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AEROSPACE
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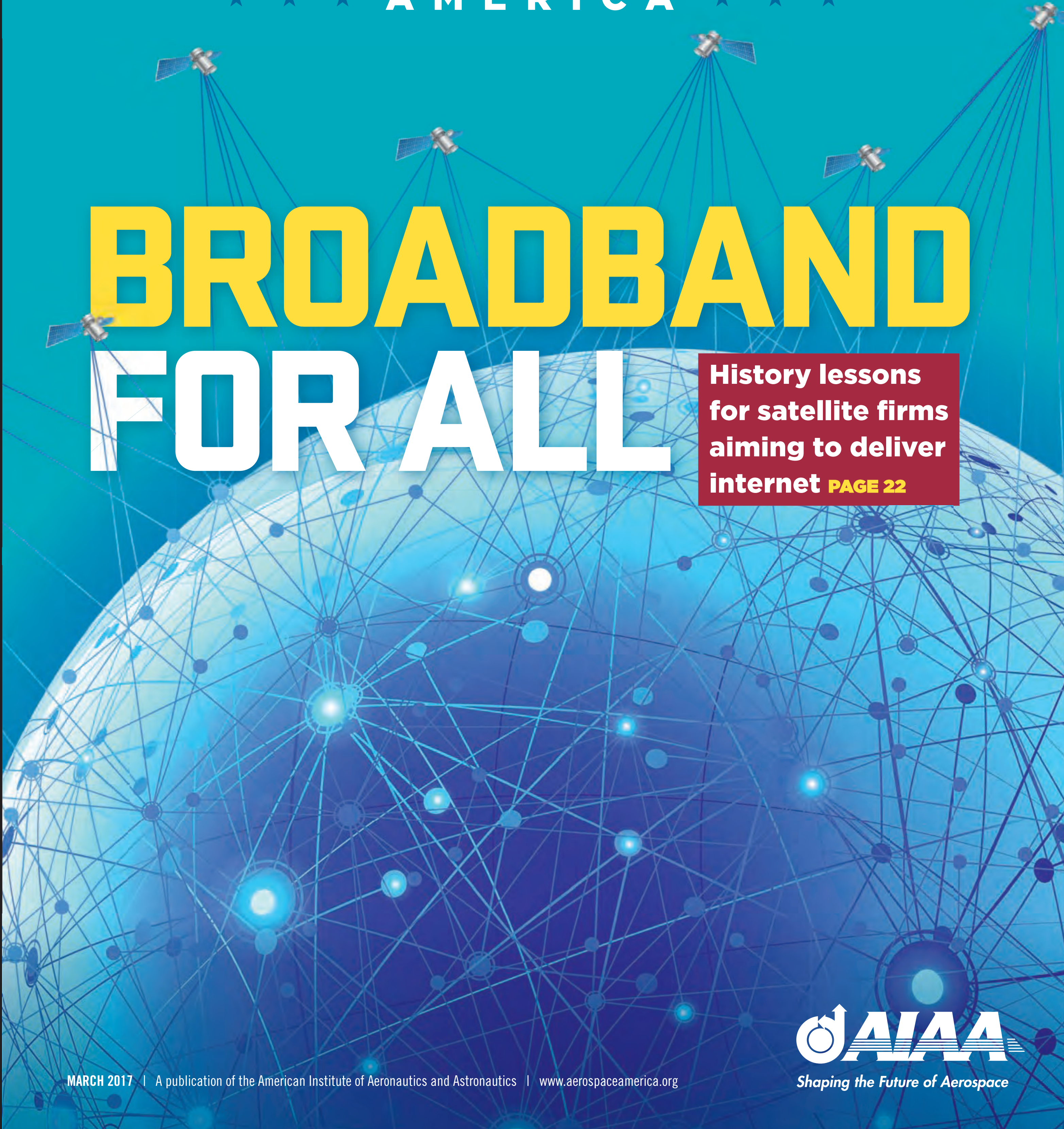

BROADBAND FOR ALL

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AIAA
Shaping the Future of Aerospace

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This is Volume 55, No. 3.

AIAA

Shaping the Future of Aerospace

IN THIS ISSUE

Tom Risen

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

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Henry Canaday

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

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Keith Button

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

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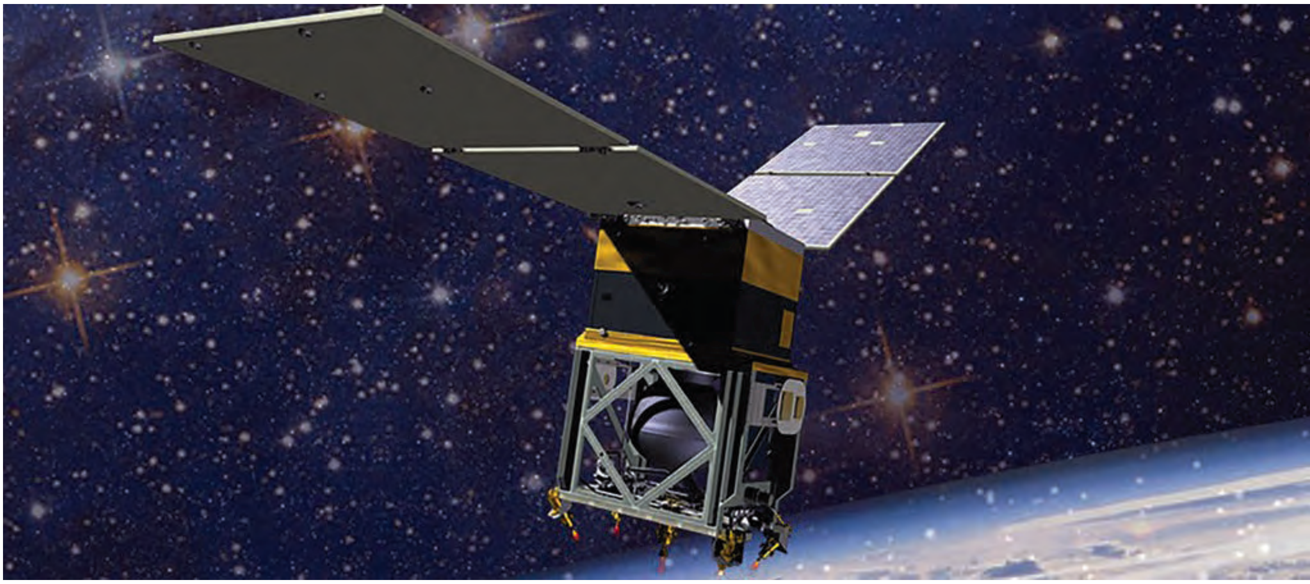
DEPARTMENTS



Ball Aerospace

▲ **An artist's rendering** shows NASA's Green Propellant Infusion Mission payload.

A new meaning for green

Under the Obama administration, NASA loved to deploy the term "green" in project names and on its webpages as a synonym for clean. "Green Aviation: A Better Way to Treat the Planet," reads the headline of a NASA fact sheet that discusses NASA's Environmentally Responsible Aviation project, a research effort that the agency wrapped up and wants to follow with a series of X-planes.

With the arrival of the administration of President Donald Trump and its focus on dollars and taxpayers, advocates of government research under the green mantle are shifting to another possible interpretation of green. That's as in cash, specifically the money that consumers and businesses will in theory save through adoption of electric propulsion on aircraft; safer sustainable fuels for planes and satellites; and more efficient aerodynamic shapes that reduce drag and maximize lift.

With this shift of emphasis toward dollars, I boldly predict that we'll hear fewer phrases like "environmentally responsible aviation" in the messaging from government agencies. That's just as well. It was too easy to draw an inference that the aviation sector was somehow irresponsible in the eyes of NASA. I doubt that's what the agency meant. The best way to clean the planet will be for clean technologies to make competitive sense to businesses, and part of creating that attractiveness will always be research paid for by NASA and other agencies.

The shift in branding does not mean anyone is being disingenuous. The cost-savings argument is nearly always the flip side of the clean coin.

Take for example the Green Propellant Infusion Mission spacecraft ["Green Propellant," Page 36] that will be launched later this year or early next for NASA. Hydrazine fuel for satellite thrusters is carcinogenic, highly flammable and therefore extremely expensive to produce and load safely into satellites. GPIM, built by Ball Aerospace, will test a nontoxic alternative fuel developed by the U.S. Air Force and components developed by Aerojet Rocketdyne specifically for the new fuel. If GPIM succeeds, for about $45 million (roughly half the cost of a single F-35), all those expensive precautions for handling hydrazine would go away forever.

The faster the satellite industry grows, the faster the cost of that mission will be amortized. Those are the kinds of arguments the new administration probably wants to hear, and there is some merit in the approach. ★

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

Doubts about climate change

Kudos to Aerospace America and Mr. [Tom] Risen for an article about global warming that doesn't attempt to demonize people who doubt the premise that humans are entirely to blame ["CO_2 Watchdogs," January]. All too often, such articles are rife with subtle innuendo and propaganda designed to silence debate on what is a matter of science. I found the article actually tried to present both sides.

However, the cover text of the magazine, when considered with a critical eye, leads to some ridiculous conclusions. It implies that anything that produces CO_2 is automatically a "polluter" that must some day be held "accountable" by some shadowy authority. Really? Since when did CO_2 become a pollutant? It is necessary to support plant life (which, by the way, supports animal life in turn). Congressman [John] Culberson's point is well-taken: There was more CO_2 in the air in prehistoric times and no humans or cars to produce it, so the cause-and-effect linkage certainly warrants a healthy dose of scientific skepticism, not mere parroting of the latest edict from the mainstream media.

While I appreciate greatly the tone and even-handedness of the article, the underlying premise of the subject (and the cover of the magazine) is not an indisputable fact. I am disappointed that Aerospace America, the flagship publication of a professional society, has been drawn in by a dishonest media and their accomplices in the scientific community. It is my hope that, in the near future, scientific inquiry will win out over hype and politics.

Most sincerely,

Pete Badzey
AIAA associate fellow
Huntington Beach, California

NASA/Bigelow Aerospace

CORRECTION

In the December issue, we misidentified a conceptual rendering of the Bigelow Expandable Activity Module as a photograph. The rendering depicted BEAM being attached to the International Space Station.

The Importance of Aerospace to Our Nation

As a new administration takes office and the 115th Congress gets underway, AIAA's public policy efforts are ramping up as well. The Institute is using this transition period as an opportunity to focus on educating both new and veteran lawmakers, their staffs, and other federal officials about the importance and impact of the aerospace community to the nation.

As in years past, our Key Issues (KI) provide the supporting pillars of the AIAA Congressional Visits Day (CVD), drive panel sessions at our annual forums, underpin our state-level advocacy efforts, and form the basis of a number of smaller focused events and activities. This year's key issues are outlined on pages 48–51.

A paramount issue that we must tackle is the ongoing struggle to achieve budget stability and predictability. We call on Congress to return to regular order and to end the mandatory across-the-board funding cuts, known as sequestration. At the same time, it is imperative for Congress to address the continuous decline in federal funding for research and development, which has caused the United States to fall behind its global competitors. Moreover, both NASA and the FAA are in need of long-term authorizations and appropriations in order to meet short- and long-term program and mission requirements. NASA has not been reauthorized since 2010, and the FAA is currently operating under a short-term extension that expires at the end of this fiscal year.

A robust and technologically proficient aerospace and defense (A&D) sector also requires policies that enhance our workforce. This includes improving the pipeline of STEM-educated workers into the U.S. economy and retaining highly-skilled foreign-born STEM graduates who receive degrees at U.S. universities.

Several other important issues must also be addressed by Congress for our nation's A&D industry to remain competitive in a growing global market. Among other things, these include establishing aircraft emissions regulations that align with our international partners, reforming the foreign military sales process, ensuring that the U.S. Export-Import Bank Board is filled so that it can process transactions of more than $10 million, and increasing priority of supersonic/hypersonic national defense capabilities.

In late January, AIAA teamed with the Aerospace Industries Association and the Space Foundation to organize two "Aerospace 101" educational briefings for congressional staff. Aerospace industry experts presented a broad overview of the sector's myriad contributions to our national defense, security, economy, and quality of life. No specific programs or priorities were promoted. The briefings were hosted by Senator Martin Heinrich (D-NM), Congressman Derek Kilmer (D-WA), and Congressman Steve Knight (R-CA).

From a grassroots perspective, our annual CVD program brings together scores of AIAA members of all levels and backgrounds from all over the country for a day of advocacy on Capitol Hill. 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's CVD will take place on Wednesday, 29 March. There is still time to register, and we look forward to our members' continued involvement in this unique and important program.

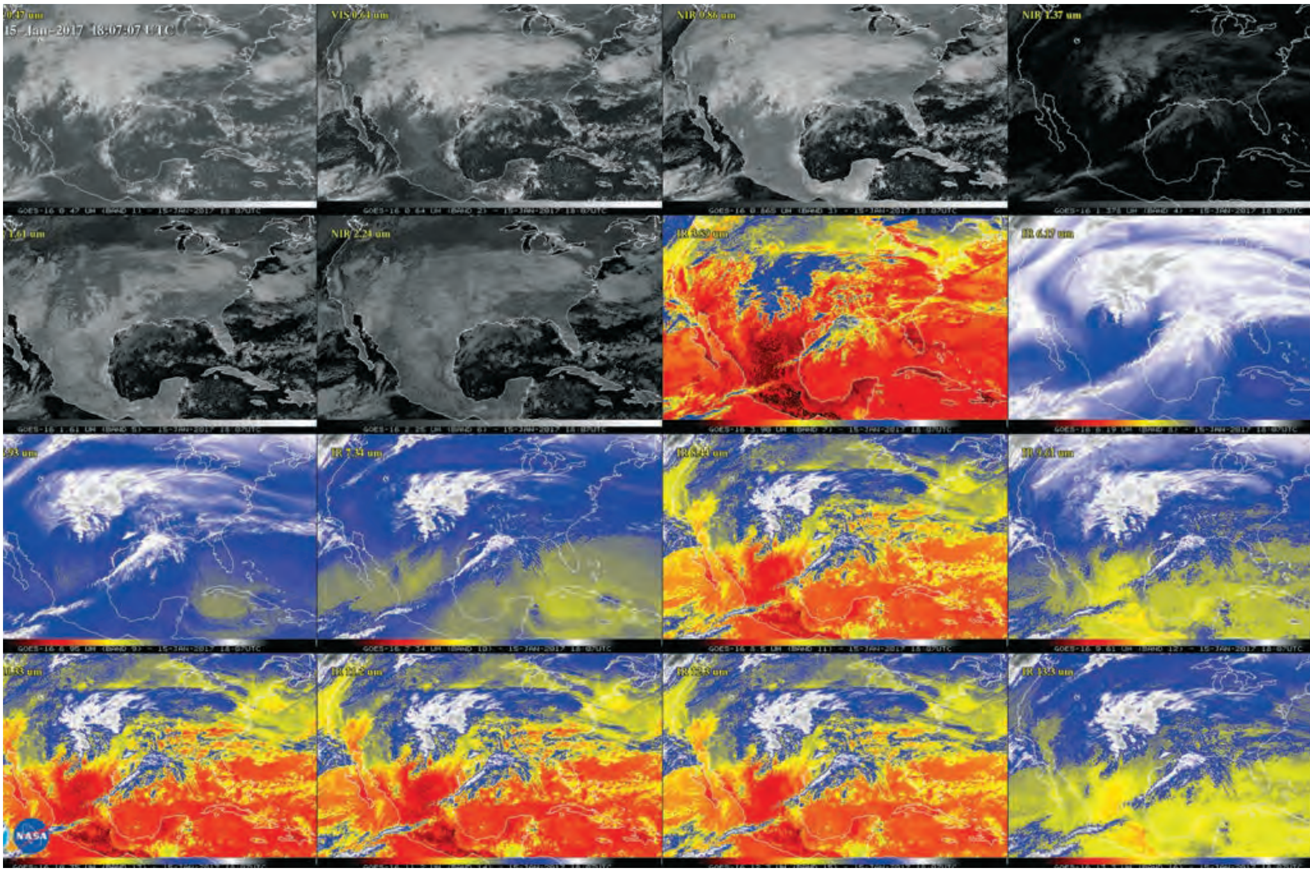
Even with a strong presence and a day of substantive member outreach during CVD it is still imperative for all AIAA members to be everyday advocates for aerospace. And you do not have to come to Washington, DC, to be an advocate. To help strengthen our grassroots efforts around the country we intend to revive the "August is for Aerospace" program this year. The best chance to meet directly with your member of Congress is while they are at home during a congressional recess. This is also an opportune time for AIAA Sections to engage elected officials in your outreach activities. You could invite them to participate in a panel to discuss a particular issue of relevance to the local aerospace community, ask them to come speak to your local chapter about one of our key issue areas, or have them attend an AIAA-sanctioned event. Additionally, you could invite the official to visit and tour your company/organization's facility. There are many ways to get your representatives engaged.

We are off to a great start, but the Institute needs your help to address the profession's public policy needs. Participation is power. Your involvement at the federal, state, and local levels drives our success and ensures that AIAA continues to lead the way on issue advocacy impacting OUR aerospace community. ★

John C. Rose

National A&D Workforce Summit: Proceedings Report

In January, AIAA and AIA published a proceedings report (www.aiaa.org/NADWS-report) of the September 2016 National A&D Workforce Summit intended to shape our own strategies on STEM education and workforce development.



NASA/NOAA

▲ **This panel of images** from NOAA's new GOES-16 satellite shows what an ice storm that pummeled the central Plains on Jan. 15 looks like in those 16 bands at the same moment in time. The bright blue patch in the largely red and orange image (second row, third from left) shows the presence of cold clouds associated with the ice storm.

Fresh satellite help for severe-storm forecasters

By BEN IANNOTTA | beni@aiaa.org

Images released by NOAA illustrate the unprecedented views of severe weather that forecasters will have later this year, provided all goes as planned with orbital checkout of GOES-16, the 5,200-kilogram satellite launched in November.

Once operational, the satellite's main instrument, the Advanced Baseline Imager built by Harris Corp. in Indiana, will generate a complete "disk" image of North and South America once every 15 minutes, plus an image of the continental U.S. once every five minutes and images of smaller areas once every minute when necesssary, says NOAA researcher Tim J. Schmit, who began conceptual work on the ABI in the late 1990s.

Just as importantly, the satellite gathers 16 bands, or ranges of wavelengths, compared to five for the other Geostationary Operational Environmental Satellites. More bands means a greater ability to distinguish features that affect storm development, such as clouds and water vapor. ABI also will watch in multiple bands for evidence of volcanic ash, the bane of airline pilots.

To improve severe storm forecasting, ABI detects water vapor in three bands (the three mostly blue images starting with the last one in the second row), compared to one band for the current satellites. "So you can depict three layers of flow in the atmosphere, instead of just one," Schmit explains. Each layer represents a different altitude, and that data will be assimilated into numerical weather prediction models to better forecast the movement of hurricanes and other storms, Schmit says.

As with today's satellites, these snapshots of water vapor also will be strung together to create time animations.

Before declaring the satellite operational, NOAA needs to validate its ability to detect actual atmospheric features, like the Jan. 15 ice storm. What's next? "To know that this works for volcanic ash, we need to have a volcanic ash event," Schmit says. ★

Mars 2020 rover landing sites narrowed to 3

By Leonard David | newsspace@aol.com

Now that a group of scientists and engineers has short-listed three possible landing sites for NASA's Mars 2020 rover, a final workshop will be scheduled to discuss the options.

That workshop will be sometime in early to mid-2018, says geologist John Grant, who co-chairs the Mars 2020 Landing Site Steering Committee and works at the Smithsonian Air and Space Museum's Center for Earth and Planetary Studies.

Grant says that "whether there is one site, a primary and backup, etc., is TBD" by NASA Headquarters.

A February workshop in Monrovia, California, brought together upward of 250 scientists and spacecraft engineers to narrow a previously selected list of eight sites. I attended the workshop, which also covered the overall engineering status of the Mars 2020 rover.

Michael Mayer, lead scientist for the Mars exploration program at NASA Headquarters, kicked off the meeting by saying the site selection "is not a contest," that there's not "a winner" and "there's no prize." He called for "open and honest" discussion.

After nearly three days of deliberative and contentious debate, the researchers cast their votes via computer.

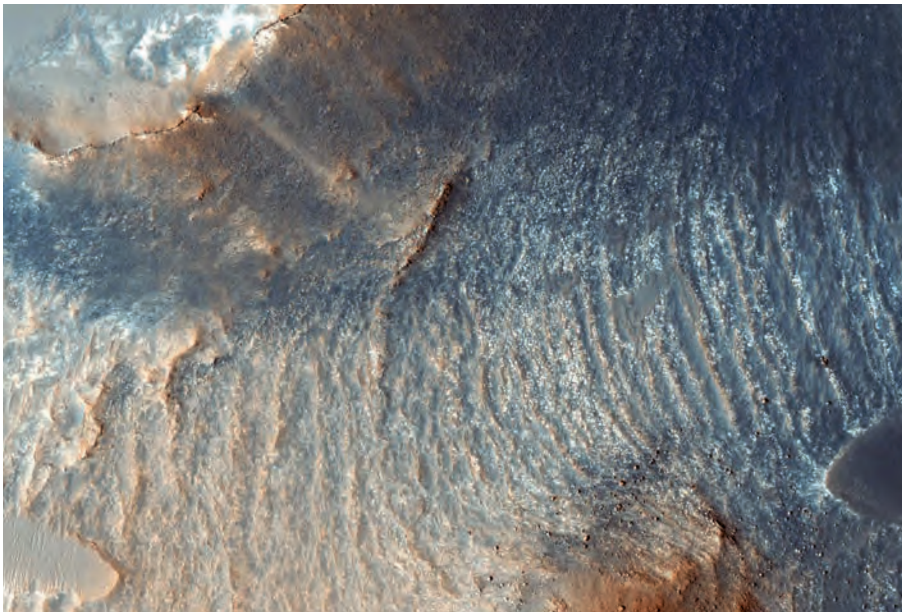
Rising to the top of the green-lighted list of sites were two areas where no spacecraft has ever touched down and one that was explored by NASA's Spirit rover before it got stuck in the sand and stopped operating in 2010. These are the locations in order of preference:

- **Jezero Crater**, the site of a dried-up lake bed and possibly a repository of past microbial life.
- **Northeast Syrtis Major**, a huge shield volcano neighboring a large impact basin and an area once warm and wet long ago.
- **Columbia Hills/Gusev Crater**, previously surveyed by NASA's Spirit rover and flush with hot spring sinter deposits that could be similar to those that harbor microbial life on Earth.

Allen Chen of NASA's Jet Propulsion Laboratory in California, who is the entry, descent and landing lead for the mission, underscored during the workshop that the ability to land at a more precise location than previously possible opens the door to being more daring. All eight sites that were appraised were cleared for a prospective landing by the Mars 2020 rover, Chen said.

The prospect of a robotic return to Columbia Hills, and not to unexplored landscape, touched off heated talk. Backers of that site said that before Spirit stopped functioning there, the machine found an ancient and eroded volcanic ash deposit. At some time a hot spring was active there and, therefore, the site has the potential to reveal signatures of past Martian life.

Wherever it lands, the Mars 2020 rover will prowl for astrobiologically relevant samples and encapsulate them for future pickup and delivery to Earth. But there's a catch: There is no funded Mars mission beyond Mars 2020. ★



NASA/JPL/University of Arizona

▲ **Northeast Syrtis Major** is a huge shield volcano neighboring a large impact basin and an area considered warm and wet long ago. It could be a spot — only partially shown here — for the Mars 2020 rover to search and find evidence of past life on the planet.

> **"Whether there is one site, a primary and backup, etc., is TBD" by NASA Headquarters."**
>
> **John Grant**
> Co-chair of the Mars 2020 Landing Site Steering Committee

Satellite Industry Association President Tom Stroup speaks on Capitol Hill.

Satellite Industry Association

Supporting an industry in transition

The private sector's interest in generating revenue by launching and operating non-government satellites has exploded during Tom Stroup's three years as president of the Satellite Industry Association in Washington, D.C. Stroup sees great opportunities for his group's 40 member organizations, which include manufacturers, launch companies and service providers. The Trump administration's intention to re-evaluate international trade, for instance, could be a chance to expand technology exports, and the "internet of things" is increasing demand for satellite services among government and private-sector clients. Stroup's training as a lawyer, his previous telecom advocacy with the Wireless Infrastructure Association, and experience launching and managing several businesses in the communications sector give him perspective on the regulatory and technological environment. I spoke by phone and email with Stroup about issues facing the industry. — *Tom Risen*

More online aerospace america.org

TOM STROUP

POSITION: President of the Satellite Industry Association since December 2014

NOTABLE: Spent a decade as president of the Wireless Infrastructure Association trade group; former CEO of Reston, Virginia-based SquareLoop, which provided location-based communication services; former CEO of Shared Spectrum Co. of Virginia, which helps government and private-sector customers apply radio frequencies efficiently in their communications

AGE: 62

RESIDENCE: Great Falls, Virginia

EDUCATION: Law degree from Georgetown University. Bachelor of Science in public administration from University of North Dakota

Miniaturization and cost cutting

Going back to the 1990s, satellites were custom built. [Compared with the 1990s] we've got much lower costs in building satellites, much lower costs in deploying them. The ability to provide ever-increasing speed and capacity with lower power requirements is driven by the improving technology. It's not just the ability to put it into a small package, it's the ability to pack a lot more capacity into large satellites. Miniaturization is already taking place. Just as Moore's Law had an impact on all forms of computing, you see that happening with satellite tech. If you looked at the deployment plans of OneWeb and SpaceX, they are planning on mass-producing satellites. They are using off-the-shelf tech for their satellites. That dramatically lowers costs of deploying satellites. The launch costs have [also] come down. There are a number of companies that have plans to offer launch services beyond those that are in the business. It's almost a combination of all of these that help drive the opportunity.

Demand for smart car wireless

There is so much software in cars today that require upgrades and it is so expensive to bring the car into the shop for an upgrade. Auto manufacturers are looking for more efficient means of reaching their cars. As you can imagine, the most efficient way to do that is via satellites. One manufacturer sells 60 percent of its cars into markets where there isn't 3G or 4G mobile services. Companies like Kymeta [of Washington state] are working with auto manufacturers to integrate their antenna technology into the cars and working with satellite operators to provide updates worldwide. You look at the ownership of Tesla, its sister company is SpaceX, so they may well view their proposed satellite broadband constellation as a potential opportunity to expand their market reach.

Space traffic management

[Shifting responsibility to FAA is] certainly worthy of examination. From the satellite industry's perspective, we want to make sure that whatever changes take place [those changes] provide the same or better level of accuracy. It's nothing more than a discussion at this point. But I know DoD and FAA have been engaged in how this could happen and how DoD could share that information. The FAA has had discussions about how they could do a pilot program, which is something that I would recommend regardless of any changes that would take place. With the change in the [presidential] administration, I'm not sure if there is going to be a change in approach.

The whole space traffic management issue is getting greater awareness right now. I won't say there are any answers or suggested changes on how it's handled. The satellite industry has long been used to coordinating amongst themselves. No one has indicated "you cannot operate all of these satellites safely" — there just needs to be sufficient spacing [in orbital altitude].

With the current administration's push for creating jobs, they will want to ensure that American manufacturers are on equal footing with their foreign competitors.

Military interest in small satellites

As some countries deploy anti-satellite capabilities, the DoD is deploying plans to protect its ability to communicate and gather information. One element of that resiliency plan is to utilize the capability of commercial satellites, so that there are such a large number of satellites either used or capable of being used by DoD that it would be impossible to shut down their ability to communicate and observe from space short of destroying the space environment for all nations. They need to have the ability to have imagery of what is happening on the battlefield or other areas of potential conflict, as well as communicating down to the individual soldier level.

Cybersecurity for satellites

Our members have been deploying tech to make sure they are not capable of being hacked. There are different types of satellites that are deployed, so we have put together a set of principles — none that I think are unique to satellites. Each company works toward ensuring they are compliant with the principles [including voluntary information sharing]. There is such heightened sensitivity, especially from a customer's perspective. It tends to be handled on a company basis. We don't have a set of requirements.

It is critical that exchanged information be confidential, secure, and used only for purposes of strengthening security and combating bad actors. Information about threats, mitigations, business processes, or capabilities is competitively sensitive and, in the wrong hands, can aid bad actors.

Trump and tech trade

Prior to the reform of the [U.S. State Department's International Traffic in Arms Regulations], commercial satellites and many components were restricted from sale outside the country by U.S. manufacturers. In 2014 those limits were modified, providing U.S. companies much greater latitude to compete in the international market. There remain restrictions on Earth imaging companies, however, and we are working with our members to seek to remove those limits. There are limits on the clarity of imagery that companies show — and limits on the aperture size of satellites that can be exported. There comes a point where a technology is available outside the U.S., so it is not affecting any intellectual property or security concern. If one can buy the same tech in Europe, it doesn't really benefit to keep American companies from selling it. With the current administration's push for creating jobs, they will want to ensure that American manufacturers are on equal footing with their foreign competitors, so we think there is an opportunity for us to be able to move it up on their list of priorities, so at least the discussion would happen. ★

Tracking dangerous NEOs

The administration of President Donald Trump inherited an asteroid and comet preparedness strategy released in the final days of Barack Obama's presidency. Former astronaut Tom Jones, who is chairman of the Association of Space Explorers' Committee on Near-Earth Objects, looks at whether the plan goes far enough.

By Tom Jones | Skywalking1@gmail.com | www.AstronautTomJones.com

▲ **An artist's rendering** of an asteroid striking Earth. NASA scientists have identified and cataloged 16,000 near-Earth objects.

The physical shock waves from the half-megaton asteroid explosion that echoed over the Russian city of Chelyabinsk sent 1,500 people to the hospital (luckily, none of their injuries was serious), but the detonation also shook governments and space agencies around the globe. Chelyabinsk was just a sample of the destructive potential of the impact of an asteroid larger than that 20-meter body.

The U.S. laid out a logical road map for asteroid and comet defense and emergency response in the "National Near-Earth Object Preparedness Strategy" released in the waning days of the Obama administration.

The strategy was the product of an interagency working group that built on earlier discussions and exercises conducted by NASA and the Federal Emergency Management Agency. The 19-page national strategy sets out the U.S. approach to preventing an asteroid disaster; an "action plan" to implement the strategy will follow.

The new administration should adopt this sensible strategy and move rapidly to implement its detection and deflection objectives.

"We are waiting for the new administration to get its feet on the ground … and learn who we'll be working with to take this forward," says Lindley Johnson, NASA's planetary defense coordination officer, in a phone interview. "I suspect that will take a few months — not too long. … We hope to work on the action plan by mid-2017."

Asteroid impetus

On Feb. 15, 2013, the Chelyabinsk asteroid shattered in the atmosphere 30 kilometers above the city, releasing light, heat and blast energy equivalent to about 30 of the atomic bombs that ended World War II. But the 12,000-metric-ton asteroid, which arrived undetected by ground-based telescopes, was just the largest recent example of the steady rain of asteroid and comet fragments that strikes Earth. A Chelyabinsk-size impact can be expected every 20 to 40 years; a 40-meter object, like the one that struck the Tunguska region in Siberia in 1908, collides with our planet once or twice a millennium. Tunguska generated a 5-megaton blast that flattened 2,000 square kilometers of forest, an area equivalent to two-thirds of the state of Rhode Island.

Fireball data from U.S. infrared sensors on a constellation of geosynchronous and highly elliptical orbit satellites show that small asteroids and comet fragments routinely strike Earth; it's just a matter of time before another large impact occurs. As of late January, NASA's NEO search program had cataloged nearly 16,000 objects; none at present has a high probability of hitting Earth.

But there's no shelter in statistics: The NEO population comprises an estimated 13,000 objects 140 meters and larger, each capable of releasing more than 60 megatons of energy. Of these, only an estimated 28 percent have been found. There are thought to be 300,000 Tunguska-size objects (40 meters and larger), while about 10 million objects exceed the diameter of the 20-meter Chelyabinsk asteroid.

The good news is that Earth is a small target: a 140-meter NEO impact occurs only every 20,000 years or so. Still, a couple of factors encouraged the U.S. to circulate a policy enabling timely detection and impact prediction, moving toward a demonstrated asteroid deflection capability. First, there's the potential for damage from a megaton-scale asteroid explosion in the atmosphere every couple of decades. Second, early detection of asteroids and timely impact predictions, coupled with effective communication of that information across the globe, should head off the worrisome confusion of an asteroid impact with a nuclear detonation in politically unstable regions, such as North Korea or southwest Asia.

Impact prevention objectives

For over six years, NASA has had the lead role in the U.S. government for researching the NEO hazard and identifying asteroids headed our way. NASA was also a co-chair with FEMA of the 2016 interagency working group that drafted and coordinated the new strategy. The NEO policy is in line with other government disaster preparedness planning, like that anticipating a future solar storm. The U.S. NEO strategy, drawing on a decade of NASA and National Research Council reports and interagency discussions, lays out objectives for enhancing NEO impact preparedness in three areas: hazard and threat assessment, decision-making and response.

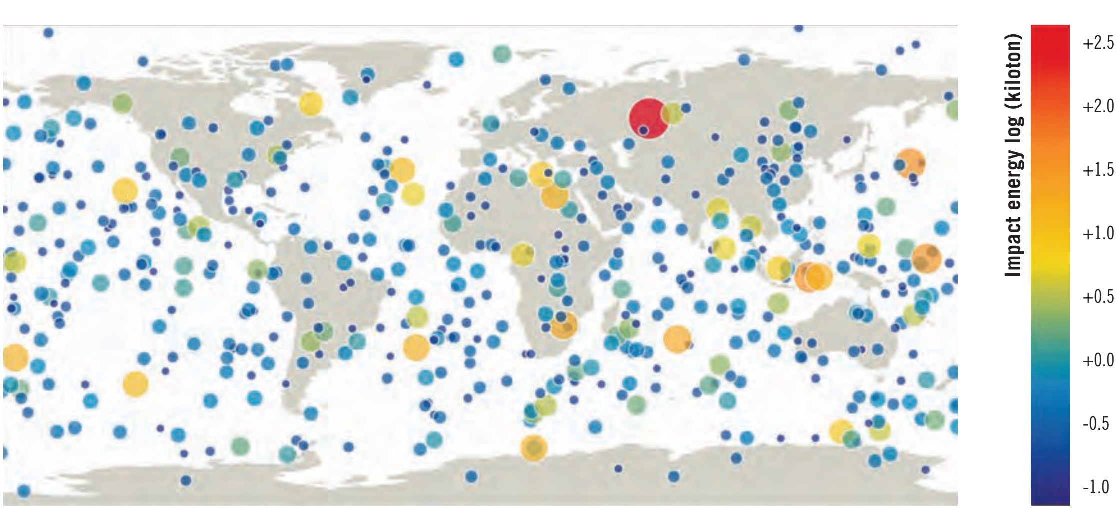
The objectives are:

- Enhance NEO detection, tracking and characterization capabilities
- Develop methods for NEO deflection and disruption
- Improve modeling, predictions and information integration
- Develop emergency procedures for NEO impact scenarios
- Establish NEO impact response and recovery procedures
- Leverage and support international cooperation
- Establish coordination and communications protocols, and thresholds for taking action

These objectives should be pursued logically and concurrently, with the more ambitious capabilities maturing after significant progress on earlier goals.

Fireball strikes

U.S. government sensors recorded these fireball events between April 15, 1988, and Feb. 7, 2017. A fireball is a comet or asteroid that is bright enough to be seen over a wide area. Each event's calculated total impact is indicated by its relative size and by the color scale at right. The red event over Russia is the Chelyabinsk impact in 2013. An event with an energy equivalent of 1,000 tons of TNT explosives is a kiloton event.

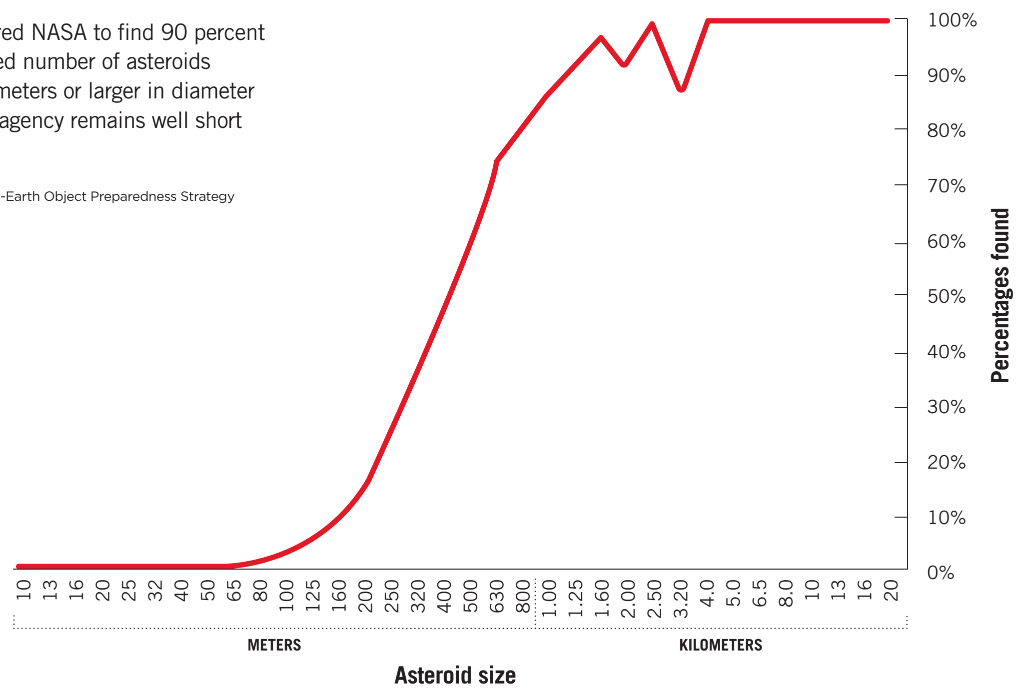


NASA/JPL/CalTech

ASTEROIDS FOUND

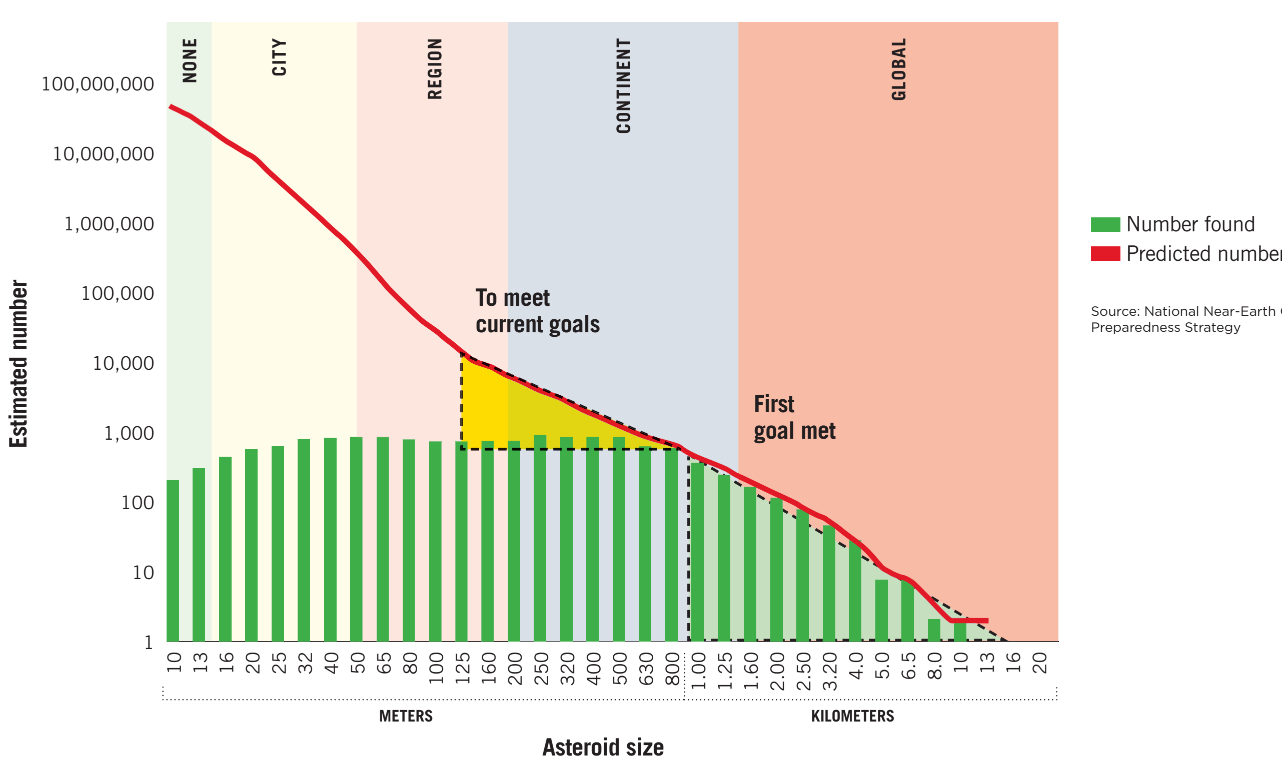
Congress ordered NASA to find 90 percent of the estimated number of asteroids of about 140 meters or larger in diameter by 2020. The agency remains well short of that goal.

Source: National Near-Earth Object Preparedness Strategy



KNOWLEDGE GAP

NASA has a solid estimate for how many near-Earth asteroids are out there, and Congress has set goals for finding them. So far, NASA has identified all those of a size that would cause global devastation. But the yellow triangle below indicates that many smaller, but still dangerous, asteroids remain unaccounted for.



Source: National Near-Earth Object Preparedness Strategy

The first two objectives are the most important: NEO detection and NEO deflection capabilities. Employing an asteroid deflection capability, for example, relies on NASA's search program finding most of the NEOs in that worrisome 140-meter-and-up range. "Finding them early" must come first; detection enables prudent technology development and mission planning, prerequisites for a practical means of asteroid deflection.

NASA's annual $50 million NEO program budget pays for most of the ground-based telescopic search efforts, which find nearly 2,000 NEOs annually.

However, ground-based telescopes cannot complete the congressionally ordered 140-meter-object survey until well into the 2030s. Detecting small, dim and usually distant NEOs requires sensitive, rapid and repeated observations, traits more characteristic of a space-based, infrared search telescope. The NASA-funded Jet Propulsion Lab's NEOCam space mission concept was designed to perform the NEO detection survey in less than 10 years, but earlier this year it failed to win funding from the Discovery planetary mission competition.

Despite the setback, NASA's Johnson says: "We still believe to do [NEO search] in a timely manner, we need to move to a space-based capability, particularly with the IR."

Finding potentially hazardous NEOs is a matter of public safety. The new Congress should allocate directed funding to design and launch such an infrared NEO survey mission. The cost? About $50 million a year (for 10 years) — about 1/386th of NASA's 2016 budget. It's cheap insurance.

Characterizing the threat

Near-Earth asteroids number in the millions, and no two are alike. Yet how many NEOs have we examined close up? Two.

Characterization is the natural follow-up to NEO discovery and orbit cataloging. It means determining the composition and physical characteristics of an asteroid, e.g., mineralogy, mass, dimensions, density, porosity, albedo and spin rate. Characterizing a threatening NEO could mean the difference between a successful deflection or a failed attempt, resulting in an Earth impact.

The next hard information we are likely to have about individual NEOs will come from Japan's Hayabusa 2 mission, which will arrive at the carbonaceous asteroid Ryugu in June 2018. Also outward-bound to a NEO is NASA's Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer, or OSIRIS-REx, mission, slated for an August 2018 rendezvous with carbonaceous asteroid Bennu. Along with the detailed mapping in 2005 of silicate asteroid Itokawa by Japan's Hayabusa 1, these new NEO data will give us a better handle on the kinds of targets a deflection campaign might one day confront.

The White House strategy calls for developing a quick-response robotic recon and characterization capability, designed to obtain critical composition and physical information on a threatening NEO. Build one of these craft every decade; if no impact threatens, NASA could launch it to study a NEO type we have yet to see close up.

Do the demo

A pair of the White House NEO strategy goals call for developing methods for NEO deflection and disruption, and leveraging and supporting international cooperation. An ideal way to achieve both is for NASA to fund its portion of the European Space Agency-NASA, dual-spacecraft Asteroid Impact and Deflection Assessment, known as AIDA, which aims to demonstrate the deflection of a harmless NEO in October 2022. If funding can be secured, NASA would undertake the $250 millionDouble Asteroid Redirection Test, or DART, mission. A 500-kilogram DART kinetic impactor would collide with the small moonlet of the binary asteroid Didymos at a speed of about 6 km/s. This hypervelocity bullet would change the orbital period of "Didymoon" around its parent asteroid.

The European Space Agency's Asteroid Impact Monitor, or AIM, craft is to orbit Didymos, study the binary system, and observe DART's collision with the moonlet. Together, these two missions would for the first time demonstrate our society's ability to change the orbit of an asteroid.

In December 2016, ESA's ministerial council chose to not approve AIM for full development, but managers are looking at plans for an "AIMLight" mission costing less than 160 million euros. If AIM can't meet its 2020 launch date, DART could still impact Didymos B, using ground observations to confirm success. However, AIDA is a golden opportunity to demonstrate the international technical cooperation needed to cope with a truly threatening NEO. NASA and the European Space Agency should ensure DART and AIM fly.

The new U.S. NEO policy lays out a sensible road map for impact protection. Says NASA's Johnson, "I think having the strategy done and available for the new administration as it comes in puts us in a good position."

Because asteroid impacts occur so rarely, policymakers might argue that there is no hurry to complete NEO surveys and test a deflection capability. Undercutting that argument is our lack of knowledge: We don't know the orbits of 99 percent of the near-Earth objects that could cause significant, even horrific damage to Earth. We will be struck again, and we should not bet our cities and civilization on the uninformed hope that nothing is headed our way. ★

New blueprint, old dream

Military commanders would love an aircraft that can fly at jet-like speeds, stop on a dime in midair to do whatever needs to be done and then speed off. DARPA, Aurora Flight Sciences and Rolls-Royce may have the answer and it is called LightningStrike. Debra Werner spoke to the designers.

BY DEBRA WERNER | werner.debra@gmail.com

Eight times over the last year, a bizarre-looking aircraft with tilted wings, tilted canards and 24 ducted fans has lifted off the tarmac of a naval facility in Maryland. The unmanned plane weighs just 147 kilograms, but it's designed to prove the feasibility of building an unmanned plane that would be substantially larger and do something no plane of that size has ever done: Hover like a helicopter and fly nearly as fast as a business jet. The closest thing to this planned aircraft, called LightningStrike, would be the U.S. V-22 Osprey tiltrotor, but that aircraft's speed tops out at about half that of a Gulfstream G650 business jet.

Aurora Flight Sciences

Engineers are flying the LightningStrike subscale model to prove that a larger version could hover like a helicopter but approach the speed of a business jet.

"This is the most difficult airplane I have worked on in my long professional life. Nothing like it has ever flown. This is truly a DARPA-hard problem."

– Systems engineer **Carl Schaefer**,
LightningStrike program manager at Aurora Flight Sciences

"This is the most difficult airplane I have worked on in my long professional life," says systems engineer Carl Schaefer, the LightningStrike program manager at Aurora Flight Sciences, the Manassas, Virginia, aviation and aeronautics research company that specializes in unmanned vehicles. "Nothing like it has ever flown. This is truly a DARPA-hard problem."

DARPA awarded Aurora an $89.4 million contract in March 2016 to build a full-scale version of LightningStrike as a demonstrator. The plane has to carry a useful load equal to at least 40 percent of its gross weight, achieve sustained air speeds of 300 to 400 knots, hover with an efficiency of at least 75 percent, which is measured by dividing the aircraft's weight by the amount of power it needs to remain aloft, and demonstrate a lift-to-drag ratio of at least 10, compared with about 18 for a 747.

Schaefer and his team are flying the subscale model, which runs on lithium polymer batteries, to test the design's aerodynamics and fine-tune its avionics and flight control algorithms. The team faces some daunting challenges for the combustion-powered full-scale demonstrator that they plan to start building shortly. The plane must be aerodynamically suited and lightweight enough for its complex role, while packing enough power for vertical liftoff and hover.

The LightningStrike team, which includes Rolls-Royce LibertyWorks and Honeywell International, will build the carbon fiber epoxy composite demonstrator around a single Rolls-Royce AE 1107C turboshaft engine housed in the fuselage. The AE 1107C is the same engine as in the V-22 transports built by Bell Helicopter and Boeing Rotorcraft Systems.

Instead of the AE 1107C engine turning a propeller or rotor, on the LightningStrike it drives a gearbox with three Honeywell 1-megawatt generators that distribute electric power to 24 enclosed fans carried in the plane's tilt-wings and tilt-canards. The three fans in each canard are 27 inches (69 centimeters) and nine fans in each wing measure 31 inches (79 centimeters). Because the fans' propulsive power helps generate lift, engineers were able to size the plane's wings and canards for efficient cruising rather than enlarging them to produce the additional aerodynamic lift for takeoff and landing, a move that saves weight and fuel.

"Once you decouple the [combustion-based] power generation from the propulsive force, you can start integrating those fans anywhere you want on the air vehicle," says Kaare Erickson, chief of advanced propulsion concepts for Rolls-Royce LibertyWorks, the company's advanced research unit in Indianapolis. The Rolls-Royce engine generates electricity that's delivered by wires to motors that weigh a fraction of what combustion engines would weigh. "It enables all kinds of interesting concepts not just for vertical takeoff and landing but for conventional flight as well," Erickson says.

This isn't the first time engineers have tried separating an aircraft's power source from its propellers or ducted fans. In the past, however, that approach made aircraft too heavy for vertical takeoff and landing because engineers had to install additional communications, power conversion and control mechanisms to link the power source with the fans or propellers. Aurora and its teammates eliminated all that equipment as well as the thermal management issues associated with each device by developing LightningStrike's Electric Distributed Propulsion, which relies on three flight control computers to ensure that the appropriate amount of power goes to each of the plane's ducted fans throughout flight.

The Electric Distributed Propulsion creates challenges of its own, though. Rolls-Royce had to figure out how to power electrical generators with an engine that normally provides shaft horsepower to a rotor that has so much inertia it doesn't accelerate or decelerate quickly. "That is a real challenge: managing the turbine engine and the power generation and making sure it all stays cool and the engine is operating at peak efficiency," Erickson says.

Another challenge will be coordinating operation of the 24 fans. Aurora and Rolls-Royce invented hardware and software to monitor the fans' performance to ensure that they start turning in a synchronous fashion and remain synchronized. "We can lose a fan or two and still land safely if we ingest a bird," Schaefer says. "But we have to make sure that when a fan drops offline, we don't lose all the fans."

Aurora and Rolls-Royce pulled LightningStrike technology from existing programs wherever possible. The demonstrator's avionics are similar to those of Aurora's Orion medium-altitude long endurance unmanned airplane, while its ground control station software stems from the company's Centaur optionally piloted airplane. Aurora engineers also relied on expertise they gained working on a DARPA contract a decade ago to build GoldenEye 80, which looks like a flying ducted fan.

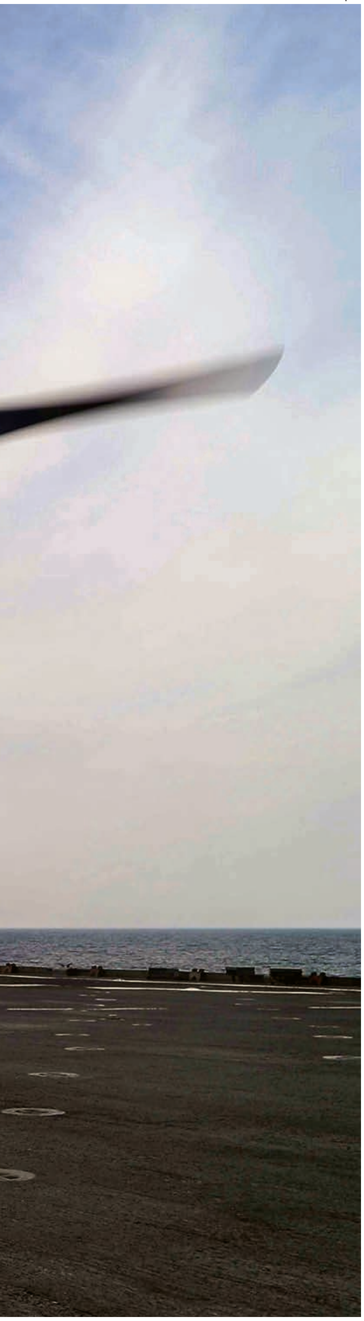
Still, a lot of LightningStrike's hardware and software is brand new, particularly the equipment that distributes electric power throughout the aircraft. To ensure that all the old and new pieces work together, Schaefer and his team planned an incremental risk-reduction strategy.

▼ The V-22 Osprey is the closest thing to the planned LightningStrike but is only half as fast as its targeted speed. Here, a U.S. Marine Corps MV-22 Osprey takes off from the deck of a ship.

The LightningStrike subscale demonstrator, weighing 147 kilograms, takes off at a U.S. Navy facility in Maryland.

Aurora Flight Sciences

U.S. Marine Corps



Since DARPA hired Aurora to build LightningStrike, the agency has allowed the team to release only one video publicly. That video, taken shortly after the contract was awarded, shows Aurora's 20 percent scale model of LightningStrike lifting off, hovering and landing. Since then, the company has flown the battery-powered 147-kilogram LightningStrike model seven more times at the U.S. Naval Air Station Patuxent River's Webster Outlying Field in Maryland.

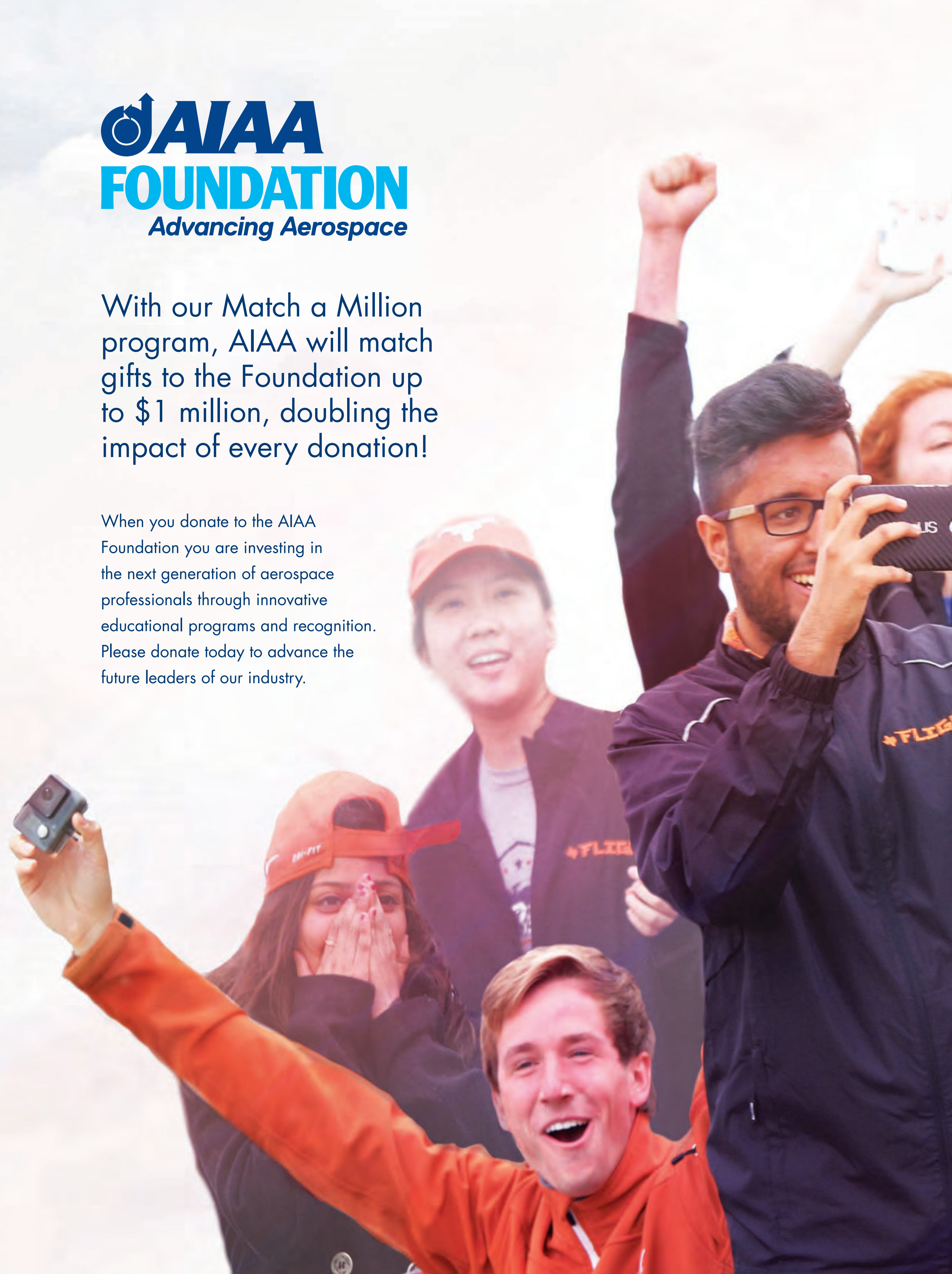
In addition to building the scale model, Aurora set up extensive ground testing equipment. One apparatus emulates the hardware and software that direct power from the Honeywell generators to each fan. Others emulate LightningStrike's landing gear, pumps, valves, and wing-tilt and canard-tilt actuators. Engineers rely on still another apparatus to see that the AE 1107C works with Honeywell's generators and LightningStrike's Electric Distributed Propulsion. "Once we are satisfied that something works, we pull items out of the test rig and it goes right onto the airplane," Schaefer says.

Aurora engineers plan to design, assemble and build the full-size LightningStrike over the next 14 months. "We will have to have an aircraft on its gear ready for engine lightoff in the spring of 2018," Schaefer says. Then, engineers plan to conduct a six- to seven-month series of ground tests at Aurora's Manassas facility and at the Naval Air Station Patuxent River or at Webster Outlying Field before flying at Patuxent River. The company may conduct additional LightningStrike flights at the U.S. Army's Yuma Proving Ground in Arizona.

Schaefer says he's hopeful one of the military services will buy some version of LightningStrike. "We want to refine the airplane a bit more to design it around some operational requirements," he adds. DARPA often pushes technology forward and then hands it off to the Army, Navy, Air Force or Marine Corps to fulfill a military role.

One unique feature of LightningStrike is its excess power. When hovering, the airplane uses 2.7 to 2.8 of its 3 megawatts of available power. When it's cruising, LightningStrike draws only about 1 megawatt, which leaves nearly 2 megawatts of excess power that could be used for sensors, jammers, lasers or weapon systems.

Whether or not anyone buys a version of LightningStrike, Schaefer and Erickson are confident the airplane's aerodynamic principles and propulsion technology will find their way into future military vertical takeoff and landing aircraft or commercial aircraft. "The aircraft was developed purely as a technology demonstrator to explore the art of the possible," Schaefer says. "We see the greatest opportunity for transition in the hybrid propulsion system because it could be adapted very easily for vertical takeoff and landing aircraft or commercial aircraft." ★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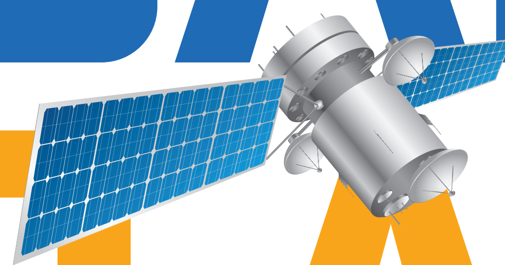

If new and established players in the satellite industry are going to deliver affordable broadband to millions who lack it today, they will need to succeed where others failed. Tom Risen interviewed CEOs and analysts and found evidence for optimism tempered by hard realities.

BAND

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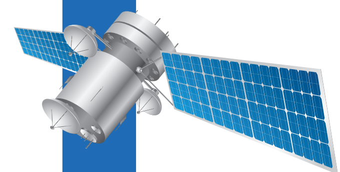


If Iridium's constellation of 66 low-Earth-orbit communications satellites sounds like a lot, try these numbers:

OneWeb, a startup based in the Virginia suburbs of Washington, D.C., plans to launch up to 700 satellites into low-Earth orbit and begin space-based broadband service as early as 2019. Boeing aims to launch 1,300 satellites within six years, and it says it will expand that constellation to 2,900. SpaceX of California told regulators it wants to launch a network of up to 4,425 satellites.

All and all, the International Telecommunication Union, which designates orbital slots for communications satellites, says that it has received 35 filings since 2015 to create broadband constellations, and that more than 25 percent of those filings were related to so-called mega-constellations of up to 4,000 satellites.

The companies want to hook billions of people into broadband internet in parts of the world where today there is no internet and perhaps not even cellular communications. Some think it will be possible to fill broadband gaps in developed countries too, including the U.S., or even to provide a lower-cost alternative to mobile broadband. In essence, the companies are trying to springboard far beyond even what Iridium tried to do in the 1990s with its short-lived plan for equipping millions of consumers with satellite phones. Iridium famously declared bankruptcy in 1999, just a year after activating its network, but re-emerged in 2001 with new investors and a new business plan.

One of those watching today's promised broadband revolution is Iridium CEO Matt Desch, who has been steering the company into new markets, including creation of an airliner surveillance service called Aireon. When he joined Iridium in 2006, some very smart people thought even 66 satellites was crazy and that it was wasteful to put communications satellites in low-Earth orbit.

"I had to sit and listen to my main competitor in the geostationary space tell me all our satellites were in the wrong places because we provided coverage at places like the poles where only penguins and polar bears live," Desch recalls. Now, he says, "we look like small fries" compared to the number of satellites other companies are proposing.

Desch has advice for the newcomers in the market. "You have to be prepared for delays," he warns. "And you need patient capital. You have to be careful about putting too much debt on yourself with people who want to be paid back quickly."

▼ **Iridium is replacing** its original global constellation of 66 cross-linked, low-Earth-orbit satellites with 75 Iridium NEXT satellites, including this one.

Iridium

Confident innovators

The aspiring entrants to satellite broadband feel good about their plans in part because of technical advances in recent years. Engineers can now fit lighter, more powerful electronics into smaller payloads. Lithium ion batteries are more commercially available and pack a charge more efficiently than they used to, including on the Iridium NEXT satellites. Solar cells made of gallium arsenide have also become more effective at converting sunlight to electricity. Gallium nitride power amplifiers, in turn, more efficiently convert electricity into a form that can be used by a satellite's transceiver. Antennas have greater surface precision than they used to, which enables newer satellites to send and receive broadband signals on higher frequencies. Companies such as Rockwell Collins of Iowa are building actively scanned array antennas for OneWeb that electronically steer radio waves in different directions, unlike previous generations of passive arrays that relied on moving protruding horn antennas to mechanically steer signals. New private launch providers such as SpaceX are also making rockets more available at lower prices to firms, including Iridium.

If it's built, will they come?

Even if these massive constellations are launched, however, the biggest challenge could be finding enough customers to pay the bills.

Many customers in the developing world may not want high-speed internet badly enough to subscribe, says Marco Caceres, director of space studies for the Teal Group market research firm. "These companies are essentially talking about radically transforming culture, and that doesn't happen as fast as people often think," he says.

OneWeb CEO Greg Wyler has heard those questions, but he nevertheless exudes confidence.

"Once internet is available to people their intellectual curiosity kicks in," he says, suggesting that demand will follow low-cost availability.

He says tech companies and mobile providers for years have sought new ways to provide affordable internet to unconnected people with the hopes of boosting their services to a global scale.

Wyler learned the challenges of building space-based broadband after founding O3b Networks, which he sold last year to Luxembourg-based SES, a firm best known for operating geostationary communications satellites. Wyler came up with the name O3b as shorthand for the "other 3 billion," a reference to those in Africa, the Middle East, Asia and Latin America who live where fiber optic infrastructure is poor or cell towers are too far away for broadband. Customers of O3b, today mainly in the Pacific islands, are connected to the internet via a cable modem that is routed to the office of their telecom provider. A cell tower linked with the telecom office connects with the O3b satellite, which extends the reach of their network by relaying a broadband signal from a distant internet server. The existing O3b satellites provide coverage that is specific to a certain area, while OneWeb plans to launch hundreds of satellites and take that mission of connectivity to the next level.

By 2022, OneWeb aims to bring online the estimated 2 million schools in the world that have little or no access to the internet, especially those in Africa, Asia and Latin America.

This will take time. "Unless you are ready to go in for the long haul, there is no way you are going to succeed," Wyler says of satellite broadband.

"You also need a lot of luck," he says, alluding to unforeseen delays such as satellite malfunctions, extra costs of doing business or even a rocket explosion.

Wyler says his investors, including SoftBank, Qualcomm and Coca-Cola, are patient financiers who are looking for long-term relevancy instead of short-term gain, which will accommodate any potential delays or extra costs. Iridium has been through the long haul, and is now focused mainly on markets other than those of the other proposed low-Earth-orbit constellations. The company was squeezed into bankruptcy partly because terrestrial broadband networks were established faster than many expected when the Iridium business plan was formulated in the 1990s.

Iridium rose from bankruptcy in 2001 with new investors and shifted away from consumer broadband and toward businesses with global reach including the airline, defense and maritime industries. The U.S. military, for instance, saw the opportunity to connect soldiers and commanders by using the global communications network and created the network known as the Distributed Tactical Communications System. Iridium's 850,000 subscribers include deep-sea fishermen, field scientists, explorers and other travelers in remote areas, but its growth plan is focused on connecting infrastructure, not merely people.

"We don't really go after the consumer market because the cost-benefit is a different business case that has yet to be proven by OneWeb and others," Desch says.

In January, a SpaceX Falcon 9 rocket launched 10 Iridium NEXT broadband satellites in the first of a series of launches through 2018 that will replace Iridium's existing constellation with 75 new satellites. Iridium announced in mid-February that its second mission of 10 Iridium NEXT satellites is scheduled to launch in mid-June.

Untapped market

The costs of network access are a major reason that nearly half of the approximately 7 billion people in the world have little to no internet connection, according to the International Telecommunication Union. Even

A Falcon 9 lifts off Jan. 14 with 10 Iridium NEXT low-Earth-orbit satellites.

SpaceX

in the U.S., 34 million people — or 10 percent of the country — lacked access to broadband-speed internet in 2015, especially in rural areas where it is difficult for providers to build infrastructure, according to the latest report from the Federal Communications Commission.

Tom Stroup, president of the Satellite Industry Association trade group, says geostationary satellite companies are investing in the proposed low-Earth-orbit constellations to boost their network coverage, but that some new entrants to satellite broadband will also compete with each other for the same customers.

Financing will be a major hurdle, but integrating the new business models into a crowded telecom sector will be an ongoing challenge. The proposed Boeing Global Broadband System constellation and OneWeb's network of satellites would operate similarly. Consumers would connect their cellphones and computers to broadband by linking with a satellite through their service provider's router. That satellite would in turn relay a broadband signal to the consumer by rebroadcasting it from a nearby cell tower. Keeping these networks running will require licenses from regulators and likely deals with businesses in numerous countries.

How they work

Iridium's satellites each have cross-link antennas that relay signals among each other, enabling the company to provide global coverage with fewer satellites than those proposed by newcomers to the broadband market. Neither OneWeb nor Boeing will equip their satellites with cross-link communication. Iridium customers, including their existing satellite phone users, will be able to connect to the internet directly from an Iridium NEXT satellite if they buy a portable modem to tap into their network.

OneWeb aims to focus on consumer broadband, especially in unconnected and underserved areas. Boeing will seek a wider range of customers by marketing to both commercial and government users.

OneWeb and SpaceX, which described its plans in less detail than other companies, would use many hundreds of satellites that will be about the size of a refrigerator. Specifically, OneWeb's will weigh up to 150 kilograms before launch and the SpaceX satellites will weigh up to 400 kg. Boeing does not specify the weight of its proposed satellites, but they are widely expected to fall within the small satellite class, meaning less than 500 kg. The new Iridium NEXT satellites are the size of a small car and weigh 800 kg.

Keeping order in orbit

Reliable technology is a key factor not just for consumer convenience but the safety of other objects in orbit. Satellites in low-Earth orbit have exhibited a roughly 10 percent failure rate on average, according to estimates by Desch and Caceres. This raises concerns about a dramatic increase in space debris that

▼ **Since Matt Desch** became Iridium CEO, the company created an airliner surveillance venture called Aireon.

Iridium

"WE DON'T REALLY GO AFTER THE CONSUMER MARKET BECAUSE THE COST-BENEFIT IS A DIFFERENT BUSINESS CASE THAT HAS YET TO BE PROVEN BY ONEWEB AND OTHERS." — IRIDIUM CEO MATT DESCH

could result if thousands of new satellites are launched and even a fraction of them malfunctioned.

Decades of space missions have cluttered orbit with pieces of debris ranging from derelict satellites to flecks of paint. The U.S. Air Force estimates more than 23,000 man-made objects orbit Earth every day, so it keeps a close watch to ensure they don't collide with other nearby objects. Companies will have to coordinate their orbits to keep their satellites out of harm's way and prevent low-Earth orbit from becoming a dangerous junkyard.

Wyler says OneWeb's satellites will use the latest electronics to build redundancies and guard against failures in orbit.

"Space is not a dumping ground for junky satellites," Wyler says. "We do not intend to have a 10 percent failure rate, or anything near that."

Low-Earth orbit in particular is becoming crowded in terms of both physical space and airwave frequencies to run broadband networks. The International Telecommunication Union says 25 percent of the 35 filings to create broadband constellations were related to so-called mega-constellations, which typically have more than 800 satellites. Companies filing to create these satellite networks include OneWeb, SpaceX, O3b, Canada-based COMMStellation, and Boeing.

The U.N. communications agency must grant approval for any company to run a satellite broadband network, and the Federal Communications Commission does the same by vetting operations on U.S. airwaves. Iridium gained these permissions in the 1990s before launching its first constellation.

OneWeb in 2012 received approval from the International Telecommunication Union to use spectrum for its broadband network. The U.N. agency requires OneWeb and every other company that receives these permissions to ensure that its signals do not interfere with antennas in the orbits below theirs. If the agency continues this vetting process to plan orbiting slots and spectrum use, then the thousands-strong constellations could be able to broadcast internet without drowning out the signals of neighboring satellites.

Newly appointed FCC Chairman Ajit Pai said during an open meeting of the commission that he aims "to bring digital opportunity to all Americans," adding that the commission is reviewing requests from companies including Boeing, SpaceX and OneWeb to provide spectrum to serve customers in the U.S.

OneWeb last year began working with companies including Qualcomm to prepare OneWeb's satellites for launch, including by performing radiation and thermal cycling tests on each of its components in a vacuum chamber. The satellite communications firm has contracts with Arianespace of France to launch its first set of satellites into orbit in March 2018, with 20 other scheduled launches from 2018 through 2020. Caceres says Boeing and SpaceX could be forced to limit their ambitions, because launch capacity is unlikely to grow sufficiently during the next five years. There may not be enough rockets to meet the demands of existing customers and also accommodate the thousands of new broadband satellites.

"When companies come out with huge [proposals like these] the number of satellites usually goes down later on," he says. "Maybe a few hundred would be more reasonable."

These firms may also consider merging their broadband efforts to ease the burden of managing thousands of satellites, rather than competing for a wireless consumer market that is still evolving in developing countries, Caceres says.

"I would not be surprised if you had a merger between SpaceX, Google and OneWeb because they are envisioning essentially the same system," he says.

Partnerships with existing mobile communications companies would also make it easier to sell broadband in the U.S., but it is unclear whether these companies will share airwaves with the satellite firms or seek to claim that increasingly scarce digital real estate for themselves.

SoftBank, the parent company of Sprint that recently announced a $1 billion investment in OneWeb, says it is working with the satellite firm to explore how to bring affordable broadband to rural areas in the U.S.

Whatever lies in store for these constellations, it is clear that getting into space will only be the beginning. ★

The main body of an **O3b communications satellite**, before being loaded into a Soyuz launcher. The company plans eight more satellites for its current constellation.

O3b Networks

STALL RECOVERY

It's rare for a passenger plane to plummet earthward in an aerodynamic stall, but the next time it happens, the FAA wants the pilot to be ready. Simulation companies, airlines and business-plane operators are racing to meet an FAA mandate for stall-recovery training. Henry Canaday found an industry that is grappling with two radically different technical approaches to the problem.

BY HENRY CANADAY | htcanaday@aol.com

A pilot begins recovery from an encounter with low altitude wake turbulence during training in a Gulfstream G550 simulator.

FlightSafety International

Despite very different circumstances, a common thread runs through the fatal crashes of a Colgan Air aircraft near Buffalo, New York, in February 2009 and of Air France Flight 447 off Brazil just four months later. In each case, the plane lost lift and fell through the sky, with the pilot's reactions inadequate to save the plane from this aerodynamic stall. The aviation world was stunned that 377 people could lose their lives in a span of months because airline pilots, who are among the most selectively recruited and best trained of airmen, could not recover from stalls under admittedly difficult and confusing conditions.

These events precipitated years of discussion and rulemaking by FAA about the need to train pilots to recover from stalls in those rare cases when they fail to avoid this deadly form of upset. Now, just two years before a tough new FAA mandate on airlines is set to go into effect, simulation companies and airlines are pursuing two divergent technical approaches. One approach requires obtaining test-flight records from aircraft manufacturers, while an alternative relies on computational fluid dynamic models, wind tunnel tests and other data.

How did we get here?

Historically, student pilots have practiced stall recovery in light aircraft early in their training curriculum. Later, in a simulator designed to replicate a passenger plane, they would train for stalls only to the point of activating a horn, buzzer or stick shaker, a mechanical vibration in the control yoke that warns the pilot.

"It was thought that was good enough," explains Dann Runik, executive director of advanced training at FlightSafety International, a New York-based company that builds simulators and operates dozens of learning centers around the world for pilots of airliners and business planes.

In the view of most observers, Air France and Colgan Air proved that this traditional approach was inadequate. The U.S. Congress in 2010 ordered the FAA to enhance pilot training. In 2012, the FAA issued an "Advisory Circular" listing recommended steps pilots should take if they find themselves in a stall. In 2013, the FAA released a final rule that required U.S.-certified airlines to begin training their pilots on recovery from stalls and other upsets by March 2019 and train all their pilots by the end of March 2020. To improve safety, many business aircraft operators also seek this training. In announcing the final rule, the FAA noted an irony: Just a month before the Colgan crash, the agency, in accordance with the federal rulemaking process, had issued a notice of proposed rulemaking for training

The FAA required U.S.-certified airlines to begin training their pilots on recovery from stalls and other upsets by March 2019 and train all their pilots by the end of March 2020.

improvements. Vulnerability to stalls also has been a concern in Europe, and since May 2016, the European Aviation Safety Agency, or EASA, has required all European airline pilots to receive training, chiefly in stall detection and prevention.

Meeting the mandate

Why is the FAA mandate still two years off? One reason is the complexity of simulating the interactions of a specific model of plane during a stall and recovery. Most stalls begin as nose-up incidents. If a pilot raises the plane's nose and wings too high relative to the direction of flight, called a high angle of attack, or AOA, the air flowing across the wings separates from the surface. This reduces lift and increases drag, and the plane starts to fall. The exact angle at which a stall begins depends on the type of plane, airspeed, banking angle, air density and many other considerations. FlightSafety's Runik says his company takes into account about 120 parameters to create a full-stall simulation, which is one that spans from the start of a stall through recovery.

To convey the scope of the problem ahead of the mandate, David Gingras, vice president of Bihrle Applied Research, a 26-person company in Virginia, estimates that today only about five simulators out of 100 or so full-flight simulators in the U.S. contain the data necessary for full-stall simulation. No one has an exact count, because the industry does not keep an official record of simulators and their attributes.

The FAA has put the cost of upgrading these simulators for scheduled airlines at about $80 million.

As yet, there is no consensus about the best strategy for updating all those simulators. Some airlines and simulation companies are talking with aircraft manufacturers about the availability and cost of obtaining stall data collected during testing of each

▼ **The cockpit** of a flight simulator for Bombardier C Series regional jets. A Bombardier executive says the C Series cockpit design organizes some information differently in an effort to make it easier for pilots to recover from stalls.

CAE

model of plane. Before a new kind of plane carries passengers, manufacturers typically fly an instrumented test version to the brink of stall, or in some cases past stall, and record the data.

Obtaining that data is FlightSafety's strategy, and the company has started with the business-aircraft market. Its simulators can now emulate Gulfstream and Dassault business jets and Pilatus turboprops. The first such data obtained came from a partnership with Gulfstream, and the experience afforded lessons for FlightSafety. "It was massive data we never had before and nearly choked our computers," Runik says. It took seven months of data cleaning and computer upgrades to exploit the data wealth, but now it takes much less time to load new aircraft data.

To apply the same approach for the airlines, the firm says it will have to obtain test data from more manufacturers, including Boeing, Airbus, Bombardier, Embraer and ATR. FlightSafety is now in discussion with airline prospects, and will be seeking test data from manufacturers.

Training for recovery

FlightSafety starts its full-stall training by teaching pilots to distinguish stalls from other potential sources of upset, including wind shear, wake turbulence and the buffeting that can happen when a subsonic plane approaches Mach 1. In some cases, pilots have only four to five seconds to recognize the specific threat and begin correct recovery actions.

If the plane is in a stall, pilots must immediately reduce AOA. Therefore, one key is for a pilot to always know the AOA. This angle is not displayed in most aircraft, so FlightSafety trains students to derive AOA from the flight path vector shown on the attitude director indicator cockpit display or on the head-up display, if the plane is equipped with one. AOA is the difference between the pitch of the nose and the flight-path vector.

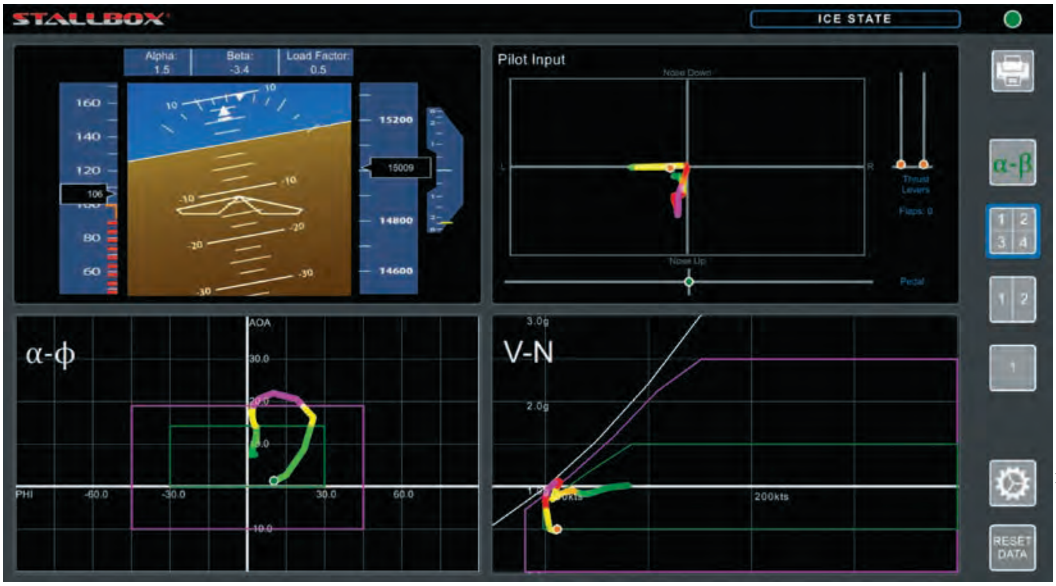
If the vector is unavailable on these displays, the firm trains students to estimate AOA using pitch and vertical velocity. For example, descent to an airport at approach speed yields a vertical velocity of about 700 feet per minute, roughly a minus-3.0 degree flight-path angle. If pitch is positive 3.0 degrees, the AOA would be about 6.0 degrees.

Apart from slowness in identifying and reacting to dangers, Runik says the most common error happens when stalls occur close to the ground, as in a banking or circling approach. "They see trees rushing up, and the reflex is to pull back on the stick." That is a fatal reflex in a stall.

Runik cautions against relying on stall warning and recovery aids in the cockpit, even though full-flight simulators replicate stick pushers, the software that automatically moves the stick forward

▼ **CAE says it is focusing** its simulators on meeting the European goals of detecting and preventing stalls. Here is the company's 7000XR Series Flight Simulator.

CAE



Bihrle Applied Research

This is a rendering of the screen of the tablet instructor displays on a StallBox, which attaches to a simulator for training pilots to recognize and recover from a stall.

to reduce the AOA, and stick shakers, the vibration alert. "Stick pushers and other stall-avoidance equipment can be defeated by icing on exterior sensors," he says.

Runik says pilots who have been through the company's stall recovery course want to retain "muscle memory" of its lessons, so would like a refresher course every one to two years.

Compromise might be needed

Nick Leontidis, CAE's group president for civil aviation training, says it will be able to meet FAA's mandated 2019 and 2020 deadlines, provided it gets the manufacturer test data in time, and he is hopeful that will be the case.

Manufacturers like Boeing and Airbus devote significant efforts to supporting simulators with accurate test data. Even so, Leontidis worries that data on some older aircraft, for example the Boeing 767, may be difficult to obtain. He says the FAA might have to compromise on its recommendation of validating simulations with aircraft-specific flight test data. Luckily, a simulator can be loaded with other aerodynamic data, and a company can be confident that a stall recovery simulation derived this way will be fairly accurate, Leontidis says.

So far, CAE has been doing well with business-aviation operators. TAG Aviation Holdings, one of Europe's largest aircraft management companies, and another large-fleet European operator, have selected CAE as their training partner. And Dassault has endorsed the firm for upset training to meet the EASA standards.

CAE is focusing first on meeting the European goals of detecting and preventing stalls. "A lot can be taught without data validation," Leontidis says. "The main emphasis of our training is teaching the science of what causes a stall and the conditions to avoid." The training includes a four-hour simulation session.

Alternative approach gains traction

Another firm and an airline are moving forward with a different technique, and one that was blessed last year by the FAA. Rather than obtaining actual stall data from manufacturers, Bihrle Applied Research combined its years of experience with military planes with data from computational aerodynamics models and its wind tunnel capabilities. This data was loaded into a separate computer that the company calls a StallBox. This computer was then plugged by Ethernet cable to an Alaska Airlines simulator that replicates the airline's Boeing 737-800 aircraft. The StallBox alleviates the need to upgrade the computing power of the simulator. Last May, Alaska Airlines announced that the FAA had certified this simulator for training pilots to recognize and recover from stalls.

"We showed stall modeling could be done separate from [manufacturer] data," Gingras says.

Gingras predicts that data may be unavailable for older aircraft like the Fokker 100, and he says it may be of limited value in many other cases. A stall simulation derived from a small number of actual stalls may be accurate only for those stalls. "The aircraft may not stall that way all the time," he says.

Although the FAA approved the StallBox only for the 737, Bihrle is working on versions for the Airbus A320 and A330 and Gulfstream G450. He says the firm is receiving many inquiries about its stall model and instructor display as the 2019 deadline gets near. Gingras notes that manufacturer validation data has always been an FAA recommendation, not a requirement, for simulation training. "We provide an alternative." ★

Hydrazine is the devil that the satellite industry knows. It's a toxic, carcinogenic liquid, but one that has flawlessly maneuvered satellites for decades. Keith Button previews a satellite experiment that could prompt a shift away from hydrazine.

Green propellan

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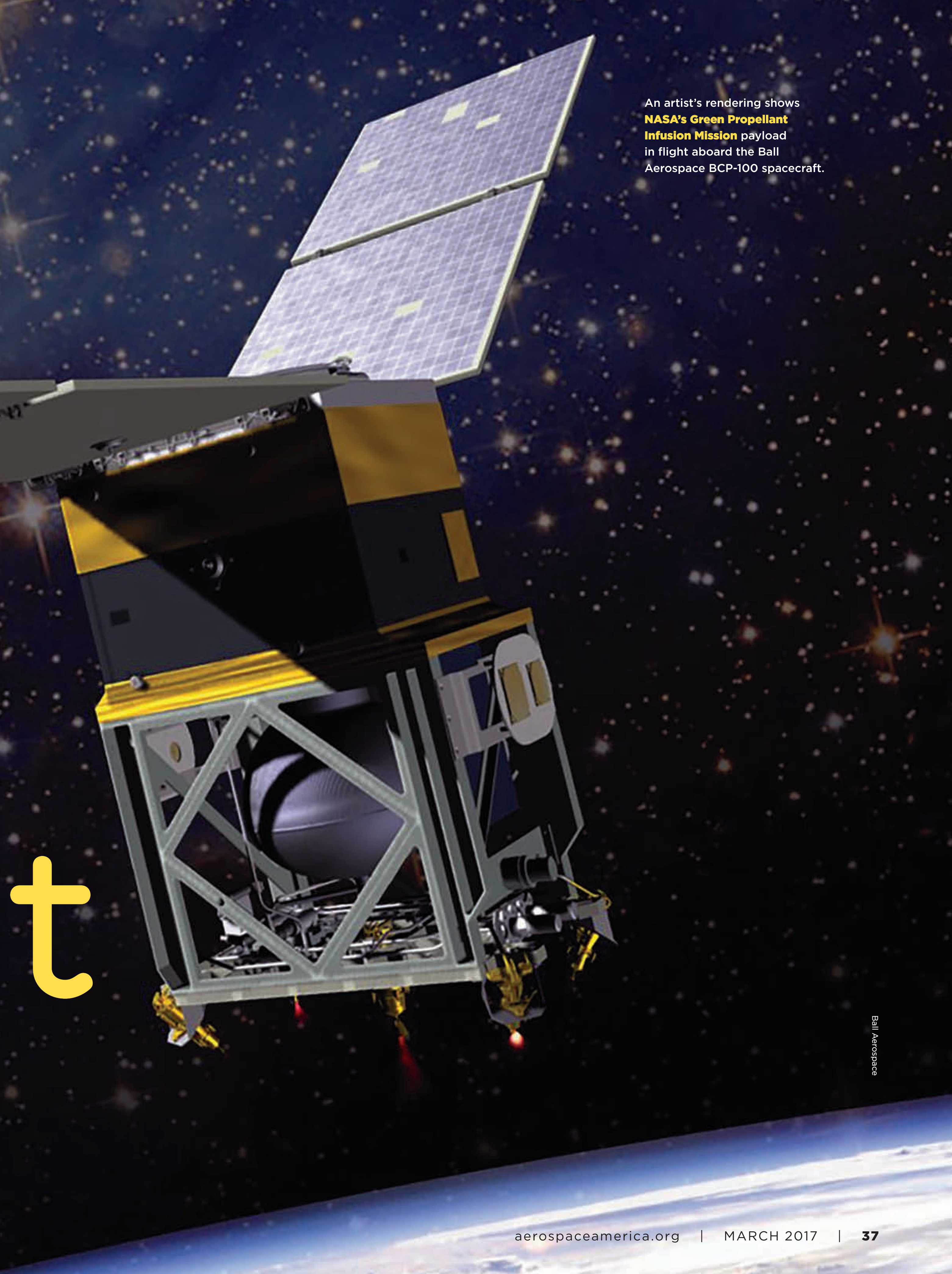


An artist's rendering shows **NASA's Green Propellant Infusion Mission** payload in flight aboard the Ball Aerospace BCP-100 spacecraft.

Ball Aerospace

At NASA Glenn Research Center's combustion laboratory in Ohio, laser operators projected green-tinted light beams into a vacuum tank depressurized to simulate space. The lasers lit up the exhaust plume from a satellite thruster as high-speed digital cameras recorded the scene to map the chemicals in the plume.

These tests in 2014 of a new liquid propellant for satellites marked a turning point in a 15-year effort by the U.S. Air Force and NASA to wean the industry from thrusters that maneuver spacecraft by releasing hydrazine gas, an ammonia-smelling, toxic chemical. Among the problems with hydrazine are that it's carcinogenic and is classified in the most hazardous category of propellants. Extensive precautions must be taken during production and pre-launch propellant loading.

In January, Ball Aerospace of Colorado completed construction of the Green Propellant Infusion Mission, or GPIM, spacecraft that will test the newly conjured propellant and Aerojet Rocketdyne components designed to accommodate it. Engineers were anxious to start the NASA-managed mission this year, but the launch on a SpaceX Falcon Heavy rocket along with other payloads will likely be pushed from September to March 2018 due to the backlog left by last year's launch-pad explosion of a SpaceX rocket.

At the moment, the $54.1 million GPIM is in storage in a Colorado cleanroom, but once in orbit it will fire its five thrusters repeatedly through a set of rigorous test objectives over the span of 13 months. The thrusters must point the spacecraft accurately; halt the spacecraft's motion when controllers intentionally make it tumble; change its altitude as commanded; and operate even when the propellant tank is nearly empty or after being left idle for several months.

If all goes as planned, GPIM might convince the often risk-averse space industry to "infuse" the propellant and new components into future satellites as a hydrazine alternative.

Building the GPIM spacecraft was not as simple as loading different chemicals aboard. Engineers had to design and ground test entirely new propellant tanks, fuel lines and valves. Aerojet Rockedyne devised a new kind of catalyst bed, which is the chamber where the liquid propellant is turned into gas via chemical decomposition. The gas is then expelled from the chamber through the nozzle to impart force on the spacecraft.

At NASA Glenn, engineers measured the size and shape of the exhaust plume partly for GPIM but more so for designers of future satellites who must avoid accidentally directing the exhaust onto solar arrays and optics.

Hydrazine is familiar

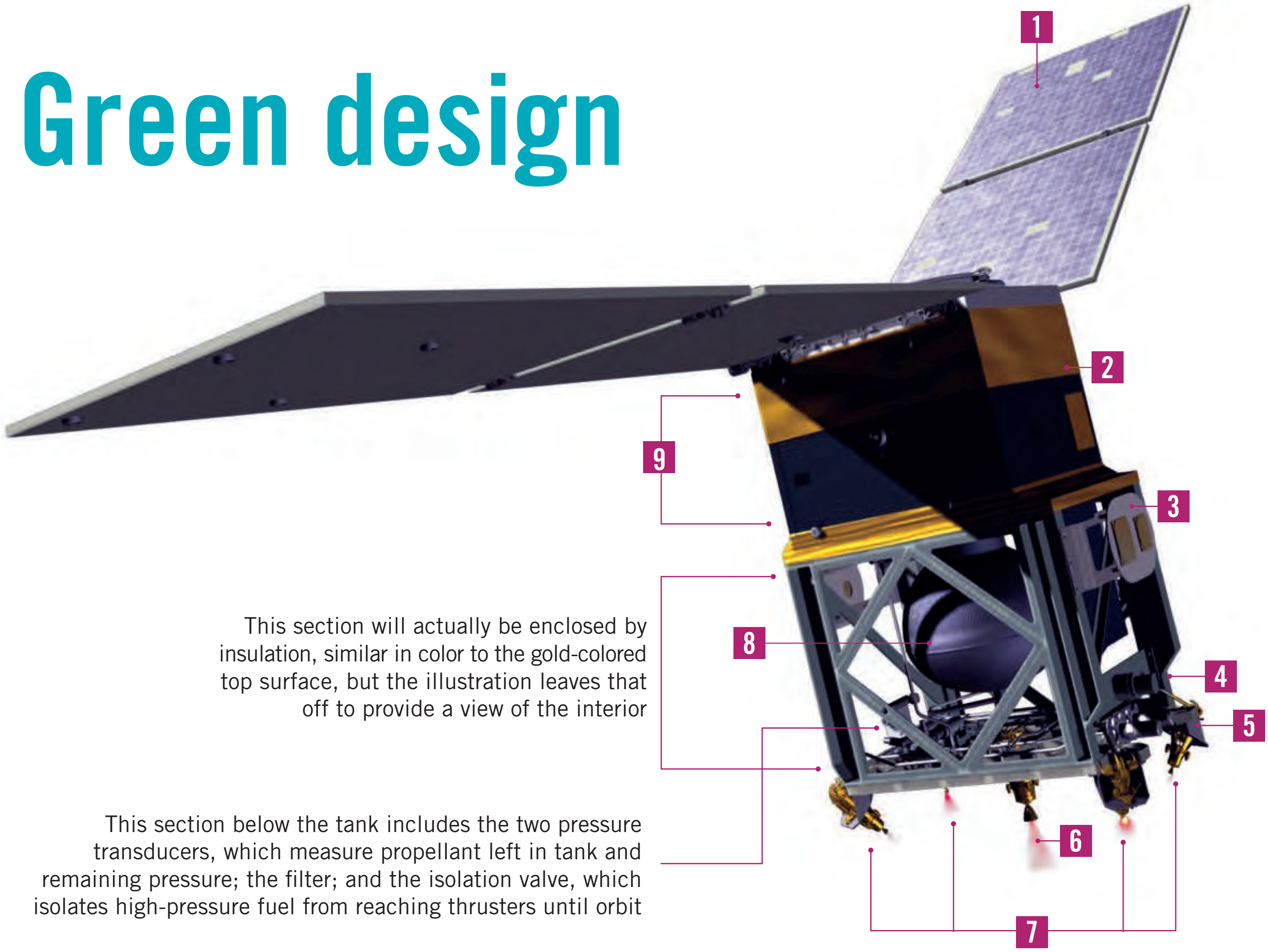
In addition to its handling risks, hydrazine is quick to evaporate and difficult to store. Despite all that, hydrazine is the dominant propellant for orbiting spacecraft, says Ball Aerospace's Christopher McLean, who is the GPIM principal investigator.

The green fuel, designated AF-M315E, is a hydroxyl ammonium nitrate fuel/oxidizer blend. Advocates like McLean enjoy contrasting it to hydrazine. When loading hydrazine onto a satellite, workers must wear positive-pressure haz-mat suits. When handling AF-M315E, they need only lab coats and splash visors. Drinking hydrazine would kill you but a bit of AF-M315E would be no more dangerous than ingesting an equivalent amount of aspirin. Hydrazine must be carried in explosion-proof tanks. The new liquid can be stored in plastic bottles and shipped via FedEx. Hydrazine fires are "incredibly nasty," McLean says, but if the new propellant leaked onto a fire, it would put it out.

A 2012 Ph.D. dissertation by Christyl Johnson, now NASA Goddard's deputy director for technology and research investments, found that green fuel processing and handling costs for a Swedish PRISMA demonstration space mission were $437,955 less than the equivalent costs for hydrazine. The U.S. Department of Transportation is reviewing proposed rules for the green fuel so that spacecraft builders can ship fully fueled, ready-to-launch green-propellant spacecraft across the country. The only step required at the launch site would be pressurizing the fuel tanks.

Perhaps the biggest advantage of the green fuel over hydrazine is its performance benefits. The green fuel is 45 percent more dense than hydrazine, meaning that a smaller volume of the fuel could substitute

Green design



1 SOLAR ARRAY
Recharges battery to supply electrical power

2 SPACECRAFT BUS
(Ball Configurable Platform) BCP-100. Contains mission payloads, power, attitude control, communications and star-tracker

3 S-BAND ANTENNA
Transmits and receives data; communicates control information from ground. There's another one on opposite side

4 FILL AND DRAIN VALVES
Where propellant is loaded and tank is pressurized

5 SAFE AND ARM PLUGS
Disable power commands to thrusters when a satellite is on the ground; connect power for mission

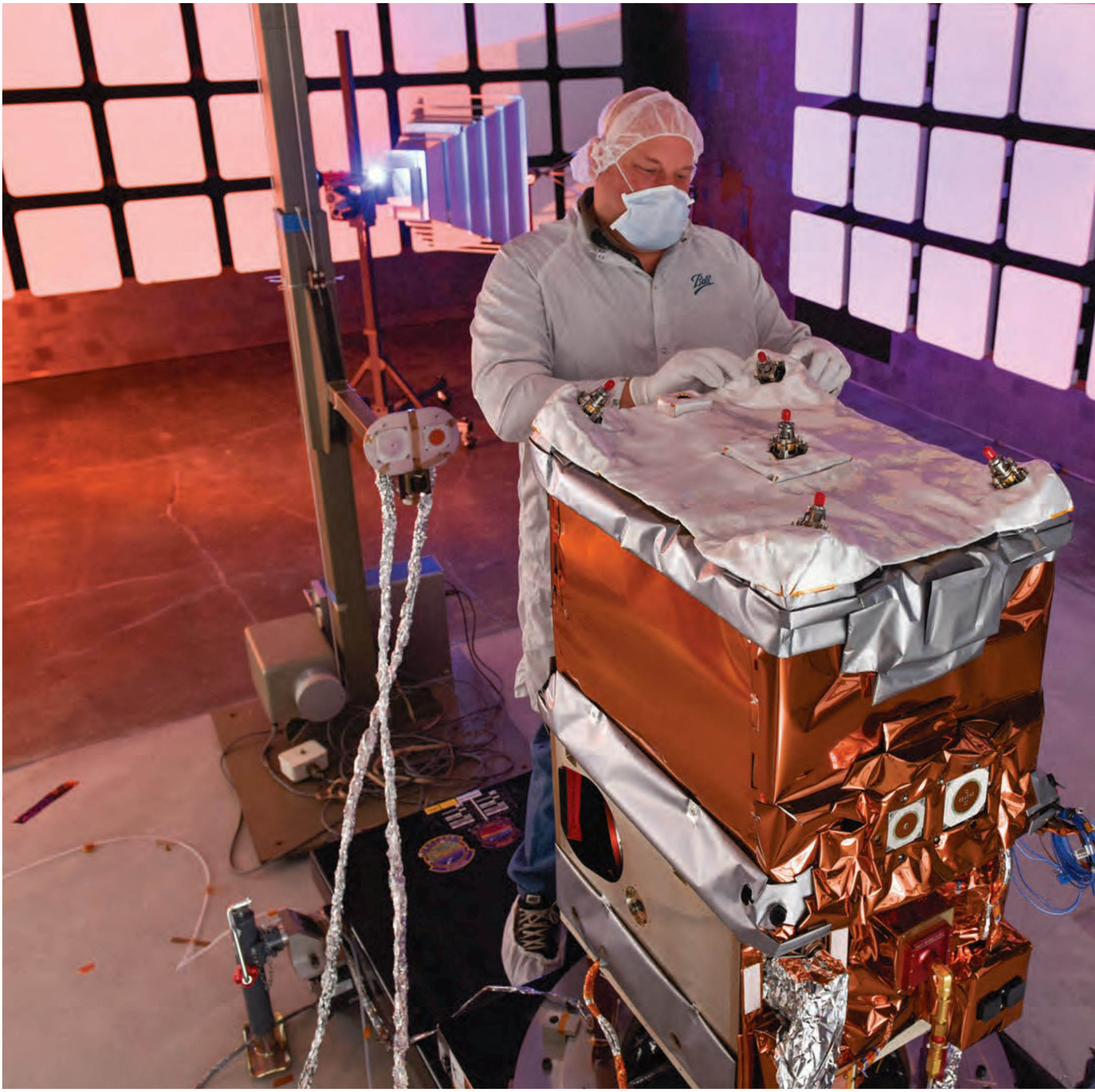
6 DELTA-V THRUSTER
1-newton thruster propels spacecraft. Positioned in center

7 4 ACS (ATTITUDE CONTROL SYSTEM) THRUSTERS
Angled at 90 degrees to each other; control attitude. Also 1-newton each. Positioned on the corners

8 PROPELLANT TANK
Mission begins with 14.5 kilograms of an Air Force-developed fuel

9 GOLD AND BLACK SURFACES
Tailored to radiate heat as required by specific missions

Source: Ball Aerospace



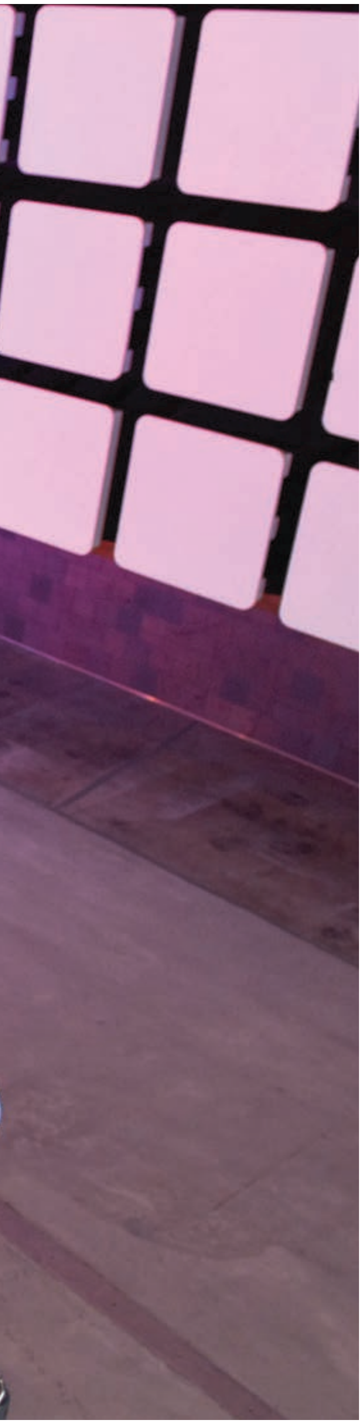
for hydrazine on a given spacecraft, and it generates 12 percent more thrust per pound of propellant, McLean says. Combined, the green fuel boosts performance by nearly 50 percent over hydrazine.

"In an industry where you're always chasing that 1 or 2 percent better, 50 percent is pretty attractive," says Julie Van Kleeck, vice president of advanced space development for Aerojet Rocketdyne, which designed and built the fuel tank, valves, lines, catalyst bed and thruster nozzles.

Solar-electric propulsion is another so-called "green" alternative for spacecraft and incredibly fuel efficient, generating 2,000 to 3,000 seconds of specific impulse, a measure of thruster efficiency, compared to 257 seconds for the green-fuel monopropellant and 235 seconds for hydrazine, McLean says. But because solar propulsion produces such minute amounts of thrust, it is better suited to beyond-Earth-orbit spacecraft that can take weeks or months to perform a maneuver.

The main challenge for NASA and proponents of the green monopropellant fuel is to convince

▲ **An engineer adjusts** the thermal insulation on NASA's Green Propellant Infusion Mission spacecraft bus. GPIM is scheduled to launch in September 2017, but a crowded launch schedule could delay it.



Ball Aerospace

"In an industry where you're always chasing that 1 or 2 percent better, 50 percent is pretty attractive."

JULIE VAN KLEECK

vice president of advanced space development for Aerojet Rocketdyne, commenting on the green fuel's increased thrust per pound

space mission planners that the alternative fuel and its thrusters, which have never flown in space, won't fail. Hydrazine is well-understood, as are its effects on components.

"It's very complex getting these new systems accepted on spacecraft, by the spacecraft user community, especially when you're talking half-billion-dollar geocom assets and can we actually put new technology on them," McLean says. Almost all of today's commercial Earth-orbiting spacecraft are propelled by 1960s-era thruster designs. New fuels have "a lot of inertia to overcome," he says.

One key to acceptance is flight heritage: showing that a green-fuel-powered spacecraft has flown in orbit — starting with a single flight — without failing. "That gives us the ability to point back and say, 'Hey, we've been through everything it takes to get this thing manufactured, integrated, processed, launched and operational,'" McLean says. "Every single one of those [steps] is a huge hurdle to overcome technically."

Another key is providing data from the testing involved in the development steps to other spacecraft designers to make it easier for the designers to accept and incorporate green fuel propulsion in their own plans, says Matt Deans, a NASA co-investigator on GPIM.

"We have our technology valley of death, where you can develop a lot of new technologies on the ground, but when you go to fly them, you have to convince the mission planners to risk their multimillion-dollar instrument or a human life on a new technology, versus a technology that's been proven in space many times," Deans says.

When designers start digitally building their rough models for a new spacecraft, Deans says, one of the first steps is to map out where the thrusters will go — typically four pointing at 90 degrees to each other for attitude control — along with the thruster exhaust plumes — ice cream cone shapes coming out of the thrusters representing "keep-out zones" for any part of the spacecraft that could be damaged by the chemicals, heat or forces in the exhaust.

The shapes and chemical makeup of hydrazine exhaust plumes are well-known, after decades of study, but the exhaust plume of the green propellant had never been characterized, Deans says. Liquid hydrazine breaks down easily through catalytic decomposition — passing over an iridium catalyst bed inside the thruster to create an exothermic reaction producing extreme heat with nitrogen and hydrogen gases, along with other small molecules, pushed out through a nozzle to generate thrust. The liquid green propellant also passes over an iridium catalyst to produce a similar chemical reaction, but with gasses with larger molecules, which can bounce off each other and push smaller molecules farther out to produce a wider-shaped plume. Also, water is one of the chief components of the green fuel's exhaust, which could form ice on, or corrode, or cloud up a spacecraft surface within the exhaust plume.

"You have on many spacecraft very sensitive optics, and the last thing people want is water getting on their optics in the cold of space, because then you're seeing ice," Deans says.

Mapping exhaust plumes

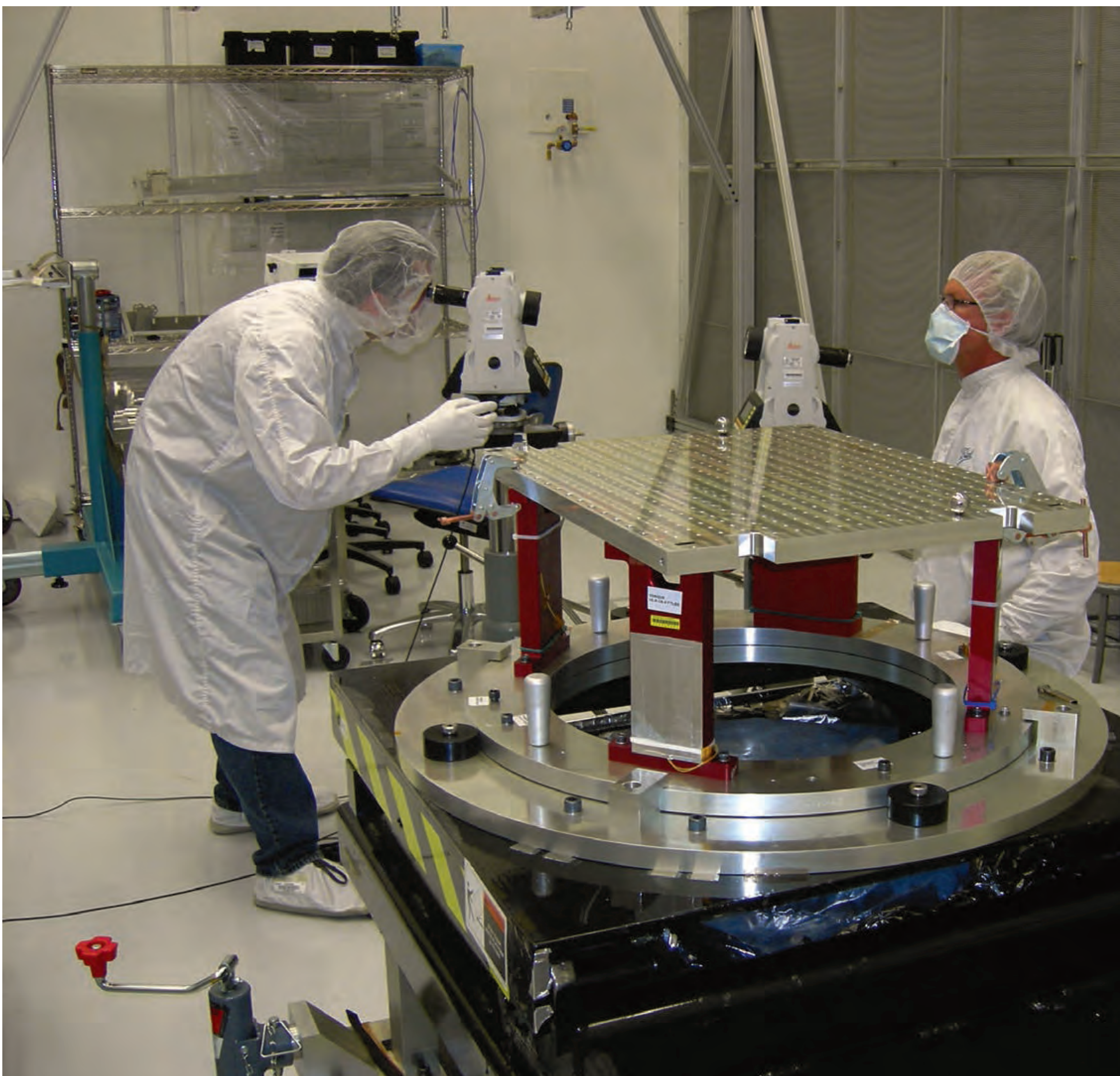
At the Glenn Research Combustion Laboratory, NASA engineers tested the exhaust plume of a green-propellant 22-newton thruster built by Aerojet Rocketdyne to find out what chemicals were in the plume, at what concentrations and where in the plume they were. Mapping the plume was important to show the designers of future green-propellant spacecraft where the potentially corroding or icing chemicals were — those that could harm cameras or solar panels, for example, if the angle of the plume was miscalculated — as well as where forces or heat from the exhaust could bend or otherwise harm instruments on the satellite. Shining lasers of specific light frequencies through the normally clear exhaust plume, with high-speed digital cameras the engineers could identify types of molecules by the range of frequencies of energy the molecules give off. They also marked the edges of the plume with Schlieren imaging, shining a bright light through the plume and recording the bending of the light passing through the plume with digital cameras. Then they checked the data against computer models, verifying the accuracy of the models and the ability of the computer models to predict other green-propellant plumes.

Deans says they discovered that the plume was generally wider than what a hydrazine plume would be from the same thruster, with the heavier molecules, like water and carbon dioxide, concentrated in the center of the plume and hydrogen on the outside, and with a tiny amount of hydrogen blowing back. At 10 centimeters away from the thruster, most of the exhaust's heat had dissipated.

With the NASA exhaust plume test results, spacecraft designers can now plug the data into their own models for different thruster or nozzle sizes. "It's a tool in everyone's toolkit now," Deans says. "We don't want mission planners to start putting together their spacecraft and say: 'I don't know this; it's too big of a risk for me.' Now, it's: 'Oh, yeah: I have this nice little cone I can drop in my model.'"

"It's one less thing for them to be concerned about when they build their missions," Deans says. "We really wanted it so that when people go to plan this in future missions, nothing is really keeping them from saying: 'I want to use this propellant.'"

▼ **Ball Aerospace** technicians work to ensure that the thrusters on the Green Propellant Infusion Mission satellite are aligned correctly.



Another difference between hydrazine and the green propellant is their flow characteristics: Hydrazine is like water; the green propellant is more like motor oil. Engineers at the NASA Goddard Space Flight Center built green-fuel delivery systems — with filters, valves and bended tubes — to assess the pressure and flow characteristics of each component. They also tested the propellant for slosh loads in tanks, which, for large volumes of liquid, could break tanks away from their moorings because of vibration during launch, or push a spacecraft slightly off course as the liquid in zero gravity resists moving in concert with the rest of the spacecraft, McLean says.

The Air Force Research Lab at Edwards Air Force Base in California, which invented the green propellant about 15 years ago, tested the green fuel to determine how much pressure it could withstand before it explodes.

"The Air Force tests it until it blows up, and then they say OK, don't exceed this pressure," McLean says. "Those guys have a lot of fun."

will slow enough to fall back to Earth, and burn up, within 25 years. During its 13-month mission, the GPIM spacecraft will fire its thrusters during the first two months, then during one month in the middle of the mission and then for one month at the end, ending up at about 425 kilometers before shutting down. GPIM engineers will measure the health of the 1-newton thrusters in orbit by firing them during 200-millisecond impulses over various fuel pressures, then charting the rotational rates of the spacecraft to infer how much torque the firings generated.

Among all the engineering hurdles for the green propellant, probably its biggest — a high combustion temperature — was cleared before the GPIM program started in 2012, McLean says. As with hydrazine, the green monopropellant exothermically decomposes as it passes over a bed of iridium-coated ceramic pebbles or sand in the catalyst chamber of the thruster. Hydrazine's combustion temperature is 800 degrees Celsius; the green fuel's combustion temperature is 1,800 degrees Celsius, and it needs to be heated before it will react with the catalyst.

"We have our technology valley of death, where you can develop a lot of new technologies on the ground, but when you go to fly them, you have to convince the mission planners to risk their multimillion-dollar instrument or a human life on a new technology, versus a technology that's been proven in space many times."

MATT DEANS
a NASA co-investigator on GPIM


Ball Aerospace

NASA engineers at Goddard took the Air Force lab's pressure test results to run a "water hammer" analysis. That term refers to the shock waves caused by fluid flow starting and stopping suddenly in fuel lines, such as when isolation valves are opened in space to allow the liquid propellant to flow into the lines connecting the tank to the thruster's catalyst chamber for the first time, and then when the valves for the fuel lines are opened and closed during each firing of the thruster.

GPIM, a Ball BCP-100 satellite frame about 97 centimeters tall, will be released at about 725 kilometers above the Earth, then fire its thrusters to drop to an orbit below 650 kilometers to ensure that it

Aerojet Rocketdyne developed a proprietary ceramic catalyst bed material, along with new materials for the walls of the thruster's reaction chamber, that can withstand the 1,000-degree temperature differences. Without the new ceramic material, the catalyst would melt and burn up in 2 to 10 seconds, McLean says, and GPIM wouldn't have been possible.

For material and process engineers, solving the extreme temperature problem and understanding its nuances was "either a nightmare or their best day, if they liked challenges," says Van Kleeck of Aerojet. "It's an engineering problem; it's not that you have to have brand-new science. But it's not an easy engineering problem to solve." ★

AIAA Bulletin

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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			
4–11 Mar†	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	
6–9 Mar†	21st AIAA International Space Planes and Hypersonic Systems and Technology Conference	Xiamen, China	22 Sep 16
17–18 Mar	Region VI Student Conference (San Jose State University Student Branch)	San Jose, CA (https://www.aiaastudentconference.org/)	
20–21 Mar	Region II Student Conference (Mississippi State University Student Branch)	Starkville, MS (https://www.aiaastudentconference.org/)	
25–26 Mar	Region III Student Conference (University of Michigan at Ann Arbor Student Branch)	Ann Arbor, MI (https://www.aiaastudentconference.org/)	
29 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (http://www.aiaa.org/CVD/)	
5–7 Apr	Region VII-Europe-Pegasus/AIAA Student Conference (Masters Division Only)	Berlin, Germany (https://www.aiaastudentconference.org/)	
7–8 Apr	Region I Student Conference (University of Virginia Student Branch)	Charlottesville, VA (https://www.aiaastudentconference.org/)	
7–8 Apr	Region V Student Conference (Metropolitan State University of Denver Student Branch)	Denver, CO (https://www.aiaastudentconference.org/)	
18–20 Apr†	17th Integrated Communications and Surveillance (ICNS) Conference	Herndon, VA (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, http://i-cns.org)	
20–21 Apr	Aircraft Noise and Emissions Reduction Symposium (ANERS)	Alexandria, VA	
25–27 Apr	AIAA DEFENSE Forum (AIAA Defense and Security Forum), Featuring: – AIAA Missile Sciences Conference – AIAA National Forum on Weapon System Effectivenss – AIAA Strategic and Tactical Missile Systems Conference	Laurel, MD	4 Oct 16
25–27 Apr†	EuroGNC 2017, 4th CEAS Specialist Conference on Guidance, Navigation, and Control	Warsaw, Poland (Contact: http://www.ceas-gnc.eu/)	
29–30 Apr	Region IV Student Conference (University of Houston Student Branch)	Houston, TX (https://www.aiaastudentconference.org/)	
2 May	2017 AIAA Fellows Dinner	Crystal City, VA	
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	3rd AIAA CFD High Lift Prediction Workshop	Denver, CO	
3–4 Jun	1st AIAA Geometry and Mesh Generation Workshop	Denver, CO	
3–4 Jun	Optimal Design in Multidisciplinary Systems Course	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

†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
5–6 Jun	Cybersecurity Symposium at AIAA AVIATION Forum	Denver, CO	
6–7 Jun	DEMAND for UNMANNED at AIAA AVIATION Forum	Denver, CO	
6–9 Jun†	8th International Conference on Recent Advances in Space Technologies (RAST 2017)	Istanbul, Turkey (Contact: www.rast.org.tr)	
7–9 Jun	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)	
10–12 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – 53rd AIAA/SAE/ASEE Joint Propulsion Conference – 15th International Energy Conversion Engineering Conference	Atlanta, GA	4 Jan 17
20–24 Aug†	2017 AAS/AIAA Astrodynamics Specialist Conference	Stevenson, WA	24 Apr 17
22–24 Aug†	International Conference on Aerospace Science and Engineering (ICASE)	Islamabad, Pakistan (Contact: http://www.ist.edu.pk/icase)	
12–14 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition)	Orlando, FL	23 Feb 17
13–16 Sep†	21st Workshop of the Aeroacoustics Specialists Committee of the Council of European Aerospace Societies (CEAS)	Dublin, Ireland	
25–29 Sep†	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	
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
3–10 Mar †	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	

2017 Key Issues

As the world's largest aerospace professional society, serving a diverse range of more than 30,000 individual members from 88 countries, and nearly 100 corporate members, AIAA urges Congress to enact and sustain policies that will enhance a robust, technologically-proficient aerospace and defense (A&D) sector that is essential to our continued national competitiveness and security.

The A&D industry is critical to our nation's well-being, providing major contributions to national defense and homeland security, the economy, our quality of life, and education and learning. According to the Aerospace Industries Association's December 2016 "The Strength to Lift America: The State of the U.S. Aerospace & Defense Industry" the sector's economic impact from 2013 to 2015:

- Supported 1.7 million jobs within businesses producing end-user goods and services;
- Generated nearly $605 billion in sales revenue;
- Created a total economic contribution of $301 billion, or 1.8 percent of the GDP;
- Provided tax revenue of $62.6 billion to federal, state, and local governments;
- Exported a record $142 billion in goods, which is 9.5 percent of all U.S. exports; and
- Provided a top net exporting industry with a positive trade balance of $81.6 billion.

To keep our technology edge, we must continue to invest in research and development and our workforce in an effort to compete with growing investments by other nations, including our adversaries. Stable and predictable funding for key A&D agencies and programs is critical to sustaining, growing, and remaining the global leader in this industry.

The adequacy and size of the U.S. STEM workforce is an ongoing concern for the A&D industry. Scientists and engineers are essential to U.S. innovation and economic growth. It is also critical to note that many middle-skilled jobs, such as those in advanced manufacturing, require an ever-increasing array of STEM skills and competencies. A 20 September 2016 article in The Hill newspaper, "A Decade is Too Long to Wait," suggested that 1.6 million STEM-literate workers will be needed in the next five years.

For the last 20 years, Aviation Week & Space Technology has conducted and published an annual A&D Workforce Study. The 2016 report highlighted the challenges for maintaining and building a strong A&D workforce, citing the aging baby boomers, the hiring and retaining of the most talented youth, and the need to diversify the talent pool to meet the economic expansion of the industry. AIAA encourages Congress to promote policies that will provide a growth-sustaining path for the A&D industry workforce pipeline.

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

AEROSPACE & DEFENSE BUDGET FUNDING AND PROCUREMENT

Issue Area: Funding Instability

The A&D industry is facing one of its greatest challenges in history as Congress and the administration deal with mounting national debt and balancing the federal budget. All federal agencies face significant budget reductions, with the DOD potentially bearing the biggest burden. At the same time, our adversaries are investing heavily in military modernization, while the United States confronts significant strategic risks due to continuing budgetary uncertainty and the potential return in Fiscal Year 2018 of the arbitrary budget caps of the sequestration process. While all areas must be examined to identify unnecessary spending that can be reduced or eliminated, we must ensure that the nation's future is not compromised by a lack of action today.

Moreover, the usage of continuing resolutions, passage of omnibus appropriations packages, and threat of government shutdowns have become commonplace. The last year all twelve appropriations were passed by Congress prior to the start of the new fiscal year was in 1996. A return to a regular appropriations process is needed immediately so that the nation, including the A&D industrial base, can begin work on initiatives critical to a robust and secure future.

- Constant funding via continuing resolutions impedes new research, the development of new products, the start of new programs and missions, and the ability to make required scope changes in a timely manner.
- An irregular and uncertain budget process impacts long-term planning, work prioritization, staff hiring and development, and getting products to their users in a timely manner.

- Funding disruptions increase cost, decrease quality, stretch schedules, hamper competition, impact the warfighter, and decrease commercial competitiveness.

Recommendation: Return to regular order, permanently eliminate sequestration, and provide adequate operational funding to support current military operations.

Issue Area: Take Longer-Term Perspectives

A vigorous and robust U.S. aerospace industry requires support that is agile enough to address changing technologies and a stable stream of funding across multiple fiscal years. The current unpredictable budgetary environment creates short-term perspectives where aerospace initiatives are delayed and under constant threat of scope reductions or termination.

Foundational and applied research can take many years to be included in the design of a new aerospace product. The infrastructure required to support this research and the development of new products is costly. The infrastructure required to produce aerospace products is complex and expensive and is often developed in conjunction with the product. A long-term perspective is essential to the health of the A&D industry and for all the benefits it provides to the nation.

Recommendations:

1. Provide DOD with stable and predictable funding that allows industry to meet the needs of national security current and future missions.
2. Provide long-term authorization and appropriations with top-line increases in the out years to properly fund NASA missions in a balanced manner in order to meet short- and long-term program and mission requirements. This will help maintain our nation's leadership in space exploration and scientific discovery, while also helping to make critical advances in technology development and aeronautics research.
3. Provide long-term authorization and appropriations with top-line increases in the out years to properly fund the FAA in order to successfully implement the Next Generation Air Transportation System, commercial space transportation operations, safely integrate unmanned aerial vehicles into the National Airspace System, and complete other priority FAA modernization initiatives.

Issue Area: Invest in Research and Development

According to the Aerospace Industries Association, U.S. government research and development (R&D) spending as a percentage of Gross Domestic Product (GDP) has fallen by 60 percent since 1964. The American Association for the Advancement of Science cites an even greater decline in federal spending as a percentage of GDP for R&D facilities of over 70 percent since 1976, which has limited the physical capabilities used to accomplish this work. Over this same time frame, and especially since the end of the Cold War, A&D industry consolidation has further reduced R&D investment. China's R&D investment, however, is the fastest growing of all advanced countries. The A&D product pipeline is being impacted by reduced R&D investment, causing our nation to fall behind our foreign competitors and placing our physical and economic security at risk.

Aeronautics research, in particular, has declined significantly over the last two decades to $640 million in fiscal year 2016. By comparison, fiscal year 2004 funding was $1.3 billion in constant dollars. Investments in aeronautics have improved aviation safety dramatically, made air travel affordable for most Americans, and significantly diminished the environmental impact of aviation through reduced community noise and emissions. Adequate funding and a long-term commitment to aeronautics R&D is essential if the United States is to continue developing revolutionary capabilities for the nation's future aviation systems that will transform and reinvigorate the A&D industry.

Recommendations:

Invest in experimental (ground and flight testing) and computational infrastructure for military and commercial R&D. This provides improved quality and reduced system development costs and timelines by providing the right tools for qualified staff to identify and remove defects early in the development process.

1. Promote greater interaction and cooperative arrangements between federal labs and research centers, industry, and academia. Tight budgets tend to drive parochial decisions while a systems view will drive idea sharing, enhanced utilization of capabilities, improved quality from using the right tools, and optimization and cost control at the system (national) level.
2. Consider legislation that increases tax incentives for corporate research.
3. Increase DOD's R&D budget to ensure the United States' qualitative technical superiority and long-term technical leadership.
4. Support robust, long-term federal civil aeronautics research and technology initiatives funded at a level that will ensure U.S. leadership in aeronautics.

AEROSPACE & DEFENSE WORKFORCE ENHANCEMENT

Issue Area: Workforce Preparation

Education and Career Training: Provide opportunities within the educational system to support and grow STEM K–12, adult education programs, and workforce initiatives that build a foundation of skills to be globally competitive in the 21st century.

- Ensure a balanced portfolio for STEM-dependent agencies with student programs, grants, fellowships, internships, co-op programs, apprenticeships, job shadowing, and teacher development programs. These agencies include DARPA, DOD, NASA, NSF, etc.
- AIAA applauds the 114th Congress's passage of the Every Student Succeeds Act and the American Innovation and Competitiveness Act.

Recommendations:

1. Continue to pass legislation that enhances the pipeline of STEM-competent workers into the U.S. economy, such as reauthorizing, modernizing, and providing appropriations for the Perkins Career and Technical Education Act.
2. Encourage industry to participate in STEM educational, training, and development programs for the incoming, existing, and transitioning workforce.

Diversity: Support initiatives that stimulate, encourage, and promote participation of underrepresented populations, specifically females and ethnic minorities, to major in STEM fields for higher education.

- According to the Aviation Week 2016 Workforce Study, the percentages of ethnic minorities and women working in A&D have remained unchanged, at less than 25 percent, for decades. Targeting underrepresented populations will open a broad talent pool of candidates to help solve the nation's skilled workforce shortage.
- Research shows that workforce diversity in organizations improves innovation; boosts ability to solve challenging problems; and increases return on investment.

Recommendation: Promote comprehensive initiatives that expand the capacity and diversity of the STEM workforce pipeline.

Issue Area: Maintaining and Retaining a Skilled Workforce

Collaboration: Promote sharing of information and facilitate exchange between industry, government, and academia.

- Collaborations would emphasize skills with cutting-edge technology such as: advanced manufacturing, information technology, control systems, cybersecurity, and autonomous systems.
- Emphasizing cutting-edge technology would more actively engage young professionals and new STEM graduates in trending, emerging career paths, i.e., making the A&D industry more attractive to the millennial generation.
- Small businesses are vital to the A&D industry. Incentivizing training collaborations between small businesses and large primes would ensure training is easily accessible and flexible to meet the increasing standards and requirements for the A&D workforce.
- Mechanisms should be put in place to encourage industry to support the transition of retiring A&D workers to new, contributing roles, such as training, teaching, and mentoring.
- Expand programs like the DOD Information Technology Exchange Program.

Recommendations:

1. Ensure federal incentives and/or grants are readily available to support industry, government, and academic partnerships that tailor training for high-level skills and provide research-focused collaborations.
2. Direct more temporary personnel exchange between government, industry, and academia in the A&D sector, and provide incentives for stakeholders to participate in these activities.

Veterans: Transition qualified military veterans to civilian A&D careers.

- Provide a seamless transition for veterans to enter the A&D workforce at the proper career level thus maximizing recruitment of a valuable resource.

Recommendation: Incentivize industry and the military to be more directly engaged with evaluating and hiring transitioning military personnel, such as creating a standard to process and categorize military skill sets.

Issue Area: Foreign Professionals in STEM Fields

Highly skilled, foreign-born workers educated at U.S. colleges and universities in STEM fields are engines of entrepreneurship and economic growth. Legislation like the STEM Optional Practical Training Program, which allows foreign-born STEM graduates up to 36 months of qualified employment, and the I-Squared Act of 2015, which would raise H-1B visa caps and exempt those who hold advanced STEM degrees from counting against the caps, represent productive approaches to realizing the needed high-skilled workforce.

Recommendation: Pass visa legislation that encourages the retention of foreign professional STEM workers in U.S. industry.

AEROSPACE & DEFENSE COMPETITIVENESS AND SECURITY

Issue Area: Aviation System Modernization

The FAA Extension, Safety, and Security Act of 2016 is set to expire on 30 September 2017. The law's expiration threatens several projects vital to our nation's future as an aerospace leader, and Congress must provide long-term reauthorization with adequate funding in order to meet program requirements.

Recommendations:

1. Improve the efficiency, transparency, and timeliness of the aircraft certification process by removing the current overly prescriptive design requirements and replacing them with performance-based airworthiness standards.
2. Provide necessary funding to fully implement the Next Generation Air Transportation System that establishes a modern air traffic management system with the capability to expand and accommodate the growing traveling public.
3. Apply common effects-based community noise standards for supersonic civilian flight over land as is applied to subsonic flight.
4. Establish aircraft emissions regulations, with the FAA as the lead U.S. regulatory agency, that align with those of the International Civil Aviation Organization and the European Aviation Safety Agency. This will allow aircraft manufacturers to comply with one set of standards.

Issue Area: UAS Safety and Integration

Much more must be done to safely, efficiently, and fully integrate unmanned aircraft systems (UAS) into the National

Airspace System. Research and policy discussions are already underway to allow beyond-line-of-sight operations, flights over people, access to higher altitudes, and platforms above 55 pounds. It has been projected that the expansion of UAS technology will create more than 100,000 jobs and generate more than $82 billion to the economy in the first decade following integration into the airspace.

Recommendations:
1. Provide necessary funding for the development and integration of a UAS Traffic Management System.
2. Implement a "risk-based, technology neutral" regulatory framework – rely on a safety risk management process that assesses the entirety of a UAS operation instead of solely regulating a specific vehicle or system.

Issue Area: Commercial Space

The DOD, through the Joint Space Operations Center, provides space situational awareness and conjunction analysis as a byproduct of its mission to protect national security assets in space; however, almost all of these analyses do not involve military spacecraft, but rather commercial. Transitioning these responsibilities to a new lead civil authority will free-up resources for military needs, enhance the safety of space operations, preserve the space environment for future users, and maximize commercial capabilities.

Recommendation: Identify the lead authority for civil space traffic management and authorize adequate resources and information access to develop and implement an overall space traffic management approach.

The level of activity for commercial space operators has grown significantly in recent years. To support this growth, while continuing to ensure public safety, it is essential that the FAA Office of Commercial Space Transportation has the resources that it needs to keep pace with industry's progress. Moreover, as emerging nontraditional commercial space activities increase in frequency and scope, it is imperative that the U.S. government define a process for authorizing and supervising these activities while fulfilling its obligations to the Outer Space Treaty of 1967, as well as identify a lead agency to execute this process. Delaying this task will result in a continued lack of stability, predictability, transparency, and efficiency, and will hinder the development of U.S. commercial space activities.

Recommendations:
1. Ensure the U.S. commercial space transportation industry is supported by a fully staffed and technically robust FAA Office of Commercial Space Transportation to assure expeditious review of permits and preclude delays that could otherwise harm U.S. industry competitiveness.
2. The FAA Office of Commercial Space Transportation should serve as the lead entity to support nontraditional commercial space activities, via an efficient and transparent registration-based regime leveraging the office's expertise and experience in successfully conducting payload reviews via the interagency process.

Issue Area: Promote Aerospace Exports

The U.S. Export-Import Bank is unable to approve transactions exceeding $10 million because its Board of Directors lacks a quorum. Three of five board positions are currently vacant and this has significantly hampered the bank's operations, placing U.S. aerospace companies at a competitive disadvantage in the global market.

Recommendation: Either confirm all open board appointments or allow the bank's two board members to approve transactions in excess of $10 million. The foreign military sales (FMS) process is cumbersome and time-consuming, straining relationships between U.S. producers and their international customers and causing them to procure military equipment from other international producers. This negatively impacts the U.S. economy and jobs.

Recommendation: Reform (streamline and shorten timelines) the FMS process to, at a minimum, make it competitive with the services international customers experience with other producers. A goal should be to level the playing field across a broader range of markets.

Issue Area: Increase Priority of Supersonic/Hypersonic National Defense Capabilities

There are demonstrated international threats resulting from robust investment in research and development, including new ground test and computational capabilities, development of new products across a range of applications, and significant flight testing to validate designs and define remaining needs.

A 2016 report by the National Academies of Sciences, Engineering, and Medicine suggests that China and Russia are demonstrating dramatic strides in hypersonic technology, while the United States is in danger of falling behind the state of the art. Unless greater urgency and cohesiveness are injected into this crucial area of defense technology, the United States will become vulnerable to the threat from a new class of superior high-speed maneuvering weapons.

Recommendations:
1. Provide support for product development that directly counters current and expected threats.
2. Provide incentives for transitioning technologies from the labs to product applications.
3. Ensure the availability of federal research, development, test, and evaluation capabilities, including sustaining/modernizing existing ground test capabilities and providing new and improved test (ground and flight) and computational capabilities targeted at new technologies research and development.

AIAA Congressional Visits Day
Raise the Image of Aerospace in Washington
Congressional Visits Day
Wednesday, 29 March 2017
Every year, AIAA members – engineers, scientists, researchers, students, educators, and technology executives – travel to Washington, DC, for a day of advocacy and awareness with national decision makers. Spend a day meeting with new and established congressional members and their staff.
Your participation, enthusiasm, and passion remind our lawmakers that aerospace is a key component of an economically strong and secure nation. If you are interested in the future of your profession, the advancement of technology, the furthering of scientific research, and the strengthening of our nation's security, this event is for you!
Online and In-Person Training Available
"I continue to participate every year because it's important to me to keep learning more about these pertinent issues and to dedicate my time to help our community develop and grow."
—Kayleigh Gordon, Aerospace Engineering graduate student, Ohio State University
Learn More!
www.aiaa.org/cvd
AIAA
Shaping the Future of Aerospace
17-1428

Richardson Awarded Honorary Fellowship to RAeS

Donald W. Richardson, Ph.D., whose membership in AIAA has spanned 69 years from student to past president to Honorary Fellow, has recently been awarded an Honorary Fellowship in the Royal Aeronautical Society (RAeS) of the United Kingdom "in recognition of the outstanding and lasting contributions he has made to the aerospace industry over a long and exceptionally distinguished career. His specific accomplishments include directing research that led to the development of the concept of area navigation which has now been implemented world-wide as the air traffic control standard. He has also directed the research that integrated rotary wing aircraft into our primarily fixed-wing air traffic control system."

Dr. Richardson's degrees in aeronautical engineering (B.S., Georgia Institute of Technology, 1951; M.S., Newark College of Engineering, 1958; Ph.D., California Coast University, 1978) led to a career in human factors, aircraft design, and air traffic control, including three patents for aircraft cockpit display systems. A licensed commercial pilot with instrument, multi-engine and seaplane ratings, he supplemented his engineering career as a research pilot for the FAA, concentrating on air traffic control operational systems. He is a retired Vice President of SAIC, where he was responsible for all corporate civil aviation activities. His election to the Presidency of AIAA (2004–2005) and the Council of the RAeS (2012–2015) reflect the respect in which he is held by colleagues and peers across the international aerospace community of which he is an eminent and distinguished member.

Dr. Richardson and his wife Kathleen Watkins-Richardson operate Donrich Research, Inc., based in West Palm Beach, which is a woman-owned small business with capabilities in technical aerospace issues, business strategy, and conflict resolution. In addition, Dr. Richardson serves on the Advisory Board of the FAU (Jupiter campus) Lifelong Learning Society.

The RAeS has been honoring outstanding achievers in the global aerospace industry since 1909, when Wilbur and Orville Wright received the Society's first Gold Medal. The list of Honorary Fellows includes other notables such as Donald Douglas, Igor Sikorsky, Winston Churchill, Theodore von Karman, Norm Augustine, and Alan Mulally.

Paxton Students Have Fun with STEM at Science Night

The K–12 STEM Outreach Committee would like to recognize outstanding STEM events in each section. Each month we will highlight an outstanding K–12 STEM activity; if your section would like to be featured, please contact Supriya Banerjee (1Supriya.Banerjee@gmail.com) and Angela Diggs (Angela.Spence@gmail.com).

Paxton School students from pre-K to high school were engaged in exciting STEM activities at the 29 November Science Night, coordinated by AIAA Educator Associate Heather Stewart. The science-themed night was held in conjunction with a home basketball game and students had the opportunity to participate in various science activities throughout the night's game, including piloting a flight simulator with the assistance of Major Justin "Astro" Elliott, a U.S. Air Force test pilot; launching straw rockets with AIAA Associate Member Dr. John Fay, a scientist with the U.S. Air Force Lifecycle Management Center at Eglin Air Force Base; and trying their hand taking photos with a thermal imaging camera with Rob Wilson, an engineer with FLIR.

In addition, students operated Sphero robots, got their hands dirty with oobleck, attempted to knock cups off a cheerleader's head with an air cannon, made aerospace artwork out of Wikki Stix, and even took science selfies. Students collected tickets for completing STEM lessons (two if they brought a parent along!) and over 550 tickets were entered into the halftime drawings.

The AIAA Northwest Florida Section provided STEM professionals to teach students and donated a Sphero robot to give away at halftime. FLIR provided a STEM professional and donated a thermal imaging camera as a prize.

Generation STEM

With support from the Lockheed Martin Corporation, the AIAA Foundation hosted its third Generation STEM event in conjunction with the 2017 AIAA SciTech Forum in Grapevine, TX. The program hosted more than 250 middle-school students in an effort to inspire and motivate the next generation of aerospace professionals. Students had the opportunity to hear about an aerospace career from Lockheed Martin's CTO and member of the AIAA Foundation Board of Trustees, Dr. Keoki Jackson. The students also engaged in mini-design competitions and challenges, viewed engaging demonstrations from various aerospace companies, learned more about aerospace careers, and discovered aerospace findings that are impacting everyday life. For more information and to engage in the AIAA Foundation, please visit www.aiaafoundation.org.

New AIAA Student Branches

Two new AIAA Student Branches were charged during AIAA SciTech Forum. They are:

- Universidad Autonoma de Baja California (UABC) (Region VII, but supported by the AIAA University of San Diego Student Branch in Region VI)
- Polytechnic University of Puerto Rico (Region II)

Congratulations AIAA Class of 2017 Fellows and Honorary Fellows



Photos from AIAA Aerospace Spotlight Awards Gala 2016

2017 Honorary Fellows

Natalie W. Crawford, *RAND Corporation*
Alan H. Epstein, *Pratt & Whitney*
Bradford W. Parkinson, *Stanford University*

2017 Fellows

Naval Agarwal, *The Boeing Company*
Karl Bilimoria, *NASA Ames Research Center*
Thomas Butash, *Innovative Aerospace Information Systems*
N. Jan Davis, *Jacobs Technology, Inc.*
Ari Glezer, *Georgia Institute of Technology*
Steven Griffin, *The Boeing Company*
Naira Hovakimyan, *University of Illinois at Urbana-Champaign*
Eric Loth, *University of Virginia*
Frank Lu, *University of Texas at Arlington*
Roger McNamara, *Lockheed Martin Corporation*
Daniel Miller, *Lockheed Martin Corporation*
Gary Polansky, *Sandia National Laboratories*
Richard Powell, *Analytical Mechanics Associates*
Mark Psiaki, *Virginia Polytechnic Institute and State University*
Lesa Roe, *NASA Headquarters*
Heidi Shyu, *U.S. Army (ret)/Heidi Shyu, Inc.*
George Sowers, *United Launch Alliance*
Ben Thacker, *Southwest Research Institute*
John Valasek, *Texas A&M University*
Julie Van Kleeck, *Aerojet Rocketdyne*
Todd Zarfos, *The Boeing Company*

AIAA Fellows Dinner

Tuesday, 2 May 2017
Hilton Crystal City
Arlington, Virginia

AIAA Fellows and Honorary Fellows are invited to join us to celebrate the Class of 2017 at the AIAA Fellows Dinner.

Reception: 1830 hrs

Dinner: 1930 hrs

Attire: Business

Tickets: $130/each

By Invitation Only

More information and registration:

www.aiaa.org/FellowsDinner2017

"The work and leadership of AIAA Fellows and Honorary Fellows consistently ensures that today's aerospace dreams become tomorrow's realities."

– James Maser, AIAA President

AIAA
Shaping the Future of Aerospace

Obituaries

AIAA Senior Member Hoult Died in November

Charles P. Hoult passed away on 23 November 2016. He was 82 years old.

Mr. Hoult was educated at MIT and UCLA. In 1958 Charles Hoult was initiated into the sounding rocket business as a freshly commissioned U.S. Air Force Second Lieutenant assigned to Air Force Cambridge Research Laboratory in Bedford, MA. After leaving the service in 1961, he continued his sounding rocket work at AFCRL until 1968. His AFCRL responsibilities included systems engineering for, and flight test of, new sounding rockets.

His experience covered the spectrum of sounding rockets from Nike-Cajun through Aerolab Argo D-4. From 1968 to 1971 he worked on the Aerobee and Astrobee sounding rocket families while employed by Space General in El Monte.

From 1971 through 1973 he was employed by Space Vector Corp., Canoga Park, working on the Aries guided sounding rocket and various guidance and attitude control systems. As a consultant he continued to work on sounding rockets until 1977.

After 1977 he worked for The Aerospace Corp. and TRW (later part of Northrop Grumman), until his retirement in 2007. During these 30 years he supported the Titan launch vehicle and various classified satellite and missile defense projects.

Starting in 2006 he returned to sounding rockets, accepting an appointment as Mentor in the Mechanical & Aerospace Engineering Department at California State University, Long Beach. Most recently, he served as an Adjunct Professor in the same Department.

Mr Hoult was a member of AIAA, the Planetary Society and the Air Force Association. His sounding rocket publications include 17 papers on mission planning, structural loads, trajectory dispersion and postburnout attitude.

AIAA Associate Fellow Parker Died in January

Charles D. Parker Sr., 79 passed away on 4 January.

Mr. Parker was an active participant in the nation's space program from the Apollo program onward. He worked as a design engineer manager for many years on several NASA manned space programs.

Throughout this time, he was an active participant in AIAA, being an active AIAA member since 1978 in the Cape Canaveral Section. Mr. Parker held numerous positions at the local section level. He served as Secretary and Treasurer before assuming the role as Section Chair.

He also served as a member of many of its committees for well over a decade of combined service. He chaired the Honors and Awards Committee for two years, where he was instrumental in creating the Section Outstanding Member Award, the Membership Committee for one year, the Nominating Committee and the Teller Committee for two years each. Mr. Parker was the Section Newsletter Editor for three years, for which the Section received the 1st place award for communication in 1999. He was one of the core group who revitalized the Section after two years of near dormancy.

A member of a design engineering AIAA Technical Committee for three years, he co-authored two publications that were published by AIAA, describing preferred practice in spacecraft system design and formulation of power requirements. In 2011, Mr. Parker received the AIAA Sustained Service Award "For sustained service to AIAA in the promotion and encouragement of activities relating to Aeronautics & Astronautics in Brevard County, Florida."

AIAA Fellow Roshko Died In January

Anatol Roshko passed away on 23 January. He was 93 years old.

Dr. Roshko received a BSc degree in engineering physics from the University of Alberta in 1945. After service in the Royal Canadian Artillery, he became a student at what is now the Graduate Aerospace Laboratories of the California Institute of Technology (GALCIT), where he earned his M.S. (1947) and Ph.D. (1952) degrees. Dr. Roshko spent the rest of his professional career at GALCIT, first as a research fellow (1952–1954) and senior research fellow (1954–1955), then as an assistant professor (1955–1958), associate professor (1958–1962), and professor (1962–1985). He was named von Kármán Professor in 1985, and retired in 1994. From 1985 to 1987, Dr. Roshko served as acting director of GALCIT.

Dr. Roshko made contributions to problems of separated flow, bluff-body aerodynamics, shock-wave boundary-layer interactions, shock-tube technology, and the structure of turbulent shear flows. With aerodynamics researcher Hans Liepmann, he coauthored the widely used textbook *Elements of Gasdynamics*, published in 1956.

Among his many awards were the 1976 AIAA Dryden Lecture in Research Award, the 1998 AIAA Fluid Dynamics Award, and the 2009 AIAA Reed Aeronautics Award. Dr. Roshko was a fellow of AIAA and the American Physical Society.

AIAA Associate Fellow Hardaway Died in January

Lisa Hardaway, a program manager at Ball Aerospace, died on 24 January. She was 50 years old.

Dr. Hardaway earned her B.S. in Aeronautics and Astronautics from MIT, an M.S. in Mechanical Engineering from Stanford University, and a Ph.D. in Aerospace Engineering Sciences from the University of Colorado Boulder.

Dr. Hardaway's career at Ball Aerospace spanned more than 20 years and over a variety of leadership roles. She was the Technical Manager for the Hubble Space Telescope's Wide

Field Camera 3. She later served as the Program Manager for the New Horizon's Ralph instrument, which helped capture the first-ever images and data of Pluto and its moons on the mission's ten-year, three-billion-mile journey.

Dr. Hardaway served as the Chief Engineer for the Orion relative navigation system, and most recently served as the Program Manager for several scientific instrument programs. She was renowned for her leadership, dedication, passion and technical excellence both within Ball and among partners and colleagues around the world. Earlier in her career, she was a structural and mechanical engineer for the International Space Station, FA 18-E/F fighter jet program, NASA's Chandra X-Ray Observatory, and Deep Impact programs.

For her work, Dr. Hardaway was named 2015–2016 Engineer of the Year by the AIAA Rocky Mountain Section. She also won the 2015 Leadership Award from Women In Aerospace.

AIAA Fellow Rosen Died in January

Harold Rosen died on 30 January. He was 90 years old.

After receiving his undergraduate degree at Tulane University, Dr. Rosen earned his Ph.D. in engineering at the California Institute of Technology.

Working as an engineer at Hughes Aircraft/Hughes Space & Communications, Dr Rosen was the force behind the development and launch of the first geostationary satellite, Syncom, in 1963. His use of spin stabilization lowered the weight of the satellite tremendously, allowing the smaller rockets of the time to deliver satellites to a geosynchronous orbit 22,000 miles high.

Syncom led to Early Bird (Intelsat I), which led the multibillion dollar communications satellite industry that had an enormous effect on our culture. The launch of the Hughes-built Intelsat II satellites in 1966–1967 provided voice and TV service across both the Pacific and Atlantic Oceans.

After retiring from Hughes in 1992, Dr. Rosen joined his brother Ben Rosen, the former chairman of Compaq Computers, to form Rosen Motors, which developed a unique hybrid car technology. Using an high-speed flywheel to store energy and regenerative braking along with a gas turbine engine for steady power, their car was successfully road tested. The technology lives on powering Capstone Turbines.

Among Dr. Rosen's many awards were the 1968 AIAA Aerospace Communications Award, the 1973 AIAA Space Systems Award, the 1995 Charles Stark Draper Prize (which he shared with John Pierce), and the 2015 Goddard Memorial Trophy.

FACULTY POSITION
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AFB, DAYTON, OHIO

The Department of Aeronautics and Astronautics seeks applicants for a tenure-track Aerospace Engineering faculty position (preferably at the assistant or associate professor level). The department's most urgent needs are in the following areas: Propulsion, Controls, or Aerodynamics. In addition to an earned Ph.D. in Aeronautical Engineering, Astronautical Engineering, Mechanical Engineering or a related field, the candidate should have a demonstrated or a potential ability in teaching at the graduate level and in conducting independent research for the Air Force and other government agencies. Good communication skills, both oral and written, are essential. Applicants must be U.S. citizens and must currently possess or be able to obtain/maintain a SECRET clearance. If selected, applicants must produce proof of citizenship at time of appointment. Link to full posting can be found at https://www.usajobs.gov.

The Department offers M.S. and Ph.D. degrees in Aeronautical Engineering, Astronautical Engineering, Space Systems and Materials Science. The Department has several state-of-the-art computer and experimental laboratories. Interested candidates should send a resume and the names of three references to:

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Candidates can login and submit a cover letter, CV, research vision, teaching philosophy, and three references at: https://aufacultypositions.peopleadmin.com/postings/1871. Cover letters may be addressed to: Dr. Brian Thurow, Search Committee Chair, 211 Davis Hall, Auburn University, AL 36849. The review process will continue until the positions are filled. Candidates may continue to apply until the search has ended. The successful candidate must meet eligibility requirements to work in the U.S. at the time the appointment begins and continue working legally for the proposed term of employment. Additional information about the department may be found at: http://www.eng.auburn.edu/aero/

Auburn University is an EEO/Vet/Disability employer.

17-1631

1917

March 1 The first production Royal Aircraft Factory S.E.5 rolls off the factory floor in Farnborough, Britain. The S.E.5 is a single-seat biplane fighter built around the new 150-horsepower Hispano-Suiza V-8 engine. This and the later, more powerful S.E.5a become the primary fighters of the Royal Flying Corps, together with the Sopwith Camel. Many of Britain's top aces, including Albert Ball, "Mick" Mannock and James McCudden, fly S.E.5s during their careers. David Baker, **Flight and Flying: A Chronology**, p. 93.

March 16 The Royal Flying Corps uses its massive Handley Page 0/100 heavy bomber for the first time when it raids German-controlled railway yards at Moulin-les-Metz. David Baker, **Flight and Flying: A Chronology**, p. 93.

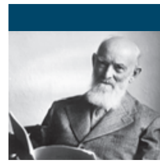
March 21 Britain tests its first Aerial Target, or A.T., at the Central Flying School of the Royal Flying Corps at Upavon, England. The A.T. is an experimental unmanned radio-controlled monoplane, a flying bomb conceived by A.M. Low, and is considered Britain's first guided missile. Low proposed the project in 1915 to the Munitions Inventions Department. He is later given approval and is assigned a team to develop it in secret. During its first test, the engine cuts off prematurely. During the next, it flies for a short time, then crashes. The third test is called a complete success. However, the A.T. never becomes operational. "The First Guided Missile," **Royal Air Force Flying Review**, May 1958, pp. 26-27; A.M. Low, "The First Guided Missile," **Air Pictorial and Air Reserve Gazette**, September 1955, p. 270.

1942

March 3 Britain's Royal Air Force launches its first large-scale air attack against the industrial region of occupied Paris, with Renault the principal target. **Interavia**, Apri1 8, 1942, p. 21.

March 4 The British House of Commons rejects the idea of splitting the air force between the army and navy and instead encourages closer cooperation among the three services. This is brought about by the renewed promise of heavy bombing of Germany. **The Aeroplane**, March 13, 1942, p. 284.

March 7 Rangoon, Burma, is abandoned by British Imperial Forces after a heavy aerial invasion by the Japanese. **The Aeroplane**, March 20, 1942, p. 318.



March 12 Robert Bosch, German inventor and founder of the company that produces gasoline injection pumps for aircraft and other engines, dies at age 80. Bosch invented the magneto and injection pumps for the diesel engine and in 1912-1913 created the first magneto for aviation engines. **Interavia**, March 16, 1942, p. 10.

March 17 Gen. Douglas MacArthur, U.S. commander in the Philippines, arrives in Australia on a Boeing B-17 Flying Fortress and assumes supreme command of the allied forces in Australia. Because of Japan's invasion and occupation of the Philippines, MacArthur shifts his headquarters to Australia as requested by the Australian government and ordered by President Roosevelt. **The Aeroplane**, March 27, 1942, p. 350; W. Manchester, **American Caesar**, p. 304.

March 19 Aerojet Engineering Corp. is formed in Pasadena, California, becoming the second rocket company in the United States. Reaction Motors Inc., which was started Dec. 18, 1941, in Pompton Lakes, New Jersey, preceeded Aerojet. Hungarian-born aeodynamicist Theodore von Kármán is Aerojet's first president. Frank Malina is treasurer; and John Parsons, Edward Forman and Martin Summerfield are vice presidents. Lawyer Andrew Haley is secretary but he takes over the presidency in August. Aerojet is an off-shoot of the Guggenheim Aeronautical Laboratory, California Institute of Technology Rocket Research Project that Malina had begun in 1936 under von Kármán's sponsorship and direction. The Aerojet team has a wealth of experience in rocketry and initially develops solid- and liquid-propellant type Jet Assisted Take Off, or JATO, units. Throughout the war, it continues this work, and becomes the nation's leading developer of low-cost, effective solid-propellant JATOs. Aerojet becomes the world's leading producer of solid and liquid propellants and rocket systems and, through mergers, is today known as Aerojet Rocketdyne. R. Cargill Hall, Editor, **History of Rocketry and Astronautics**, AAS History Series, Vol. 7, Part II, (Univelt Inc., 1986), pp. 194-195.

March 20 Japan's Mitsubishi J2M1 Raiden ("Thunderbolt") prototype naval fighter makes its first flight. Later versions, which the allies call "Jacks," will be heavily armed and built for speed rather than maneuverability, in a break with Japanese aviation tradition. The planes never go to sea but are flown in the southwest Pacific campaign and on the home front as interceptors against the Boeing B-29 attacks that begin in late 1944. Rene J. Francillon, **Japanese Aircraft of the Pacific War**, pp. 388-396; Aviastar.org.

1967

March 7 France's Vesta rocket is launched from the Hammaguir Range in Algeria and carries a macaque monkey named Martine to an altitude of 233 kilometers in an experiment to measure the effects of extreme altitude and weightlessness on reactions of the monkey, who had been trained to push a button in response to a red light. The monkey is recovered when the capsule containing her lands by parachute 157 kilometers from the launch site after the 21-minute flight, and is reported to be in good health. **New York Times**, March 8, 1967, p. 24.

March 8 NASA's Orbiting Solar Observatory, OSO-3, is launched from Cape Kennedy by a three-stage Thor-Delta to study the sun and its influence on the Earth's atmosphere. The 284-kilogram satellite carries nine experiments and its primary purpose is to obtain high-resolution spectral data. The experiments are designed to map the distribution and energy of solar radiation. This is the third of eight spacecraft in the OSO series. NASA Releases 67-32 and 67-52; **Flight International**, March 16, 1967, p. 423.

March 8 The first contract from NASA for a launch vehicle and launch services for a foreign satellite is signed in Paris by Pierre Auger, director general of the European Space Research Organization, or ESRO, and Robert Seamans, deputy administrator of NASA. The contract covers the launch of ESRO's HEOS-A satellite by a Delta vehicle that is scheduled for launch from Cape Kennedy. **Flight International**, March 23, 1967, p. 457.

March 16 The Reaction Motors Division of Thiokol Chemical Corp. presents to the Smithsonian Institution's National Air and Space Museum several World War II artifacts. The gifts are rocket motors developed by the division's predecessor, RMI; the American Rocket Society's ARS Test Stand No. 2; and engines used in the Lark surface-to-air missile and the MX-774 test missile. RMI was the first U.S.-based commercial liquid-propellant rocket company and was formed on Dec. 18, 1941, mainly to develop Jet Assisted Take Off units for the Navy's seaplanes during the war in the Pacific theater. The ARS Test Stand No. 2 is an especially important artifact since James Wyld's regeneratively cooled rocket motor was tested on this stand several times from 1938 to 1941 and led to the formation of RMI. Smithsonian Institution release; Frank H. Winter and Frederick I. Ordway III, **Pioneering American Rocketry: The Reaction Motors, Inc. (RMI) Story, 1941-1972**, AAS History Series, Vol. 44 (Univelt Inc.: San Diego, 2015).

March 17 The Honeysuckle Creek Tracking Station near Canberra, Australia, the newest member of NASA's 16-station tracking network to support coming Project Apollo manned missions, is dedicated by Australian Prime Minister Harold Holt and senior NASA officials. NASA Release 67-65.

March 21 France's Sahara Missile Proving Grounds at Hammaguir in Algeria closes, marking the end of a 20-year history of the site that opened in 1947 and came to include launches of the Veronique and other early sounding rockets, on up to the three-stage Diamant space launch vehicles. Going forward, French launches will be from a new site at French Guiana. **Aviation Week**, March 27, 1967, p. 50.

March 31 U.K.'s Royal Artillery Institution donates two 19th-century war rockets to the Smithsonian Institution's National Air and Space Museum. One is a rocket made by Sir William Congreve (1772-1828) in 1815. The other is a 10.8-kilogram spin-stabilized rocket of 1863 developed by William Hale (1797-1870). Congreve rockets were used against the Americans during the War of 1812 while Hale rockets were used by the Americans during the Mexican-American War of 1846-1848. Some were also used on both sides during the Civil War. Many other countries went on to use Congreve and Hale rockets, though Hale types were last used in the 1890s in British colonial campaigns. Smithsonian release; Frank H. Winter, **The First Golden Age of Rocketry: Congreve and Hale Rockets of the Nineteenth Century** (Smithsonian Institution Press, 1990).

1992

March 17 Soyuz TM-14, with the crew of Alexander Viktoenko, Alexander Kaleri and Klaus-Dietrich Flade of Germany, is the first space mission of the Commonwealth of Independent States. TM-14 docks with the Mir space station. Russia hopes the mission will attract foreign investors to help finance its future space program. Flade's experiments help determine the effects of zero gravity on the human body. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 179, 187-188, 687-688.

March 24 Dirk Frimout becomes the first Belgian in space as a crew member of STS-45, a mission by the orbiter Atlantis. This space shuttle flight is the first of 10 NASA "Missions to Earth" to monitor Earth's polluted atmosphere. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 189-190, 688; **New York Times**, March 25, 1992.

March 27 James Webb, NASA's administrator from 1961 to 1968, who guided the United States' first manned space flight programs and helped establish the Apollo missions to the moon, dies at age 85. **New York Times**, March 29, 1992.

ROBERT WATTS, 32

Aerospace Engineer, Bihrle Applied Research

When two high-profile air crashes prompted the FAA to give airlines until 2019 to start training their pilots to recover from stalls, Robert Watts and his colleagues knew that airlines would not want to change their flight simulators. Working at Bihrle Applied Research, a 26-person company in Virginia, they came up with the idea of loading aerodynamic models into a small computer that could be plugged by Ethernet cable into a simulator. The devices are called StallBoxes, and in April an Alaska Airlines simulator equipped with one became the first airline simulator to be qualified for full stall training by the FAA. Watts wrote the code that enabled the first StallBox to interact with its host simulator.

How did you become an aerospace engineer?

I remember early on marveling at how a massive aircraft could be suspended in the air. Even as a kid, you understand that doesn't really make sense. I started learning the science of how things actually work and about the technology that drives aviation including flight control systems. In high school, I took a computer science course that got me involved in software development. When I went to Georgia Tech, I went in undecided, but had this feeling I wanted to do something in aviation. I opted to do my bachelor's degree in computer science. I was attracted by the breadth of applications since pretty much everything uses software. I spent four semesters working at Intellisync Corp. and had a summer internship at Microsoft testing its exchange server. I enjoyed my time at Microsoft and I was tempted to go there full time, but working on planes and helicopters was so much more exciting to me than delivering email. So I stayed at Georgia Tech and got my master's in aerospace engineering. I joined Bihrle Applied Research in 2010. Having the ability to understand problems and create solutions is unique from some of the folks who only have an aerospace degree. To be able to see and understand the software side and have the master's degree in aerospace gives me domain-focused, specific knowledge that some software engineers don't have. It's that combination that's really been critical for me in fulfilling the role I have now.

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

I think we will have aircraft that are faster and cleaner, smarter and cheaper. But I think particularly about the impact technology will have on the role of pilots. 2050 is 33 years from now, so look at how far we've come in the past 33 years and how the role of a pilot has changed. We will continue to struggle with the balance of allowing the technology to do what it's good at, to be precise and efficient in flying, navigating, communicating, but also keeping the pilots in the loop during flight, keeping pilots prepared to use their skill and judgment when the need for that comes up. I don't necessarily think that we'll be to a point where we don't need pilots. Of course, with my experience with StallBox, I think technology will continue to evolve in the way that pilots are trained because as their role changes, pilots need to be prepared for things that very rarely happen and will happen even more rarely in the future. But as a dreamer, I do think we will see a lot more unmanned aircraft. I dream of having a more personal flight vehicle. Will it happen in 2050? We'll see. ★

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