valuable for space vehicle applications because they are extremely lightweight.

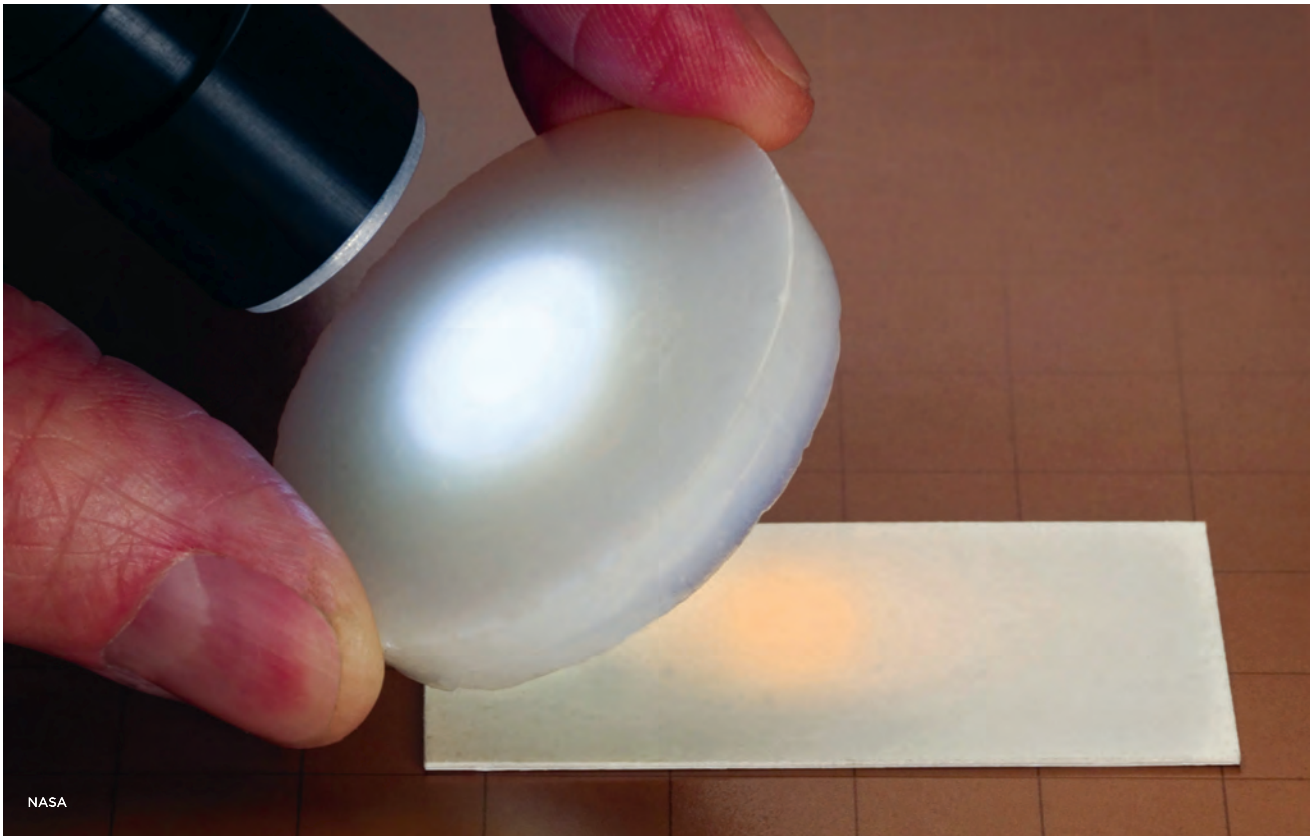
In theory, researchers could control the insulation properties of the material by manipulating the pore shapes and sizes. The engineers are also studying how the pore sizes change when they heat-treat the aerogels, a possible step in turning aerogels into high-temperature insulators. Specifically, they want to see if the pore structure might predict changes in thermal conductivity, density and shrinkage, Hurwitz says.

Another potential application would be for decelerating a spacecraft that is entering the atmosphere of Earth or other planet. The aerogel could be folded and packed into a small space, then inflated by an attached gas membrane to act as a reverse umbrella to slow descent while also acting as a heat shield.

"We're trying to push the temperatures as high as we can," Hurwitz says. The engineers formulated an aerogel that withstood exposure to 1,100 degrees Celsius temperatures for 96 hours, and 1,200 degrees for 24 hours without collapsing the pore structure.

Developing superalloys

For superalloy research, the NASA engineers will create 3-D printed parts, like those that might form part of a rocket engine, from a powder form of Inconel 718. Parts makers at NASA's Marshall Space Flight Center in Huntsville, Alabama, will superheat the powder with a laser to form the parts, layer by layer, as is typical in additive manufacturing. Then the Glenn engineers will examine the parts under the new microscope — checking for voids, fissures or other microscopic defects, for example. They will also measure the metal's nanoscale properties against more conventionally made alloys, because a 3-D printed metal can be quite different than its die-cast version. The new microscope can produce 3-D images, or anaglyphs, in real time, created from



NASA

▲ NASA scientists who study aerogels expect the new MAIA3 microscope to give them clear views of certain structures for the first time.

images taken from two slightly different angles and viewed by the microscope user through 3-D glasses, which can make it easier for the viewer to see deformities and cracks in the microscopic structures.

By checking the Inconel 718's properties at each step, the engineers hope to develop specifications of optimal properties as a starting point for parts manufacturers to develop their own standards and steps for production. Among the critical properties are tensile strength and fatigue. "We're doing work upfront so they don't have to start from scratch," says Peter Bonacuse, the analytical science group lead at NASA Glenn.

The NASA engineers will view the nanoscale particles dispersed in the Inconel 718. These serve a strengthening role similar to that of the bits of sand or gravel in concrete. The nanoparticles in this case provide strength and help prevent the part from deforming at high temperatures. Fatigue and creep are among the concerns. By noting the volume and size of those particles, and how those figures correspond to measurements of the strength of that version of the metal, the engineers can determine the optimal blend of the nanoscale particles.

Inconel 718 has two different shapes of nanoparticles. Some are spherical with a typical radius of 2 to 5 nanometers. These particles are either nickel-aluminum or nickel-titanium. Inconel 718 also has nickel-niobium particles that are plate-shaped with a radius of about 15 nanometers. With the sub-nanometer resolution of the new microscope, the scientists hope to distinguish between the two shapes, Smith says.

With the resolution of the older microscopes, scientists could "maybe get a sense" of the particles in the superalloy, but they couldn't measure or quantify the particles reliably in terms of their size, he adds.

"Hopefully with the new scope we can actually give them a value. Something that's important about that: If we have numbers that we trust, we can then work on producing models that predict their size and volume fractions so we can now calibrate these models because we have numbers that we can trust experimentally."

The scientists are also additively manufacturing Inconel 718 tensile bars that they will test for yield strength and fatigue. The variable in their testing is the powder. They create it in different batches with slightly different chemistries, and when the parts are 3-D printed the different batches create different microstructures with different distributions of the nanoparticles. They hope to find the optimum powder chemistry that produces the strongest version of the superalloy, and identify that version by its nanoparticle characteristics.

The work is expected to go quickly now that the new telescope has arrived. Fundamental research is expected to wrap up in 2018 or 2019. ★

BACKING THE STATION

The International Space Station is entering its final decade of international research and operations. NASA often touts the station as a proving ground for technology aimed at deep space — the moon and Mars. Veteran astronaut and station-builder Tom Jones examines what exploration work NASA and its partners are planning at ISS, and whether the results from their orbiting lab will arrive in time to help.

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NASA points to the International Space Station as its test bed for technologies and techniques needed to establish humans at the moon and, eventually, Mars. But continued ISS funding beyond 2024 is uncertain, and may reduce those funds needed for human expeditions into deep space. If NASA wants to eliminate the deep-space unknowns facing its astronauts, and reap a bigger return on the more than $80 billion the U.S. has spent on its construction and operation, it must step up its game at the ISS. That means finding the resources needed to keep the ISS open for research beyond 2024, and accelerating its exploration-focused research there.


NASA

▲ The inflatable Bigelow Expandable Activity Module, center, is a potential deep-space habitat in the middle of a two-year demonstration mission at ISS.

Searching for exploration answers

Since crews began living and working on the station in 2000, some research has always been aimed at enabling humans to conduct long-duration expeditions to the moon, near-Earth asteroids, or Mars, such as studies of how to keep astronauts healthy during months spent living in free fall.

For example, physiologists have worked hard to understand and prevent the debilitating effects of free fall (weightlessness) on the heart, lungs, skeletal muscles and bones. Over the past 16 years of ISS habitation, crew health experts have developed a vigorous exercise protocol — 90 minutes per day — that largely maintains cardiac health, lung capacity and muscle tone. Even bone mass loss has been reduced to "tolerable" levels for six months or more in free fall. The exercise machines — a treadmill bicycle ergometer and a strength-training device — are bulky and heavy. Their extensive use and failure history at ISS are aiding the design of smaller, lighter and more reliable fitness machines for service in deep space.

But questions on long-term health in free fall remain. More than half of ISS astronauts experience changes in vision, usually nearsightedness, which sometimes persists well after return to Earth. The retinal changes observed are similar to those experienced by patients with elevated cerebrospinal fluid pressure. Researchers suspect that the headward shift in body fluids seen in free fall puts increased pressure on the optic nerve and retina, changing their shape and altering vision. NASA is just beginning to evaluate countermeasures such as applying negative pressure to the lower extremities to reduce intracranial pressure. Preventing

◀ The International Space Station can be the base of important research before the countries that support it withdraw funding, according to scientist and former astronaut Tom Jones.

NASA

Questioning spending on ISS

The House Committee on Science, Space and Technology cautioned against applying NASA funds to operate the International Space Station beyond 2024. It tweeted on March 22, “The longer we operate the ISS, the longer it will take to get to Mars,” and included this chart.

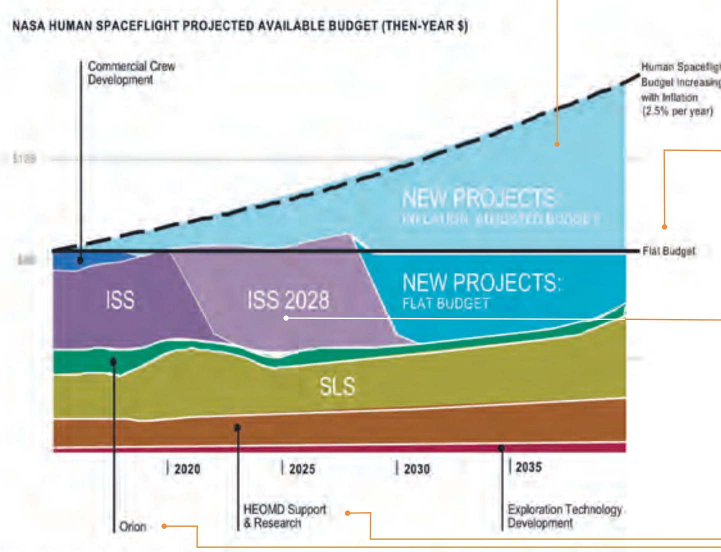


FIGURE 4.29 Projected available budget and costs of the currently planned human space flight program.

Source: “Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration (2014),” National Academies Press

adverse (and perhaps permanent) vision changes is a high priority, and deserves sustained NASA focus.

One of the most highly visible exploration-driven experiments at ISS was astronaut Scott Kelly’s 340-day stay in orbit in 2015-16 — longer than a transit to or from Mars. After landing, Kelly showed some deficiencies in muscle dexterity, postural control and fine motor skills. Overall, however, Kelly’s experience showed that a year in space is not significantly more stressful than a six-month stay.

Reliable and efficient human life support systems are essential on journeys far from Earth, where spare parts are not available and system performance is a matter of life and death. Future systems may include space-grown plants, which can recycle crew CO_2 and waste while producing oxygen and fresh food. At ISS the Vegetable Production System (Veggie) is testing methods for plant growth in free fall. The experiment grows salad-type crops like lettuce or cabbage to supplement the shelf-stable, preserved foods comprising the astronauts’ menu. A new Advanced Plant Habitat will expand farming to arabidopsis, small flowering plants related to cabbage and mustard.

The new plant habitat was to arrive at the ISS on an Orbital ATK Cygnus cargo freighter in April. Crews still grapple and berth arriving cargo ships like Cygnus, Dragon and Japan’s H-II Transfer Vehicle using manual robot arm controls. Future modules bound for deep space will probably be assembled robotically, as various components arrive to become integral parts of a larger craft.

To develop such autonomous techniques, NASA launched to the ISS in February a relative navigation sensor suite, called Raven. The size of a roll-on suitcase, Raven will operate from the ISS port truss, tracking arriving and departing spacecraft with visible and IR cameras and a flash LIDAR (laser) ranging system. Using Raven, NASA hopes to mature the sensors, machine vision algorithms and processing needed to conduct autonomous rendezvous and docking, both for satellite servicing and assembly of future Mars-bound spacecraft.

These are all worthy investigations, but NASA’s challenge now is to make sure it gets remaining answers out of ISS before its decommissioning, perhaps as early as 2024. Because of the time needed to conceive, develop and launch exploration-driven experiments to ISS, NASA must put its most important research in motion within the next couple of years — certainly before 2020.

Keeping the research window open

The station’s programmed demise means NASA must prioritize exploration work there to reap results in time. Although NASA would like four extra years to conduct vital deep-space research at ISS, doing so would force difficult funding choices. On March 21, President Trump signed the NASA Transition Authorization Act of 2017; the new law calls for "maximizing utilization of the International Space Station," including research meant to develop and test exploration technologies. But the law provides no extra funding to do so.

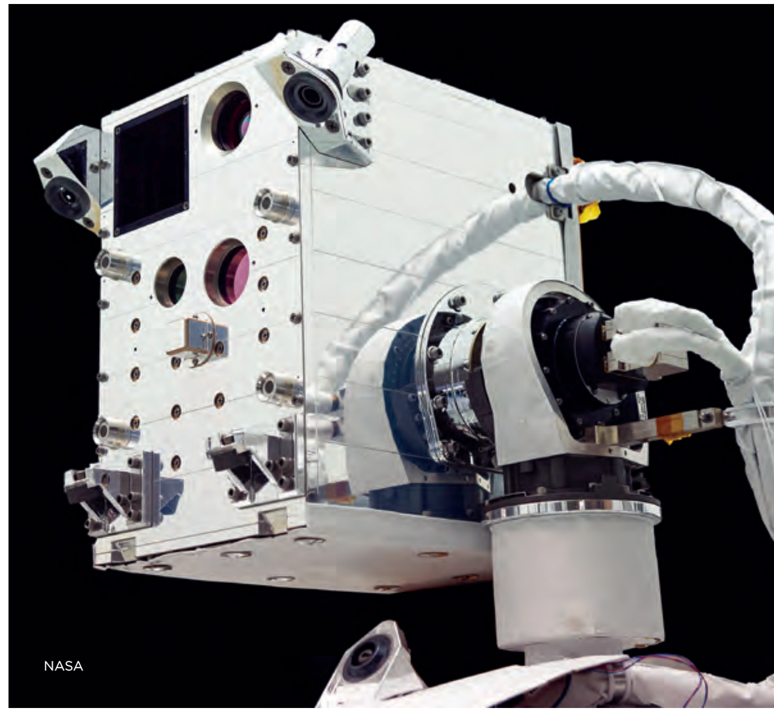
Some in Congress view ISS funding (about $3 billion annually) as diverting NASA's focus from Mars. At a March 22 hearing on the station's future, Rep. Brian Babin, R-Texas, chairman of the House Space subcommittee, said in his opening statement, "We ought to be aware that remaining on the ISS [beyond 2024] will come at a cost." Babin further warned, "Tax-dollars spent on the ISS will not be spent on destinations beyond low Earth orbit. …The longer we operate the ISS, the longer it will take to get to Mars."

NASA associate administrator for human exploration and operations, Bill Gerstenmaier, responded in testimony: "It's ... wrong to assume that ISS and exploration are competing. … They're really helping each other." Gerstenmaier cited the crew health research underway at ISS, but there are many opportunities for exploration technology and science work still unfulfilled. NASA must start planning, developing and flying these investigations as soon as possible, lest its research window close in 2024 with vital questions left unanswered.

Open work

To take full advantage of ISS in solving its exploration challenges, NASA should put new or expanded demonstrations like these on its station "to do" list, shifting funds within the human spaceflight budget as necessary:

- Expanded trials of deep-space habitats, such as the inflatable Bigelow Expandable Activity Module. NASA should commission and fly a full-scale inflatable habitat structure and evaluate it for strength, radiation protection and durability against micrometeoroids.
- Tests at ISS of next-generation life support systems, further closing the recycling loop for wastewater and exhaled carbon dioxide. These systems should demonstrate improved efficiency, reliability and reduced maintenance.
- Rigorous ISS testing of a new exploration spacesuit with greater dexterity, mobility and durability. Astronauts could identify any flaws in its life support system, high-capacity batteries, radiation shielding and human-machine interfaces before committing it to more demanding planetary surface work.
- Evaluation of new radiation protection materials and countermeasures to reduce astronauts' cosmic ray exposure. Promising materials and methods can then be tested further in lunar orbit, outside Earth's magnetosphere.



▲ Raven is deployed outside the ISS to test sensors that may make it easier to operate spacecraft autonomously.

- Introduction of improved food technologies that reduce packaging weight, yet preserve the taste and nutritional value of space fare.
- Deployment of a portable centrifuge at ISS, testing the ability of a rotating, partial-G environment to maintain the health of laboratory animals in extended free fall.
- Tests of free-fall extraction of water and metals from meteorites, and later, returned asteroid material, aimed at in-space propellant production to support Mars expeditions.

Not every deep-space challenge can be solved at ISS. The station's low Earth orbit, for example, is well within Earth's magnetosphere, and so doesn't replicate the solar flare and cosmic ray radiation environment found at the moon and beyond. But if NASA uses a small fraction of its exploration funding to fly and test real hardware at ISS, it can show rapid and sustained progress in eliminating its deep-space unknowns.

By extending station operations through 2028, NASA will be able to demonstrate frequent, visible progress toward deep space, showing the seriousness of its efforts to reach the moon and Mars. By maximizing its technology and operations return from ISS and keeping those answers coming through 2028, NASA can also showcase its value to potential commercial operators, who would ideally take over station operations in the late 2020s.

Instead of treating ISS as a financial millstone beyond 2024, NASA should ensure that its expansive orbital outpost, purchased so dearly over three decades, could deliver the exploration answers we need. ★

Toward a CisLunar Marketplace

In the progression of the human economy, only one domain remains undeveloped: outer space. The high cost of reaching orbit has been an obvious hurdle, but another challenge is that goods and people must move efficiently from place to place once they are in space. United Launch Alliance, the joint venture of Boeing and Lockheed Martin, is addressing both problems through its CisLunar-1000 initiative. Michael Holguin of ULA shares an insider's account about progress to date.

Creating an economy in the space between Earth and the moon's surface, called cislunar space, has always posed a chicken and egg dilemma. The cost of launching, building and operating orbiting facilities makes the business case difficult to close, but without being in business, it's difficult to lower costs and prove the business case. As a result, the great potential of space has sat idle on terra firma, despite the intriguing results of years of experiments aboard the International Space Station.

What's needed to set the space economy in motion is a basic commercial infrastructure, especially the ability to affordably launch and transport cargo among various locations. If this lynchpin can be created, the possibilities are myriad. Here are a few examples:

- Solar power might be beamed from space to remote locations on Earth to transform the energy industry with substantial benefits for humanity.


United Launch Alliance

▲ An artist's rendering depicts United Launch Alliance's Advanced Cryogenic Evolved Stage, ACES, transporting a module to a new orbit.

■ Fiber optic cables and computer chips could be manufactured with properties better than anything reproducible here on Earth.

■ Water in the form of ice could be harvested from the moon or asteroids to make it unnecessary to resupply propellants from Earth's deep gravity well, making the economy nearly self-sustaining. It's estimated that the lunar poles hold more than 90 billion metric tons of ice.

Steady progress

It was with this in mind that in 2015 United Launch Alliance announced an initiative called CisLunar-1000 that envisions 1,000 men and women working and living in space in just 30 years, part of a self-sustaining space economy benefiting those on Earth. February was an important month for ULA and others involved in this effort. ULA hosted a workshop with participants from several sectors of the space, manufacturing and mining industries. This workshop established the construct of the CisLunar Marketplace, a forum in which contributors to current and future space development can discuss strategies to overcome the obstacles of expanding the space economy and sphere of human influence. We worked together to create the broad outlines of a road map for creating the necessary infrastructure. For example, the key milestones enabled by the development of reusable in-space transportation technology will pave the way for the following major CisLunar Marketplace epochs:

■ Today to 2022: Foundations — Improved access to space and the first commercial habitat in low Earth orbit. Surveys of near Earth objects and exploration of the lunar poles.

■ 2022 to 2027: The Tipping Point — Infrastructure development for a cislunar outpost to host orbital manufacturing facilities. Demonstration of orbital propellant refueling technology.

■ 2027 to 2032: Space Industrial Revolution — Creation of space-based power generation infrastructure. Commercial crops on orbit. In-space resource utilization and space tourism beyond LEO.

■ 2032 to 2037: Safeguarding Our World — Generation of clean, affordable energy via space solar power beyond 2 gigawatt capability. Large-scale in-space manufacturing.

■ 2037 and Beyond: New Era of Exploration — Cislunar space as a stepping stone for propellant staging for Mars missions. Greater than 10 gigawatt space solar powered infrastructure. Mars mission staging node established in cislunar space.

This timeline was among the accomplishments at the Feb. 14 workshop attended by more than 60 entrepreneurs, investment bankers and others interested in building the infrastructure, which will include asteroid and lunar mining equipment, space habitats, space solar power systems and in-space transportation vehicles. NASA and U.S. Air Force participants described how the national interests would benefit from and become an anchor tenant for some of the CisLunar Marketplace, much like the current transition to commercial providers for secure communications and Earth observation. We divided up into cross-functional teams that addressed transportation, resources, habitats, space energy and manufacturing. These teams developed intercompany dependencies, such as the space habitats and manufacturing facilities that will be required in order to house crew and machines for on-orbit production of goods. The workshop also demonstrated a burgeoning need to get these business interests working together as a marketplace to overcome the technical and financial hurdles. The business case for the technology will need to be demonstrated, as well as the infrastructure for supporting the ongoing manufacture and return of goods from space. Much like the major industrial titans did in the days of the American industrial age, these entrepreneurs are determined to make the CisLunar Marketplace a reality. (Also: "Strategizing about Mars," Page 40.)

A space superhighway

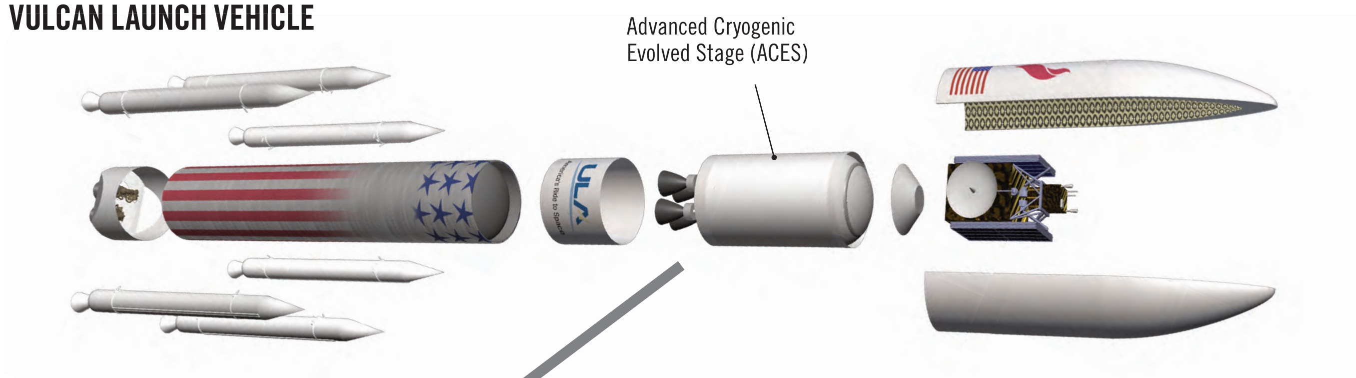
In the early 2000s, my colleagues and I, whose careers took us from the early Atlas and Titan programs at General Dynamics Space Systems to the Lockheed Martin Atlas 3 and 5 programs, and now ULA, began looking at the factors that were holding back space entrepreneurs. One was the lack of a reusable in-space, long-duration rocket stage that could move goods and people between orbits. There are numerous possible applications. Propellant could be carried from the lunar surface to a refueling location at a Lagrange point, one of the places in space where a spacecraft can remain while expending little fuel. Propellant could be carried to Earth orbit to refuel another stage that would boost a satellite to a new location. Resources could be brought to a manufacturing facility or goods could be moved to a staging location for return to Earth. To do those things, an ACES upper stage would need to remain ready for action over a span of weeks, months or years.

The long-duration requirement seemed like an unreachable goal when we looked at existing technologies. When delivering a satellite to orbit, an upper stage might need to operate for at most one to eight hours and conduct up to three main engine burns. Upper stage propellants, battery power and maneuvering capability, after all, are finite resources. Enter the ever-creative genius Frank Zegler, who patented an idea based on his experience with the Atlas rockets and their Centaur upper stages

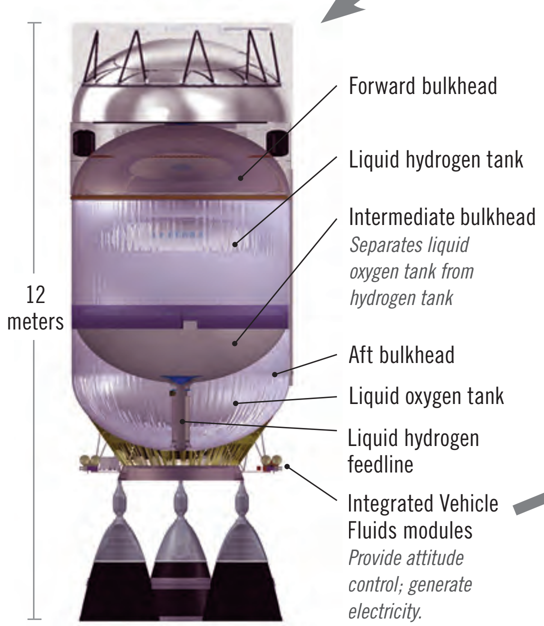
Transportation for the space superhighway

Creating an economy in space will require transporting raw materials and finished products among orbits. United Launch Alliance wants its Advanced Cryogenic Evolved Stage, or ACES, to fill the role when it debuts in the 2020s.

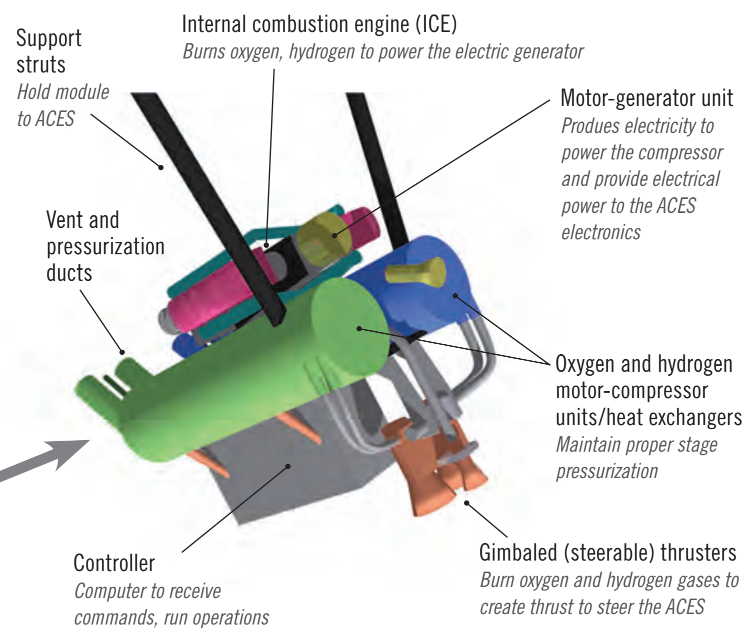
VULCAN LAUNCH VEHICLE



ADVANCED CRYOGENIC EVOLVED STAGE



INTEGRATED VEHICLE FLUIDS MODULES



Advanced Cryogenic Evolved Stage at a Glance

Propellant capacity 68,000 kilograms

Engine Thrust 222,000 to 534,000 newtons

Engine options One BE-3U; two or four RL10s; or two or three XCOR 8H21

Notable Three times greater propellant capacity than today's Centaurs. Tanks and intermediate bulkhead are stainless steel. External shell (not shown) relies almost exclusively on cylindrical shape and internal pressure to handle loads.

Source: ULA

In the future, dozens of these and other reusable stages could move goods and crew back and forth through cislunar space to enable the marketplace and serve as a potential staging point for expansion of commercial space beyond.

that propel massive satellites into orbit. If we could find a way to produce electricity from the propellants carried in the Centaur, we could devote that electricity to pressurizing the tanks, powering the stage's electronics and providing attitude control for maneuvering. His idea was to run an internal combustion engine off the hydrogen and oxygen gases in the ullage, or empty portion, of the Centaur's cryogenic tanks and use that to power a generator. This way, the stage could produce enough electricity to power itself, eliminating the need for batteries, along with other benefits. Power could be supplied to recirculate the ullage gases through a compressor and heat exchanger to add heat and energy to maintain the proper pressure in the stage. This would eliminate heavy and expensive helium bottles and plumbing. In addition, those same ullage gases could fuel small hydrogen/oxygen thrusters mounted on a steerable gimbal to eliminate the need for toxic hydrazine fuel and the required bottles and plumbing.

We decided to call this combination of components the Integrated Vehicle Fluids system, or IVF. Today, this technology is at the heart of our Advanced Cryogenic Evolved Stage, or ACES, now in development, and will be a successor to Centaur. Another key innovation for ACES was developed by my colleague Bernard Kutter through his years as a thermodynamics engineer. He worked to find passive insulation and other technological breakthroughs that would keep propellant boil-off inside the tanks to just enough for the internal combustion engine. Cryogenic propellants would last inside ACES for weeks.

ACES will open the door to creation of a space superhighway. Once in space, an ACES stage would be ready to move cargo among orbits and the moon's surface as long as propellant remained available. It could be refueled by tankers launched from Earth or propellant derived from water mined from asteroids or the moon. Dozens of these and other reusable stages could move goods and crew through cislunar space to enable the marketplace and serve as a potential staging point for expansion of commercial space beyond. Also, IVF's capacity to generate several thousand watts of power creates other opportunities. Habitats or on-orbit factories could depend on the upper stage for power generation, life support, experiments, production or other uses.

Access to space

Just as important as the in-space operations will be the impact of ACES and IVF on space launch. Today, each of our Centaur stages requires a complex set of power, reaction control and pressurization subsystems to deliver satellites to orbit. Each of these subsystems is independent of the other and requires plumbing, control systems and power. By combining those functions in a single IVF module, the weight and complexity of the stage will be reduced and the aft end will be much cleaner. IVF brings the added benefit of reducing propellant boil-off by maintaining optimal pressurization of the cryogenic tanks. This boil-off would otherwise shorten upper stage life. IVF also will be modular, meaning it can be built and tested offline and integrated as a component onto the vehicle, simplifying stage build and test operations at the factory and launch site.

IVF will be a key enabling technology for our line of Vulcan ACES launch vehicles in development. During launch, ACES will fire high above the atmosphere, just as Centaur does. Because the IVF performs the function of the helium pressurization and reaction control and electrical power systems, the bottles, plumbing and associated hardware can be eliminated, allowing more performance to be allocated to lifting payload rather than upper stage support systems. We calculate Vulcan ACES will increase the performance capability of a single stick configuration launch vehicle with six solid strap-on motors significantly beyond our most powerful launcher, the Delta 4 Heavy, with its three side-by-side Common Booster Cores. A Vulcan ACES launch will cost a fraction of that for a Delta 4 Heavy launch. ACES will have three times the propellant capacity of Centaur and be able to fly up to four RL10s (or equivalent alternative engines) with the goal of producing ACES for roughly the cost of today's Centaur.

Vulcan ACES with IVF will exceed the requirements defined by the U.S. Air Force in the Evolved Expendable Launch Vehicle program that created today's versions of the Delta 4, Atlas 5 and Centaur. Early testing of the IVF combustion engine and compressor components show great potential for this technology infusion.

By bringing new launch and in-orbit transportation capabilities to bear, space entrepreneurs and others have greater access to space and infrastructure to extend the reaches of humankind in space and increase the security of our planet and population. ★

Michael Holguin
is United Launch Alliance's program manager for development of the Integrated Vehicle Fluids module and a member of the company's Advanced Programs team. Michael began his career at General Dynamics in the 1980s as a flight operations engineer for the Space Shuttle/Centaur program, and later managed 17 successful Atlas Centaur launches. He recently served as the Commercial Crew Program manager at ULA. He earned a Bachelor of Science degree in mechanical engineering from New Mexico State University in 1983, a Master of Business Administration from University of Phoenix in1996 and a telecommunications degree from University of Denver in 2001.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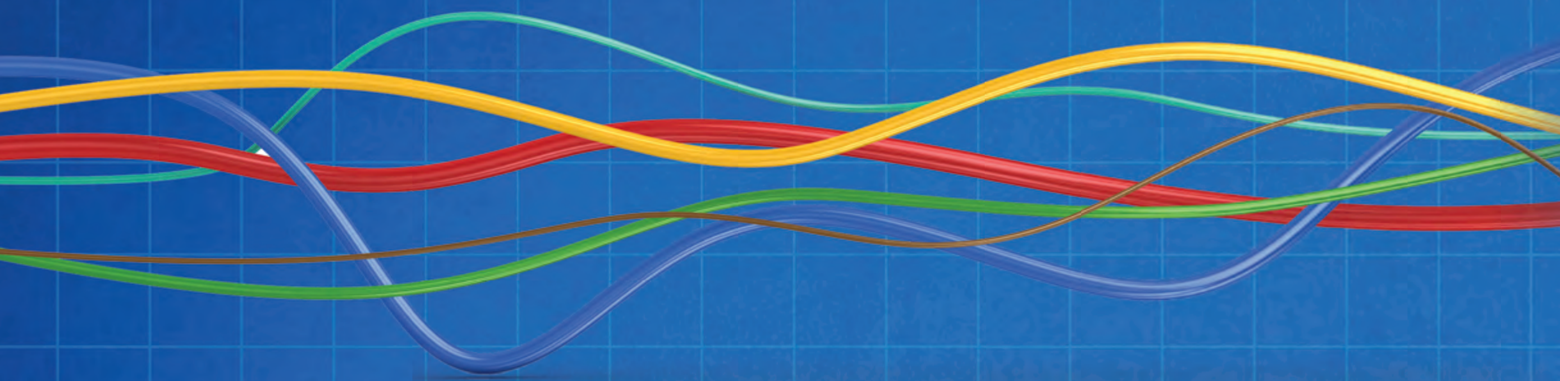
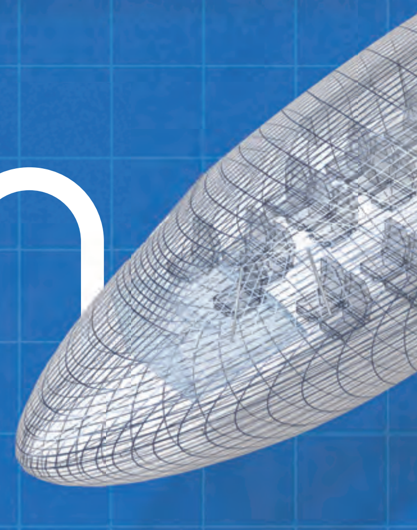
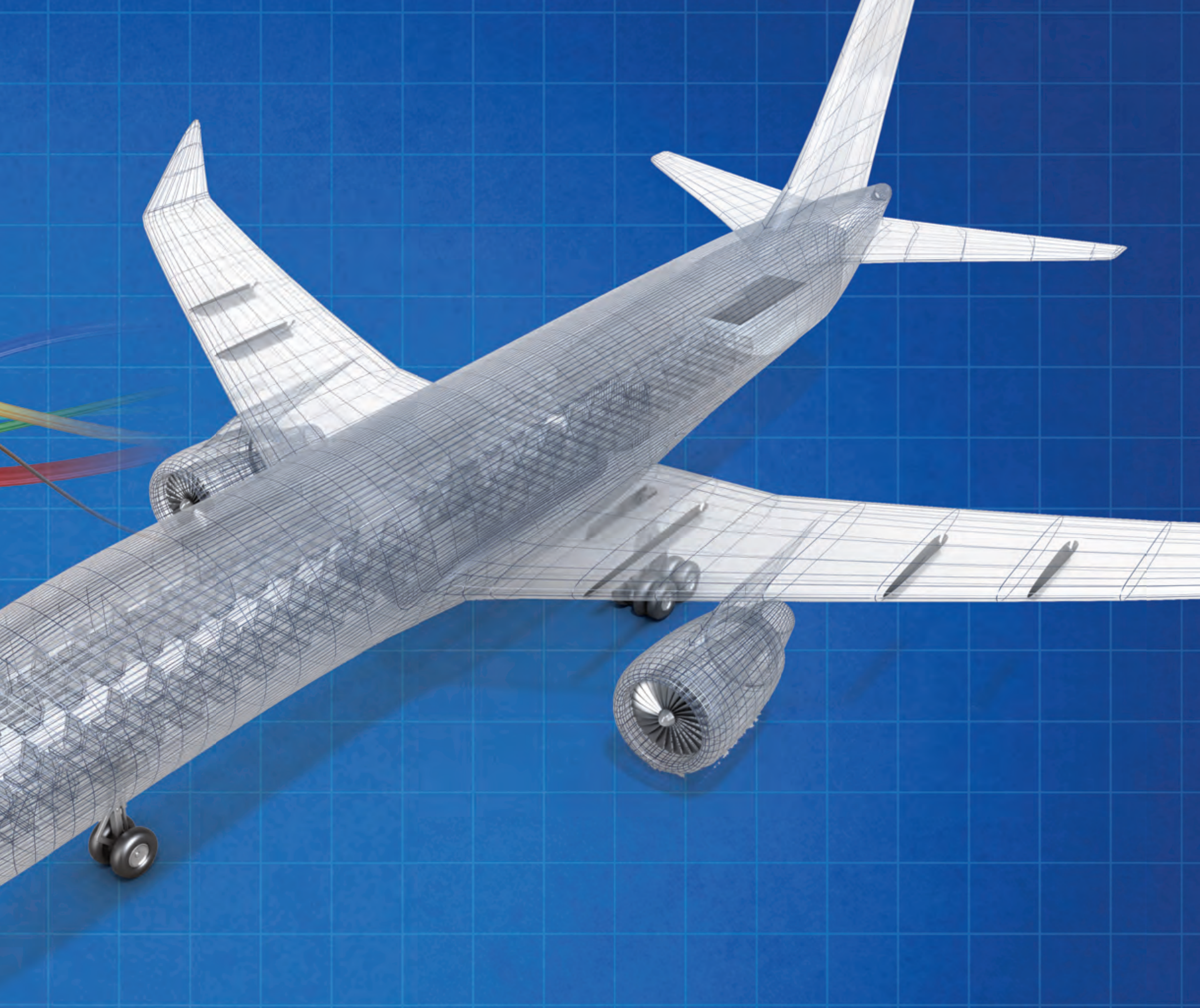


War on wiring





Hidden in a modern passenger jet are wires and more wires. Some supply electricity, but many route "health monitoring" data gathered from around the plane while others carry flight commands through its fly-by-wire network. Watching society go wireless has given avionics experts ideas about how they might do the equivalent inside airliners. Henry Canaday looks at the payoffs and challenges of the wireless revolution.

If you removed all the wires from a widebody passenger jet and strung them end-to-end, you could connect St. Louis to Chicago or London to Amsterdam, distances of approximately 500 kilometers. If you rolled these 100,000 wires into a ball with the harnesses that hold them to the aircraft structure and put the ball on a scale, it would tip to nearly 7,400 kilograms or about 3 percent of the aircraft's weight.

Many of these wires supply electricity to components, but many others transmit operational data, including avionics, flight-control commands and sensor data on the performance of components like pneumatic and hydraulic systems. Research engineers think that in five years they will have cleared enough technical and regulatory hurdles to begin replacing many data-carrying wires with wireless transceivers.

First to go would be wiring for non-avionics functions, such as control of cabin lighting and passenger audio-video equipment or devices gathering routine health-management data from around the plane. Next might be safety-related wiring linked to smoke detectors, emergency lighting, cabin-pressure sensing and avionics, and eventually even commands that move the plane's flight-control surfaces.

All told, it might be possible for a modern widebody to shed up to 1,800 kilograms of wiring, according to Mauro Atalla, vice president for engineering and technology at United Technologies Corp.'s Sensors and Integrated Systems division in Minnesota, one of the companies researching internal wireless communications for airliners.

Removing that much wiring is an ambitious goal, driven in part by a pressing desire among airlines to accommodate more and more health-monitoring equipment to identify failing parts before they pose a safety risk or disrupt airline schedules. The shift toward wireless communications also would enhance safety and make it easier to upgrade components, advocates say.

Some of the world's top avionics and airframe experts have taken up the challenge under a project called WAIC, short for wireless avionics intra-communications, coordinated by Texas A & M University's Aerospace Vehicle Systems Institute. The work is self-funded by participating organizations and includes a growing list of avionics companies and aircraft manufacturers. U.S. component suppliers Honeywell and United Technologies have been involved, as have Airbus, Boeing, Bombardier of Canada, GE Aviation, Embraer of Brazil and Gulfstream. Most recent to join are NASA, Lufthansa Technik of Germany, Thales of France and Zodiac Inflight Innovation of California and Germany. They will contribute their expertise to laboratory and flight tests.

IN 1984, A BOEING 767-200ER HAD 140 KILOMETERS OF WIRING. TODAY, A MODERN TWIN-AISLE AIRCRAFT LIKE THE BOEING 787 HAS ABOUT 500 KILOMETERS.

How might a wireless system work? United Technologies, better known as UTC, agreed to describe its approach for us. Transceiver modules weighing less than 13 grams would be installed on components throughout the plane. Each would send data from the component or receive commands from the flight crew or automated systems.

To power these modules, UTC is considering different methods. Power could be supplied by a long-life lithium battery or by harvesting ambient energy and storing it in super capacitors. Any batteries would be non-recharging to avoid risks of overheating and fire.

These transceiver modules, or nodes, would be connected to remote data concentrators, weighing less than 200 grams, located strategically around the plane. These concentrators, similar to routers in homes and buildings, would be powered by the aircraft's electrical system. They would collect data from (or send it to) transceiver modules and route it where it needs to go. That could mean to the aircraft interface device for transmission to the ground by radio, broadband or cell network. If the crew needed to see the data, it would be transmitted to a cockpit tablet interface module that would be connected wirelessly or by wires to tablet PCs for display to the pilots.

The WAIC research is aimed at the boldest part of the wireless shift, which would be transmission of data related to safety and regularity of flights. Passenger entertainment and communications are going wireless too, but with different systems, although partly for the same reasons: to reduce weight, cost and complexity.

The need for replacing wiring is increasing, especially for widebody aircraft. In 1984, a Boeing 767-200ER had 140 kilometers of wiring. Today, a modern twin-aisle aircraft like the Boeing 787 has about 500 kilometers of wiring. Wiring weight on a single-aisle jet is about half the twin-aisle total, but the proportional burden is the same.

David Redman heads the Aerospace Vehicle Systems Institute's efforts to coordinate research on WAIC. He recalls it took from 2008 to 2015 to take the first regulatory step: securing a dedicated WAIC frequency of 4,200 to 4,400 megahertz from the World Radiocommunication Conference, which meets every three to four years to make decisions about radio spectrum.

Redman is coordinating research to help the RTCA, an association founded in 1935 as the Radio Technical Commission for Aeronautics, to establish performance standards for WAIC equipment. A key aim is to ensure that WAIC applications won't interfere with those on other aircraft, with each other or with radio altimeters, which derive altitude by measuring the time it takes a radio wave to reflect from the ground and return to the plane. All of these devices operate in the same 4,200 to 4,400 megahertz band.

Atalla of UTC expects the minimum operational performance standard for WAIC to be developed by mid-2019. Redman expects certified WAIC applications in about five years.

Wireless nodes must be light, small, low power and cheap if they are going to be attractive and realistic replacements for wires. How to power the nodes remains a major question. Lithium batteries and harvesting ambient energy are among the options, but there is a third idea. Passive radio-frequency identification tags might remain dormant until powered briefly by signals from the RFID readers that interrogate them.

For both nodes and power, Redman hopes that WAIC can piggyback on advances in consumer or other industrial markets that have much higher volumes on which to recover investments.

As confidence in the technology grows, some of the wires that carry data in fly-by-wire jets might be replaced. That would be a big breakthrough, because safety-related connections now require two or three redundant wires to ensure functions if one of the wires chafes or fails for some other reason. If a wireless link were installed in place of one wire, the result would be what Redman calls a dissimilar redundancy, which is often a preferable strategy. The same safety data would be carried by both wire and wireless connections, rather than relying solely on wires that could all fail for the same reason.

And Redman notes that the weight reduction for WAIC might be proportionally greater than if engineers could reduce the wiring required to supply electricity to components. Wires that carry data, including fiber-optic cables, are typically heavier and more expensive and complex than those that carry electric power.

Redman observes that eliminating wires also frees up space, always at a premium on aircraft. Wires take up space themselves and need additional room for their separation.

Upgrading equipment on today's jets can be a major undertaking, but with the new approach mechanics would just have to replace the component and attached module, rather than disentangle, remove and safely replace bundles of wires. Especially for new aircraft, installing wireless devices could be much easier than installing all those connecting wires.

On top of these benefits, advocates suspect there will be payoffs that haven't yet been anticipated. In today's designs, sensors need wires, and that limits where they can be placed. Functions that are not practical or economic today with wired systems might suddenly make sense. ★

Potential wireless safety uses

The Aerospace Vehicle Systems Institute says wireless technology potentially could be used throughout an aircraft, including these safety applications:

Smoke detection
1 Door sensors
Fuel tank and line monitor
Temperature
2 Engine sensors
Humidity and corrosion detection
Cabin pressure
Emergency lighting
3 Ice detection
Flight controls position feedback
Air data
Flight deck and cabin crew imagery/video
4 Landing gear
Avionics communications bus
Structural health monitoring
Active vibration control

Source: Aerospace Vehicle Systems Institute

SPECIAL REPORT:

DRONES

Lofty predictions of growth in the small drone and large unmanned aircraft markets are partly based on faith that industry technologists and the FAA can figure out how to safely open more of the U.S. National Airspace System to them. DEBRA WERNER contacted current and former FAA officials, leading technologists and a market analyst to take stock of what's been achieved and what's still to come.

FAA pushes tech breakthroughs, safety in drone planning

Earl Lawrence's job at the FAA is to get unmanned aircraft flying in the same airspace as the 50,000 commercial and general aviation flights that occur daily in the United States, and do so without compromising safety. Lawrence declined to be interviewed but provided written responses to Debra Werner's questions about UAS integration in the U.S. National Airspace System.

Q: What are the primary challenges of integrating UAS in the national airspace?

Further expanding allowable UAS operations and having this emerging technology safely achieve its full potential requires resolving several key challenges. Before operations beyond visual line-of-sight can become routine, FAA must address risks posed by drones to other manned aircraft, as well as risks posed by drones during a loss-of-operator-control event. We are working with the seven UAS test sites, our UAS Center of Excellence and NASA to address many of the technical challenges. Additionally, preemption, privacy, enforcement, and security — both physical and cyber — remain key issues as UAS integration progresses.

Q: In recent congressional testimony, you mentioned pilots reported 1,800 unmanned aircraft sightings in 2016. Do you expect that number to continue to climb?

Although the numbers aren't final, we believe the sightings have leveled off in the last couple of months. We are actively engaged in public education and outreach efforts, such as "Know Before You Fly" and the small UAS registration process to make sure operators are aware of UAS regulations and where they can fly without posing a hazard to manned aircraft.

Q: What is the FAA doing to prevent unmanned aircraft from colliding with manned aircraft?

Education is a key part of our efforts, but not the only part. We also continue to work closely with our industry partners to evaluate promising drone-detection technologies, some of which have been tested in airport environments at New York's JFK Airport, Atlantic City International Airport and Denver International Airport. Further testing will take place at Dallas-Fort Worth later this year. In addition, the FAA is working with our interagency partners to develop policies and procedures for restricting UAS operations over fixed site facilities, as directed by Section 2209 of the 2016 FAA Extension.

Q: How do UAS fit into the FAA's Next Generation Air Traffic Control System?

NextGen will allow UAS to operate safely and efficiently inside domestic airspace. The FAA and industry both have key roles to play in the implementation process; neither of us is going to solve all of the challenges and deliver the capability by flying solo.

Our Center of Excellence is conducting UAS research in the areas of air traffic integration, airworthiness, control and communication, detect and avoid, human factors, low-altitude operations safety and training. NASA is engaged with the seven FAA-selected UAS test ranges to research NASA's unmanned aircraft traffic management system, better known as UTM. NASA is researching prototype technologies that could be implemented by the UAS community to enable safe and efficient low-altitude UAS operations.

Q: What technologies need to be improved before UAS can fly in controlled airspace alongside manned aircraft?

The key technologies are drone-detection systems (as mandated in Section 2206 of the 2016 FAA Extension), robust systems for control and communication, effective detect and avoid systems, whether ground-based or airborne, and workable traffic management systems to support operators in identifying potential conflicts, provide an automated capability for the FAA to approve or deny requests for airspace usage and notify users of any constraints. ★

Earl Lawrence

- Director of FAA's UAS Integration Office
- Formerly head of FAA's Small Airplane Directorate
- Managed government affairs for the Experimental Aircraft Association

Job No. 1: Detect and avoid

If engineers succeed in winning FAA approval for sensors to prevent unmanned aerial systems from crashing into buildings and other aircraft, they will be clearing the way for UAS to perform jobs ranging from pipeline monitoring to package delivery. For now, UAS developers are wrestling with the challenge of making onboard detect-and-avoid technology small and lightweight enough to fit in the fastest growing segment of the market — UAS under 55 pounds.

Jay Gundlach

- President and co-founder of FlightHouse Engineering of Portland, Oregon
- Formerly of Aurora Flight Sciences of Virginia and Insitu of Washington; helped design and develop more than 35 unique unmanned aircraft
- Ph.D. in aerospace and ocean engineering from Virginia Tech

Michael Guterres

- Principal, Navigation and Unmanned Aircraft, at Mitre Corp.'s Center for Advanced Aviation System Development
- Formerly of Textron Unmanned Systems in Maryland; oversaw development and engineering of Aerosonde and U.S. Army Shadow
- Ph.D. in aerospace engineering from University of Maryland

Writer **Debra Werner** discussed detect-and-avoid technology and its implications for aircraft design with Jay Gundlach, a pioneer in UAS design, and Michael Guterres, a leader in efforts to integrate drones in national airspace. Gundlach established his own firm, FlightHouse Engineering, in 2016 to help commercial and government teams create unmanned aircraft of all sizes to perform specific missions. Guterres leads an FAA initiative to help BNSF Railway find ways to use drones to safely inspect tracks far beyond the view of their operators. Guterres also leads a multi-institution research partnership focused on integration of small drones in urban areas.

Q: What is challenging about developing detect-and-avoid systems for large and small unmanned aircraft?

Michael Guterres: Most of the larger unmanned aircraft that fly at higher altitudes are optionally piloted modified manned aircraft, military derivatives or military systems altogether. Those tend to have a lot of capacity in terms of internal volume, power and the ability to carry systems and equipment. Also, they fly in airspace that requires some type of equipment onboard. Smaller UAS fly at lower altitudes and have a different set of challenges: the necessity to avoid other aircraft, but also to negotiate ground obstacles such as buildings, cranes, trees and even people. Those small, light unmanned aircraft do not have the ability to carry or power a lot of equipment.

Q: What is happening in the large UAS category?

Guterres: There has been a pretty significant standards development effort. The RTCA [Radio Technical Commission for Aeronautics] brought together industry and government to develop a set of requirements and performance thresholds for larger aircraft, like Predator and Global Hawk, to transition to Class A airspace [above 18,000 feet]. Those standards, when published, will make it easier for operators using some of these larger systems to transition through those first 18,000 feet to Class A airspace. That transition phase from ground to 18,000 feet is a little bit riskier [than flying above 18,000 feet] because there are a lot of folks flying in that airspace that are not necessarily equipped. The UAS has a responsibility that normally would be handled in a manned aircraft by the pilot and co-pilot. When the aircraft are in Class A, they work with air traffic control. Some of the larger unmanned aircraft are able to carry TCAS [Traffic Alert and Collision Avoidance System], a system used by manned aircraft, and also onboard radars.

Q: Is it more challenging to provide detect-and-avoid capabilities for smaller unmanned aircraft?

Guterres: In some ways, yes. There are no defined performance requirements, no published standards for what a detect-and-avoid system should do around buildings, people, UAS, and to avoid manned aircraft. On the small side, I think you'll have a combination of onboard systems with ground systems as well. For example, small UAS flying over infrastructure, pipelines or a rural railroad, where you have very little air traffic activity and low population density, may be able to use one type of detect-and-avoid solution. For UAS flying in a different type of environment, urban or suburban, close to people and buildings, the threshold for technology performance will be elevated. Then you may need different types of detect-and-avoid systems, onboard, ground or a combination of both. The technology solution may also depend on the operational concept and the risk level.

Q: In terms of onboard systems, what options are there for small UAS?

Guterres: There are quite a few that have been experimented with, from onboard radar to visual systems, using cameras and interpreting the imagery to identify objects and other aircraft, to acoustic sensors. These sensors are looking for aircraft that are not engaging with you. On the cooperative side, you have electronic communications: ADS-B [automatic dependent surveillance-broadcast] or Mode S transponders. If you have multiple aircraft using transceivers to communicate with each other, then they can communicate speed, heading and altitude electronically. This makes it a little bit easier and safer, but there is no mandate for all aircraft at low altitude to have those. So, you have to contend with other aircraft that are cooperating and those who are not.

Q: How do aircraft designers integrate detect-and-avoid systems in unmanned aircraft?

Jay Gundlach: There are a few different design considerations. The primary considerations are size, weight and power. Especially for small unmanned aircraft that weigh less than 55 pounds, which are covered by the current [FAA] Part 107 regulations, you really don't have that much capacity. So, for example, a lot of unmanned aircraft tend to have payload capacities of about 5 to 20 percent of the takeoff gross weight. For a 50-pound [23 kilograms] unmanned aircraft, that's only 2.5 to 10 pounds of payload. For a 10-pound UAV, that's half a pound to 2 pounds of payload. So a 2-pound detect-and-avoid system has a tremendous impact on those vehicles.

Other considerations are the required field of regard, all the azimuth and elevation angles that the sensor can view. Then, there's the field of view, where the sensor can see at any given instant. For a small unmanned aircraft operating at less than 400 feet, most of the air traffic would be above it. It would not need to look below for collision risk. For low altitude flight, it might need a bump on top of the aircraft that might look like a satellite communications antenna dish that you might see on a Predator or Global Hawk. But if the unmanned aircraft is flying at higher altitudes, it might need to look below itself as well. If it is a slow-moving unmanned aircraft, things may come at it from any orientation, including from behind. A fast-moving unmanned aircraft probably wants to look more in front. All these considerations dictate what the sensors need to see.

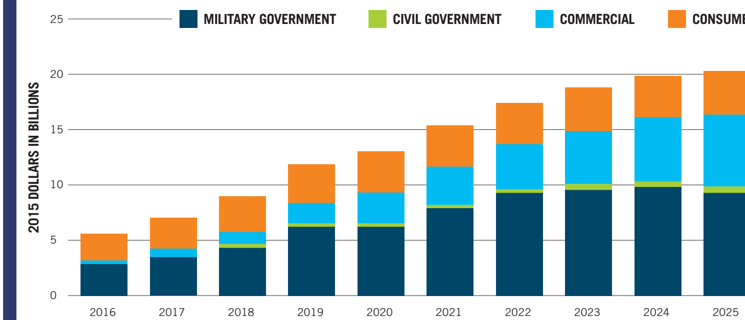
Another consideration is what kind of sensor the unmanned aircraft is operating. Is it RF-based or an optical sensor? If the sensor has line-of-sight obstructions from the wings, tails or fuselage, that can block where it can look. For a radar-based system, it might have some nonintuitive, non-line-of-sight interactions from the aircraft, especially if it is operating at low frequencies. There are a lot of competing requirements.

Some sensors may also be transponders, like ADS-B. The designer may have to consider frequency computability with other essential functions, such as the command-and-control link and the payload downlink. To a large extent, installing a detect-and-avoid system is not that much different than trying to install other payload types.

Q: Will every unmanned aircraft model need its own detect-and-avoid solution?

Gundlach: The detect-and-avoid system integration may be airframe-specific. For example, camera-based systems will need to provide a sufficient number of sensors with the correct positioning and orientation on the airframe to provide the necessary field of regard. The most convenient locations may be blocked by elements of the airframe, which may necessitate redesign. In contrast, an aircraft that is designed to accommodate a detect-and-avoid system upfront may avoid these difficulties.

MARKET FORECAST



Source: Teal Group

More than a quarter-million people are registered to operate unmanned aircraft in the United States, and analysts say military and commercial demand will grow exponentially in the next 10 years.

Analysts expect the global market for unmanned aircraft and small drones to surge past $20 billion in the next decade. They divide the market into four segments: military, with sophisticated aircraft and their ground control stations, including large planes such as Predators and Reapers; consumer; civil government, including federal, state and local agencies that fly everything from small Typhoon quadcopters to Predators for patrolling borders; and the commercial sector, which includes drones like the DJI Phantom with longer battery life and higher resolution cameras than most consumer drones.

"The commercial market segment is the most interesting because that's going to be the most dynamic over the next decade," says Philip Finnegan, corporate analysis director for the Teal Group, an aerospace and defense analysis and forecasting firm based in Fairfax, Virginia. "We see the worldwide commercial UAS market growing from about $387 million in 2016 to about $6.5 billion by 2025," as construction, energy, insurance and agriculture companies begin to prove that using UAS can save them money, Finnegan says.

In spite of that dramatic growth, the international military market will remain the largest even though it is not expected to increase as quickly as the commercial sector. "You see a proliferation of these systems," Finnegan says. "An increasing number of countries are seeking to emulate the success of the United States in using unmanned systems." The Teal Group also expects the U.S. military to purchase new UAS designed for combat.

▲ The FAA published rules in June 2016, known as Part 107, for drones weighing less than 55 pounds. They permit such aircraft to perform commercial jobs during the daytime at a maximum altitude of 400 feet and close enough for the operator to see it. The operator must pass an aeronautical test and receive an FAA remote pilot certificate. Firms can apply for FAA permission to waive the restrictions.

The most convenient locations may be blocked by elements of the airframe, which may necessitate redesign. In contrast, an aircraft that is designed to accommodate a detect-and-avoid system upfront may avoid these difficulties.

– Jay Gundlach, FlightHouse Engineering

Q: Is it better to think about detect-and-avoid capabilities as you design the aircraft?

Gundlach: Correct. Otherwise you can picture some of these sensors located remotely to the primary aircraft structure in order to get the required field of regard. Or having to locate multiple sensors to avoid obstructions, for example.

Q: As you develop and test detect-and-avoid technologies, are you focusing on size, weight and power?

Guterres: Size, weight and power are critical. Typically, you start with an existing UAS. The aircraft is a piece. You don't often have the flexibility to modify the aircraft to accommodate some piece of equipment. So, system weight and power requirements are critical. That often becomes a funnel for picking options. Then you integrate it, figuring out how it works and make the best of it. However, if there is a significant enough impetus, there may be cases where the aircraft is modified to accommodate a certain system onboard.

Small unmanned aircraft systems bring a lot of advantages: low cost, easy transportability, and flexibility as far as supply chain. It has not been our observation that people are moving to bigger systems to accommodate onboard technology. There is an expectation that the onboard technology has to get smaller, lighter and use less power.

If you start with an existing aircraft, you are pretty limited in what you can do. If you can modify the aircraft, you are a little bit more able to accommodate things. Still, you quickly bump up into a load factor. If you add 10 pounds to the payload, you are most likely going to add quite a few more pounds to the aircraft itself. Staying with small aircraft is a very important thing, in general, to the operators we come across.

Gundlach: Larger detect-and-avoid systems can also make a difference in overall risk. If we were to add detect-and-avoid systems to an unmanned aircraft, then to achieve a similar level of performance in terms of payload capacity and endurance, we would need a larger aircraft. Now that new aircraft is less likely to collide with other air traffic. However, the consequences if there was an impact would be greater because it's a heavier aircraft. Also, the risk to people on the ground may go up as well.

Generally, there is a trend toward unmanned aircraft going down in size, but depending on what the detect-and-avoid technology is, this could be a counterpressure that pushes toward larger and heavier aircraft.

Guterres: It's a very interesting double-edged sword. An airplane can be a little heavier and much, much safer because of the technology you put on it. There is a bit of a fine balance. ★

Tips from the FAA's drone pioneer

Jim Williams took over the FAA's Unmanned Aircraft Systems (UAS) Integration Office one month after Congress directed the agency to write rules to allow drones to fly in U.S. airspace within four years. Although many drone developers were frustrated by the slow pace of the FAA's regulatory process, people who worked closely with Williams give him credit for helping to draft regulations that have opened U.S. skies to hundreds of thousands of drones that weigh less than 55 pounds, flying within view of their operators and below 400 feet.

Jim Williams

- Principal at Dentons, a multinational law firm, where he advises clients on aviation technology, regulatory and compliance issues
- Spent 28 years at the FAA before retiring in June 2015

Q: A lot has happened in last year or two.
You can say that again.

Q: What has to happen to integrate unmanned aircraft into the national airspace?
I would argue they are already being integrated as we speak. FAA rules that came out last summer started the process. At low altitude, you have commercial and personal drones flying all the time. There have been a lot of reported sightings of drones where maybe they shouldn't be. That is, I think a little bit overblown, because pilots are notorious for not identifying objects very well. And I think a lot of the sightings will never be validated because there is no way to validate them. Drones don't show up on radar. But the good news is we have not had any reported collisions or any reported accidents where drones have caused serious injury or collisions with aircraft. That's the good news. Even with the proliferation, we are still maintaining an excellent safety record. So there is already integration happening at lower altitudes in uncontrolled airspace but more and more aircraft are being approved to fly near airports for commercial operations by the FAA. There's a whole bunch approved to fly at night. It's really moving forward.

Q: What has to happen for drones to operate beyond line of sight?
The big impediment there is that the aircraft are going to have to be approved. The initial rules the FAA came up with essentially mitigated any potential problems with the aircraft by restricting when and how they can be flown. The FAA's assumption is that at any point in time that aircraft could stop working and fall out of the sky, so you need to have operating rules that protect against that. As soon as you want to fly over people or you want to fly beyond visual line of sight, the FAA's position is the aircraft has to be approved. There are a whole bunch of ways to get the aircraft approved, but the bottom line at this point is the only ones that have been approved are some military surplus aircraft. Those were approved while I was at the FAA and they are still operating in various functions. They are very restricted to where they can go. In fact, their approval is called restricted category aircraft.

The big barrier that everybody is waiting to see is that first commercial aircraft approved. There's a company called AeroVironment that builds the Puma and the Raven and the Wasp for the militaries around the world. The FAA publicly announced they have agreed on a certification basis for their aircraft to get design approval. That was a huge step forward. Now it's up to the folks at AeroVironment to demonstrate they meet those rules they negotiated with the FAA. They are in the process of doing that. Once that happens, things are going to start to open up. It still remains to be seen what sort of limitations are going to be placed on that aircraft once it's approved. I assume it's going to be approved for flying over people and flying beyond visual line of sight, at least in remote areas. When that happens, I think you are really going to see applications.

Q: Like what?
There are thousands of miles of linear infrastructure, everything from rail lines to pipelines to power lines. Regulations require those to be inspected. You could do it with a Puma. Right now, a lot of them use rotorcraft to do that. The railroads actually use trucks with people in them on the rails to do their inspection. They have to shut the rail lines down while they are inspecting them. There seems to be a lot of interest and a lot of companies investigating it but until they get an approved aircraft, they can't get moving forward. That is the biggest impediment at this point. The initial standards that can be used to approve these aircraft are out there. Things are starting to fall into place. In the next couple of years, I think you will start to see beyond visual line-of-sight applications in remote areas.

Q: Are there technologies that still need to be developed, like sense and avoid?

Sense and avoid has been developed, demonstrated and approved. The problem is that the initial technology, like so many initial technologies, are fairly crude and very expensive. The one NASA demonstrated last year requires a pretty large aircraft because it uses military grade phased array radars to detect the aircraft in the environment and feed that information back to the pilot so they can avoid them. There are other technologies that are being explored and eventually they will be certified. This is typical of how the aviation industry works. Things are developed in the military and proven out in the military and they migrate their way into the civil market as the cost comes down and the availability comes up. That's the same situation we have with detect and avoid.

There are a lot of people out there experimenting with different solutions, everything from LIDAR [light detection and ranging] to acoustic sensors and stereoscopic visual. That's what Intel has demonstrated. They sent one of their quadcopter drones to a forest and told it to fly to the other side. It found its way through the forest without running into anything using stereoscopic vision. Then there's the radar solution the military and NASA developed. What is happening is the natural evolution of technology is going to take the need and turn it into systems that can be deployed on multiple size aircraft. The technology is proprietary so I don't know what it is but AeroVironment, as part of their certification, is going to have some form of detect and avoid on their aircraft. That is a key piece. The technology is there, but getting a system that can be approved by the FAA is really the next step.

Q: Is detect and avoid a better term than sense and avoid?

Detect and avoid is the term being used internationally in aviation.

Q: Are there issues with command links?

The real problem is not creating a link. It's creating a link the FAA would approve for beyond visual line of sight. The current crop of drones use bands that are available for public use. Like Wi-Fi. Both the 2.4 and 5 gigahertz signals that are out there are being used for the commercial off-the-shelf visual line-of- sight-type aircraft. The problem with those links is they are limited in range and the range is not deterministic. The way these systems work — since everyone is transmitting on the same frequency and there is no deconfliction of the signals — they all transit at once and try to rely on the fact that everything is a little bit different in distance apart and so therefore the signals arrive at different times. That works when there are not too many transmitters. But as soon as you get a stadium full of people or an outdoor concert and everyone has their cellphones on with their Wi-Fi transmitters going, all of the sudden that interference goes up. So your range will go down. That makes the range of the signals nondeterministic, which is something the FAA doesn't like. If you are going to depend on that link to help you avoid collisions, you have to depend on that link to the level that you would be able to assure that you would be able to avoid a collision if one arose as you were flying the aircraft. There are solutions cropping up out there that are not commercially available but will be shortly. There is some work going on in satellite and terrestrial systems, but they are not all out there and deployed yet. Again, that will depend upon you having a customer, people who invest in putting the systems out there to allow them to communicate. The technological solutions are resolved, but the implementations of the solutions and getting approval by the FAA are the challenges being worked on now.

> Unmanned aircraft "are already being integrated as we speak. FAA rules that came out last summer started the process. At low altitude, you have commercial and personal drones flying all the time. ... So there is already integration happening at lower altitudes in uncontrolled airspace but more and more aircraft are being approved to fly near airports for commercial operations by the FAA."

Q: It sounds like once things are developed and approved, it will take time for them to become small and inexpensive enough for widespread adoption.

Initially the approvals will be fairly conservative. They will be remote areas. They will be of limited duration. But as the experience grows and the systems mature, the FAA will expand the approvals. That's always the way it's gone with aviation in general. It used to be you couldn't fly over the ocean with only two engines. You had to be within 100 miles of an airport with only two engines. Now there are airplanes flying four or five hours from the nearest airport with only two engines. As the technologies are validated and demonstrated to the FAA, they get more and more permissive with the use of them. ★

Toward "a beautiful web of airplanes"

It would be hard to find anyone who has done more to begin integrating unmanned aircraft into the U.S. national airspace than Dallas Brooks. After an Air Force career that included a stint as the chief of unmanned aircraft systems integration policy, Brooks led a Pentagon task force that worked to ease restrictions on military UAS flights in the U.S. He's now director of Raspet Flight Research Laboratory, which specializes in unmanned and conventionally piloted flight testing and is an FAA UAS test site. Debra Werner spoke with Brooks about the challenge of integrating a wide range of UAS, from hand-launched 1.9 kilogram Ravens to 2,200 kilogram military Reapers, into U.S. airspace.

Dallas Brooks

- Director of Mississippi State's Raspet Flight Research Laboratory
- Co-chairs the UAS Scientific Research Panel, a group led by the FAA, Defense Department, NASA and the Department of Homeland Security to align UAS airspace integration science and research initiatives
- 26 years in U.S. Air Force
- Mississippi State leads the Alliance for System Safety of UAS through Research Excellence, or ASSURE, a group of 23 research institutions designated by the FAA as the country's UAS Center of Excellence

Q: How do you get your arms around a problem as large as integration of UAS of all sizes in the national airspace?

Introducing a new technology like UAS into an airspace system that has been predicated on a human pilot being in a cockpit for 100-plus years is a huge challenge. Virtually all of today's flight regulations levy the ultimate responsibility for safe flight upon that human pilot in the cockpit. In the case of UAS, that paradigm is turned on its head. The cockpit is no longer in the airplane and the pilot no longer directly sees out of the window. So we have to look at how we allocate duties and responsibilities in a way that keeps the rules appropriate and enforceable without necessarily reinventing everything.

Beyond the technical and regulatory integration challenges, there are some cultural and human challenges as well. When you are not sitting in the cockpit, are you as cognizant of the dangers? Are you as alert as you might otherwise be?

It is an extraordinarily large and complex problem set. Trying to treat it like a single problem is usually the way that you fail.

Q: How do you succeed?

One of the most successful approaches is to eat away at it a bite at a time. Divide it into component problems and determine what is achievable today in terms of finding compromises between current regulation, advanced aviation technology and new processes or procedures. To do that effectively, you have to truly understand the processes that drove the original regulations. Only then can we effectively look at how we can either modify UAS to meet those concepts or, when UAS can't be modified and there is substantial public benefit, then potentially look at revising some of those regulations to allow for those benefits to be realized. Not just because it's a UAS, but because the public truly sees a value and is rewarded by the operation of the UAS.

Q: What is that value?

There are so many aspects of unmanned systems that are tremendously beneficial. In some respects, UAS represent the future of aviation. UAS can put sensors in the air to accomplish scientific research, everything from analyzing crops to monitoring the environment to finding and repairing power line or pipeline problems. Because they can stay in the air far longer than a human pilot, UAS can search for lost people, track environmental disasters, or help contain extremely hazardous situations, such as radiation leaks. The benefits are tremendous, and that's before you even begin to assess the potential economic benefits.

Q: What are the component problems that need to be tackled?

Probably the most important one is the reliability of the system. Since there is no human pilot in the cockpit, the UAS has to be absolutely, fundamentally reliable to do what you expect it to do in the event of some malfunction or other off-nominal event. While we do our best as a government to regulate the design and construction of the systems that go into an aircraft, at the end of the day if the system breaks down and other systems break down, the fallback is the pilot's judgment and the pilot's actions. If everything else fails and your cockpit goes dark, and you cannot reach air traffic control, that human pilot takes over and uses his best judgment to navigate his way to a safe outcome. When you have an unmanned system in the air, and those same systems sometimes fail, even if they are built to the same level of reliability, then what happens? We can build aircraft to take over for the pilot and do very reliable things, such as auto-divert and auto-land, but our air traffic system must be set up to accept that.

Q: If the command link is lost, what do the UAS do?

One of the benefits of UAS is that should the aircraft lose contact with its control station, it does exactly what it is programmed to do. Human pilots don't always do that. In some cases, that programming is simple, in other cases, it can be very complex. The Air Force's Global Hawk is capable of executing a "decision tree" depending on a variety of factors such as location, altitude, et cetera. These contingency options might in some cases provide a divert path to an alternate airport, where the aircraft would automatically fly the published approach and land. Another option might be to alter course to a more remote location, away from other aircraft. But to execute such options safely and without disruption, our air traffic management system, including the pilots of other aircraft, must understand what to expect as well as the UAS pilot does. We're not there yet, but we're getting closer.

Q: How does the FAA's Next Generation Air Traffic Control System help or hinder UAS integration?

The devil is in the details with NextGen. I maintained in 2005, when NextGen was still being formed, that if you designed the system around the most highly automated aircraft — unmanned systems — that would unlock the highest efficiency. From there, you can back down the technology to accommodate less automated, less capable aircraft. But if you designed the system fundamentally around the same stick and rudder stuff that we've been doing for years, then it's going to be very tough to integrate new technologies. That argument fell on deaf ears for a number of years.

Q: Why would that approach make sense?

If you design the system to accept an aircraft that will take off, climb, level off, compute the most effective route corrections, negotiate those corrections directly with the air traffic system, make it all the way to its destination and taxi to its hangar, all with literally not a single radio call, then you've optimized what the air traffic system is capable of doing.

Q: That would all be done by transferring data?

Yes. When you think of what NextGen was going to provide, it was going to automate systems, and provide more efficient routing. Every aircraft, as opposed to following our current system of "roads in the sky," would compute the most efficient route. The computers that run the system would deconflict by time, altitude or other means to ensure that two aircraft would never cross the same place at the same time. We have that kind of computing power and reliability today. Quite frankly, the least reliable piece of that equation is the human pilot. Their skill levels vary. But with an automated system talking to an automated system in a way that both tie in directly and can adjust to each other, the efficiency goes through the ceiling. It becomes a beautiful interconnected web of airplanes going where they need to go when they need to go there.

> "Unmanned aircraft systems don't have eyeballs looking out of a cockpit saying, 'That's probably close enough.'"

Q: What insights are you drawing from the ASSURE research initiative?

The research being done by ASSURE is addressing the most critical questions that must be answered if we are to truly integrate UAS into the NAS. One example is assessing the severity of an impact between a UAS and a manned aircraft. For years, we assumed if there's an impact, it would automatically be assumed as catastrophic. If a UAS hits an airplane, we are going to assume that airplane is going to crash, period. That assumption makes it very tough for any UAS to pass certain safety thresholds for operating in dense flight environments.

But we know that a collision between a UAS and a manned aircraft isn't necessarily catastrophic — partially because it's happened. There was an incident overseas where an RQ-7 Shadow hit a C-130 and the C-130 landed safely. The Shadow is a 375-pound [170 kilogram] airplane, not a small UAS, so that was a serious incident — but it wasn't catastrophic. The question is, when does it become catastrophic? Under what conditions? What size or weight, what density, what relative airspeed, what angle of collision? We've never had the data, because true impact testing has never been done. While it's pretty easy to assume that below a certain weight or density the UAS might scratch the airplane or chop the propeller a little bit but the airplane is going to be OK, but we don't know for sure until we test it exhaustively.

Q: How do you gather that data? Do you crash UAS?

In some cases yes, but not with airplanes flying in the sky. We're doing extensive 3-D modeling, and following that up with actual test-firing of UAS components at various aircraft components to verify that our models are accurate. As you might expect, it's not the small plastic parts on the outside of a UAS that cause the damage. It's the dense pieces like the motor or the battery. As part of our research scheme, we are firing UAS motors and batteries into aircraft components like wing skins and engines to see what damage they might do. At what level of penetration would the skin begin to separate or rupture? At what velocities? At what densities? At what angles?

We're doing similar work to assess how harmful a UAS can be if it impacts a person on the ground. That's a very different thing, and the safety thresholds must be much, much higher. The UAS must be relatively small, slow, and light to ensure they won't harm an unprotected person. We're evaluating just how small, slow and light is enough. ★

OPINION

Sense and avoid for satellites

European Space Agency

▲ The debris field in this artist's rendering is based on actual density data. However, the sizes of the debris and satellites are exaggerated.

The conventional approach to avoiding collisions in space centers on estimating where satellites and debris will be relative to each other on subsequent orbits. Technologists are also working on concepts for removing dead satellites and spent rocket stages from orbit. Given the plans private companies have for launching thousands of satellites, these strategies may not suffice. Space expert Dave Finkleman says it's time to consider an alternative approach.

Given the scope of the space-debris problem and the small satellite revolution, technologists are considering active debris-removal options ranging from nets to sophisticated large object capture and deorbit devices. As innovative as these concepts are, there will soon be too many satellites to mitigate risk of collisions through this sweeping-sand-from-the-beach approach. This will be particularly true in low Earth orbit (below 2,000 kilometer maximum altitude).

More than 8,000 satellites in low Earth orbit are seriously planned soon, and the numbers are already growing fast. A significant milestone was reached in February when India launched the most satellites ever on a single launch vehicle, including 88 imaging satellites for the California company Planet. China announced intent to deploy even more with a single launch. No matter how well small satellites are designed, some will always fail in short order. As of March 2017, of the 685 nanosats (spacecraft weighing less than 10 kilograms) launched since the late 1990s, 405 remain in orbit, and only 321 remain operational, per the nanosatellite database maintained by Estonian satellite expert Erik Kuku. The rest are now debris. Lacking guidance and propulsion, many will remain in orbit for 25 years or longer.

An Indian Polar Satellite Launch Vehicle launched 104 satellites in February, an indication of the rapid increase in the number of satellites in low Earth orbit in the future.

The debris mitigation industry should consider alternatives to traditional strategies for reducing the risk of debris-causing collisions. Instead of trusting our ability to track objects from the ground and mathematically estimate possible conjunctions, manufacturers might equip their spacecraft for obstacle avoidance. Satellites might be able to sense and avoid dangerous encounters, returning to their operational trajectories autonomously with very little mass or volume impact. Research has demonstrated that the probability of a collision between two objects closing in on each other at kilometer-per-second relative velocities can be reduced to insignificance by imparting relatively little maneuvering energy on one of them. This maneuver would have to be executed only about one revolution ahead of the estimated time of closest approach. Arrival at this estimated closest approach would only need to be accelerated or delayed by milliseconds (or the estimated separation adjusted by meters) for the objects to miss each other. The greater the relative velocity, the easier it would be to mitigate risks of collision.

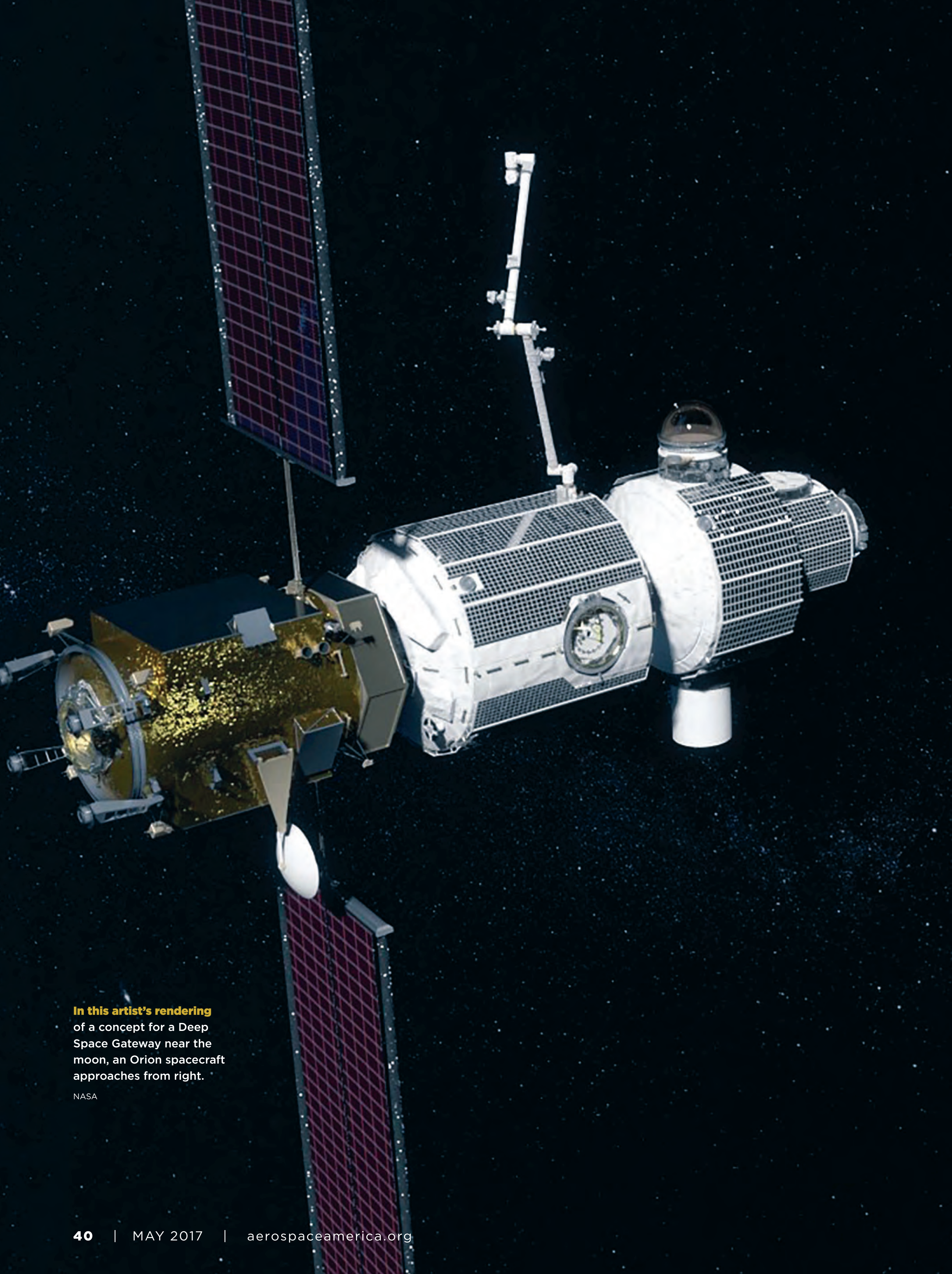
Sense and avoid technologies are mature. They are in practice for automobiles, unmanned aircraft, and on some ships. Even hobbyist quadcopters now sense and avoid obstacles autonomously. No doubt, there are issues of range and bandwidth, but similar difficulties were overcome in orbit 30 years ago in the U.S. Strategic Defense Initiative's Delta Star missile-tracking experiment.

Satellites will become so numerous that the launching country may not be able to meet its responsibilities within the 1972 Convention on International Liability for Damage Caused by Space Objects International Liability Convention. Even when a launch vehicle and satellites are privately owned, governments are responsible for the consequences of launches from their territories.

Another question is whether those who plan to establish these vast constellations would voluntarily agree to include obstacle avoidance and propulsion systems on their spacecraft. There are paradigms in maritime navigation. While there are command and control sites ashore, no one expects these sites alone to prevent collisions. It is up to the captain of the ship to maintain situational awareness of the locations of other vessels and avoid collisions with prescribed rules of engagement. Similar satellite rules of the road have been suggested.

We will likely never be able to track every active or threatening object in space, and certainly not with the precision required for timely and relatively assured maneuver. We need not and could not sweep all the sand off the beach or clear the passages of every dynamic obstacle. Onboard sense and avoid is feasible and arguably essential.★

Dave Finkleman is an AIAA Lifetime Fellow, a retired Air Force colonel and chief engineer of Sky Sentry LLC in Colorado. He is a former chief technical officer of the North American Regional Aerospace Defense Command, U.S. Space Command and U.S. Northern Command, and was the senior scientist at Analytical Graphics Inc. for 10 years. He has a Ph.D. in aeronautics and astronautics from MIT.



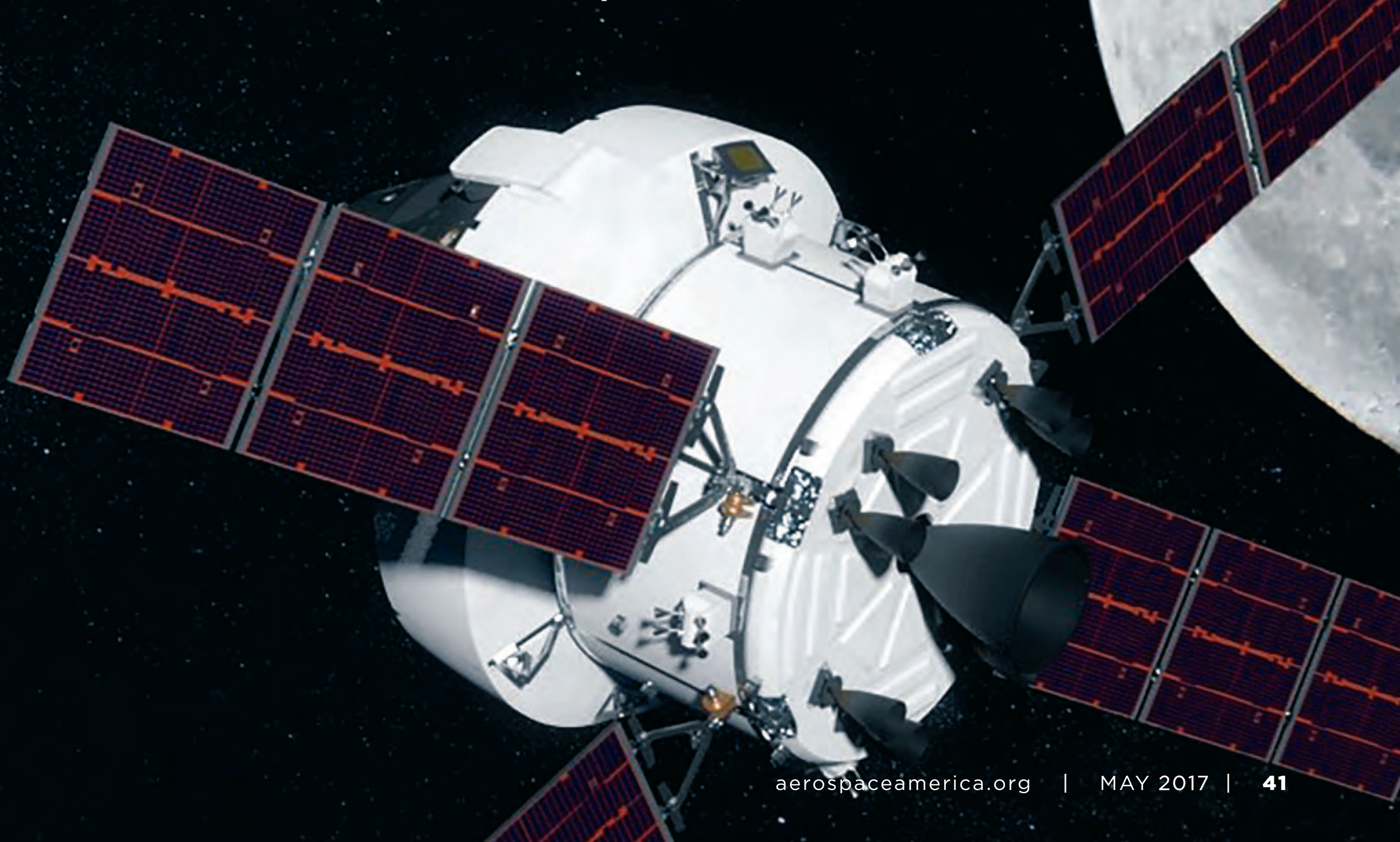
In this artist's rendering of a concept for a Deep Space Gateway near the moon, an Orion spacecraft approaches from right.

NASA

STRATEGIZING ABOUT MARS

BY TOM RISEN | tomr@aiaa.org

Little consensus exists among scientists and policymakers about the best strategy for getting humans into orbit around Mars and someday to the surface. The Trump administration and a re-established U.S. National Space Council are expected to take yet another look at a possible role for the moon in the Mars strategy. Tom Risen spoke to NASA's Bill Gerstenmaier, Mars exploration visionary Robert Zubrin and others about their views of the best path ahead.



The far side of the moon never faces Earth but it gets two weeks of sunlight during each of its synchronous rotations. This would give astronauts riding in one of NASA's forthcoming Orion capsules an opportunity to telerobotically pilot rovers on the surface while also proving the performance of equipment including communications, life support and other technology in anticipation of a voyage to Mars orbit. The crew, perhaps in the 2020s, could do all this with little propulsive energy by orbiting around a position 65,000 kilometers from the moon known as a Lagrange point, one of the gravitational sweet spots between planetary orbits, in this case between the gravity of Earth and the moon.

This was one of the visions proposed before the inauguration by then-President-elect Donald Trump's NASA transition team. For some space watchers, a mission like this or a proposal to swing astronauts around the moon in an Orion capsule as early as 2019 would be a stroke of genius. These bold steps could be taken relatively soon while still holding as the ultimate goal a journey to Mars orbit and eventually the surface. Others fear that putting astronauts in an Orion capsule on an untried Space Launch System rocket could be a deadly distraction and that any near-term focus on the moon could squander the funds needed to reach Mars during what they see as a unique window of American public interest in such a mission.

This is the tradeoff that the Trump administration must weigh in the months ahead as it puts its brand on NASA's human exploration strategy.

Conversations about whether the moon or Mars should be the first priority are not new for space policy experts. Similar debates played out fiercely during the George W. Bush and Obama administrations. For now, NASA's long-term goal remains nearly identical to the Obama administration's, which is to have humans depart on a mission to orbit Mars by the early 2030s.

It's fallen to NASA's Bill Gerstenmaier, associate administrator for human exploration and operations, to make peace between the camps.

"It's a false discussion to talk about destinations," says Gerstenmaier. "We are really moving human presence in the solar system." In his view, every mission or contract should be approached with the thought of how it would help NASA build deep space travel capability.

He wants NASA and its contractors to target the equipment that will be required no matter the destination. Current NASA thinking calls for setting up a Deep Space Gateway in lunar orbit, a spaceport that would be tended by crews who would arrive in Orion capsules and stay for up to 42 days to hone techniques and innovations for the trip to Mars. NASA aims to launch several pieces to assemble the gateway: a propellant bus so it could move to different orbits, followed by a habitat module, an airlock, and one or more logistics modules where astronauts could conduct scientific experiments. When completed, it would be smaller than the International Space Station. Eventually, one of the visiting crews would depart from the gateway toward Mars orbit inside a Deep Space Transport, a spacecraft propelled by chemical engines and solar electric propulsion that could be home to four astronauts for up to 1,000 days. NASA would launch the transport from Earth toward the gateway on a Space Launch System rocket.

Public-private cooperation

One point all seem to agree on is that private companies should play a far greater role in reaching Mars than they did in building and operating the space station. Jack Burns, an astrophysicist at University of Colorado who was a member of the NASA Trump transition team, suggests that companies including Blue Origin and SpaceX could sell cargo launches and other services to NASA. This way, the agency would not have to do these tasks on its own, which would free up resources for NASA to explore Mars or perhaps land humans on the moon again, something that was not in the Obama plan.

Some in the industry are eager for this larger role. United Launch Alliance, the joint venture of Boeing and Lockheed Martin that makes the Atlas and Delta rockets, in February hosted a workshop

Deep space strategy

Lagrange points are positions in the orbits of two large celestial bodies, such as the Earth and moon, where a smaller object can stay in a stable orbit while expending little fuel. The Trump administration is reviewing a proposal from its pre-inauguration NASA transition team to place an Orion capsule at Lunar Lagrange point 2, or LL2, where astronauts could stay in contact with Earth while remotely piloting rovers on the moon's surface. Space contractors have also discussed LL1 as a potential location for commercial projects like deep space manufacturing.

Source: NASA and Aerospace America research

to discuss potential commercial projects and infrastructure development in what ULA calls a CisLunar Marketplace. Representatives from universities, NASA and space contractors discussed potential projects, including solar energy collection, lunar prospecting and deep space manufacturing, says Burns, who attended. [Read more: "Toward a Cislunar Marketplace," Page 18]

Burns says work like this closer to Earth will be critical. "The American public is not going to wait 20 years to develop a pathway to Mars, their interest is going to wane," he cautions. "Developing space infrastructure around the moon gets us something tangible to show people we are on that track. The economics have changed in the last decade, so NASA doesn't have to do this all on its own."

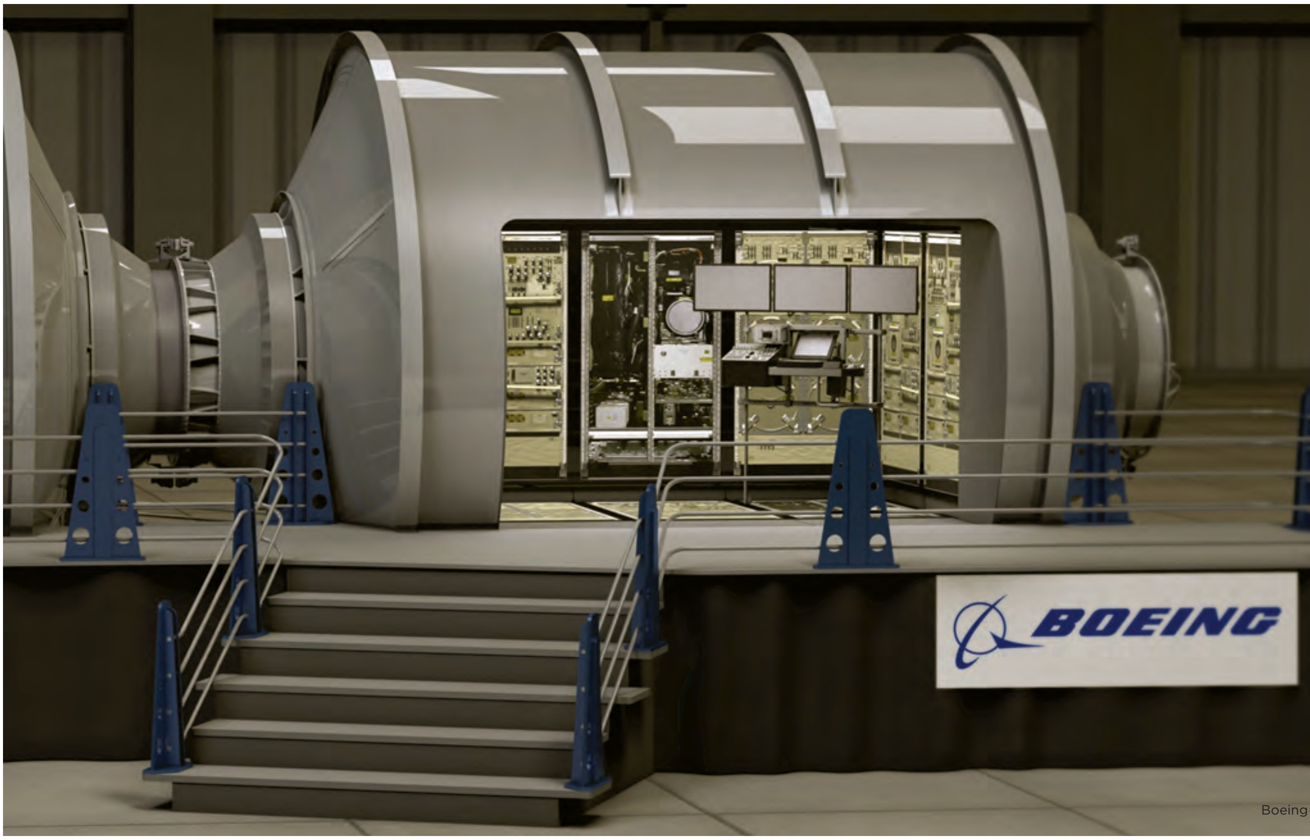
In 2013, Burns and his University of Colorado team set up a lunar surface obstacle course at NASA's Ames Research Center in California. Astronauts aboard the space station controlled a rover on the course to simulate steering it from lunar orbit.

Prudence

NASA expects to complete a study before June about whether to add a crew of two on Exploration Mission-1, which would be the first launch of a Space Launch System rocket. The current plan calls for launching an Orion loaded with instruments rather than a crew for a three-week round-trip mission that would include orbiting the moon for several days. The Trump administration and Acting NASA Administrator Robert Lightfoot asked NASA in February to look at the feasibility of a crew option.

Considerations include whether an initial flight without a crew could encourage more rigorous testing to include precision maneuvers, deep space navigation and heat shield tests. On the downside, in addition to the risks of putting a crew on the first launch of a new kind of rocket, crew safety preparations would push the launch to mid-2019.

As risky as it might sound, the crew option does have supporters. One of them is former astronaut Leroy Chiao, who commanded the space station in



▲ This is an artist's rendering of a ground prototype that Boeing is developing as part of NASA's program to test deep space habitats.

2004 and 2005, and is a member of the Human Exploration and Operations Committee of the NASA Advisory Council. He argues that the initial flight of the capsule and rocket around the moon would have little technical benefit besides a test run, so he advocates including a crew, if funding allows.

"It would have a much bigger impact on public opinion if we launched EM-1 with a crew on board because it would be the first time humans leave Earth's orbit since 1972," Chiao says.

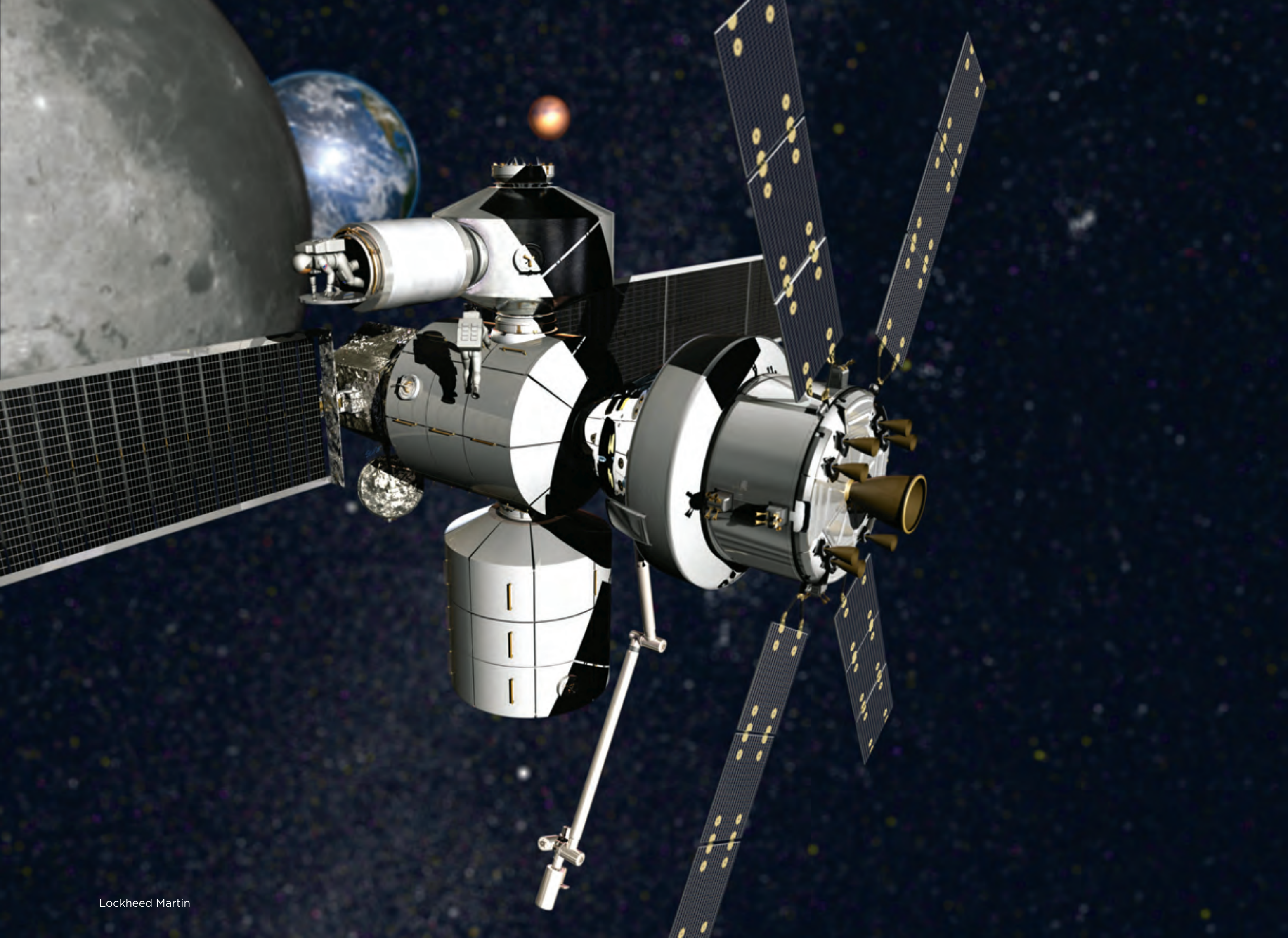
If NASA's timetable remains unchanged and humans are not sent on the first flight of the Space Launch System, astronauts will be launched on Exploration Mission-2 by 2023 to orbit the moon. After EM-2, NASA wants to launch an SLS and Orion with a crew and cargo to lunar orbit each year to begin building the gateway.

Prudence also figures into the broader discussion of a possible role for the moon on the way to Mars, a staggering 225 million kilometers away. If something went wrong with equipment that far from Earth, astronauts would be in a tough spot during the up-to-eight-month journey home. By contrast, if the Trump administration elected to land astronauts on the moon again, astronauts could return in three to five days in an emergency. At the moon, humans could test their on-site, or in-situ, resource utilization skills with less risk than trying them for the first time on Mars.

For some, the moon is an exciting place once again now that scientists are confident it holds water ice in the shade of at least some of its craters and might also have water beneath its surface. In 2009, NASA intentionally directed the Lunar Crater Observation and Sensing Satellite and a rocket stage to crash into a lunar crater. Scientists reported detecting water in the resulting plume. If NASA were to send astronauts to the surface, they and their robotic helpers could conduct a survey to identify a suitable location for a lunar base. A mining operation could be set up to create drinking water or rocket propellants, providing a supply line outside of Earth's orbit to support space travel.

The drawback to including the moon in the Mars plan would be that establishing a human presence on the surface would take years. The European Space Agency has expressed interest in building a lunar lander, but so far not NASA. Gerstenmaier says landing on the moon is "not necessary" for the journey to Mars despite the long-term potential of a base on the surface. An ideal lander would be reusable, but the difference in gravity between Mars and the moon would make it difficult to build one capable of safely landing on both worlds. It also would take time to design and build a durable lodging for astronauts with amenities like oxygen filters and heat on the airless moon.

"I would rather build the Deep Space Transport than go back to the surface of the moon," Gerstenmaier says.


Lockheed Martin

The Deep Space Transport, which NASA would launch from Earth in several pieces and dock with the gateway, would carry food, sanitation, exercise and science gear for a trip to Mars and back that could last up to three years. The transport, which could be reused for three missions to Mars, will likely include a combination of chemical propulsion and solar electric propulsion. Once completed in 2029, a crew of four astronauts would fly a test mission on the transport for up to 400 days near the moon.

To Mars or bust?

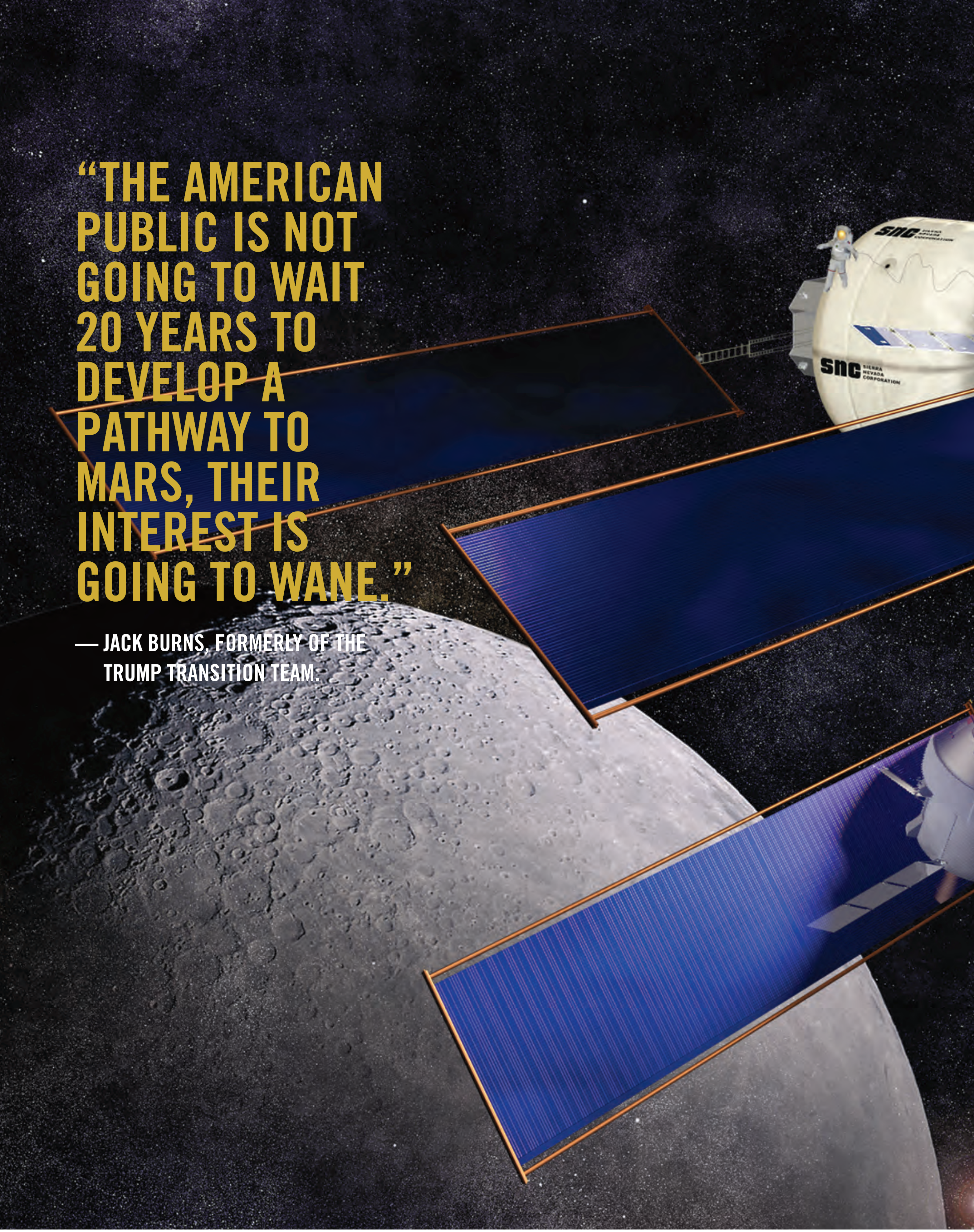
SpaceX CEO Elon Musk is among those who are impatient for a bigger commitment to travel to Mars, and he expressed his frustration in a Twitter post about Trump's proposed 2018 budget that would not increase NASA funding. "Perhaps there will be some future bill that makes a difference for Mars, but this is not it," Musk wrote.

Critics say the underlying problem with NASA's exploration strategy is that the agency has ordered construction of specific technologies, including Orion, and now it is trying to decide how to use them. Better, they say, would be to decide on a detailed exploration plan and develop the equipment needed for it. One of the critics is Robert Zubrin, president of the Mars Society, a nonprofit dedicated to furthering the exploration of the red planet.

"We do not need a lunar orbit base camp for any purpose other than to spend money on a lunar orbit base camp," Zubrin argues. "There is some interest in a return to the moon. I think this could work if the program was a parallel moon-Mars program."

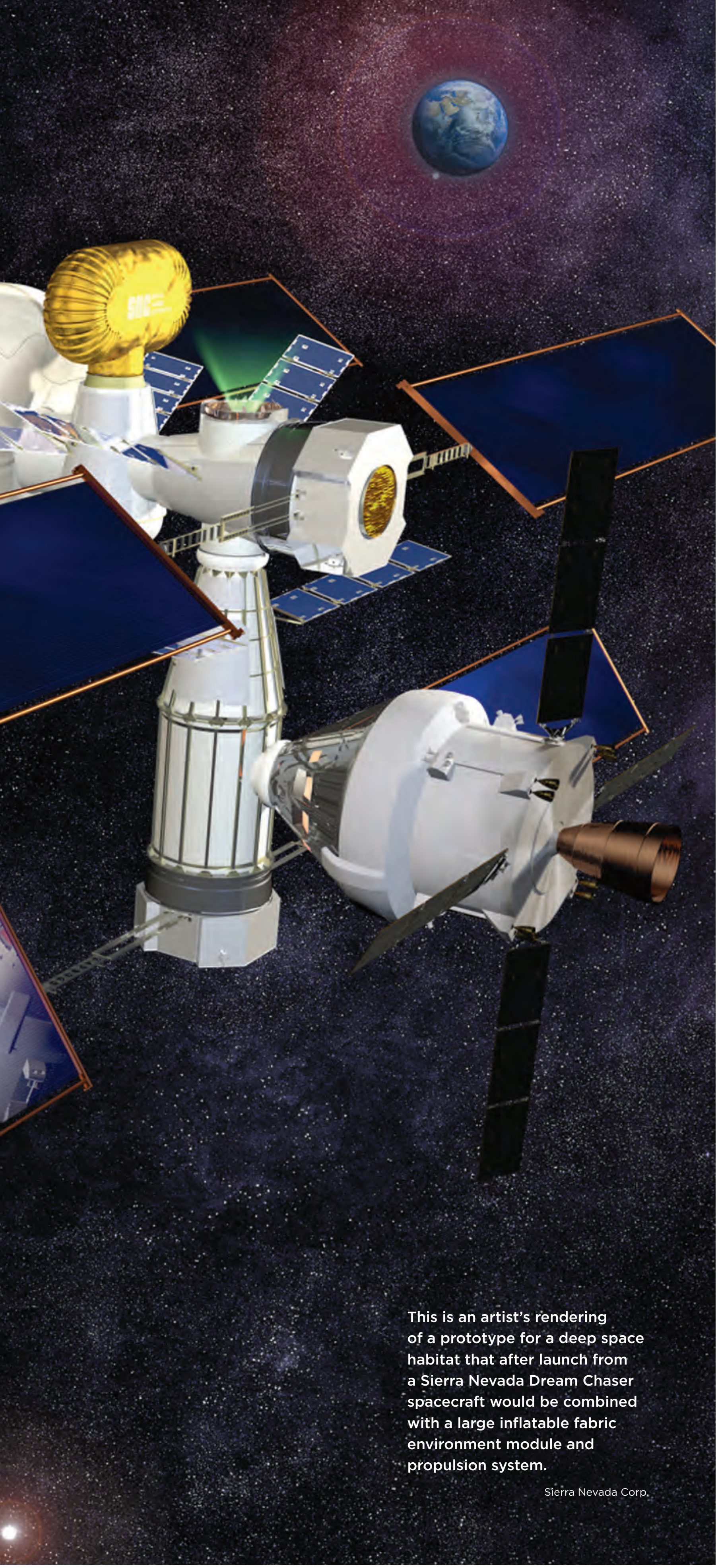
Returning humans to the moon's surface by 2020 as a proving ground for Mars was the goal of the Constellation program started in 2005 by the George W. Bush administration. Unlike the Space Launch System rockets that would launch crews and equipment into space, in the Constellation program NASA envisioned an Ares rocket that would launch only the Orion capsule. President Barack Obama in 2010 canceled Constellation, stating in his proposed budget for 2011 that the program was too costly, "behind schedule, and lacking in innovation." NASA was told to continue work on Orion and scrap Ares to begin work on the Space Launch System.

▲ Lockheed Martin plans to refurbish a multipurpose logistics module, seen in an artist's rendering, into a habitat prototype under NASA's Next Space Technologies for Exploration Partnerships, or NextSTEP.



"THE AMERICAN PUBLIC IS NOT GOING TO WAIT 20 YEARS TO DEVELOP A PATHWAY TO MARS, THEIR INTEREST IS GOING TO WANE."

— JACK BURNS, FORMERLY OF THE TRUMP TRANSITION TEAM.



This is an artist's rendering of a prototype for a deep space habitat that after launch from a Sierra Nevada Dream Chaser spacecraft would be combined with a large inflatable fabric environment module and propulsion system.

Sierra Nevada Corp.

Constellation is not the only example of how new presidencies can change space priorities. The Asteroid Redirect Mission could become the latest program to meet the chopping block. Trump's proposed 2018 budget would cut NASA's plan to move part of an asteroid closer to Earth so astronauts could study it. The plan has failed to gain broad enthusiasm among congressional Republicans and Democrats, some of whom have cited it as an example of a mission that distracts from the goal of reaching Mars.

Cutting red tape

The Trump administration thinks it can free up funds for Mars by improving the space bureaucracy's efficiency. That will be one role for Vice President Mike Pence and the National Space Council that he will chair. This executive branch board, created in 1958, has been defunct since 1993. The council had successes, including brainstorming the Kennedy administration's plan to send humans to the moon. Presidents eventually came to ignore it as another level of bureaucracy.

The Trump administration says things will be different under Pence. "The administration looks forward in the months ahead to further detailing the President's goals for the National Space Council, NASA and the private sector interests that are engaging in commercial spaceflight and expanding our understanding of the universe," says an email from Marc Lotter, press secretary for Pence.

Rep. Jim Bridenstine, R-Okla., considered the front-runner to be NASA's next administrator, discussed the council during a speech at the Washington Space Business Roundtable luncheon in March. He praised the council as a chance to make U.S. space business more competitive by streamlining contracting, and he cited China's ambition to send robotic rovers to the far side of the moon.

"You think of all the different stovepipes that exist already," Bridenstine said of federal space operations. "You can't figure out who is in charge of anything."

Gerstenmaier says the council would need to influence the budget process and policymaking of Congress and contractors to be significantly effective in assisting with NASA's deep space missions.

"We have enough people giving us guidance," Gerstenmaier says.

Political will for space travel is hard to maintain even during the best of times, so Gerstenmaier says inspiring people is not a sufficient reason to do a mission. Politicians during the 1960s debated ending the Apollo program before the first moon landing happened with Apollo 11, for instance, despite public interest in the space race with the Soviet Union.

Gerstenmaier often hears people say, "If we just had a compelling vision, this would all be sold." He disagrees: "I don't think that's the case." ★

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

Calendar

Notes About the Calendar

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2017			
3 May	AIAA Aerospace Spotlight Awards Gala	Washington, DC	
8–11 May†	AIAA/AUVSI Symposium on Civilian Applications of Unmanned Aircraft Systems	Dallas, TX (www.xponential.org)	
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 †	Dawn of Private Space Science Symposium 2017	New York, NY (Contact: www.privatespacescience2017.com)	
3–4 Jun	1st AIAA Geometry and Mesh Generation Workshop	Denver, CO	
3–4 Jun	3rd AIAA CFD High Lift Prediction Workshop	Denver, CO	
3–4 Jun	Optimal Design in Multidisciplinary Systems Course	Denver, CO	
3–4 Jun	Practical Methods for Aircraft and Rotorcraft Flight Control Design and Hands-On Training Using CONDUIT® Course	Denver, CO	
4 Jun	Seven Axioms of Good Engineering 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 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	Transformational Electric Flight Workshop & Expo 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)	
27–28 Jun†	Cognitive Communications for Aerospace Applications (CCAA) Workshop	Cleveland, OH (Contact: www.ieee.org/CCAA)	
8–9 Jul	Emerging Concepts in High Speed Air-Breathing Propulsion Course	Atlanta, GA	
8–9 Jul	Hybrid Rocket Propulsion	Atlanta, GA	
8–9 Jul	Liquid Rocket Engines: Fundamentals, Green Propellants, & Emerging Technologies Course	Atlanta, GA	
8–9 Jul	Missile Propulsion Design, Development, and System Engineering Course	Atlanta, GA	
8–9 Jul	Turbulence Modeling for Modern Industrial CFD Course	Atlanta, GA	
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

†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
20–24 Aug†	2017 AAS/AIAA Astrodynamics Specialist Conference	Stevenson, WA	24 Apr 17
22–24 Aug†	International Conference on Aerospace Science and Engineering (ICASE)	Islamabad, Pakistan (Contact: http://www.ist.edu.pk/icase)	
10–11 Sep	Decision Analysis Course	Orlando, FL	
11 Sep	Space Standards and Architectures Workshop	Orlando, FL	
12–14 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition)	Orlando, FL	23 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
16–19 Oct†	Joint 23rd Ka and Broadband Communications Conference and 35th International Communications Satellite Systems Conference (ICSSC)	Trieste, Italy (www.kaconf.org)	10 May 17
13–15 Nov†	1st International Academy of Astronautics (IAA) Conference on Space Situational Awareness	Orlando, FL (www.icssa2017.com)	
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 – 5th AIAA Spacecraft Structures Conference – 36th Wind Energy Symposium	Orlando, FL	12 Jun 17
22–25 Jan †	64th Annual Reliability & Maintainability Symposium (RAMS)	Reno, NV (Contact: http://www.rams.org)	
3–10 Mar †	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	
8–10 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum), Featuring: – AIAA Missile Sciences Conference – AIAA National Forum on Weapon System Effectivenss – AIAA Strategic and Tactical Missile Systems Conference	Laurel, MD	
28–30 May †	25th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru)	
28 May–1 Jun	SpaceOps 2018: 15th International Conference on Space Operations	Marseille, France (Contact: www.spaceops2018.org)	6 Jul 17
25–29 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – 24th AIAA/CEAS Aeroacoustics Conference – 34th AIAA Aerodynamic Measurement Technology and Ground Testing Conference – 36th AIAA Applied Aerodynamics Conference – AIAA Atmospheric Flight Mechanics Conference – 10th AIAA Atmospheric and Space Environments Conference – 18th AIAA Aviation Technology, Integration, and Operations Conference – AIAA Flight Testing Conference – 9th AIAA Flow Control Conference – 48th AIAA Fluid Dynamics Conference – 12th AIAA/ASME Joint Thermophysics and Heat Transfer Conference – AIAA Modeling and Simulation Technologies Conference – 19th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference – 49th Plasmadynamics and Lasers Conference	Atlanta, GA	
3–6 Jul †	ICNPAA-2018 - Mathematical Problems in Engineering, Aerospace and Sciences	Yerevan, Armenia (Contact: http://www.icnpaa.com)	

2017 Board of Trustees and Council of Directors Election Results

AIAA is pleased to announce the results of its 2017 Board of Trustees and Council of Directors election. The newly elected board and council members are:

- **President–Elect**
  John Langford, Aurora Flight Sciences Corporation
- **Director–Technical, Aircraft and Atmospheric Systems Group**
  Dimitri Mavris, Georgia Institute of Technology
- **Director–Technical, Engineering and Technology Management Group**
  Nancy Andersen, Johns Hopkins University Applied Physics Laboratory
- **Director–Technical, Space and Missiles Group**
  Mark Whorton, University of Tennessee Space Institute
- **Director–Region I**
  Steven Bauer, NASA Langley Research Center
- **Director–Region II**
  Kurt Polzin, NASA Marshall Space Flight Center

“I look forward to working with President-Elect John Langford, and the rest of the winners of this year’s AIAA Board of Trustees and Council of Directors election,” said AIAA President Jim Maser. “I congratulate each of them and am confident that they will represent the membership and the strategy of the Institute well.” The newly elected board and council members will begin their terms of office on May 2017.

2017 AIAA/ACC/AAAE Speas Award Presented in February

On 22 February, the AIAA/ACC/AAAE Jay Hollingsworth Speas Award was presented at the 2017 ACC/AAAE Airport Planning, Design and Contruction Symposium. Jaap van der Salm accepted the award on behalf of **Lodewijk van Nieuwenhuijze**, advisor, H+N+S Landscape Architectures, and **Frans Schenk**, project leader, Amsterdam Airport, Schiphol. van Nieuwenhuijze and Schenk were recognized for "vision, strategy, and development of the Buitenschot Land Art Park near Amsterdam's Schiphol Airport, which features a "labyrinth of noise-deflecting landscape architecture, land art, and innovative technology which protects the surrounding communities from noise pollution as well as providing breathtaking views and recreation green space." The artist Paul de Kort who executed several large-scale land art works in The Netherlands and abroad, collaborated with van Nieuwenhuijze for the spatial design.

Left to right: T. J. Schultz, president of the Airport Consultants Council; Jaap van der Salm, landscape architect, H+N+S Landscape Architects, and Dirk Speas.

AIAA Orange County Section Is Keeping Busy!

By Dr. Amir S. Gohardani, Chair-Elect, AIAA Orange County Section

Here are some recent activities from the AIAA Orange County (OC) Section.

STEM

The section is committed to supporting STEM outreach activities, many of which are spearheaded by Jann and Bob Koepke. The section has created a STEM education through rocketry program that has continued with the 2nd annual SPARC (Student Payload and Rocketry Challenge) as a follow-on to TARC (Team America Rocketry Challenge) to encourage students to do more complex projects. SPARC is open to 7th–12th grades and runs across the summer months. It places the emphasis on an electronic scientific or engineering payload as well as the rocket. Last year CanSats were added to the SPARC challenge. CanSats are an electronic payload where teams fit their payload and experiment into a 12-ounce soda can (their "Satellite") and the section provides launch services. SPARC not only inspires students and AIAA members, it also educates and inspires teachers and schools in regard to the value of STEM education and AIAA. Many activities of the OC Section's rocketry activities can be followed on: http://aiaaocrocketry.org.

Outreach and Collaboration with Other Societies

The AIAA OC Section consistently supports engineering endeavors with a specific focus on aerospace engineering. Three examples are presented.

- *Society of Women Engineers (SWE)*

To reach out to women engineers, Dr. Amir S. Gohardani, Section Chair-Elect, gave a presentation at the Society of Women Engineers' (SWE's) Sonora Region Conference (9–12 February) on "Overcoming Challenges against All Odds," addressing various challenges and the hurdles that girls and women face in the aerospace sector and tools that can help in facing these challenges.

- *Orange County Engineering Council (OCEC)*

Dr. Gohardani served as a panel member on the Leaders' Forum presented by the OCEC on 12 October to address potential opportunities in Aerospace, Biomedical, Civil, Electrical/Electronic, Energy and Mechanical Engineering; and to explore related collaboration avenues within Southern California for local companies, universities, professional societies, government agencies, and the OCEC.

Springs of Dreams Corporation (SODC)

The Orange County Section also collaborates with the Springs of Dreams Corporation, a non-profit organization dedicated to enlightening society and enriching human lives through knowledge and education. The SODC sponsors the Gohardani Presentation in Aeronautics and Aerospace during the AIAA OC Section's annual ASAT Conference.

ASAT 2017

The section is excited about the upcoming ASAT 2017. The conference will bring together seasoned and new engineers, researchers, leaders, managers, academia, and students and provide a forum to exchange new ideas, review achievements, and chart a new course for aerospace in the area. This year we look forward to hearing about "Beyond the Black Box," "Preparing for the Final Mission of Space Shuttle Endeavour," and "Perspectives from Saturn." More details about the conference, led by conference chairs Dino Roman and John Rose, can be found at: https://info.aiaa.org/Regions/Western/Orange_County/default.aspx.

Congressional Visits Day — Educating Lawmakers About Aerospace

AIAA's 20th Congressional Visits Day (CVD) program was held on 29 March. CVD offers professional and student members an experience that opens their eyes to the inner workings of the legislative process, enhances their career development, and presents the opportunity to be a champion for the aerospace community. This year 123 members representing 29 different states attended the event. A majority of the participants were students and young professionals. The attendees, who were divided into state teams, visited approximately 222 congressional offices to help promote the Institute's key issues and raise awareness of the long-term value that science, engineering, and technology bring to the nation. A reception was held on the Hill that evening where Congressman Derek Kilmer (D-WA) provided remarks to the participants.


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1 Team Alabama with staff from Senator Richard Shelby's (R-AL) office. **2** Team Delaware. **3** Post-CVD reception. **4** Team Arizona speaking with Senator Ted Cruz (R-TX). **5** Team Virginia with Congressman Don Beyer (D-VA). **6** Congressman Kilmer speaking at the reception. **7** Team Louisiana with Congressman Ralph Abraham (R-LA). **8** Team Michigan. **9** Team Maryland and Team Delaware with Senator Chris Van Hollen (D-MD). **10** Team South Carolina with Congressman Mark Sanford (R-SC). **11** Team Arizona with Senator Jeff Flake (R-AZ).


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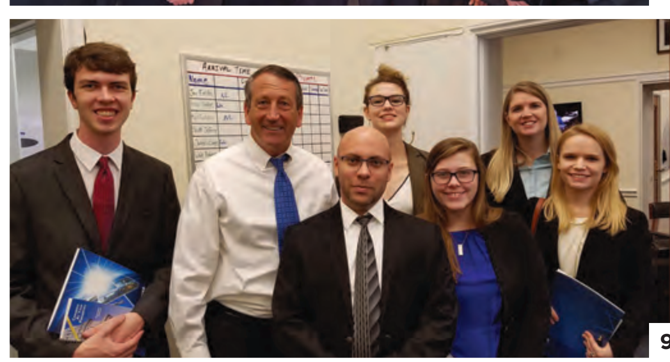
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Left: The Warwick Middle School Future City Team. **Right:** NCS judges Bernie Collins and Sri Ayyalasomayajula. (Photographs by Bruce Cranford)

National Capital Section Presents Future City Special Award

By Bruce Cranford

From 19 to 21 February, regional Future City winners from 43 middle schools nationwide, Canada, Egypt and China participated in the Future City National Finals in Washington, DC. Regional winning teams received an all-expense-paid trip to the National Finals.

Future City, in its 25th year, asks middle school students to create cities of the future, first on a computer and then in large tabletop models. Working in teams with a teacher and volunteer engineer mentor, students create their cities using the SimCity 3000 TM video game donated to all participating schools by Electronic Arts, Inc. of Redwood City, CA. They write an abstract and an essay on using engineering to solve an important social issue. Then they present and defend their cities before engineer judges at the competition. More than 40,000 students from more than 1,350 schools participated in 2016–2017.

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

As part of the Future City's program, the AIAA National Capital Section (NCS) presented a Special Award for the Best Use of Aerospace Technology to the team from Warwick Middle School (Future City Region: Pennsylvania Central, Future City Name: Pompeii, student team members: Gavin Troop, Shaddy Makhlouf, Amber Houser, Adam Ciampaglia, Maxwell Davis, Aaron Dickinson, Nolan Rucci, Bobby Schroeder, Katy Kramer, Lauren Reinhart, Ben DuBosq, Ethan Enteria, Katie Jeanes, Christian Kegel, Theo Lance, Will Wickenheiser, Kendall Morgan, Alexa Wenger, Educator: Michael Smith, and engineering mentor: Michael Makhlouf). The AIAA NCS congratulates the team for their outstanding efforts in winning this award.

Martin Frederick, NCS chair, and Bruce Cranford presented the award on 21 February. The award consisted of a savings bond for each student team member, and a plaque highlighting the award for each member of the team. The AIAA NCS also wishes to thank the NCS judges for the Best Use of Aerospace Engineering: Sri Ayyalasomayajula, (Research Scientist at Intelligent Automation, Inc.) and Bernie Collins.

For more information and a list of all the winners, visit http://www.futurecity.org.

News

The AIAA Clarkson University Student Branch recently welcomed AIAA Distinguished Lecturer Dr. Paul Bevilaqua. Several hundred students attended Dr. Bevilaqua's lecture on "Inventing the Joint Strike Fighter." After the lecture, senior class members and several professors joined Dr. Bevilaqua for dinner at the Clarkson Alumni Club.

News

AIAA Sections Organize a Drone Race

The AIAA Northern New Jersey, Southern New Jersey, and Greater Philadelphia Sections planned and coordinated a drone race event and display at the 2017 New Jersey Wing/Northeast Region Combined Conference for the Civil Air Patrol in Atlantic City, NJ, on 11 March.

The conference had 125 cadets and 350 attendees. In addition to the display, the team setup two practice tracks and two race tracks, approximately 10'x10' with archways for the participants to fly the supplied mini-drone.

There were 44 participants in the official races, and many more participants that practiced but did not participate in the official races. There were three 50-minute sessions, and the top two race times were awarded a free drone. The winners had times between 9 and 17 seconds.

News

Introduce a Girl to Engineering Day

AIAA Northern New Jersey Section

On 23 February, the AIAA Northern New Jersey Section (AIAA NNJ) hosted a booth at the Introduce a Girl to Engineering event held at Picatinny Arsenal, NJ. This is the event's fifth year and AIAA-NNJ has been a part of this event every year. There were over 70 students (over 150 attendees) from 23 schools in eight counties in Northern New Jersey. The AIAA-NNJ had a table display, engineers who engaged in conversations with the students and mini-drones for students to demonstrate their ability to land on a target.

AIAA University of Texas (UT) at Austin Student Branch

Every year, the AIAA UT Austin Student Branch hosts an activity for UT's Introduce a Girl to Engineering Day. The purpose is to engage young elementary and middle school level students in hands-on activities that can teach them valuable lessons in basic engineering concepts. The students get to participate in activities from over 150 student organizations, learning basic applications of STEM topics as well as problem solving skills. The main emphasis is for the kids to have fun and have a positive opinion of the engineering field.

To allow more creativity in the student designs, AIAA opted for straw planes, basically a straw with a thin loop of paper at each end. While we had a few example designs, we encouraged the students to try something outside of the box. Through this activity, the students were able to build and fly their own straw plane through some target hoops, and also get a cursory overview of simple aerodynamics. The most important takeaway was the trial-and-error design process for kids who went back and forth between the design table and flight testing. While simple, it was a great way to expose them to some important aspects of engineering.

Left: Section members & students in front of General Chappie James' F-4 at Tuskegee University. **Right:** Section Vice Chair Dr. Naveen Vetcha presents the section coin to Tuskegee University Student Branch Vice Chair Jessica Dedeaux.

Greater Huntsville Section Commemorates Black History Month

by Ken Philippart

The Greater Huntsville Section commemorated Black History Month 2017 throughout February with a full slate of activities to honor the contributions of African-American citizens to our nation and profession. Section Chair Brandon Stiltner stated that the month was "a time to celebrate the achievements of our African American colleagues, forebears and fellow citizens and their indispensable contributions to our institute, industry and nation." The events included a Section viewing of the movie Hidden Figures, a presentation on the Tuskegee Airman, promotion of the Southern Museum of Flight's student art contest honoring the first African American military pilot, a meeting of the section book club to discuss Hidden Figures, and a section trip to Tuskegee to tour the Tuskegee Airman National Historic Site, Tuskegee University, Booker T. Washington's house and to visit with the section's Tuskegee University Student Branch.

There was a great turnout for the viewing of Hidden Figures on 7 February with sixteen section members and guests attending. This was followed on 14 February by the Section's monthly lecture luncheon featuring NASA Marshall Space Flight Center's Don Harris. Mr. Harris' talk, "The Tuskegee Airmen and Me: Their Impact on My Life," provided a brief history of the Tuskegee Airmen. The attendees included fellow professionals from the North Alabama Chapter of the National Society of Black Engineers. Mr. Harris spoke about how individual Tuskegee Airmen guided him and served as role models from his high school in Detroit to earning his degree at Tuskegee University to his career as an engineer at NASA.

On 25 February, members of the Section visited Tuskegee, where they met with 18 AIAA Tuskegee University Student Branch members for a full day of tours and networking. The group visited the Tuskegee Airmen National Historic Site at Moton Field, and toured the museum and the flying field where Tuskegee Airmen trained. This was followed by a tour of Tuskegee University given by AIAA Tuskegee Student Branch Vice President and Tuskegee Ambassador Jessica Dedeaux.

The group was also given a tour of the Aerospace Engineering Department's facilities, followed by a presentation by student branch members on their branch's activities. The presentation conveyed the students' enthusiasm and commitment to engineering.

Finally, the section capped its Black History Month activities with a meeting of the Greater Huntsville Section Book Club for an in-depth discussion of the best-selling book Hidden Figures by Margot Lee Shetterly.

Obituaries

AIAA Fellow Thibodaux Died in April 2016

Joseph G. Thibodaux Jr. died on 26 April 2016. Mr. Thibodaux received a Bachelor of Science in Chemical Engineering from Louisiana State University (LSU) in 1942. Upon graduation, he served as an Officer in the Army Corps of Engineers and was stationed in Burma during World War II, where he played a role in the construction of the Ledo and Burma Roads.

After the war, Thibodaux began his career as an Aeronautical Research Scientist in the Pilotless Aircraft Research Division for the National Advisory Committee for Aeronautics. In 1964, he moved to Houston, TX, where he assumed the role of Chief of the Propulsion and Power Division at the Johnson Space Center until his retirement in 1980.

Thibodaux held five patents on solid rockets and solid rocket manufacturing techniques. He specialized in the fields of vehicle propulsion, liquid rockets, thermal protection, high temperature materials, meteoroid and impact phenomena, thermal arc technology, flight test technology and pyrotechnics. He received many accolades, including the Wyld Propulsion Award in 1970, the Presidential Medal of Freedom and induction into the LSU Engineering Hall of Distinction in 2005.

AIAA Associate Fellow Pollard Died in November 2016

Colonel Ben Pollard died on 11 November 2016. He graduated with a degree in engineering from Purdue University and was commissioned a 2nd lieutenant before completing flight training in 1956. He was an Interceptor Weapons Instructor before receiving an Air Force Institute of Technology assignment to Purdue University to complete his Master's Degree in Mechanical Engineering. He then served as an instructor at the U.S. Air Force Academy (June 1961–August 1966).

Maj. Pollard completed F-105 Thunderchief Combat Crew Training and was assigned to the 13th Tactical Fighter Squadron in February 1967. He was forced to eject over North Vietnam on 15 May 1967, and was taken as a Prisoner of War. After spending 2,120 days in captivity, he was released during Operation Homecoming on 4 March 1973. Col. Pollard returned to the Air Force Academy as an aeronautical engineering instructor in August 1973, later becoming the Deputy Commandant of Military Instruction and the Commander of the Air Force Academy Preparatory School before retiring from the Air Force in 1981.

After leaving the Air Force, Pollard served as vice president of STARNET Corporation, as well as president of the NAMPOW Vietnam POW organization. He received the Distinguished Engineering Award from Purdue University in 1979 and was the recipient of an Honorary Ph.D. in 2012 from Purdue University. During his Air Force career, he also received two Silver Stars, two Legions of Merits, two Bronze Star Medals with the "V" Device to signify combat heroism, and two Purple Hearts. He also received the 1974 AIAA J. Leland Atwood Award.

AIAA Associate Fellow Holtz Died November 2016

Tobenette (Toby) Holtz died 25 November 2016 at the age of 86. She had been a member of AIAA for over 60 years.

Dr. Holtz earned her Bachelor of Science degree in Aeronautical Engineering from Wayne State University (1958), her Master of Science degree in Aeronautical/Astronautical Engineering from Ohio State University (1964), and her Doctor of Philosophy degree from the University Southern California, Los Angeles (1974).

Dr. Holtz retired as a manager from TRW in 2000. During her, she was responsible for research and development of ICBM reentry systems and hypersonics, including ground test simulation and flight test. Previously she was a project engineer and staff engineer at The Aerospace Corporation, the Acurex Corporation, McDonnell Douglas Corporation, Northrop Corporation, and at North American Aviation where she started her career in 1954.

She served on the AIAA Orange County Council for many years and received a Special Service Citation award from the Council in 2014 for extensive contributions and leadership of the Council activities. At the AIAA national level, she served as a technical committee member (on the Weapon System Effectiveness and Ground Testing Technical Committees) and an organizer of national conferences. Dr. Holtz received the AIAA Distinguished Service award in 1983.

AIAA Associate Fellow Layton Died in February

Professor Emeritus Donald M. (Red) Layton died on 26 February. He attended Wooster (Ohio) College and The Ohio State University prior to entering the U.S. Naval Academy where he graduated in 1945. His 23 years of service as a naval officer included the command of two ships and 20 years as a naval aviator qualified in single and multi-engine and sea planes. He earned a Bachelor of Science degree from the Naval Postgraduate School (NPS), a Master of Science in Aeronautics from Princeton University, and a Master of Science Degree in Management from NPS. He received his doctor of science degree from Canterbury University of South Africa. He was the first director of the Navy Safety School in Monterey.

Professor Layton retired from active duty in 1968, and accepted an appointment as an associate professor at the Naval Postgraduate School. He was later promoted to full professor and served three years as acting head of the Aeronautics Department. During his teaching career he received the Carl Mennecken Award of the Society of Sigma Xi for his research on Surface Effect Ships and was named Safety Educator of the Year by the

System Safety Society. He retired in 1988 to teach overseas with the National Test Pilot School in South Africa, Taiwan, and Australia. He also taught for five terms in the Graduate School in Stellenbosch, South Africa. In 2006, he was named a Distinguished Alumni of the Naval Postgraduate School.

Professor Layton was the author of nine textbooks and numerous papers on airships, helicopters and system safety. He also conducted a course on Helicopter Conceptual Design for AIAA in 1991–1992.

Layton was a founder member of the AIAA Point Lobos Section and a member of the Lighter-Than-Air Technical Committee. As well as being a member of both the System Safety and Effectiveness and the Marine Vehicles Technical Committees, he also served as editor-in-chief of the *Journal of Hydronautics* and was an associate editor of the *Journal of Aircraft*. He served as a general chair, technical chair, and session chair for several AIAA meetings as well as presenting numerous papers at these meetings.

Honorary Fellow Mar Died in March

James W. Mar, a former of the Department of Aeronautics and Astronautics (AeroAstro) at the Massachusetts Institute of Technology (MIT), passed away on 4 March. He was 96.

Mar received his B.S., M.S., and Sc.D. from MIT, all in civil engineering, in 1941, 1947, and 1949, respectively. Between 1941 and 1944, he was employed by Curtiss-Wright as an aeronautical engineer. He served in the U.S. Navy from 1944 until 1946.

Mar's MIT career spanned 41 years. He was head of the AeroAstro department from 1981 to 1983. He retired in July 1990 as MIT's Jerome C. Hunsaker Professor of Aerospace Education.

Mar's research focused on advanced filamentary composite materials and large structures in space. He headed the AeroAstro Division of Structures, Materials, and Aeroelasticity. Mar founded and directed both the Technology Laboratory for Advanced Composites, and, with Professor Rene Miller, the Space Systems Laboratory. Mar was instrumental in creating the Unified Engineering subjects, which formed the foundation of AeroAstro's undergraduate education.

Following his retirement, Mar served as a member of NASA's Space Systems and Technology Advisory Committee and the Air Force Studies Board, and chaired the FAA's Technical Oversight Group for Aging Aircraft.

Mar also took part in advisory assignments that examined development of Air Force and Navy jet engines, and the operation of the Air Force Logistic Command and the Military Airlift Command. Between 1970 and 1972, he served as the U.S. Air Force Chief Scientist. He chaired a committee reporting to the NASA Associate Administrator Office of Space Flight on the design of the graphite/epoxy filament-wound solid rocket motor, and was vice-chairman of the National Academy of Engineering panel that provided oversight of the Space Shuttle's solid rocket booster redesign following the 1986 Challenger disaster.

In 1987, he received the Structures, Structural Dynamics, and Materials Award.

UNITED STATES OFFICE OF NAVAL RESEARCH

Aerospace Engineer, Aerodynamics

The Office of Naval Research is seeking exceptional candidates for the position of Program Officer for Aerospace Engineering in the Air Warfare & Weapons Department (ONR 35), with expertise in Aerodynamics. The successful candidate will initiate, manage, and coordinate sponsored basic research, applied research, and advanced technology development programs that are essential to the Department of the Navy (DON) in the areas low-speed, high-speed, and hypersonic aerodynamics. This person must possess a detailed and advanced knowledge of theory, analysis, and modern experimental and computational methods in aerodynamics and fluid mechanics, along with an understanding of air-vehicle and missile design, development, and ship suitability. High lift devices, unsteady aerodynamics, and flow control are major thrust areas in the portfolio. The portfolio includes fixed-wing and rotary-wing aircraft as well as missiles. An advanced degree, particularly an earned doctorate in Aerospace or Mechanical Engineering, is preferred along with a background in research and development and program management experience. Must have or be eligible for a Top Secret Clearance.

Send an application letter and curriculum vitae to **Knox Millsaps** at knox.millsaps@navy.mil. For more information see: https://www.usajobs.gov/GetJob/PrintPreview/458594200. The job location is in Arlington, VA and the salary range is $110,240 to $161,900. The grade is NP-04, in the 0861 series, with Direct Hire Authority.

THE UNIVERSITY OF ARIZONA®

Postdoctoral Position

Department of Aerospace and Mechanical Engineering

The University of Arizona
Tucson, Arizona

The Department of Aerospace and Mechanical Engineering at The University of Arizona is accepting applications for a Postdoctoral Research Associate I to join its team of researchers under the direct supervision of Dr. Anatoli Tumin.

This position will lead a research effort in analysis of hydrodynamic stability of high-speed boundary layers. Additional duties will include advising graduate students and assisting with writing proposals.

Applicants must have a Ph.D. in Aerospace Engineering, Applied Mathematics or related field. Applicants with a Ph. D. degree in Applied Mathematics should demonstrate an experience in fluid dynamics (experience in compressible fluid dynamics is preferable) and applicants with a Ph.D. in Aerospace Engineering should have solid skills in Applied Mathematics. An understanding of high-temperature gas dynamics is preferable.

Review of applications is ongoing and will continue until the position is filled. Interested applicants should consult the university website URL: https://uacareers.com/postings/17179 then follow instructions to make a formal application for this position.

1917

May 7 German bombers start night bombing of London. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 6.

May 9 U.S. Navy Lt. Patrick Bellinger makes the first night seaplane flight, at Pensacola, Florida, and begins the Navy's first instruction in night flying. In this year he also conducts the first machine gun fire from a seaplane. Among Bellinger's previous accomplishments were the first Navy live bombing tests from a plane, spotting battleship gunfire by plane, and radioing from a seaplane. **New York Times**, June 1, 1962, p. 28.

May 22 Italy originates the first official airmail stamps for its inaugural airmail service between Rome and Turin. The stamps are standard 25 centesimi express letter stamps with overprints denoting the special service. Typically, airmail letters contain a postmark with a silhouette of an airplane flying over mountains. There are also privately printed airmail stamps. In the U.S., the first official airmail stamps, of 24-cent denomination, are issued May 15, 1918, and first used on the New York-Washington route. A single sheet of this stamp is mistakenly printed with the biplane upside down and becomes prized among collectors. **Flight**, March 25, 1920, p. 344.

May 24 Now that the United States has entered the war, the French government strongly requests that America deliver 5,000 pilots and 4,500 aircraft before spring 1918. The ambitious goal is not met. A. van Hoorebeeck, **La Conquete de L'Air**, p. 123.

1942

May 6 The Curtiss P-40F, the first American aircraft equipped with a British-designed, Packard-built Rolls-Royce Merlin engine, flies a demonstration for the first time. **The Aeroplane**, May 15, 1942, p. 550.

May 7-8 U.S. and Japanese forces fight the battle of the Coral Sea, which involves American carrier-based dive bombers and torpedo planes. It is the first naval engagement in which personnel on opposing ships do not see each other because carrier-based planes do all the fighting. The Japanese lose two carriers and other ships, about 100 planes and 3,500 men, which stops their advance to Australia. America loses the aircraft carrier Lexington (seen here) and other vessels, 65 planes and 540 men. David Baker, **Flight and Flying: A Chronology**, p. 273.

May 12 All American Aviation, known for collecting and delivering cargo by air, celebrates its third anniversary. All American has made almost 100,000 pickups and deliveries since its creation and transported 375,762 pounds of mail. **American Aviation**, May 15, 1942, p. 16.

May 15 As an emergency measure, the U.S. military requisitions about half of all U.S. airliners and curtails all but essential routes and schedules, as well as claiming early priority on travel space and mail service. **Aviation**, June 1942, p. 221.

May 26 A Brewster F2A-3 aircraft makes a jet-assisted takeoff with five standard British anti-aircraft rockets at Naval Air Station Anacostia in Washington, D.C. Cmdr. C. Fink Fisher is the pilot. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 43.

May 26 Northrop's XP-61 "Black Widow" prototype aircraft makes its first flight. It is the first U.S. Army Air Forces night fighter designed to carry radar and begins flying in the Pacific theater in 1944. David Baker, **Flight and Flying: A Chronology**, p. 273.

May 28 Lord Brabazon delivers the prestigious annual Wright Memorial Lecture to the Royal Aeronautical Society in London. He talks about postwar control of civil flying and recommends that the United Nations control civil flying under the protection of an Allied Air Police Force. **The Aeroplane**, June 6, 1942, p. 629.

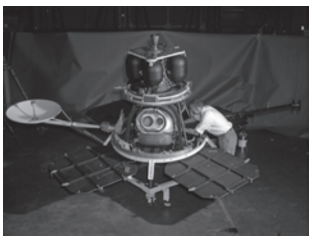
May 30-31 The Royal Air Force makes the first air raid using 1,000 or more aircraft, against industrial targets at Cologne, Germany. About 60 percent of the planes are Vickers Wellingtons. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 43.

1967

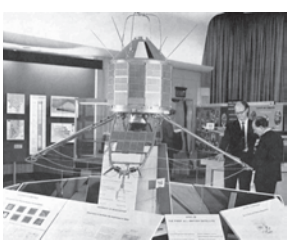
May 1 American TV audiences see the Soviet Union's May Day parade through a TV signal that is picked up by the Early Bird (Intelsat 1) communications satellite in geosynchronous orbit over the Atlantic, then relayed across the U.S. to ground receiving stations in Andover, Maine, and Brewster Flat, Washington. The program is also transmitted across the Pacific via Intelsat 2 for viewers in Japan. The transmissions are made with the cooperation of the USSR and the ComSat Corp. NASA, **Astronautics and Aeronautics, 1967**, pp. 133-134.

May 3 The first London-to-Buenos Aires Boeing 707 service by Aerolineas Argentinas begins. **Flight International**, May 11, 1967, p. 736.

May 3 The Mullard Space Science Laboratory opens in Surrey, England. It is to house the largest scientific space research group in Britain. The laboratory, which is part of University College, London, is to undertake a major program involving experiments on eight satellites and over 30 sounding rockets. **Flight International**, May 11, 1967, p. 770.



May 4 An Atlas-Agena D launches Lunar Orbiter 4, which is designed to obtain a broad systematic photographic survey of the lunar surface to improve researchers' knowledge of the moon as well as to contribute to selecting landing sites for the upcoming Apollo manned lunar landing missions. On May 8, it becomes the fourth spaceflight to orbit the moon and is placed in a 6,111-by-2,706 kilometer orbit, but on May 26 the lunar photography is stopped due to an electrical problem. Still, the satellite achieves 90 percent of its planned photographic coverage. NASA Release 67-101; **New York Times**, May 28, 1967, p. 50; **Aviation Week**, June 5, 1967, p. 45.



May 5 The U.K.'s Ariel 3 scientific satellite, the first to be designed, built and tested in Britain, is launched by a NASA all-solid propellant Scout rocket from Vandenberg Air Force Base, California. The 90-kilogram satellite is the third in a series that carries experiments to investigate the Earth's atmosphere and ionosphere. NASA Release 67-115; **Flight International**, May 11, 1967, p. 770.

May 5 Dr. Heinz von Diringshofen, the German pioneer in aerospace medicine, dies in Frankfurt, Germany. He was among the first to study the effects of weightlessness in vertical flight. He helped develop systems used in the training of U.S. astronauts, including a centrifuge capable of producing 17 Gs. **New York Times**, May 9, 1967, p. 43.

May 13 A light aircraft world altitude record of 13,319 meters is set at Upland, California, by W.D. Cable flying a Cesna Turbo-System Centurion. **Flight International**, June 8, 1967, p. 949.

May 14 A flyable replica of the Spirit of St. Louis of famed aviator Charles Lindbergh is transported in parts via an Air Force Lockheed C-141 from New York to Paris where it will be reassembled to be featured at the 27th International Air Show at Le Bourget Airport. The plane helps commemorate the 40th anniversary of Lindbergh's flight in 1927. The replica took 60 days to construct from exact specifications of the original plane and was test flown by Frank Tallman, owner of Tallmantz Aviation Inc., which built the replica. **Aviation Week**, May 8, 1967, p. 71.

May 23 The prototype of Britain's Hawker Siddeley HS.801 maritime-reconnaissance bomber, afterward called the Nimrod, makes its first flight and is piloted by John Cunningham, Hawker Siddeley's chief test pilot. **Flight International**, June 1, 1967, p. 867.

May 24 The Explorer 34 Interplanetary Monitoring Platform is launched by a Thrust-Augmented Improved Delta rocket into a near-perfect polar orbit. The satellite is to make measurements of solar and galactic cosmic rays. **Wall Street Journal**, May 25, 1967, p. 1.

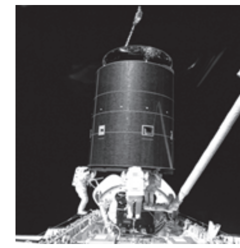
May 25 The USSR launches its Molniya 1-E communication satellite for relaying TV signals from the Soviet Far East to Moscow and on to Paris. The Molniya's mission is also to further explore long-distance two-way television, telephone and radio communications via satellite for the USSR. **New York Times**, May 26, 1967, p. 3.

May 26-31 French President Charles de Gaulle opens the 27th International Air Show at Le Bourget Airport, Paris. More than 450 aerospace companies representing 16 countries participate. Among the highlights are the Douglas DC-8 Super 63, the world's largest aircraft; and the Soviet Union's first public exhibit of its Vostok booster similar to the one that launched Yuri Gagarin, the first man into space. **Washington Post**, May 30, 1967, p. A1; **Aviation Week**, May 8, 1967, p. 71, and May 29, 1967, p. 193.

May 29 ESRO 2, the first satellite designed, developed and constructed by the European Space Research Organization, is launched by a U.S. Scout rocket from Vandenberg Air Force Base, California, though it does not achieve its planned orbit because of a malfunction in the fourth stage of the booster. The ESRO-1A is launched Oct. 3, 1968. **New York Times**, May 31, 1967, p. 1.

May 31 The Air Force launches eight satellites with a Thor-Agena D from Vandenberg Air Force Base, California. This mission is to contribute to the development of a satellite system to assist the navigation of aircraft and ships using celestial reference points. **Washington Post**, June 1, 1967, p. C4.

1992



May 15 In a first, three U.S. astronauts walk in space at the same time. They capture a wayward satellite, Intelsat 6, with their hands. Normally a remote manipulator arm is used. During this same mission of the space shuttle Endeavour, Kathryn Thornton becomes the second woman to walk in space. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 209, 689.

During May 1992
Customers begin using the first all-digital passenger communications service, known as FlightLink, aboard a U.S. Air Boeing 757. The in-flight phone permits passengers to make calls, send faxes and play electronic games while in their seats. **Flight International**, May 27-June 2, 1992, p. 10.

LINDSEY SWEENEY, 24

Junior Chief Engineer, Northrop Grumman MQ-4C Triton

Triton unmanned planes look a lot like U.S. Air Force Global Hawks, but they are tailored for maritime surveillance with stronger airframes, reinforced wings, lightning protection, and de-icing coils in their tails and wings. The Navy plans to bring them into its fleet in 2018, and the Tritons have caught the eye of Germany and Australia, which may buy them too. Each carries a maritime surveillance radar, electro-optical and infrared video cameras, and an automatic identification system receiver for tracking friendly ships. A complex aircraft like Triton relies heavily on software to operate properly. That's where Lindsey Sweeney comes in. She manages Triton software-related work in Northrop Grumman's Autonomous Design Center of Excellence in San Diego.

How did you become an aerospace engineer?

I have always enjoyed problem solving. Engineering itself is such a vast field, but I was sold on aerospace engineering from the time I won a trip to Space Camp through the California Science Fair in middle school. It was amazing. I really nerded out. I liked the idea of seeing a problem, solving that problem, and witnessing how it helped others complete tasks more easily. It's satisfying. Engineering has always been intoxicating for me. I attended the University of California, Los Angeles, to study aerospace engineering. My first summer, I interned at Carlisle Interconnect Technologies, assisting in the analysis of automated machinery. After my sophomore year, I began interning at Northrop Grumman, where I performed detailed design work of metallic structures and completed thermodynamic and propulsion analyses on the Firebird engine and intercooler systems to help improve power output and general efficiency. I was hired full time as an aerospace engineer by Northrop Grumman in 2014. I now support the Triton program's chief engineer.

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

In the past 10 years, I've seen a lot of momentum in the aerospace industry. The contribution toward groundbreaking innovation is accelerating exponentially. You can already feel it. In 2050, I expect to see incredible advancements toward exploring our universe and our Earth, with greener, faster, more efficient aircraft. The autonomous portion of the industry, for example, is just getting started. Autonomous flight opens doors that lead to discoveries we haven't even thought of yet. It's really exciting to be sitting at the threshold of that at Northrop Grumman in San Diego. I think there was a time when some of the larger companies were at risk of becoming stagnant and redundant, but companies like Northrop Grumman have become very nimble and diverse. Places like our FabLabs are fine-tuning unique talents. FabLabs [in California and Florida] provide our engineers with cutting-edge tools and technologies we can then apply to our hobbies, which helps us learn, create and bring new ideas to the company. It's inspiring! ★

By Debra Werner | werner.debra@gmail.com