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YOUR PILOT'S NEW VIEW

Cameras on passenger jets will ease fog of flying PAGE 22

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On the cover: An enhanced-vision simulation by Elbit Systems


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This is Volume 54, No. 10.

AIAA
Shaping the Future of Aerospace

IN THIS ISSUE

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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Debra Werner

is a frequent contributor to Aerospace America and is a West Coast correspondent for Space News.

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is an illustrator and a contributor to Aerospace America and Space Smithsonian magazines.

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is Boeing's vice president and general manager for space exploration. He was Boeing's program manager for construction and assembly of the International Space Station from 2003 to 2006.

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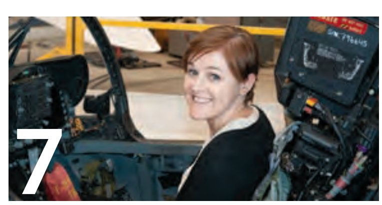
DEPARTMENTS



Elbit Systems

▲ **FalconEye** head-up display from Elbit Systems.

Glimpsing the future of flight

When I'm at an airport, I sometimes daydream about what air travel will be like for my children and their children.

Our cover story, "New eyes for airline pilots," page 22, provides plenty of fodder for the curious, with its details about sensing technologies that can cut fog and darkness, and software that can merge disparate wavelengths into unified images on screens in front of pilots.

If the FAA decides to give airline pilots greater freedom to descend in low visibility with approved versions of this technology, as the industry expects it to do, this development could have near-term impacts in the form of reduced weather delays. That's important, but there could be a longer-term impact. Such an approval might be more evidence, along with driverless cars, that we are reaching a turning point in our willingness to trust technology as an extension of our eyes and minds.

It's one thing to have faith in the view from a camera to steer a rover on Mars, but I'm guessing it's quite another to trust the scene on a computer display to steer a plane full of people through a low visibility scenario.

Once that mental breakthrough is made, the door could be opened to all sorts of fascinating developments in air transportation, some near, some far. Maybe it wouldn't be so radical for a crew on the ground to be ready to take charge of a jet by remote control in an emergency, as envisioned by technologist Seymour Levine and others. If enough automation were aboard, maybe regulators and the traveling public would accept having only one person aboard a large passenger plane who knows how to fly it. Levine has noted that buses have only one driver.

Someday, decades from now, we might even need to ponder the need for a human pilot aboard at all. It's a thought that makes me shudder, to be honest, but then again, I was born in the 20th century. ★

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

AIAA to Host IAC 2019 in Washington, DC

I am excited to share with you that in late September—at the 67th International Astronautical Congress (IAC) in Guadalajara, Mexico—AIAA was officially selected by the International Astronautical Federation (IAF) to host the 70th IAC in Washington, DC, in October 2019. The IAC was last held in the United States in 2002, when AIAA hosted the event in Houston, TX. It is fitting to bring the Congress back to the United States after so many years abroad in the year humanity will celebrate the 50th anniversary of a feat once thought impossible: humans walking on the moon. Washington, DC, presents a unique location to highlight the global progress in space utilization and exploration inspired by those first steps of U.S. astronauts Neil Armstrong and Buzz Aldrin. Fifty years later, in 2019, our community will gather in Washington, DC, to celebrate the benefits to humanity of the Apollo program and look forward to the exciting next half century. Hosting the Congress in the nation's capital provides the U.S. aerospace community a chance to engage with both national leaders, as well as international peers. The Institute believes it is the perfect opportunity to invite the world to commemorate that "one giant leap for mankind" and celebrate the international accomplishments and partnerships to date that have become the hallmarks of space exploration,

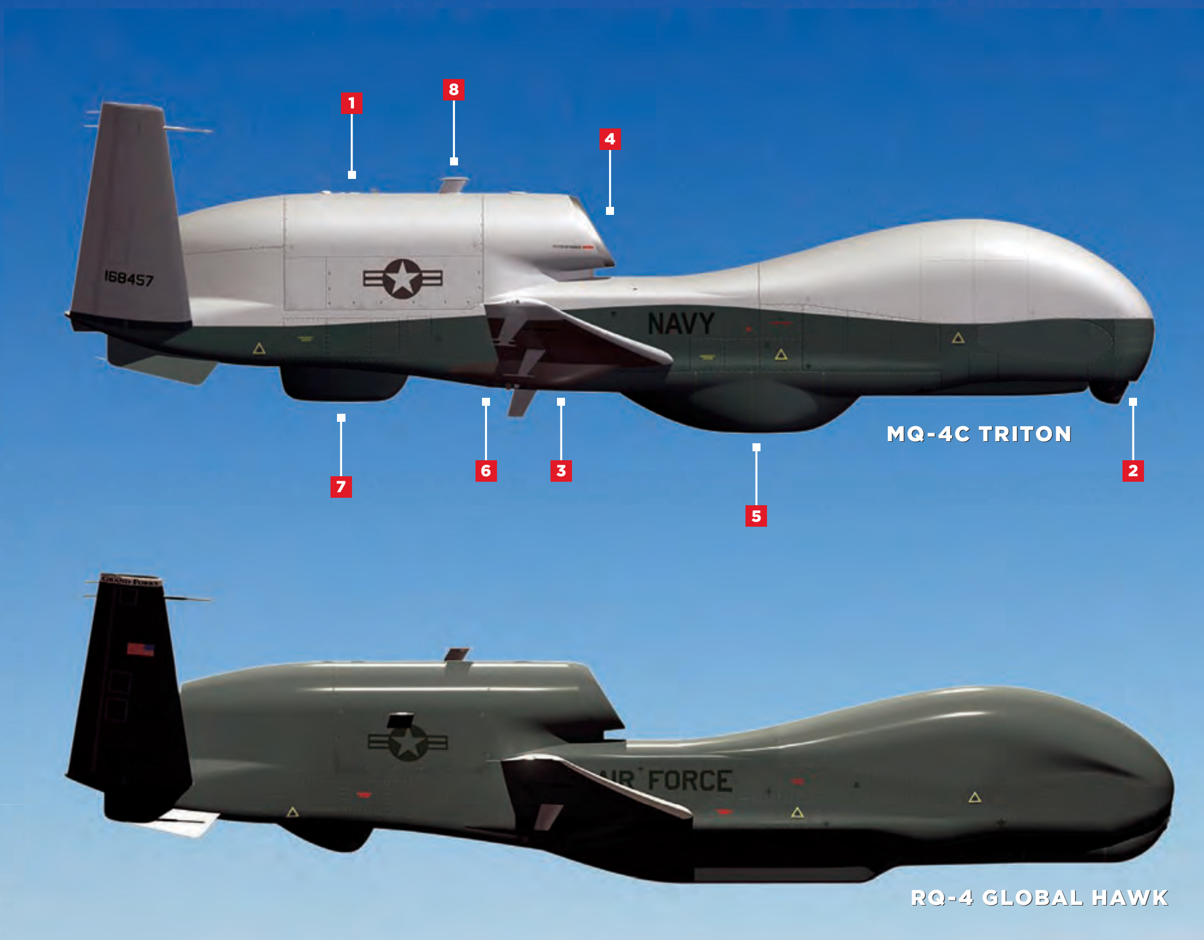
The IAC is the premier annual event of the IAF and its partner organizations, the International Academy of Astronautics (IAA) and the International Institute of Space Law (IISL). The event brings together thousands of decision makers from across all sectors of the global space industry, to discuss the latest space discoveries and developments, as well as to explore opportunities to partner and collaborate. Many AIAA members participate in the IAC, and some are active on the committees that comprise the IAF, IAA, and IISL. The IAF was founded in 1951 to allow the spacefaring nations of the time to engage freely at the height of the Cold War. Its primary missions include promoting cooperation, advancing international development, sharing knowledge, recognizing achievements, preparing the workforce of tomorrow, and raising awareness of global space activities.

As one of the founding members of the IAF, AIAA has served as IAC host for five previous Congresses, two World Space Congresses, and as the co-organizer with the IAF of the Global Space Exploration Conference. Our long-standing membership in, and partnership with, the IAF ensures the teamwork necessary for success.

The Institute worked tirelessly over the last two years to prepare an exemplary bid package that was endorsed by a number of supporters across government (federal, state, and local), industry, and academia, including Lockheed Martin Corporation, who has agreed to be the Industry Anchor Sponsor for the event. Currently, we are in the process of forming our local organizing committee, led by Michael "Obie" O'Brien, former associate administrator for International and Interagency Relations at NASA. This group will be responsible for all aspects of planning and execution of the Congress and ensuring that members of the local and international aerospace communities are well informed of prospective IAC 2019 activities and able to regularly contribute to the planning of the Congress. Because the Congress will take place in the fall of 2019, the Institute will host both the AIAA Propulsion and Energy and AIAA SPACE forums together in August 2019. We will provide more information to members as we get closer to 2019.

We appreciate the confidence of the IAF and all our bid supporters in this endeavor, and we look forward to sharing with the global space community the wonderful, diverse, and fun city that is Washington, DC. To learn more about our bid to host the 2019 IAC in Washington, DC, please visit: http://www.iac2019dc.org. ★

Sandra H. Magnus, AIAA Executive Director



Triton: Flying high, flying low

By Henry Kenyon | hkenyon@hotmail.com

Northrop Grumman is about to start producing Triton unmanned intelligence planes for the U.S. Navy after eight years of research and test flights. The similar Air Force Global Hawks watch targets from placid high altitudes, but Tritons must also dip below the clouds to study suspicious vessels. This requirement drove some design differences.

MQ-4C TRITON

1 ENGINE: Rolls-Royce AE3007H turbofan. Popular for business jets. Same engine as Global Hawks.

2 STEERABLE VIDEO CAMERA: Raytheon Multi-Spectral Targeting System-B. Also flown on Air Force Predator drones.

3 REINFORCED WINGS protect against low-altitude hazards, including bird strikes, hail and wind gusts. Electric de-icing coils heat leading edges and also tail.

4 INLET: Redesigned to prevent icing.

5 RADAR: Northrop Grumman Multi-Function Active Sensor for all-weather detection.

6 SIERRA NEVADA CORP. electronic support measures system detects signals emitted by vessels.

7 SAAB AUTOMATIC IDENTIFICATION SYSTEM, or AIS, to track and identify ships — even if they have turned off their AIS broadcasts.

8 UHF-VHF radio antennas.

www.brookeowensfellowship.org

▲ **The late Brooke Owens** in one of her favorite places, the cockpit.

New fellowship will honor youthful trailblazer

By Debra Werner | werner.debra@gmail.com

Virgin Galactic, SpaceX, Blue Origin and Scaled Composite are a few of the companies inviting female college undergraduates planning to pursue aviation or space careers to apply for the new Brooke Owens Fellowship, which offers students paid summer internships plus travel stipends and assigned mentors.

The fellows, who will work on-site at an aviation or space-related business for 10 to 12 weeks, will be assigned two mentors. One will be a senior person within the company where they work. The other will be someone outside the company. The list of outside mentors includes: Lori Garver, a former NASA deputy administrator and now general manager of the Airline Pilots Association (ALPA); Cassie Lee, Vulcan Aerospace's director of aerospace applications; Diana Trujillo, mission lead and deputy chief of engineering operations for NASA's Mars Science Laboratory; and Will Pomerantz, Virgin Galactic vice president for special projects.

Brooke Owens Fellowship applications are available online at www.brookeowensfellowship.org. Applications are due by Dec. 5 and women accepted will be notified by the end of January. According to the website, all applications will be narrowed to about 60 finalists, from which 19 fellows will be chosen.

With a single application, students can apply for internships at all the companies. On the application, students will rank their employer preferences, which will be one of the criteria used to match them with internships.

"Applicants can come from a wide range of academic or professional disciplines: engineering, science, aeronautics and pilot training, law and policy, business, non-profit management, history, art, or anything else. However, successful applicants must be able to draw a convincing connection between their chosen field(s) and aviation or space exploration," according to the website.

The list of participating businesses, which continues to grow, includes ALPA, Arianespace, Ball Aerospace, Commercial Spaceflight Federation, Seattle's Museum of Flight, Planetary Resources, Sierra Nevada Corp., Space Systems Loral, Planet, and the Mojave Air & Space Port. Other prospective employers are the technology news site GeekWire, the Moak Group, a marketing, advocacy and consulting firm, and Tauri Group, an analytic consulting firm.

Aerospace executives established the fellowship in memory of Dawn Brooke Owens, who died of cancer in June at the age of 35. Owens, a certified pilot, worked at NASA's Johnson Space Center, the nonprofit XPrize Foundation, the White House Office of Management and Budget and the FAA's Office of Commercial Space Transportation. She attended Embry-Riddle Aeronautical University and the International Space University.

"She was intelligent, professional, kind and warm-hearted," says Pomerantz, who announced plans for the fellowship Sept. 13 at AIAA Space 2016. "Her friends were looking for a way to honor her, while growing and training a generation of future Brookes."

In addition to her professional accomplishments, Owens' resume is filled with activities and hobbies ranging from reciting spoken word poetry to competing in triathlons. Owens also devoted her time to charitable organizations fighting poverty, seeking to end human trafficking and assisting children whose parents died of HIV/AIDS.

"She was fearless and open to trying everything," Pomerantz says. "While the rest of us might say, 'Wouldn't it be cool if I ever did this.' She found a way to do it." ★

AIAA

Jeff Bezos addresses AIAA members on Sept. 15.

A Gettysburg Address for new space

Jeff Bezos of Amazon and Blue Origin accepted AIAA's 2016 George M. Low Space Transportation Award on behalf of the team that built the New Shepard reusable rocket. Here are his comments to the luncheon audience in September:

Sometimes we get asked, "Why is Blue Origin doing the things that we're doing. What's the purpose?" For me, it's about putting in place infrastructure so that the next generation can do amazing things. If you look at Amazon.com and look at the entrepreneurial dynamism that you've seen in the internet space over the last two decades … we're talking about an arena in which two kids in a college dorm can invent an entirely new kind of company and can grow very, very quickly. How is that possible? And how can we get the same dynamism and entrepreneurialism in space that we have seen on the internet?

Twenty years ago, I was driving the packages to the post office myself, hoping one day that Amazon would be able to afford a forklift. And 20 years later, it's completely a different story. How do you get that kind of progress and speed … ? We were doing e-commerce but we didn't have to deploy a package delivery system. It already existed. It was called the United States Postal Service and UPS and FedEx. If we had had to deploy that it would have taken billions and billions of dollars in cap-ex. The same thing with a remote payment system. We didn't have to build that, it already existed. It was called the credit card. And so it goes on. The backbone of the internet was already deployed because it had been deployed for long-distance telephone networks. The internet could piggyback on top of that. Again, that would have been billions of dollars of infrastructure. And so, if you get all the infrastructure in place, the heavy lifting, high cap-ex infrastructure, then you can see entrepreneurial explosion.

And that's really the mission of Blue Origin. We want to make it easy to get into space. We need to take what today costs thousands of dollars per pound and through diligence, hard work, methodical deliberate practice, get it to where it costs tens of dollars per pound. Get it to the point where the costs of propellants are a driving cost, just as they are in commercial aviation. And, that's very possible. There are no laws of physics against this, and, what you do need is really good, operable usability …. Eventually we as a species will get there, and Blue Origin is dedicated to that. And believe me, if, when I'm 80 years old I can look back on my life and say "One of the things that Blue Origin achieved was to put that heavy-lifting infrastructure in place so that there could be a dynamic entrepreneurial explosion in space for the next generation," I will be one happy 80-year-old. So thank you very much for this award on behalf of the team. ★

"We are closer to sending humans to Mars today than anyone has ever been."

Charles F. Bolden Jr., administrator of NASA, on the prospect of landing astronauts on the Red Planet in the 2030s

"Space 2.0 is the new gold rush of space."

John Steinmeyer, director of business development for Orbital ATK's Launch Vehicle Division, on the idea that growth in the space industry will come from the commercial sector

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at aiaa-space.org

Preparing the way to Mars

Many of the smaller pieces needed to eventually achieve the goal of landing humans on Mars are already in progress.

"There are probably more human spaceflight vehicles in development than there ever have been in one time, and a lot of them are pointed to Mars," said Frank Morring Jr., senior editor for space with Aviation Week and Space Technology, kicking off the "Next Stop Mars" panel.

William H. Gerstenmaier, associate administrator for NASA's Human Exploration and Operations, described a strategic pivot toward a journey to Mars.

"We are starting to see low Earth orbit taken over by the private sector, and that frees the government up to move farther out," he said, emphasizing that the International Space Station has been a necessary learning environment for NASA. "The station is really the first piece of exploration. We're learning how to do long-term life-support; we're learning how to keep crews healthy. We took life-support systems that work fine on the ground and moved them to the station, and they work for a week."

Those type of problems can be overcome where there is close access to supplies from Earth, but astronauts going to Mars will not have an entire planet full of redundant capabilities nearby, AIAA's **Hannah Thoreson** reported.

NASA's Michael Barratt also stressed that the ISS has been a good proving ground for eventually sending humans to Mars.

"One of the big things is just the practical operations of living in space," he said. "We have a clear understanding of how to do that now."

Barratt, an astronaut and medical doctor, said research has helped mitigate some of the health problems that result from spending time in space.

"One of our big enemies was always musculoskeletal decrease," he said. "We are preserving bone and muscle fitness better now than any other time in history."

NASA has had to change its mindset to adapt to longer spaceflight missions and the reality of humans living in space on board the ISS.

"The astronaut office has radically changed in the last 20 years," Barratt said. "We have shifted paradigms from the short-duration shuttle flights to long-duration station missions." ★

Juno mission explores our largest planet

What happens when you set out to explore Jupiter — our solar system's largest planet with the largest magnetic field and fiercest radiation? Good things, according to Rick Nybakken, project manager of the Juno mission at NASA's Jet Propulsion Laboratory.

AIAA's **Duane Hyland** reported that during the William H. Pickering Lecture titled "The Juno Mission," Nybakken took audience members through the entire Juno program, from inception to the current status of the mission, and shared some amazing video and images collected so far.

Launched Aug. 5, 2011, the Juno mission is studying the planet Jupiter by performing multiple polar orbits of the gas giant until 2018, when the spacecraft will deorbit the planet. Nybakken explained that the science gained from the Juno mission will "rewrite the history of how Jupiter was formed and the history of our solar system."

The Juno spacecraft is packed with instruments set up to measure everything from the planet's density, to the properties of its gaseous outputs, to the flow of liquid metal hydrogen on the planet's surface, to the speed of its winds and the ferocity of its eternal storms. Equipped with a solar array "the size of an NBA basketball court," the Juno spacecraft will be able to soak up all the available sunlight — only about .04 percent of what is available on Earth's surface — to perform its mission.

Engineers built the Juno spaceship to overcome Jupiter's radiation field and its overpowering magnetic field, which Nybakken explained is bigger than the sun.

To protect the craft from Jupiter's massive radiation field, the engineers programmed it to travel a very narrow passage in the middle of the field where radiation is at a minimum. Nybakken described it as "flying through the eye of a hurricane" but noted that to be successful, they would have to do that 36 times during the mission. He explained that over time, Juno would drift into the larger field, effectively ending the mission.

Among the images Nybakken shared with the audience were views of Jupiter from both the northern and southern polar orbital tracks, infrared imagery of the planet's auroras and a detailed photograph of the planet's great "red eye," which is about the size of Earth. ★

"We all need to engage and work together to respond and find meaningful solutions, especially in space."

Wanda A. Austin, president and CEO of The Aerospace Corp., on the importance of diversity in having the space industry grow

"We are investigating habitability and looking for ingredients of life: water, chemistry and energy."

Brian Cooke, Europa project system engineer at JPL, on searching for signs of life on distant planets and moons

Ben Iannotta/Aerospace America

Seizing an 'incredible opportunity'

More online aerospaceamerica.org

See the extended transcript for more about Europa, climate change and Mars.

Given the nature of its mission to study Earth and the cosmos, the director of the Jet Propulsion Laboratory can always claim a fascinating future, but perhaps never more so than now given the politics of science in the United States.

Against NASA's wishes, allies in Congress have boosted funding for a JPL-led robotic mission to Jupiter's moon Europa. Closer to home, the lab's satellites are feeding data to scientists enmeshed in the hot-button field of climate change research. In addition, JPL is developing technologies that could one day prove Earth is really not special in terms of an ability to host advanced life.

This is the scientific and political situation that greeted Michael Watkins, a longtime JPL engineer and manager, in July when he succeeded Charles Elachi, who retired from JPL after a 45-year career — the last 15 as director. Watkins calls his director role an "incredible opportunity," given that this NASA-funded arm of the California Institute of Technology is addressing some of the country's toughest scientific questions.

He spoke to Ben Iannotta in his Pasadena office.

MICHAEL WATKINS

POSITION:
Director of the NASA-funded Jet Propulsion Laboratory in Pasadena, California, since July 2016.

NOTABLE:
Spent 22 years at JPL as an engineer, manager and scientist before leaving in 2015 to become director of the Center for Space Research at the University of Texas in Austin, his alma mater. At JPL, he was mission manager for the Mars Curiosity rover; project scientist for GRAIL, the Gravity Recovery and Interior Laboratory lunar probes; and the Earth-focused Gravity Recovery and Climate Experiment, GRACE, satellites.

AGE: 52

RESIDES: Glendale, California

EDUCATION:
Bachelor's, master's and doctoral degrees in aerospace engineering from the University of Texas in Austin.

Science priorities

There's a couple of new program types that are really starting to boom now. One of them is Europa, the outer planets and the ocean worlds of the outer solar system. That's going to be a big part of our future in the coming decades. We want to be ready for that and have the capabilities we need to execute that successfully for NASA and for the country.

The exoplanet search is something that's also really starting to catch the public's eye. [The Wide Field Infrared Survey Telescope] will have a coronagraph to demo that technology. That could evolve to star shades as well, where you're blocking the star with a separate shade. We want to make sure that we're ready and we have the right skill and the right capabilities to do that.

Europa lander and Clipper

We would launch [the lander] after Clipper, so we would get information back from Clipper, [which] would most likely go on a direct trajectory. It's a big advantage for the program if the [Space Launch System] rocket is available as a launch vehicle. That allows you to launch direct from the Earth and get the first flyby mission there pretty fast.

If the lander were to launch on an SLS, there's the option to not go direct, partly because it's heavier than the flyby. It's got to have a carrier spacecraft and the lander and a lot of fuel and such. So it gives you more time for the Clipper data to come back and learn more about the surface.

Science goal for Europa lander

It's mostly a chemistry mission, because we don't really know how exactly to find life. It's hard to say I can design an instrument that definitely finds something that we don't know about. The Science Definition Team is off trying to say, "OK, what is the right suite of instruments?" and trying to be kind of minimalist about it because payload mass, landed mass, is going to be a problem. And also, how do you actually get some ice and analyze it?

Congressional Europa directive

I think everyone's now coming to agreement that a separation of a couple of years [between the launch of the flyby probe and the lander] is optimal.

Science advice from Rep. John Culberson, R-Texas

It is helpful to have that much intellectual support in Congress, because he's pushing to make things happen faster. He's pushing to make them better, and I think that's a good thing. And he's a big advocate for the agency across the board, not just Europa. It's always good to have strong advocates in Congress.

Earth's climate

You have to monitor in order to understand the system and understand the physics well enough to ever have a prayer to predict with quantitative accuracy. We're in the learning phase, trying to say, "Are we really measuring enough of the physics that we really understand this problem and exactly why this El Niño happened? Or this amount of sea level rise happened? This amount of glacial mass-loss in Antarctica or Greenland? What is that telling us about the physics and underlying processes that we need to know better?"

Approach to Earth vs. planetary science

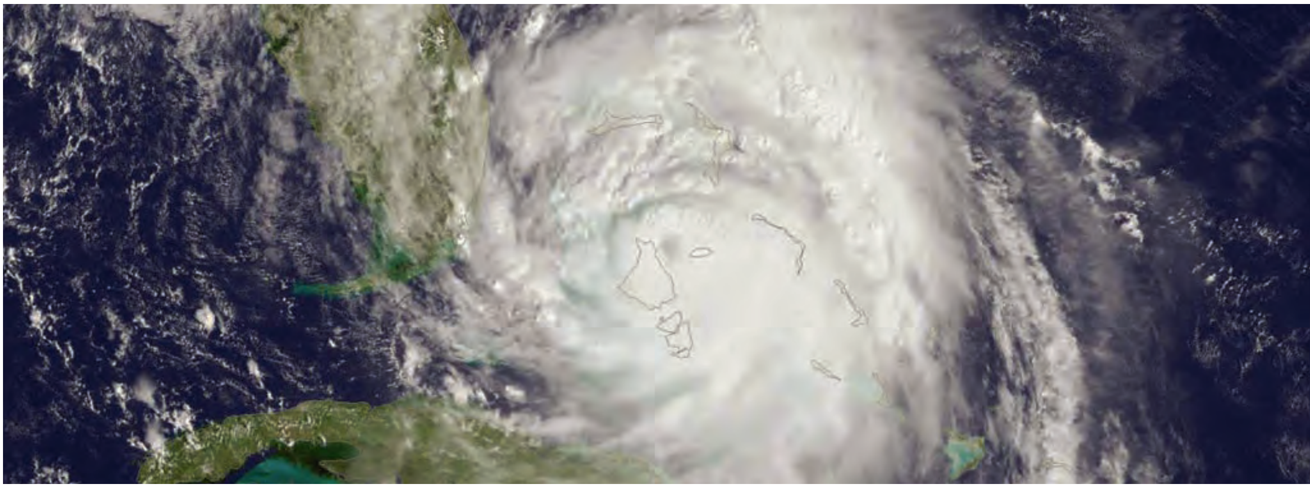
I don't think it's all that different. A lot of the most important scientific papers about what's on Mars or what's in Europa actually come from our university colleagues that actually are part of the science team or they propose to be on the science team ... . The project scientist on Europa is also primarily trying to ensure that the right data is acquired and it meets the scientific requirements that the decadal survey and NASA have established for that mission. They're trying to be the scientific conscience of the project to make sure that instruments aren't descoped or the data is not descoped or something inaccurate.

View of climate change

I think there's a component of it that is natural, and there appears to be a component of it that is anthropogenic. Exactly how big those are relative to each other and what the acceleration, what the rate of growth of those are, I think is still a research topic. We still need more data and longer spans of data to really answer that with the kind of precision that we need ... . [This is] in line with [the Intergovernmental Panel on Climate Change] in the sense that IPCC is trying to understand what's going on and trying to forecast what's going to happen, right? And there's a range in those forecasts depending on what exactly you model for the physics and what your climate model says and how you initialize it. And so, it's a matter of increasing accuracy in those numbers. ★

Improving the ground game

One of six antennas that will receive weather data from GOES-R, NOAA's newest Geostationary Operational Environmental Satellite. Harris Corp.



NOAA

Here's a truism that's sometimes overlooked: A weather satellite is only as good as the system of antennas, computers and software on the ground that receive, process and deliver its data to forecasters and repositories for retrieval later. The ground segment for NOAA's newest geostationary satellite, GOES-R, and the identical S and T satellites to come, was particularly challenging to build due to the volume and fidelity of the data. We asked Harris Corp.'s Robert Basta, the technical lead for development of the ground segment, to explain how the company solved the challenges.

Our biggest challenge in developing the ground segment for NOAA's new series of geosynchronous weather satellites was planning for the volume and speed of information compared to the existing Geostationary Operational Environmental Satellites. GOES-R has six instruments that will collect three times the number of spectral channels as the current satellites with a four-times-finer resolution. The data must be transmitted from the satellite five times faster. On the ground, 40 trillion floating point operations, or FLOPS, must be performed to transform this data into at least 3.5 terabytes of data products each day. That's about the same amount of data as in 777 high-definition movies.

In space, a satellite in the current GOES-N series transmits sensor data at a rate of 2.62 million bits per second, while GOES-R, S and T will transmit sensor data at a rate of 120 mbps.

Like all geostationary satellites, the GOES-R series must have a team and ground system managing it; the computing power to create actionable information from the sensor data and the networking equipment to reliably distribute information to forecasters at the National Weather Service. The information must also be sent to data repositories for retrieval later and back to the satellite, where the spacecraft then broadcasts key data products to users in the Western Hemisphere who are equipped with GOES Re-Broadcast terminals.

For GOES-R, NOAA's comprehensive system requirements gave us the design guidance for everything from the enterprise-level monitor and control of the system to the distribution of informational products for a long list of environmental conditions on Earth and also for solar events in space. An enormous volume of data must come down from the spacecraft with extremely low latency (within seconds of the instruments measuring the event). We must maintain very high availability rates to control mission management functions, meaning actions that maintain the health and safe-

▲ **Hurricane Matthew** as seen by GOES East, one of NOAA's Geostationary Operational Environmental Satellites, on Oct. 6. The newest GOES spacecraft will deliver more information faster to forecasters.

NOAA

▲ **The Advanced Baseline Imager** is installed onto GOES-R at Lockheed Martin's facility in Littleton, Colorado, in 2014. ABI was built by Exelis which was purchsed by Harris Corp. in 2015. ABI will image weather and the ocean from a NOAA's newest Geostationary Operational Environmental Satellite.

▶ **A Harris Corp. engineer** installs cable at one of the ground stations for the GOES-R weather satellite series. The ground system for the new NOAA Geostationary Operational Environmental Satellites consists of stations in Maryland, Virginia and West Virginia that are linked by 160 kilometers of cable.

ty of the satellites, and to control the weather sensors. Management data is critical for keeping remote sensing data flowing to the ground, and in fact, we must have less than two seconds of downtime per year for the key mission management functions. High-availability requirements are also in place for producing and delivering the most critical products such as cloud and moisture imagery. This was most challenging for our team.

We knew that a bottleneck of data would defeat the purpose of flying more sophisticated instruments on GOES-R, including the Advanced Baseline Imager. So we decided to customize the ground system design around the processing infrastructure. Unlike NOAA's polar-orbiting weather satellites, GOES satellites transmit the data as the instrument captures it. Harris invested internal research and development funds to understand the problem and created multiple architectures for high throughput product processing that optimized the input and output of sensor and processed data among many computer servers. We benchmarked these architectures against each other to get to the right solution, which is one that will easily scale to greater and greater data rates and volumes to meet needs beyond GOES-R. We conducted rigorous end-to-end system testing with large volumes of test data to confirm the team's design selection.

To meet the throughput and latency demands of GOES-R, the ground system will begin processing the data by applying weather product algorithms as soon as the data is received from the satellite without waiting for receipt of the full scene from the satellite and without waiting for data from an up-stream algorithm. With GOES-R, the algorithms send the data to the next algorithm to perform the next processing function. To support the flow of data through the system, the team developed a very creative caching approach to avoid input-output bottlenecks. High-speed memory rather than a disk communicates sensor and processed data to algorithms that need this data to execute algorithm code on high-performance computer servers.

Polar orbiting satellites have a somewhat different mission, one that requires capturing less data per unit of time. GOES-R and other geostationary satellites are positioned 35,000 kilometers above the equator to continuously stare at weather features as they develop to aid in nowcasting. By contrast, polar orbiters pass over those features at 800 kilometers viewing only about a 3,000-kilometer swath of the Earth versus the whole hemisphere. However, polar satellites will eventually cover the whole Earth, including the poles, and typically downlink their stored raw data every 50 minutes.

The architecture we created maintains data flow and minimizes latency or delays. The required latency for a solar event, in which measurements of electromagnetic radiation must be made, was particularly stringent: 1.8 seconds from the time the instrument

Harris Corp.

Lockheed Martin

makes the measurement to the time the data is provided to the Space Weather Prediction Center in Boulder, Colorado. Near-real time delivery is critical because solar flux data can harm our nation's vital communications and navigation infrastructure. Having sufficient time to react is essential in safeguarding this infrastructure. As severe weather events increase, a reliable ground system with the ability to support forecasters' needs is increasingly critical.

Given that the protection of lives and property are at stake, NOAA also required that the system be resistant to a single point of failure. NOAA told us which sites to use and for what, but we developed an enterprise management system to monitor and control execution at all sites concurrently. Those sites are Suitland, Maryland, Wallops, Virginia, and Fairmont, West Virginia. While the ground system sites are interconnected to operate as one system, they can operate independently from each other to offer failover redundancy.

Each enterprise system our team delivered to NOAA contains approximately 300 racks of computers and network equipment, about 160 kilometers of interconnecting cables, and six 16.4-meter antennas designed to operate in sustained winds of 110 miles per hour (177 kilometers per hour), or a strong Category 2 hurricane. Each of the three sites can handle the tremendous volume of data required to support the GOES-R mission, but also positions NOAA to support new missions well into the future.

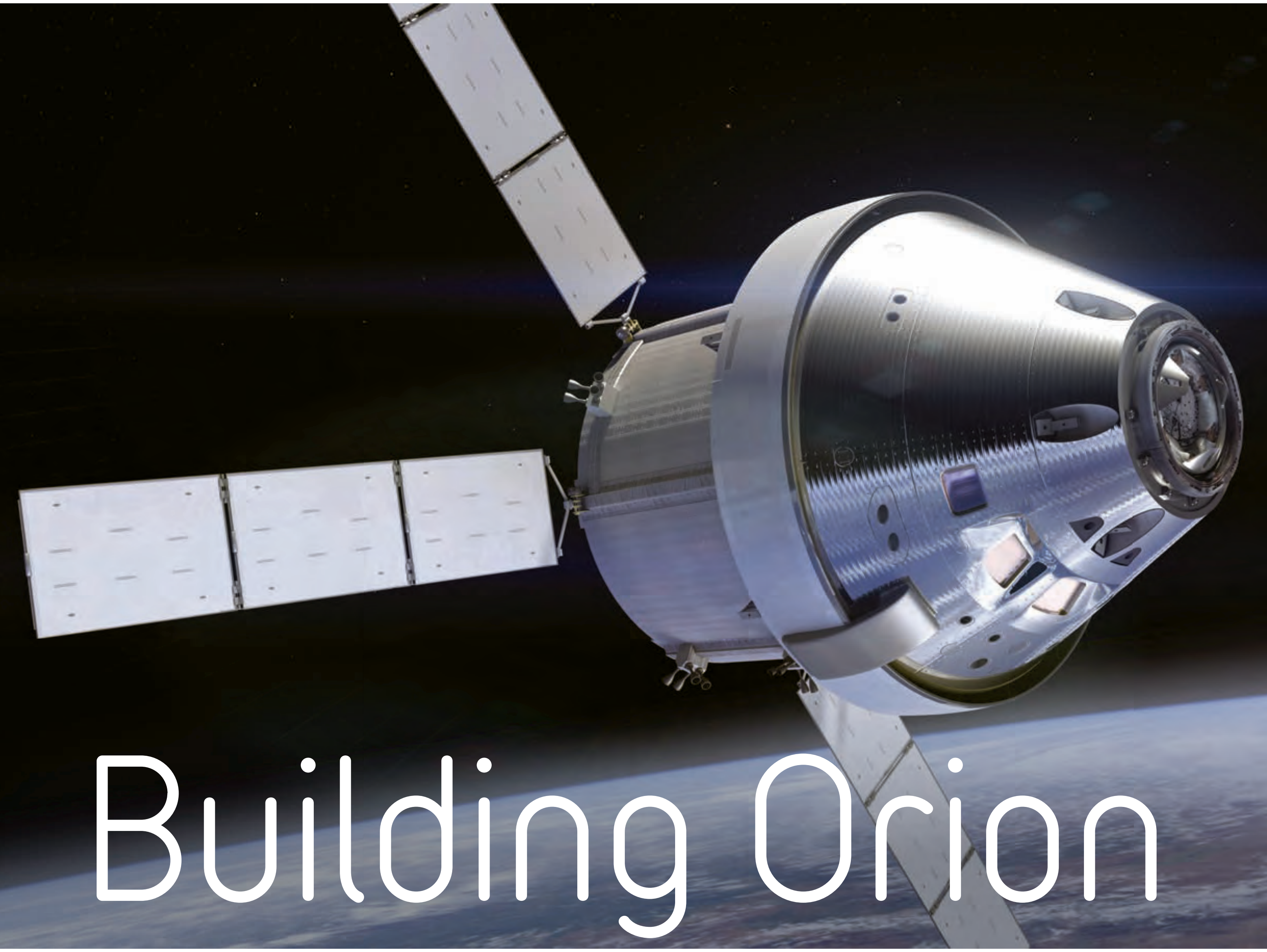
Because it takes years to develop a satellite ground system on the scale of GOES-R, it is critical to imagine the future.

We needed to develop a system that could expand with science. The architecture is highly scalable to add computing capacity for future missions, and required algorithms can be updated without affecting ongoing operations.

Our work means meteorologists will know more about the early formation of storms than they know today, which will improve severe weather preparedness and curtail unnecessary evacuations. There will be more time to prepare for thunderstorms and tornadoes. Airlines will be able to better plan their flight routes. In the same amount of time it takes to upload a selfie, meteorologists will know whether to advise us to carry an umbrella – or not. ★

Robert Basta is chief systems engineer for the ground segment of GOES-R, which is NOAA's new series of Geostationary Operational Environmental Satellites and also the name of the first satellite in the series. Basta is a senior systems engineer at Harris Corp. in Melbourne, Florida. Before GOES, Basta worked in the program definition and risk reduction phase of NPOESS, the National Polar-orbiting Operational Environmental Satellite System program. He also was chief systems performance engineer for the FBI's NCIC-2000 program, which updated the filing system for the National Crime Information Center. Basta has a bachelor's degree in computer science from the University of South Florida and also a master's from the school in computer engineering.

▲ **Lockheed Martin** engineers and technicians test the deployment of the GOES-R satellite solar array before the spacecraft undergoes environmental testing.



Building Orion

Two years from now, a Space Launch System rocket will boost an Orion crew vehicle past the moon. There won't be a crew inside for this mission, but the flight will be a key milestone nonetheless as NASA works to open deep space to human explorers. Retired astronaut Tom Jones chronicles the work underway to get ready for the mission.

By Tom Jones
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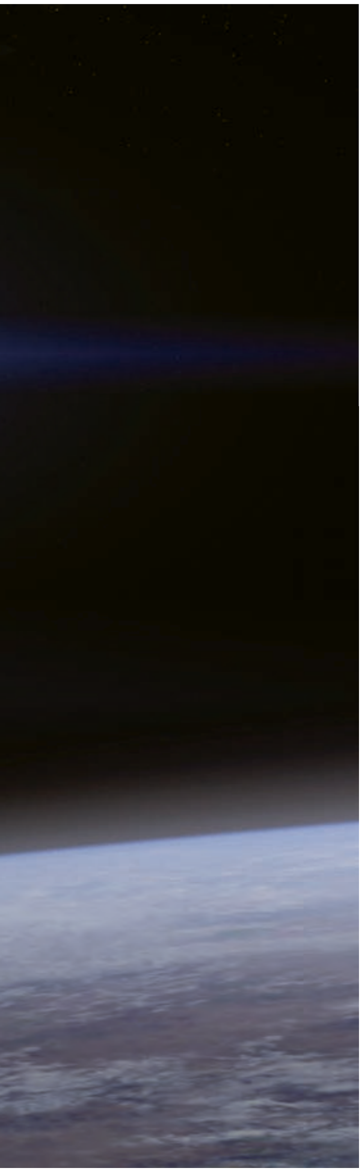
At Kennedy Space Center in Florida, Lockheed Martin has begun assembling an Orion crew vehicle for an ambitious but unmanned flight beyond the moon in late 2018. The NASA team faces challenging development and test milestones to execute Exploration Mission-1, which will be a far more difficult test flight than 2014's five-hour-long Exploration Flight Test-1.

EM-1 will last up to three weeks to check out Orion's most critical systems in a deep-space environment. This will be the first human-capable spacecraft to reach lunar orbit since 1972, and will journey farther from Earth than any Apollo crew. A successful EM-1 will be a giant step toward launching astronauts on their own lunar orbit journey in 2021.



NASA rendering

▲ The Orion spacecraft is shown as it would look just after departure from low Earth orbit, with the crew module at right and the service module at left. A silvery thermal protection coating will cover the sides of the crew module.

Orion explained

Orion will be NASA's deep-space workhorse for the next three decades. In independent flight, it carries enough propellant, oxygen and water to reach lunar orbit with a crew of four, on missions lasting about three weeks. For journeys to near-Earth asteroids or the Mars system, Orion would dock with a larger spacecraft incorporating a habitat, propulsion and power modules.

Each Orion spacecraft will consist of three major components from top to bottom: a launch abort system, the crew module and the service module, all launching atop a Space Launch System booster. The launch abort system, or LAS, can respond within milliseconds to a launch emergency and rocket the crew module free of its failing booster and onto a proper splashdown trajectory. After the 400,000-pound thrust abort motor burns out, a jettison motor then pulls clear the spent rocket and protective shroud, positioning the crew module for parachute deployment.

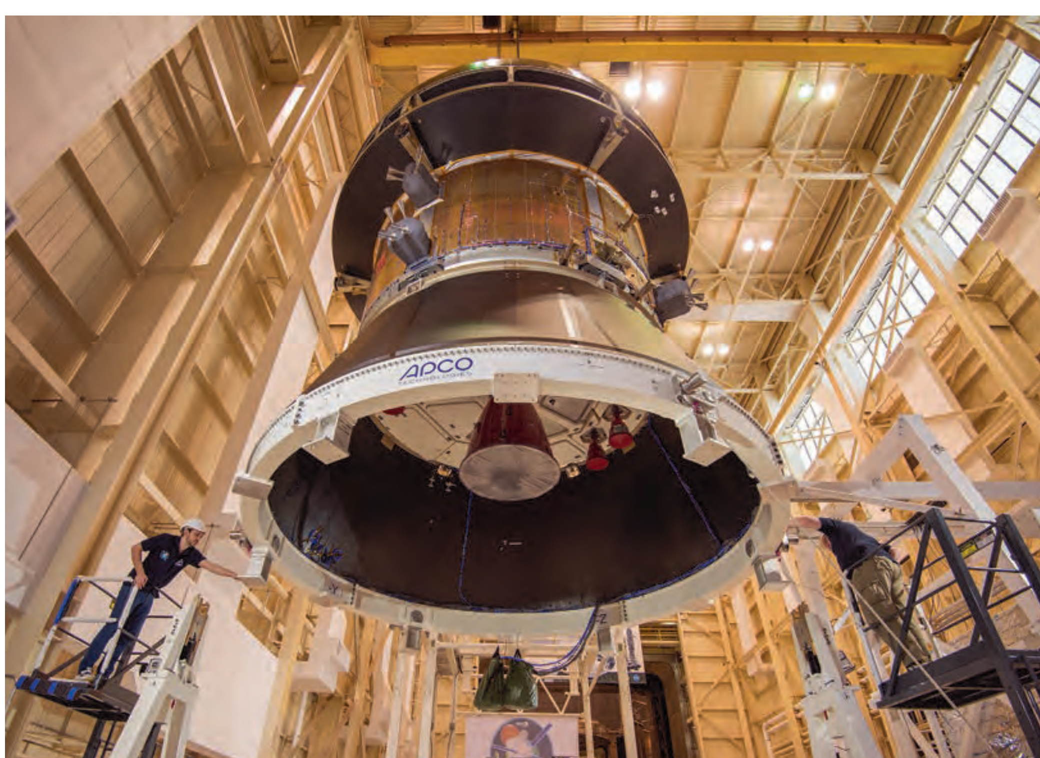
The LAS shroud shelters the crew module, which provides living space for up to four astronauts and protects them from the deep-space environment during missions lasting as long as three weeks. Recovery parachutes surround the nose docking hatch, while at the base is a titanium-and-composite heat shield, covered with ablative Avcoat resin to protect the module from peak re-entry temperatures of 5,000 degrees Fahrenheit (2,760 Celsius).

The crew module contains four seats that the astronauts will fold and stow after launch. "Orion won't be a roomy ship, but it does have 150 percent more elbow room than Apollo," says Rick Mastracchio, the astronaut office's representative to the Orion program. The galley is spartan, with just a water dispenser and food warming case. Nearby is a small, resistive exercise machine. Tucked into the lower deck will be a very compact toilet compartment, rigged with pop-up curtains to preserve a modicum of privacy.

Another astronaut working on Orion, Lee Morin, leads the Rapid Prototyping Lab at Johnson Space Center, which is tasked with producing the crew displays. Orion will have three computer monitors, whose screens can be divided into two displays. The space shuttle's more than a thousand switches and gauges have been reduced in Orion to just 60 or so for controlling emergency and lighting systems; the only gauge will be a combination voltmeter-altimeter. To control the spacecraft, the crew can bring up any of the 70 to 90 interactive displays being planned by using some of the 30 keys around each monitor's bezel. When the g-forces of launch and re-entry make it difficult or impossible to reach the bezel keys, the crew can command the ship through a seat-mounted cursor device, using only the forefinger on the left glove. Morin's team knows these displays and software are in the spotlight: They must be delivered to Lockheed Martin by March 2019 to support the first crew launch — EM-2 — in 2021.

Service module in critical path

Beneath the crew module heat shield is the 13,500



NASA

▶ Structural integrity tests and solar array deployment for Orion's service module took place in February at Glenn Research Center, in Cleveland. Here, the main propulsion engine, a recycled shuttle maneuvering engine, is visible beneath the launch vehicle adapter skirt.


NASA

NASA

▲ **The heat shield for the Exploration Mission-1 Orion** is delivered to the crew module assembly line at Kennedy Space Center by Lockheed Martin. The titanium and composite structure will have about 180 blocks of Avcoat ablative resin bonded to the back shell.

▲▲ **The Orion crew module pressure vessel for Exploration Mission-1**, top, is secured in an upgraded version of a test stand called the birdcage in the Neil Armstrong building at Kennedy Space Center. It will be outfitted with the systems necessary for flight, including its thermal protection system.

kilogram service module, which houses propulsion, attitude control, thermal control and electrical power systems, and also carries oxygen, nitrogen and water tanks to sustain the crew. This module is being built by the European Space Agency based on the design of its Automated Transfer Vehicle, which made five supply runs to the International Space Station. Europe is contributing the module under a barter arrangement with NASA to fulfill its share of ISS operating costs through 2020. NASA has consciously placed the service module in the critical path for Orion, hoping to cement a NASA-European relationship for exploring deep space. "We will need partners to get to Mars. It's our intent to keep ESA involved for the duration of the Orion program," says Mark Kirasich, NASA's Orion program manager.

Because fuel cell-generated electricity (using tanks of oxygen and hydrogen reactants, as on Apollo and the shuttle) is impractical for Orion's long missions, the service module gets its power from the Sun. Four arrays spanning 19 meters gather solar energy and store enough of it in lithium ion batteries to power Orion through 90 minutes of eclipse (in the moon's shadow, for instance).

The module's single main engine will be a repurposed shuttle Orbital Maneuvering System engine, producing 26,690 newtons of thrust for deep space maneuvers or entering and leaving orbit. This pressure-fed Aerojet Rocketdyne design flew 30 years of shuttle missions without a failure. For Orion, each engine will fly with new propellant lines and tanks. Kirasich says NASA will fly out the existing inventory of shuttle OMS engines, then build new ones starting in the 2020s.

Assembling Orion

Exploration Flight Test-1 in 2014 proved that Orion's crew module could withstand launch, the space environment and re-entry from a high Earth orbit. Its heat shield protected the crew module as it re-entered at a near-lunar return speed of 32,187 kilometers per hour. After recovery from the ocean off southern California, Orion's performance, structure and systems were assessed in preparation for building the EM-1 crew module. By analyzing flight loads and improving manufacturing efficiency, engineers reduced the mass of the crew and service modules by 1,590 kilograms, including 365 kilograms of structural weight, says Jules Schneider, senior Orion operations manager for Lockheed Martin's assembly team at Kennedy Space Center. The number of welds needed to build the crew module's pressure vessel, for example, was reduced from 33 to seven.

"We've completed the build of the pressure shell and secondary structure; now we're inside the clean room to install the propulsion system, thruster valves, helium lines, and the fluid lines for the propylene glycol and ammonia cooling systems," Schneider says. He and his team must deliver the EM-1 spacecraft to Kennedy's ground operations group in the first quarter of 2018, so they can integrate the spacecraft onto the SLS booster.

Manufacturing and EFT-1 flight experience has helped improve and streamline the building of the heat shield. Instead of curing the ablative Avcoat resin in a monolithic honeycomb layer covering the composite heat shield structure, Lockheed Martin for EM-1 will bond 180 separate blocks of Avcoat-filled honeycomb to the back shell. The new heat shield build-up, to be completed at Kennedy, will allow more precise control of the curing process, meet all structural strength requirements for future Orion missions, shorten manufacturing time by two months and save money.

Schneider says that after the clean room work, the crew module will receive its wiring, electronics and batteries in preparation for power-up of the crew module in February or March 2017. Meanwhile, the front and back sections of the service module will come together at Kennedy by March or April 2017, followed by separate testing of crew and service modules before umbilical connections tie them together.

The entire EM-1 Orion will then be flown to Glenn Research Center's Plum Brook Station for a crucial two months of environmental tests. In Plum Brook's mammoth thermal-vacuum chamber, the ship will be cooled to minus 20 degrees Fahrenheit and baked at 150 degrees to verify the function of its pressurization, insulation and thermal control systems. After acceptance tests back in Florida, Orion will then go through hypergolic propellant loading, installation of the launch abort system atop the crew module, and stacking atop the SLS booster in the Vehicle Assemble Building. The EM-1 launch is planned for sometime during the last three months of 2018.

The tempo at the Orion assembly line in Kennedy's Armstrong Operations and Checkout Building is quickening. Assembly of the crew module structural test article, intended for intensive loads testing at Lockheed Martin in Denver, starts in November. In March, Lockheed Martin will begin construction at Kennedy of the EM-2 crew module, which will carry the first Orion crew in 2021.

Exploration Mission One

EM-1 in 2018 will be the first flight of the heavy-lift Space Launch System booster. Its upper, Interim Cryogenic Stage will propel Orion out of low Earth orbit on a 21-day flight designed to prove the spacecraft can safely support a crew in deep space. After a week-long outbound transit, Orion will skim within 100 kilometers of the moon and, firing its main engine, enter a distant retrograde orbit some 70,000 kilometers beyond the lunar far side. After a week of systems tests, another engine firing will drop Orion through a lunar swingby that will steer it toward Earth for re-entry and splashdown. The crew module will enter the atmosphere at 40,500 kph and deploy three main parachutes for a West Coast splashdown and recovery.

"EM-1 was intended to be a dress rehearsal for the EM-2 crewed mission in 2021, but it will be missing some key elements," says the astronaut office's Mastracchio. "It won't have a life support system or crew displays, for example." The astronauts will be watching EM-1's results closely. "Where do you draw that line—where you understand the vehicle's performance well enough to put people aboard on the next flight?"

Orion's future

Kirasich, the Orion program manager, notes that "on EM-1, Orion will fly farther and longer than Apollo. We want it to be a capable, flexible spacecraft that can take on many classes of exploration missions." After the first crewed flight, he would like to see NASA fly an Orion mission at least annually, maybe twice a year, but for that "we need more budget." Orion is funded this fiscal year at $1.27 billion. Through partial reuse and manufacturing efficiencies, Kirasich hopes to drive down production and operations costs to create a funding wedge for more frequent flights. In the mid-2020s, after several piloted test flights, NASA hopes to fly Orion astronauts to lunar orbit to sample a captured asteroid boulder in the piloted portion of the Asteroid Redirect Mission.

What are the program's big challenges? "Spacecraft mass," says Kirasich. "EM-1 will not have all of the crew systems, like life support and crew displays, due to both weight and budget." Lockheed Martin's Schneider says "the biggest variables for EM-1 will be getting the European service module here on time, and the two months of environmental testing at Plum Brook. That's making some of us nervous," he admits, "but we're going to be ready to go."

What gets Schneider past the daily frustrations of running an assembly line for NASA's new spaceship? "I enjoy showing kids a spacecraft that's going to go around the Moon. Their eyes light right up. It's good to keep that perspective on things." ★

NASA

▲ **Astronauts**, left to right, **Stephanie Wilson**, **Karen Nyberg** and **Rick Mastracchio** evaluate equipment on a model of the Orion spacecraft to ensure that a fully suited crew member carrying survival equipment can exit the spacecraft through the docking hatch if necessary.

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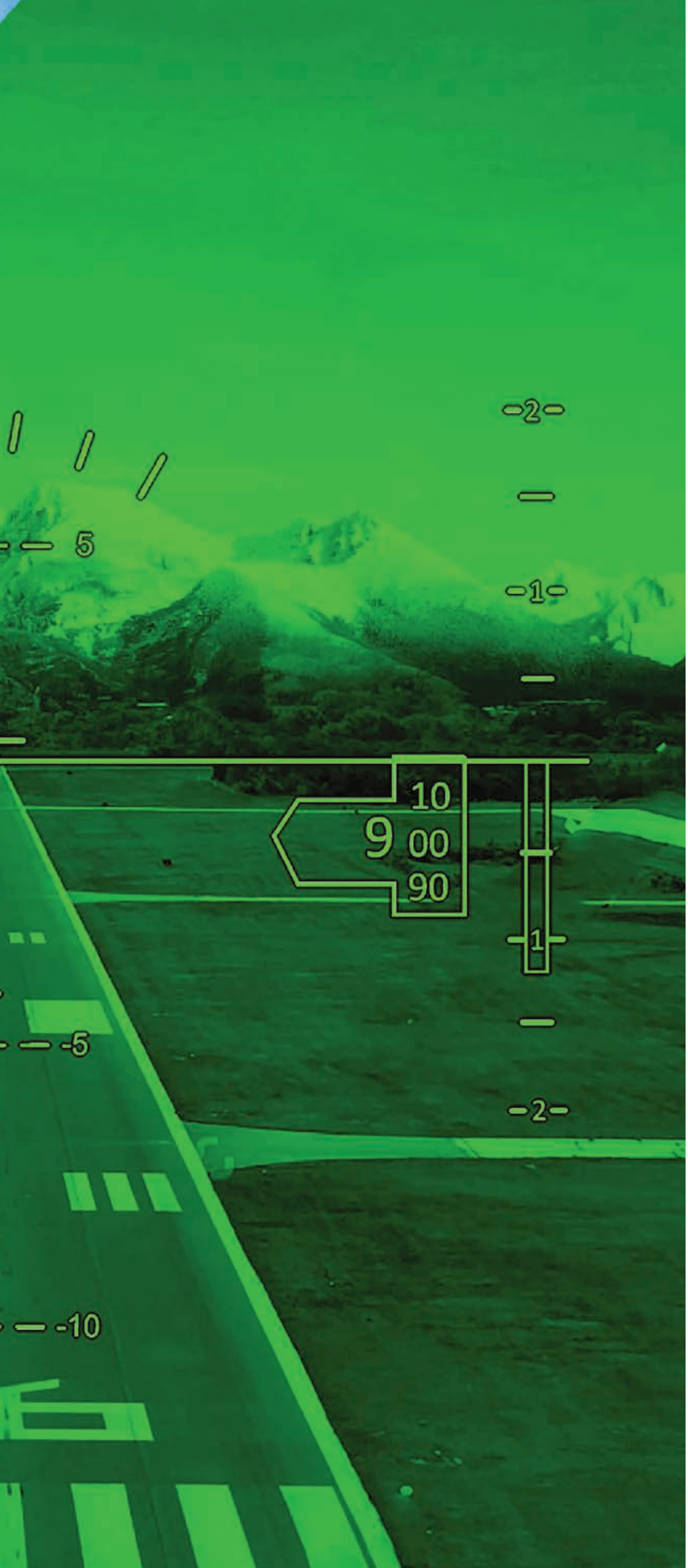
New eyes for airline pilots

An enhanced-vision simulation produced by Elbit Systems.



The FAA has for years allowed business and cargo jets equipped with certain infrared cameras to descend and land in conditions that passenger jets are barred from. Now, the FAA is poised to allow passenger planes equipped with these systems to have similar freedom. Henry Canaday explains how the underlying technology was developed and the difference it could make for airlines.

By the end of the year, the FAA is expected to issue a rule that will permit passenger planes equipped with certain kinds of infrared and other cameras to operate much more freely in low-visibility conditions. The new rule could provide substantial economic incentives for commercial and other aircraft to adopt a technology that has been installed on relatively few aircraft, mostly high-end business jets and some express-cargo jets.

It's been a long road getting to this point.

In 2013, the FAA issued a notice of proposed rule-making saying it intended to allow more operational freedom in bad weather for aircraft — including airline passenger planes — with adequate enhanced flight vision systems. In the cockpit, infrared and other images will be projected onto a transparent screen, called a head-up display, or HUD. Large passenger aircraft with the systems would be allowed to take off, head toward and land at airports where they'd previously been barred during times of low visibility caused by weather. Overall, the change should mean fewer delays, cancellations and re-routings.

To justify installing enhanced vision systems, developers realized they'd need to focus on cost so that the airlines would judge the technology affordable. That meant minimizing the cost of the equipment as well as its installation and maintenance. Downtime would have to be acceptable, as would the size, weight and power needed by the enhanced-vision equipment. All this would have to be done even during the shift to new airfield lighting technology that complicates matters for cameras.

Elbit Systems, Honeywell and Rockwell Collins led the way on enhanced vision — in Elbit's case,

Elbit Systems

▲ **A Dassault Falcon 2000 business jet** is shown with Elbit's ClearVision EVS multispectral camera installed in its nose. FalconEye, as Dassault calls the camera, fuses wavelengths from six sensors into one image.

by applying technology originally developed for defense applications. In 2013, Rockwell decided to develop a new enhanced-vision system in hopes of increasing performance over an earlier iteration while also restraining life-cycle costs to make installation attractive to airlines and other operators.

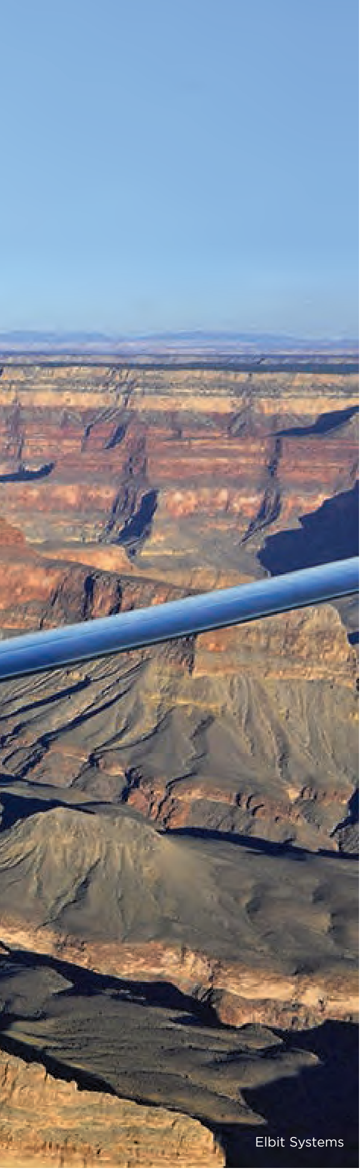
Improving an existing system

Rockwell's Carlo Tiana, a principal system engineer, says the company capitalized on improvements in sensing materials and processing power and made wise technology and design choices. Key was dealing with the change in airfield ground lighting with some clever programming to make it work.

Rockwell began installing simple versions of HUDs in airline cockpits in 1985 to display basic information, such as flight paths, speed and altitude. In 2004, it began adding systems made by other manufacturers to show enhanced-vision video on the HUD. These first-generation systems imaged the scene in front of an aircraft with a single, cooled, extended midwave infrared camera on the nose of the plane to sense wavelengths of 1 micron to 5 microns. Early systems required liquid nitrogen refrigeration to achieve very low focal plane temperatures for detection of small temperature differences.

That is the way infrared works: By detecting differences in the temperature of objects — either self-generated or retained from solar heat — it distinguishes different objects and surfaces. But cooling for sensitivity added weight, cost and reliability problems.

Early systems usually came in three parts. A camera with the sensor was recessed in the nose of the



Elbit Systems

Rockwell Collins

A cockpit photo taken during a Rockwell Collins test flight of its Head-up Guidance System over Jackson Hole, Wyoming. The display combines synthetic and enhanced vision.

aircraft. The sensor looked through a window in the fuselage made of transparent sapphire stone, a material chosen for such applications because of its hardness. This window had to be large to provide sufficient field of view, and it had to be heated for de-icing. Sometimes, a separate processor converted sensor data into images for the HUD. In other cases, there was a separate de-icing heater control. This complexity added weight far forward of the aircraft's center of gravity, took up premium space and decreased mean time between failures.

Rockwell wanted a better performing system that was simpler, lighter, smaller and more reliable.

According to Nate Kowash, Rockwell's program manager and engineer for enhanced vision, cooling had been needed to achieve necessary performance. A mechanical cryo-cooler maintained a sensor's focal plane array — the device that takes the image — at very low temperatures, as low as minus 196 Celsius (minus 321 Fahrenheit). The goal was maintaining the array at this temperature, but other components, such as its vacuum insulation vessel, also had to be cooled to achieve this, which caused additional inefficiency in cooling. But by 2013, Rockwell could buy customized, uncooled long-wave systems at one-fourth the cost of cooled sensors. Demand in military and law enforcement markets had prompted advances in uncooled infrared technology. And using a long-wave sensor and a short-wave sensor had always been preferable to using one midwave sensor.

Midwave infrared is good at detecting temperature differences in terrain, but it is not so accurate at detecting short-wave infrared radiation of 1 micron to 1.5 microns from incandescent airport approach lights. By 2013, high-performance uncooled short-wave sensors were available that were more sensitive in this band than cooled midwave sensors, and Rockwell decided to add one to see lights better.

Demanding applications

Enhanced-vision performance is measured in several ways. Noise-equivalent temperature difference describes the ability of thermal sensors to detect differences in temperature, which equates to an ability to distinguish more objects on terrain. Technologists who work on short-wave sensors refer to this as detectivity. By selecting an uncooled short-wave sensor with a focal plane made of the alloy indium gallium arsenide instead of indium antimonide, Rockwell improved detectivity by about 100 times over old systems that stretched midwave sensors to see shortwave radiation. Indium gallium arsenide at room temperature detects shortwave infrared much better than indium antimonide.

Another metric is dynamic range. At high altitudes, sensors must see very weak signals through many layers of atmosphere. Nearer to landing, sensors must not be blinded by extraordinarily bright airport lights.

"They must adapt to both tiny and immense signals," Tiana explains.

The one-sensor systems had trouble with this challenge. But with two sensors for different tasks, Rockwell could optimize each for different degrees of brightness.

Another requirement is preventing blooming. Blooming occurs when light scatters on a wet window or in the atmosphere. This effect can be caused by a camera flash or oncoming high-beam headlights. Rockwell prevents blooming from wet surfaces optically by not focusing sensors on the window where moisture gathers. The system mitigates atmospheric blooming by processing images from the shortwave sensor.

As efforts proceeded, airports were changing infield lights (but not approach lights) to light-emitting diodes or LEDs. These require about 40 percent less power than incandescent bulbs and on average last much longer. But LEDs don't get warm enough to be visible to infrared sensors, either short- or midwave. So Rockwell needed a visible-light sensor to see better than the human eye in low visibility. "It's hard to beat the human eye," Tiana notes.

Rockwell modified the optics of this visible-light sensor to improve imagery during day and night. It also added gain-control algorithms to process visible-light images and extract maximum performance in poor weather.

"Nonetheless," Tiana acknowledges, "there are fundamental physics" that made the challenge hard. Seeing LED lights when they are blocked by fog, smoke or rain better than the human eye is difficult, but that is just what the new system had to do.

So three well-tailored sensors — long-wave, shortwave and visible light — dramatically improved performance. "The three current sensors each performs an essential function, and the suite detects all airfield features required for landing and taxiing," Tiana explains.

Rockwell also had to make sure the system would not be barred from export under the U.S. International Traffic in Arms Regulations.

"The performance requirements for our application are very different from those of military applications," Tiana says. "We customized our technologies to make sure they would provide maximum performance for our environment and not be useful for offensive battlefield applications."

But three sensors presented a computing challenge, because different images would have to be fused into one view of the environment. Tiana describes that fusion as a major hurdle. The most visually beneficial portions of each sensor's data had to be fused while excluding nonbeneficial elements. Fused video images also have to overlay the real world outside the cockpit exactly where they should be. And fusion must be done almost instantaneously. FAA certification requires no more than 100 milliseconds of latency from the moment a photon enters the sensor to the moment the corresponding photon exits the HUD toward the pilot's eye.

Rockwell engineers tapped all the available literature on image merging. Still, they had to do a lot of customization to come up with fusion algorithms suited to the enhanced-vision problem. Sufficient original programming was done that Rockwell took out a couple dozen patents on its image-fusion software. The entire effort took several years.

The elaborate, rapid calculation for fusing images once would have required a supercomputer. Today, a much smaller processing device can handle it. That compactness was essential for the design of Rockwell's new enhanced vision system, the EVS-3000.

Instead of the three-piece earlier system, Rockwell designed a single line replaceable unit to ease maintenance for cost-sensitive airlines. All processing is done in a processor embedded in the enhanced vision camera. Instead of creating a window in the fuselage for the camera, Rockwell designed the camera to sit on the nose of an aircraft. Video imagery passes through a fiber-optic cable to a computer and then to the HUD.

Putting the camera up front posed challenges. While the former window method required de-icing by heat-control units, it could be set flush with the fuselage, minimizing drag without affecting the optical train of the camera. In the new system, Rockwell had to minimize drag by jointly setting the optical train of the lenses and the window position. The simplicity of an integrated package and elimination of cooling cut costs, increased reliability and eased maintenance. Tiana estimates the new system has two to three times greater mean time between failure compared to the old, three-part, cooled system. It weighs a little less than 5 kilograms and requires a third less power at peak.

Rockwell completed the EVS-3000 in 2015, after two years of development. The company anticipates the FAA will soon certify the EVS-3000 on the Embraer Legacy 450 and 500. Embraer and other manufacturers are anxious for the FAA to issue the final rule for enhanced-vision operations. The 2013 draft would allow pilots in suitably equipped aircraft to continue descending below 100 feet in bad visibility. Aircraft with enhanced vision could take off under instrument flight rules even when visibility is less than that now prescribed for instrument approaches.

Views from other sectors

Rockwell hasn't been the only company working on enhanced vision. Honeywell developed a system that projects images on head-down displays in the cockpit. And Elbit Systems of America was the first to certify enhanced vision and began installing a second-generation system — with a single cooled

Elbit Systems

▲ This photo of Elbit's head-up display was taken in flight from the pilot's position.

sensor to detect 1-5 micron wavelengths — on HUDs in FedEx Express MD10s and MD11s in 2008.

FedEx has since equipped about 270 aircraft with enhanced vision systems and is currently installing them on new 767 and 777 freighters upon delivery. Installation takes 12 days for each aircraft.

FedEx installed the systems partly because the company saw benefits in seeing in the dark during its many night landings and takeoffs. Passenger carriers take off and land mostly in daytime. Furthermore, the FAA allows properly equipped FedEx aircraft to use enhanced vision, rather than the pilot's natural vision, to descend to 100 feet on landing approaches and to begin these approaches when natural visibility is as little as 1,000 feet. This is especially useful at small and midsize airports that do not have the most advanced instrument landing systems.

"There are improvements in situation awareness, energy management and basic flight path control," says FedEx's Dan Allen, managing director of flight operations and regulatory compliance. Other benefits include safer taxiing and better airport awareness in reduced visibility.

Elbit's newer ClearVision enhanced vision system uses six uncooled sensors covering the full spectrum of energy between visible light and long-wave infrared.

"It's a multispectral system," explains Dror Yahav, Elbit vice president of commercial aviation. "Each has its own range depending on conditions and weather. For example, thick fog is different than smoke. Software fuses sensor images for the best picture."

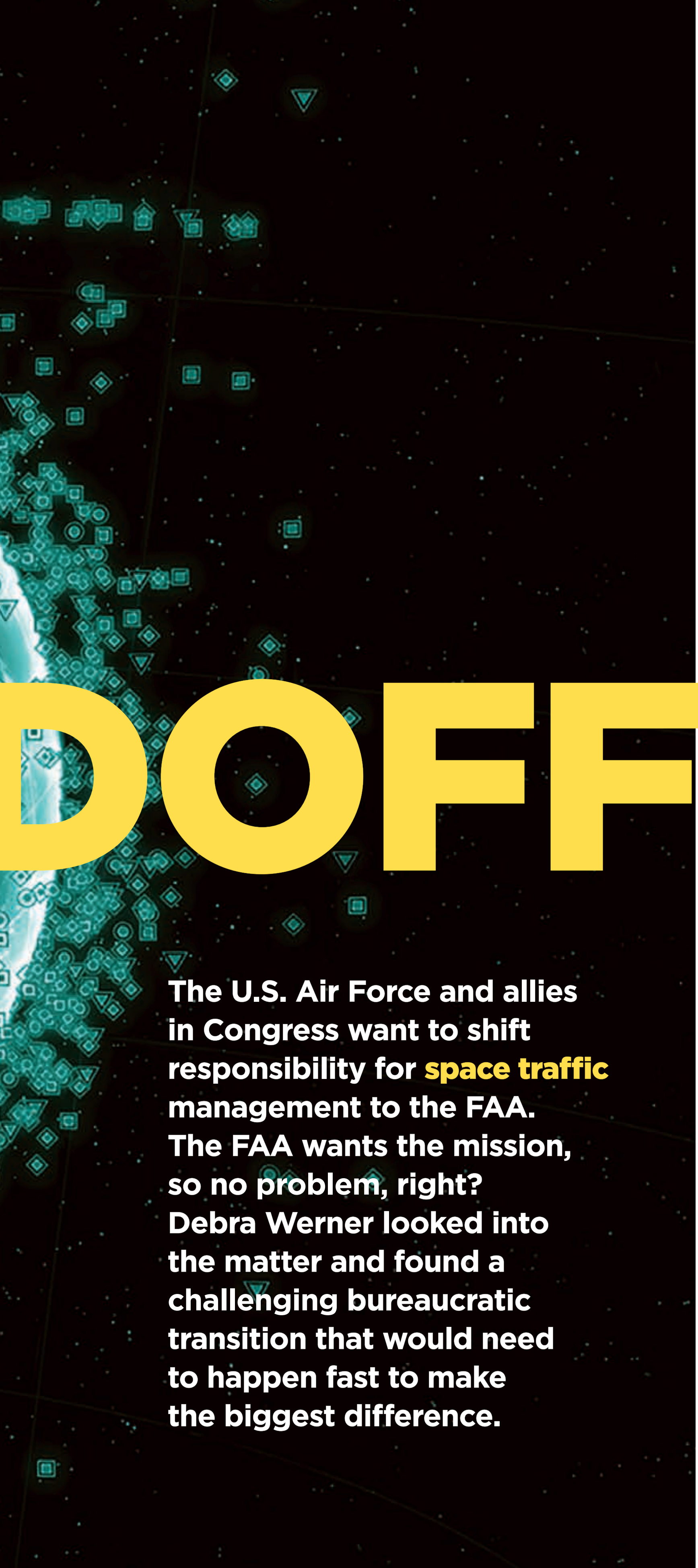
In developing image-fusion algorithms for commercial enhanced vision, Elbit applied its long experience with military enhanced vision. But Yahav emphasizes the civilian application is a "clean-sheet system with no military content."

Yahav notes that Elbit enhanced vision is standard equipment on many of the latest Gulfstream business jets; has been certified on MD10s, MD11s, 757s 777s, 767s and A300s; and has been selected for the new COMAC C919.

Elbit has been working closely with the FAA on the new enhanced-vision rule. Yahav believes it will be a strong operational advantage for aircraft equipped with enhanced vision to descend to touchdown in bad weather beyond even the limits now allowed with the most advanced instrument landing systems. And many airports have much more basic instrument systems. ★

FEATURE DEBRA WERNER | werner.debra@gmail.com

THE HAN



Lockheed Martin

DOFF

The U.S. Air Force and allies in Congress want to shift responsibility for space traffic management to the FAA. The FAA wants the mission, so no problem, right? Debra Werner looked into the matter and found a challenging bureaucratic transition that would need to happen fast to make the biggest difference.

A new U.S. radar is taking shape on a spit of land in the Pacific Ocean. This radar and companions at 12 other sites will send a harmless curtain of radio frequencies into space. Each time a satellite or chunk of debris passes through the curtain, some of the radio energy will be reflected back to the ground. The Space Fence will spot debris or satellites as small as a golf ball, a considerable improvement over today's softball-sized limit. That's good, because miniature satellites are all the rage, and even a tiny object traveling 29,000 kph (nine times faster than the average rifle bullet) can destroy a spacecraft. Here's the bad news. A team of experts somewhere will have to track 10 times as many objects as before and apply algorithms to estimate when or if any of these previously undetectable objects will collide with each other or spacecraft.

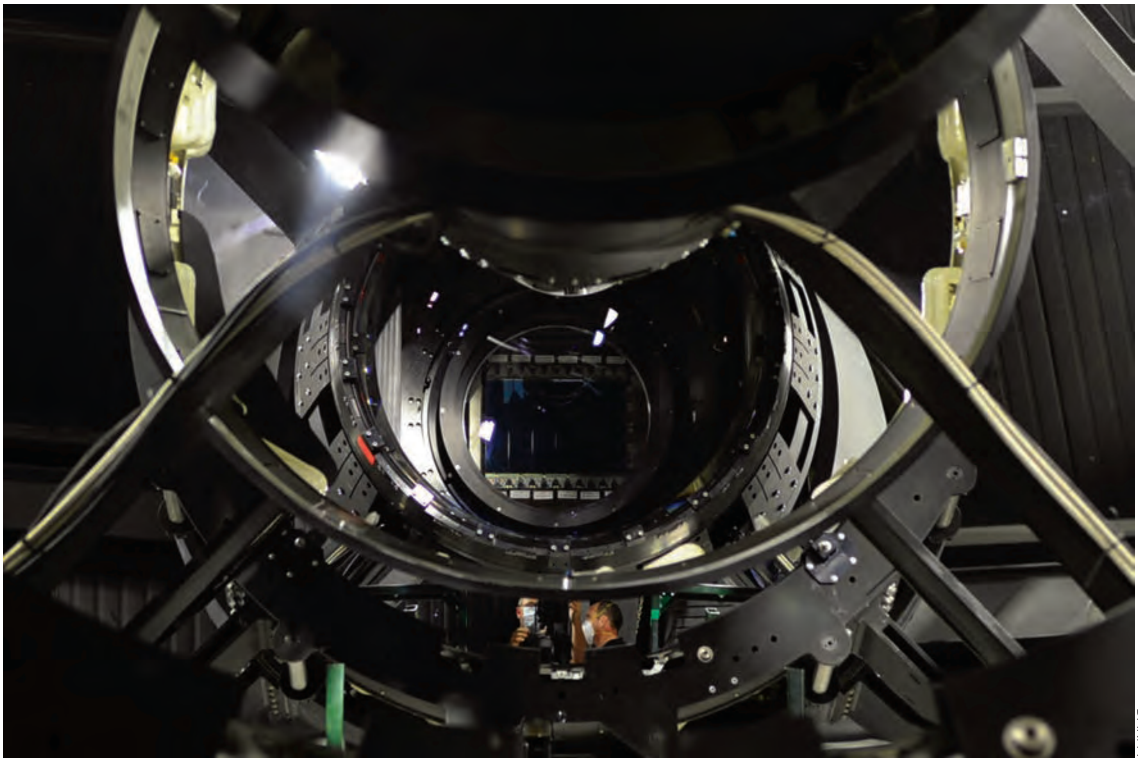
"It will be like putting on glasses and seeing a lot more scary things," says one Air Force official.

If nothing changes, that team of experts would be headed by the Air Force. Just as now, possible conjunctions must be anticipated; spacecraft operators must be asked to maneuver or not to maneuver. Consensus is growing in the U.S. that the Air Force should stop acting like the world's space traffic cop and concentrate instead on figuring out what China, Russia or others are up to militarily in space and figuring out how to counter that if necessary.

Specifically, the Defense Department wants to hand off its satellite tracking data and traffic management duties to the FAA but keep its Joint Space Operations Center, or JSpOC, pronounced Jay-Spock, a gymnasium-sized room in California where specialists from the service branches depict the tracks and identities of space objects on large screens for commanders. The Pentagon says the FAA "has the right mechanisms in place" to provide guidelines for safe operations in space. The FAA's Office of Commercial Space Transportation likes the idea, too.

"We are ready to roll up our sleeves, partner with the Defense Department and other stakeholders to see if we can make that work," says the FAA's George Nield, associate administrator for commercial space transportation.

What this adds up to is a race of sorts. A tidal wave of data is coming, and decisions about personnel, data sharing and funding will need to be made quickly — in bureaucratic time — if a transition to the FAA is to happen before the wave breaks. The Space Fence is due for completion in 2019, and the marketplace is loaded with proposals for vast constellations of small satellites for imaging, communications and weather forecasting. OneWeb, Boeing and SpaceX alone plan to launch about 6,000 small satellites within the next 15 years.


DARPA

The DARPA-designed Space Surveillance Telescope will test enhanced small-object-detection algorithms for objects in geosynchronous orbit. At center is its wide field camera. In 2013, the U.S. and Australia agreed to relocate the telescope from New Mexico to western Australia, but the move has not been made yet.

As for the shift to civilian space traffic management, "This is not the kind of thing where you can snap your fingers and switch it overnight," the Air Force's Winston Beauchamp told reporters in September during a briefing at the AIAA Space conference in Long Beach, California.

"The 25-year rule was an ad hoc number that was settled upon because some folks felt 50 years was too long."

– MORIBA JAH, the University of Arizona's director of space object behavioral sciences and a former principal investigator at the Air Force Research Laboratory, on the timeline for spacecraft to stay in space

Struggling to keep up

Why the eagerness for change? For decades, the Air Force has been responsible for tracking satellites and orbital debris with the Space Surveillance Network, a worldwide array of radars and ground telescopes, including a version of the Space Fence that was shut down in 2013 as well as the new one to come. The locations and identities of spacecraft, if that can be determined, are put into a catalog. The job of parsing this data and warning satellite operators around the world about possible collisions seemed manageable when the United States, Russia and China were the only ones launching spacecraft. Over the past few years, falling launch prices and miniature electronics have led to a surge in satellite activity that promises to double, triple or quadruple the number of spacecraft in orbit within a decade.

Already, the Air Force feels overwhelmed. The Space Surveillance Network takes more than 400,000 snapshots each day showing the orbital position of objects. In 2015, the JSpOC sent nearly 1.3 million emails to government and commercial satellite operators warning them of close approaches. Those warnings led to at least 148 collision avoidance maneuvers last year, including four by the International Space Station.

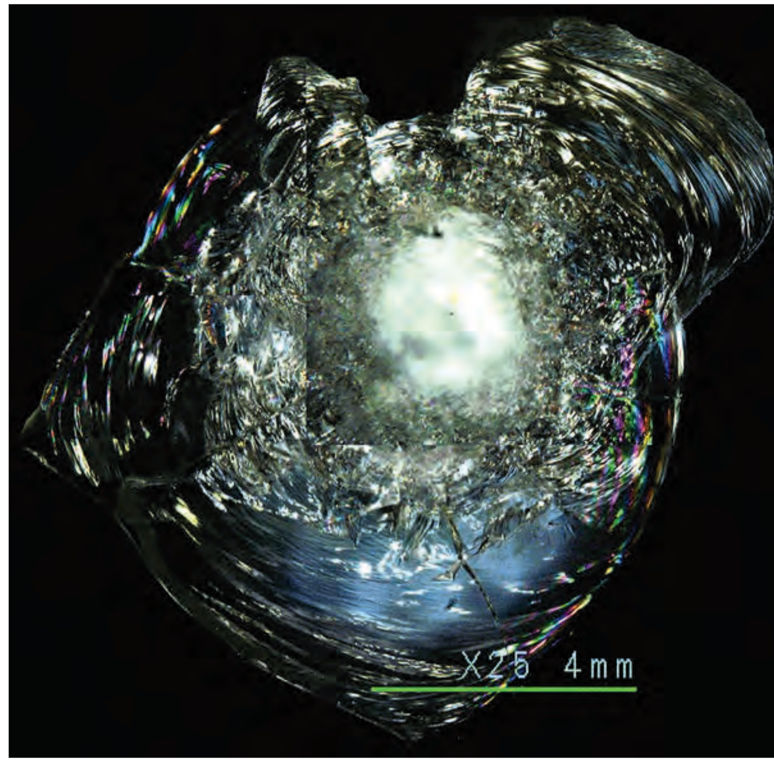
CLOSE CALLS

In 2015, the FAA's Joint Space Operations Center sent nearly **1.3 MILLION** emails to government and commercial satellite operators warning them of close approaches. Those warnings led to at least 148 collision avoidance maneuvers.

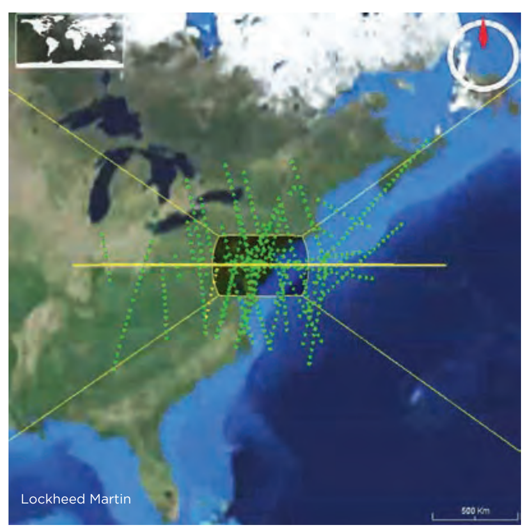
At the same time, potential U.S. adversaries are working on weapons that threaten the satellites the U.S. military relies on for communications, navigation, surveillance and missile warning. The Air Force would rather focus on those military matters by characterizing a spacecraft into its type, discerning its capabilities and determining the intent of its owner.

No matter who has the job, heavy space traffic makes it more likely that pieces of space debris will collide with satellites or spent rocket stages. As NASA's Donald Kessler pointed out in a 1978 paper, each collision increases the chance of additional collisions, which could lead to a cascade and a dangerous belt of debris that would ruin some orbits or threaten satellites traveling through the area into higher orbits.

Even once the Air Force makes the handoff, it will continue to keep close tabs on everything in



NASA



▲ **A micro-meteroid** estimated at just 0.15 millimeter in diameter struck the Endeavour orbiter during the STS-126 shuttle mission in 2008, resulting in this damage to a window.

◀ **This screen capture** of a Space Fence operator display shows the tracks of objects over Moorestown, New Jersey, during a critical-design-review demonstration.

orbit, because that's essential to protecting its spacecraft and those of U.S. allies.

"The Defense Department needs to understand what's up there, how its behaving and what it can do in terms of a threat," explains Moriba Jah, the University of Arizona's director of space object behavioral sciences and a former principal investigator at the Air Force Research Laboratory. "But having the additional burden of informing planet Earth of all this is the piece that doesn't make sense."

The Air Force space surveillance expert was more blunt, saying, "The JSpOC will contribute, but we can't be the only ones holding the bag."

Tragedy of the commons

Until recently, satellite operators paid little thought to space traffic. They would note that there is a lot of empty space in space. That view is changing. Space is undeniably a big place, but more spacecraft than ever are poised for launch, and they will not be spread uniformly throughout Earth's orbit. Instead, they will be clustered in specific kinds of orbits and in specific altitude ranges. Remote sensing satellite operators, for example, generally prefer polar orbits at altitudes of around 800 kilometers so spacecraft pass over farms, forests and cities at the same time every day. That's also an attractive orbit for communications satellites.

"We are now approaching the tragedy of the commons," Jah says. "People are acting in complete self-interest without looking at the needs of the whole community."

He hopes that all the attention on space traffic management will improve this situation. As an example, Jah cites the international rules describing how satellite operators should handle satellites when their missions end. The Inter-Agency Space Debris Coordination Committee publishes debris mitigation guidelines, which have said satellites should be positioned to either fall back into the atmosphere within 25 years or should be dispatched to "graveyard" orbits. Even those rules, which many debris experts say are far too lenient, are not strictly monitored or enforced.

Debris experts also say that space traffic collisions could be avoided more easily if a catalog showed the size and shape of various objects. If satellite operators knew whether space debris headed for their satellite was a rocket body, a dead satellite or a bolt, they would have a better idea of the severity of the threat and how quickly they should move their spacecraft out of the way. Swerving rapidly requires a lot more fuel than a slow and steady maneuvering.

"More rigorous science is needed to help us fully understand the space traffic and orbital safety problem," Jah says. "The 25-year rule was an ad hoc number that was settled upon because some folks felt 50 years was too long. In other words, it's not based on any rigorous analysis that actually shows that 25 years is a magic number for debris mitigation."

He suggests tailoring the rules. Massive spacecraft and large constellations should get out of the way quickly once their jobs are done, Jah says.

There are currently about 1,400 satellites in orbit that their owners can track, control and maneuver. That number is expected to grow quickly, but just how quickly is hard to tell. Entrepreneurs, established firms, universities and government agencies are raising money for 3,000 new satellites. Meanwhile, the International Telecommunication Union, the United Nations agency that dispenses radio spectrum and orbital slots, has received filings from

U.S. Air Force

▲ **Operators at the** Joint Space Operations Center at Vandenberg Air Force Base, California, monitor systems that track and identify artificial objects in Earth's orbit. In 2015, the center sent nearly 1.3 million emails to satellite operators warning them of close approaches.

satellite operators listing 10,000 to 11,000 potential new satellites.

"I wouldn't bet that all the new satellite constellations will become reality, but some will," says Paul Graziani, co-founder and CEO of Analytical Graphics Inc., which licenses software for modeling trajectories of objects in orbit and estimating the likelihood of collisions. "Regardless, smaller satellites are here to stay."

Information explosion

Orbiting alongside the small satellites are half a million pieces of debris. They range from tiny paint chips and foam insulation (dangerous because of their velocities) to spent boosters and spacecraft, like the defunct Russian Cosmos satellite that crashed into an Iridium telecommunications satellite in 2009, creating a debris cloud.

That's the type of collision the Air Force now tries to prevent by telling satellite operators when their spacecraft may be headed for other spacecraft or orbiting debris. Prior to the Cosmos-Iridium collision, the JSpOC focused primarily on military satellites. It was not tracking the Iridium constellation, so it could not warn Iridium Communications. That incident led to major changes. The JSpOC immediately began tracking the Iridium constellation. By June, four months after the collision, the Air Force was paying contractors to start designing the Space Fence. By the end of the year, the JSpOC was tracking all spacecraft in orbit, about 1,150 compared with the 120 military satellites it previously tracked. Since the Iridium-Cosmos collision, the Air Force also signed agreements to share space tracking data with 11 U.S. allies, two U.S. government agencies and 52 commercial firms. Air Force Space Command also boosted staffing in the JSpOC from 43 in 2009 to 56 now.

The string of new S-band radars Lockheed Martin is building on Kwajalein Atoll will help the Air Force track 200,000 objects instead of the 20,000 it now sees. At the same time, the Air Force is negotiating agreements with U.S. allies to share data gathered by foreign telescopes and sensors. Meanwhile, private companies are expanding their efforts to collect, process and share space data.

"We are certainly expecting an explosion in the information and the data we are going to have," said Maj. Gen. David Thompson, vice commander of Air Force Space Command, at the AIAA Space conference in September.

"To be able to deal with it and manage it and still do the mission we have to do, we recognize that as a challenge."

Unanswered questions

Instead of worrying about whether two cubesats are going to smash into each other in low Earth orbit — and if so, how to notify their owners — the Air Force wants to concentrate on protecting military satellites.

"Obviously, we have potential adversaries that recognize the importance of space to the U.S. and its allies from a national security position and are increasingly developing capabilities to attempt to deny that if we ever find ourselves in conflict,"

EVASIVE MANEUVERS

Satellites and the International Space Station must sometimes be steered out of the path of debris. Since its launch in 2014, Orbital ATK has maneuvered the Orbiting Climate Observatory-2 out of the path of debris **SIX TIMES**, says Program Manager Joseph Bushman. The company operates OCO-2 for NASA from Dulles, Virginia. NASA maneuvered the space station four times in 2015.

Lockheed Martin

▲ **A mockup** of Space Flight Operations Center.

Thompson said during the AIAA conference. "If we understand an adversary has a capability and intends to use it against us in space, how do we protect and defend our space assets? How do we prevent them from destroying or damaging those capabilities?"

The Air Force will be able to focus on those questions better once it hands off some of its space traffic management duties to the FAA.

Transportation Secretary Anthony Foxx, whose department includes the FAA, told Congress in a September report that the FAA could take on space data processing and issue safety warnings if it gets congressional authority; protection from lawsuits that might arise from this role; and a $20 million initial expenditure for additional personnel and computer systems.

Nield, of the FAA's space office, thinks it would be wise to begin with a pilot program to practice collecting, processing and sharing space traffic data while protecting information the military does not want to share. Meanwhile, the Air Force would continue in its current role, including issuing collision warnings.

"That [pilot] will allow us to try some things and get our hands dirty," Nield says. "To the extent that there are remaining questions about cost or schedule or the accuracy of the data, we can address those. If it's just not going to work, we can pull the plug and say, 'We tried.'"

But no one expects this transition to fail. The stakes are too high.

"When you are dealing with national security, there always needs to be a sense of urgency," says U.S. Rep. Jim Bridenstine, R-Oklahoma. He proposed legislation in April that would give the FAA authority to take on some of the work currently performed by the Air Force. "We are seeing a proliferation of threats from nation states and non-nation state actors that we didn't foresee even five years ago."

The FAA Office of Commercial Space Transportation could "provide information and services to civil, commercial and foreign actors, while the DoD focuses on what it's good at: fighting and winning wars," he says.

Bridenstine agrees that an FAA pilot program is the appropriate first step, adding that Congress will need to provide the FAA with authority to proceed, and congressional appropriators will have to find funding for the pilot by identifying offsets, which means spending cuts elsewhere in the budget to ensure the new program does not add to the federal deficit.

Through the pilot, the FAA could demonstrate its ability to provide satellite operators with warnings that are as good or better than they currently receive from the JSpOC. If the pilot is successful, the FAA could request funding to expand this work. Then, it will be up to Congress to give the FAA the appropriate authority and funding to carry it out, Bridenstine says.

Meanwhile, work continues on the Space Fence. On one level, "ignorance may be bliss" when it comes to objects in space, Thompson, the vice commander, said during the AIAA conference, but on another level, the Space Fence promises to improve spaceflight safety. The job will just get that much bigger. ★

Debra Werner

is a frequent contributor to Aerospace America and is a West Coast correspondent for Space News. She earned a bachelor's degree in communications from the University of California, Berkeley, and a master's degree in journalism from Northwestern University.

GETTING ITS SPACE MOJO BACK

After the Cold War, Russia emerged as a force to be reckoned with in the commercial space launch arena. Its rockets were relatively inexpensive and famously reliable. More lately, Russia has been beset by launch failures, economic woes and scandals on top of growing competition from long-standing rival Arianespace and newcomer SpaceX. Russia set out to make 2016 a turning point year. Space journalist Anatoly Zak analyzes Russia's strategy.

Russia announced an ambitious rocket modernization strategy at the start of 2016 with some unusual public reflection from its top space leaders. The occasion was the Korolev Readings, an annual gathering of Russian space strategists in Moscow named for the late Sergei Korolev, the founder of the Russian space program. Igor Komarov, the head of Roscosmos, the state-run corporation that is in charge of matters of space, cited a "considerable lag in the use of modern development methods, low productivity and worn machinery," according to my translation of his remarks. He said "modern management systems are still in the process of implementation," and he criticized what he called duplication within the industrial infrastructure. In April, Komarov doubled down, promising to direct 30 billion rubles ($482 million) of the industry's profits into modernization.


Russian Ministry of Defense

An Angara-5 lifts off from Plesetsk, Russia, in 2014 for the first flight of this Russian rocket.

The modernization strategy marks Russia's attempt to keep pace with its international competitors who are adjusting their offerings and embracing technologies such as reusability and additive manufacturing. The Russian strategy is outlined in the latest Federal Space Program, known as FKP-2025, which sets key goals, timelines and budget estimates for all civilian space-related activities in the nation from 2016 to 2025.

Implementing the new strategy will mean conducting the first paid flights of the Angara rocket series that will replace today's faltering Protons; establishing a manufacturing base for Angara production in the Siberian city of Omsk; and expanding a launch site in Vostochny in the Russian Far East to accomodate Angara. Beyond that, today's array of rockets must be consolidated into two families: the Soyuz and the Angara, with six variants of the two rockets to continue flying instead of 12. Komarov outlined the consolidation plan during the cabinet approval hearing for the FKP-2025 program, according to a government transcript.

Quality control

The first order of business for Roscosmos will be to bring its manufacturing house in order after a string of 12 Proton and seven Soyuz rocket launches since 2001 that did not go as planned, with at least two of them failures that suggested quality control issues. In 2010, a Proton rocket plunged into the ocean because too much propellant was loaded onboard. In 2013, flight control sensors mistakenly installed in the upside-down position sent another Proton into a spectacular salto mortale just seconds after liftoff.

This year, besieged by failures and with its customers increasingly fleeing to competitors, Proton might set an anti-record of sorts. It is on pace to fly at most five missions by year's end, its lowest annual launch rate in a decade. Three missions had been flown by mid-October.

As a result, the Khrunichev State Research and Production Space Center, which builds Protons in Moscow, faced a severe funding shortage, requiring layoffs, salary cuts and a huge financial bailout from the Kremlin.

To address quality control problems, the industry attempted to respond with a multiprong approach. "We are doing everything possible to minimize the influence of the human factor on the production process," Andrey Kalinovsky, the head of Khrunichev, told the Izvestia daily in July. "That is, we are implementing modern measurement diagnostic systems, which register results automatically … . By the end of the year, we plan that around 75 percent of all operations at the Proton's final assembly line will be computer controlled."

In August, Roscosmos initiated a three-year program with a 1.9-billion ruble ($30.5 million) price tag aimed at upgrading its propulsion systems. The effort includes identifying replacement materials and components for rocket engines, new measures to ensure flawless operation of propulsion systems, new failure diagnostics, and improvements in production and quality control.

Across the industry, its leaders promised a multitude of measures to improve overall efficiency of the work, to retain the workforce, and to invest in new machinery and computerization. Amazingly, only in the past couple of years have major Russian rocket developers come around to digitizing the design process, and this effort is still ongoing.

Last year, Prime Minister Dmitry Medvedev signed a decree creating a monitoring center for personnel training within the defense industry, including its atomic and rocket sectors. Among the ideas proposed in the Russian Duma or parliament was to free young qualified employees entering the defense industry from the compulsory military service.

Proton might set an anti-record of sorts, flying only five missions during 2016, its lowest annual launch rate in a decade.

PLANNING

Long-range planning: Every 10 years, Russia approves an updated space strategy outlining key goals, timelines and budget estimates. The latest strategy, called FKP-2025, short for Federal Space Program, was approved in March and spans from 2016 through 2025.

Roscosmos also created a directorate specifically for quality and reliability, although the situation might already have been improving. In May, Vladimir Evdokimov, the executive director for quality and reliability at Roscosmos, said defects across the industry have been reduced by 21 percent over the last two years. With just weeks left in 2016, Russia has not had any launch failures, compared to three failed launches in 2015 and three more in 2014.

Adapting for smaller payloads

On the engineering front, Khrunichev looked at various low-cost options for adjusting its fleet to carry a wider range of payloads. For Proton, that means not only increasing payload capacity, but also scaling down the rocket for lighter cargo. Kalinovsky, the Khrunichev chief, announced plans for a new addition to the Proton family, known as Proton-Light, to deliver smaller commercial spacecraft.

In its new configuration, Proton-Light could fill the gap in the payload range between 3.5 and 5 tons delivered to the geostationary orbit popular for commercial communications satellites. This gap in lifting capacity of the Russian space fleet was left by the absence of Zenit rockets, which are made in Ukraine and are no longer available to Russia following its annexation of Crimea in 2014. The lighter, cheaper Proton variant will exactly overlap the capabilities of the American Falcon-9 rocket, putting it in direct competition with SpaceX.

Kalinovsky told the Tass news agency that he had hoped to have Proton-Light ready for launch as early as 2018. According to Khrunichev, the company aims to reduce the cost of making the Proton rocket to 1.38 billion rubles ($22.2 million) apiece, in part, by winning enough commercial orders for up to seven launches per year. If that reduction is achieved, it would likely give Russia a significant competitive edge on the international market.

Troubled generation

The Proton upgrades are seen as stopgap measures before this Cold War-era, toxin-emitting behemoth is replaced with the Angaras. Protons burn dimethylhydrazine fuel with nitrogen tetroxide oxidizer, chemicals that are dangerous for workers and the environment. These components have been largely phased out by the world's other major space launch providers in favor of kerosene or liquid hydrogen fuel and liquid oxygen oxidizer. According to the strategy Russia set in the 1990s, the Proton rocket along with its launch pads based in the former Soviet republic of Kazakhstan were to have been retired by now in favor of Angaras launched from Russian territory. The Angara, burning nontoxic kerosene fuel, was also designed around a modular architecture, enabling the use of common booster stages in at least three different configurations with their own mass categories. The largest, five-booster variant, could match Proton, or so Angara's developers hoped.

Like many other things in Russian history, the Angara's path toward the market has not been straightforward or easy. In 2014, after a decade of delays, the light and heavy versions of the Angara rockets performed as planned in test flights, but two years later, the new shiny booster is still years away from being able to replace Proton. The development work was complicated by the simultaneous effort to shift the rocket production from Moscow to Omsk to reduce the manufacturing cost and match the rock-bottom price of the Proton. To achieve that, the Siberian factory needs to operate 24/7 in three shifts to churn out up to 100 Angara boosters per year by 2021.

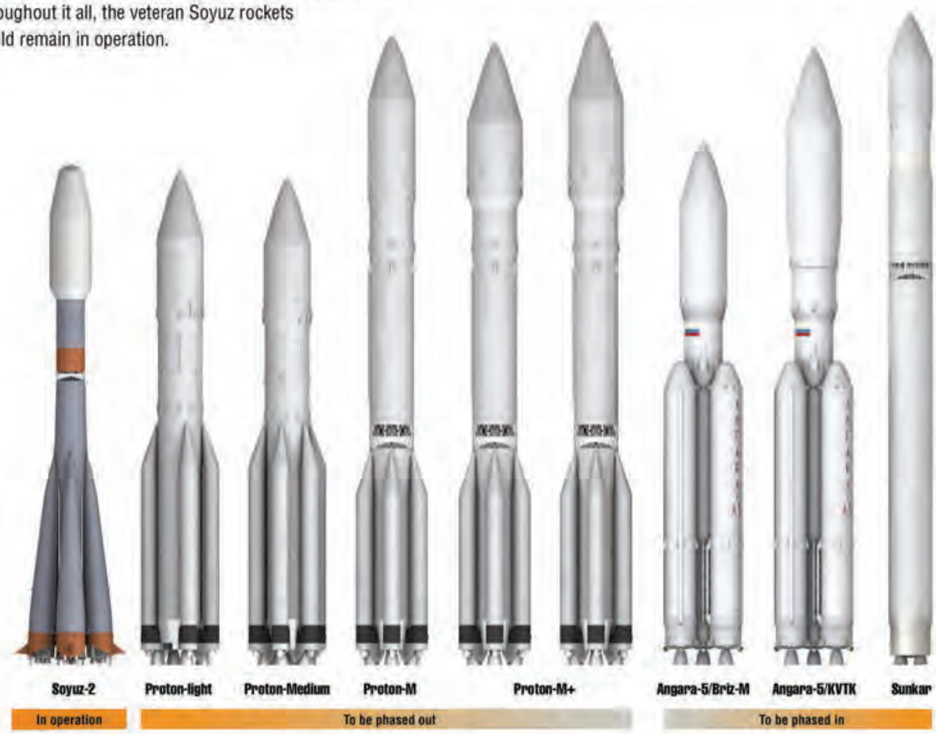
The silver lining for this monumental transition is the creation of the first state-of-the-art rocket facility of the post-Soviet era. "Trust me, from the point of view of production organization and its philosophy, our company will be one of the most advanced," Kalinovsky told the official RIA Novosti news agency in June.

The Angara has a possible Achilles' Heel, namely the rocket's launch pad in Plesetsk. Built according to the 1990s requirements of the Russian military, the near-polar-circle facility is ill-suited for a competitive commercial race to the equatorial orbit. To fix the problem, Roscosmos now plans to expand

Russian rockets circa 2025

The Roscosmos State Corporation plans to replace its workhorse Proton rockets, burning toxic propellants and based in neighboring Kazakhstan, with a new Angara series relying on environmentally neutral fuel and based at a launch site in Vostochny in Russia's Far East. Simultaneously, a new type of booster, dubbed Sunkar, might reach the launch pad, replacing the Ukrainian-built Zenit and paving the way for super heavy rocket later in the 2020s.

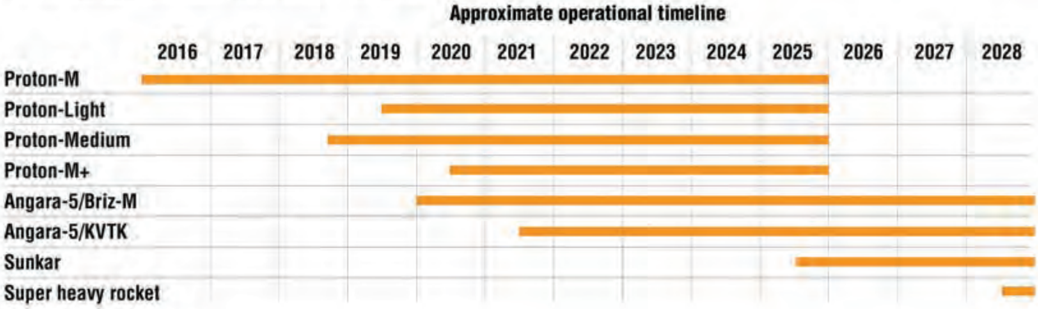
Throughout it all, the veteran Soyuz rockets would remain in operation.



	Soyuz-2	Proton-M Phase 4	Angara-5/Briz-M	Sunkar
Liftoff mass	312 tons	~705 tons	773 tons	520 tons
Payload to Low Earth Orbit	8.2 tons	22 tons	24.5 tons	17 tons
Payload to Geostationary Transfer Orbit	3.06 tons*	6.35 tons	5.4 tons**	5.0 tons

**from Europe's Spaceport in Kourou, French Guiana; ** from Plesetsk Cosmodrome in Russia*

Approximate operational timeline



Anatoly Zak

the new Vostochny spaceport in the country's Far East to launch Angara vehicles. With the evergreen taiga hardly cleared around the future launch pad, the facility is not expected to enter operations until the early 2020s. In the meantime, expect Proton to continue flying until at least the mid-2020s. Recent economic problems in Russia put more hurdles before the project, raising serious questions about the realistic completion date for the Angara's commercial launch pad.

Will Phoenix rise?

Even with Angara progressing, Russian rocketeers have little time to rest. One of the criticisms leveled against the Angara is that its modular boosters were sized too small during the economically difficult mid-1990s, severely limiting its growth potential in terms of payload.

Now, Roscosmos feels it is time to address that problem, as well, with the project dubbed Feniks, pronounced like Phoenix. The original goal was to

Russian Ministry of Defense

▲ **Russia's first** Angara-5 rocket undergoes pre-launch processing in Plesetsk, Russia. The Angaras will burn nontoxic kerosene fuel, making them an attractive successor to the country's Protons.

build a rocket that would burn cryogenic methane fuel and replace the historic Soyuz boosters. After several course corrections, Russia this year began steering toward development of Feniks as a Zenit rocket on steroids. Generally resembling its Ukrainian predecessor, the Russian version will have a slightly larger diameter of 4.1 meters, which is the maximum for transporting the oversized first stage along the Russian rail network to the launch site at Baikonur in Kazakhstan. Also, that diameter had already been adopted for the Proton, so, theoretically, the same tooling and machinery could be used to make the new rocket, greatly cutting the development time and reducing the cost of the overall project.

The first stage of the Feniks will be propelled by the RD-171 engine inherited from the Zenit, giving a new job to the world's most powerful rocket motor, despite Russia's annexation of Crimea. Moscow-based NPO Energomash still produces a half-size version of the same engine dubbed RD-180 for the American Atlas and a quarter size designated RD-191 for the Angara.

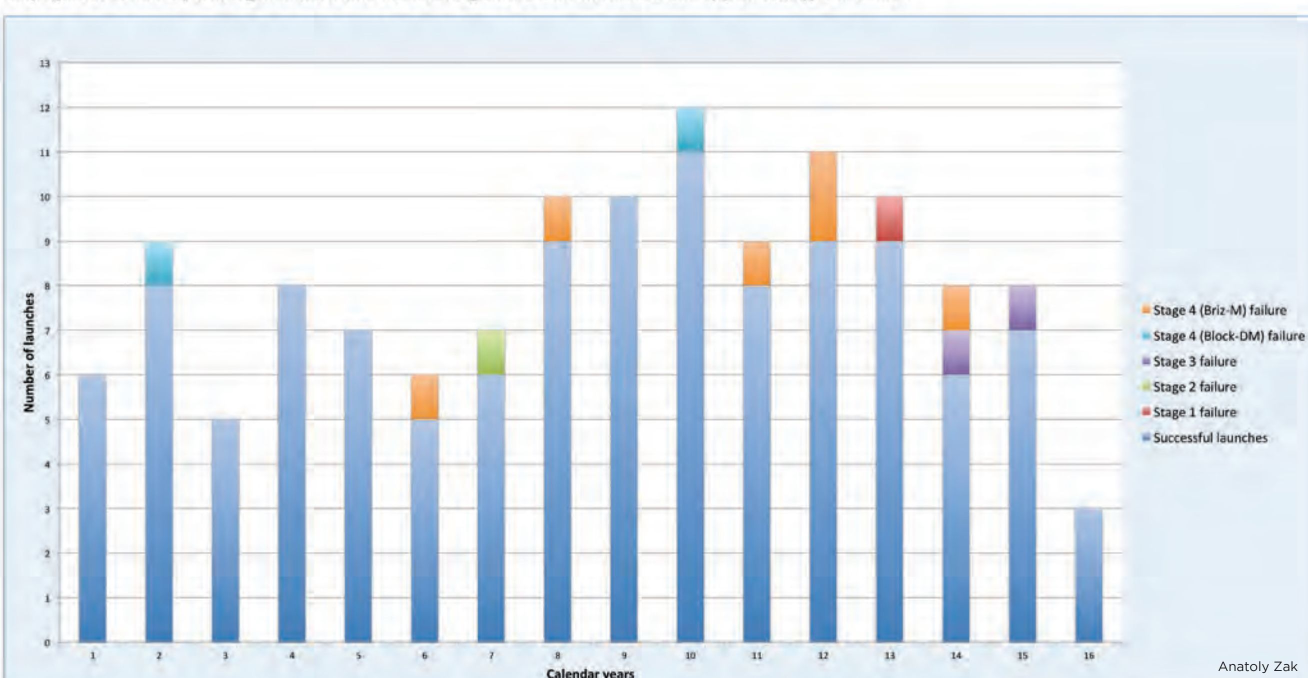
The second stage on the Feniks will be propelled by a pair of RD-0124A engines borrowed from the Angara.

The Feniks launcher could reach the launch pad around 2024 (right about the time of the Proton's expected retirement) and deliver an estimated 17 tons to the low-Earth orbit and around 2.5 tons to the geostationary orbit.

To improve chances for Feniks' success, Russia resumed talks with Kazakhstan on the long-stalled Baiterek project. Its original goal set in 2004 was to deploy a commercial version of the Angara rocket at the Kazakh-paid launch pad in Baikonur. However, the idea withered, apparently after Kazakh landlords had gotten a price quote for the future facility from Russian contractors. Now, the strategy evolved to put jointly funded Feniks-based rockets at the unused Zenit pad in Baikonur. Specifically for the joint Russian–Kazakh venture, the future rocket was dubbed Sunkar. It is positioned to fill the market niche that would be initially served by the Pro-

Proton launch numbers through the years

Russia has launched 129 Protons since 2001, with just three launches so far this year compared with a peak of 12 in 2010. Twelve of the launches have experienced varying levels of failure, with eight of those failures occurring since 2010. The launch rate by year and type of failure:



Anatoly Zak

ton-Light vehicle before it retires.

Not coincidentally, Russian strategists believe that the market segment of medium-sized satellites requiring Proton-Light, and later Sunkar-Feniks, will see sizable growth in the coming years. They expect almost flat orders among heavier satellites and a drop in sales predicted for smaller satellites. Roscosmos officials are banking on the emerging use of electric engines on commercial satellites to lighten them into the medium category, because they will not carry the traditional liquid-propellant thrusters.

Back to super booster

In addition to its commercial role, the Feniks booster could become a stepping stone toward a super rocket approaching the capabilities of NASA's Space Launch System booster now in development. Angara's standard rocket modules would never be able to provide that kind of capacity.

The yet-to-be approved, let alone funded, Russian super rocket would be linked to the future of Russian human spaceflight. Because the Kremlin sees the moon as the main strategic destination for its cosmonauts, several attempts have been made in recent years to devise a lunar-exploration strategy not reliant on giant rockets. One idea called for pushing the Angara to its absolute limit with hydrogen-powered upper stages to deliver payloads to the moon. Speaking at the International Astronautical Congress in 2015, Vladimir Solntsev, the head of RKK Energia, Russia's main human spaceflight contractor, said that a lunar expedition based on four Angara-5V rockets could have four times cheaper costs than a similar mission launched by a single SLS rocket.

However, this year's calculations made at RKK Energia showed that these plans would be too risky for a trip to the moon. Splitting the mission into four launches would bring down the probability of its success to 67 percent compared with 90 percent when sending cosmonauts to the moon with the help of only two larger rockets.

As a result, Roscosmos reportedly dropped plans to develop a hydrogen-powered booster for the Angara-5V rocket and will switch any possible lunar expeditions to a super-heavy vehicle similar to the SLS. The latest Russian concept of this giant rocket calls for clustering together up to seven Feniks boosters. "I am sure we can develop the super heavy rocket under this scheme in a record time — we are talking five, seven years," Solntsev told Izvestia in August.

Russian officials optimistically hope that the rocket capable of delivering 80 tons into orbit could be ready for flight around 2025, or just a few years after a new-generation spacecraft designed to carry cosmonauts to the moon is expected to come online. Further upgrades of the rocket could boost its payload to 120 or even 160 tons.

Whether Roscosmos manages to carry out FKP-2025 will depend heavily on the state of the Russian economy, which relies on oil prices and trade relations with the outside world. Those factors will decide the actual budget that Roscosmos will receive and they are beyond the space industry's control. What it can control is attaining success in its new strategy of reforming the industry and modernizing the nation's space fleet.

Those factors will ultimately determine success and that's why 2016 could go down as a turning point year for the Russian space enterprise. ★

Roscosmos

▲ **A Russian** Proton is erected on the launch pad at Baikonur Cosmodrome in Kazakhstan. Proton launches have declined sharply in recent years but Russian officials have plans to reverse the slide with a new version, called Proton-Light.

Anatoly Zak
grew up in Moscow and publishes the RussianSpaceWeb.com news site from New Jersey.

Setting the pace to Mars

With so much being said about exploring the Red Planet, Aerospace America invited Boeing executive John Elbon to help us make sense of it all. His company is one of six funded by NASA in August to develop prototype equipment for the journey to Mars.

▲ **In this Boeing concept**, astronauts would live and work inside conjoined habitats in cislunar orbit near the moon. A power and propulsion module would provide electricity and motion control for their spacecraft. The crew would conduct operations, scientific studies and test hardware needed to reach Mars.

Mars is at the center of a global conversation about space exploration.

Everyone seems to have a theory on the best way to get humans beyond low-Earth orbit to live and work on the Red Planet. We're seeing the invention of new options, a retreading of old ideas, and sometimes a combination of both. Thinking big is a good thing, and then we must get to work on a plan that's practical and possible. Apollo-era visionaries did the same thing and then executed a plan within the parameters of what was possible given current technologies and enduring laws of physics.

Enthusiasm and excitement generated by ideas for advancing human space exploration, like those of Boeing, SpaceX, Blue Origin and Lockheed Martin, are key to generating widespread support. Ideas are meant to motivate people, to drive exploration fueled by curiosity.

It's an exciting time in the space industry as we build rockets for launch, test new spaceships, and develop innovative technologies for keeping humans alive on orbit in deep space.

Boeing's approach for human missions to Mars, embodied in our "Path to Mars" campaign, could be viewed as more pragmatic because we believe a more gradual approach is required. The vision challenges us to leverage our human spaceflight experience to achieve a permanent — and steadily expanding — human presence in deep space.

There will always be risk in human space flight and it's important that we don't allow ourselves to be stymied by risk aversion. At the same time, approaches for making stepwise progress, building on lessons learned as we go, are critical to long-term success.

Space flight is challenging — one miscalculation could cost years in research, millions of dollars in production or the loss of life. It's critical to set realistic expectations and align those with an achievable timeline. Getting to Mars and back safely is going to be a marathon, not a sprint. The first step is the research and technology developments on the International Space Station.

ISS is the cornerstone of current space operations and supports the development of a broad array of exploration capabilities.

Science research and technology demonstrations on the space station — such as autonomous rendezvous and docking trials and ongoing human health and behavioral research — bring us closer to new destinations.

The station's One Year Crew mission, in which astronaut Scott Kelly and cosmonaut Mikhail Kornienko spent 340 days on the outpost, is a prime example of researchers using the ISS as a platform for preparing humanity for exploration into deeper space. During this and earlier missions on ISS, scientists and researchers gained valuable and often revealing data on the effects of microgravity on bone density, muscle mass, strength, vision and other aspects of human physiology.

Today, astronauts grow food on the space station. The ability to produce high-energy, low-mass food during spaceflight maintains crew health during long-duration missions while reducing the resources that must be carried for long-distance travel.

Crews on ISS are also using 3-D printing to manufacture tools and spare parts. This is the first step toward establishing an on-demand machine shop in space.

And on ISS, the Environmental Control and Life Support System recovers and recycles water from everywhere: urine, hand washing and oral hygiene. Through the Water Recovery System, almost 99 percent of the water is reclaimed, filtered, and ready for consumption.

Commercial Crew is the first NASA human spaceflight program that will utilize a commercial-government partnership to provide crewed transportation to the ISS. Boeing will manufacture, own and operate one of those vehicles, the CST-100 Starliner. There will be a fleet of reusable Boeing Starliners.

NASA will essentially purchase a seat for their astronauts. This model of contracts in the long run will free up funds for NASA to focus on future deep space exploration missions like going to Mars.

When Bill Boeing started this company in 1916, his relatively modest goal of helping to deliver mail for the U.S. Postal Service grew into an international commercial transportation market. Today, we're extending that market to space travel.

Over the next decade, the space station might be joined in low-Earth orbit by other orbiting research facilities. Space tourism is a potential growth area but only if low-Earth orbit can sustain a viable market and we can lower costs to a more consumer-friendly ticket price. Those of us in industry, partnered with NASA, have focused primarily on developing the capabilities to live and work in low-Earth orbit. Crew and cargo transportation and LEO destinations represent the "supply side" of the economic model. Developing robust commercial markets in LEO now requires focus and investment on the "demand side."

Boeing is also a part of NASA's journey to Mars as a prime contractor building the Space Launch System or SLS, the largest, most powerful rocket ever built. This is the rocket that will get humans to Mars.

SLS represents the cornerstone of the nation's push beyond low-Earth orbit into deep space in the 2020s. The program is on track to meet its cost and schedule commitments. Flight hardware is being built. And it continues to make sustained progress toward the first deep-space test flight in 2018 and first crewed mission in 2021. These early missions to the proving ground will provide the basis for the private sector to build upon.

SLS is capable of carrying more than twice the payload to deep space of any other launch vehicle today. It is uniquely designed to safely and effectively enable early exploration proving ground missions near the moon to validate our systems and operations. Those missions will create the confidence necessary to embark on human missions to Mars in the early 2030s and provide systems, standards and technology for the private sector to use.

With this capability, humans will be capable of a variety of missions, whether it's building an outpost near the moon; placing in orbit bigger, better telescopes that can look more deeply into the universe; or landing on the Red Planet.

The "Path to Mars" is a reference scenario that reflects a step-wise evolution of critical capabilities from ISS to missions in the lunar vicinity in preparation for the human journey to Mars. The architecture behind this scenario involves assembling and operating an outpost near Earth's moon between 2021 and 2025. The five components of the outpost include two habitat modules, an airlock, a logistics module, and a power bus and augmentation module.

Boeing is already working on a full-scale ground prototype cislunar habitat demonstrator as part of NASA's Next Space Technologies for Exploration Partnerships 2 or NextSTEP-2 program. Building an outpost in cislunar space will also offer international partnerships and commercial opportunities for lunar exploration and collaborative research. The outpost could also serve as a staging ground for governments and private companies that are interested in activities around or on the moon.

Crews would spend the rest of the 2020s evaluating deep space habitability, logistics, operational procedures and vehicle systems in an environment similar to what will be experienced on the journey to Mars.

Under the Boeing plan, a landing on the surface would follow in the mid- to late 2030s.

A century of innovation changed the way we work, live and play around the globe and in space. Developing new technologies for Mars could feed economic growth on Earth. Methods for conducting agriculture under extreme conditions and generating power, including improved solar cells, could benefit our planet.

Mars is our ultimate goal because it holds the promise of a better tomorrow for generations to come. It's a big part of why we're here. ★

John Elbon is Boeing's vice president and general manager for space exploration. He was Boeing's program manager for construction and assembly of the International Space Station from 2003 to 2006. Elbon has a bachelor's degree in engineering from Georgia Institute of Technology.

MEMBERSHIP MATTERS

Your Membership Benefits

1. **Get Ahead of the Curve –** Stay abreast of in-depth reporting on the innovations shaping the aerospace industry with ***Aerospace America***, and a daily dose of vetted industry news in the ***AIAA Daily Launch*** – both delivered free with AIAA membership.

2. **Connect with Your Peers –** Whether you are ready to travel to one of AIAA's five forums, or you want to stay close to home, AIAA offers the best opportunities to **meet the people working in your industry and interest.**

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4. **Publish Your Work –** If you are searching for the best place to publish or present your research, look no further! AIAA has five targeted **forums**, eight specifically focused **journals**, and a number of co-sponsored conferences to choose from. Find your peers, publish your work and progress in your career!

5. **Save Money –** Get free access to all our **standards documents** and get discounts on forum registrations, journal subscriptions and book purchases. These savings can quickly pay for your membership!

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AIAA

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AIAA Bulletin

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

Calendar

Notes About the Calendar

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2016			
7–10 Nov†	International Telemetering Conference	Glendale, AZ (Contact: www.telemetry.org)	
8–10 Nov†	Aircraft Survivability Symposium 2016	Monterey, CA (Contact: http://www.ndia.org/meetings/7940)	
15–16 Nov†	Drone World Expo (DWE)	San Jose, CA (http://www.droneworldexpo.com/)	
2017			
7 Jan	Space Standards and Architecture Workshop	Grapevine, TX	
7–8 Jan	Introduction to Shock-Wave/Boundary-Layer Interactions Course	Grapevine, TX	
7–8 Jan	Liquid Atomization, Spray, and Fuel Injection in Aircraft Gas Turbine Engines Course	Grapevine, TX	
7–8 Jan	Six-Degrees-of-Freedom Modeling of Missile and Aircraft Simulations Course	Grapevine, TX	
7–8 Jan	2nd AIAA Sonic Boom Prediction Workshop	Grapevine, TX	
8 Jan	Hypersonics Test Course	Grapevine, TX	
8 Jan	7 Axioms for Good Engineering Workshop	Grapevine, TX	
9 Jan	2017 Associate Fellows Recognition Ceremony and Dinner	Grapevine, TX	
9–13 Jan	AIAA SciTech 2017 (AIAA Science and Technology Forum and Exposition) Featuring: – 25th AIAA/AHS Adaptive Structures Conference – 55th AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – 19th AIAA Non-Deterministic Approaches Conference – 58th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – 10th Symposium on Space Resource Utilization – 4th AIAA Spacecraft Structures Conference – 35th Wind Energy Symposium	Grapevine, TX	6 Jun 16
22–26 Jan†	97th American Meteorological Society Annual Meeting	Seattle, WA (Contact: https://annual.ametsoc.org/2017/)	
23–26 Jan†	63rd Annual Reliabiltiy & Maintainability Symposium (RAMS 2017)	Orlando, FL (http://rams.org/)	
5–9 Feb†	27th AAS/AIAA Space Flight Mechanics Meeting	San Antonio, TX (Contact: www.space-flight.org/docs/2017_winter/2017_winter.html)	7 Oct 16
4–11 Mar†	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	
6–9 Mar†	21st AIAA International Space Planes and Hypersonic Systems and Technology Conference (Hypersonics 2017)	Xiamen, China	22 Sep 16
29 Mar	AIAA Congressional Visits Day (CVD)	Washington, DC (http://www.aiaa.org/CVD/)	
18–20 Apr†	17th Integrated Communications and Surveillance (ICNS) Conference	Herndon, VA (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, http://i-cns.org)	
25–27 Apr	AIAA DEFENSE 2017 (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

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

AIAA Continuing Education offerings

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
25–27 Apr†	EuroGNC 2017, 4th CEAS Specialist Conference on Guidance, Navigation, and Control	Warsaw, Poland (Contact: robert.glebocki@mel.pw.edu.pl; http://www.ceas-gnc.eu/)	
2 May	2017 Fellows Dinner	Crystal City, VA	
3 May	Aerospace Spotlight Awards Gala	Washington, DC	
8–11 May†	AUVSI/AIAA Workshop on Civilian Applications of Unmanned Aircraft Systems	Dallas, TX (www.xponential.org/auvsi2016/public/enter.aspx)	
15–19 May†	2017 IAA Planetary Defense Conference	Tokyo, Japan (Contact: http://pdc.iaaweb.org)	
25–29 May†	International Space Development Conference	St. Louis, MO (Contact: ISDC.nss.org/2017)	
29–31 May†	24th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: Ms. M. V. Grishina, icins@eprib.ru, www.elektropribor.spb.ru)	
3–4 Jun	3rd AIAA CFD High Lift Prediction Workshop	Denver, CO	
3–4 Jun	1st AIAA Geometry and Mesh Generation Workshop	Denver, CO	
5–9 Jun	AIAA AVIATION 2017 (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
6–9 Jun†	8th International Conference on Recent Advances in Space Technologies (RAST 2017)	Istanbul, Turkey (Contact: www.rast.org.tr)	
19–21 Jun†	9th International Workshop on Satellite Constellations and Formation Flying	Boulder, CO (Contact: http://ccar.colorado.edu/iwscff2017)	
10–12 Jul	AIAA Propulsion and Energy 2017 (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 2017
12–14 Sep	AIAA SPACE 2017 (AIAA Space and Astronautics Forum and Exposition)	Orlando, FL	21 Feb 17
13–16 Sept†	21st Workshop of the Aeroacoustics Specialists Committee of the Council of European Aerospace Societies (CEAS)	Dublin, Ireland	
25–29 Sept†	68th International Astronautical Congress	Adelaide, Australia	

News

AIAA Announces Candidates for 2017 Board of Trustees and Council of Directors Election

AIAA is pleased to announce that its Nominating Committee has selected candidates for next year's openings on the AIAA Board of Trustees and Council of Directors. The Committee's Chairman, Jim Albaugh, and AIAA Corporate Secretary, William Seymore, confirmed the names of the officer and director candidates who will appear on the 2017 ballot. The nominees are:

President–Elect

- John Langford, Aurora Flight Sciences Corporation
- Vigor Yang, Georgia Institute of Technology

Director–Technical, Aircraft and Atmospheric Systems Group

- Dimitri Mavris, Georgia Institute of Technology

Director–Technical, Engineering and Technology Management Group

- Nancy Andersen, Johns Hopkins University Applied Physics Laboratory
- Sophia Bright, Boeing Defense, Space & Security

Director–Technical, Space and Missiles Group

- Steven Griffin, Boeing Defense, Space & Security
- Peter Montgomery, Jacobs Technology
- Lawrence Robertson, Air Force Research Laboratory
- Mark Whorton, University of Tennessee Space Institute

Director–Region I

- Steven Bauer, NASA Langley Research Center
- Martin Frederick, Northrop Grumman Corporation

Director–Region II

- John Blanton, Classic Engineering LLC
- Kurt Polzin, NASA Marshall Space Flight Center

The AIAA Constitution also allows nominations to be made via petition. The petition must be supported by at least 300 eligible voting members of the Institute. Members intending to follow this process are asked to contact the AIAA Secretary, Bill Seymore, at 703.264.7540 or bills@aiaa.org, as soon as possible before the 19 December 2016 petition deadline for more specific instructions and coordination.

All eligible voting members of AIAA will be able to cast their ballot beginning in February 2017.

AIAA Announces Class of 2017 Associate Fellows

AIAA is pleased to announce its Class of 2017 Associate Fellows. AIAA will formally honor and induct the class at its AIAA Associate Fellows Recognition Ceremony and Dinner on Monday, January 9, 2017, at the Gaylord Texan Hotel & Convention Center, Grapevine, Texas, in conjunction with the AIAA Science and Technology Forum and Exposition 2017 (AIAA SciTech 2017), January 9-13.

"I extend my warmest congratulations to the Class of 2017 Associate Fellows," said AIAA President Jim Maser. "Each of these individuals has performed extraordinary work and advanced the state of the art in aerospace science and technology. I look forward to celebrating their achievements with them at AIAA SciTech 2017 this January. AIAA thanks them for their efforts, and we look forward to seeing how their continued work and effort will shape the future of aerospace."

The grade of Associate Fellow recognizes individuals "who have accomplished or been in charge of important engineering or scientific work, or who have done original work of outstanding merit, or who have otherwise made outstanding contributions to the arts, sciences, or technology of aeronautics or astronautics." To be selected as an Associate Fellow an individual must be an AIAA Senior Member in good standing, with at least twelve years professional experience, and be recommended by a minimum of three current Associate Fellows.

The Class of 2017 AIAA Associate Fellows are:

Farooq Akram, *National University of Sciences and Technology, Islamabad, Pakistan*

Edward Alyanak, *U.S. Air Force Research Laboratory*

Paul Anderson, *Lockheed Martin Corporation*

Matthew Angiulo, *Raytheon Missile Systems Company*

Keith Bergeron, *U.S. Army*

Jaime Bestard, *U.S. Air Force Research Laboratory*

Gaudy Bezos-O'Connor, *NASA Langley Research Center*

Mahendra J. *Bhagwat, U.S. Army Aviation Development Directorate - AFDD*

Subodh Bhandari, *California State Polytechnic Institute, Pomona*

Raktim Bhattacharya, *Texas A&M University*

Trevor Birch, *The Defence Science and Technology Laboratory*

John Blevins, *NASA Marshall Space Flight Center*

Ruxandra Botez, *École de Technologie Supérieure*

Salvatore Bruno, *United Launch Alliance*

Jonathan Burt, *NASA Glenn Research Center*

Chunpei Cai, *Michigan Technological University*

Victor Canacci, *Jacobs Aerospace & Technology Inc.*

Melissa Carter, *NASA Langley Research Center*

John Celli, *SSL*

Sandy Coleman, *Orbital ATK*

William Cousins, *United Technologies Research Center*

Jeffrey Crouch, *The Boeing Company*

Chris Crumbly, *NASA Marshall Space Flight Center*

Darold Cummings, *consultant*

Dana Dabiri, *University of Washington*

Misty Davies, *NASA Ames Research Center*

Anthony J. *Dean, General Electric Corporation*

Paul DesJardin, *University at Buffalo, the State University of New York*

Atilla Dogan, *University of Texas at Arlington*

Robert Dougherty, *OptiNav Inc.*

Kevin Duda, *The Charles Stark Draper Laboratory Inc.*

Parker David *Elrod, II, Jacobs Aerospace & Technology Inc.*

Roberta Ewart, *Air Force Space Command, Space and Missile Systems Center*

Karen Feigh, *Georgia Institute of Technology*

Barry W. *Finger, Paragon Space Development Corporation*

Scott Fouse, *Lockheed Martin Corporation*

James Fritz, *United Technologies Research Center*

Bharathram Ganapathisubramani, *University of Southampton*

Daniel Garmann, *U.S. Air Force Research Laboratory*

Michael Gazarik, *Ball Aerospace*

Brian German, *Georgia Institute of Technology*

Debasish Ghose, *Indian Institute of Science*

Bryan Glaz, *U.S. Army Research Laboratory*

Ryan Gosse, *U.S. Air Force Research Laboratory*

Christopher Greek, *U.S. Air Force*

Matthew Grismer, *U.S. Air Force Research Laboratory*

Brian Gulliver, *Kimley-Horn*

Linda Habash-Krause, *NASA Marshall Space Flight Center*

John Hanson, *NASA Marshall Space Flight Center*

Jason Hatakeyama, *The Boeing Company*

Jennifer Heeg, *NASA Langley Research Center*

Joseph Roger *Herdy, Government Energy Solutions Inc.*

Ann Heyward, *Ohio Aerospace Institute*

Robert Hiers, *QuantiTech, Inc.*

Serhat Hosder, *Missouri University of Science and Technology*

Florence Hutcheson, *NASA Langley Research Center*

Gregory Hyslop, *The Boeing Company*

William Janick, *Schnader Harrison Segal & Lewis LLP*

Thomas Jenkins, *Metro Laser Inc.*

Naibo Jiang, *Spectral Energies LLC*

Gregory Jones, *NASA Langley Research Center*

Stephen Jurczyk, *NASA Headquarters*

H. Alicia *Kim, University of California, San Diego*

Youdan Kim, *Seoul National University*

William Kimmel, *NASA Langley Research Center*

Teresa Kinney, *NASA Kennedy Space Center*

Christian Klein, *German Aerospace Center*

Mykel Kochenderfer, *Stanford University*

Kimiya Komurasaki, *University of Tokyo*

Ajay Kothari, *Astrox Corporation*

Daniel Kwon, *Lockheed Martin Corporation*

Tonghun Lee, *University of Illinois at Urbana-Champaign*

Allen Li, *U.S. House of Representatives, Committee on Science, Space, and Technology*

Daniel Livescu, *Los Alamos National Laboratory*

Randal Lycans, *Jacobs Aerospace & Technology Inc.*

Samantha Magill, *Honda Aircraft Company*

Rodney Makoske, *Lockheed Martin Corporation*

James Masciarelli, *Ball Aerospace*

Naomi Mathers, *Australian National University*

James Maus, *Aerojet Rocketdyne*

Todd May, *NASA Marshall Space Flight Center*

Robert McAmis, *National Aerospace Solutions*

Christopher McLean, *Ball Aerospace*

Kevin Melcher, *NASA Glenn Research Center*

Jason Merret, *Gulfstream Aerospace Corporation*

Michael Meyer, *NASA Glenn Research Center*

Samy Missoum, *University of Arizona*

James Moore, *ManTech Nexole Corporation*

Mark Moore, *NASA Langley Research Center*

Theodore J. *Muelhaupt, The Aerospace Corporation*

Mark Mueller, *The Aerospace Corporation*

John J. *Murphy Jr., Wright-Patterson Air Force Base*

Sudheer Nayani, *Analytical Service and Materials Inc.*

James C. *Newman, University of Tennessee at Chattanooga*

Craig Nickol, *NASA Langley Research Center*

Melike Nikbay, *National Institute of Aerospace*

Michael Oelke, *Iron Ring Technologies, LLC*

Carl Ollivier-Gooch, *University of British Columbia*

Timothy Ombrello, *Wright-Patterson Air Force Base*

Gustavo Ordonez, *Aurora Flight Sciences Corporation*

Jeffrey S. *Osterlund, The Boeing Company*

Evangelos Papadopoulos, *National Technical University of Athens*

Dario Pastrone, *Polytechnic of Turin*

Tim Pickens, *Pickens Innovations*

Timothee Pourpoint, *Purdue University*

David Richie, *U.S. Air Force Academy*

Donald Rockwell, *Lehigh University*

Julie Sattler, *Lockheed Martin Corporation*

Ramin Sedaghati, *Concordia University*

Toru Shimada, *Japan Aerospace Exploration Agency*

Babak B. *Shotorban, University of Alabama in Huntsville*

Eric Silk, *NASA Goddard Space Flight Center*

Kumar Singh, *Miami University*

Rabindra "Rob" *Singh, SSL*

Jeffery Slotnick, *The Boeing Company*

Edward Smith, *Pennsylvania State University*

Henry Sodano, *University of Michigan, Ann Arbor*

Julio Soria, *Monash University*

James Steck, *Wichita State University*

John Paul *Steinbrenner, Pointwise Inc.*

Cornel Sultan, *Virginia Polytechnic Institute and State University*

Eric Swenson, *Air Force Institute of Technology*

Kunihiko Taira, *Florida State University*

Nigel John *Taylor, MBDA UK Ltd.*

William Tomek, *NASA Langley Research Center*

Aaron Tucker, *U.S. Air Force*

Anthony Washburn, *NASA Langley Research Center*

James Weber *Jr., U.S. Air Force Research Laboratory*

Joseph Wehrmeyer, *Arnold Engineering Development Center*

Marc Weinberg, *The Charles Stark Draper Laboratory*

Lesley Weitz, *The MITRE Corporation*

Gerard Welch, *NASA Glenn Research Center*

Edward Whalen, *The Boeing Company*

Andrew Williams, *U.S. Air Force Research Laboratory*

Richard Wirz, *University of California, Los Angeles*

Nicholas Wyman, *Pointwise Inc.*

Robert Yancey, *Altair Engineering Inc.*

Hong Yang, *CFD Research Corporation*

Xin Zhang, *Boston University*

Zhili Zhang, *University of Tennessee, Knoxville*

For more information on the AIAA Associate Fellows Program, please contact Patricia A. Carr at triciac@aiaa.org or 703.264.7523.

Di Pippo Receives AIAA International Cooperation Award

Simonetta Di Pippo (right), director of the United Nations Office for Outer Space Affairs, receives the AIAA International Cooperation Award for outstanding and sustained contribution to promoting international space projects and leadership in forging and implementing international intergovernmental space cooperation agreements. With Di Pippo is AIAA Executive Director Sandy Magnus.

The AIAA Foundation organized an "Evening of Astronaut Stories" in conjunction with AIAA SPACE 2016 in Long Beach, CA, to inspire and encourage students to follow their dreams. All proceeds from the event support the Foundation's educational programs. Many thanks to Northrop Grumman and The Boeing Company, especially Boeing Huntington Beach, Boeing Network & Space Systems, and Boeing Defense, Space & Security Engineering for their support of this event. Pictured with students from the Long Beach area are astronauts Sandy Magnus, Carl Walz, Greg Johnson, Garrett Reisman, and James Voss (from left to right in the center of the back row).

New Editor-in-Chief Sought for the *Journal of Spacecraft and Rockets*

AIAA is seeking an outstanding candidate with an international reputation for this position to assume the responsibilities of Editor-in-Chief of the *Journal of Spacecraft and Rockets* in early 2017.

The Editor-in-Chief is responsible for maintaining and enhancing the journal's quality and reputation as well as establishing a strategic vision for the journal. He or she receives manuscripts, assigns them to Associate Editors for review and evaluation, and monitors the performance of the Associate Editors to ensure that the manuscripts are processed in a fair and timely manner. The Editor-in-Chief works closely with AIAA Headquarters staff on both general procedures and the scheduling of specific issues. Detailed record keeping and prompt actions are required. AIAA provides all appropriate resources including a web-based manuscript-tracking system.

Interested candidates are invited to submit resumes and letters of application for consideration. A selection committee will seek candidates and review all applications received. A final recommendation will be made to the AIAA Board of Directors for approval. This is an open process, and the final selection will be made only on the basis of the applicants' merits. All candidates will be notified of the final decision. Questions may be referred to Heather Brennan, Director, Publications, at heatherb@aiaa.org.

Complete application requirements and submission deadlines are available in Aerospace Research Central http://arc.aiaa.org under Featured Content on the home page and also on the landing page for *Journal of Spacecraft and Rockets*: http://arc.aiaa.org/loi/jsr.

Call for Papers for *Journal of Guidance, Control, and Dynamics*

On 2 July 2016 the guidance, navigation, and control (GN&C) community lost its eminent ambassador, with the passing of Rudolf Emil Kálmán. Although Kálmán made significant advances to general control and estimation theory, his greatest legacy is the invention of the legendary "Kalman filter," first published in 1960. The *Journal of Guidance, Control, and Dynamics* (*JGCD*) will dedicate a special issue on "The Kalman Filter and Its Aerospace Applications." The focus of the special issue is specifically targeted to novel aerospace GN&C applications involving the Kalman filter. The applied research paper must address original and/or unique uses of the Kalman filter.

More information as well as guidelines for preparing your manuscript can be found in the full Call for Papers on the journal website in Aerospace Research Central http://arc.aiaa.org/loi/jgcd.

Deadline: 1 December 2016 with prior approval of the Guest Editor

Contact Email: John L. Crassidis, Guest Editor (johnc@buffalo.edu)
Ping Lu, Editor-in-Chief of *JGCD* (plu@mail.sdsu.edu).

Mark Your Calendars: CVD 2017 Scheduled for 29 March

The 20th annual Congressional Visits Day (CVD) Program will take place Wednesday, 29 March 2017, on Capitol Hill. AIAA will once again offer limited subsidies to assist members in their efforts to attend CVD. Registration will open later this fall.

Teach the Spectrum

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).

On 14–15 June, the Tennessee Section, in partnership with the University of Tennessee Space Institute (UTSI) and the Tullahoma Hands On Science Center (HOSC), conducted our first workshop for STEM teachers: "Teach the SpEcTruM." Nine teachers from the surrounding area attended the event, which included tours of the UTSI laboratories, a visit to the Arnold Engineering Development Complex (AEDC) STEM outreach, HOSC, and the STEM Lending Library from Tennessee Technological University (TTU). Carole Thomas (UTSI program manager for STEM Outreach), Jim Burns (AIAA Tennessee Section Education Outreach), Dr. Pat Murphy (HOSC director), and Jere Matty (AEDC STEM coordinator) developed this initiative to bring their combined resources together to grow STEM interest among students, and provide teachers with insight into local STEM facilities and support from the organizations.

During the two days the teachers had the opportunity to assemble and try out a large variety STEM kits provided by the Millard Oakley STEM Center at TTU. These kits are provided for teachers to check out for two weeks of classroom use and provide everything from mechanical and electronic demonstrations, sensors, math manipulatives, and Lego Mindstorms. The teachers also participated in space-themed educational activities where they competed in teams to be the first to complete a space mission.

The teachers had several sessions on exciting classroom presentations for STEM. Kellye Burns, a junior at ClemsonUniversity and summer intern at HOSC, presented a session on spectral color mixing using a kit containing LED light sources and optics. Excitement grew when Katrina Sweetland, UTSI Space Grant research assistant, presented information about the solar observatory under development at UTSI. The solar observatory will track the sun and provide livefeed images to a website that will be available to the public. Educators and students will be able to request an account that will allow them to capture images of the sun, track sunspots and other solar activity and use them in the classroom or after-school clubs.

As a culminating event, Dr. Joe Sheeley, AIAA Tennessee Section chair, presented a session on using soda straw rockets and a launcher kit as a way to teach math and statistics. He provided insight into how the same basic kit could be used for simple angles and distances in elementary classrooms to in-depth statistical analysis at the high-school level.

Tennessee is changing its state standards to Next Generation Science Standards and the teachers have asked for our help aligning Continuing Education with the new standards, and bringing more themed modules to them. We look forward to an exciting and bigger event next year.

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1 Event participants (left to right): Sam Molton, Lincoln County High School; Brook Davis, Huntland Middle School; Carole Thomas, UTSI; Kari Cruze, Franklin County High School; Veronica Leech, Franklin County High School; Amanda Green, Franklin County High School; Ashley Magrini, South Middle School Franklin County; Jaelynn Walker, Franklin County High School; Susan Hampton, Lincoln County High School; Carlene Guerin, Franklin County High School; and Kellye Burnes, a junior at Clemson University. (Photo by Laura Horton)

2 Teacher Carlene Guerin prepares to launch a straw rocket while Ashley Magrini and Kari Cruze look on.

3 Teacher "Astronauts" Susan Hampton and Ashley Magrini tackle their space mission while wearing "space gloves" following remote guidance from "Mission Control." (Photo by Jim Burns)

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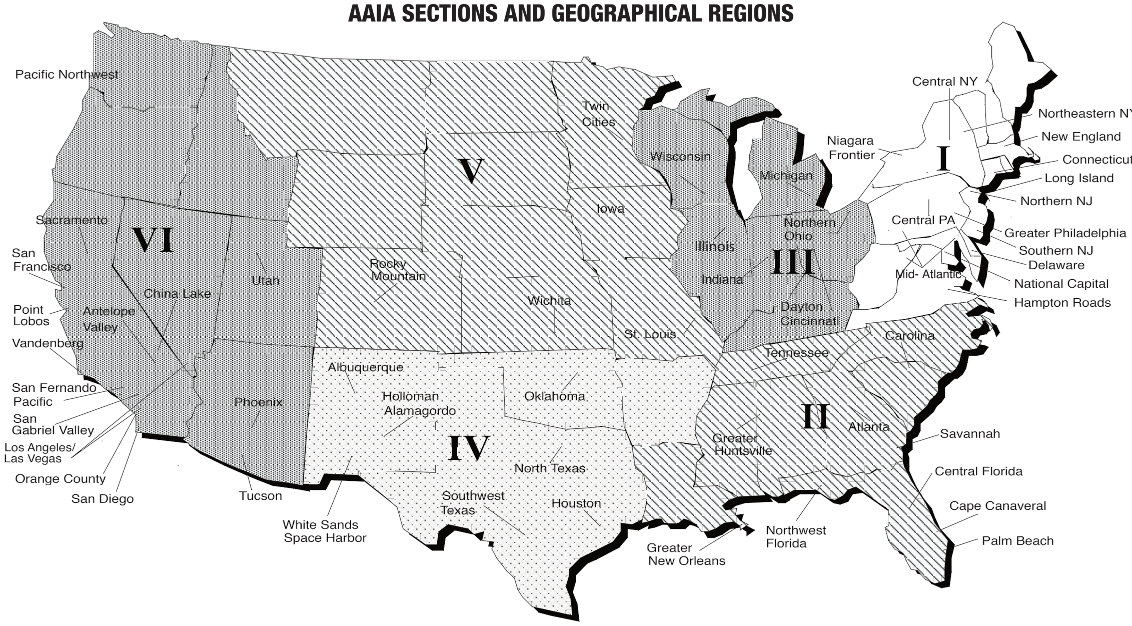

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2016 Best Papers

During 2016, the following best papers were selected. Authors were presented with a certificate of merit. Congratulations to each author for achieving technical and scientific excellence!

AIAA Aerodynamic Measurement Technology Best Paper

AIAA 2016-0791, "Time-Resolved PIV in a Shock Tube," Justin Wagner, Steven Beresh, Edward Demauro, Katya Casper, Daniel Guildenbecher, Brian Pruett, and Paul Farias, Sandia National Laboratories.

AIAA Air Breathing Propulsion Systems Integration Best Paper

AIAA 2016-0011, "Turbine Powered Simulator Calibration and Testing for Hybrid Wing Body Powered Airframe Integration," Patrick Shea and Jeffrey Flamm, NASA Langley Research Center; Kurtis Long and Kevin James, NASA Ames Research Center; and Daniel Tompkins and Michael Beyar, The Boeing Company.

AIAA Applied Aerodynamics Best Paper

AIAA 2015-2718, "Origins and Further Development of the Jameson-Schmidt-Turkel Scheme," Antony Jameson, Stanford University.

AIAA Atmospheric Flight Mechanics Best Paper

AIAA 2015-2401, "Rapid, Robust Trajectory Design Using Indirect Optimization Methods," Michael J. Grant, Purdue University; and Michael A. Bolender, Air Force Research Laboratory.

AIAA Atmospheric and Space Environment Student Paper

AIAA 2016-3734, "Computational and Experimental Ice Accretions of Large Swept Wings in the Icing Research Tunnel," Gustavo Eijdi and Camarinha Fujiwara, University of Washington.

AIAA CFD Flow Visualization Showcase

- Most Artistic Flow Visualization Animation – AIAA 2015-2617, "The Effect of Initial Conditions on Streamwise Vortices in the Plane Turbulent Mixing Layer," William A. McMullan and Stephen J. Garrett, University of Leicester.
- Most Quantitatively Descriptive Flow Visualization Animation – AIAA 2015-3410, "EPIC – An Extract Plug-In Components Toolkit for in-Situ Extracts Architecture," Earl Duque and Daniel Hiepler, Intelligent Light; Robert Haimes, Massachusetts Institute of Technology; Christopher Stone, Computational Science and Engineering, LLC; Steven E. Gorrell, Matthew Jones, and Ronald A. Spencer, Brigham Young University
- Most Comprehensive Flow Visualization Animation – AIAA 2015-3419, "A Multi-Phase CFD Technique with Cavitation and Fluid-Structure Interaction," Hong Q. Yang, CFD Research Corporation.

AIAA Collier Research Hypersizer/AIAA Structures Best Paper

AIAA 2015-0452, "Mass Optimization of Variable Angle Tow, Variable Thickness Panels with Static Failure and Buckling Constraints," Rainer M.J. Groh and Paul Weaver, University of Bristol.

AIAA Computational Fluid Dynamics Best Paper

AIAA 2015-2605, Improving High-Order Finite Element Approximation Through Geometrical Warping," Devina Sanjaya and Krzysztof Fidkowski, University of Michigan.

AIAA David Weaver Best Student Paper

AIAA 2016-0509, "Heat Transport in Aqueous Suspensions of Alumina Nanoparticles," Murali Gopal Muraleedharan, Dilip Srinivas Sundaram, and Vigor Yang, Georgia Institute of Technology.

AIAA Electric Propulsion Best Paper

AIAA 2015-4005, "Non-Invasive Hall Current Distribution Measurement in a Hall Effect Thruster," Carl Mullins, Rafael Martinez, and John Williams, Colorado State University; Casey Farnell and Cody Farnell, Plasma Control LLC; David Liu, Air Force Institute of Technology; and Richard Branam, University of Alabama Tuscaloosa.

AIAA Energetic Components and Systems Best Paper

AIAA 2015-3708, "Analysis of Dissipation Induced by Successive Planar Shock Loading of Granular Explosive," Pratap Thamanna Rao and Keith A. Gonthier, Louisiana State University.

AIAA Fluid Dynamics Best Paper

AIAA 2016-1062, "An Overview of Combined Uncertainty and A-Posteriori Error Bound Estimates for CFD Calculations," Timothy Barth, NASA Ames Research Center.

AIAA Gas Turbine Engines Best Paper

AIAA 2015-4028, "A Composite Cycle Engine Concept with Hecto-Pressure Ratio," Sascha Kaiser, Bauhaus Luftfahrt e.V.; Stefan Donnerhack, MTU Aero Engines AG; Anders Lundbladh, GKN Aerospace Engine Systems; and Arne Seitz, Bauhaus Luftfahrt e.V.

AIAA Green Engineering Best Paper

AIAA 2016-0267, "Impact of Ultra-High Bypass/Hybrid Wing Body Integration on Propulsion System Performance and Operability," Wesley Lord, Gavin Hendricks, and Michael Kirby, Pratt & Whitney; and Stuart Ochs, Ray-Sing Lin, and Larry Hardin, United Technologies Research Center.

AIAA Ground Testing Best Paper

AIAA 2015-2861, "Unsteady Low-Speed Wind Tunnel Design," David Greenblatt, Technion – Israel Institute of Technology.

AIAA Guidance, Navigation, and Control Best Paper

AIAA 2015-0599, "Swarm Assignment and Trajectory Optimization Using Variable-Swarm, Distributed Auction Assignment and Model Predictive Control," Daniel Morgan and Soon-Jo Chung, University of Illinois at Urbana-Champaign; and Fred Hadaegh, Jet Propulsion Laboratory.

AIAA High Speed Air Breathing Propulsion Best Paper

AIAA 2016-0658, "Establishing the Controlling Parameters of Ignition in High-Speed Flow," Timothy Ombrello, Ez A. Hassan, and Campbell D Carter, Air Force Research Laboratory; Brendan McGann, University of Notre Dame; Hyungrok Do, Seoul National University; David M. Peterson, Innovative Scientific Solutions, Inc.; Philip Ivancic and Edward A. Luke, Mississippi State University

AIAA Hybrid Rockets Best Paper

AIAA 2015-3829, "Visualization Study of Self-Pressurizing Propellant Tank Dynamics," Jonah Zimmerman and Brian Cantwell, Stanford University; and Greg Zilliac, NASA Ames Research Center.

AIAA Hybrid Rockets Best Student Paper

AIAA 2015-3832, "Flight Performance Simulations of Vertical Launched Sounding Rockets Using Altering-Intensity Swirling-Oxidizer-Flow-Type Hybrid Motors," Kohei Ozawa and Toru Shimada, Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency.

AIAA Intelligent Systems Best Paper
AIAA 2015-1113, "Trajectory Prediction and Alerting for Aircraft Mode and Energy State Awareness," Kimberlee Shish, Millennium Engineering and Integration Company; John Kaneshige, Diana Acosta, Stefan Schuet, and Avinash Madavan, NASA Ames Research Center; Thomas Lombaerts, German Aerospace Center (DLR); and Lynne Martin, San Jose State University.

AIAA Intelligent Systems Best Student Paper
AIAA 2016-0129, "Intent-Based Abstraction For Formal Verification of Flight Deck Mode Confusion," Jayaprakash Suraj Nandiganahalli, Sangjin Lee, and Inseok Hwang, Purdue University.

AIAA Liquid Propulsion Best Paper
AIAA 2015-3769, "CFD Modeling of the Multipurpose Hydrogen Test Bed (MHTB) Self-Pressurization and Spray Bar Mixing Experiments in Normal Gravity: Effect of the Accommodation Coefficient on the Tank Pressure," Olga Kartuzova and Mohammad Kassemi. NASA Glenn Research Center.

AIAA Modeling & Simulation Best Papers
- AIAA 2015-0906, "A Coupled Lateral/Directional Flight Dynamics and Structural Model for Flight Control Design" Ondrej Juhasz and Mark Tischler, NASA Ames Research Center; Steven Hagerott, David Staples, and Javier Fuentealba, Textron Aviation
- AIAA 2015-2653, "A Bifurcation Study of a Dynamic Model of a Nose Landing Gear Mechanism Subjected to External Disturbances," James Knowles, Loughborough University.

AIAA Multidisciplinary Optimization Design Student Paper
AIAA 2016-3992, "A Robust Analytical Sensitivity Analysis for Coupled Aero-Structural Systems," Koorosh Gobal, Ramana V. Grandhi, and Christopher Koehler, Wright State University.

AIAA Nuclear and Future Flight Propulsion Best Paper
AIAA 2015-3774, "Affordable Development and Demonstration of a Small NTR Engine and Stage: A Preliminary NASA, DOE and Industry Assessment," Stanley K. Borowski and Robert J. Sefcik, NASA Glenn Research Center; James E. Fittje and David R. McCurdy, Vantage Partners LLC; Arthur L. Qualls and Bruce G. Schnitzler, Oak Ridge National Laboratory; James E. Werner, Idaho National Laboratory; Abraham Weitzberg, DOE Consultant; and Claude R. Joyner, Aerojet Rocketdyne.

AIAA Plasmadynamics and Lasers Best Student Paper
AIAA 2016-1698, "Development of a Cavity Enhanced Thomson and Raman Scattering Diagnostic," Adam Friss, Christopher Limbach, and Azer P. Yalin, Colorado State University.

AIAA Propellants and Combustion Best Paper
AIAA 2015-3972, "Multi-Injector Impinging Jet Studies of Ignition Delay for Hydrogen Peroxide and Gelled Hydrocarbon Fuel Containing Reactive or Catalytic Particles," Terrence L. Connell, Grant A Risha, and Richard A. Yetter, The Pennsylvania State University; and Benveniste Natan, Technion—Israel Institute of Technology.

AIAA Solid Rockets Best Papers
- AIAA 2014-4016, "Improved Mean Flow Solution for Solid Rocket Motors with a Naturally Developing Swirling Motion," Joseph Majdalani, Auburn University; and Andrew Fist, University of Tennessee.
- AIAA 2015-4107, "Time-Temperature Superposition Principle Applied to Thermally Aged Composite Propellant," Luciene D. Villar and Luis C. Rezende, Institute of Aeronautics and Space.

AIAA Space Architecture Best Paper
ICES-2015-56, "What Do We Give Up and Leave Behind?" Marc Cohen, Astrotecture and Sandra Haeuplik-Meusburger, TU-Vienna, Institute for Architecture and Design.

AIAA Spacecraft Structures Best Paper
AIAA 2015-0431, "Recent Advances in Heliogyro Solar Sail Structural Dynamics, Stability, and Control Research," William Wilkie, Jay Warren, Lucas Horta, Karen Lyle, and Jer-Nan Juang, NASA Langley Research Center; Samuel Gibbs and Earl Dowell, Duke University; and Daniel Guerrant and Dale Lawrence, University of Colorado, Boulder.

AIAA Terrestrial Energy Best Paper
AIAA 2016-0990, "Component and System Modeling of a Direct Power Extraction System," Omar D. Vidaña, Mariana Chaidez, Brian Lovich, Jad Aboud, Manuel J. Hernandez, Luisa A. Cabrer, Ahsan Choudhuri, and Norman Love, The University of Texas at El Paso.

AIAA Thermophysics Best Paper
AIAA 2016-1981, "Spectral, Directional Emittance at Elevated Temperatures for Various Materials," Michael Winter, Robert Bickel, Dusan Sekulic, Helmut Koch, Bradley Butler, and Hai Fu, University of Kentucky.

AIAA/AAS Astrodynamics Specialist Best Paper
AAS 15-748, "Analytical Assessment Of Drag-Modulation Trajectory Control For Planetary Entry," Zachary Putnam, University of Illinois at Urbana-Champaign; and Robert Braun, Georgia Institute of Technology.

ASC Student Paper in Composites Award
AIAA-2016-1499, "Modeling the Bistability of Laminated Composite Toroidal Slit Tubes," Geoffrey Knott and Andrew Viquerat, University of Surrey.

ASME/Boeing Best Paper
AIAA 2015-0462, "Computational Techniques for the Thermostructural Analysis of Composites" Vinay Goyal, Jacob Rome, Matthew Conway, James Tuck-Lee, and Steven Frolik, The Aerospace Corporation.

ASME Propulsion Best Paper
AIAA 2015-4231, "Leak Rate Quantification Method for Gas Pressure Seals with Controlled Pressure Differential," Minel Braun, Heather Oravec, and Janice Mather Wasowski, University of Akron; and Christopher Daniels and Shawn Taylor, NASA Glenn Research Center.

Jefferson Goblet Student Paper Award
AIAA 2016-1241,"Thermally-Driven Morphing with High Temperature Composites," Eric Eckstein and Paul Weaver, University of Bristol; and Michael Halbig, NASA Glenn Research Center.

Harry H. and Lois G. Hilton Student Paper Award in Structures
AIAA 2016-0724, "3D Delamination Profile Reconstruction For Composite Laminates Using Inverse Heat Conduction," Tishun Peng and Yongming Liu, Arizona State University.

Lockheed Martin Student Paper Award in Structures
AIAA 2016-0490, "Thermal Response of a Spatially Graded Metal-Ceramic Structural Panel to Non-Uniform Heating in Hypersonic Flow," Phillip Deierling and Olesya Zhupanska, University of Iowa; and Crystal Pasiliao, Air Force Research Laboratory.

Southwest Research Institute Student Paper Award in Non-Deterministic Approaches
AIAA 2016-0952, "Robust Test Resource Allocation using Global Sensitivity Analysis," Chenzhao Li and Sankaran Mahadeven, Vanderbilt University.

Obituaries

AIAA Associate Fellow Deutsch Died in August

Edward J. Deutsch died on 4 August. He was a 60-year member of AIAA.

Mr. Deutsch enlisted in the U.S. Army in 1942 and saw action in Africa and Italy. He earned a B.S. in Aero. Engineering from New York University and an M.S. in Industrial Management from Brooklyn Polytechnic. He began his aerospace career at Grumman and was employed in the aerospace industry for 50 years, until he retired as V. P. Engineering, Product Development at Arkwin Industries in 1992. He served as senior engineer and program manager on Penetration Aid Devices on the Minuteman ICBM, hydraulic components for the Space Shuttle, and hydraulic components for the B-2 bomber and other aircraft. His technical contributions ranged from steam turbines to centrifugal compressors to air cushion vehicle lift fans. He published in *Computerized Stress Analysis for Rotating Components of Turbomachinery*, and holds patents for pneumatic and mechanical devices.

A member of the Long Island Section Council for many years, Mr. Deutsch had served as Section Secretary from 2010 to 2016. He also served on the Nominating Committee and as Essay Committee Chairman.

AIAA Honorary Fellow Sutter Died in August

Joseph Sutter died on 30 August. He was 95. Sutter was the former chief engineer of Boeing's 747 program, and was credited with leading the development of the first widebody aircraft.

Sutter graduated from the University of Washington, and then served for two years with the U.S. Navy during World War II. After studying at the Navy's aviation engineering school, Sutter accepted an engineering job with Boeing where he worked on Boeing's first jet transport, the 367-80.

Among the other aircraft that he worked on were the 707, 720B, 727 and 737. But he is best known for leading the Boeing 747 project, including changing the design from the proposed narrow, double-decker concept to a larger, wide-bodied aircraft. His decision to place the aircraft's cockpit above the aircraft's main deck led to the creation of the 747's iconic humped-shaped body. In his later career with Boeing, Sutter—first as vice president of operations and product development and later as executive vice president for engineering and product development—was involved with the creation of Boeing's 757 and 767 aircraft. After retirement from Boeing in 1986, Sutter stayed involved with the 747 program as a consultant and his work was instrumental to completing the design changes that created the 747-400 and the 747-800 models of the jetliner.

In addition to his career at Boeing, Sutter also served on the presidential commission that investigated the explosion of the space shuttle Challenger in 1986.

Sutter's awards include the 1990 AIAA/ASME/SAE/AHS Daniel Guggenheim Medal, the 1986 Wright Brothers Trophy, the 1985 National Medal of Technology and Innovation, the 1980 AIAA/SAE William Littlewood Memorial Lecture, and the 1971 AIAA Aircraft Design Award.

AIAA Honorary Fellow Iacobellis Died in September

Sam F. Iacobellis, who was president of AIAA from 1998 to 1999, died on 3 September. He was 87 years old.

Iacobellis began his career as a draftsman in 1952 at the North American Aviation Company (NAAC), soon after graduating from California State University, Fresno. While at NAAC, Iacobellis became an engineering supervisor attached to the company's Saber jet engine modification program. In 1967, Rockwell International acquired NAAC. After the merger, Iacobellis became head of Rockwell's B-1 Lancer bomber program. Iacobellis led the B-1 program through numerous political obstacles, including cancellation by President Jimmy Carter, before its renewal by President Ronald Reagan, with the first bombers entering service in 1984. During his tenure at Rockwell, Iacobellis also headed the company's rocket engine and space shuttle business units. He retired from the company as executive vice president and deputy chairman in 1995.

AIAA Fellow Straub Died in September

Friedrich K. Straub died on 5 September. He was 65 years old.

Mr. Straub graduated summa cum lauda, with a Masters in Mechanical Engineering from University of Hannover, Germany, in 1975. From there, he received a scholarship to attend the University of California, Los Angeles, and earned his Ph.D. in Aerospace Engineering in 1980 and started working for Hugh's Helicopters in Culver City, CA. He moved to Mesa in 1985 and worked for Boeing after that. Mr. Straub had an outstanding career as a researcher and manager spanning 36 years.

He co-authored several patents, presented dozens of papers at national and international technical conferences and published several papers in technical journals. An AIAA Fellow, he was also a Technical Fellow of the American Helicopter Society (AHS).

CYBERSECURITY

Recognizing the importance of cybersecurity in the aviation and space domains, AIAA has sought to educate members and raise the profile of cyber risk within its community. Through tabletop exercises, keynote speeches, forum sessions, and workshops over recent years, AIAA has established itself as a principal resource in building cybersecurity capabilities and thought leadership in aerospace.

In the coming months, AIAA will expand your access to cyber insights and other resources through a new partnership with renowned cybersecurity expert Richard Clarke and his firm Good Harbor Security Risk Management. In November, you will receive the first issue of AIAA's new cybersecurity e-newsletter, Aerospace Cybersecurity. Each month Aerospace Cybersecurity will deliver commentary and expert analysis on the most pressing cybersecurity issues of the day, along with curated links to stories of interest. AIAA welcomes your feedback on topics for future editions. Visit **www.aiaa.org/cybersecurity** to sign up today!

Frontier Faculty

The College of Engineering at The Pennsylvania State University announces openings for two tenure-system Frontier Faculty positions in, but not restricted to, the areas of Optimal and Secure Cyberenvironments (e.g. cybersecurity, cyberphysical engineering and healthcare systems, cultural technical system integration), Resilient Infrastructure Systems (e.g., autonomous, optimized and adaptive systems; advanced land, air and sea vehicles) and Sustainable Water-Energy-Food Nexus (e.g., modeling, optimization and management of interacting water-energy-food systems; optimized and socially responsible energy, water and food production and distribution). Senior and mid-career faculty as well as exceptional junior faculty in emerging areas in engineering are invited to apply. This Frontier Faculty search is being conducted at the College of Engineering level and is led by the Dean's office. The academic home of the successful candidates will be determined during the hiring process. Additional information about these positions and the College's plan for growth may be found at www.engr.psu.edu/frontier. Review of applicants will begin on November 15, and will continue until the positions are filled. Applicants should submit a statement of professional interests, a curriculum vitae, and contact information for four references. Please submit these items in one pdf file.

Apply to **http://apptrkr.com/882113**

CAMPUS SECURITY CRIME STATISTICS: For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to http://www.police.psu.edu/clery/, which will also provide you with detail on how to request a hard copy of the Annual Security Report.

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

THE UNIVERSITY of MISSISSIPPI

UNIVERSITY OF MISSISSIPPI, **THE DEPARTMENT OF MECHANICAL ENGINEERING** invites applications for a tenure-track position at the Assistant Professor level starting August 2017.

Applicants must possess a Ph.D. in Mechanical Engineering or related field, demonstrated teaching and communication skills, Thermo-Fluids-Energy expertise, and a research focus that complements current and planned research interests of the department; to include multiscale computational modeling of highly nonlinear problems involving turbulence, low Reynolds number, and combustion flows, and preferably thermal emphasis. The selected candidate will be expected to teach both lectures and laboratories, as well as performing laboratory development at the undergraduate level in the area of thermodynamics, fluid mechanics and energy. Graduate-level instruction as well as mentoring both M.S. and Ph.D. will also be expected. The candidate is expected to develop a long term externally funded research program, and provide professional service, both external and internal, to the University.

The applicant should submit a detailed curriculum vita, statement of teaching philosophy/experience and research interests, and a list of at least three references. Submissions will only be accepted electronically through the University of Mississippi jobsite: jobs.olemiss.edu. Screening of applicants will continue until the position is filled.

The University of Mississippi is dedicated to the goal of building a culturally diverse and pluralistic faculty committed to teaching and working in a multicultural environment and strongly encourages applicants from minorities and women.

The University of Mississippi is an EED/AA/Title VI/Title IX/Section 504/ADA/ADEA employer.

UNIVERSITY OF MINNESOTA
Driven to Discover℠

Aerospace Engineering and Mechanics

UNIVERSITY OF MINNESOTA

The Department of Aerospace Engineering and Mechanics seeks to fill one or more faculty positions in aerospace systems. Applications are invited in all areas of aerospace systems, particularly those that complement current research activities in the department. These research activities include but are not limited to control system analysis and design; state estimation; multi-sensor fusion; dynamics; and guidance, navigation and control of aircraft, spacecraft and autonomous aerial vehicles. The department has close ties with other departments and on-campus multidisciplinary centers. In addition, the department has access to excellent experimental and computational facilities. Information about the department is available at http://www.aem.umn.edu/

The successful candidate will participate in all aspects of the Department's mission, including teaching undergraduate and graduate courses in aerospace engineering mechanics and aerospace systems; supervision of undergraduate and graduate students; service responsibilities; and developing an independent, externally funded research program.

Applicants must have an earned doctorate in a related field by the date of appointment. The intent is to hire at the assistant professor rank. However, exceptional applicants may be considered for appointment at the rank of associate professor with or without tenure. It is anticipated that the appointment will begin fall 2017.

To apply for this position, candidates must apply on-line at:

http://humanresources.umn.edu/jobs and search for Job ID No. 312589; or visit: http://z.umn.edu/17ts

If searching for the Job ID number, it may be necessary to broaden the "Jobs Posted Within" range.

Please attach your cover letter, detailed resume, names and contact information of three references, and a statement of teaching and research interests as one PDF.

The initial screening of applications will begin on **December 1, 2016**. Applications will be accepted until the position is filled.

The University of Minnesota is an equal opportunity educator and employer.

AUBURN UNIVERSITY
SAMUEL GINN
COLLEGE OF ENGINEERING
AEROSPACE

Multiple Tenure-track Faculty Positions

The Department of Aerospace Engineering at Auburn University invites applications for multiple tenure track faculty positions at the assistant or associate professor level. Candidates with expertise in flight dynamics & control or orbital mechanics are particularly encouraged to apply. Other areas of consideration include aerospace systems, design, guidance & control, unmanned and manned aerial systems, structural dynamics and other areas related to aerospace engineering. Candidates will be expected to fully contribute to the department's mission and the development of a strong, nationally recognized, funded research program. The candidate is expected to have a demonstrated track record of scholarship, an active interest in engineering education and strong communication skills. Candidates must have an earned doctorate in aerospace engineering or a closely related field.

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 begin on December 2, 2016 and 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.

Massachusetts Institute of Technology

Come work with us!

Tenure-Track Faculty Position Aeronautics and Astronautics

The MIT Department of Aeronautics and Astronautics invites applications for tenure-track faculty positions with a start date of July 1, 2017, or on a mutually agreeable date thereafter. The department is conducting a search for exceptional candidates with a strong background in any discipline related to Aerospace Engineering, broadly defined. Areas of interest include, but are not limited to, autonomous systems, materials and structures, atmospheric and space sciences, space and jet propulsion, manufacturing, real-time safety-critical software, cyber-security, space systems and exploration, air transportation, and fluid mechanics. We are seeking highly qualified candidates with a commitment to research and education. Faculty duties include teaching at the graduate and undergraduate levels, advising students, leading a research program, and service to the institute and the profession.

Candidates should hold a doctoral degree in a field related to aerospace engineering by the beginning of employment. The search is for a candidate to be hired at the assistant professor level; however, under special circumstances, a senior faculty appointment is possible.

Applications must include a cover letter, curriculum vitae, 2-3 page statement of research and teaching interests and goals, and names and contact information of at least three individuals who will provide letters of recommendation. Applicants with backgrounds outside aerospace should describe how a substantial part of their work will apply to aerospace problems.

Applications must be submitted as a pdf at:
https://school-of-engineering-faculty-search.mit.edu/aeroastro/register.tcl.

Letters of recommendation must be submitted directly by the recommenders at:
https://school-of-engineering-faculty-search.mit.edu/letters.

To ensure full consideration, complete applications should be received by December 1, 2016. Applications will be considered complete only when both the applicant materials and at least three letters of recommendations are received.

MIT is building a culturally diverse faculty and strongly encourages applications from female and minority candidates.

For more information on the MIT Department of Aeronautics and Astronautics, please visit http://aeroastro.mit.edu/. Applicants may find reading our Strategic Plan (http://aeroastro.mit.edu/aeroastro/strategicplan2015) helpful in preparing their applications. Questions can be directed to faculty search chair Prof. Steven Barrett (sbarrett@mit.edu).

MIT is an Equal Opportunity/Affirmative Action employer.

http://web.mit.edu

DEPARTMENT OF AEROSPACE ENGINEERING - Open Rank Faculty Search

College of Engineering

University of Illinois at Urbana-Champaign

The Department of Aerospace Engineering at the University of Illinois at Urbana-Champaign seeks highly qualified candidates for multiple faculty positions in all areas of aerospace engineering, with emphasis on the areas of orbital mechanics, space systems, multi-functional composites, and additive manufacturing. Preference will be given to qualified candidates working in emerging areas of aerospace engineering whose scholarly activities have high impact. Please visit **http://jobs.illinois.edu** to view the complete position announcement and application instructions. Full consideration will be given to applications received by **December 16, 2016**. Applications received after that date may be considered until the positions are filled.

The University of Illinois conducts criminal background checks on all job candidates upon acceptance of a contingent offer.

Illinois is an EEO Employer/Vet/Disabled - www.inclusiveillinois.illinois.edu and committed to a family-friendly environment (http://provost.illinois.edu/worklife/index.html).

AEROSPACE ENGINEERING
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Stanford | ENGINEERING

Faculty Opening

STANFORD UNIVERSITY

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

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

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

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

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

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

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

South University of Science and Technology of China (SUSTC)

Assistant/Associate/Full Professors of Department of Mechanics and Aerospace Engineering

The Department of Mechanics and Aerospace Engineering at the South University of Science and Technology of China (SUSTC) invites applications for a number of tenured or tenure track faculty positions in all ranks. Candidates with research interests in all areas of Mechanics and Aerospace Engineering are encouraged to apply. Candidates should have strong commitment to teaching and demonstrated excellence in research. An earned doctoral degree is required at the time of appointment. Candidates for senior positions must have an established record in conducting globally recognized research and securing external funding.

Established in 2012, the South University of Science and Technology (SUSTC) is a public institution funded by the municipal of Shenzhen, a special economic zone city in China. SUSTC is a pioneer in higher education reform in China. The mission of the University is to become a globally recognized institution which emphasizes academic excellence and promotes innovation, creativity and entrepreneurship. The University currently has over 200 faculty members, and is planning three faculties: Faculty of Science, Faculty of Engineering, and Faculty of Life and Health Science. The target faculty number will be 200 for Science, 300 for Engineering, and 150 for Life and Health Science Faculty.

The newly founded Department of Mechanics and Aerospace Engineering is one of the nine departments in the College of Engineering. The department expects to add more than twenty new faculty members in core research areas in Mechanics and Aerospace Engineering.

Shenzhen is a major city located in Southern China, situated immediately north of Hong Kong SAR. As one of China's major gateways to the world, Shenzhen is the country's fast-growing city, the high-tech and manufacturing hub, and home to some of China's most recognized enterprises such as Huawei, Tencent and DJI. As a State-level innovative city, Shenzhen has chosen independent innovation as its development strategy. A picturesque coastal city, Shenzhen is also a popular tourist destination and was named one of the world's 31 must-see tourist destinations in 2010 by The New York Times.

SUSTC offers internationally competitive compensation packages with fringe benefits including medical insurance, retirement and housing subsidy. Salary and rank will commensurate with qualifications and experience.

To apply, please provide a cover letter identifying the primary area of research, curriculum vitae, research and teaching statements, and arrange for at least three recommendation letters, all forward to hiring@sustc.edu.cn.

1916

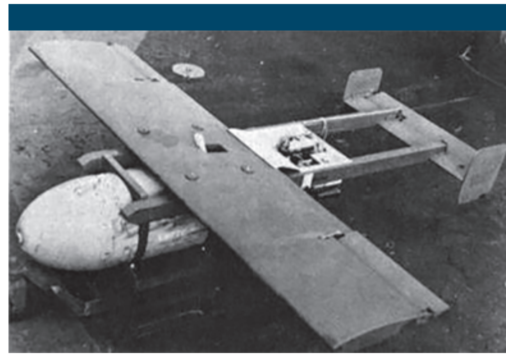
Nov. 21 The Breguet 14 single-engine, two-seat light bomber completes its first flight. It was built for the French Air Force and served with distinction throughout the remaining years of World War I. The U.S. Army Air Service also received some 250 of the approximately 8,000 produced. A. van Hoorebeeck, La Conquete de L'Air, p. 120.

Nov. 23 German fighter pilot Manfred von Richthofen, flying an Albatros D.2, downs British Army Royal Flying Corps Maj. Lanoe Hawker, in an Airco DH.2. The pair twist and turn from 8,000 feet to ground level before a burst of fire from Richthofen's machine gun brings down Hawker, a Victoria Cross recipient. It was Richthofen's 11th victory. David Baker, Flight and Flying: A Chronology, p. 487.

Nov. 23 The National Advisory Committee for Aeronautics selects a 1,650-acre lot near the Back River in Hampton, Virginia, as the site for its new research facility. It opens as the NACA Aviation Experimental Station and Proving Grounds; the name is soon changed to Langley Field in honor of former Smithsonian Secretary Samuel Pierpont Langley, and by 1917, construction begins on the Langley Memorial Aeronautical Laboratory. James R. Hansen, Engineer in Charge: A History of the Langley Aeronautical Laboratory, pp. 9-11; NASA Langley Office of Public Affairs.

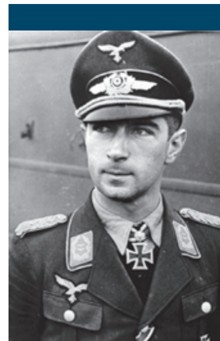
1941

Nov. 1 By an executive order from President Franklin D. Roosevelt, the U.S. Coast Guard becomes part of the Navy, making it subject to orders of the secretary of the Navy. The Coast Guard, established in 1790, is responsible for enforcing maritime law, rendering assistance to disabled U.S. vessels and patrolling the coasts for illegal activities. For these tasks, the Coast Guard uses aircraft as well as boats and ships; one such plane is the Grumman J4F-1 Widgeon. Placing the Coast Guard under the Navy gives it added responsibility for the nation's defense. Aircraft Year Book, 1942, pp. 149-150.



Nov. 7 The U.S. Army Air Force's GB-1 preguided glide bomb, one of the first U.S. guided missiles, makes its initial flight. E.M. Emme, ed., Aeronautics and Astronautics, 1915-60, p. 42.

Nov. 17 World-famous aviator Col. Gen. Ernst Udet, chief of the German Air Ministry's technical sections, commits suicide. Born in 1896, Udet was Germany's second-highest scoring ace from World War I with 62 victories. He toured the United States after the war; introduced the dive bomber to Germany; and in 1938, set a world speed record. He was also instrumental in creating the Luftwaffe. Hitler orders a state funeral, but the circumstances of Udet's death are kept secret. Interavia, Nov. 18, 1941, pp. 22-23.



Nov. 22 Leading German ace Werner Mölders dies in the crash of a Heinkel He 111 in which he is a passenger on the way to the funeral of Col. Gen. Ernst Udet (see Nov. 17 entry). Mölders began his combat career fighting in Spain, where he downed 14 Republican aircraft. He was the first pilot to down 100 aircraft. He had downed 115 aircraft by the time he died. David Baker, Flight and Flying: A Chronology, p. 487.

1966

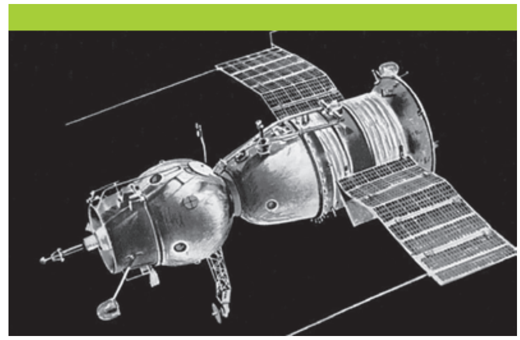
Nov. 6 NASA's uncrewed 385-kilogram Lunar Orbiter 2 probe is launched by an Atlas-Agena D booster. The Lunar Orbiter's primary purpose is to obtain high-resolution images of various lunar surface areas to help assess their suitability for the landings of the Surveyor and manned Apollo spacecraft, as well as to learn more overall about the moon. A total of 422 photos are taken that include 13 potential Apollo primary landing sites and 17 secondary ones. The spacecraft also records two micrometeoroid hits during its orbits, the first ever detected by a U.S. spacecraft in the moon's vicinity. The Washington Post, Nov. 10, 1966, p. A2.

Nov. 11-15 The Gemini 12 mission is carried out as the last of the Gemini series. It begins with the launch of the Gemini Agena Target Vehicle from Cape Canaveral, followed almost two hours later with the launch of the manned Gemini 12 by a Titan booster. The astronauts are James A. Lovell Jr., command pilot, and Edwin E. Aldrin Jr., pilot. After nine maneuvers, the spacecraft docks with the target vehicle, and the target vehicle's propulsion system positions the Gemini 12 for photography. Through the spacecraft's window, the astronauts take motion and still pictures of a total solar eclipse over South America on Nov. 12. The following day, Aldrin performs two umbilical extravehicular activities, or space walks, that involve experiments with a hand-held space sextant and photography for a total EVA time of 5 hours, 28 minutes. Another experiment involves the study of weightlessness on living cells using newly fertilized frog eggs. The re-entry of Gemini 12 is made in the 59th orbit, and the spacecraft splashes down in the Atlantic about 4.8 kilometers from the recovery ship USS Wasp. New York Times, Nov. 12, 1966, pp. 1, 14 and Nov. 15, 1966, pp. 1, 17.

Nov. 16 U.S. Interior Secretary Stewart Udall approves the site at Pakachoag Hill, outside Auburn, Massachusetts, as a national landmark since it was here, on March 16, 1926, that Robert H. Goddard launched the world's first liquid-propellant rocket. NASA, Aeronautics and Astronautics, 1966, p. 350.

Nov. 20 The launch of a French Centaure two-stage solid-propellant sounding rocket opens the European Space Research Organization's new range at Kiruna, near Paksuniemi, Sweden, to study the aurora borealis. Kiruna subsequently becomes the organization's equivalent of the NASA Wallops Island facility in Virginia. The Washington Post, Nov. 21, 1966, p. A14.

Nov. 21 The Soviet Union discloses in a brief article appearing in Pravda that it had installed an atomic clock in its Cosmos 97 spacecraft launched Nov. 26, 1965. The satellite is placed in an elliptical orbit with an apogee of about 2,100 kilometers and perigee of about 220 kilometers. The clock test is carried out as part of a relativity experiment to help verify Einstein's Theory of General Relativity in checking the comparative performances of a space-borne and ground-based atomic clock. Aviation Week, Nov. 21, 1966, p. 36.



Nov. 28 The Soviet Union launches its first Soyuz spacecraft, an uncrewed test version, under the designation of Cosmos 133. Cosmos remains in orbit until Feb. 9, 1967, when it re-enters the atmosphere and crashes into the Aral Sea, though the capsule is retrieved by divers. After two prior failures, this test flight is considered successful enough and leads to a series of manned Soyuz spacecraft that remain in operation today. The first manned version, Soyuz 1, is launched April 23, 1967, though its pilot Vladimir Komarov is killed upon landing because of a parachute failure. The first successful manned flight mission is made with Soyuz 3, launched Oct. 26, 1968. David Baker, Spaceflight and Rocketry, pp. 202, 203; Soyuz file, National Air and Space Museum.

1991

Nov. 1 Pan American World Airways completes the sale of its Pacific and Silk Route flights as Delta Air Lines takes over these operations. Delta acquires 52 aircraft; 6,600 former Pan Am employees join Delta. The sale of these assets is not enough to stave off bankruptcy for Pan Am next month. David Baker, Flight and Flying: A Chronology, pp. 486-487.

Nov. 24 U.S. Army Chief Warrant Officer Thomas Hennen, an imagery intelligence specialist, flies as a mission specialist on the space shuttle Atlantis, mission STS-44. He is to assess reconnaissance from orbit by operating a payload called Terra Scout. The mission's main purpose is to deploy an infrared-sensitive Defense Support Program satellite to detect exhaust trails from missiles and jet afterburners. Flight International, Dec. 4-10, 1991, p. 16; NASA Johnson Space Center, Biographical Data.

PAUL VOSS, 49

Associate Professor of Engineering,
Smith College Picker Engineering Program

It was July 2014. The FAA had just released an interpretation of its model aircraft rule to clarify what researchers could and could not do with drones, which were exploding in popularity. Among those who took notice was Paul Voss, who had developed tiny meteorological balloons for gathering data in hard-to-reach places to validate weather and climate models. Voss penned a letter voicing concern and pointing out the rich history of model aircraft flights for research. Twenty-eight fellow academics signed on, and news of the letter went viral. Today, Voss says the FAA has made "enormous progress" in managing drones, including enacting a new rule that went into effect in August. He says it's possible the letter contributed.

How did you become interested in flight?

There is an elegance to machines and creatures that float through the air and appear to defy gravity. As a child, I built numerous flying contraptions in my basement workshop. I distinctly remember flying a small battery-powered trainer I built in the early '80s — it made one lumbering circle around the field, sort of controlled, which seemed amazing at the time.

I majored in engineering at Brown University and subsequently became interested in how our weather and climate are governed by the same physical laws as engineered systems. I had the great privilege of doing my Ph.D. research in professor Jim Anderson's lab at Harvard, developing photochemical instruments for NASA's high-altitude ER-2 aircraft.

I currently teach fluid mechanics, atmospheric processes and aerial-vehicle design at Smith College. I have developed altitude-controlled weather balloons that are utilized in international collaborations to study the lower atmosphere. It is a strange feeling to sit at a laptop in Massachusetts while commanding a 300-gram balloon to land on the ice in Antarctica or navigate the river breezes in the Amazon. Our students have been deeply involved in this research, too.

What do you see as the long-term impact of the FAA's drone rule?

I am excited to begin using small unmanned aircraft systems in my teaching and research. These aircraft are microcosms of engineering, with everything from aerodynamics and material science to electronics and control theory in one small package. The FAA's enactment of Part 107 of the Federal Aviation Regulations in August is a major step forward. The agency has done a great job of addressing safety while still facilitating innovation, for example, by allowing researchers, inventors and startups to develop airframes and avionics. The mandatory knowledge test has many good questions related to airspace, communications, safety and understanding the rules.

With the right policies in the future, I believe that UAS could soon move beyond line of sight to do some amazing things. For example, monitoring flights over farms and pipelines, with landowner consent, could be some of the first opportunities. Even far-fetched ideas like package delivery could make sense if these aircraft were to travel in established corridors connecting designated landing areas, such as industrial zones. In the same way that digital technology has enabled more intensive use of the radio spectrum, GPS could confine transiting to narrow airways at altitudes high enough that they don't create a nuisance, harm wildlife or significantly restrict other users of uncontrolled (Class G) airspace. This would be a future we could look forward to. ★