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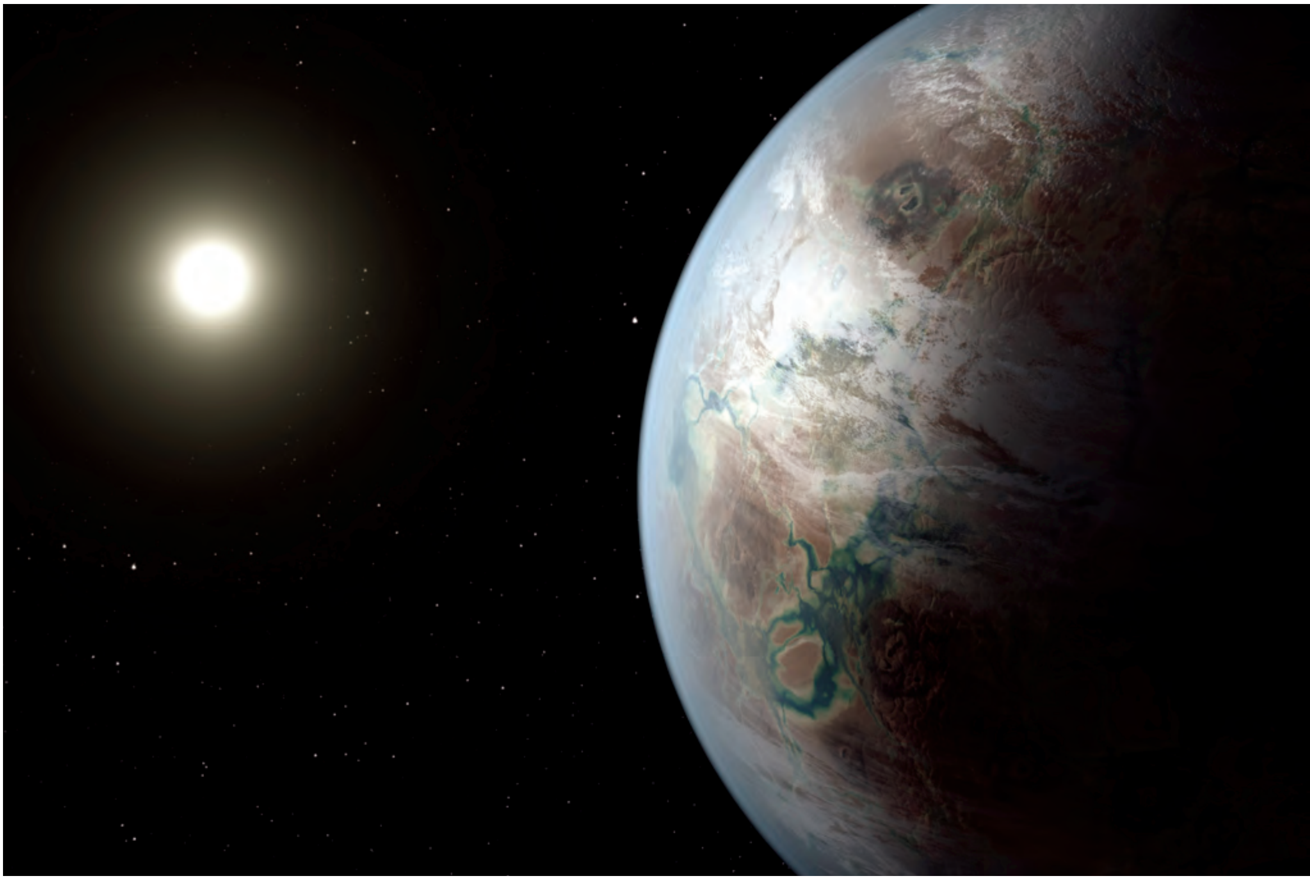
AIAA
Shaping the Future of Aerospace



On the cover: Artist's rendering of Kepler-186f, the first Earth-sized planet detected orbiting a hospitable zone near a star other than our sun.

Image credit: NASA Ames/SETI Institute/JPL-Caltech

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AIAA
Shaping the Future of Aerospace

IN THIS ISSUE

Keith Button

has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns hedge fund blowup that kicked off the global credit crisis. Keith's article "Carrier drone debate," on page 28, examines the U.S. Navy's decision to make a carrier-based refueling drone.

John Cook

worked as an engineer on the International Space Station and space shuttle programs. John's article about the space station's on-orbit assembly and what it says about the future, "Springboard," appears on page 34.

Adam Hadhazy

writes about astrophysics and technology. His work has appeared in Discover and New Scientist magazines. In "Planet spotting" on page 20, Adam tells us about technologies for imaging exoplanets.

James Knauf

retired from the U.S. Air Force as a colonel in 2006. Jim is chair of AIAA's Space Transportation Technical Committee. His analysis of the RD-180 conundrum, "Freedom from Russian rocket engines," begins on page 38.

DEPARTMENTS

U.S. Navy

An X-47B unmanned demonstrator flies ver the flight deck of the U S George H.W. Bush in 2013.

Aerospace America 2.0

You've probably noticed that this issue of Aerospace America unveils a new look and feel. As the stories inside prove, one thing that has not changed is our commitment to dig into aerospace technologies and issues with a depth and clarity we know readers demand.

The cover story on planet-hunting technologies captures the human excitement and scientific understanding that would come with deli ering a photo, even a rudimentary one, of an Earthlike planet. The article describes the technical tradeoffs between coronagraphs and starshades for teasing planetary photons from the blinding light of their host stars. I came away with a new appreciation for the technical work in this area, and a hope that there will always be a reasonable level of funding available in the U.S. and abroad for this kind of work.

"Carrier drone debate," on page 28, shows why it's hard for the U.S. and other countries to devote resources to knowledge for knowledge's sake. It seems clear that the U.S. Navy's decision to forgo an unmanned combat-intelligence plane was driven by budget considerations. The U.S. could be missing a chance to stay ahead of potential adversaries such as China, which is adopting a bolder military posture on the sea and in the air.

Ben Iannotta

Ben Iannotta
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Around the Institute

I wanted to spend some time updating everyone on a few of the various activities that are ongoing around the Institute, both in the volunteer and staff communities. First I would like to give you a quick update on the governance project. The Board of Directors and Institute Development Committee discussed transition plans at their June meetings. The decision was made to keep the current structure until the May 2017 Board meeting. In the next year the group will be working to develop the policies and procedures necessary for a smooth transition. In May 2017 the new structure will be established with the current elected leadership. Over the course of the next three years, using the normal election cycle, a complete transition to the new structure will be completed. In addition, a preliminary set of Bylaws has been voted on and will be posted to the Governance Project webpage (www.aiaa.org/Governance). We will continue to communicate the progress and changes that are happening as they occur.

Another important project that we are starting concerns public access (and open access). The term "public access" identifies published wo ks that must comply with the February 2013 memorandum from the Office of Science and Technology Policy (OSTP) to the heads of executive departments and agencies. The subject of this Executive Order concerned increasing access to the results of federally funded research. The memo requires any federal agency with over $100 million of extramural research funding to make the results of the research publicly available after a defined emba go period. (Recently the embargo period was defined as 12 months). The OSTP policy targets only peer-reviewed journal publications; it does not include conference papers or books. Open access, on the other hand, is a term used to identify material that is immediately available for free to the public. This category can include any kind of media or product and any source.

Federal agencies impacted by this policy are implementing different compliance solutions, and it is important for our research community to be cognizant of the various requirements. The procedural details and steps that authors must take to comply with the policy are still being developed at the various agencies (and will likely be written into the grant information). We will continue to monitor this topic and communicate information as we get it. In addition, we are examining the impact of the public access policy on AIAA as a publisher.

An additional issue yet to be addressed concerns scientifi data. Per the OSTP memo, not only is the published paper to be made publicly available after an embargo period, but also the data used to support the paper. The agencies are still debating how this policy could and should be implemented. There are a lot of thorny questions around how to store, find access, and document data that have yet to be worked out. Again, we will communicate details as they develop.

A lot has been going on in other areas across the Institute. In June, AIAA held the inaugural DEMAND for UNMANNED UAS symposium in conjunction with AIAA AVIATION 2016 in Washington, DC. The response from the community was very positive with over 250 people attending to discuss technical and policy issues related to this very fast moving field. The Unmanned Systems Program Committee will continue to develop AIAA activities, building on the great success of the first symposium. We are reaching out to develop collaborative relationships with other organizations in this area to facilitate communication between our membership and the UAS manufacturing, sales and operator communities.

We are also moving to address the evolution of energy as it affects the economics and environmental impact of the aerospace industry. A workshop on hybrid-electric propulsion was held at AIAA Propulsion and Energy 2016 with AIAA stakeholders, as well as invited experts from other technical and industry sectors including energy storage, electric machines, and electric utilities. A strategic roadmap was developed that identified the technical challenges that mus be addressed to realize hybrid electric propulsion; this roadmap will guide AIAA's program and product development to help our profession bring this technology to fruition. We also are planning an electric aircraft workshop and expo for AIAA AVIATION 2017.

The Diversity Working Group presented a plan of action to the Board at its June meeting that was unanimously adopted. (The AIAA Diversity Working Group page [http://www.aiaa.org/Diversity] will be updated with the plan soon.) The working group has spent the last year talking to many different groups in the community and has incorporated this feedback in its action plan. If you are interested in becoming engaged in this activity, please contact us at DiversityWG@aiaa.org.

We have been experimenting with a STEM program called "Generation STEM: Discovering Aerospace through Experience" at our forums. The program debuted at AIAA SPACE 2015, and also took place at AIAA Propulsion and Energy 2016. The program, targeting middle school students, provides a day of hands-on activities related to concepts and principals relevant to the aerospace industry. It also features several interactive corporate demonstrations provided by key industry leaders.

I want to close by thanking everyone for the time and energy that you put into AIAA. I know how busy your "day jobs" keep you and how important free time is. We all have a lot to fit into our 24 hours a day! I am ext emely impressed and grateful for the time that our volunteers dedicate to AIAA, and hence, the aerospace profession. With your contributions we are making a difference in moving our industry, our profession, and the world forward! ★

— Sandy H. Magnus, Executive Director

U.S. Air Force

Northrop Grumman's RQ-4 Global Hawk was pressed into service 15 years ago without de-icing capability. The U.S. Air Force is reviewing whether to lift operational restrictions on the high-flying drones

No de-icing necessary?

By Michael Peck | michael.peck1@gmail.com | @Mipeck1

The U.S. Air Force is considering whether to lift the ban on the RQ-4 Global Hawks flying in icing weather. The high-flying unmanned intelligence planes were pressed into service during the wars in Iraq and Afghanistan without de-icing systems, and test flights conducted in April and May now suggest that the planes might not need them.

Global Hawks typically cruise at about 60,000 feet, where the atmosphere is too cold and dry for ice to form. But getting to that altitude requires traversing the 8,000- to 22,000-foot altitude band where icing can be an issue. Though a Global Hawk spends only about five minutes passing through this zone, the Air Force currently mandates that if its onboard ice probes detect icing, the plane must climb or dive until the ice melts, before attempting to penetrate the icing zone again.

Responding to ice is a particularly sensitive issue for unmanned aircraft like the Global Hawks. While some drones are flown by pilots who are at the ready in ground stations to respond to ice, the Global Hawks fly preprogrammed flight paths and are largely autonomous, with their pilots intervening only to issue general instructions to change altitude, course and speed. On the other hand, unlike other drones, Global Hawks have ice sensors that can alert their pilots to icing conditions. The fleet has accumulated about 200,000 flight hours without a single ice-related mishap. That led prime contractor Northrop Grumman to believe that the aircraft could safely pass through icy weather.

"We had anecdotal information, so the purpose of this test was to provide flight test data that unequivocally stated we could fly through known icing conditions," says Mick Jaggers, who heads Northrop Grumman's Global Hawk work.

Formal testing would be required to prove it. Northrop Grumman assisted the Air Force with a series of Global Hawk flights at Edwards Air Force Base, California. Rather than waiting for icy weather, researchers brought the clouds to the plane. The fastened nylon shapes — formed by 3-D printers — to the wings and tail of the aircraft to mimic the airflow disruption from ice as the Global Hawk conducted climbs and dives. The aircraft was also flow with medium and heavy fuel loads to determine if this affected its icing survivability

The results showed that "our flight control algorithms are sufficien to safely maneuver the vehicle through known icing conditions," Jaggers says. As for Global Hawk's maximum tolerance for ice, Jaggers says "the final icing limit has not yet been determined, but the Global Hawk was not designed to operate in sustained icing conditions."

The Air Force has not said how or when it might rule on the ban. ★

Honoring a legacy algorithm

By Kyung M. Song
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Ryan Morris

Rudolf E. Kalman receives the National Medal of Science from President Barack Obama in 2009.

Even decades after, Rudolf Emil Kalman's former Ph.D. students recall being roused out of bed early by a ringing telephone, with Kalman on the line dissecting perceived flaws in their theorems. They had come to study from Japan, France, Turkey and the U.S., despite Kalman's intimidating reputation and worries about their own command of abstract algebra.

Kalman, a polylingual mathematician and electrical engineer, in 1960 wrote a groundbreaking algorithm that was quickly adopted by NASA researchers who had been stymied by how to guide Apollo astronauts to the moon and back. Called the Kalman filter, the algorithm became a mainstay in high-performance military and commercial flight-control software

The Kalman filter helps calibrate each Orbital ATK Cygnus cargo ship's docking position on the International Space Station. It calculates the correct altitude for releasing an Orion capsule's drogue chutes that slow the crew module on its return to Earth. It also helps forecast the weather, pinpoint cellphone locations and fine tune trajectories of drones, submarines and missiles.

To those in the field of guidance, navigation and control, Kalman is what "Steve Jobs is to the mobile device community or Elon Musk is to the electric car industry," says Lesley Weitz, lead simulation modeling engineer with the Center for Advanced Aviation System Development at MITRE, which operates federally-sponsored research centers.

The Hungarian-born Kalman died July 2 in Gainsville, Florida. He was 86.

In 2008, Kalman's elegant algorithm earned him the National Medal of Science, the nation's highest recognition for scientific achievement. Though Kalman was blunt and demanding, generations of students from the University of Florida, Stanford University and ETH Zurich credit "REK" with profound influence on their careers

Kalman conceived the idea for his algorithm in the late 1950s while at the Research Institute for Advanced Studies in Baltimore, which later became part of Martin Marietta. The Kalman filter was a solution to the imperfectness of mathematical models. All statistical estimations can be undermined by faulty sensor measurements, unexpected disturbances and other variables.

Kalman's computer-programmable algorithm reduced the uncertainties through two dynamic equations, said Angus Andrews, a former senior scientist at the Rockwell Science Center. In Kalman fi -tering, one equation generates estimates of the unknown variables. The second equation estimates the accuracy of the uncertainty estimates.

Kalman published his research, "A New Approach to Linear Filtering and Prediction Problems," in March 1960 in a journal of the American Society of Mechanical Engineers.

At the time, Stanley Schmidt, then the chief of the Dynamic Analysis Branch at NASA's Ames Research Center in California, had difficulty understanding Kalman's paper. But Schmidt believed the theory was the answer to the challenge of plotting the Apollo mission's circumlunar orbit. Not only was the moon a moving target, the spacecraft's sensitive trajectory was buffeted by a host of factors — such as the need to change velocity in tandem with changes in altitude — that could send the astronauts careening off nto deep space.

The "extended" Kalman filter that was eventually loaded on Apollo 11 worked fast. It continuously generated new best estimates based on the most-immediate previous state without using much memory. That was no small matter for the Apollo guidance computer, which had less than one megabyte of memory, not enough to store even one song on an iPhone.

Andrews regards the Kalman filter as peerless. He calls it the "Maslow hammer" for complex, nonlinear estimation problems, citing the American psychologist Abraham Maslow's observation that to someone with only a hammer, everything is a nail. ★

Call for Papers

The Journal of Guidance, Control, and Dynamics will publish a special issue devoted to the Kalman filter and its aerospace applications.

See the call for papers at: arc.aiaa.org/loi/jgcd.

Deadline is December 1.

AIAA PROPULSION AND ENERGY 2016 | SALT LAKE CITY

Highlights

Green aviation

Turboelectric propulsion, which uses fuel-burning engines to generate electricity, has the best shot at making a big dent in commercial aviation's carbon footprint within the next 30 years rather than batteries or hybrid engines.

That was the key finding presented by the federal Committee on Propulsion and Energy Systems to Reduce Commercial Aviation Carbon Emissions, which is advising NASA on research priorities.

The committee concluded that turboelectric propulsion, coupled with distributed propulsion and boundary layer ingestion, could lower emissions and fuel burn by at least 20 percent compared with today's large commercial aircraft, AIAA's **Ben Iannotta** reported.

No current "battery chemistries" are capable of powering commercial jets carrying 100 passengers or more, said Alan Epstein, vice president for technology and environment for Pratt & Whitney. What's more, the U.S. lacks "megawatt class" facilities necessary for advanced research on battery propulsion, said Karen Thole, a committee co-chair and professor of nuclear and mechanical engineering at Penn State.

Thole cautioned that the committee's message was not, "Stop working on batteries."

On the topic of engine technologies, including nacelles and heat-tolerant internal coatings, Epstein said ultimately, propulsion and aircraft designs will need to be considered together as a system, even if that was not the committee's focus.

The committee also lauded the potential of sustainable alternative fuels to reduce aviation's carbon footprint. That's critical, said Steven Csonka, executive director of the Commercial Aviation Alternative Fuels Initiative, because "we expect to be using fuel in aircraft at least for the next five decades."

Reusable rockets: Holy Grail or chasing our tail?

Space visionary Wernher von Braun was the first to imagine reusable launch systems, once proposing to build components that could be reused nearly 1,000 times to send crews to Mars.

That von Braun's dream is possible has been borne out by the X-33, X-34 and X-37, panelists told a capacity crowd, reported AIAA's **Duane Hyland**.

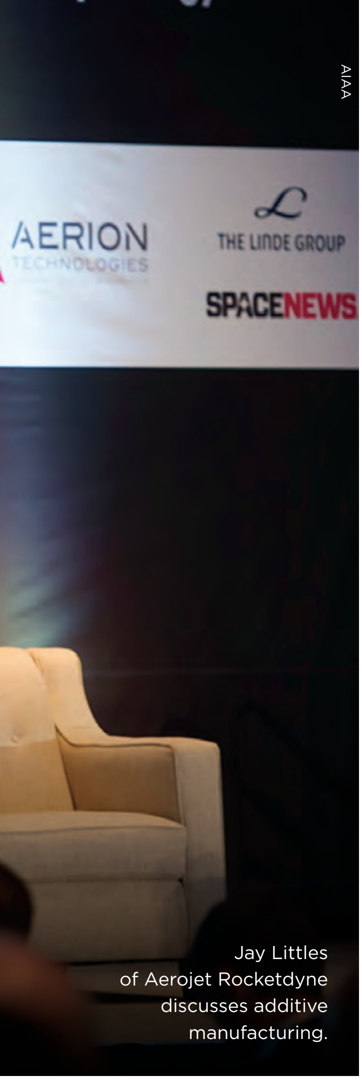
Experts agreed that reusable systems — especially from the perspective of liquid engine technology — wasn't a question of feasibility, but rather, as Doug Bradley, chief engineer of ad-

"If they screw up, fi e them. If they succeed, give them the things they need to get their job done."

Bran Ferren, chief creative officer of Applied Minds, on encouraging innovation

"I think you should learn to say yes to the point of discomfort."

Rex Geveden, chief operating officer of BWX Technologies, on one way to propel your career



AIAA

Jay Littles of Aerojet Rocketdyne discusses additive manufacturing.

"It will be China that does it."

Pierre Chao, founding partner of Renaissance Strategic Advisors, on who will break the Boeing-Airbus duopoly in commercial aviation

"You'll have no regrets, and you'll be able to sleep well at night."

Allan McDonald, retired manager at Morton Thiokol, builder of Challenger's solid rocket motors, on speaking up about safety concerns

vanced space and launch at Aerojet Rocketdyne, put it, "an inability."

Bradley meant that the need to explore space more cheaply will drive the demand for reusable launch vehicles.

Ben Goldberg, vice president of science and engineering for the Propulsion Systems Division at Orbital ATK, cautioned that reusing systems may not always make sense due to costs and mission needs. For instance, an ocean landing, due to the corrosive nature of seawater, might not make sense for a reusable system, while a land touchdown may.

Reusability in space systems is at a crossroads, but the panelists predicted a bold turn toward greater and greater reliance on reusable systems, making the goal of cheap and dependable spaceflight a reality.

Nuclear-powered space exploration

As the U.S. continues to explore deeper reaches of the solar system, it's becoming apparent that nuclear power — either in the form of radioisotope power systems, fusion reactors or fission reactors — can play a significant role in powering those missions.

Duane Hyland reported on a panel discussion on how going beyond solar-powered space missions could make venturing to farther edges of the solar system practical and reduce transit times.

"Once you get to Jupiter, you have 1/25th of the sun's solar rays available to you, and when you get to Saturn, it's 1/100th of the rays," noted Leonard Dudzinski with NASA's Science Mission Directorate.

Rex Geveden, chief operating officer for BWX Technologies, said nuclear-fueled spacecraft could cut the journey time between Earth and Mars by a month or two.

Nuclear power's high cost, however, could limit its use in space. The U.S. space program uses plutonium-238, which is available only from Russia. It costs $3 million per kilogram, said John Casani, an independent consultant formerly with NASA's Jet Propulsion Laboratory.

Dudzinski said that price tag means missions would cost $400 million on average, making them unattractive to most planners. Panelists recommended switching to uranium, which costs just $2,500 per kilogram and is widely produced and easily integrated.

READ MORE at
aiaa-propulsionenergy.org

Nuclear power faces other disadvantages. They include heavier weight relative to energy output, public wariness and a lack of visionary advocates.

Getting beyond additive manufacturing's "Betamax" stage

Additive manufacturing has made significant inroads with rocket engine makers. The next steps are to define standards and inspection processes to ensure confidence and wide acceptance of additively-manufactured components.

"We're in the Betamax-tape part of this additive thing," said Jay Littles, director of advanced launch vehicle propulsion at Aerojet Rocketdyne, referring to the 1970s-era Sony videotape standard that was beat out by VHS. "It's going to be interesting to see where we go over the next decade."

Ben Iannotta reported that several panelists pointed out obstacles to greater use of additive manufacturing, which uses laser or electrons to fuse metal powder into parts.

Elizabeth Robertson, leader of the Liquid Engine Systems Branch of NASA's Marshall Space Flight Center in Alabama, said that until inspection issues are figured out, there may be limits on "human rating" of additively manufactured parts, referring to the ratings NASA requires before trusting technologies to launch people.

Littles agreed that quality assurance is a big challenge, given the complex geometries and larger sizes of such components.

Littles said other goals include making larger components and understanding the performance of specific additive manufacturing machines.

"Additive really does open up the design window, but there's also a lot of stuff that you can't do — geometries to avoid," Littles said.

On the other hand, Robertson said, fewer part counts translates to "fantastic" reliability."

She recounted that in 2012, NASA decided to make components for a prototype engine to demonstrate additive manufacturing. Managers saw a 30 percent reduction in cost and part reduction from 250 to six.

Robertson said the quality of additive manufacturing currently varies more depending on the individual worker instead of the company. "Right now, additive is still an art." ★

NASA

Tony Antonelli steers the Discovery orbiter toward the International Space Station in 2009.

More online
aerospaceamerica.org

Tony Antonelli explains why investing in Mars exploration would be a good deal, and shares memories of his shuttle days.

Can this man's team get us to Mars?

When former astronaut Tony Antonelli looks out the window of his Houston offi , he doesn't see any mountains. His colleagues at Lockheed Martin's Waterton Canyon Campus in Colorado can't miss them. In May, Antonelli's team unveiled a mountain-eering-inspired proposal to pre-position key pieces of an outpost in orbit around Mars, and launch the remaining elements and a crew of six to it in 2028. Once aboard, the crew would robotically explore Mars with rovers and maybe with unmanned aircraft before a crew would be dispatched to the surface.

The co pany's Mars Base Camp proposal amounts to a gentle nudge to NASA and Congress to set a fi m target date for reaching Mars with a human crew. Antonelli led the team of architects and engineers that drew up the plan. The eam looked at the date question and determined that a crew could be launched toward Mars in 2028, whereas NASA says only that it aims to send humans to Mars "in the 2030s." Also, technical literature is often fill d with calls for exotic propulsion technologies, radiation protection breakthroughs and in situ resource utilization. Antonelli says existing technology could be developed into the components necessary to put a crew into orbit around Mars.

I spoke with him by phone from his offi .

– Ben Iannotta

BIO

POSITION:
Lockheed Martin chief technologist for exploration systems since July 2015.

NOTABLE:
Two-time NASA space shuttle pilot: Discovery, Space Transportation System-119, 2009; Atlantis, 2010, STS-132. Former Navy captain; piloted an F/A-18C during Operation Southern Watch, the mission to enforce the no-fly zone ove Iraq after the 1991 Persian Gulf War.

AGE: 48

RESIDES: Houston

EDUCATION:
Bachelor's degree from MIT and a master's degree from the University of Washington, both in aeronautics and astronautics.

PERSPECTIVES

Social impact of spacefligh

I looked down at Earth and thought, "Everybody I know lives there." I didn't fully appreciate that all of us together live on this one spaceship Earth. I'm actually surprised we don't treat each other more neighborly when we think about how close we all live together relative to the bigger picture.

Somehow, [those of us who have flown are] leavin something out of telling the story, because people aren't able to wrap their minds around it. Certainly, if this crew of six in Mars orbit is able to discover life somewhere else, that I think really will be changing for us.

Setting a specific date for reaching Mar

My boss [Wanda Sigur, vice president and general manager of civil space] said, "This idea of human exploration of Mars has excited me my whole life. The idea of reaching Mars [decades from now] is too far for me to get my hands on. It doesn't feel very real, it feels too far in the future." So, she tasked me with putting together a plan that makes human exploration of Mars real and tangible. The idea was, "With the technology that we have today, with the country's investment in SLS [Space Launch System] and Orion what else do we need to get human exploration on Mars well underway, kind of make it achievable in our careers as opposed to, you know, dreams of our grandchildren?" We can make this happen in the 2028 time frame, which feels real.

Value of a deadline

When you say, "the 2030s," it kind of brings this idea of a range. We're trying to focus in on what we can accomplish specifically and as quickly as we can and safely. If you don't put a date on it, then for example, "What's the very best in-space propulsion to use?" You'll never be forced to pick and move out on a plan, if there's no sense of urgency in going.

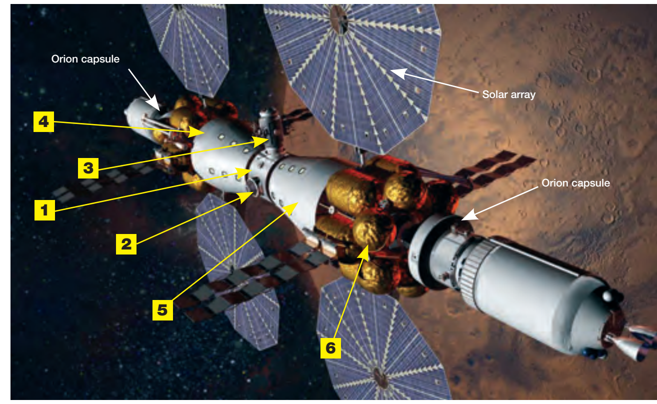
Working with what you know today

The future will consist of the in situ resource utilization: The water, the rocks and the dirt [on Mars]. But you don't have to wait for all that technology to be fully developed to get started … We've got [SLS] well on its way, and Orion well on its way, the EM-1 [Exploration Mission-1] vehicle got welded together, it got proof tested. It just recently got moved into the clean room so they can add the propulsion system to that spacecraft that's going to go out past the moon in 2018.

Controlling drones and rovers from orbit

I'm convinced that one of our rovers has driven past something that was scientifically significant but we weren't there in real tim controlling it [from orbit] and collecting all the data. You could fly UAVs, you could fly helicopters. ou could serve an important role in the Mars sample return, [which] has been at the very top of the decadal survey for a few rounds now.

There [are] significant planetary protection rules with forward contamination and backwards contamination. With the scientists in a laboratory in orbit around Mars and robotically launching samples off of the surface of Mars, you could help break the chain that would then satisfy the planetary protection requirements for Mars sample return. ★



Reaching Mars orbit by 2028

Lockheed Martin proposes a step-by-step strategy for establishing a Mars Base Camp in orbit for human exploration of the moons Deimos and Phobos, followed by excursions to the surface at a date to be determined.

In **2024**, NASA would launch a Space Launch System rocket carrying the center node **1**; the cupola viewing area **2**; and the excursion system **3** for exploring Martian moons. This unoccupied spacecraft would be propelled to Mars orbit by solar electric propulsion. In **2025**, an Orion crew would be launched by an SLS to cislunar space, a region defined by the moon's gravity. The crew would test the habitat **4**. In **2026**, an SLS would launch the lab **5** directly toward Mars, propelled by solar electric propulsion. Also, in **2026**, an SLS would launch the first of two crew quarters **6** to cislunar space (nestled among propellant tanks for crew radiation protection). In **2027**, an SLS would launch the second crew quarters and propellant tanks. A crew would join together the habitat, the crew quarters and two solar arrrays, and take this spacecraft on a shakedown mission, returning home in their Orion spacecraft. In **2028**, a six-person crew would dock their Orion capsule with this spacecraft, plus additional propulsion stages, and embark on the journey to dock with the outpost in Mars orbit.

"When you say, 'the 2030s,' it kind of brings this idea of a range. We're trying to focus in on what we can accomplish specifically and as quickly as we can … "

An asteroid companion

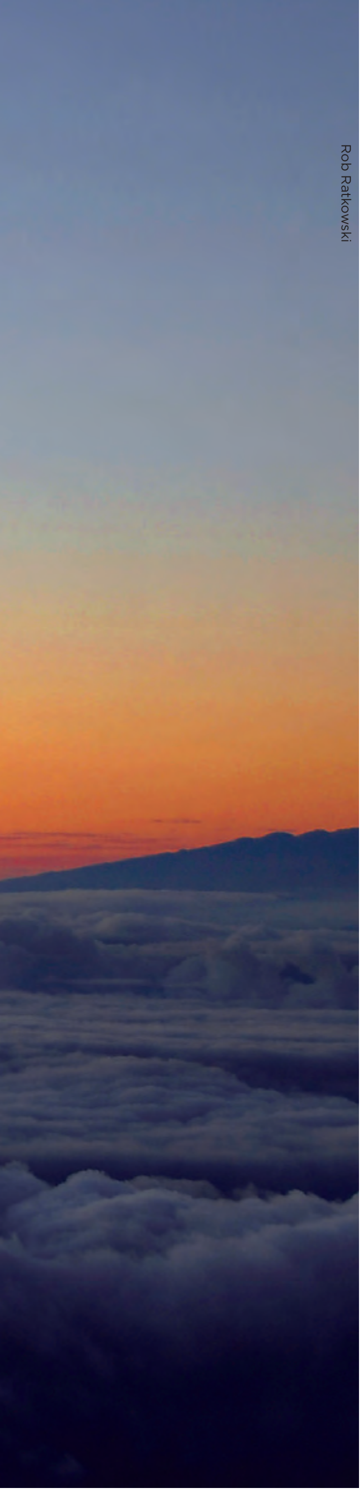
A newly discovered asteroid will orbit in loose formation with Earth for centuries. Its presence reminds NASA exploration planners of attractive opportunities for robotic and human exploration as they examine varied paths toward deep space and Mars.

By Tom Jones | skywalking1@gmail.com | www.AstronautTomJones.com

University of Hawaii's Panoramic Survey Telescope & Rapid Response System in April detected a near-Earth asteroid, designated 2016 HO3, that has been orbiting in Earth's celestial backyard for almost a century — and will be around for centuries longer.

In April, astronomers sifting through images from the University of Hawaii's Panoramic Survey Telescope & Rapid Response System in Maui discovered a faint near-Earth asteroid, now designated 2016 HO3. Analysis of its orbit soon showed that the 50- to 100-meter-wide object circles the sun on a path very much like Earth's, flying formation within a few million miles of our planet for at least the next century.

The discovery of HO3 underscores the practical possibility of exploring nearby asteroids as a way to gain valuable deep-space experience in preparation for journeys to Mars. A skeptical Congress seems unwilling to fund NASA's proposed Asteroid Redirect Mission, a crewed mission to an asteroid fragment placed in lunar orbit. HO3 and other, even more accessible asteroids may serve as alternate destinations: far enough beyond the moon to test astronauts on a multi-month, deep-space expedition, but not nearly as challenging and risky as a full-up, multi-year journey to the red planet. A reasonable path toward Mars may take astronauts from a lunar orbit outpost, to one or more near-Earth asteroids, and then to the Mars system in the 2030s.



Upper right: This painting by artist Pat Rawlings shows astronauts exploring a near-Earth asteroid. Asteroids could serve as alternate destinations to Mars and provide deep-space experience.

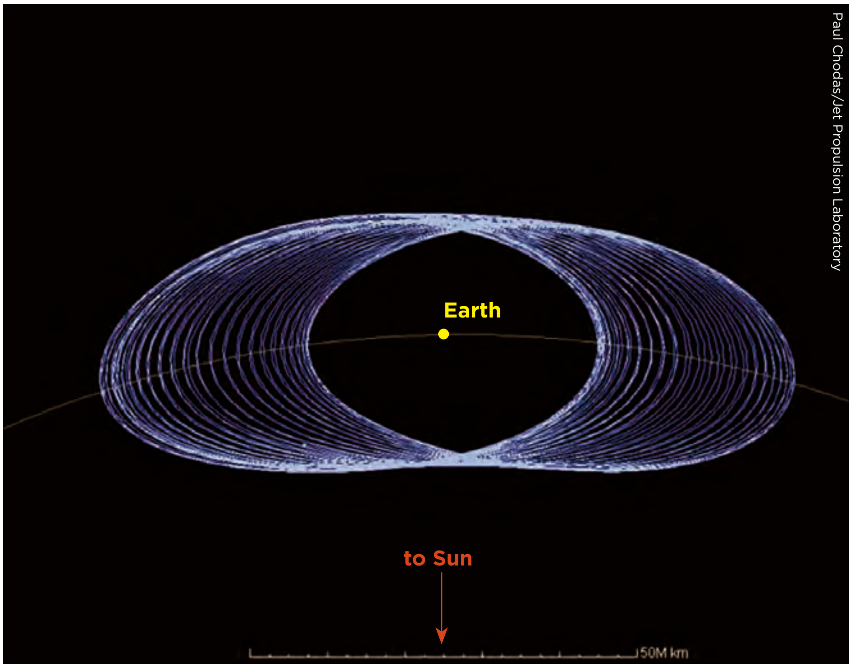
Because of HO3's relative proximity, "we refer to it as a quasi-satellite of Earth," Paul Chodas, manager of NASA's Center for Near-Earth Object Studies at the Jet Propulsion Laboratory in Pasadena, California, said in an article on nasa.gov. "Our calculations indicate 2016 HO3 has been a stable quasi-satellite of Earth for almost a century, and it will continue to follow this pattern as Earth's companion for centuries to come."

As HO3 alternately races ahead of and falls behind Earth in its yearly trek around the sun, it ranges out to about 100 times the moon's distance, then closes to as few as 38 lunar distances: from 38 million down to 14.7 million kilometers.

Other asteroids make closer approaches to Earth, and can be reached with less rocket propellant. But what makes HO3 special is that it's always around for a visit: It offers a launch opportunity every year for the next few decades. Other typical near-Earth asteroids offer only periodic, infrequent launch windows. HO3's discovery is a timely reminder to NASA that if it wants to get astronauts out beyond the moon in the 2020s or early 2030s, either HO3 or another attractive target is nearly always within range.

Sifting the skies

HO3's discovery resulted from NASA's ongoing survey of the inner solar system for potentially hazardous objects. Since 1998, when Congress directed NASA to search for near-Earth objects such as comets and asteroids large enough to cause global damage if they struck Earth, the space agency has been funding a growing array of dedicated search telescopes and the astronomers who operate them. Today, the NASA search program's $50 million annual budget covers search, orbit cataloging, asteroid deflection research and spacecraft mission defin - tion. It also identifies candidate targets for NASA's planned Asteroid Redirect Mission, ARM, in which robotic spacecraft would lift a 10- to 20-ton boulder from an asteroid and nudge the fragment into lunar orbit. Once stabilized there, an Orion astronaut crew



Paul Chodas/Jet Propulsion Laboratory

Left: Asteroid 2016 HO3 has been orbiting the sun in near proximity to Earth for decades. For an observer looking down on Earth as it orbits the sun, the blue lines track the asteroid's movement relative to Earth between 1960 and 2020.

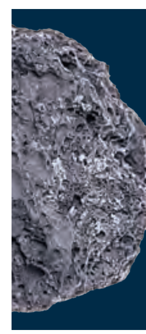
Center: Artist's rendering of Asteroid Redirect Mission, NASA's proposed crewed mission to an asteroid fragment placed in lunar orbit. Congress seems unwilling to fund the mission, providing impetus to send astronauts to nearby asteroids instead.

would rendezvous with the object, examine it, and carry samples to Earth.

NASA-funded telescopes are discovering close to 2,000 near-Earth objects each year; the program has found 98 percent of the nearly 15,000 of those cataloged so far. NASA today is working to fulfill a 2005 congressional mandate to find asteroids capable of causing regional damage on Earth, meaning those 140 meters or larger in diameter. It has already cataloged an estimated 95 percent of those larger objects (based on near-Earth object population statistics and the rate at which search telescopes "rediscover" known objects). As of July 13, 1,714 objects in the catalog — some 12 percent — were termed "potentially hazardous," capable of colliding with Earth in the distant future. None poses a significant threat of impact within the next century.

Accessible asteroids

HO3 joins dozens of other known near-Earth asteroids, NEAs, accessible to human explorers. NASA filters NEA discoveries through its NEO Human Spaceflight Accessible Targets Study, or NHATS, identifying objects whose orbits make possible roundtrip expeditions by robots or humans in 450 days or less, and a total mission velocity change, rV, of 12 kilometers per second or less (think of rV as a stand-in for how much rocket fuel you'll need to fly the mission). President Obama set a goal of an astronaut expedition to an asteroid in its native, solar orbit by mid-2020s. But when it became evident under the president's budgets that the combination of Orion, the Space Launch System booster, deep-space propulsion and a habitation module would not be ready by the end of the 2020s, NASA proposed the Asteroid Redirect Mission instead. With ARM, astronauts could visit an asteroid fragment delivered to lunar orbit no earlier than 2026, but NASA would still fulfill the presidential asteroid directive, after a fashion.

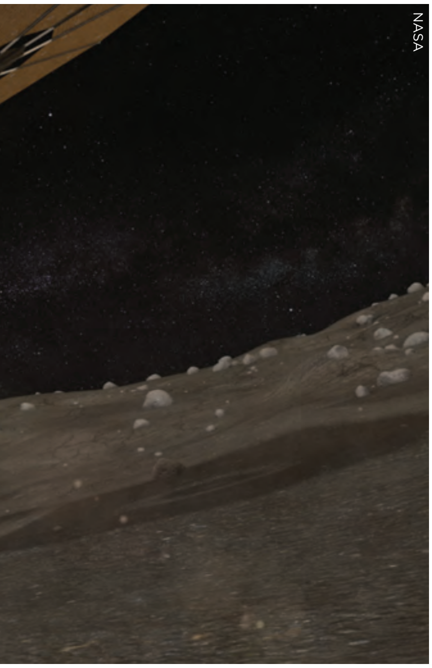


NAMING ASTEROIDS

An asteroid's initial designation is assigned by the Minor Planet Center following a formula based on the year of discovery, two letters and, if need be, further digits. 2016 HO3, for example, was discovered in 2016, in the second half of April (H), and was the 90th object discovered in the latter half of April (O3).

Does HO3 offer NASA a new, game-changing asteroid target? Veteran astrodynamicist and former NASA Johnson Space Center flight dynamics officer Dan Adamo told me in an email that although 2016 HO3 has long-term proximity going for it, it's hardly the most attractive target out there. Writes Adamo: "As of July 11, 2016, a total of 1765 NHATS-compliant near-Earth objects was known. Of these, 566 near-Earth objects can be accessed with shorter round-trip durations than any 2016 HO3 mission. Likewise, 184 NHATS-compliant near-Earth objects can be accessed with less delta-V than any 2016 HO3 mission."

In fact, HO3's orbital tilt, or inclination, of 7.77 degrees imposes a significant velocity-change penalty on visiting spacecraft. By contrast, the NEA 2000 SG344 has an inclination of just 0.11 degrees, yielding a minimum mission velocity change of 3.56 kilometers per second, according to Adamo. In 2029, for example, a five-month roundtrip to SG344 requires a velocity change of only about six kilometers per second.



Right: Rendering of a near-Earth asteroid. A handful of asteroid candidates exist that astronauts could reach in the next two decades at a lower propellant cost than going to the lunar surface.

Nevertheless, HO3's loitering behavior makes it a regularly accessible exploration target — a launch window to it is always handy. In any given year, for example, a 154-day round trip to HO3 could be mounted for a total velocity change of roughly 12 kilometers per second. Stretching the mission duration to one-year reduces the velocity change to 6.1 kilometers per second — significantly less than landing that same spacecraft on the moon, which takes about 9 kilometers per second. Both HO3 missions would include eight days of surface exploration time at the asteroid.

Where next — if anywhere?

Although far from the optimum candidate, HO3's discovery in our celestial backyard keeps asteroids, along with the moon, in the conversation as targets for science, human exploration and possible commercial exploitation. It's a timely discussion: If ARM does not win support in 2017 from a new administration and a skeptical Congress, near-Earth asteroids like HO3 represent the closest physical destinations for astronauts beyond the moon.

By the mid-2020s, NASA should have flown its Orion spacecraft and SLS booster several times. By adding habitation and propulsion modules to Orion, NASA would then be able to dispatch astronauts to nearby objects like HO3.

NASA is already conducting habitation module studies, and such extra living space could be available a decade from now for an asteroid roundtrip. But such a deep-space journey will still confront planners with many of the risks of a Mars expedition: radiation exposure, the effects of prolonged free-fall, and psychological isolation as Earth recedes to the size of Carl Sagan's "pale blue dot." Supply considerations are daunting, too: a crew of four would need to pack almost 2.5 metric tons of food for a one-year asteroid roundtrip.

Still, an asteroid expedition would be less challenging in terms of time, distance, and logistics than the two-plus-year journey to the Martian moons and back. An NEA mission could offer NASA just the right-sized first step on the road to Mars

Carpe diem

More accessible NEAs like HO3 and SG344 will be found in the coming decade, offering NASA more asteroid targets of opportunity. NASA could team with robotic mining companies to send small robotic scouts to a promising few. By the mid-2020s, Orion and SLS should be ready. If ARM delivers its asteroid boulder to lunar orbit, astronauts should visit it forthwith. But in case ARM is detoured, NASA is probably already thinking of how to reorient its exploration hardware: from lunar orbit, to "local" near-Earth object missions, to eventual journeys to the Mars system.

Although I think NASA's interest in human Mars exploration is genuine, the proof of that commitment will be its willingness to seek approval and funding for an earlier deep-space foray, millions of kilometers beyond the Earth-Moon system. A near-Earth asteroid expedition is just such a "no kidding" step toward Mars, far more daunting than a return to the moon (whose advantages I've discussed in recent columns). A NASA serious about Mars must move beyond talk, and actually do. Near-Earth asteroids represent just the terra incognita needed to demonstrate that seriousness of purpose. ★

NASA

Destination Mars

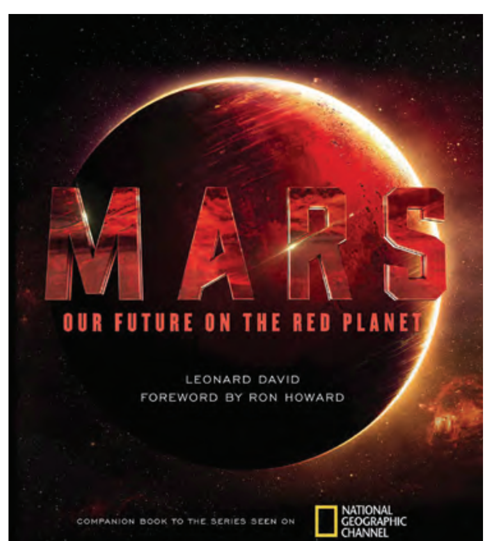
Review by Kristin Davis | kristin.grace.davis@gmail.com

NASA flight engineer Karen Nyberg gazes through the cupola windows of the International Space Station in 2013. Extended stays aboard the ISS provide some indication of what future travelers to Mars might endure.

Scientists are just starting to grasp the technical requirements of getting humans to Mars. But what happens to a person's psyche after being flung into such faraway isolation?

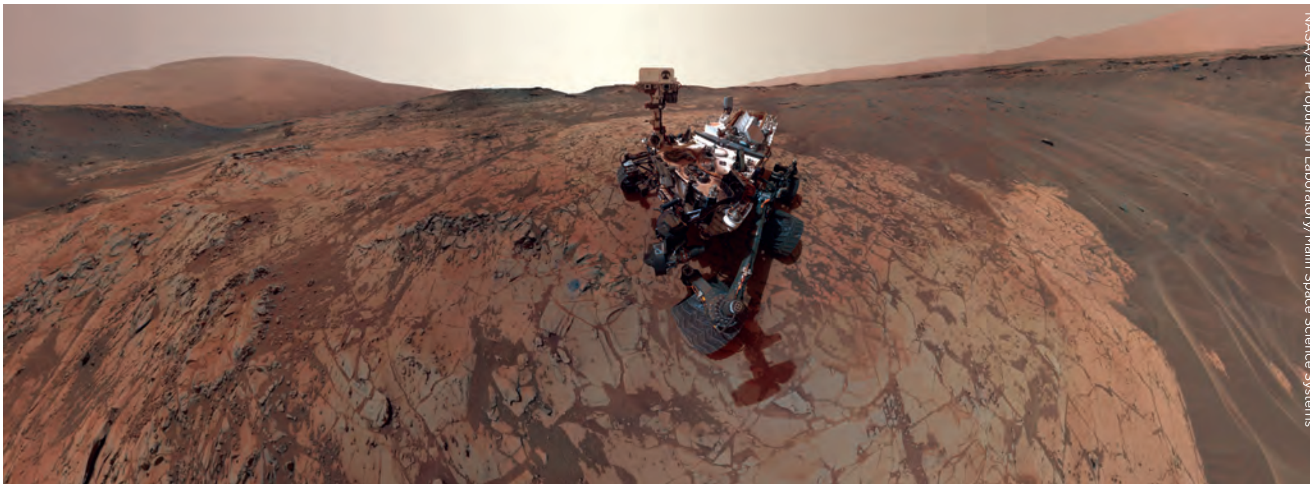
Space journalist Leonard David digs into this and other territory in "Mars: Our Future on the Red Planet," due out in October from National Geographic. David gives readers a big dose of science and technology, taking readers on a journey to laboratories and test chambers around the world where scientists are working on the challenges of reaching Mars and living there. He unabashedly predicts that people will one day inhabit and even thrive on the extraterrestrial globe.

The book serves as a companion to the National Geographic Channel's miniseries by Ron Howard and Brian Grazer set to premiere in November. Called "Mars," the show tracks in docudrama fashion a notional human mission to Mars in the year 2033. An international crew faces trouble from the time of touchdown dozens of kilometers away from the intended target. Problems mount as the months pass, with the governments and private investors back on Earth ready to end a mission they feel they can no longer justify. Then an unexpected discovery gives hope that humanity may endure on Mars after all.



The project builds on momentum created by "The Martian," the best-selling book and blockbuster movie about an astronaut stranded on the red planet. The miniseries includes interviews with current-day pioneers who are researching and developing technology to get us there.

The book, in six parts and with a foreword by director Ron Howard, explains in often poetic prose what seems like every conceivable challenge



NASA's Curiosity Mars rover took this self-portrait on Mount Sharp in 2015. Putting humans on the red planet would require finding a suitable landing site and generating breathable oxygen from Martian carbon dioxide.

of putting "boots on Mars." They include forging international partnerships to finding a suitable landing site to generate breathable oxygen from Martian carbon dioxide to protecting colonists against radiation, falling boulders and toxic microbes.

"In the 2030s a peculiar shadow slips across the reddish vista that is Mars," David begins. "In the 21st century, the sandy face of that faraway world is to be dotted by the first footprints of humans."

In a series of profiles called "Heroes," David introduces us to the experts working on solutions to those problems. They are among dozens of scientists and academics David interviewed, including twin astronauts Mark and Scott Kelly and NASA planetary protection officer Catharine Conley, whose job is to ensure responsible space exploration.

"I think we hit a chord of things I haven't seen in one place," David tells me in a phone interview from his home in Golden, Colorado.

In National Geographic fashion, the book features stunning photos taken by the Opportunity and Curiosity rovers and the Mars Global Surveyor probe, showing the crumbling copper walls of Victoria Crater, the meringue-like peaks of Bagnold Dunes and the smoke-like trails of dust devils.

A chapter called "Mind on Mars" explores the physiological dimensions of exploring those distant, beautiful places.

"The voyage of a crew to Mars is a protracted, perilous one. It is an interplanetary adaptation of the loneliness of a long-distance runner," David writes. "Confronting and enduring the emotional and mental stresses and strains of just getting to the Red Planet is rough enough, putting aside the psychological tensions of chalking up any lasting stay on Mars."

Which begs a series of questions: Who should go? What qualities does the ideal interplanetary traveler possess? How do people cope with close-quarter living, cut off from the world they know? The International Space Station provides some indication. So does a series of simulated Mars missions in Earth's most faraway places, including Devon Island in the Canadian Arctic, an isolation chamber in Russia, and research stations in Antarctica.

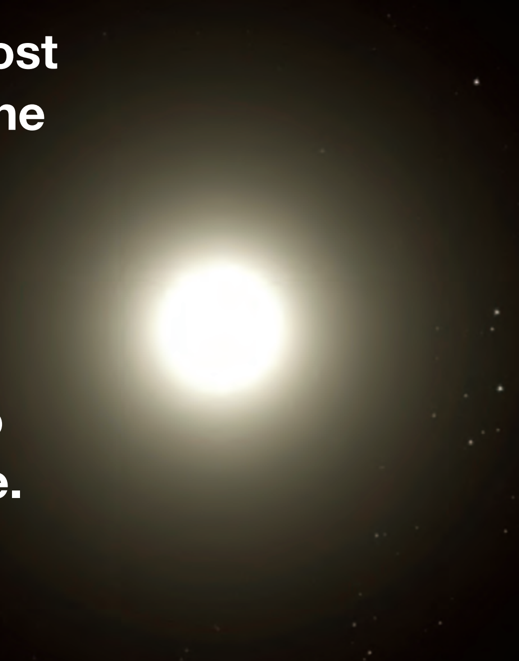
So far, David writes, these projects have shown a need to select a Mars crew as a team, rather than individuals. He talked to aerospace engineer and author Robert Zubrin, who argues that the human psyche, while perhaps least understood, will prove to be among the greatest assets.

Finally, David takes us to Marsland — the red planet decades into the future, after humans have established communities there. He challenges us to imagine the unique culture of life on another planet and the children who will be born there. He writes of the shifting values and social changes inevitable in the settlement of new frontiers. He asks us to look beyond the primitive, connected structures in which the first inhabitants will live and work, to a planet that has been terraformed by humans.

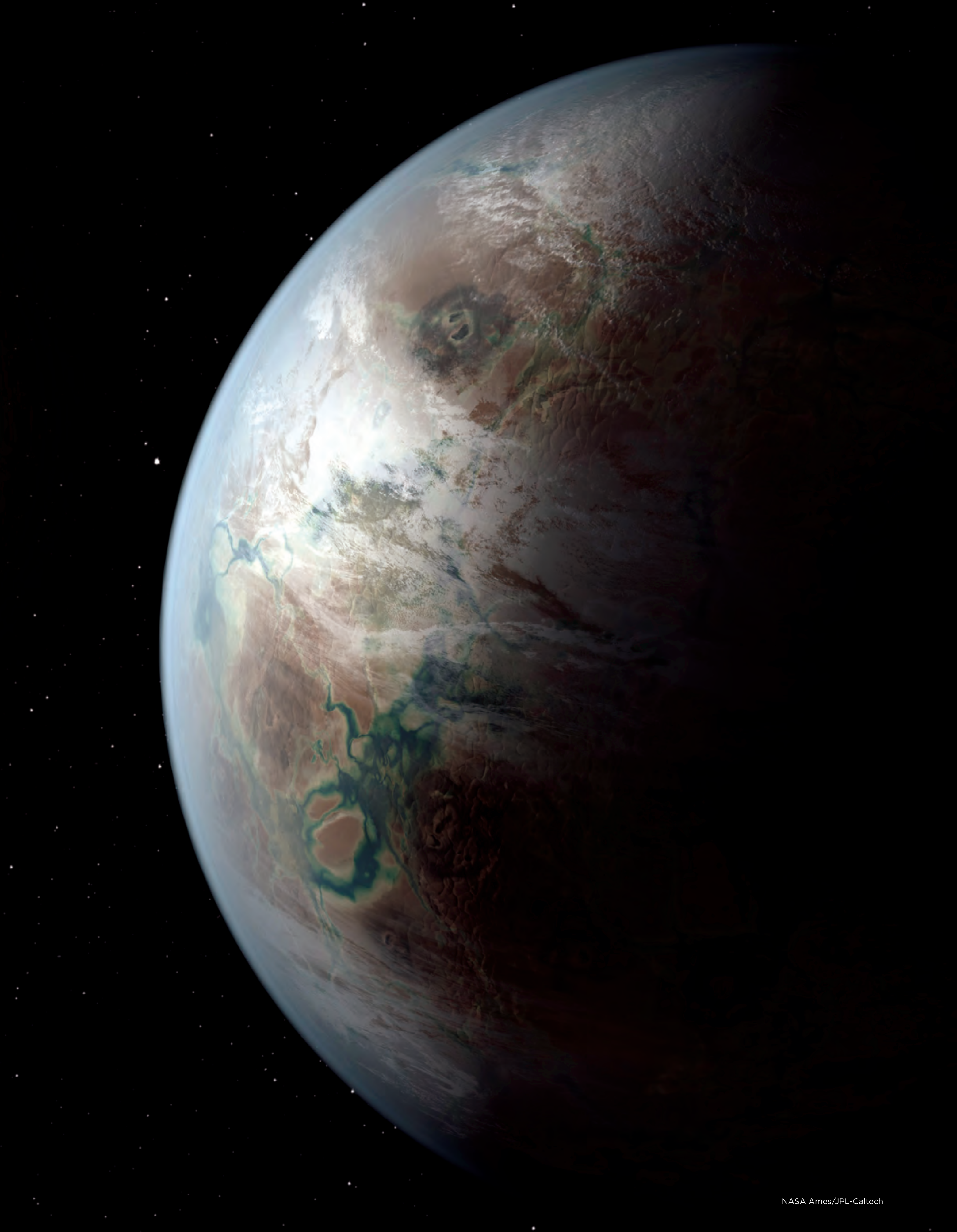
NASA space scientist Christopher McKay is already on that task, David writes. The planet could be turned into a place more hospitable to humans by building up the atmosphere with super greenhouse gases. The process, which David acknowledges raises a series of ethical questions, would take generations. Even then, humans would need oxygen outdoors. Such a transformation is also predicated on a successful first mission.

"Mars: Our Future on the Red Planet," makes a case that success is imminent and that humans will establish a community on Mars relatively soon. As David reminds us: "Danger is always present on the boundaries of exploration, but that hasn't stopped us before and it won't stop us this time." ★

Earthlike exoplanets seem almost certain to exist somewhere in the galaxy, and someday delivering a photograph of one might be astronomy's most amazing achievement. Adam Hadhazy spoke to the technologists who are trying to make that possible.



Planet spotting



NASA Ames/JPL-Caltech

Astronomers have cataloged about 30 planets beyond our solar system that might optimistically harbor life, although none of these worlds is thought to be Earthlike. Researchers are confident that within decades, they'll find what they believe to be a bona fide Earth 2.

If such a discovery were made today, it might generate as much frustration as exhilaration. The vast majority of the worlds discovered since 1995 were detected by measuring the gravitational tug on their host stars, or more lately by sensing the dip in brightness of the host star as a planet crossed in front. Right now, no one has the technology to image an Earthlike planet, if one exists. Scientists would have only equations to make the case that their discovery is a planet like ours. What they really want is direct imaging, which would mean gathering photons reflected from the planet's surface and clouds. Such an image would probably look more like a gleaming dot than a Polaroid, but the underlying data would be enough for scientists to deduce the planet's atmospheric conditions.

Not only that, direct imaging could find candidates that the indirect methods might fail to detect. A small planet like Earth would induce only a slight side-to-side "wobble" in the star's position, and the planet might not happen to transit the face of its star from our vantage point.

Direct imaging can't be done today for an Earth-sized object because of the daunting optics challenge. The glow of a terrestrial exoplanet could be 10 billion times fainter than that of its host star. Scientists would have to block or occult much of that light to reveal the planet, and they'd have to do it in space to avoid the distorting eff cts of Earth's atmosphere.

NASA and a host of researchers are determined not to let that status quo stand.

"What's driving all of us is the search for life in the universe," says NASA's Gary Blackwood, manager of the Exoplanet Exploration Program at the Jet Propulsion Laboratory in Pasadena, California. "That's appealed to all of us since we were kids and it still does."

Engineers at JPL, Princeton University in New Jersey and other facilities have taken up that challenge, and within a decade their work could give astronomers the ability to image an Earth 2.0.

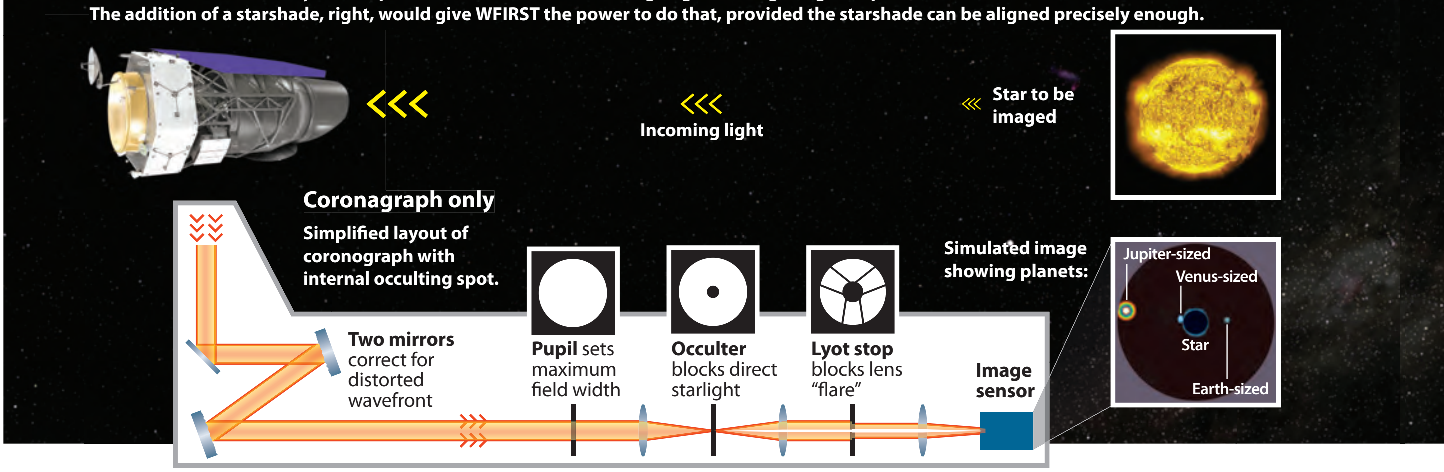
One kind of occulter is a coronagraph, which is a set of filtering optics installed within a telescope's housing. Scientists have photographed the sun's corona or atmosphere this way from the ground since the 1930s.

A more spectacular idea would be to block the light from the host star with a sheet of opaque material positioned beyond the telescope in the light path from the star. Dreamed up in the 1960s, starshades have only recently become technologically feasible due in part to the advent of precision-alignment software and microfabrication techniques. A starshade would be deployed thousands of kilometers in front of its companion telescope, shrouding its aperture in deep shadow and letting just the dim light of the stars' exoplanets seep in.

Both occulter types, old and new, have a long way to go before they can suppress starlight sufficiently to reveal Earthly twins, currently as invisible as fireflie encircling a spotlight. A race is underway

"The reality at the moment is we're still working on both coronagraphs and starshades — why would you kill one now when you don't know which will work?"

SARA SEAGER, professor of planetary science and physics at MIT



Revealing Exoplanets

The key to imaging an exoplanet is to block or occult the light from the planet's host star. A coronagraph-only version of NASA's planned Wide Field Infrared Survey Telescope, below, could filter out enough light to image large exoplanets but not dimmer Earth-sized ones. The addition of a starshade, right, would give WFIRST the power to do that, provided the starshade can be aligned precisely enough.

Source: NASA/Jet Propulsion Laboratory to build two different kinds of next-generation coronagraphs and a starshade to test them in space in the mid-2020s. The coronagraphs would be installed inside the housing of NASA'S Wide Field Infrared Survey Telescope, or WFIRST, the planned successor to the forthcoming James Webb Space Telescope, whereas the starshade would be positioned 50,000 kilometers in front of it.

A lot is riding on that starshade work. WFIRST's 2.4-meter mirror won't collect enough light for its coronagraphs to image a dim Earth 2.0. That ability will have to wait until an even larger telescope is launched in the 2030s. But by flying a starshade in precise formation with WFIRST, the telescope might be able to deliver an Earthly twin by more efficient suppressing starlight than the coronagraphs. That' because the mirrors and filters of a coronagraph would inevitably lose a large portion of the incoming planetary light. That said, starshades are relatively new to the scene. Researchers must prove that today's small-scale, grounded test versions can suppress light as effectively as has been theorized

Worldly wheat from chaff

NASA's transit-detecting Kepler space telescope is responsible for the lion's share of the exoplanets discovered so far.

"The Kepler mission results have told us the universe is teeming with planets — there's at least one for every star," says Blackwood. "If we look, we will find them.

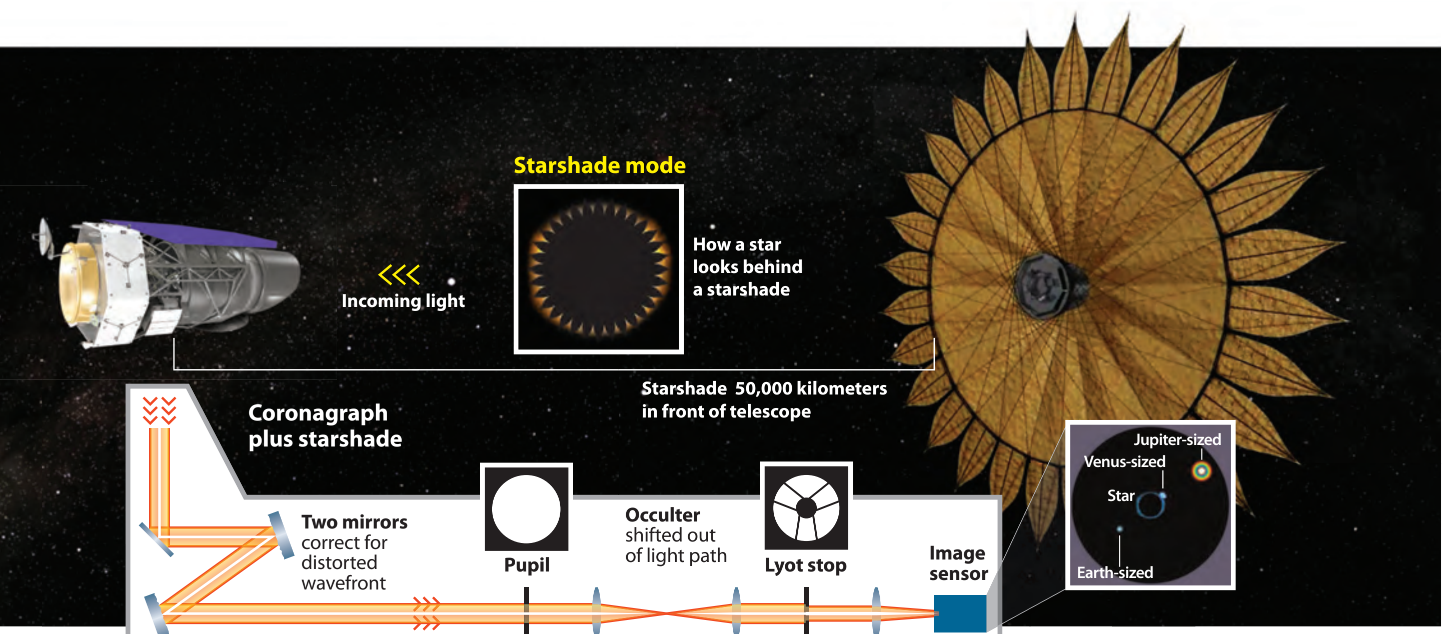
Scientists want an imager, because Kepler's transit detections yield little information beyond the object's mass, size and orbital parameters. Direct imaging has been done to date in only a limited fashion on a handful of worlds, all gas giants, and with only a small portion of the meager light collected from them. Applying the technique to more promising objects could identify telltale signs of alien life such as the right proportion of oxygen, carbon dioxide and methane. Or an imager might examine the closest stars within 100 light-years or so and find an Earthlike planet on its own, perhaps even in the Alpha Centauri star system four light-years away.

"Direct imaging is how we're going to get Earths," says aerospace engineer Jeremy Kasdin of Princeton University.

That will require occulters, and they must be more than an outstretched hand crudely eclipsing a star. They must also reduce the spreading, or diffra - tion, of lightwaves. Like water flowing around a rock in a stream, light changes course in response to its surroundings, diffracting when it hits an impediment's edges, like the rim of a telescope's aperture and the optical components inside.

Typical coronagraphs consist of lenses, masks and mirrors installed inside a telescope. The light from an observed star enters the telescope and bounces off its primary mirror to a secondary mirror that directs the light into the coronagraph. The light is tightly focused on an opaque occulting mask the size of a pinhead. This mask blocks out most of the starlight, but some light still diffracts around it. Thi remaining starlight goes through a series of other mirrors, lenses and masks to continue filtering it out. Meanwhile, the light from an object beyond the periphery of the star, such as an exoplanet, passes unimpeded through the optics to a camera.

A starshade deals with diffraction differently. If the starshade were simply a dark disk, starlight would



John Bretschneider

inconveniently diffract around its hard edges. Instead, a starshade has petals radiating off a central disk, like a sunflower. The shape of those petals causes the light diffracting around them to form interference patterns that overlap and largely cancel out each other. The starshade therefore casts a central, ultra-dark shadow where the telescope sits. The starshade can be positioned relative to a star so that the telescope captures only the light shining from its exoplanets.

Drawing board to reality

In two NASA reports released last year, one called "Exo-C" for exoplanet coronagraph and another called "Exo-S" for starshade, technologists described how these occulters might each be deployed for under a billion dollars. The "Exo-C " report assumed a telescope with a small mirror of 1.1 meters, while "Exo-S" looked at 1.4- and 2.4-meter mirrors. Extensions to these studies were published in April 2016 to explicitly consider WFIRST's 2.4-meter primary mirror. That mirror was one of two spare mirrors and telescope housings given to NASA in 2012 by the National Reconnaissance Office the agency that buys and operates U.S. spy satellites. The larger diameter means the telescope's housing — which NASA will modify significantly — has enough volume for NASA to include two different kinds of coronagraphs as a technology demonstration.

NASA doesn't see a need to choose between coronagraphs and the starshade technology, especially not before each has been battle tested in space.

"We see both starlight suppression methods as promising and worthy of investment," explains John Gagosian, program executive for the WFIRST mission and the Exoplanet Exploration Program at NASA headquarters. "NASA is committed both to performing the coronagraph flight demonstration on WFIRST and to maturing starshade technologies to enable a possible starshade flight demonstration" during the WFIRST mission."

Of course, WFIRST is not all about planet hunting. The telescope will map galaxies to study dark energy, the strange force that might explain why the universe is expanding at an accelerated pace instead of slowing due to gravity. Currently, less than 10 percent of the $3 billion WFIRST project is ultimately projected for its coronagraph development and operations covering a six-year mission length. For the starshade, concept work is underway now to identify the necessary components and their costs, which are expected to be relatively modest, says Kevin Grady, the WFIRST project manager at NASA's Goddard Space Flight Center in Maryland.

Researchers continue to make strides on starshades with NASA funding. A few years ago, JPL demonstrated in the lab how a starshade might be stowed small for launch and then unfurl its petals in space. Meanwhile, Northrop Grumman has run tests in the Nevada desert. Last year, the company positioned a mini-starshade on a pedestal between the 2.1 meter mirror in the McMath-Pierce Solar Telescope in Arizona and a camera to practice imaging around bright objects, such as Jupiter and the star Vega. In April, NASA formally declared the starshade a "technology development activity." The move brought various starshade-related initiatives under one roof with the goal of fostering the technology for endorsement in the National Academy of Sciences' next Astronomy and Astrophysics Decadal Survey, scheduled for release in 2020. These recommendations about priorities from scientists and technologists carry enormous weight in Congress, at NASA and the White House. Kasdin has a unique perspective on coronagraphs and starshades because, as he puts it, "I'm the only person in the community who works on both." A contributor to the "Exo-S" report, Kasdin is also the lead scientist for WFIRST's coronagraph.

"I don't view this as a competition," Kasdin goes on. "Each of them has hard things. Coronagraphs have had a little bit more time spent on them, so we know where the warts are, but we're making a lot of progress with starshades."

While the coronagraph and starshade research communities are indeed largely separate, neither views its efforts as zero sum


Adam Hadhazy

Experiments inside a 77-meter tube at Princeton University will test a protoype starshade made by NASA's Jet Propulsion Laboratory.

NASA/Tim Jacobs

NASA's Kepler space telescope has found the lion's share of the several thousand exoplanets that astronomers have cataloged over the last two decades.

"The reality at the moment is we're still working on both coronagraphs and starshades — why would you kill one now when you don't know which will work?" says Sara Seager, a professor of planetary science and physics at MIT.

She and Blackwood are co-chairs of NASA's StarShade Readiness Working Group formed in January to build on the work of the Exo-S science and technology definition team, which Seager chaired. Even so, Seager is quick to point out the scientific advantages of each approach. Coronagraphs would be more efficien at finding exoplanets, Seager says, because they look wherever the telescope housing points. Starshades, on the other hand, can cast dark shadows onto smaller, nearer-term, less expensive telescopes. But because starshades must be moved in sync with the telescope for each exo-solar system to be studied, they cannot cover as many systems as coronagraphs.

"Ideally, you have both," Seager says. "The coronagraph does the survey, finds the planets we want, then the starshade goes in" for a closer look.

Testing a starshade

In a long hallway underneath Princeton's Frick Chemistry Lab, a yard-wide, sealed steel tube runs nearly the length of a football field. Its interior is painted pitch black and represents the darkness of space.

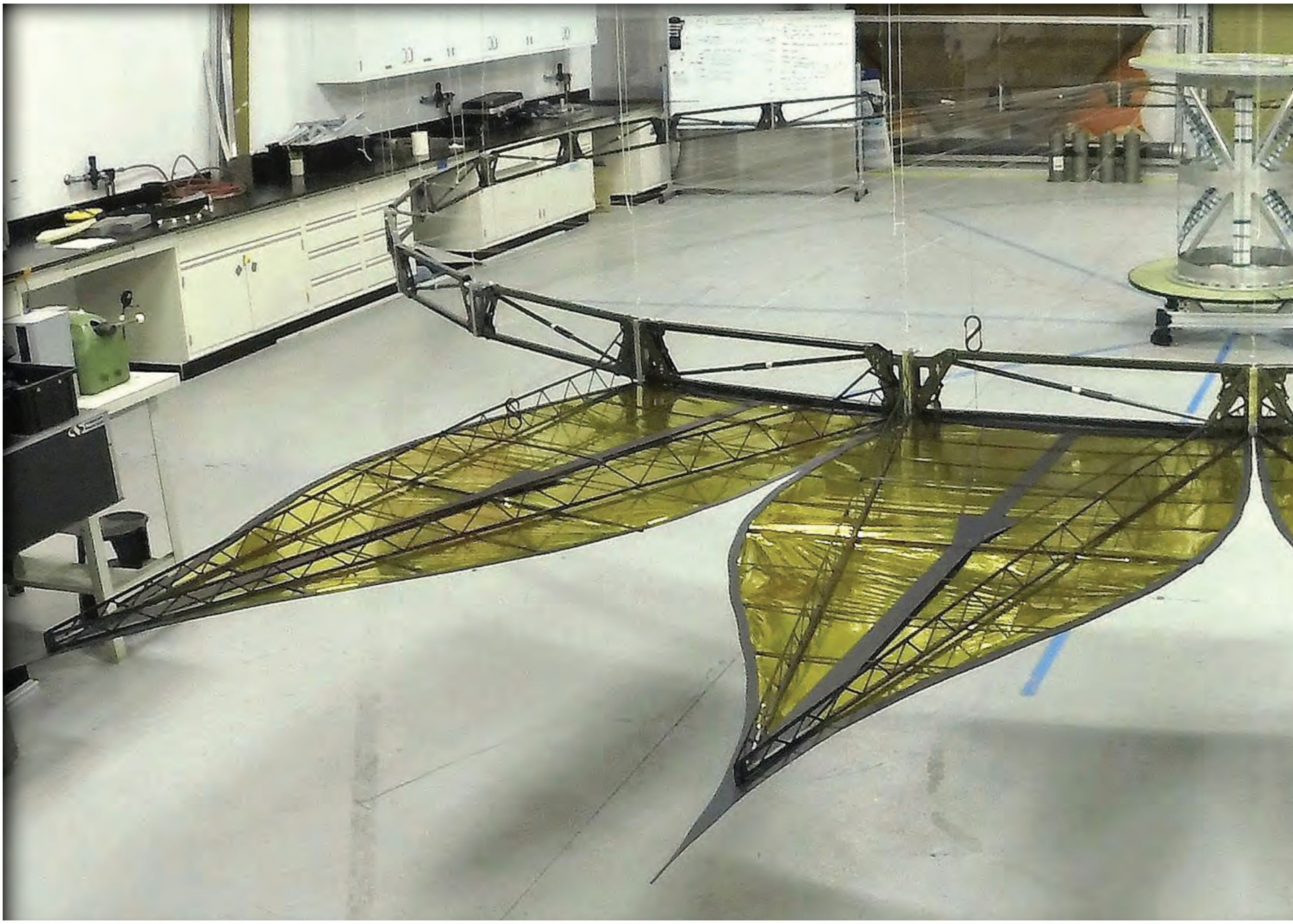
"It's fun to put your head down the tube," says Kasdin. "It's very black, very existential."

The tube is bookended by large boxes. One contains a camera, representing a space telescope; the other, a 21-megawatt, helium-neon laser, representing a star. In between, the metal tube passes through a third box, where a one-inch-wide slice of silicon with 16 petals — a micro-starshade, manufactured by JPL — intersects the laser beam.

In tests likely to run through early next year, Kasdin's team of colleagues and students will shine laser light through the tube to see how well the starshade suppresses the laser light. Next year, they'll install a communications link between the camera and the starshade mount to investigate formation flying, keeping the instruments synced when one or the other is moved.

"This experiment is a scaled version of the real flight version so we can ensure that the starshade can work in space," says Yunjong Kim, one of Kasdin's post-doctoral researchers.

Depending on how these tests and others go ahead of the decadal survey, NASA may well be in a position to give a green light to a starshade for a future mission. If that mission is to be WFIRST, starshades will probably not be considered technologically developed enough for a simultaneous launch and deployment with the telescope. The likelier scenario would be a rendezvous mission, in



A mockup starshade tested by NASA's Jet Propulsion Laboratory. The yellow petals are micro-starshades that radiate out from a central disk. The petals' shape causes the light diff acting around them to form interference patterns that overlap and cancel out each other.

which the starshade launches subsequent to WFIRST and pairs with it in space. To enable this meet-up, mission planners must decide by mid-2017 whether WFIRST will be designed as "starshade ready," with components including a crosslink for formation fl ing and data transfer with its late-arriving, occulting partner.

"With just a few more dollars of investment in being starshade ready, we can be available for the next technological step of this external occulter," says Grady, the WFIRST manager. "I think it's just a great story in further leveraging our investment for this telescope."

Should a starshade with a 40-meter diameter indeed end up paired with WFIRST, it might be able to obtain images of more than three dozen planets over the mission's duration, including a few Earths.

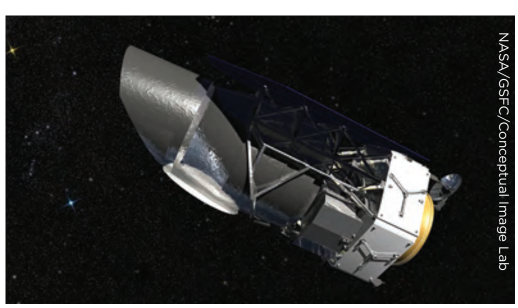
Improved coronagraphs

Astronomers have more modest science ambitions for the coronagraphs in development for WFIRST. It is hoped they can provide deep-enough contrast to behold gas giants like Jupiter, Neptune-like ice giants, maybe even a super-Earth or two, the enigmatic worlds several times more massive than our own and without analogs in our solar system.

To achieve this, the two coronagraph types slated for WFIRST must dramatically improve on the rudimentary devices flown on Hubble, Spitzer and in 2018, the James Webb Space Telescope. Th se new coronagraphs will include sophisticated, active wavefront control, which corrects for optical aberrations that reduce the high contrast needed to observe exoplanets. For maximum light suppression, actuators move deformable mirrors to keep a star centered in the coronagraph. Although such mirrors have never flown in space, the technology behind them is well-understood from their use on ground-based observatories offsetting the distortion caused by Earth's atmosphere.

Because the WFIRST telescope was inherited by NASA and not initially planned to accommodate a coronagraph, engineers are having to cleverly address certain inherent design limitations. A key one is WFIRST's ability to stay precisely pointed at target stars. For the clean, deep observations scientists desire for studying exoplanets, WFIRST's coronagraphs will require exquisite stability of 0.4 milliarcsecond, meaning the telescope cannot waver more than about half the apparent width on the sky of a typical,

A race is underway to build two kinds of next-generation coronagraphs in time to test them in the mid-2020s on NASA'S Wide Field Infrared Survey Telescope, the planned successor to the forthcoming James Webb Space Telescope.



point-like star as seen from Earth. The challenge is that WFIRST will naturally jitter as much as 11 milliarcseconds. To solve that problem, the coronagraphs will have what Feng Zhao, the WFIRST coronagraph instrument manager, likens to an anti-shaking feature found on expensive, terrestrial cameras. A sensor in the coronagraph will detect the telescope's jitter and then feed that information to a fast steering mirror that will immediately shift to compensate and keep the incoming light centered. The wavefront control system must also compensate for diffraction and fragmentation of observations caused by the six struts, or "spider arms," supporting WFIRST's secondary mirror.

"Despite all that, WFIRST is still a really good opportunity to see a bunch of exoplanets," says Wesley Traub, the project scientist for the WFIRST mission at the JPL. By working through these issues, the coronagraphs on WFIRST should pave the way for future instruments designed hand-in-glove with their telescope architectures.

Earths in abundance?

Early planning has begun for WFIRST's successors. Two concepts, the Large UV/Optical IR surveyor, or LUVOIR, and HabEx, short for the Habitable Exoplanet Imaging Mission, could have primary mirrors from eight to 12 meters and come outfitted with both coronagraphs and starshades for direct imaging. If WFIRST has not already spotted Earth 2.0, these instruments should finish the job, and then some

"With LUVOIR, and HabEx, now it's getting really exciting," says Blackwood. "We'll be able to survey many, many systems and look for the signs of life in planets' atmospheres."

When it comes to finally answering the question of whether we are alone in the universe, Blackwood adds: "I'm as impatient as you are." ★

CARRIER DRONE DEBATE

An X-47B Unmanned Combat Air System Demonstrator drone flies ver the flight deck of the ai craft carrier USS George H.W. Bush. In 2013, the ship was the site of the fir t catapult launch of an unmanned aircraft from a flight deck.

The Navy has decided that its first full-sized carrier-based unmanned aircraft will be a refueling drone with some intelligence capabilities, rather than an unmanned equivalent of an F/A-18. For some, it's a big and possibly dangerous letdown. Keith Button spoke to those on both sides of the issue.

U.S. Navy

The vision was spectacular: A drone that could take off and land on an aircraft carrier, flying combat missions from day one of a battle; firing weapons; collecting intelligence, surveillance and reconnaissance; flying farther and lingering longer than any manned fighter in the U.S. Navy's arsenal; and evading modern-day air defenses with stealth technology.

But the reality now looks mundane to those who favored this vision. The Navy announced in February that its forthcoming carrier-based drone will be a tanker for aerial refueling of traditionally piloted fighter jets, with some intelligence, surveillance and reconnaissance equipment aboard.

Critics inside and outside of the Pentagon are now speaking out about the Navy's decision. They suggest it puts the service out of sync with the increasingly sophisticated weapons abroad, including vastly improved air defenses and a Chinese antiship missile that could force U.S. aircraft carrier groups to stay farther away from their intelligence or strike targets. For its part, the Navy says it hasn't given up on fielding unmanned combat planes at some point, and it maintains that this was the right budget choice for the state of unmanned technology. The debate shows no signs of abating, with a report due in 2017 from the Government Accountability Office, and the Navy in the throes of planning the unmanned tanker acquisition.

High expectations

During the Unmanned Carrier-Launched Airborne Surveillance and Strike, or UCLASS, program, the carrier drone concept came with high expectations. A demonstration version built for a UCLASS predecessor program had aced automated aircraft carrier landing and takeoff tests. That plane, a Northrop Grumman-built X-47B, nailed all seven of its autonomous carrier landings in 2013. Hooking the third arresting wire out of four available for an aircraft carrier landing is the goal for U.S. Navy pilots — one of the most difficult tasks that any human pilot can accomplish — and the X-47B not only hit the three wire, but touched down within seven centimeters of its target with every landing.

Besides its autonomous carrier takeoff and landing performances, the stealthy X-47B also demonstrated autonomous mid-fl ght refueling, taking on 1,815 kilograms of fuel from a Boeing 707 Omega tanker in 2015.

The idea behind UCLASS was for the Navy to improve its intelligence, surveillance and reconnaissance capabilities and its ability to fight battles where the enemy has integrated air defenses with dense layers of overlapping sensors, airplanes and missiles, including anti-ship missiles. The X-47B was designed without a tail in a strategy to reduce its radar signature, so that a successor combat or ISR version could penetrate hostile airspace. Without a human pilot aboard the plane, engineers could design the plane to stay airborne much longer, enhancing its range and the ability of the Navy to strike distant targets or gather intelligence with cameras and eavesdropping equipment.

Among those worried about the Navy's decision to abandon that role for the X-47B's successor is retired Adm. Gary Roughead, the Navy's chief of naval operations from 2007 to 2011 and now a Northrop Grumman board member.

"One of the objectives of any potential adversary is to keep our air power as far away as possible," Roughead says. "The last decade or so, we've really been able to operate unfettered in the skies where we're conducting combat operations. I don't think that's going to be the case in the decade, decade-plus going ahead."

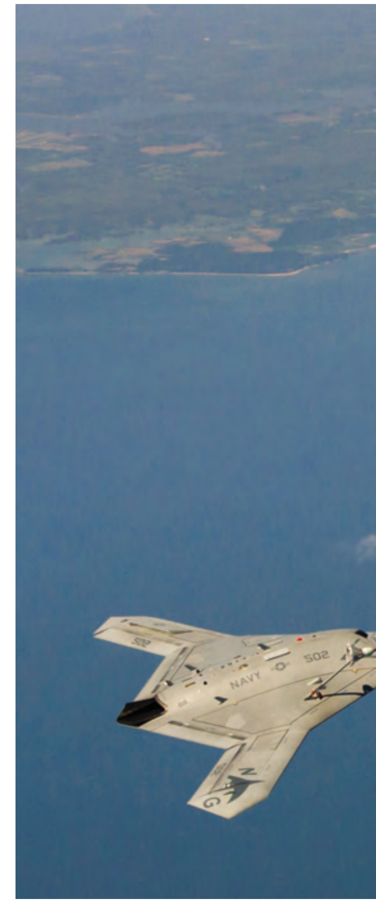
Roughead would like to see the Navy make it a priority to incorporate unmanned, long-range, refuelable, strike-capable airplanes into its carrier air wings. As matters stand, the Navy plans to hold off on unmanned combat-ISR planes, probably for at least fi e years and the targeted time frame for the tankers will have them field d in 2023 or 2024.

For aircraft carriers, one threat that could push them farther away from the enemy is the Chinese DF-21D anti-ship ballistic missile, dubbed a "carrier killer" in an analysis of threats to U.S. ships. It is a hypersonic weapon with a 1,850-kilometer range that could knock out a carrier in one hit. That compares to the unrefueled combat radius of about 930 kilometers for the F/A-18 E/F Super Hornet, and to about 1,110 kilometers for the planned F-35C Joint Strike Fighter. The X-47B demonstrator has a range of 3,890 kilometers.

As envisioned by one proponent, Jerry Hendrix — a retired Navy captain and senior fellow at the Center for a New American Security, a Washington, D.C., think tank — an unmanned airplane developed along the lines of the X-47B would have an unrefueled combat radius of more than 2,780 kilometers, the ability to fly for 14 hours without mid-air refueling or 50 hours with it, the capacity to carry 1,815 to 2,720 kilograms of bombs, stealthy radar-avoiding characteristics, and the ability to provide ISR coverage for the carrier and its escort ships.

The range and loiter advantages of drones give them a big advantage over conventional planes, says retired Lt. Gen. David Deptula, dean of the Mitchell Institute for Aerospace Studies in Arlington, Virginia, and the Air Force's ISR chief from 2006 to 2010.

"It's the persistence that allows time to observe, evaluate, act really quickly or take all the time that's necessary to be sure of a particular action, but that also translates in the case of the Navy into range, which



U.S. Navy

“It’s a bit like saying, ‘We designed a Formula 1 race car, and it’s pretty much good to go, so let’s buy a scooter, and we can always go back to the Formula 1.’”

Consultant Keven Gambold on the contention that a naval unmanned combat and intelligence plane could be revived if the need arises.

An X-47B receives fuel from an Omega K-707 tanker in 2015. The autonomous refueling came after the stealthy X-47B aced its automated aircraft carrier landing and takeoff ests.

will be standoff, so you can still have an eff ct much farther away from the launch and recovery deck than with a manned aircraft,” Deptula says.

UCLASS-type drones also could boost the eff c-tiveness of manned planes when they are flying in contested airspace. The drones could complement the planned B-21 Long Range Strike Bomber by gathering target data in contested airspace that the bomber would use when it arrives, says Keven Gambold, head of Unmanned Experts, a consulting fi m based in Colorado, and a former commander of a Predator drone squadron.

The switch

Officially, the Navy until February was planning to spend more than $3 billion on UCLASS development through fiscal year 2022. But in the Department of Defense’s fiscal year 2017 budget proposal, the Navy switched gears away from UCLASS to a carrier-based refueling drone with some ISR capabilities. Initially called CBARS, for Carrier Based Aerial Refueling System, and then MQ-25A, the tanker drone will cost more than $2 billion through fiscal year 2021, or $1 billion less than UCLASS, according to a Navy spokesman.

The budget reveal was a surprise for outsiders tracking the UCLASS development, and even for the Congressional committees involved with defense budget planning, one congressional aide said.

UCLASS fans see the switch as a mistake.

“It’s a bit like saying we designed a Formula 1 race car, and it’s pretty much good to go, so let’s buy a scooter, and we can always go back to the Formula 1,” says Gambold, the unmanned aircraft consultant. “Th y have a successful program, it looks like it’s going all the way, it looks like it literally is world-beating, and they turn it into a tanker.”

Deptula counts himself as a skeptic too. “Frankly, the logic of going from the UCLASS design as an ISR strike aircraft to an unmanned refueler is pretty thin,” Deptula says. “What is ultimately the benefit of this if you don’t have ISR and you don’t have strike, why are you doing this? To say that you’re just going to off et some F-18s that you otherwise would have to use for buddy refueling, that’s pretty soft logic for incorporating an entire new system into the panoply of carrier assets.”

Another issue is the timeline, says Roughead, the former chief of naval operations. Because it takes eight to 10 years to develop an airplane and field it, if long-range strike/stealth is a priority today, going with a tanker/ISR plane just pushes the strike/stealth option — and its eight-to-10-year development — even further into the future.

Devolving drone requirement

The U.S. Navy's controversial decision to shelve plans to develop the drone equivalent of a carrier-based F/A-18 in favor of an unmanned refueling plan did not spring from nowhere. The seeds of the decision are visible in years of back and forth over just how ambitious the requirements for the plane should be. **Here is a timeline:**

U.S. Navy

An X-47B demonstrator test aboard USS Theodore Roosevelt. The X-47B hooked the third wire on all its attempted autonomous carrier landings.

FEBRUARY 2006: The Pentagon's 2006 Quadrennial Defense Review proposes a long-range, carrier-based drone capable of being air-refueled. The Navy Unmanned Combat Air System, or N-UCAS, must have "persistent, penetrating surveillance, and penetrating strike capability in high threat areas" and "suppress enemy air defenses." The Navy starts the Unmanned Combat Air System Demonstration, UCAS-D, program to demonstrate operating an unmanned airplane from a carrier.

AUGUST 2007: The Navy awards Northrop Grumman a six-year, $635.8 million contract to build two X-47B demonstrators to show the ability of a tailless, ghter-sized drone to land on and launch autonomously from aircraft carriers. The demonstrators are to be built under the Unmanned Combat Air System Demonstration program.

JUNE 2011: The Pentagon's Joint Requirements Oversight Council, JROC, approves a program called UCLASS, for Unmanned Carrier-Launched Airborne Surveillance and Strike System, to develop "a persistent, survivable carrier-based Intelligence, Surveillance, and Reconnaissance and precision strike asset."

DECEMBER 2012: The JROC alters the requirements for UCLASS to favor intelligence capabilities in "permissive airspace" in what is widely interpreted as a cost-cutting decision.

JULY 2013: Off the coast of Virginia, an X-47B makes the fi st autonomous landing on a carrier, the USS George H.W. Bush.

AUGUST 2013: Northrop Grumman, Lockheed Martin, General Atomics Aeronautical Systems and Boeing each receive a $15-million contract for competing preliminary designs for a UCLASS plane.

SEPTEMBER 2013: The Government Accountability Of ce reports that the Navy's scaling back of the UCLASS requirements is a step toward affordability and that the GAO disagrees with the Navy's plan to develop and eld UCLASS before a Pentagon Milestone B review establishes a baseline for cost, schedule and performance. The Navy disagrees, saying it is complying with acquisition regulations. Congress responds by limiting the number of UCLASS drones that the Department of Defense can acquire before receiving Milestone B approval.

DECEMBER 2013: The Fiscal 2014 National Defense Authorization Act passed by Congress orders the Government Accountability Of ce to review the UCLASS program annually.

APRIL 2014: The Navy issues a draft request for proposals for UCLASS. The document is classi ed, but according to the Government Accountability Offi e, it emphasizes affordability and quick elding, while de-emphasizing operations in "highly contested environments."

MAY 2014: The Navy completes the preliminary design review of the UCLASS proposals submitted by the four contractors.

MARCH 2015: Softening of the UCLASS requirements does not sit well with Sen. John McCain, R-Arizona, chairman of the Senate Armed Services Committee. He writes to Defense Secretary Ashton Carter to say that a carrier-based drone should be capable of strike and ISR missions in "medium- to high-level threat environments" while carrying 1,800 kilograms of weapons and flying several times longer and farther, without refueling, than conventional carrier aircraft.

Glossary

CBARS Carrier Based Aerial Refueling System

JROC Joint Requirements Oversight Council

N-UCAS Navy Unmanned Combat Air System

UCAS-D Unmanned Combat Air System Demonstration

UCLASS Unmanned Carrier-Launched Airborne Surveillance and Strike System

APRIL 2015: An X-47B demonstrator conducts the rst autonomous aerial refueling of an unmanned aircraft.

MAY 2015: The Government Accountability Of ce reports that questions about the UCLASS mission and capabilities led to delays. GAO notes that the UCLASS program is expected to fi ld its rst drone no earlier than fi cal 2022, or about two years later than originally planned. The report cautions that the Navy might have to repeat the entire preliminary design process if it were to restore requirements for strike, increased payload or fuel capacity, or operating in highly contested airspace, as urged by Congress.

FEBRUARY 2016: The Navy announces the switch from UCLASS to CBARS, or Carrier Based Aerial Refueling System, a tanker for refueling other aircraft, in its proposed budget for fi cal 2017. CBARS is designated the MQ-25A.

Navy perspective

The Navy says it had to choose the tanker-ISR path because moving forward with plans to develop a stealthy strike airplane, without the funding or current technology to make it possible, was going to lead to cancellation of the carrier-based drone program.

Otherwise, the Pentagon's budget managers tell the Navy, "we're going to stop funding it, and we'll come back when you guys have your stuff together," says a Navy expert within the Department of Defense who asked not to be identified. Stealth capabilities are extremely expensive, and strike missions would require extensive advances in autonomous flight and machine learning technologies. "They could not deliver, in the budget and the time line, all the requirements that they wanted. It just wasn't possible."

The chief of naval operations, Admiral John Richardson, speaking at a conference in March, says his goal with the tanker-ISR plan is for the Navy to begin operating an unmanned plane, with a legitimate mission, from carriers so the Navy can learn about how to integrate drones into its carrier air forces. And when new technology is made available, it can be incorporated into the unmanned plane's design.

The Navy plans to work with the four bidders on the UCLASS preliminary design — Lockheed Martin, General Atomics, Boeing and Northrop Grumman — to gather information about their technology that might apply to the MQ-25A. The Navy expects to issue that request for proposals, then the information gathered from the contractors will help shape its final design requirements, which are expected sometime after Oct. 1. The Navy would field the plane on aircraft carriers as early as 2023, but more likely after 2024.

For five years, congressional leaders have been pushing the Navy to equip the forthcoming carrier-based planes with strike, stealth and ISR capabilities to penetrate highly contested airspace. Even before switching to the tanker option, the Navy has pushed back with lower-cost plans for drones that would conduct mostly surveillance missions in less-contested air space, with the goal of getting the planes fielded quickly and maximizing flight time endurance.

Congress is still insistent on the strike capability, and for operating in highly contested airspace in its report on the 2017 defense authorization.

The House Armed Services Committee characterizes the tanker option as a "slight variation" on earlier UCLASS requirements — a characterization that UCLASS advocates would argue with — and notes that planned drone requirements still include ISR and strike, though now the capabilities list includes "future precision strike." The committee also expresses concern that the Navy will be leaving strike capabilities out of its request for proposals for the tanker design and "may be excluding a critical capability and precluding future growth in a platform that will likely be integrated into the carrier air wing for the next 30 years."

U.S. Naval Institute

An artist's rendering of Boeing's proposed Unmanned-Carrier-Launched Airborne Surveillance and Strike System combat drone. The Navy no longer plans to build UCLASS.

The bill includes a directive to the U.S. Comptroller General, who directs the Government Accountability Office, to report on the Navy carrier drone program's progress by March 2017.

While strike and stealth won't be part of the initial design requirements for MQ-25A, they will still be available as options that the Navy could add at some point after the test flights begin, maybe in about five years, says the Department of Defense naval expert.

The notion that the X-47B — the demonstrator drone with the impressive autonomous carrier landings — could be simply turned into a strike-stealth airplane is misguided, says the Department of Defense expert. The plane was a prototype, and it proved the concepts it was designed for — the autonomous refueling and takeoffs/landings. But it also had flight systems that are now at least 10 years old, which the Navy wouldn't use for a future aircraft, and it was designed as a test bed, making it inherently inefficient for other specific requirements.

By taking an approach that will allow for flexibility as new technology is developed, the Navy is also keeping options open that aren't yet known. Just as when smartphones were introduced and society at first didn't know how they would be used, new technologies should give carrier-based drones novel capabilities, not just allow the drones to perform the same functions of manned aircraft, the Defense Department expert says. For example, technology advances may push ahead the concept of unmanned aircraft operating as surrogates deployed from the wings of larger aircraft, such as a P-3 Orion or C-130 Hercules, or in swarms of four or five wingmen controlled from an F-35. ★

SPRING

The International Space Station was assembled in space with few fit checks on the ground. The project's international partners had to overcome many obstacles to collaboration, including incompatible software and measurement units.

NASA

BOARD

Getting humans to the moon or Mars will almost certainly need to be an international endeavor like the construction of the International Space Station. John Cook, a veteran engineer of the space station, shares his insights from his time on the program.

The International Space Station has been continuously crewed since 1998. Six astronauts are currently aboard. Each crew is called an expedition. The next expedition to the ISS will launch on a Soyuz rocket September 23.

A tremendous amount of real-world testing, fit checks and collaboration between American and Soviet engineers occurred in preparation for the 1975 docking between an Apollo Command Module and a Soyuz. An adapter was required between the two spacecraft to accommodate their very different docking mechanisms. The Soviet Union had its APAS, or Androgynous Peripheral Attachment System, and NASA had the Apollo Probe and Drogue docking system.

The International Space Station assembly was verified in a much different fashion. U.S. and international partner engineers conducted very few one-on-one fit checks on the ground before joining the major elements in space. The pieces came together well, and to casual observers, the assembly probably looked easy.

In reality, that success was hard earned, as I know from my years as lead of the assembly analysis team from 1996 to 2014. I believe it's important to share information about how the station elements were constructed and assembled in low Earth orbit, because this complex program is the best model we have for the kind of international cooperation and technological integration that we'll need for human missions to cislunar space — the region near the moon — or near Mars.

Reliance on computing

We attached, depending on the count, about 40 major discrete modules and structures to create a spacecraft with a habitable volume of about 915.5 cubic meters. We could not have feasibly fit tested each piece, so the U.S. segment instead relied heavily on master tooling and computer aided design, CAD, to verify the initial assembly. The success of this approach can be attributed to simulation and modeling technology, plus some luck. My late father posted a sign in his garage that said, "Funny — hard work and good luck seem to go together."

Behind the scenes we worked fervently to ensure a safe and uneventful assembly. It's astonishing to me that the End to end Berthing Integration Team, EBIT, made the assembly of ISS appear as simple as snapping a plastic toy together. That massive effort required a great deal of behind-the-scenes coordination and communication among EBIT members, who represented all the major stakeholders in ISS assembly: Astronauts or their proxies, astronaut trainers, representatives for structures and mechanisms and robotic-arm experts. Additionally, we had a team called MAGIK, short for Manipulator Analysis Graphics and Interactive Kinematics, as well as lighting experts and me. The MAGIK guys performed 3D CAD analysis with medium-fidelity models to determine how to get the payload from the payload bay to the preinstall position (60.96 centimeters from the fully berthed position). I performed 3D computer simulations with very detailed high-fidelity CAD models of the interface to verify there were no interferences to the on-orbit assembly of the major elements of the ISS from the pre-install position to fully berthed position.

Leadership

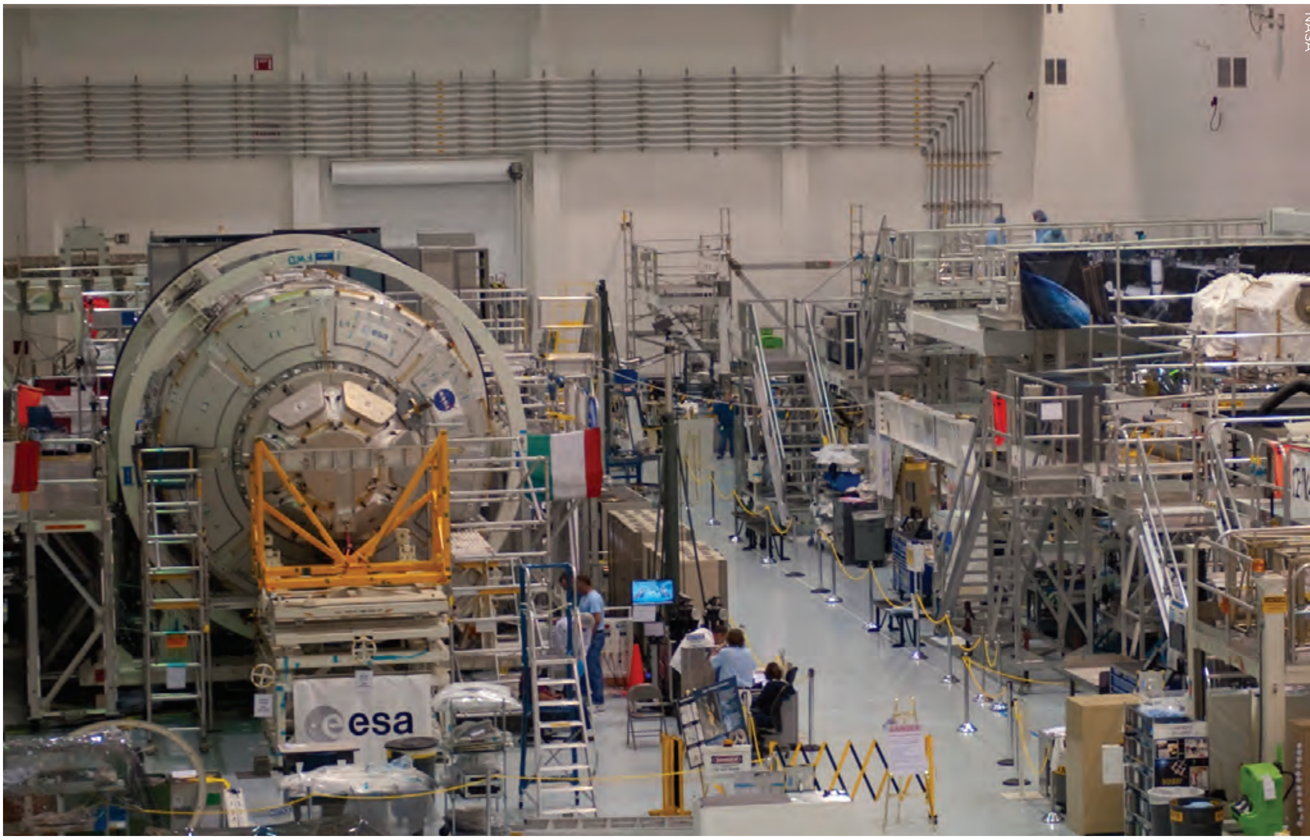
In 1966, at the peak of its funding, NASA received four cents of every dollar in the federal budget. Today, it receives about half a penny of every federal dollar — not pennies on the dollar as some politicians have claimed.

In an ideal world, we would have built the ISS, assembled it on the ground, tested it and then taken it apart and launched it and assembled it again on-orbit. We did not do that. It is almost absurd to think of the ground support equipment required to do such a thing. It would have been difficult, time consuming and expensive. So leadership decided to fast track the program. We started launching hardware to orbit before hardware that was going to attach to it had been built yet or even designed.

The station was built with a swarm mentality, with the program sometimes changing directions as swiftly as a throng of bees. It is usually not easy to pinpoint which individual initiated the change, but the group changes direction nonetheless.

Space innovation through cooperation

International cooperation in space provides a stimulus for technological innovation similar to war, but without the devastating toll. To paraphrase John F. Kennedy, it serves to focus our efforts. Multinational human spaceflight, in particular, brings out the best in us. Expanding cooperation for missions beyond low Earth orbit is likely to bring diplomatic benefits as well as technical breakthroughs. We've known this since the Apollo days. For a moment at least, the world was unified in wonderment at the feat of landing on the moon. Technology-wise, the series of missions spurred the miniaturization of electronics that paved the way for the revolution of personal computers and smartphones. — John Cook



The International Space Station's cupola, a bay-window shaped workstation on the yellow stand, is joined to Node 3. The cupola was originally designed to be attached to a different Node 3 port.

On ISS, the need for a change order could originate from anywhere within the organization. The top management might cancel a planned module, as was the case with the Centrifuge Accommodation Module (used for experiments with variable gravity using a centrifuge as well as a major source of stowage volume) or a worker bee like myself might find an issue that would require an unanticipated operational workaround or redesign, or even removing hardware on-orbit.

Take, for instance, the space station's cupola, a bay window robotic workstation. When the space shuttle program was canceled in 2011, NASA decided to launch the cupola attached to Node 3, because there would be no shuttle flight available for the cupola as planned. That meant attaching the cupola to the Node 3 axial port, instead of attaching it one of the radial ports as designed. Picture a cylinder. An axial port would be on either flat end of the cylinder; a radial port would be on the curved part of the cylinder. I performed analysis to determine how Node 3 would need to be modified to fit the cupola and then be de-berthed and attached to a Node 3 radial port. Precision digital preassembly measurements were then used to guide the delicate ground installation, using a repurposed pressurized mating adapter piece of ground support equipment and a six degree of freedom translation table. In plain English, we used a work stand originally intended for the Pressurized Mating Adapter and used it to support the cupola while we installed it with a six degree of freedom (roll/pitch/yaw/X/Y/Z) translation table.

The swarm mentality stems in part from dealing with international partners with individual agendas as well as the inherent technical uncertainty of such an audacious integration endeavor. It was akin to assembling an airplane while it is rolling down the runway.

We did not know exactly what the ISS would turn out to be, and it turned out to be different than what we anticipated. We changed our minds along the way and are still changing our minds. We launched the Permanent Logistics Module, or PMM, and installed it on the ISS to compensate for the loss of about 45 percent of the storage space we incurred when we canceled the centrifuge. Then, we changed our mind and moved it to another location in order to allow for more visiting vehicle access to the nadir, or Earth-facing ports. The PMM was not in the original game plan but the centrifuge was. It was a contribution from Japan and had actually been built.

Technical challenges

We encountered and overcame almost every conceivable obstacle: language barriers, cultural differences, multiple time zones, incompatible measurement units, and different software and software fonts.

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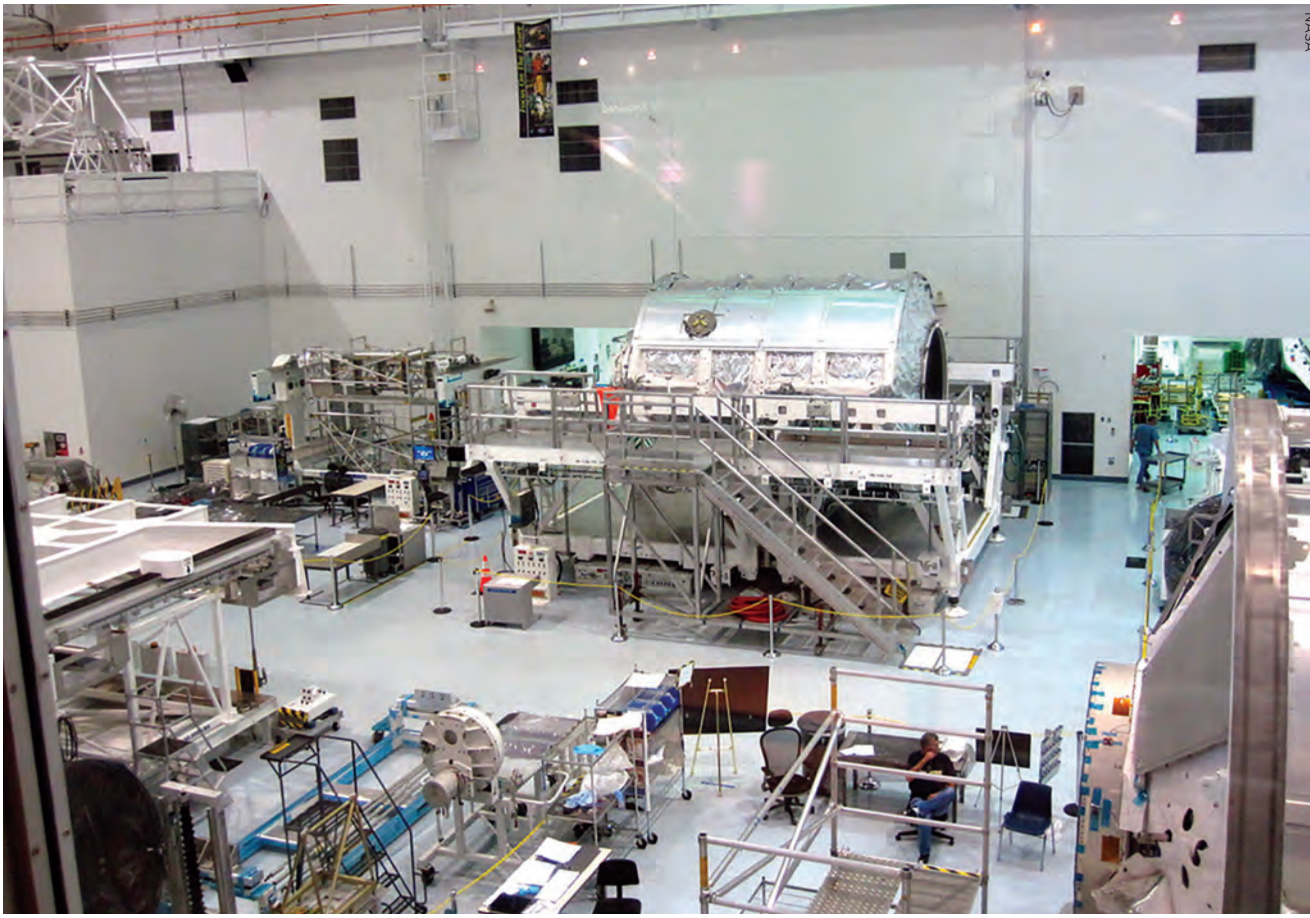


Equipment and payload headed to the International Space Station made a final top at the Station Processing Facility at NASA's Kennedy Space Center. At the peak of activity, the processing facility operated 24 hours a day.

The station experience demonstrated that it's much cheaper to fix a problem in the conceptual phase than in the design, manufacturing or operational phases. In order to most efficiently fix problems in the conceptual phase, team collaboration is critical. In planning future exploration, for instance, it would be wise to have astronauts and engineers and scientists and operations people talk to each other from the beginning.

The CAD environment is an ideal one for virtually verifying and optimizing the design. Doing that on a large scale ideally requires creating all CAD models in the same software and coordinate system for analysis and simulation.

Simulation in the conceptual and design stage is not enough. A strong leadership team needs to keep things on schedule and minimize change orders during production and operation. Equally important is the management team below that level, working the front lines of integration to flag potential issues as soon as possible. You want to nip problems at the lowest pay grades, but you also need an effective method to elevate issues up to management.

Our space station teams, including the End to end Berthing Integration Team and those working on digital preassembly and cable and fluid assessment groups, served as objective third party "referees" who bridged the gap among contractors. What we brought to the table was an independent assessment, with the perspective of the big picture, and the expertise and familiarity with both sides of each interface in minute detail. Our team had strong support from NASA management and the astronaut corps. A similar integration team structure might be beneficial to any large-scale integration effort, especially one involving numerous contractors and international partners.

Murphy's Law, paraphrased

If it can go wrong, it will, at the worst possible time, especially in the space business.

Ways to mitigate Murphy's Law are to be ready early, know what you are doing and practice it. Also know what you will do if something goes wrong and practice that.

We followed that procedure. The result is that we made the assembly at least look easy. But it was harder than it looked, and it'll be the same for getting into cislunar or deep space.

As humans, we are hard wired to explore. We have always wondered what is over that next hill, across that lake, on the other side of that ocean. Deep space is our next ocean. We should remember the sailing lessons learned from the ISS program. ★

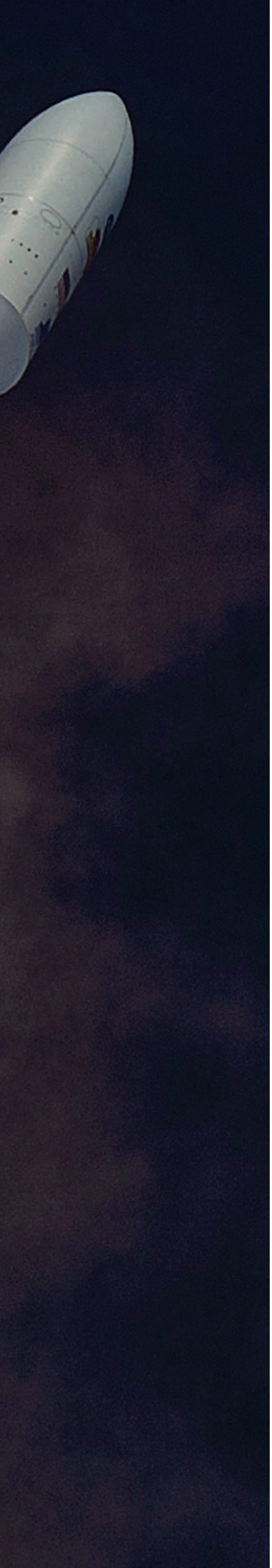
 JAMES KNAUF | jamesknauf@verizon.net

Freedom from Russian rocket engines

Those who don't know history are doomed to repeat it. In that spirit, retired U.S. Air Force Col. **James Knauf** analyzes how the U.S. military and intelligence communities became dependent on rocket engines from a geostrategic foe. He provides advice for those who must solve the Russian RD-180 conundrum.

U.S. Air Force

Lockheed Martin's Atlas 5 rocket was developed with help from the U.S. Air Force on the condition that its Russian-made RD-180 engine eventually be made in the U.S. The U.S. did not follow through on that mandate.



The long odyssey that has left the U.S. worrisomely dependent on Russia's RD-180 rocket engines for national-security satellite launches should serve as a cautionary tale as the Pentagon attempts to end that reliance by awarding millions of dollars in contracts to American engine and rocket companies. A key lesson from the RD-180 saga is this: While sound designs and performance are critical to success, other matters must also be considered when selecting launch suppliers, including the viability of a launch company's business plan, the long-term health of the U.S. space-launch industrial base and geopolitics.

1995: A turning point

The Air Force in 1995 started the Evolved Expendable Launch Vehicle, EELV, program after years of studies and false starts. Seeing predictions that the commercial launch market was about to boom, and to address Air Force requirements, McDonnell Douglas (now Boeing) developed today's medium and heavy-lift Delta 4 rockets from elements of the short-lived Delta 3 rocket. Meanwhile, Lockheed Martin refined the Atlas 2 into the Atlas 5 fleet.

The Air Force invested $1 billion to encourage Boeing and Lockheed Martin to modernize, in the belief that these contractors would flourish and compete well in the competitive international commercial market. Success there would reduce the cost of launching satellites, including U.S. military and intelligence-community satellites. To make it happen quickly, the Atlas 5 would need a powerful first stage, and the U.S. government agreed to allow Lockheed Martin to import the RD-180s, provided the engines were eventually manufactured in the U.S. through what was called coproduction.

The U.S. failed to follow through on that requirement, setting the stage for today's dependence on RD-180s. Complicating matters, the envisioned robust commercial launch market had not materialized. Instead, the EELV program encountered an anemic market, one that threatened the financial viability of Boeing and Lockheed Martin space-launch programs. The erstwhile competitors formed a join venture, United Launch Alliance, in 2006 to sell launch services. That move left the Air Force with two rockets from a single U.S. launch provider. That was the state of affairs when Russian geopolitical aggression, including annexing Crimea in 2014, uncorked long-suppressed concerns in Congress about U.S. dependence on the RD-180.

Beginning in 2015, as directed by Congress, the Air Force began creating a palette of technology options for weaning the U.S. off RD-180s and promoting competition in the government launch market. Early this year the service awarded a total of $242 million in contracts to Aerojet Rocketdyne, Orbital ATK, SpaceX and United Launch Alliance. The agreements require at least one third of the total cost of each prototype project be paid by other than the federal government. These Rocket Propulsion System prototype agreements are just initial steps. By eschewing foreign suppliers, by investing in partnerships with domestic industry without fully funding its development efforts and by encouraging competition from multiple launch service providers, the Air Force shows it has learned from the decades-long arc of the EELV experience.

Searching for consensus

There is a wide consensus in the U.S. that reliance on an increasingly antagonistic foreign power should end. But there is less agreement on just how to phase out the Russian engines.

According to its 2017 budget request, the Air Force plans to spend $1.2 billion over the next five years "in the development of new or upgraded domestic launch systems with domestic launch providers."

A variety of engines and one booster are in play: Aerojet Rocketdyne's AR1; Blue Origin's BE-4; the already-flying Merlin and the future Raptor from SpaceX; and Orbital ATK's Common Booster Segment solid rocket motor. Each rocket provider will design its proposed vehicle around whichever engine it selects, an engineering process never as easy as simply dropping in a new engine.

Conflicting legislation from Congress has clouded the Air Force plans. Authorization and appropriations committees have clashed over the number of future RD-180 imports needed to add to the existing stockpile to last until replacement launch services are available, with proposed limits ranging from zero to 18 new engines.

Earlier National Defense Authorization Acts also insisted money be spent only on a replacement engine. The Air Force has pushed for flexibility to address the whole launch system and would get some relief if the fiscal 2017 Authorization Act, based on versions passed by the House in May and the Senate in June, becomes law and paves the way for actual budget appropriations. Current authorization language would permit new engine imports through 2022

SpaceX's Falcon rockets were certified in 2015 by the U.S. Air Force for military launches. Falcons are contending to replace Atlas 5s powered by Russian-made RD-180 engines.

but cap the number at 18 and would allow up to 31 percent of fiscal 2017 funds made available to be spent on other portions of new launch vehicles, not just engines.

Learning from history

To fully understand how we got to this point, look back to the start of the EELV program in 1995. U.S.-produced rocket engines represented only incremental modifications to those designed in the 1960s, the exception being the space shuttle main engines. This was intentional. In 1972, the U.S. had settled on the space shuttle architecture of Solid Rocket Boosters and liquid hydrogen-fueled main engines as the way of the future. National Space Policy in 1982 then declared the shuttle as "the primary space launch system for both United States national security and civil government missions." Production of other launch systems was slated to end. Even after the Challenger accident, years of studies and several aborted programs had yielded no new U.S. engine programs or launch systems.

The EELV program was the Pentagon's response to a seminal 1994 congressionally directed study conducted after all the previous studies and false starts failed to modernize space launch. Industry's four initial competing EELV booster proposals each relied on a different solution for its first stage; either solid rocket motors, recoverable Space Shuttle Main Engines, a new hydrogen-fueled engine — the RS-68 — for the Delta 4s, or the imported RD-180 for the Atlas 5. The Air Force ultimately decided to retain two rockets, selecting the McDonnell Douglas Delta 4 and Atlas 5 families of launch vehicles.

For the Atlas 5, the RD-180 was attractive to Lockheed Martin and the Air Force because it was comparatively "off-the-shelf" and fueled with rocket-grade kerosene, a hydrocarbon, called RP-1, in a high performance, staged combustion design the U.S. lacked. In fact, RD-180 was the only hydrocarbon engine among the initial EELV proposals. Given fiscal constraints, the huge national investment in the space shuttle program, and the relatively easy access to the Russian engines, it is not surprising that the U.S. did not have a new hydrocarbon-fueled engine quickly available.

Furthermore, U.S. engineers would be able to get their hands on the former Soviet Union's long-rumored staged-combustion technology that burns an oxygen-rich propellant mixture while preventing coking, or carbon residue, in the engine machinery. Russia had mastered this unique technology that delivered a roughly 25 percent specific impulse increase over other available hydrocarbon engines.

Generating options

When the U.S. began steps to move away from RD-180s, the initial alternatives were limited. One was the Delta 4 family of vehicles, which are more expensive than Atlas 5 and consequently slated by ULA to be phased out, with the exception of the heavy variant. The other possibility was the SpaceX Falcon rockets — the Falcon 9 propelled by a cluster of nine then-relatively unproven Merlin engines, and the yet to be flown Falcon 9 Heavy. The Air Force had not yet certified Falcon rockets for military launches. After the Air Force agreed to expand the number of competitive opportunities for launch services and SpaceX dropped its lawsuit claiming it had been shut out of Air Force launch contracts, the Air Force certified the Falcon 9 in May 2015.

The limited available alternatives and promising developments in private industry efforts are the reasons the Air Force has decided to support the industry's work on a variety of new engines. Two of them, the Aerojet Rocketdyne AR1 and Blue Origin's BE-4, will combine staged combustion with hydrocarbon fuel, something never tried in a production U.S. rocket engine. Even the Apollo program's giant, powerful F-1 engines, though hydrocarbon-fueled, did not use staged combustion, nor does the Merlin.

A new hydrocarbon fuel, methane, commercially available as Liquified Natural Gas, is coming into play in the BE-4 and Raptor. While studied and tested as rocket fuel, methane has never been used in a production engine. Many of methane's properties fall between those of the RD-180's RP-1 and hydrogen. It can be stored at warmer temperatures than hydrogen, although not at ambient temperatures like RP-1. It burns more cleanly than RP-1, according to Blue Origin, but not as cleanly as hydrogen.

The Air Force hasn't given up on its 1995 vision of a commercially competitive U.S. launch industry.

"Having two or more domestic, commercially viable launch providers that also meet national security space requirements is our end goal," Lt. Gen. Samuel Greaves, the Air Force's program executive officer for space and commander of the Space and Missile Systems Center, was quoted in a January 2016 Air Force press release. The propulsion awards made earlier this year "are essential in order to solidify U.S. assured access to space, transition the EELV program away from strategic foreign reliance, and support the U.S. launch industry's commer-

Shotgun approach

The U.S. Air Force has turned to leading American rocket companies to find a solution to the country's reliance on Russian RD-180 rocket engines. Congress wants the research funds to be applied to engine development only, the implication being that a new engine could be plugged into the Atlas 5s, each of whose first stage is powered by an RD-180. The Air Force and White House prefer to spend the money more broadly on rocket technology, but with an emphasis on propulsion. The Air Force has awarded $277 million in technology contracts since November with options that the figure could grow to $1 billion

The bulk of the money has been allocated to four awardees under the Rocket Propulsion System prototype initiative that the Air Force started on orders from Congress. Each awardee must chip in its own money equal to at least a third of the total funds. These partnership arrangements are possible because of a federal acquisition mechanism called OTA, for "other transaction agreement." The funds are paying for the following work.

▸ **AEROJET ROCKETDYNE** to continue development and testing of its AR1 kerosene-fueled main engine. The AR1 is a possible RD-180 replacement on Atlas 5 and is a backup candidate as the main engine for the new Vulcan rocket proposed by United Launch Alliance, the Boeing and Lockheed Martin venture that makes the Atlas 5s. Aerojet Rocketdyne has been testing the AR1's preburner at NASA's Stennis Space Center in Mississippi.

Value: $115 million from the Air Force; $536 million if all options are exercised. Plus $57 million from the company.

▸ **UNITED LAUNCH ALLIANCE** for work on its proposed Vulcan rocket. Under current plans, the Vulcan first stage would be powered by a singl Blue Origin BE-4 engine, but Aerojet Rocketdyne's AR1 is a backup candidate. The BE-4 is unusual because it would be fueled by liquified natural gas. Blue Origin is conducting component testing on the BE-4, including preburner combustion tests, at its West Texas facility.

Value: $46 million from Air Force; $202 million if all options are exercised. Plus $40 million to be spent by ULA.

▸ **SPACEX** for its planned methane-fueled engine called Raptor. This engine was originally conceived for the company's planned human missions to Mars.

Value: $34 million from Air Force; $61 million if options are exercised. Plus at least $67 million to be spent by SpaceX.

▸ **ORBITAL ATK** to develop two different solid-rocket boosters and an extendable nozzle for Blue Origin's planned BE-3U upper stage engine. These could power a new rocket the company intends to develop to compete in the government and commercial marketplace.

Value: $47 million from Air Force; $180 million if all options are exercised. Plus $31 million to be spent by Orbital ATK.

Booster agreement

In addition to the prototype agreements, the Air Force allocated $35 million among eight companies and institutions to conduct research under its Booster Propulsion Maturation Broad Agency Announcement initiative. The awardees will explore additive manufacturing, advanced materials, non-destructive testing methods, and components such as ignition systems and thrust nozzles. The awardees are: Johns Hopkins University's Whiting School of Engineering in Baltimore, two contracts totaling $1.48 million; Tanner Research of Monrovia, California, known for microelectronics research, $902,000; component maker Moog of East Aurora, New York, $728,000; Orbital ATK of Dulles, Virginia, $3.1 million; Aerojet Rocketdyne of Sacramento, California, $6 million; Northrop Grumman Aerospace of Redondo Beach, California, two contracts for $5.4 million and $7 million each; Boeing of Chicago, $6.1 million; Arctic Slope Regional of Beltsville, Maryland, an engineering services and information technology firm, $3.7 million

Value: $34.5 million combined value.

WARREN FERSTER
fersterx@gmail.com

NASA

Russia's twin-nozzled RD-180 engine continues to propel U.S. rockets despite a two-decade effort to end reliance on imported engines.

cial viability in the global market."

A larger U.S. share of the global market would translate into to more cost competitive options for the Air Force.

Indeed, according to a July 2016 Government Accountability Office report, the Defense Department and the Air Force are analyzing the business cases of potential launch providers and "information on the global launch market to help ensure multiple domestic launch providers can remain viable to compete for future launches." History suggests this will be a challenge.

While the issue surrounding imported RD-180s appears to be coming to a resolution, the broader strategy for a replacement and future launch services is still unclear. The goal must be to avoid repeating mistakes from the last two decades: relying on overly optimistic commercial market projections and opting for near term expediency over follow through on established well-conceived long-term strategy to address engine supply risks. ★

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			
5–7 Sep†	Advanced Satellite Multimedia Systems Conference	Palma de Mallorca, Spain (Contact: www.asmsconference.org)	
7–8 Sep	2016 National Aerospace & Defense Workforce Summit	Washington, DC	
7–8 Sep†	20th Workshop of the Aeroacoustics Specialists Committee of the Council of European Aerospace Societies (CEAS): Measurement Techniques and Analysis Methods for Aircraft Noise	University of Southampton, United Kingdom (Contact: www.southampton.ac.uk/engineering/research/groups/acoustics-group/ceas-asc-workshop-2016)	
11 Sep	Space Standards and Architecture Workshop	Long Beach, CA	
11–12 Sep	Introduction to Space Systems	Long Beach, CA	
11–12 Sep	Systems Engineering Fundamentals	Long Beach, CA	
13–16 Sep	AIAA SPACE 2016 (AIAA Space and Astronautics Forum and Exposition) Featuring: – AIAA SPACE Conference – AIAA/AAS Astrodynamics Specialist Conference – AIAA Complex Aerospace Systems Exchange	Long Beach, CA	25 Feb 16
25–30 Sep†	30th Congress of the International Council of the Aeronautical Sciences (ICAS 2016)	Daejeon, South Korea (Contact: www.icas.org)	
25–30 Sep†	35th Digital Avionics Systems Conference	Sacramento, CA (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, www.dasconline.org)	
26–30 Sep†	67th International Astronautical Congress	Guadalajara, Mexico (Contact: www.iac2016.org)	
27–29 Sep†	SAE/AIAA/RAeS/AHS International Powered Lift Conference	Hartford, CT	
12–13 Oct†	12th Annual International Symposium for Personal and Commercial Spaceflight (ISPCS 2016)	Las Cruces, NM (Contact: http://ispcs.com/)	
17–20 Oct†	22nd KA and Broadband Communications Conference and the 34th AIAA International Communications Satellite Systems Conference	Cleveland, OH (Contact: Chuck Cynamon, 301.820.0002, chuck.cynamon@gmail.com)	
7–10 Nov†	International Telemetering Conference	Glendale, AZ (Contact: www.telemetry.org)	
15–16 Nov†	Drone World Expo (DWE)	San Jose, CA (http://www.droneworldexpo.com/)	
2017			
7–8 Jan	2nd Sonic Boom Prediction 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
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

†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
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
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
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)	
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		
3–4 Jun	1st AIAA Geometry and Mesh Generation Workshop		
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)	
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	23 Feb 17
25–29 Sep†	68th International Astronautical Congress	Adelaide, Australia	

AIAA Aerospace Spotlight Awards Gala

AIAA presented its highest awards at the AIAA Aerospace Spotlight Awards Gala on 15 June, at the Ronald Reagan Building and International Trade Center, in Washington, DC. Inside the building's soaring atrium, nearly 500 people gathered to celebrate our community's luminaries. And what a great evening it was – from the presentation of the newly elected Class of 2016 Fellows and Honorary Fellows, to the presentation of all of the evening's awards, the atrium ballroom resounded with enthusiastic applause as our community's best and brightest were recognized.

Below: Class of 2016 Fellows and Honorary Fellows.

Front row (L-R): Dennis Bushnell, Mark Lewis, John Tracy; second row (L-R): Jonathan How, Brian Argrow, Mary Cummings, Je-Chin Han, Russ Joyner, Marilyn Smith, Konstantinos Kontis, Ping Lu; third row (L-R): Jean-Jacques Dordain, Mark Whorton, Daniel Baker, Russell Cummings, Stephen Cook, Walter O'Brien, Ajit Roy, Kent Pugmire; fourth row (L-R): John-Paul Clarke, Robert Strain, James Gord, James Crocker, Ganesh Raman, Brian Smith. Not shown: Richard Ambrose and Kyung Choi.

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1 Alabama Lt. Governor Kay Ivey (right), 2016 recipient of the AIAA Public Service Award, with AIAA President James Albaugh (left).

2 2016 recipient of the AIAA Foundation Award for Excellence and John and Adrienne Mars Director at the National Air and Space Museum, Smithsonian Institution, John "Jack" Dailey (right), being congratulated by AIAA Foundation Chairman Michael Griffin (left).

3 AIAA President James Albaugh (left) presenting 2016–2018 Incoming AIAA President James Maser (right) with his presidential gavel.

4 AIAA President James Albaugh (left) with 2016 AIAA Reed Aeronautics Award recipient, Earl Dowell (right) of Duke University.

5 Wanda Austin, president and CEO of The Aerospace Corporation, 2016 recipient of the AIAA Goddard Astronautics Award (right), with AIAA President James Albaugh (left).

6 AIAA President James Albaugh (left) with Tom Crouch (right), 2016 recipient of the AIAA Distinguished Service Award and Senior Curator, Aeronautics Department, National Air and Space Museum, Smithsonian Institution.

7 Daniel Guggenheim Medal recipient Antony Jameson (2nd from right) of Stanford University with Rakesh Kapania of Virginia Polytechnic Institute and State University representing ASME (right), AIAA President James Albaugh (left), and Bruce Mahone of SAE International (2nd from left).

News

Call for Board of Trustees and Council of Directors Nominations

By Bill Seymore, *AIAA Corporate Secretary/Treasurer*

The transition to the new AIAA governance model will take place starting in May 2017. Details of the New Governance Transition Plan from the existing Board of Directors to the new Board of Trustees and Council of Directors can be found on the AIAA Governance Project webpage (http://www.aiaa.org/Governance/). Until that time, the existing nominations process and schedule will remain in effect.

The 2016–2017 AIAA Nominating Committee, chaired by AIAA Immediate Past President Jim Albaugh, will meet in mid-September 2016 to review nominees and select candidates for the Institute's Board of Trustees and Council of Directors. The following positions will be up for election in 2017:

Board of Trustees

- President-Elect

Council of Directors

- Director–Technical, Aircraft and Atmospheric Systems Group
- Director–Technical, Engineering and Technology Management Group
- Director–Technical, Space and Missiles Group
- Director–Region I
- Director–Region II

AIAA members may put into consideration themselves or other members qualified for the position by submitting a nomination through the AIAA website no later than 1800 hours ET, 9 September 2016. Visit www.aiaa.org/aiaaelection-nomination, log in, and click "continue" to access the nomination system.

AIAA DEMAND for UNMANNED puts focus on drone technology and research

By David Hodes

Some of the most influential names in the drone and aviation industries participated in the AIAA inaugural DEMAND for UNMANNED symposium, 15–16 June, which was held in conjunction with the AIAA Aviation and Aeronautics Forum and Exposition 2016 (AIAA AVIATION 2016) in Washington, DC. More than 250 engineers, developers, and pilots attended the symposium to discuss issues ranging from regulation to autonomy in a series of panel sessions and keynote addresses.

AIAA brought the UAS and aviation industries into the same space for a deeper dive into overlapping goals and issues with the intention to help the emerging UAS industry develop wisely. Stakeholders from academia, government, and industry spoke about the importance of UAS in aerospace development and the contributions UAS developers have made, and continue to make, in autonomy and robotics. NASA representatives also unveiled a roadmap for the continued evolution of the industry in a broad range of applications.

Sandy Magnus, executive director of AIAA, said attendees liked the fact that the UAS symposium was included within an aviation forum because they could more easily do a "cross talk" about both industries. "That's what we were trying to get," she said. "A lot of the people who are using drones are at both the entry level and very high end. But there are a lot of practical applications that could use some mindful technology development."

Among the speakers at the symposium were aviation leaders and UAS experts such as John S. Langford, chairman and chief executive officer of Aurora Flight Sciences Corporation; Dallas Brooks, director of Raspet Flight Research Laboratory at Mississippi State University; and Parimal H. Kopardekar, manager of the Safe Autonomous System Operations Project and principal investigator for Unmanned Aerial Systems Traffic Management at NASA Ames Research Center.

One of the bigger issues discussed was how to integrate, manage and control unmanned vehicles in the National Airspace System (NAS). In the session "UAS Traffic Management System," Craig Marcinkowski, director of strategy and business development for Gryphon Sensors, said there needs to be a rating system for drones that indicates not only what they can and cannot do in the airspace, but also how the UAS interact with other.

Kopardekar said that what is needed is an understanding of what it means to go beyond line of sight and stay clear of each other. "This may be something as simple as leveraging technology we already have," he said.

Jonathan Evans, CEO of Skyward IO, argued that standards are needed to organize management of the NAS. "UAS Traffic Management is the beginning of that in an organic way," he said. "What we are doing with traffic management is writing the first protocols. That is a profound piece of this transformation."

Other sessions dealt with different discussions on topics such as trust in the operational elements of unmanned aircraft, control of them in the U.S. airspace and more collaboration from manufacturers and users to accelerate development.

Assured trust in a system means the right logic is created for the task, according to Mike Francis, chief, advanced programs and senior fellow at United Technologies Research Center. He noted that any system in place needs to be able to learn. "That's the part of autonomy that is going to grow," Francis said. "We are at the start of a revolution. We have the whole future in front of us, and it's all driven by computing power."

One of the key presentations at DEMAND for UNMANNED focused on NASA's roadmap for UAS development.

The strategic plan is meant to not only advise industry, but also increase the collaboration between stakeholders on research challenges and advancement strategies.

"We want to push the envelope of autonomy," said Sebastian Scherer, systems scientist for The Robotics Institute at Carnegie Mellon University. "But that is hard to do."Both he and fellow presenter Mark Ballin, technology integration manager for the Airspace Operations and Safety Program at NASA Langley Research Center, said everyone in the aviation community needs to be involved. "This roadmap is in progress now," Ballin said. "So we really need input from you and the aviation community to make sure that we are all going down the right path together."

Presenters also discussed the FAA's role in developing regulations.

Mary Louise "Missy" Cummings, associate professor at the Department of Mechanical Engineering and Materials Science and director of the Humans and Autonomy Laboratory at Duke University, said the FAA is "not even playing in the ballfield about how to certify autonomous systems" though the process for certifying commercial aircraft already exists.

Other presenters acknowledged that the FAA is behind in writing rules and regulations but said it is moving as fast as it can. There was a consensus that decision making on this emerging industry is a daunting challenge. [Editor's Note: The FAA finalized the first operational rules for routine commercial use of UAS and made them public on 21 June 2016, shortly after the symposium.]

John-Paul Clarke, professor from the Daniel Guggenheim School of Aerospace Engineering and director of the Air Transportation Laboratory at the Georgia Institute of Technology, said one of the technical barriers to implementing autonomy is human-machine integration, in which decision making has to be made on adaptive, nondeterministic systems. Without a human involved, decision making where there is uncertainty becomes more difficult, he explained. "How do we verify the judgment of a UAS system?" Clarke asked. "The certification regime relies on the judgment of people and how a process is followed."

More FAA work was presented in a session outlining the effort of the Alliance for System Safety of UAS through Research Excellence, or ASSURE, the FAA's Center of Excellence for UAS research. "ASSURE exists to turn UAS research into FAA rules," said retired U.S. Air Force Maj. Gen. James Poss, ASSURE's executive director, adding that Congress is expected to give the center $10 million in funding in 2017 on top of the $10 million it has received.

Hitting on the theme of the UAS symposium within the aviation conference was Langford, the Aurora CEO. He said that today's aviation designers need to pay attention to what is coming from the UAS industry. "Traditional aviation engineering was about making aircraft that were lighter and faster" but priorities have shifted, he said. "It's about making them smarter." The version of the future in which unmanned vehicles are transporting humans — as seen in "The Jetsons" — is "not as close as you may think," he said. "But what we have seen in the last five years of consumer drones will expand into other areas of aviation."

In one of the last presentations of the symposium, Andy Lacher, UAS integration research strategist for The MITRE Corporation, demonstrated a drone from camera manufacturer Lily that is programmed with flying boundaries set by the user. The drone flies above and tracks the user automatically—but there's more. "You don't fly it as it films you," Lacher explained. "This aircraft is making complex decisions. It's picking its flight path, its speed and its direction. When the battery begins to die, it lands on its own. It's like a selfie stick that flies."

Lacher also talked about autonomous cars and some of the lessons learned that could apply to the UAS industry. The autonomous Google car was confronted with a broom-wielding woman, in a wheelchair, herding a duck in the middle of a road. "It's these non-normative conditions that need to be thought about for any autonomous vehicle," he said.

Aerospace experts also added their thoughts to the significance of UAS development. Doug Cooke, an aerospace consultant and former NASA engineer who worked on space shuttles and the International Space Station, said innovative people like those working in the UAS industry will consistently come up with new things and new applications. "When you get the capabilities, the applications present themselves," he said.

What we are trying to do is bring UAS users and the people who have missions together with the technology community so they can start to talk about creating the drones that are targeted…

Retired U.S. Air Force Maj. Gen. Joe Engle, who test piloted the X-15 and was a space shuttle commander, said the UAS industry has helped drive advances in electronics, communication and telemetry. "The UAS industry is building a future right now," Engle said.

AIAA's Magnus said they were pleased with the symposium. "What we are trying to do is bring UAS users and the people who have missions together with the technology community so they can start to talk about creating the drones that are targeted, as opposed to trying to use platforms that exist and sort of rig them," she said. "How can AIAA have a role in helping to define and develop the technology and applications that are more sophisticated and more widespread? DEMAND for UNMANNED was an attempt to start those kinds of conversations."

Full coverage of DEMAND for UNMANNED and AIAA AVIATION 2016 can be found at www.aiaa-aviation.org/Headlines2016/.

DEMAND for UNMANNED Student Competition

As part of the DEMAND for UNMANNED symposium held in conjunction with AIAA AVIATION 2016, the AIAA K–12 STEM Committee, led by Tucker Hamilton, presented a concept for a new student competition. Christopher Reynolds, chair of the Aerospace Robotics Competition Working Group of the K–12 STEM Committee, led a group of University of Michigan students in developing an idea for high school students to build and program UAVs. The idea was to design a competition that would stimulate students' imaginations and excitement in the field of aviation.

The University of Michigan students designed a prototype UAV and sent the bill of materials to seniors Brandon Nelson, Keenan Brown and Kyrie Nesmith of McKinley Technology High School in Washington, DC. With the help of their teacher, Kenneth Lesley, and mentors from the University of Maryland and the University of Michigan, the McKinley students used the instructions and materials provided to build their own vehicle. They also used an off-the-shelf quadcopter to expand their programming skills to fly particular patterns and develop an understanding of autonomous flight.

After just a few weeks of working with the materials and quadcopter, the students were very enthusiastic about aviation and unmanned vehicles. The K–12 STEM Committee will continue to work on this concept in hopes of expanding the idea to include more high schools and incorporate new aspects, such as fully autonomous flight.

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

Special Issue on "The Kalman Filter and its Aerospace Applications"

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. For his pioneering work he was given many prestigious awards.

In honor of Rudolf Kálmán, 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 about this special issue 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: Submissions are due by **1 December 2016** with prior approval of the Guest Editor
Contact Email: John L. Crassidis, Guest Editor (johnc@buffalo.edu) and Ping Lu, Editor-in-Chief of JGCD (plu@mail.sdsu.edu).

AIAA Releases its 2015–2016 Annual Report and Foundation Impact Report

AIAA has released and posted its 2015–2016 Annual Report, "Heading for New Horizons" (https://www.aiaa.org/AnnualReports/). Covering June 2015 through May 2016, it includes the President's Report, Executive Director's Report, and President-Elect's Report. The document also contains the latest member statistics, and information from across the Institute. As always, a detailed account of the Institute's finances for fiscal year 2015 rounds out the 31-page report.

This year the AIAA Foundation has published its first annual AIAA Foundation Impact Report, which is available at http://www.aiaafoundation.org/ImpactReport/. The independent report details the impact of the Foundation's engagement in STEM K–12, College and University, and Recognition programs. Also included are a list of generous corporate and individual donors, and the Foundation's fiscal year 2015 financial results. Details of the Foundation's programs and activities from prior years can be found in previous editions of the AIAA Annual Report available at www.aiaa.org/AnnualReports.

Notice for AIAA Journal Subscribers

AIAA Journal (*AIAAJ*), covering pioneering theoretical developments and experimental results across a far-reaching range of aerospace topics, will be moving to an online-only format in 2017. *AIAAJ* was launched along with AIAA in 1963 and is once again leading the way. Print customers transitioning to the online format will be able to maximize the user experience with research tools and access to the most up-to-date versions of articles in Aerospace Research Central, http://arc.aiaa.org.

If you have questions about online access and features, go to http://arc.aiaa.org/page/aiaajonlineonly.

Rocky Mountain Section Annual Awards Banquet

On 22 April, the AIAA Rocky Mountain Section (RMS) held its Annual Awards Banquet to recognize its Young Engineer, Engineer, Educator (College), and Educator (K–12) of the Year recipients. Additionally, the RMS used this venue to thank the outgoing 2015–2016 Council members and officially announce the incoming 2016–2017 Council members.

The banquet, held at The Wildlife Experience, included an opportunity to visit the

Globeology exhibit, which showcases seven biomes of Earth. Daniel Adamo, an astrodynamics consultant, gave the featured presentation on "Questioning the Surface of Mars as the 21st Century's Ultimate Pioneering Destination in Space," which discussed limitations on Mars colonization. The event sold out with 80 guests in attendance.

More information about the 2016 Annual Awards Banquet can be found at the RMS website: www.aiaa-rm.org.

The 2016 awards winners are (shown left to right):

1 **Young Engineer of the Year**
Capt Brian Kester, USAF Academy

2 **Engineer of the Year**
Dr. Lisa Hardaway, Ball Aerospace and Technologies

3 **Educator of the Year (College)**
Capt Grant Thomas, USAF Academy

4 **Educator of the Year (K–12)**
Karin Pacot, Ellicott Elementary School (Kindergarten)

Greater Huntsville Section Attends Armed Forces Celebration and Redstone Arsenal Dinner

By Ken Philippart, *AIAA Greater Huntsville Section*

The AIAA Greater Huntsville Section attended the 2016 Armed Forces Celebration and 75th Anniversary of Redstone Arsenal Dinner on 30 June. The dinner capped a weeklong celebration of the U.S. armed forces and commemorated the diamond anniversary of Redstone Arsenal and its contributions to the Huntsville community. It was the first time the Greater Huntsville Section participated in the festivities and signaled the section's renewed outreach to and recognition of its military and Department of Defense constituencies.

Over 700 people attended the Armed Force Celebration and anniversary dinner, and AIAA was well represented. Section members and military veterans John Lassiter and Ken Philippart hatched a plan to fill an AIAA table, and 10 AIAA members and guests registered as part of the section's contingent. Other section members sat at their employers' tables, helping to wave the AIAA flag there as well.

Photos from top to bottom:

1 (Left to Right): Vice Chair Naveen Vetcha, John Lassiter, Ken and Lisa Philippart. Chris & Sheree Gay, Allison Cash, Anne & Rick Tuggle, Jan & Ron Miller. *(Image courtesy of Jeff White)*

2 General Dennis L. Via gives the keynote address (Image courtesy of Lisa Philippart)

3 The U.S. Army Old Guard Fife & Drum Corps entertained the crowd. (Image courtesy of Lisa Philippart)

The keynote speaker for the evening was General Dennis L. Via, Commanding General of the U.S. Army Materiel Command. General Via outlined a whirlwind history of Redstone Arsenal from its World War II beginnings as an ordnance plant to the birth of the U.S. Army ballistic missile program under Dr. Wernher von Braun and subsequent creation of the NASA Marshall Space Flight Center to the leading edge, full-spectrum warfighter support that Redstone Arsenal provides to the military services today.

AIAA members and guests who attended the event included Todd May, director of Marshall Space Flight Center; section Vice Chair Dr. Naveen Vetcha, Lt. Col. (retired) John Lassiter, Lt. Col. (retired) Ken and Lisa Philippart, Sheree and Chris Gay, Dr. Ron and Jan Miller, Major Rick and Anne Tuggle, Allison Cash, and Colonel (retired) Buzz Toth.

Besides enjoying the dinner, AIAA members did some serious networking, developing contacts for future tours of Department of Defense facilities and ideas for collaborating with other organizations on Redstone Arsenal. The Greater Huntsville Section salutes our military and Department of Defense members and all those who support them.

Inspiring the Next Generation of Aerospace Engineers Through Science Fairs

By Elishka Jepson, *AIAA Region VI Deputy Director, K–12 STEM*

TOP: Ashley Beard receives an award from Cape Canaveral Section Chair David Fleming for her project, "Investigating the Effects of Microgravity on Growing Copper Sulfate Crystals."

BOTTOM: Students participate in the Orange County Section's Rocket Science Fair at SPARC.

The AIAA Section Engagement and Best Practices STEM Standing Committee has pondered the question: what STEM activities have many AIAA sections had success with? After studying section submissions for the Harry Staubs STEM K–12 award, the committee noticed one activity many successful sections participated in—local science fairs.

How can your section start participating in science fairs, or take your science fair interactions to the next level? Read on!

Start Small: If your section is looking for ways to participate in science fairs, a great place to start is within your membership; members with children can provide an avenue to building a partnership with local schools. For example, the Tucson Section recently gave several science project awards to a local elementary school where one of the leadership council member's children attends. This begins a relationship with this school that can be built upon in future years, or expanded to other schools in the district.

Sponsor Awards: Contact the organizers of your local science fairs and see if they have any award sponsorships available. The Northern Ohio Section sponsored awards for projects with an aerospace focus at the Annual Northeastern Ohio Science and Engineering Fair and the Northwest Ohio District 2 Science Day, both of which are regional science fairs for middle and high school students. The Cape Canaveral Section sponsors an award for a senior high school student who demonstrates sound judgment on the application of the scientific method and interpretation of data with regard to aeronautics or space sciences subject areas. Awards don't need to be only monetary — the National Capital Section sponsors a three-day STEM engagement activity at NASA Goddard Space Flight Center (GSFC) for science fair winners, which includes a visit to GSFC's many laboratories, a trip to Wallops Flight Facility, and interaction with NASA leaders. Partnering with local universities and aerospace companies for tours or STEM activities is another great option as an award prize.

Provide Judges: Coordinate with your local science fairs to recruit judges from your section members. Science fair organizers are usually more than happy to have engineers approach them about volunteering! The San Diego Section participates in judging the greater San Diego Science and Engineering Fair, where volunteers interact with students regarding their science projects and discuss their interests in the aerospace field. The section selects one middle school student and one high school student from the event and invites the students and their families to showcase their science fair projects and set up a booth at their annual banquet. The Cape Canaveral Section and Orange County Section also provide judges for their local fairs, as well as many other sections not listed here.

Host Your Own Science Fair or Competition: If there is not already an established science fair in your area, and if you have a sufficient volunteer base, your section can start your own science fair, or add an aerospace focus to an existing event. The Orange County Section sponsors a rocket science fair at the end of the Student Payload and Rocketry Competition (SPARC). If you are looking for a project for a science competition, the AIAA Educator Academy program provides three different modules that can be used. In fact, the Mars Rover module was created by the Houston Section, which now holds an annual Mars Rover competition in conjunction with the University of Houston.

Inspiring Ideas for Moon and Mars Bases from Middle School Students in AIAA Space Systems Technical Committee Essay Contest

In this fifth year of the AIAA Space Systems Technical Committee's (SSTC) middle school essay contest, the TC continues to improve its commitment to directly inspire students and local sections. Each year, additional local sections start parallel contests to feed into selection of a national winner awarded by the SSTC.

In 2016, seven sections submitted official entries to the contest, from which 7th and 8th grade students in Long Island and Hampton Roads were selected as winners to receive $100, plus $250 for their classroom toward STEM materials or activities. The two student winners also receive a one-year membership with AIAA. The 2016 topic was "Discuss how either a moon base or a Mars base could help us learn about the Earth and space."

The winners are 7th grader Nikhil Keer and teacher Leslie Maynard at Wisdom Lane Middle School, in Levittown, NY, and 8th grader Jennifer Lin and teacher Mike Webster at York Middle School, in Yorktown, VA. Ms. Maynard will use the award money to purchase introductory telescopes for her school's Earth and Space Club that will be available for all students in their library.

The 2016 winning essays can be found on the Aerospace America website.

The topic for 2017 is "Choose one of the aspects of the Juno spacecraft listed on the webpage below. Describe how it works and why it helps discovery about Jupiter." (**https://www.missionjuno.swri.edu/spacecraft/juno-spacecraft**)

If your section is interested in participating in the 2017 contest, please contact Anthony Shao (ant.shao@gmail.com).

TOP: AIAA Long Island Section awards ceremony. From left to right: Michael Vota (2nd place), Long Island 1st-place winner Nikhil Keer and national 7th-grade winner, and Siena Beck (3rd place).

BOTTOM: AIAA Hampton Roads Section awards ceremony. From left to right: Jack Hutchinson (4th place), Sam Doty (3rd place), Vishwa Malaisamy (2nd place), Hampton Roads 1st-place winner and national 8th-grade winner Jennifer Lin, and Karen Berger (AIAA Hampton Roads Essay Contest Chair).

Membership Anniversaries

AIAA would like to acknowledge the following members on their continuing membership with the organization.

50-Year Anniversaries

Edward Gootzait, Delaware
Bobby L Berrier, Hampton Roads
William L Hallauer, Jr, Hampton Roads
Jerry N Hefner, Hampton Roads
Robert M Jones, Hampton Roads
Jaroslaw Sobieski, Hampton Roads
Charles P Vick, Hampton Roads
Steven F Yaros, Hampton Roads
Theodore Balderes, Long Island
George E Salser, Long Island
Charles R Larsen, Mid-Atlantic
Paul G Kaminski, National Capital
Norman C Weingarten, Niagara Frontier
Peter M Brodie, Northern New Jersey
Howard A Bueschel, Northern New Jersey
Donald A Massett, Atlanta
Ben T Zinn, Atlanta
Richard E Leithiser, Cape Canaveral
J. C Sawyer, Jr, Cape Canaveral
Rolin F Barrett, Sr., Carolina
William L Norris, Carolina
Jack L Heckel, Central Florida
Gordon R Woodcock, Greater Huntsville
Ms. Mireille M Gerard, Palm Beach
Harold J Rosenstein, Palm Beach
Awatef A Hamed, Dayton/Cincinnati
A. W Adam, Illinois
Robert L Glick, Indiana
Leland A Carlson, Houston
John E French, Jr, Houston
John P Shea, Houston
Otto M Friedrich, Southwest Texas
David G Hull, Southwest Texas
Robert D Culp, Rocky Mountain
Henry R Sebesta, Rocky Mountain
Peter B Teets, Rocky Mountain
James H Bennett, Jr, St. Louis
Hoyt W Wallace, St. Louis
Wilhelm Behrens, Los Angeles-Las Vegas
Robert Gilroy, Los Angeles-Las Vegas
Kenneth P Horn, Los Angeles-Las Vegas
Robert E King, Los Angeles-Las Vegas
Leslie M Lackman, Los Angeles-Las Vegas
David R Scott, Los Angeles-Las Vegas
Frank O Chandler, Orange County
John C Grafton, Orange County
William G Beecroft, Pacific Northwest
Richard H Haase, Pacific Northwest
Bruce G Schnitzler, Pacific Northwest
Ronald L Van Mierlo, Phoenix
Kyle T Alfriend, Point Lobos
Robert E Ball, Point Lobos
Edsel R Glasgow, San Fernando Pacific
Gene A Hanover, San Fernando Pacific
Robert H Eustis, San Francisco
L. Skip Fletcher, San Francisco
Howard E Goldstein, San Francisco
Robert K Heffley, San Francisco
C. T Snyder, San Francisco
Toshio Fujita, San Gabriel Valley
Rune Evert, Vandenberg
Truman M Stickney, Vandenberg
Didier G Compard, International
Eveline Gottzein, International
Koryo Miura, International

60-Year Anniversaries

Anthony Fasano, Connecticut
Robert L O'Brien, Connecticut
Harris D Weingold, Connecticut
Henry E Hudgins, Greater Philadelphia
Charles S Stokes, III, Greater Philadelphia
Bert Zauderer, Greater Philadelphia
Roy V Harris, Hampton Roads
Gerald D Walberg, Hampton Roads
Clifton J Callahan, Long Island
John Schwaninger, Long Island
Herbert Watman, Long Island
Everett Jones, Mid-Atlantic
Michael A Calabrese, National Capital
John E Draim, National Capital
Richard Hartke, National Capital
William C Ragsdale, National Capital
George W Sutton, National Capital
Frank H Durgin, New England
Robert Greif, New England
Gerald A Ouellette, New England
Albert R George, Niagara Frontier
Eugene D Krumm, Niagara Frontier
D. E Ordway, Niagara Frontier
Damel D Brunda, Northern New Jersey
George J Simitses, Atlanta
William W Macdonald, Cape Canaveral
William Cutler, Carolina
Hassan A Hassan, Carolina
Thomas K Schminke, Central Florida
Jack L Sanders, Greater Huntsville
Spiridon N Suciu, Palm Beach
Eino K Latvala, Tennessee
Robert E Melnik, Tennessee
Herbert J Hickey, Dayton/Cincinnati
Joseph P Martino, Dayton/Cincinnati
Charles F Suchomel, Dayton/Cincinnati
Thomas J Mueller, Indiana
Michael A Reynolds, Michigan
Leonard K Tower, Northern Ohio
Samuel J Smyth, Albuquerque
Prof Alan Powell, Houston
William H Simmons, Houston
William D Best, North Texas
Richard G Bradley, North Texas
Louis D Cass, North Texas
Kenneth K Warlick, Oklahoma
Julius H Braun, Southwest Texas
Humboldt C Mandell, Jr Southwest Texas
Austin J Bailey, Iowa
James D Iversen, Iowa
H Harvey Album, Rocky Mountain
Ralph A Herzmark, St. Louis
Milton H Hieken, St. Louis
Bertha M Ryan, China Lake
Thomas R Byar, Los Angeles-Las Vegas
Milton H Cohen, Los Angeles-Las Vegas
Charles P Hoult, Los Angeles-Las Vegas
Paul F Massier, Los Angeles-Las Vegas
Michael Moroso, Los Angeles-Las Vegas
Wayne L Pierson, Los Angeles-Las Vegas
Simon Ramo, Los Angeles-Las Vegas
Walter W Watson, Los Angeles-Las Vegas
Ralph M Eden, Orange County
Clifford Y Kam, Orange County
Ronald L Richmond, Orange County
Robert M Wood, Orange County
Donald J Beck, Pacific Northwest
George L Kosboth, Pacific Northwest
Edward T O'Neill, Pacific Northwest
Roy B Phillips, Pacific Northwest
William L Ullom, Pacific Northwest
Anthony Pietsch, Phoenix
Allen E Fuhs, Point Lobos
William G Haymes, Sacramento
Stanford S Penner, San Diego
Donald A Wallace, San Diego
George J Friedman, San Fernando Pacific
X Stewart E Bowen, San Francisco
Alan C Brown, San Francisco
Charles J Cook, San Francisco
Alfred Kuhn, San Francisco
John S Mackay, San Francisco
Anthony M Smith, San Francisco
Homer F Harper, San Gabriel Valley
Richard H MacNeal, San Gabriel Valley

70-Year Anniversaries

William D Deveikis, Hampton Roads
Jung G Chung, Long Island
Donald W Ellison, National Capital
Norman F Stanley, New England
Henry F WeisenburgerNew England
Abe Bernstein, Northern New Jersey
Bayard T McWilliams, Northern New Jersey
Robin B Gray, Atlanta
Claude V Williams, Atlanta
Joseph W Coddou, Southwest Texas
Virgil A Sandborn, Rocky Mountain
Stanley L Gendler, Los Angeles-Las Vegas
D. J Scrooc, Los Angeles-Las Vegas
Charles J Daros, Orange County
James W Craft, San Diego
Howard H Dixon, San Diego
Clarence B Cohen, San Fernando Pacific
James E Broadwell, San Francisco
George E Cooper, San Francisco
J. C Floyd, International

25- and 40-Year Anniversaries appeared in the July–August AIAA Bulletin.

Obituaries

AIAA Fellow Steinberg Died in January

Morris A. Steinberg, an AIAA Fellow who joined in 1959, died on 6 January. He was 95 years old. Dr. Steinberg earned a B.S in Science from MIT in 1942. He then served in the U.S. army during World War II as a Captain in Ordinance. He was awarded his Doctor of Science in Metallurgy from MIT in 1948, and began work as chief metallurgist for Horizons Corporation in Cleveland, OH. In 1958, Morris left Horizons to organize and manage the Material Science Laboratory of the Lockheed Missiles and Space Company in Palo Alto. In 1966 he became director of Technology Applications at the Lockheed headquarters in Burbank, CA, and worked there until retirement age in December 1985. At the time of his retirement, he held the position of vice president of Science.

Dr. Steinberg had numerous patents in the field of metallurgy and his lab was responsible for the tiles on the Space Shuttle. His achievements in the field of aeronautics and metallurgy were recognized when he was inducted into the National Academy of Engineering in 1977. He was also an adjunct professor in the Material Science and Engineering Department at the University of California, Los Angeles. A fellow of ASM, AIAA, AIC and the Institute for the Advancement of Engineering, he served on numerous boards and committees for the Department of Defense, NASA, the National Research Council and Department of Commerce.

AIAA Honorary Fellow Ramo Died in June

Simon Ramo, co-founder of aerospace company TRW, died on 27 June. He was 103. Mr. Ramo earned a doctorate in electrical engineering and physics from the California Institute of Technology at age 23. In his early career, he worked for General Electric Co., where he helped develop the electron microscope.

After World War II, Ramo moved to Hughes Aircraft Co. to begin a division devoted to military electronics. In the 1950s Ramo and Dean Wooldridge founded the Ramo-Wooldridge Corp., which became TRW in 1958. TRW was asked to work on the development of the intercontinental ballistic missile (ICBM) program for the United States, and the company worked on the development of other military weapons as well. Before it was acquired by Northrop Grumman Corp. in 2002, TRW had grown to about 100,000 workers.

In 2013, at age 100, Ramo received a patent for a computer-based learning invention. Over his lifetime, he wrote or co-wrote 62 books on different subjects including a textbook on electro-magnetic fields. He was also an advocate for robotic space exploration.

In 1984, Ramo was awarded the Durand Lectureship for Public Service by AIAA.

AIAA Senior Member Osborn Died in July

Russell F. Osborn Jr., 81, died on 3 July 2016. Mr. Osborn was an aeronautical engineer and received his bachelor of science degree at the University of Cincinnati. He was employed at the Air Force Research Laboratory at Wright-Patterson Air Force Base for 35 years and FlexSys Inc. for 10 years. He continued to do research and consulting while at Heartland of Bellefontaine.

AIAA Fellow Fleeter Died in July

Dr. Sanford Fleeter, 72, died on 7 July 2016. Dr. Fleeter completed all of his degrees (B.S., M.S. and Ph.D.) in mechanical engineering at Case Western Reserve University. He was a research engineer at Detroit Diesel Allison (Allison Gas Turbine), before being promoted to principal engineer – aeroelasticity, supervisor – aerodynamic research and finally section chief – cascades and flow systems research.

In 1978, Dr. Fleeter joined Purdue University as an associate professor of mechanical engineering. He moved through the ranks and was finally appointed as the McAllister Distinguished Professor of Mechanical Engineering in 1996. His contributions included conducting research and providing leadership in research in the important areas of turbomachines, mentoring graduate students as well as teaching graduate and undergraduate courses in turbomachines, propulsion, aeromechanics and fluid mechanics and instrumentation. He served in many administrative and leadership roles, including as the director and principal investigator of the Army University Research Initiative on Rotorcraft Engine Unsteady Aerodynamics, director of Purdue University Center for Bladed Disc Unsteady Aerodynamics Research and Technology, co-director of GUIde Consortium on Forced Response of Bladed Discs and director of the Purdue Thermal Sciences and Propulsion Center.

Dr. Fleeter was a fellow of the American Society of Mechanical Engineers and AIAA. He authored more than 350 technical publications and served as the major professor for nearly 85 masters and Ph.D. thesis graduates. He was an Associate Editor for the *AIAA Journal* from 1994 until 1997.

AIAA Senior Member Macauley Died in July

Molly Macauley, an economist specializing in satellites and the space program, died on 8 July. She was 59. Macauley was a member of the space policy community for decades and renowned for her expertise on the economics of satellites, especially in the Earth observation arena. Her professional portfolio included the use of economic incentives in environmental regulation, climate and Earth science, and recycling and solid waste management. She testified before Congress many times and was the author of more than 80 journal articles, books, and book chapters.

She was vice president for Research and a senior fellow at Resources for the Future, a Washington-based think tank that focuses on the economics of natural resources. She was a past member of the Space Studies Board and of the Aeronautics and Space Engineering Board of the National Academies of Sciences, Engineering and Medicine and served on many of its study committees. She was also a member of the steering committee for the ongoing Decadal Survey for Earth Science and Applications from Space at the time of her death.

Macauley had been a member of AIAA's Public Policy Committee for several years. She was also a Women in Aerospace board member.

Technical Committee Nominations

Membership nominations are now open for AIAA Technical Committees (TC) for 2017/2018. Our TCs have between 30 and 35 members each. Nearly one-third of the members rotate off the committees each year, leaving six to ten openings per TC.

The TC chairs and the Technical Activities Committee (TAC) work diligently to maintain a reasonable balance in 1) appropriate representation to the field from industry, research, education, and government; 2) the specialties covered in the specific TC scopes; and 3) geographical distribution relative to the area's technical activity. TAC encourages the nomination of young professionals, and has instituted a TC associate member category (see associate membership guidelines). Associate members, with identified restrictions, are included on TCs in addition to the 35 regular member limit.

If you currently serve on a TC, do not nominate yourself. You will automatically be considered for the 2017/2018 TC year.

Enclosed are instructions for nominations. Nominations are submitted online. The TC nomination form can be found on the AIAA website at **www.aiaa.org**, under My AIAA, Nominations and Voting, Technical Committee Online Nomination. We look forward to receiving your nominations. If you have any questions, please call Betty Guillie at 703.264.7573.

Nominations are due by **1 November 2016**.

Current AIAA Technical Committees

Adaptive Structures
Aeroacoustics
Aerodynamic Decelerator Systems
Aerodynamic Measurement Technology
Aerospace Power Systems
Air Transportation Systems
Aircraft Design
Aircraft Operations
Applied Aerodynamics
Astrodynamics
Atmospheric and Space Environments
Atmospheric Flight Mechanics
Balloon Systems
Communications Systems
Computer Systems
Design Engineering
Digital Avionics
Economics
Electric Propulsion
Energetic Components and Systems
Flight Testing
Fluid Dynamics
Gas Turbine Engines
General Aviation
Ground Testing
Guidance, Navigation and Control
High Speed Air Breathing Propulsion
History
Hybrid Rockets
Information and Command and Control Systems
Inlets, Nozzles, and Propulsion Systems Integration
Intelligent Systems
Legal Aspects of Aeronautics and Astonautics
Life Sciences and Systems
Lighter-Than-Air Systems
Liquid Propulsion
Management
Materials
Meshing, Visualization and Computational Environments
Microgravity and Space Processes
Missile Systems
Modeling and Simulation
Multidisciplinary Design Optimization
Non-Deterministic Approaches
Nuclear and Future Flight Propulsion
Plasmadynamics and Lasers
Product Support
Propellants and Combustion
Sensor Systems and Information Fusion
Small Satellite
Society and Aerospace Technology
Software
Solid Rockets
Space Architecture
Space Automation and Robotics
Space Colonization
Space Logistics
Space Operations and Support
Space Resources
Space Systems
Space Tethers
Space Transportation
Spacecraft Structures
Structural Dynamics
Structures
Survivability
Systems Engineering
Terrestrial Energy Systems
Thermophysics
V/STOL Aircraft Systems
Weapon System Effectiveness

Instructions for Completing Technical Committee Nomination Forms

1. Nominations are submitted online via www.aiaa.org, My AIAA, Nominations and Voting, Technical Committee Online Nomination. Nominees who are not selected for committee membership for 2017 will automatically be considered for membership in 2018. As the nomination forms are held for an additional year, it is not necessary to resubmit a form for someone not selected for the 2016/2017 term. You may send updated information to be attached to an existing nomination form.

2. You do not have to be nominated by someone else; you may submit an application for yourself.

3. A resume or biographical data can be uploaded with the online nomination form.

4. Membership is usually restricted to one technical committee (TC) at a time. Please list the TCs in order of preference if applying to two TCs. If accepted to the 1st priority, the nominee will be added to that TC. All information should be detailed and complete.

5. The Technical Activities Committee (TAC) strongly suggests that special consideration be given to members 34 years of age and under or who obtained their professional degree less than 10 years ago. See attached Technical Committee Associate Membership Guidelines.

6. All TC members must join AIAA (if they are not already members) within 45 days of their appointment to a technical committee.

7. TC membership is generally for one year with two additional years possible, but contingent upon committee participation, ongoing projects, and AIAA membership. It is not necessary to send a new nomination form for someone who is already on a committee. All committee members are automatically considered for a second and third year of membership.

8. Deadline for receipt of nominations is **1 November 2016**. Nominations received after this date will be held for consideration until the next year.

Technical Committee Associate Membership Guidelines

1. Associate membership is restricted to those who have not yet reached their 35th birthday, or who obtained their professional degrees less than 10 years ago.

2. Associate membership is a one-year term renewable to three years.

3. Associate membership is restricted to current AIAA members.

4. Selection to associate membership is based on technical merit. The associate members should show promise within the field of the technical committee.

5. Associate members may attend TC or subcommittee meetings and will assist in carrying out committee work.

6. At the discretion of the TC, associate members may be assigned a volunteer full member as a counselor. The counselor will advise and guide the associate member on TC procedures and activities.

7. Associate members will not count toward the TC regular membership limit.

8. Application forms for associate membership are the same as those of full membership, but a resume is a required attachment. Applicants for full membership who were not selected may be considered associate members provided they meet the age restriction.

9. At least two associate members should be appointed to each TC. At no time should the number of associate members exceed that of full members.

10. An endorsement statement from the nominee's department head, indicating that the nominee may travel to two meetings per year and have some time to devote to committee business, must be completed during the online process.

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Young and research-intensive, Nanyang Technological University (NTU Singapore) is ranked 13th globally. It is also placed 1st amongst the world's best young universities. The **School of Electrical and Electronic Engineering (EEE)** at NTU Singapore is one of the largest EEE schools in the world and ranks 8th in the field of Electrical & Electronic Engineering in the 2016 QS World University Rankings by Subjects.

The School invites outstanding applicants for a Professorship in Space Technology position. The ideal candidate is expected to have extensive experiences and be a renowned leader in Space Technology which includes but not limited to satellite platform and formation; space-borne instruments and systems (for optical, infrared and SAR remote sensing, navigation and control, etc.). He is expected to play a leading role in the satellite team of the School to grow new capabilities, nurture innovative ideas and develop strategies to secure external resources for Space Technology projects on a sustainable basis. As a tenured full Professor, he is also expected to provide academic leadership in the areas pertaining to Space Technology.

Emoluments and General Terms and Conditions of Service:
Salary will be competitive and will commensurate with qualifications and experience. The University offers a comprehensive fringe benefit package.

Application Procedure:
IMPORTANT – Please indicate clearly the post applied for Professorship in Space Technology when submitting an application or inquiring about this job announcement.

To apply, please refer to the Guidelines for Submitting an Application for Faculty Appointment: (http://www.ntu.edu.sg/ohr/career/submit-an-application/Pages/Faculty-Positions.aspx) and send your application (cover letter and a full CV) via email to:

Chairman, School Search Committee
c/o School of Electrical & Electronic Engineering
Email: eeehr@ntu.edu.sg

Electronic submission of applications is encouraged. Only shortlisted candidates will be notified.

For details visit this website: http://www.eee.ntu.edu.sg/aboutus/CareerOpportunities/Faculty/Pages/ProfessorshipTenuredInSpaceTechnology-27April2016.aspx

Application Deadline: Position is open until filled.

www.ntu.edu.sg

UNITED STATES AIR FORCE ACADEMY
Assistant Professor of Engineering Mechanics (#16-33DFEM)

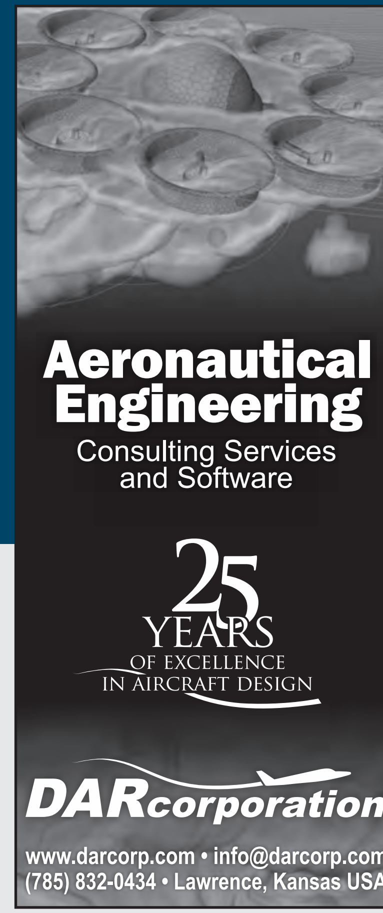
The Department of Engineering Mechanics anticipates filling an Assistant Professor position not later than June 26, 2017. Responsibilities include teaching undergraduate core and majors' mechanical engineering courses to officer candidates, and performing research in mechanical engineering. The selected candidate will participate in academic advising, mentoring, accreditation reviews, and fulfilling departmental duties. The initial appointment will be three years; reappointments of up to four years each are possible.

By the time of application, an earned doctoral degree with demonstrated expertise is required in Engineering Mechanics, Mechanical, Aeronautical, or Astronautical Engineering focused in mechanics of materials, aerospace structures, finite element analysis, fatigue and fracture, composite materials, structural dynamics, experimental mechanics, or materials science. Essential qualities include integrity, industry, cooperation, initiative, enthusiasm, and breadth of intellectual interests. Successful candidates will have a strong commitment to undergraduate teaching.

The United States Air Force Academy is located just north of Colorado Springs, Colorado. It is an undergraduate institution that awards the Bachelor of Science degree. Its mission is to educate, train, and inspire men and women to become officers of character, motivated to lead in the United States Air Force and in service to our nation. The student body consists of approximately 4,000 men and women representing every state and several foreign countries. The curriculum includes core academic and professional courses and 26 disciplinary and interdisciplinary majors.

To Apply: Applications must be received by **October 14, 2016**. Go to www.usajobs.gov. Search for #16-33DFEM in the "Keyword" box, or type in "USAF Academy" in the "Location" box. Click "Search," then scroll down until you locate this position.

U.S. citizenship is required and the selected candidate must complete a security investigation.
The U.S. Air Force Academy is an Equal Opportunity Employer.



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.

1991

Sept. 15 The 6,540-kilogram Upper Atmosphere Remote Research Satellite, UARS, is deployed by the space shuttle Discovery's Remote Manipulator System. The 10 experiments within UARS add to the understanding of humanity's effect on Earth's atmosphere and ozone layer. NASA, Astronautics and Aeronautics, 1991-1995, p. 682.

Sept. 15 Powered by four Pratt & Whitney F117 turbofan engines with 18,915 kilograms of thrust each, the fir t McDonnell Douglas C-17 Globemaster 3 makes its initial flight. Designed as a heavy-lift military transport, the C-17 can carry 77,519 kilograms of payload or 102 troops. Rene J. Francillon, McDonnell Douglas Aircraft Since 1920, Vol. 2, pp. 398-401.

1966

Sept. 11 Collett Woolman, one of four founders of Delta Air Service (later known as Delta Air Lines), dies in Houston, at 76. Under Woolman's leadership, Delta grew from a small crop dusting company helping to battle cotton-destroying boll weevils in 1925 to one of the nation's major airlines. Aviation Week, Sept. 19, p. 43.

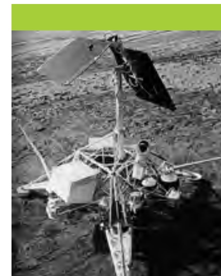
Sept. 11 Andrew Haley, a leading pioneer in space law, one of the founders of Aerojet-General who helped found the International Academy of Astronautics, dies at 61 in Washington, D.C. Born in Tacoma, Washington, Haley earned law degrees from Georgetown University Law School and George Washington University in Washington, D.C. In March 1942, he drew up the papers of incorporation for Aerojet-Engineering, the second rocket company in the U.S. (after Reaction Motors in 1941). A few months later, Haley became Aerojet's second president. In 1960, Haley was instrumental in founding both the International Academy of Astronautics and the International Institute of Space Law under the auspices of the International Astronautical Federation. He also wrote extensively on space law, including his book, "Space Law and Government (1963)," and in 1956 created the concept of "metalaw" that theoretically provides legal "ground rules" for a relationship if and when humans establish communication with, or encounter an intelligent extraterrestrial race elsewhere in the universe. Washington Post, Sept. 12, p. B7; Flight International, Sept. 22, p. 535.

Sept. 11 Balloonist Tracy Barnes completes the fir t hot-air balloon flight ac oss the continental U.S. when he lands in Cape May, New Jersey. He departed from San Diego on April 9 and made a series of 34 flights across the country in a total flight time of ver 200 hours. Washington Post, Sept. 12, p. D11.

Sept. 12 The two-man Gemini 11 spacecraft is launched into orbit by a Titan 2 booster, with astronauts Charles Conrad, Jr. as the command pilot and Richard Gordon, Jr., as pilot, for a three-day mission. About 100 minutes earlier, the unmanned Gemini Agena Target Vehicle, GATV, had launched. The Gemini 11 subsequently becomes the fir t manned spacecraft to achieve fir t-revolution rendezvous and docking, using the GATV. The astronauts also conduct additional practice docks and space walks with the help of a tether, along with photographic and other experiments. Their spacecraft reenters the atmosphere and is recovered from the Atlantic Ocean, an event broadcast live on television via the Early Bird 1 communications satellite. New York Times, Sept. 13, pp. 1, 28 and Sept. 16, pp. 1, 24.

Sept. 16 Marina Solovyeva, the Soviet "air sportsman," sets an international woman's speed record of 2,043 kph around a 500-kilometer closed course in a MiG-built E-76 production-line figh er aircraft. She beat the previous official ecord of 1,813 kph by American Jacqueline Cochran, who piloted a Lockheed F-104G Starfigh er. Aviation Week, Oct. 10, p. 33; Flight International, Oct. 20, p. 661.

Sept. 19 Air France inaugurates its Paris to Shanghai route with a Boeing 707, thus becoming the fir t Western airline to offer regular service to the People's Republic of China. Aviation Week, Sept. 26, p. 45.

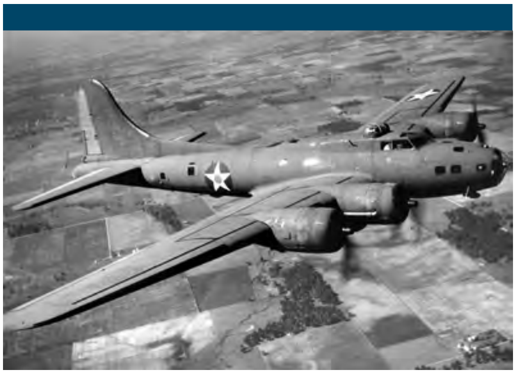


Sept. 20 NASA's Surveyor 2 unmanned probe designed to soft-land on the moon is launched, though during a midcourse maneuver, one of its three vernier rockets fails to ignite and causes the spacecraft to tumble. Additional attempts are made to ignite the verniers but a thrid vernier again fails to fi e. The spacecraft continues to the moon but communication is lost 30 seconds after the retro rocket is fi ed and the Surveyor 2 impacts on the moon without gathering data. New York Times, Sept. 23, pp. 66, 25.

COMPILED BY ROBERT VAN DER LINDEN and FRANK H. WINTER

1941

Sept. 1 A party of purchasing agents arrives in Nome, Alaska, from the Soviet Union in two Consolidated PBY flying bo ts built in the Soviet Union under license. The boats are met at sea by B-18A bombers from the Army Air Corps base in Nome. Each flying bo t holds 47 passengers sent to buy critically needed supplies. The Aeroplane, Sept.12, p. 269, and Oct. 3, p. 353.



Sept. 6 The Boeing B-17E, called the "Fortress II" by the Royal Air Force, makes its fir t flight and immediately goes into large-scale production, with 1,000 ordered by the RAF. The B-17E weighs more than the earlier B-17D. A long fin xtended forward along the top of the fuselage gives stability at great heights; the plane also has a greatly increased span, a re-designed tailplane, and increased internal armor. The Aeroplane, Sept. 26, p. 326.

Sept. 12 The H.P. 57 Halifax, biggest and fastest airplane ever built by Britain's Handley Page, is officially launched y Lady Halifax. The 30-meter midwing span, 21-meter-long monoplane, one of the world's most formidable long-range heavy bombers, is powered by four Rolls-Royce Merlin motors. The Aeroplane, Sept. 19, p. 306.

1916

Sept. 3 The fir t airship lost in combat is downed by Royal Flying Corps 2nd Lt. William Robinson while flying a BE2c biplan . Robinson brings down Schutte-Lanz Airship SL 11 over Suttons Farm, England, after the airship catches fi e. SL 11 was one of 15 airships that were attacking Britain that evening. David Baker, Flight and Flying: A Chronology, p. 89.

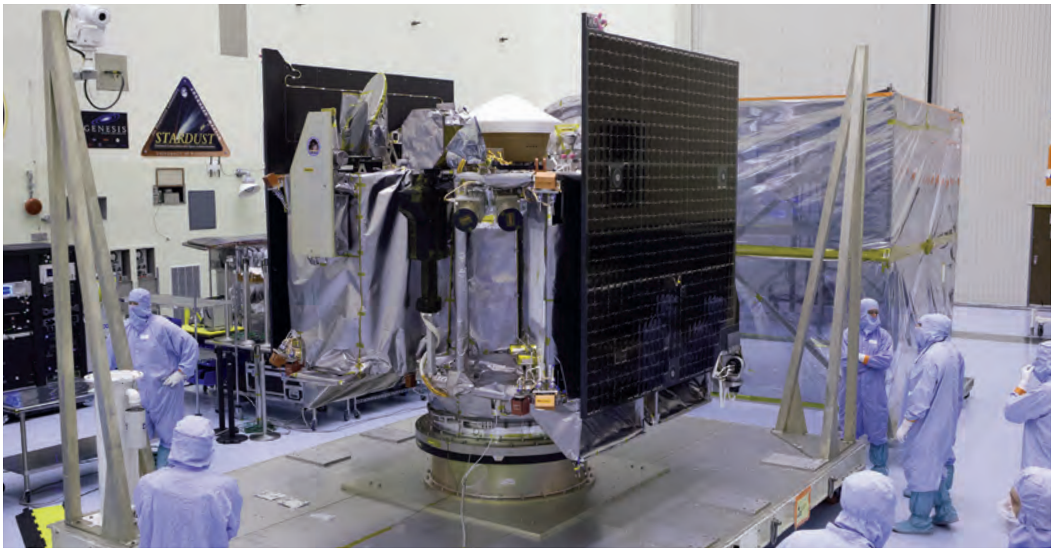
Sept. 9 The Bristol F2A "Brisfi " two-seat figh er and reconnaissance biplane completes its fir t flight. he F2A has outstanding speed and maneuverability with added benefit of a ear gunner. It is quickly adopted by the Royal Flying Corps. C.H. Barnes, Bristol; Aircraft Since 1910, pp. 104-106.

Sept. 14 Royal Flying Corps Lt. A.M. Walter becomes the fir t pilot to destroy an enemy aircraft using an air-to-air missile. He attacks a German LVG observation aircraft with unguided Le Prieur rockets that do not carry explosives. One of the rockets ignites the target with heat from its casing and exhaust. David Baker, Flight and Flying: A Chronology, p. 90.

Sept. 15 The Foucault French submarine becomes the fir t sub lost in open water under aircraft attack when two Austrian Lohner flying bo ts drop bombs on the submarine as it lies 10 meters below the Adriatic Sea. Alfred Price, Aircraft versus Submarine, p. 18.

Sept. 17 Lt. Manfred von Richtofen, better known as the Red Baron, scores the fir t of his 80 victories when he shoots down an F.E. 2b from No. 11 Squadron, Royal Flying Corps. David Baker, Flight and Flying: A Chronology, p. 90.

Sept. 27 Robert Goddard writes to the head of the Smithsonian Institution in Washington, D.C., outlining his work in rocketry and requests financial support o develop a rocket to investigate meteorological phenomena in the upper atmosphere. After much internal review, the Smithsonian Secretary Charles Walcott grants $5,000 for Goddard's research. This is the fir t of several grants Goddard receives throughout his career. Esther C. Goddard and G. Edward Pendray, eds., The Papers of Robert H. Goddard, Vol. I, pp. 170, 190.



MICHAEL DONNELLY, 55

Project manager, NASA's OSIRIS-REx, the Origins-Spectral Interpretation-Resource Identification-Security-Regolit Explorer mission.

You can't sit in an office and issue edicts via email. You need to go where the work is being performed.

Four years ago, NASA aerospace engineer Michael Donnelly took on the coolest assignment of his three-decade career. He manages the mission to send a spacecraft to the asteroid Bennu, where it will pluck 60 to 2,000 grams of material, and send it to Earth. This would be the largest sample brought home from space since the Apollo era. Donnelly is responsible for the OSIRIS-REx spacecraft, instruments, ground system and launch processing. The spacecraft was set to launch in September, and if all goes as planned, it will collect the sample in 2020 and journey back toward Earth, ejecting the sample capsule to land in the Utah desert in 2023. Scientists expect to learn about the formation of the solar system and about the composition of the 492-meter-wide Bennu, in case we ever need to deflect or destroy it or other asteroids to protect Earth.

When did you know you wanted to be a NASA project manager?

My father was in the U.S. Air Force and we spent a lot of time moving from location to location. One of those duty stops was in Hawaii, and I spent four years of my life — the prime Apollo years — watching the Apollo astronauts come back from the moon and stop in Hawaii on their way back to the States. That probably planted the seed. In my senior year at the University of Maryland, in addition to bein a bartender, I was a part-time employee with Ford Aerospace. Once I graduated, Ford offered me full-time job flying satellites at Goddard Space Flight Center. It wasn't long before I joined NASA an started down the management path. It was while I was the Aqua spacecraft manager that I first voice it out loud that I would like to be a project manager. There's a huge difference between a spacecra manager and project manager, but I didn't know it at the time, and I wouldn't listen to the Aqua project manager when he told me so. A spacecraft manager ensures that a spacecraft is built to specification or contract requirements. It is a singular effort. A project manager is responsible for the entire effor Looking back now, life would've been much easier staying as a spacecraft manager, but probably not nearly as rewarding. Being responsible to the agency [NASA] for delivering a project on time, on (or under) budget, and meeting the customer's requirements is a huge responsibility — and one that you cannot do on your own. Leading and managing a diverse team of people, and accomplishing something that within NASA hasn't been done before, that is rewarding .

What are the ingredients for success?

Managing people is about relationships. There are untold numbers of books on managing, but i the end, one needs to meet people where they are: Understand what motivates them, what they're struggling with, where they need help and where they don't. You can't sit in an office and issue edic via email. You need to go where the work is being performed. The other piece is leadership. A projec manager needs to adopt a leadership style or strategy that fits his or her personality. I'm not a consensu builder. I fit more into the benevolent dictator model. However, I know where my weak areas are and make sure that I do not let my own personal style drive me to make foolish or uninformed decisions. I know that I tend to shoot from the hip, making quick decisions based upon my own expertise or value judgments. I need to staff my project with people who are not clones and do not think like me. My tw deputy project managers are more along the lines of consensus builders. This works for me, becaus they slow me down when I need to be slowed down. Since I still retain ultimate decision authority, I can chose to act, or not, on their recommendations. Bottom line — know thyself. ★