AIR SAFETY 36
Defeating MCAS

AEROPUZZLER 8
Flying inverted

TRENDING 9
Predicting aircraft electric needs

# AEROSPACE
## ★ ★ ★ AMERICA ★ ★ ★

# Homo sapiens astronauta

**Should we modify our bodies for deep space travel? Here’s how it might be done.**

PAGE 10

**Apollo 11**
PAGE 20-34

JULY/AUGUST 2019 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

AIAA
SHAPING THE FUTURE OF AEROSPACE



**Above:** NASA astronaut Anne McClain participates in an experiment onboard the International Space Station.

Image credit: NASA

# WILLIAM H. PICKERING LECTURE

PROPULSION ENERGY FORUM

## Rocketing to the Future: Space Electric Propulsion

19 August 2019 | JW Marriott, Indianapolis, Indiana

OPEN TO THE PUBLIC

One of NASA's most remarkable interplanetary missions, the Dawn spacecraft, used ion propulsion to orbit and explore the two largest uncharted worlds in the inner solar system, dwarf planet Ceres (2015–2018) and protoplanet Vesta (2011–2012). Dawn is the only spacecraft ever to orbit a body in the main asteroid belt, the only spacecraft to orbit a dwarf planet, and the only spacecraft to orbit two extraterrestrial destinations. Dawn's mission would have been impossible without its xenon-fueled ion propulsion system, which ultimately provided a total effective velocity change of 11.5 km/s (25,700 miles per hour) — comparable to that provided by the entire three-stage Delta II launch vehicle that started the spacecraft on its deep-space journey.

Ion propulsion is a type of space electric propulsion, a technology that has now been used on nearly 600 spacecraft. Over 40% of commercial geosynchronous satellites launched in recent years rely on the extraordinary capability of this technology.

Eight deep-space exploration missions with electric propulsion have been launched and yet we have just scratched the surface of what electric propulsion can do. Under development in 20 countries around the world, electric propulsion will continue to see widespread use on commercial communication satellites with likely prolific use in large constellations in low altitude orbits. It will be used for exciting new deep-space robotic science missions. Higher power versions are expected to benefit all forms of planetary defense techniques, human missions to Mars, and asteroid mining, and advanced versions will ultimately enable rapid transportation throughout the solar system.

The Pickering Lecture will describe this extraordinary space propulsion technology and how Dawn and other missions take advantage of it to accomplish amazing interplanetary adventures.

**aiaa.org/PickeringLecture2019**

## SPEAKERS:

**JOHN BROPHY**
Expert in Space Electric Propulsion, JPL Fellow

**MARC RAYMAN**
Dawn Mission Director,
JPL Chief Engineer for Operations and Science, JPL Fellow

*The William H. Pickering Lecture is named for the former NASA Jet Propulsion Laboratory Director, to honor his initiation and leadership of America's unmanned scientific space program, from Explorer I in 1958 through the development of the Viking orbiters and the Voyager outer planet and interstellar missions. The lecture is open to all attendees and the general public.*

AIAA
SHAPING THE FUTURE OF AEROSPACE

# AEROSPACE AMERICA

JULY/AUGUST 2019, VOL. 57, NO. 7

**EDITOR-IN-CHIEF**
Ben Iannotta
beni@aiaa.org

**ASSOCIATE EDITOR**
Karen Small
karens@aiaa.org

**STAFF REPORTER**
Cat Hofacker
catherineh@aiaa.org

**EDITOR, AIAA BULLETIN**
Christine Williams
christinew@aiaa.org

**EDITOR EMERITUS**
Jerry Grey

**CONTRIBUTING WRITERS**
Adam Hadhazy, John M. Logsdon, Robert van der Linden, Jan Tegler, Debra Werner, Frank H. Winter

John Langford **AIAA PRESIDENT**
Daniel L. Dumbacher **PUBLISHER**
Rodger S. Williams **DEPUTY PUBLISHER**

**ADVERTISING**
**advertising@aiaa.org**

**ART DIRECTION AND DESIGN**
**THOR Design Studio** | thor.design

**MANUFACTURING AND DISTRIBUTION**
**Association Vision** | associationvision.com

**LETTERS AND CORRESPONDENCE**
**Ben Iannotta**, beni@aiaa.org

Aerospace America (ISSN 0740-722X) is published monthly except in August by the American Institute of Aeronautics and Astronautics, Inc., at 12700 Sunrise Valley Drive, Suite 200 Reston, VA 20191-5807 [703-264-7500]. Subscription rate is 50% of dues for AIAA members (and is not deductible therefrom). Nonmember subscription price: U.S., $200; foreign, $220. Single copies $20 each. Postmaster: Send address changes and subscription orders to Aerospace America, American Institute of Aeronautics and Astronautics, at 12700 Sunrise Valley Drive, Reston, VA, 20191-5807, Attn: A.I.A.A. Customer Service. Periodical postage paid at Reston, Virginia, and at additional mailing offices. 

AIAA
SHAPING THE FUTURE OF AEROSPACE

## IN THIS ISSUE

### Adam Hadhazy

Adam reports on astrophysics and technology. His work has appeared in Discover and New Scientist magazines.

PAGE 10

### John M. Logsdon

John is professor emeritus at George Washington University and has written books on the space policies of U.S. Presidents Kennedy, Nixon and Reagan. He founded GW's Space Policy Institute in 1987 and directed it until 2008. He is editor of "The Penguin Book of Outer Space Exploration."

PAGE 20

### Jan Tegler

Jan covers a variety of subjects, including defense, for publications internationally. He's a frequent contributor to Defense Media Network/Faircount Media Group and is the author of the book "B-47 Stratojet: Boeing's Brilliant Bomber," as well as a general aviation pilot.

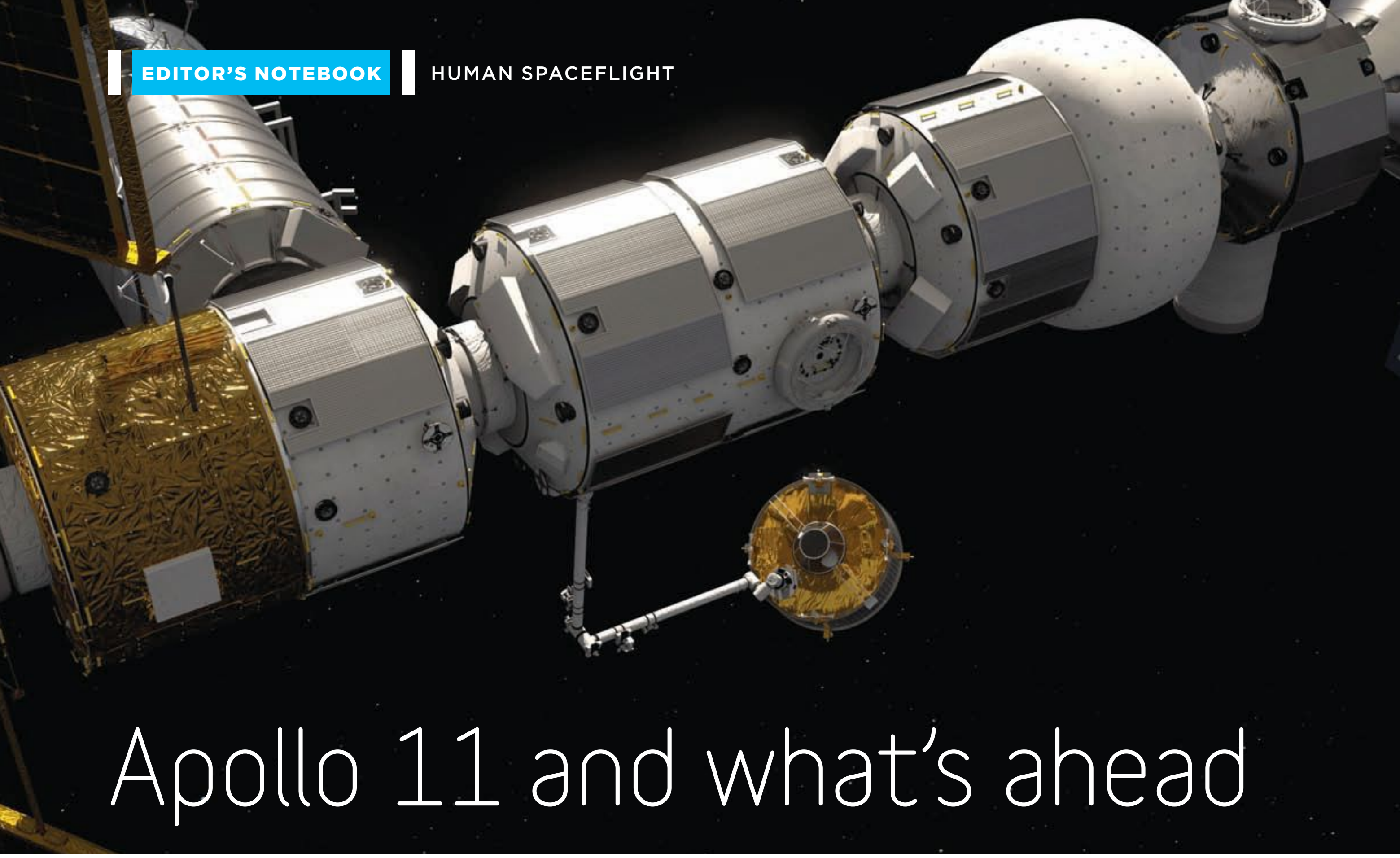
PAGE 36

### Debra Werner

A frequent contributor to Aerospace America, Debra is also a West Coast correspondent for Space News.

PAGES 28, 64

## DEPARTMENTS



# Apollo 11 and what's ahead

For this issue, we did not deliberate long over whether to make our Apollo 11 anniversary section the cover story. As important as it is to look back at the moon landing 50 years ago in July [see pages 20-35], we decided that the cover should air a possible solution to the greatest obstacle to humans living and working in deep space.

Human biology cannot survive for very long outside of Earth's protective magnetosphere. Humans would be pummeled by deadly radiation if we tried to set up shop permanently on Mars or elsewhere in the solar system.

Today, humanity doesn't actually have the choice outlined by Jeff Bezos when he accepted the 2016 Collier Trophy on behalf of his company Blue Origin. "Either we stay here on Earth and have this civilization of stasis, or we expand into the solar system and have a dynamic, exciting civilization of exploration and pioneering," Bezos said.

Toying with our genes sounds like an outlandish way to expand into the solar system. But colonization sounds outlandish too, so maybe the answer needs to match. Of course, there could be other answers. If Earth can create a magnetosphere, perhaps humans can too. Or maybe the solution lies in materials and structures or in taking shelter in natural structures such as volcanic caverns. Whatever the answer, advocates of space colonization should make sure that humans can survive in deep space, less their exuberance draws more money than warranted to the fun stuff like deep space rovers, transports, mining tools and habitats.

In the meantime, there ought to be ways to avoid the "stasis" that Bezos rightly warns of. Humanity could do more to define the environmental intricacies of our home planet and make our presence here sustainable. We could continue launching robotic probes into the solar system and building amazing space telescopes.

Perhaps along the way we will discover that these devices are the pioneers and that humanity is already living and working in space. ★

▲ **An artist's impression** of the European Space Agency's Heracles spacecraft arriving at the proposed lunar Gateway.
European Space Agency

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

# Trusting the nonhuman factor


Air taxis seem to be the fad of the moment, as the article "All aboard" implies in May's edition of Aerospace America. With modern technology, I feel sure that these kinds of vehicles could be developed. But how about operating them, especially when Murphy's law is considered?

Each of these uncrewed aircraft is going to have to have a "keep out" volume of air around it while flying plus an emergency volume below it when (not "if") Murphy's Law rears its ugly head. Has anybody looked into the amount of available air volume over the metropolitan areas where these are proposed to operate? This probably becomes even more significant if the taxis fly randomly, as the article notes.

Speaking of uncrewed vehicles, I recall an old story that went something like this:

Preflight announcement: "Welcome to Spacey Airlines and our all-new aircraft. This is the first commercial flight of this highly advanced aircraft which has been under testing for years. You will note that there is no flight crew on board as we have totally automated all of our flight operations. The flight control system has been fully and exhaustively perfected so be assured that nothing can go wrong … can go wrong … can go wrong…" Mr. Murphy had something to say about that!

**Carl Ehrlich**
AIAA associate fellow emeritus
Calabasas, California
ehrliccf@ix.netcom.com

# IAC 2019—Closer Than You Think

AIAA is proud to be the host for the 70th International Astronautical Congress (IAC 2019), 21–25 October in Washington, DC. The event is nearly upon us and the local organizing committee (LOC), AIAA staff, and industry anchor sponsor Lockheed Martin have been working closely with the International Astronautical Federation (IAF) staff and Bureau members to ensure an out-of-this world event. Since being formally handed the baton at the close of IAC 2018 in Bremen, Germany, a lot has happened! Most notably, aligning with the Congress theme "The Power of the Past, the Promise of the Future," the International Program Committee has established a plenary program that celebrates what the space community has accomplished in the past half century, while looking forward to the goals and challenges facing us over the next fifty years. Besides the traditional opening plenary featuring the heads of many global space agencies, the plenary program addresses:

- Evolving Apollo: The Next 50 Years in Human Spaceflight
- The Long-Term Sustainability of Outer Space: Advancing the Space Economy and Sustaining the Space Industry Through Solutions to the Space Security Issue
- Inspiring by Leading: Building and Sustaining the Global Space Workforce for the Future
- Heads of Emerging Agencies
- Clipper Exploring Europa: Making a Mission to Understand Our Place in the Universe (#EuropaClipper)

The late afternoon and early evening highlight lectures provide attendees with opportunities to engage in more depth on selected topics, including space exploration and space utilization:

- MARSIS: The Successful Search for Liquid Water on Mars
- The Challenge of Exploring our Sun—The 60-Year Odyssey to Parker Solar Probe
- Monitoring Coastal Waters from Space—Highlighting the Chesapeake Bay Region—Dramatic Advances Enable Better Understanding and Protection of these Vital Ecosystems and Their Immense Coastal Populations and Infrastructure

Of course, at the core of the IAC is the substantial technical program with 20 concurrent sessions covering every aspect of international space activity, from human to robotic exploration to design, development, and operations. Reflecting the incredible energy and excitement present today in the global space industry, the number of abstracts submitted was overwhelming (4,327 abstract submissions from 86 countries). For those interested in engaging in ways other than the technical presentation format, there are over two dozen special sessions. Finally the Global Network Forum (GNF) program is also taking place. Clearly there will be something for everyone at the IAC!

The Congress encompasses more than just talks, panel discussions, and lectures, however. The LOC has also been busy working on STEM programming, creating a comprehensive public day experience, vetting potential tours for attendees, and other details related to ensuring an extraordinary attendee experience. Of particular priority to the LOC is engaging with our U.S. government leaders—both in the administration and on Capitol Hill—to encourage them to attend IAC 2019 and experience what the domestic *and* international space communities have to offer. The LOC, working with many of our sister space societies, has established a summer outreach program to build excitement and educate members of Congress and their staffs about current events in space, providing a preview of what they can expect to see at the IAC in October. We are looking forward to hosting many of them at a reception in the Exhibit Hall and on personal VIP tours of the hall where they can experience our industry first hand.

The Congress is collocated with several other events as related organizations take advantage of the presence of the global space community to host their meetings and activities. The Space Generation Advisory Council (SGAC) hosts its workshop the four days prior to IAC 2019 and provides delegates an out-brief on their results during the IAC. The International Academy of Astronautics (IAA) holds its meetings and Academy Day the weekend prior, culminating in a banquet to welcome new members. The International Institute of Space Law holds a series of moot court competitions with the final being judged by judges from the International Court of Justice at The Hague. On 20 October, the Members of Parliaments seminar brings together legislative personnel from around the globe to discuss space topics of international interest. And, of course, a theme threading through all of the events is a celebration of the 50th anniversary of the Apollo program. It's going to be a jam-packed week!

Please consider attending IAC 2019 to take advantage of the opportunity to interact with the global space community. Spend the week with us this October and be inspired by not only what the U.S. space sector is doing, but also the breadth of activities that are happening around the globe. See you there! ★

IAC 2019 LOC Co-Chairs **Vincent Boles and Sandra Magnus**

# Flying inverted

**Q.** In the 2012 film "Flight," Denzel Washington as Capt. Whip Whitaker crash lands his fictional JR-88 by flying it upside down, after the plane's elevators become stuck. Justify in terms of physics and technology why this maneuver would or wouldn't be worth a shot in an actual emergency.

**Draft a response of 250 words or fewer and email it by midnight Eastern time on July 8 to aeropuzzler@aiaa.org.**

## FROM THE JUNE ISSUE

**ICY RUNWAY:** We asked you to explain whether an airliner that was being chased by zombies could take off from an ice-covered runway.

Your responses were reviewed by Jeff Eldredge, a professor at the University of California, Los Angeles, who submitted the puzzler. Here is the top submission:

**WINNING RESPONSE:** This sounds like the hypothetical situation in which an airplane takes off from a treadmill rotating in the opposite direction of its movement. Assuming the airplane is able to maintain directional control adequately through coordinated use of differential engine thrust and rudder movement, the engines would only be overcoming the very low friction between the wheels (which may or may not rotate) and icy surface as well as the typical airframe drag. In short, yes, the aircraft would be capable of performing its takeoff to avoid the zombie apocalypse.

**Devin Boyle**
NASA's Glenn Research Center
Flight Vehicle Acoustics
Amherst, Ohio
Devin.k.boyle@nasa.gov

**For a head start ...** find the AeroPuzzler online on the first of each month at https://aerospaceamerica.aiaa.org/ and @AeroAmMag.

# Visualizing electrical loads

BY CAT HOFACKER | catherineh@aiaa.org

Aircraft companies can encounter unpleasant electrical surprises when they begin flight testing a freshly minted design. Modern cockpit displays, electronically controlled control surfaces and other components can draw so much power that some electrical systems need to shut down so the aircraft has enough power to keep flying.


In fact, the amount of electricity that the average passenger jet requires has skyrocketed by a factor of 10 over the past 50 years, says Anthony Nicoli, director of aerospace and defense at Mentor Graphics, a Siemens-owned software company in Oregon.

If excessive power demands are not discovered in the flight tests that precede compliance testing, adjusting the design to win regulatory approval can be expensive and time-consuming.

In hopes of solving the problem, Mentor Graphics in May introduced software called the Capital Load Analyzer. It predicts electrical power demand throughout the stages of flight, so designers can then root out most problems long before the plane starts compliance testing.

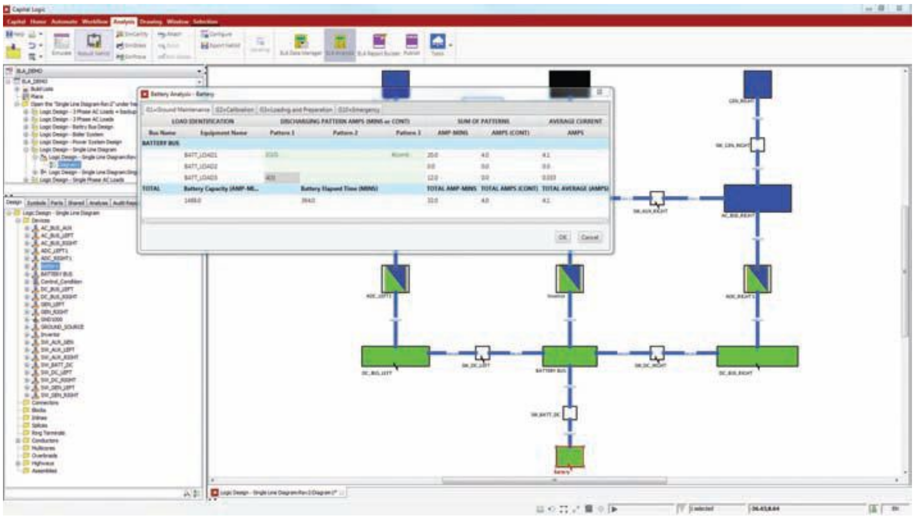
The process starts with a customer downloading Mentor's software and creating a digital twin of the aircraft's electrical systems. The Load Analyzer displays the aircraft's electrical system to the customer as a single line diagram in which blocks represent the different electrical components, such as batteries, and the lines are the wiring that provides the power. An engineer can click on each block to see the power levels of each battery, generator, rectifier and bus throughout various stages of flight. Previously, engineers had to manually calculate the aircraft's power demand using spreadsheets and other tools.

In compliance testing, aircraft must demonstrate enough power to operate in normal conditions as well as in emergencies. To test performance during an emergency, engineers practice load shedding, in which they simulate failure of various electrical systems.

"You see which nonessential systems can be turned off so the essential systems can stay on," Nicoli says. "You identify a critical device, and you want to make sure you have enough voltage and current to function in an emergency scenario."

▼ **The line diagram** represents an aircraft's electrical system, with blocks for each electrical component.

Mentor



These charts and graphs can be exported to Mentor's publishing software to create a certification report for a regulatory agency such as the FAA or the European Union Aviation Safety Agency.

The Load Analyzer and Capital Publisher are part of a series of programs that can be tied to the same digital twin. The Capital series "is an environment that allows our customers to incrementally develop their electrical systems from concept through architectural definition into design, manufacturing, and then through the maintenance life of the platform," Nicoli says. ★

# Homo sapiens astronauta

**Gene therapy could one day make it possible to biologically enhance humans to live and work in deep space. Adam Hadhazy checks in on this nascent idea.**

BY ADAM HADHAZY | adamhadhazy@gmail.com

It's fitting that many cultures place gods in the heavens above, for living beyond Earth does indeed require a degree of supernaturality.

Spacecraft technology can supply the basics: food, air, water and shelter. Yet during their record-setting, yearlong stays on space stations, astronauts and cosmonauts have dealt with myriad health problems due to exposure to weightlessness and radiation. These brave explorers have not suffered, it seems, any serious, lasting deficits. Those embarking on longer-duration missions outside of the relative protection of low Earth orbit, and thus out past our planet's radiation-diverting magnetosphere, would likely have greater damage inflicted. Current countermeasures such as exercise, diet and radiation shielding could fall far short in keeping astronauts healthily productive on extended expeditions to the moon, Mars and destinations unbound.

A radical-sounding solution, now gaining traction in academia, is biologically enhancing people for space travel. Increasingly feasible due to galloping advances in medicine and biotechnology, this enhancement would involve altering genes to render would-be astronauts more robust against the ravages of space. The genes could, for instance, make bones superhumanly strong, or ramp up the repairing of DNA strands sundered by radiation.

If one coldly analyzes the hazards of life beyond the magnetosphere, manipulating genes could be the only way. "The idea of human enhancement should be considered by mission planners as a reasonable option," says Konrad Szocik, an assistant professor of philosophy who studies the topic at the University of Information Technology and Management in Rzeszow, Poland.

The concept is not so far-fetched. After decades of halting progress, gene therapy — the modification of DNA in cells to treat or prevent disease — has arrived. The very first gene therapy approved by the U.S. Food and Drug Administration, for a type of advanced cancer,

went on the market in 2017. Hundreds more gene therapies are in clinical trials. "It's regular medicine," says Harvard University's George Church, a pioneer in human genetic engineering.

Nevertheless, gene therapy is still too new for NASA or other space agencies to fund research for, let alone consider adopting the technique. Before changing the genes of someone shot off into space, the therapies must accumulate a substantial record of safety and efficacy terrestrially. Gene therapy is "definitely on our radar, but it's so immature," says Jennifer Fogarty, the chief scientist of NASA's Human Research Program. "We're cautiously optimistic."

**▲ NASA astronaut** Nick Hague sequences DNA samples on the International Space Station as part of an experiment to determine how space radiation affects DNA and how to repair it.
NASA

Prominent biologists, some of whom work closely with NASA, are furthering the case for enhancement, not just from a scientific basis but also from an ethical one. "There may come a time when it would be ethically irresponsible to send people out into space without some form of genetic protection if we're able to do it," says Christopher Mason, an associate professor of physiology and biophysics at Weill Cornell Medical College in New York City.

Mason says that the ethical arguments about applying genetic engineering to human beings fundamentally changes in the astronaut scenario.

### Genethics

At first blush, gene therapy's scientific argument looks overshadowed by its gnarly ethical implications, such as the propriety of introducing desirable traits to the human population through eugenics or creating "designer babies." Those concerns could be managed as follows: The genetic changes for astronauts, as well as most Earthly patients, would not be to the germline cells of sperm and egg, and so the effects would not be heritable. Instead, the modifications would be to DNA in the body's somatic cells, comprising all other cell and tissue types. In this way, gene therapies intended for astronauts arguably would be little different from today's conventional drugs and treatments.

> **"Pharmacology can only take you so far. ... To some degree, we need our biology to fundamentally be adapted to space."**
>
> **— Christopher Mason,** Weill Cornell Medical College, New York City

"The application is in a different space, literally, for someone going to another planet," he says.

"In my opinion," adds Szocik, "there is only one strong objection to human enhancement in space — the risk of failure and negative medical consequences. However, I do not see any reasons to treat seriously other kinds of objections, such as an argument of 'playing god' or some kind of limitation of autonomy and freedom."

In these early days for the concept of enhancement, initial progress is coming largely out of work funded for and focused on identifying genes involved in normal deleterious Earthly experience, such as aging, neurodegeneration and disease. The second step is then to characterize those genes for potential modification, with the bonus that many of those same genes also hold promise for helping out humans engaged in long-duration spaceflight.

### Harsh final-frontier living

In terms of why deep space is so hazardous to humans, researchers are now gaining granular knowledge about those impacts, which range from broad metabolic and cellular effects to risks of damage to DNA.

NASA's Twins Study, which culminated with the release of a paper in the April issue of the journal Science, provides the most comprehensive look yet at the response to weightlessness and radiation. "The study itself was by far the greatest resolution of what happens to the body during spaceflight," says Mason, a principal author of the study. "We used the entire modern armada of molecular biology and technology."

The study followed now-retired NASA astronauts Scott Kelly during his March 2015 to March 2016 stay on the International Space Station, and his brother, Mark, who served as a control subject over the same period on Earth. Both Kellys underwent a battery of tests, from blood and urine sampling to gauging their gene expression (activity) levels to psychological and cognitive assessments.

The Twins Study confirmed with sharper precision much of what the hundreds of prior astronaut deployments have documented. The most concerning ailments include muscle atrophy, bone deterioration, weight loss and bodily fluid redistribution.

Physiologists expect that astronauts going farther afield and for longer will fare worse. Barring breakthroughs in propulsion, a roundtrip Mars mission

▼ **A vertical treadmill** imitates exercise in microgravity by countering the pull of gravity on the body. Astronauts' exercise on the International Space Station is designed to counteract the effects of weightlessness on the body, which include muscle and bone deterioration.
NASA

would last over a year. Mason says the voyage would subject astronauts to roughly eight times the radiation dose Scott Kelly received during his year in low Earth orbit. "It's more," says Mason, "but not crazy high amounts more," suggesting countermeasures of some sort could be in reach. Daily exercise, now standard on ISS stays, slows bone and muscle loss from weightlessness but cannot compensate fully. An osteoporosis drug is standard issue on orbit as well, though again, pills won't be a magic bullet.

"Pharmacology can only take you so far," says Mason. "To some degree, we need our biology to fundamentally be adapted to space."

▲ **Astronaut Scott Kelly**, right, undergoes ultrasound measurements while wearing a pressure suit. NASA

## Genetic switches to throw

Toward this end, Harvard's Church co-founded the Consortium for Space Genetics in 2016. The consortium aims to bring about better living here on Earth, setting the stage for eventual off-planet living. Church and his colleagues have identified a few dozen genes that hold promise, covering a gamut of desirable traits for astronautical life. These range from needing less sleep to growing tougher bones, high altitude (low oxygen) adaptions, larger and leaner muscles, reduced pain sensitivity, and trans-

missible and nontransmissible disease resistance.

Robust mental health is another aim. An example is a gene associated with low rates of bipolar disorder and higher cognitive test performance. Other genes seem to decrease anxiety levels, boost memory and improve spatial learning abilities. If these traits jibe with the declines tied to growing old on Earth, that's no accident; living in space is comparable to aging in overdrive.

"Radiation can accelerate aging, and low gravity can accelerate osteoporosis," says Church. "A lot of what my lab works on, besides space genetics, is aging reversal via gene therapy, and those are related topics."

Church's hope is that the terrestrial demand for gene therapies to ease aging and potentially treat neurodegenerative diseases such as Alzheimer's will be the impetus for having therapies approved that could also benefit astronauts.

Meanwhile, Mason, who is affiliated with the consortium, is conducting in vitro studies of human cells in the lab to see how they function with enhanced genetics. A prime example: the repair gene designated p53, located in cells throughout our body. When DNA damage occurs in a cell, p53 cranks out its associated protein, which triggers either repair or, if the DNA's too far gone, initiates a cell's self-destruct mechanism. In this way, p53 works as a tumor suppressor gene, heading off potential neoplasms that emerge from botched DNA repair jobs. People with only a single functioning copy of p53 in their genome often develop multiple cancers, and often in childhood. That's in contrast to elephants, which possess 20 copies and hardly ever develop cancer — all the more remarkable given these pachyderms' vastly greater cell count, which presents more opportunities for accumulating genetic errors that lead to malignancies. If sprinkled liberally into astronaut genomes, p53 could augment DNA repair from cosmic radiation damage.

Mason's investigations also go beyond the realm of human genetics entirely, looking to animals for evolutionary innovations. For example, Dsup, short for "damage suppressor," is the genetic ace up the sleeve of tardigrades, the astoundingly robust microscopic critters popularly known as water bears. These eight-legged animals can survive all manner of extreme conditions, including high and low temperatures and pressures, starvation and desiccation, plus exposure to a vacuum and radiation. Dsup suppresses breakages in the rungs of the molecule's double helical ladderlike structure, helping tardigrades famously withstand environmental stressors. If Dsup can be made to get along with human genetics, it could be quite the fortifier.

Still another approach, proposed by Columbia University systems biology professor Harris Wang, calls for genetically modifying human kidneys to manufacture the nine "essential" amino acids. Unlike the other amino acids our bodies require for building proteins, these nine cannot be generated

## 5 CATEGORIES OF RISKS TO THE SPACE TRAVELER TO MARS

**1. Gravity.** An astronaut would experience three gravity fields: Earth, weightlessness in spacecraft, surface of Mars. Transitioning can be hard.

**2. Isolation/confinement.** Groups of people who are confined to small spaces for long periods experience moodiness, depression and lack of appetite.

**3. Hostile/closed environments.** Human immune systems can become compromised; benign microbes may become virulent; stress hormones increase.

**4. Space radiation.** Earth's magnetic field protects humans on the International Space Station, but they still receive 10 times the radiation they do on Earth.

**5. Distance from Earth.** NASA is planning for the types of medical events that can be expected over six months.

Source: NASA

inside our cells, so they must be obtained from food sources. Instead of dedicating tons of spacecraft mass and precious volume for said food supplies, astronauts enhanced in this way could drink sugar water for sustenance. Mason likes the concept. “The perfect complement to increasing [astronaut] defensive capability” through DNA damage-resistance genes, says Mason, “is to increase survivability and independence from needing anything else.”

**“When astronauts come back to Earth, we won’t just say ‘sorry you’re mutated.’ We can reprogram things back the way they were before.”**

**— Christopher Mason**, Weill Cornell Medical College

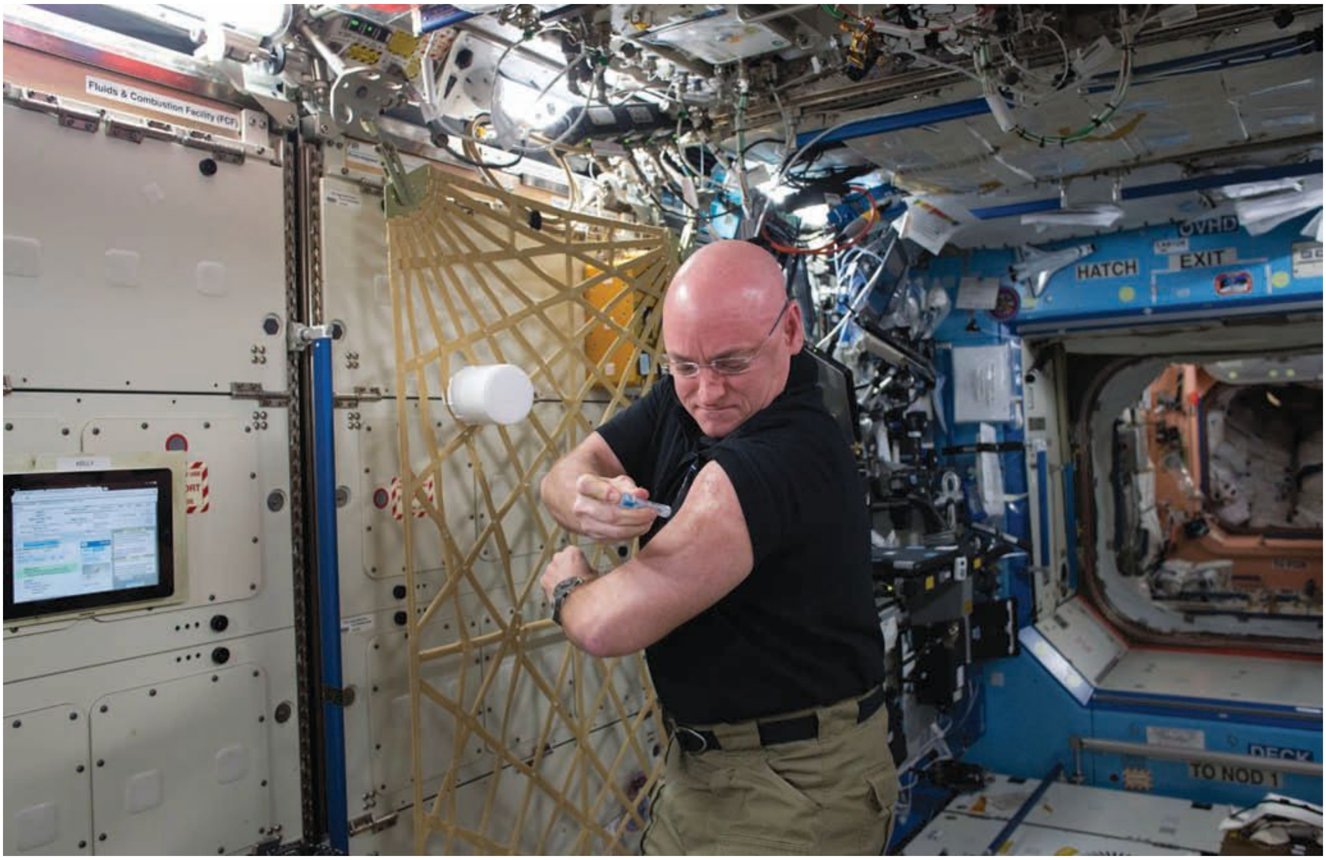
### From the lab to the clinic

Gene therapy is in use today to treat certain cancers and eye disease, and the treatments are administered intravenously or through an injection. In one method, doctors harvest cells from a patient and genetically modify them to create specific proteins or suppress protein creation, whatever the treatment requires. These engineered cells are then returned to the body where they replicate as usual, engendering a line of cells programmed for specific tasks. In another method, doctors tailor viruses to insert genes into the patient’s genome. Both these mechanisms are part of FDA-approved gene therapies.

Over the past decade, a highly efficient way of gene editing, called CRISPR-Cas9, has taken the field by storm. “It’s a dramatic shift,” says Mason, “and a very welcome one.” An enzyme, Cas9, zeroes in on particular sequences of DNA called CRISPRs (clustered regularly interspaced short palindromic repeats) that can be introduced into genomes, bracketing a particular gene. The whole gene can be cut out, scissorlike, or modified with precision. The first human trials with CRISPR in the United States, for relapsing cancers, got underway in April. China has done most of the human CRISPR work to date, though in 2018 scandal erupted from the apparently unsanctioned editing by a Chinese scientist of embryos to confer resistance to HIV infection. These “CRISPR babies” have provoked calls for a formal moratorium on all germline engineering.

As promising as CRISPR is, ethicists say an abundance of caution must still be taken. CRISPR and

▼ **Astronaut Scott Kelly** gives himself a flu shot on the International Space Station as part of NASA’s Twins Study. Kelly spent a year aboard the ISS in 2015-16 while brother Mark stayed on Earth.
NASA



other gene editing techniques can have off-target effects, splicing up a genome in unintended locations with potentially lethal impacts. Furthermore, individual genes rarely work in isolation. In most cases, they do not act as simple on/off switches for a single, discrete trait. Instead, genes interact complexly with each other and environmental exposures. Accordingly, boosting (upregulating) — or knocking out (downregulating) a gene to prevent bad function X can instead cause bad function Y — an unintended consequence that may not reveal itself until years after treatment, or only in certain individuals.

"Upregulating a DNA repair gene — like going the p53 route — is very practical," says NASA's Fogarty. "But is that the only thing p53 does? Likely not. If you're going to upregulate, you need to be very mindful of the other roles it plays."

## Tomorrow's astronauts

When might any of this come to pass? From gene target to therapy, clinical studies demonstrating safety and efficacy necessary for FDA approval usually take eight to 10 years. For serious diseases with few or no other treatments, regulators can approve expedited trials, and the genes in question — say, for thwarting the neurodegeneration of Alzheimer's — could extend to astronauts. Church is therefore quite bullish on gene therapy, even eyeing it for the first crewed missions to Mars that NASA has talked about launching as soon as the 2030s. "We'll work hard to try to get it [ready] in time," he says.

Fogarty suggests that gene therapy's first use in astronauts might not be as preventative medicine, but rather as treatment after arriving back home from a grueling long-duration mission. This strategy would avoid the risks of unexpected effects from fledgling gene therapies, especially which might only manifest in the uniquely health-stressing environment of space.

On the ethics of adjusting an astronaut's genes, Mason points out that the engineering would be reversible. "When astronauts come back to Earth, we won't just say 'sorry you're mutated,'" says Mason. "We can reprogram things back the way they were before."

Mason argues that the bold step of genetic enhancement to ensure human durability, and thus accessibility to space, is not just a matter of scratching the itch for exploration, or scaling up new industries and economies. Instead, it's a matter of survival of Homo sapiens, enabling us to colonize new worlds or live off-world, permanently. Right now, all of humanity's eggs, so to speak, are in one planetary basket; the same goes for all life we know of in existence.

"We have a duty not only to our species," says Mason, "but everything else on Earth." ★

▲ **NASA astronaut Peggy Whitson**, left, Roscosmos cosmonaut Fyodor Yurchikhin, center, and NASA astronaut Jack Fischer are examined by medical personnel after their Soyuz MS-04 spacecraft landed in Kazakhstan in 2017. Whitson was in space 288 days, Yurchikhin and Fischer 136.
NASA

## FEATURED SPEAKERS INCLUDE

**ROBERTO GUERRERO**
Deputy Assistant Secretary of the Air Force for Operational Energy, Office of the Assistant Secretary of the Air Force for Installations, Environment and Energy

**ALAN NEWBY**
Director,
Aerospace Technology and Future Programmes,
Rolls-Royce

## TECHNICAL PROGRAM WILL OFFER OVER 900 PRESENTATIONS ON TOPICS SUCH AS:

- Advanced Propulsion Concepts
- In-space Electric Propulsion
- Nuclear and Future Flight Propulsion
- Space Launch Systems, Space Propulsion and Space Transportation
- And more!

## COURSES AND WORKSHOPS

- Aircraft Electrified Propulsion Systems and Component Design
- Applied Model-Based Systems Engineering
- Hypersonic Air-Breathing Propulsion: Emerging Technologies and Cycles
- Integrated Performance Assessment of Boundary Layer Ingesting Aircraft and Highly Integrated Propulsion Concepts
- Missile Propulsion
- Rocket Testing Workshop at Purdue Zucrow Labs

## SPONSORS

ROLLS ROYCE

LOCKHEED MARTIN

AEROJET ROCKETDYNE

BASTION TECHNOLOGIES

AIAA
SHAPING THE FUTURE OF AEROSPACE

APOLLO 11 | 50TH

**Astronaut Buzz Aldrin** and the U.S. flag, with the lunar module on the left and Aldrin's and Neil Armstrong's footprints visible in the moon's soil.
NASA

# WINNING THE MOON RACE

## MORE APOLLO 11

**The Apollo 11 moon landing still amazes, not just as a technological achievement but as a feat of political will by a democratic society. Space scholar John Logsdon has spent a good part of his career thinking about why and how this bold mission succeeded. Logsdon depicts how the U.S. made what is arguably humanity's greatest achievement.**

BY JOHN M. LOGSDON | logsdon@gwu.edu

On the early morning of July 16, 1969, I was one of a small crowd standing outside the Operations Building at Kennedy Space Center. At 6:27 a.m. Eastern time, a door opened, and Neil Armstrong, Mike Collins and Buzz Aldrin exited the building and strolled past us — on their way to the moon. Just over three hours later, at 9:32 a.m., I stood in the field in front of the press bleachers as the Saturn V carrying the Apollo 11 crew accelerated ever so slowly off of launch pad 39A. Nothing in my lifetime will compare to the combination of the physical experience of a Saturn V taking off plus knowing that I was experiencing history being made.

My involvement with Apollo began two years earlier. In 1967, I decided to write my doctoral dissertation in political science using President John F. Kennedy's 1961 decision to send Americans to the moon as a case study of foreign policy decision-making. I had the good fortune of having access to many of Kennedy's close associates. The dissertation soon turned into a book published in 1970, "The Decision to Go to the Moon." The manuscript was completed by mid-1969, and that was what earned me an invitation to view the launch.

For me, the run-up to the 50th anniversary of the Apollo 11 mission has afforded an opportunity to tie together decades of research and thoughts about how the U.S. managed to win the race to the moon.

### Why did we go?

Something that is often forgotten today is that Kennedy's preference when he entered the White House in January 1961 was to work with the Soviet Union in space, with the aim of keeping it an arena for peaceful cooperation. Then the Soviet Union began preparations to launch MiG pilot Yuri Gagarin into orbit. When Kennedy went to bed on the evening of April 11, he was told that the launch would likely happen overnight; he was asked if he wanted to be woken if that indeed happened. His response was "no," so he learned of Gagarin's feat on the morning of April 12 and saw the Soviet Union being lauded. The Vatican newspaper characterized the achievement as a "universal good," as Moscow claimed that it "embodied the genius of the Soviet people and the powerful force of socialism." The Washington Post said the flight marked "a psychological victory of the first magnitude for the Soviet Union." These reactions convinced Kennedy that he could not let the Soviet Union by default dominate outer space. He asked his advisers to identify "a space program that promises dramatic results in which we could win." The answer came back — "go to the moon." The U.S. and the Soviet Union would have to develop powerful new rockets, and the White House was told by Wernher von Braun that the country had an "excellent" chance of winning a rocket-building race. Kennedy accepted this advice and on May 25, 1961, addressed a joint session of Congress, saying, "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to Earth."

### Motivator in chief

Kennedy backed up his words with a massive, warlike but peaceful, mobilization of financial and human resources. Leaders of Congress were consulted in advance of Kennedy's speech to make sure that they would approve funding for the mission. In the following weeks there was little congressional questioning of the wisdom of Kennedy's proposal. Project Apollo became the largest U.S. technology-based project, surpassing the Panama Canal and the Manhattan Project. Apollo was assigned the highest government priority, and after Kennedy's speech the NASA budget for fiscal year 1962 was increased by 89% over the previous year's level, and another 101% the following year. By 1965, NASA's budget was almost 5% of all government spending.

The NASA workforce doubled, and contractors working on Apollo increased fourfold. Although the average age of the Apollo workforce was 27, the project's leaders, most of them in their 40s and 50s, brought extensive experience in managing large-scale military and aeronautics developments. (See box.) Chief engineer Max Faget helped design the Apollo spacecraft, and flight operations director Chris Kraft basically invented the methods that would guide that spacecraft to the moon and back. German émigré von Braun, now a U.S. citizen, led his rocket team in Huntsville, Alabama, and Florida. Many others in NASA, industry and academia made critical contributions to program success.

Another key to success was the clear and crisp goal that Kennedy had set, which combined a specific destination — the moon — and a precise deadline for getting there and safely back — "before this decade is out." Without that deadline, arguments about how best to get to the moon could have dragged on. With the deadline, expeditious decisions were needed.

## THE BEST AND THE BRIGHTEST

Managing Apollo matters overall in Washington, D.C., were NASA Administrator James Webb, Deputy Administrator Hugh Dryden and Associate Administrator Robert Seamans. Human spaceflight head George Mueller and Apollo program manager Air Force Gen. Sam Phillips bridged the gap between maintaining political support for Apollo and providing wise technical direction. In Houston, Robert Gilruth, the director of the new Manned Spacecraft Center, had been in charge of NASA's human spaceflight efforts since the agency's inception in 1958. His deputy, George Low, had been one of those most involved in 1961 in telling the White House that Apollo was technically doable. Throughout Apollo, Low's technical judgments proved crucial to the success of the effort.

### Early decisions

The choice of Houston as the location for a new Manned Spacecraft Center, announced in September 1961, was politically driven. Vice President Lyndon B. Johnson was a Texan, and even more importantly, Rep. Albert Thomas of Houston, who chaired the House committee that controlled NASA's budget, made it clear that putting the facility in Houston was key to his support. By the end of that year, NASA had given the contract to build the Apollo command and service module to North American Aviation and had decided to add a fifth engine to the advanced version of von Braun's Saturn design, making it the Saturn V.


▼ **Apollo 11 walkout:** The crew heads to the launch pad.
NASA

▲ **President John F. Kennedy** presents astronaut Alan Shepard, the first American in space, with the NASA Distinguished Service Award after his flight on May 5, 1961.
NASA

Boeing would build the booster's first stage, North American the second stage and Douglas Aircraft the third stage, with Rocketdyne providing the rocket engines for all three stages.

In 1962, after much internal agonizing and over White House opposition to its technical judgment, NASA chose the lunar orbit rendezvous approach. A separate small spacecraft would detach from the command and service module in moon orbit. This lunar excursion module (later shortened to lunar module) would land on the moon; after the astronauts carried out surface activities, its ascent stage would lift off and rendezvous with the command module as it orbited the moon. After the moonwalkers and their cache of moon rocks transferred back to the mother ship, the ascent stage would be sent to crash on the lunar surface.

The contract for the lunar module was awarded to Grumman Aerospace in November 1962. The selection of this "mission mode" meant that only one Saturn V launch would be needed for each lunar voyage. Also in 1962, NASA acquired land on Merritt Island, Florida, adjacent to the Air Force-operated Cape Canaveral facility and began construction of Launch Complex 39, including the towering Vehicle Assembly Building. This would be the nation's "moonport." When the Apollo schedule in 1963 appeared in jeopardy, NASA, at human spaceflight head Mueller's insistence and over the von Braun team's opposition, adopted an "all up" approach to testing the Apollo-Saturn system. Booster and spacecraft elements would be tested together rather than separately. This decision saved many months in the Apollo schedule, making the "end-of-the-decade" goal achievable.

### Second thoughts

By 1963, criticisms of Apollo had emerged, and future political support for the fast-paced effort was far from certain. Kennedy himself seems to have had second thoughts. In both 1962 and 1963 he requested in-depth reviews of the overall national space program. In a September 1963 speech at the United Nations, Kennedy returned to his original idea of space as an arena for peaceful cooperation, suggesting turning Apollo into a joint U.S.-Soviet undertaking. The idea was greeted with an ambiguous response from Nikita Khrushchev.

Kennedy traveled to Texas in November, a few days after visiting Cape Canaveral, where he had seen a Saturn I on its launch pad and was told that it would give the U.S. the lead in lifting power. Kennedy's excitement about going to the moon seemed reenergized, after he waivered earlier in the year with his call for review of the program. He told a San Antonio audience: "This nation has tossed its cap over the wall of space, and we have no choice but to follow it." The next day, Nov. 22, he traveled to Dallas, where he was assassinated.

It is impossible to say what might have happened if Kennedy had lived to complete two terms in the White House. He may have continued to push for cooperation, turned off the "end-of-the-decade" deadline, or continued along the planned path. But after Kennedy's death, achieving the Apollo goal quickly became a memorial to a fallen young president. Even after the Apollo 1 launch-pad fire in 1967 killed astronauts Gus Grissom, Roger Chaffee and Ed White, there was no thought given to abandoning the push to the moon. Unfortunately, it was Kennedy's death that was the final key to being first to the moon.

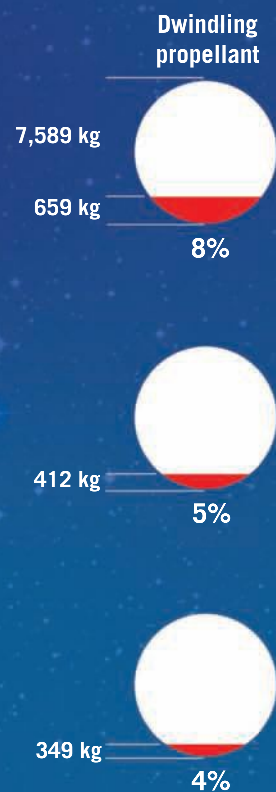
In contrast to the U.S. Apollo triumphs that unfolded after Kennedy's death, the Soviet lunar program was beset by internal bureaucratic and personal rivalries, the lack of both adequate resources and centralized leadership, and the 1966 death during surgery of the charismatic Soviet "chief designer," Sergei Korolev. Even so, the Russian program came close to getting to the moon before the United States. At the end of 1968, only a last-minute Kremlin decision aborted a plan to send cosmonauts looping around the moon before Apollo 8. Before Apollo 11 was launched in July 1969, two attempts to test their massive N-1 booster, the Soviet equivalent of the Saturn V moon rocket, failed, with one accident severely damaging the booster's launch pad. The United States won the race to the moon, and a race it was.

### "One giant leap for mankind"

When in 1961 Kennedy decided to send Americans to the moon, he wanted to impress on the people of the world that, despite Soviet claims to the contrary, the United States remained the global leader in technological and military power and the nation most worth emulating. Apollo was an exercise in propaganda — sending to the world, and ourselves, a

# Landing the Eagle

For two minutes, humanity's greatest technical accomplishment rested on teamwork by Apollo 11 commander Neil Armstrong and lunar module pilot Buzz Aldrin as they descended toward a surprisingly rough lunar landscape. Land on a boulder, and the lunar module could have tipped over. Run out of propellant, and the best scenario would have been an abort to the orbiting command module, where astronaut Michael Collins waited.




## Two minutes to history

With their hydrazine and oxidizer running low, the situation turned critical as commander Neil Armstrong and pilot Buzz Aldrin searched for a safe place to set down the Eagle.

**TIME**
**L minus 02:30**
Armstrong warns of landing in a "pretty rocky area" and takes control of Eagle to avoid it. Aldrin monitors altitude.

**L-02:00**
"OK, how's the fuel?" Armstrong asks at 82 meters from the surface.
Aldrin: "Eight percent."

**L-01:30**
Armstrong identifies new landing site. "Gonna be right over that crater," he says, indicating a small crater they will later explore.

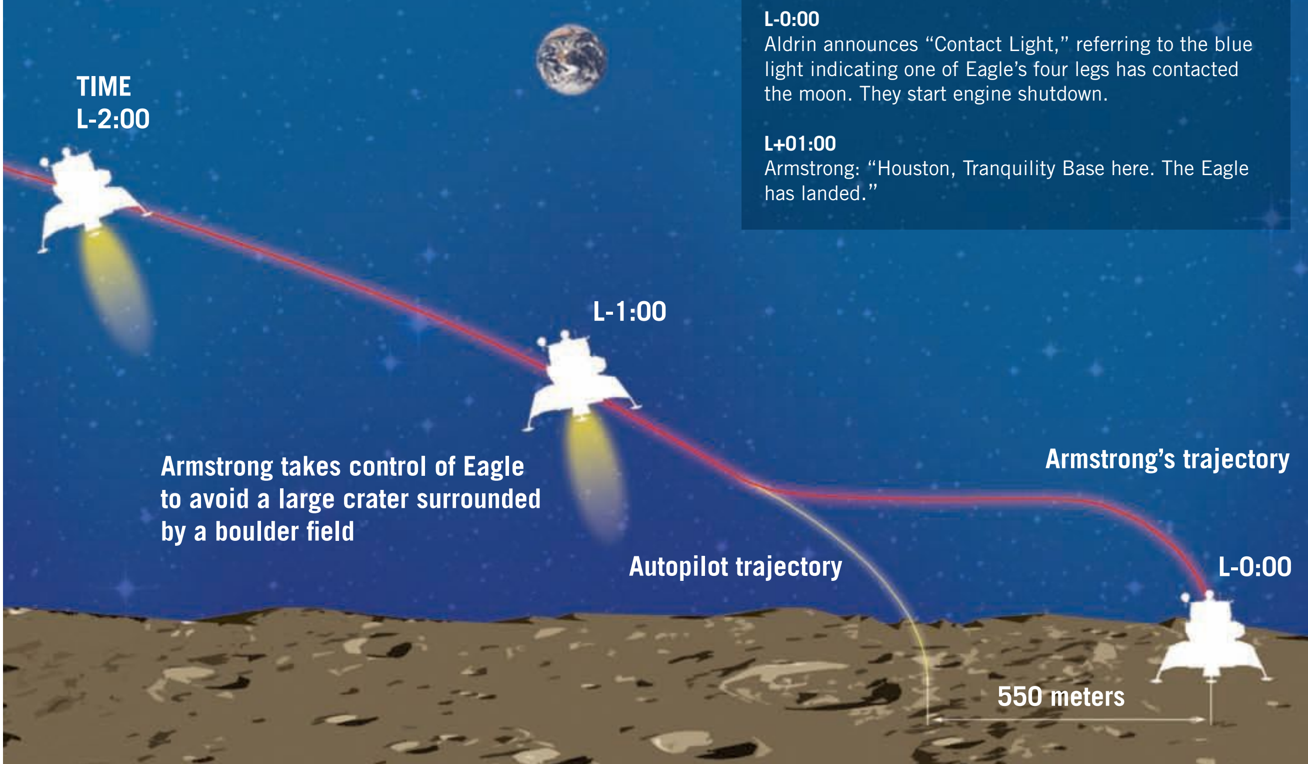
**L-01:00**
At 30 meters, Aldrin declares "five percent" propellant remaining.

**L-00:40**
From Houston, Charles Duke, capsule communicator or capcom, warns: "60 seconds" of propellant left before land or abort.

**L-0:10**
"30 seconds," Duke warns.

**L-0:00**
Aldrin announces "Contact Light," referring to the blue light indicating one of Eagle's four legs has contacted the moon. They start engine shutdown.

**L+01:00**
Armstrong: "Houston, Tranquility Base here. The Eagle has landed."




*Not to scale*

*Reporting by Cat Hofacker; Graphic by Anatoly Zak / RussianSpaceWeb.com*


▲ **The Saturn V rocket** carrying Apollo 11 lifts off from Launch Complex 39 at Cape Canaveral on July 16, 1969.
NASA

message of American superiority and exceptionalism. Kennedy's advisers told him that the prestige from being first to the moon would be "part of the battle along the fluid front of the Cold War."

It is doubtful, at least at its inception, that Kennedy saw his Cold War initiative in broad historical terms. But as I wrote in 1970, "the politics of the moment had become linked with the dream of centuries." Humans from varied civilizations around the globe had made traveling to the moon a central theme in their stories about the future; now, at the end of the 1960s, the United States intended to make that mythical voyage a reality.

That Apollo would have a global impact that transcended its Cold War origins became evident as the Apollo 8 crew entered lunar orbit on Christmas Eve 1968. As the crew read from the Bible and sent back contrasting images of the barren lunar surface and the cloud-streaked, ocean-covered Earth, the American poet Archibald MacLeish was prompted to write: "To see the Earth as it truly is, small and blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on the Earth together, brothers on that bright loveliness in the eternal cold — brothers who know now they are truly brothers." Praise for the Apollo 8 mission flooded the White House and NASA from both the world's leaders and the general public. Soon after, the "Earthrise" photo taken by Apollo 8 crew member Bill Anders was published and immediately achieved iconic status.

The exultant worldwide reaction to the Apollo 8 success reminded U.S. leaders, if they needed reminding, that the first steps on the moon a few months later would be celebrated as a global event. It would be crucial to the political success of the mission to craft words and images that recognized that reality.

The first landing attempt could come with the mid-July Apollo 11 mission. The crew for that mission, announced on Jan. 9, 1969, would be Armstrong, Aldrin and Collins. From that day on, there was recognition that their names would be certain to go down in history. It soon became known that Armstrong, the mission's commander, would take the first steps on the lunar surface. One early NASA decision was that what Armstrong would say as he stepped on the moon would not be scripted in advance; those words would be Armstrong's personal choice. His brief statement — "That's one small step for man, one giant leap for mankind" — ended up fitting the moment perfectly.

What of a symbolic character Armstrong and Aldrin would do in their just over two hours on the lunar surface was carefully considered at NASA's top levels; the result was a success story in message shaping. A NASA "Symbolic Activities Committee" decided that the objective of what was done on the

**Earthrise:** The lunar surface as photographed by Bill Anders aboard Apollo 8, the first crewed spacecraft to orbit the moon.
NASA

moon was to portray "the first lunar landing as an historic first step of all mankind that has been accomplished by the United States of America." To achieve the "all mankind" part of this message, a plaque would be attached to the part of the lunar module that would remain on the moon. That plaque would show "the two hemispheres of the Earth and the outlines of the continents, without national boundaries"; it would say "Here men from planet Earth first set foot upon the moon. We came in peace for all mankind."

To show that it was the United States which had reached the moon, the astronauts would plant an American flag (and no other) in the lunar soil "in such a way as to make it clear that the flag symbolized the fact that an effort by the American people reached the moon, not that the U.S. is 'taking possession' of the moon." There was a White House suggestion that the U.S. national anthem be played after the flag was planted, but that idea was quickly rejected. Armstrong did snap a photograph of Buzz Aldrin saluting the flag, and that photo, like Apollo 8's "Earthrise," became a lasting icon of Apollo's achievement.

In a fortunate coincidence of technological progress, the third Intelsat communications satellite that would make possible global viewing of the first steps on the moon was put in service only 19 days before the Apollo 11 landing on July 20, 1969. The 3:18 p.m. landing, Houston time, was not broadcast live, but hours later some 600 million people, about one-fifth of the world's population, watched on a Sunday evening in the U.S. as the ghostly image of Armstrong descended the ladder on the side of the lunar module. At 9:56 p.m. he took humanity's first step on another celestial surface. Armstrong was joined 19 minutes later by Aldrin. The two spent about two hours on the moon's surface, described by Aldrin as

▲ **Witnesses to history:** 600 million people watched the TV broadcast of Neil Armstrong and Buzz Aldrin, from the surface of the moon, talking to President Richard Nixon in the White House.
NASA

◀ **Neil Armstrong**, Michael Collins and Buzz Aldrin ride through New York City during the ticker tape parade in their honor after the Apollo 11 mission.
NASA

"magnificent desolation," collecting rock and soil samples, taking photographs, carrying out the planned symbolic activities, and taking a brief phone call from President Richard Nixon in the White House. Orbiting overhead in the Apollo command module was Collins. Mission Control in Houston reminded him "you're about the only person around that doesn't have TV coverage of the scene"; Collins responded, "That's all right. I don't mind a bit." The televised moon walks were perhaps the first instance of what historian Daniel Boorstin would later characterize as "shared public discovery."

The impact of the Apollo 11 landing was immediate, global and positive. Even today, most people who were old enough to understand what was happening can tell you where they were when Armstrong and Aldrin walked on the moon. Streets around the world were quiet as people crowded around television sets and radios. Newspapers around the world hailed the achievement in banner headlines. Two months after the Apollo 11 crew returned to Earth, the White House sent them on a 39-day, 24-country tour. Throughout their journey, the crew heard over and over the words "we did it," with the "we" being humanity, not just the United States. There was almost universal identification with the moon voyage and admiration for the nation that had carried it out.

### Can there be another "Kennedy moment"?

It is important to recognize the Apollo 11 achievement for what is was — and what it was not. Apollo neither solved the national rivalries of the 20th century by translating a brief transcendent moment into lasting political harmony, nor (at least so far) began the movement of humanity off its home planet. By the way that Apollo 11 was framed, the global reaction was one of excitement and inspiration; the superpower rivalry that had fueled Apollo was pushed to the background. Apollo achieved Kennedy's goal of sending a message of U.S. exceptionalism and power to the world in a way that engaged, rather than threatened, others. While the immediate impact of the lunar landing quickly dissipated, it left a lasting legacy of admiration for the country that could carry off such a feat and a lingering sense of pride among Americans that underpins this year's Apollo celebrations.

The circumstances of Apollo were unique, and for that reason the experience has little to teach us about the conduct of future space endeavors beyond reminding us that once, a half century ago, we did indeed go to the moon. Today's initiative to resume lunar voyages will have to find its own path to success.

More than three centuries before Armstrong and Aldrin left their footprints on the lunar surface, British clergyman, polymath and author John Wilkins wrote: "It is likely enough that there will be a means invented of journeying to the moon. And how happy they shall be who are first successful in this attempt." As we look back on Apollo 11, we should recognize that we indeed are joined in celebrating a "happy" moment in humanity's history. Whatever the future of human exploration of space, that moment is certain to be remembered for centuries to come. ★


JOHN M. LOGSDON
is professor emeritus at George Washington University and has written books on the space policies of U.S. Presidents Kennedy, Nixon and Reagan, including "John F. Kennedy and the Race to the Moon." He founded GW's Space Policy Institute in 1987 and directed it until 2008. He is editor of "The Penguin Book of Outer Space Exploration."

# WOMEN REFLECT ON APOLLO

**There was only one woman in Mission Control when Apollo 11's lunar module landed on the moon; today women make up 34% of NASA's workforce. Debra Werner talked to one of the pioneers.**

BY DEBRA WERNER | werner.debra@gmail.com

**JoAnn Morgan** was the only woman engineer among scores of men listening to Vice President Spiro Agnew congratulate the members of NASA's Apollo 11 launch team in the Firing Room at the Kennedy Space Center on July 16, 1969, after the spacecraft launched.
NASA

When Neil Armstrong first stepped onto the moon, Frances "Poppy" Northcutt wasn't at her desk at NASA's Manned Spaceflight Center, now Johnson Space Center. She was resting up for her job the next day: helping guide the astronauts home.

As the only woman on the Mission Control technical staff to that date, Northcutt was highly visible not simply for her blonde hair and fashionable miniskirts. Most of the women working for NASA or its contractors during the Apollo 11 mission typed letters, sewed spacesuits or assisted the overwhelmingly male engineering staff with calculations and reports.

"There were some extraordinary women who stood out," says William Barry, NASA chief historian. "But for the most part the roles women played at NASA and in many government agencies at the time were secretarial and those sorts of jobs."

Fifty years later, NASA is poised to begin sending astronauts to the International Space Station in commercial crew taxis. This time female engineers, while still in the minority, will share far more of the credit.

At Boeing's Space and Launch Division, chief engineer Michelle Parker oversees the engineering team building CST-100 Starliner, the crew capsule scheduled for an October flight debut. Aerospace engineer Melanie Weber leads Starliner's launch-pad team, and Starliner's crew and cargo accommodations subsystem. Weber appreciates the mix of men and women working on Starliner after college courses in which she was sometimes the only woman in a class of 200. "Being female and Hispanic isolated me even more," she says.

▲ **NASA biomedical** engineer Judy Sullivan was one of the people who kept track of astronauts' respiration, body temperature and heartbeat through small sensors attached to their bodies, including the Apollo 11 crew.
NASA

▲ **Frances "Poppy" Northcutt**, left in her early NASA days. Right, she talks about her role at the agency during a panel discussion of the PBS documentary "Chasing the Moon," which premieres July 8-10.
LBJ Library/Jay Godwin

SpaceX, NASA's other Commercial Crew contractor, did not make anyone available for interviews, but Gwynne Shotwell, the company's president and chief operating officer and a mechanical engineer by training was recognized by Women in Aerospace with its outstanding achievement award in 2012 for her "extraordinary technical and business sense with a charisma and passion for space, education and advancement of sciences."

Jessica Jensen directs mission management for the Dragon vehicles, including the cargo and crew versions. Crew Dragon could fly for the first time with crew by the end of this year.

Women still make up only 34% of NASA's 17,373-person civil servant workforce and 28.4 percent of space agency employees are not white, according to NASA's Workforce Strategy Division and Office of Diversity and Equal Opportunity. But that's a dramatic change from the late 1960s, when women comprised about 17% of a staff of 218,000, Barry said. NASA began tracking minority employment in 1970 when 4.7% of civil servants were not white.

As the only woman in Mission Control, Northcutt attracted the attention of fellow engineers and media coverage. She was featured in Life magazine and Paris Match, the French weekly magazine. "I always felt that as a woman, I needed to prove myself more because people were watching," she says. "I also felt the media coverage was an opportunity to get a message out to other women and to girls that women could do these jobs."

A graduate of the University of Texas with a bachelor's degree in mathematics, Northcutt took a job with NASA contractor TRW Systems Group

▲ **Katherine Johnson, shown in 1968,** has become world renowned as one of the black women whose work was at the heart of many NASA achievements. She has a doctoral degree in mathematics, and her calculations helped synch Apollo's lunar lander with the command module. Her professional life was a focus of the book and movie "Hidden Figures." President Barack Obama awarded her the Presidential Medal of Freedom in 2015.
NASA

in 1965 as a computress, a title like "computer" given to women who performed complex calculations. By the time Armstrong, Buzz Aldrin and Michael Collins traveled to the moon in July 1969, TRW had promoted Northcutt to an engineering role. Beginning with Apollo 8, she led a trans-Earth injection team, plotting the command module's optimal trajectory on its return trip, tracking its progress in flight and revising the engine firing schedule if necessary to ensure the spacecraft would enter Earth orbit at the proper angle to splash down within range of U.S. Navy recovery ships.

Northcutt was still working for TRW in the early 1970s as she became increasingly involved in the women's rights movement, inspired primarily by demands for equal pay, and in 1978 when she attended night school at the University of Houston Law Center. After graduating in 1981, Northcutt worked in the district attorney's office prosecuting domestic violence before becoming a criminal defense attorney. "I'm semiretired at this point," Northcutt says, "but I still do a lot of work for women's rights. My experience in the space program illuminated that for me."

IN THEIR WORDS

## Elaine Denniston

*Keypunch operator for Apollo Guidance System Data at the MIT Instrumentation Lab (now Draper Laboratory)*

I punched the cards that eventually were turned into the program for the guidance system for the Apollo project. Punching cards is punching cards whether you're in an insurance company or working on the Apollo project. The programmers would give me 11-inch by 17-inch sheets of paper. They would write the program in blocks. My job was to keypunch it onto the cards. Remember, direct access to computers didn't happen back then. After I'd been doing it for a while, I could spot a missing symbol and say, "Should you have that?" They would say, "Yeah. Thanks." I was known for that and for telling them to get their programs in on time.

**Denniston became a** lawyer following her role punching computer cards during Apollo.
NASA

## Mary Gene Dick

*Secretary to the deputy director Mississippi Test Operation now Stennis Space Center)*

I did whatever needed to be done: type something up, run a letter, make travel arrangements, take somebody to the airport. We were on a mission to do the biggest exploration mankind had ever done, and it was thrilling. My husband and I were invited to the launch at Cape Canaveral. When we saw it was a good launch, I cried, I sang. I wanted to wave my American flag and sing "God Bless America." We were on our way to the moon.

**Mary Gene Dick** meets astronaut Fred Haise, who flew on Apollo 13.

NASA

"My husband and I were invited to the launch at Cape Canaveral. When we saw it was a good launch, I cried, I sang. I wanted to wave my American flag and sing 'God Bless America.' We were on our way to the moon."

**Mary Gene Dick**, a secretary at the Mississippi Test Operation, now NASA Stennis.

## Frances "Poppy" Northcutt

*Apollo 11 engineer*

You can't communicate directly with the spacecraft when they are doing their maneuver, and you don't have any tracking because it's on the backside of the moon. You don't know whether the maneuver went well or didn't go well. You lose signal for about 30 minutes. Bad things can happen if they overburn or underburn or the burn doesn't start on time. When they come around, it takes a few minutes for folks to tell you where the spacecraft is. Is it where it's supposed to be? If it's not, you might have to act quickly to get the information up there to correct their trajectory. Their onboard computer didn't have nearly enough capacity to compute trajectories.

## Saydean Zeldin

*Apollo software engineer, MIT Instrumentation Lab (now Draper Laboratory)*

I started as an engineer working on Apollo guidance. The astronauts knew it as P40 [software] because that's what they would key in when they wanted to burn an engine. I had to figure out the change in trajectory, when to burn an engine and how long it should burn. I did the programming for the Apollo computer and for the simulator, which used a very sophisticated compiler that could use matrix and vector equations. Every time you would key in a matrix times a vector, you had to use three punch cards: one for the exponent, one for the mainline and one for the postscript. I had three daughters. I would work all day, come home late in the afternoon, let the babysitter go, have dinner and go back to the lab.

**Zeldin** circa 1969

DRAPER

# TAKING INSPIRATION FROM APOLLO

## The art of the impossible

Generation Z has some big science and technology goals in mind, from stopping climate change to going to Mars. Much of this zest can be traced to the Apollo 11 landing. Morgan Kopecky, a 2019 high school graduate and aspiring engineer, explains.

BY MORGAN KOPECKY

MORGAN KOPECKY graduated in June from Woodbridge High School in Irvine, California. She will be a freshman at the University of California, Los Angeles, where she will study engineering.

With the benefit of hindsight, I now know that the moon landing on July 20, 1969, made it possible for me, a 17-year-old California girl, to discover her passion for space. I didn't always know that I was interested in space or even STEM. I knew of the moon landing from history class, but I was not an Apollo wonk. In fact, I never felt a true connection to space until my freshman year in high school.

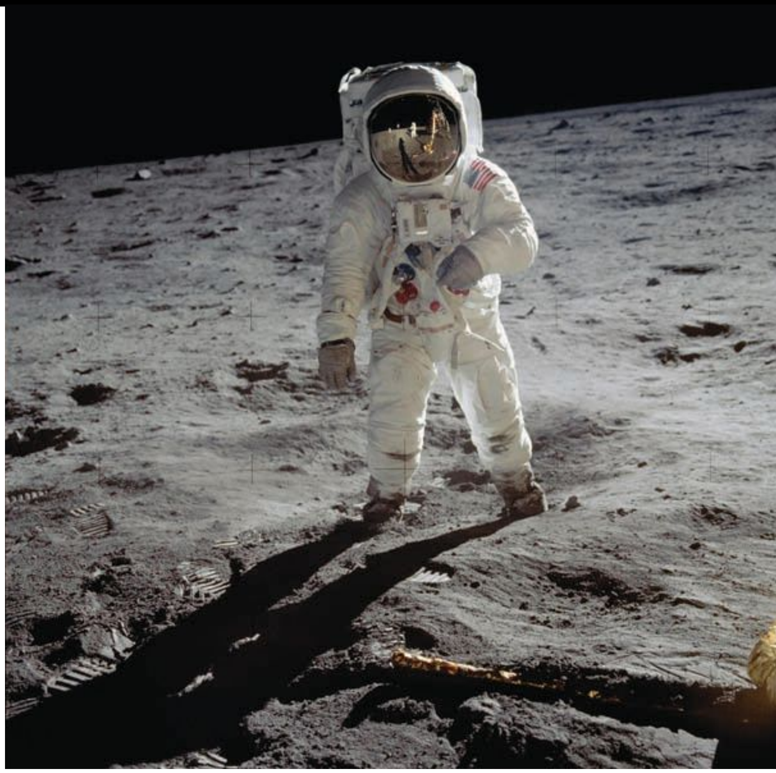
I was sitting in my biology class when a teacher walked into the classroom to pitch a new program that our school was going to participate in called Irvine CubeSat. The six high schools in my school district would work together to build and launch nanosatellites called cubesats. This teacher spoke about how we would have the opportunity to work with professional scientists and engineers from around the world and how we would be launching our satellites into space. I was 14 years old at the time and had next to zero experience in science, but I decided to try out for our school's team anyway. When I opened my acceptance email a few weeks after applying, I was excited. Looking back four years later, I could not have comprehended the ways that this opportunity would change my life.

I did not realize it at the time, but without the moon landing and work of thousands of brilliant scientists before my generation, the opportunity to build cubesats would not have come about, especially for high school students. Through this program, I have assembled satellites, spoken to NASA scientists and tracked cubesats in space. I built relationships with my team, our mentors and experts in industry. But the moon landing means so much more to me than the actual opportunities that it has provided for my classmates and my generation.

When I spoke at the 2019 Goddard Memorial Dinner, I stated, "Space is not generational," meaning our triumphs belong to no single generation. Space unites the generations. The greatest generation watched the moon landing, baby boomers remember where they were when the space shuttle Challenger was lost, and my generation, Generation Z, watched online as Falcon 9 stages flew back from space. When Generation Z thinks about space, we are excited about going to Mars. We cannot wait to watch rocket launches, and we understand the importance of using satellites to monitor climate change. These are things that everyone can be excited about regardless of their scientific background. The moon landing has made all this possible, even though not everyone lives and breathes the details of the historic mission.

For this essay, I spoke to my high school classmates who possess a large range of interests. Whether my classmates aspire to be engineers or are non-STEM majors, everyone said they found meaning in those grainy black and white images from 50 years ago. We realize that when President John F. Kennedy promised to put a man on the moon in 10 years, he did not know how we would get there. We did it anyway. No two of my classmates are the same, but one thing that unites us is that we each have a professional passion. Many of us are interested in technology, and we want to change the world. Our can-do attitudes, undying need to explore and desire to do the seemingly impossible were born on July 20, 1969.

When I asked my high school friend Rohan Go-



rajia what the moon landing meant to him, he said, "I was not alive for it, but it helped show me that the technology at your disposal is not what is holding you back. It is the will to work hard for what you are trying to achieve." When I asked my Russian friend Vasily Tremsin, he told me, "It serves as a guide for my own life, and drives me to do the next big thing that may seem undoable or impossible." And when I asked my art-oriented 13-year-old sister, Ava, she said, "It inspires me to achieve my own dreams."

▲ **Buzz Aldrin** walks on the moon in this photograph taken by Neil Armstrong.
NASA

Apollo 11 affects our cubesat team too. We have a running joke that goes: "If we can put a man on the moon, we can arrive to our meetings on time … get our cubesat's communication radio system to work … figure out how to code" and so on. We laugh at these jokes, but we also find motivation in them. Putting a man on the moon was the greatest generation's "impossible." Our team's "impossibles" are balancing our homework so we can get to meetings on time, solving issues with our radio even when we can't find a solution in the manual and learning new programming languages. If our past generations can achieve their impossibles, we can certainly achieve ours.

The events of the first moon landing may live half a century in the past, but its influence will undoubtedly carry us into the future. My generation has our fair share of challenges ahead of us. Our impossibles are climate change, bacteria resistance, science education and technology addiction, among other issues. We need our can-do attitudes now more than ever. When I look at the people around me, I see that the moon-landing mentality lives in all of us. My generation is ready to tackle our impossibles, and we have Neil and Buzz to thank for that.

# Curb your disillusionment

**Today's space program is not the space program of the 1960s. True, but the changes are not all bad, says Samantha Walters, a 2015 graduate of the University of Maryland.**

BY SAMANTHA WALTERS

SAMANTHA WALTERS is a space mission planner at the Johns Hopkins University Applied Physics Lab. She graduated from the University of Maryland in 2015 and was an Alexander R. Norris intern at AIAA.

When I was born in 1993, the space shuttle program had been around for 12 years, and launches were almost routine. The push for Mars exploration was still in its early days, and the Curiosity Rover wouldn't launch for almost two decades. As a kid growing up in Woodbury Heights, New Jersey, where there was no real connection to the space industry, from my perspective, there wasn't much happening.

For most of my childhood, I didn't think much about space exploration. Then, as a middle schooler, I saw the movie "Apollo 13" for the first time. That movie, and specifically the scene where NASA engineers dump boxes of random junk onto a table and work together to create a $CO_2$ filter to keep the astronauts alive, showed me exactly what I wanted to be. There was something about the fearless risk -taking, the almost-impossible goals and, of course,

▲ **Deke Slayton,** center, director of flight crew operations, explains to NASA officials how a lithium hydroxide canister aboard the command module could be adapted to remove excess carbon dioxide from the Apollo 13 lunar module cabin. The emergency was depicted in the movie "Apollo 13."
NASA

those stylish short-sleeved white button-downs that completely captivated me. Now, 14 years and a whole lot of studying later, I'm a real-life, grown-up aerospace engineer, working at the Johns Hopkins Applied Physics Laboratory in Maryland on NASA missions to explore our solar system.

In going from a space program superfan to a full-time employee, I have realized that the Apollo-era NASA that I dreamed about is not the same agency that exists today. Rapid technology development has been slowed by shrinking budgets and increased risk aversion. Without leaders like John F. Kennedy to rally support for human spaceflight, opportunities to work on such missions have decreased. Plus, I've never once been offered a cigar in a control room.

I love my work, but I spend most days behind a desk, writing computer code and responding to emails; a stark contrast to the slide-rule-carrying, astronaut-saving engineers I saw in "Apollo 13." I find myself feeling somewhat disillusioned, but I'm not the kind to accept disillusionment.

To better understand this feeling and see if my millennial peers had a similar perspective, I called a friend who helps to develop future human missions to Mars. He has greater natural optimism than I do and generally disagreed with the idea that today's space industry is less exciting than that of the 1960s. He pointed out that the Apollo missions were extremely risky — maybe too risky by today's standards — and that increased cautiousness means more safety for future astronauts. He asserted that engineers who work with missions to the International Space Station probably feel similar excitement and intensity to the Apollo engineers we look up to. I'm not sure if I agree with him, but neither of us knows anyone working on current human missions to ask. If there are any ISS engineers reading this, I'd love to know what you think!

Our talk got me thinking about the many reasons that I am lucky to be a part of today's space industry, not the least of which is that, because I am a woman, I probably would not have been an Apollo engineer. My options would have been, in a best-case scenario, to work as a human computer or a secretary. But most likely I could have been a housewife to a NASA engineer. Since joining the workforce in 2015 initially at NASA, I have had more bosses who were women than men. I have had the privilege of working with people of different races, sexual orientations, ages and nationalities who have each brought their unique perspectives to the industry. This is a welcome change from the wall of white, cisgender, middle-aged men who can be seen in most photos from the Apollo era.

Diversity has also increased with the advent of international and private-industry collaborations. Some large missions involve dozens of collaborators, including universities, international space agencies, private companies and research centers like APL, where I work. Payloads are launched on Russian rockets, or more recently by SpaceX. While reliance on foreign and private entities is sometimes seen as a negative, I am excited to be working in a time when space exploration is encouraging international cooperation instead of Cold War-era competition. In the 1960s, the fear of falling behind drove our innovation in human spaceflight. Today, human missions to places like Mars will be made possible by global collaboration and will be celebrated as human achievements, not just American ones.

With the lowered focus on crewed missions beyond low Earth orbit to explore our universe, NASA has focused its efforts on robotic exploration. While landers and orbiters don't often inspire the public to crowd around their TVs the same way the Apollo landing did, spacecraft are going farther for less money and without risking human lives. Advances in space robotics have allowed us to discover water on Mars, dive through the rings of Saturn and fly past Pluto on interstellar trajectories. While putting footprints on Mars is still further off than we might like, I'd argue that rover tracks are a pretty good start.

For better or worse, the space program of today looks a lot different than it did in 1969. Sometimes, while sitting behind my computer on my fourth conference call of the day or reading through what seems like thousands of mission requirements, I wish NASA could be like it was then. I wish things moved a little faster, or that we had a little more funding, or that I could sit around a table and try to "put a square peg in a round hole" and save some astronauts like the engineers in "Apollo 13." My peers and I may never get to experience the magic of the Apollo era, but we're creating our own, through innovative technologies and international collaboration, in workplaces that are more diverse than ever before. I'm confident that before I retire, I'll get to witness, and even be a part of, a few more giant steps in the exploration of our universe. Maybe I'll even get my first celebratory cigar (in a designated outdoor smoking area, of course). ★

# 1969

**July 2** NASA announces that the Apollo 11 astronauts will leave three items on the lunar surface to commemorate their planned landing on the moon: 1) a small silicone disc carrying statements by Presidents Eisenhower, Kennedy, Johnson and Nixon on the goal of achieving a manned moon landing, goodwill messages from the leaders of 73 countries, a list of names of leaders of Congress responsible for NASA legislation, and the names of NASA's top managers past and present; 2) a small American flag on an aluminum staff; 3) a plaque with images of the Earth's Western and Eastern hemispheres, an inscription and date commemorating the lunar landing, and the names of the Apollo 11 astronauts and President Nixon, to be left on the lunar module descent stage. NASA, **Astronautics and Aeronautics, 1969**, p. 196.

**July 16** At 9:32 a.m. EDT, the Saturn V booster rocket lifts off from Launch Complex 39, Pad A, at the Kennedy Space Center in Florida in the first manned mission to land on the moon. The astronauts on this Apollo 11 mission are commander Neil Armstrong, command service module pilot Michael Collins and lunar module pilot Buzz Aldrin. They first enter into a circular parking orbit around Earth at 118.5-mile (190.7-kilometer) altitude. After 1½ orbits, the S-IVB third-stage engine pushes the spacecraft onto its trajectory toward the moon. About 30 minutes later the command service module, named Columbia, is separated from the spent third stage and is turned around; it docks with the lunar module called Eagle, still attached to the stage. The combined modules are then ejected, and the spacecraft heads for the moon. NASA, **Astronautics and Aeronautics, 1969**, p. 212.

**July 19-20** The joined Apollo 11 spacecraft passes behind the moon, then fires its service propulsion system engine to enter into a lunar orbit. During the 30 orbits that follow, the crew sees passing views of their planned landing site in the southern Sea of Tranquility. NASA, **Astronautics and Aeronautics, 1969**, p. 212.

Apollo 11 crew, from left, Neil Armstrong, Michael Collins and Buzz Aldrin.

**July 20** Armstrong and Aldrin enter the lunar module called Eagle and start the final preparations for a lunar descent. Eagle fires reaction-control-system thrusters to separate it from Columbia. Collins, the command service module pilot, remains alone aboard Columbia and continues to orbit the moon. He also observes that the landing gear on the Eagle is correctly deployed. Finally, at 4:18 p.m. EDT, the Eagle lands safely on Tranquility. Armstrong reports to Mission Control at the Johnson Space Center: "Houston, Tranquility Base here. The Eagle has landed." NASA, **Astronautics and Aeronautics, 1969**, p. 215.

**July 21** A record TV audience of 600 million people watch Apollo 11 commander Neil Armstrong climb backward down a ladder from the Eagle and, after describing the lunar surface dust as "very fine-grained" and "almost like a powder," at 02:56:15 a.m. EST, or 6½ h½ours after the landing, he steps off Eagle's footpad and declares: "That's one small step for man, one giant leap for mankind." Nineteen minutes later, Aldrin joins him, and they spend 2¼ hours outside the spacecraft, collecting 21.5 kilograms of lunar material including core samples to bring back to Earth, shooting photos and deploying passive seismic, solar wind composition and laser ranging experiments. Their experiments outside the Eagle include Aldrin walking, running and leaping to assess mobility on the moon. Following their 21 hours, 36 minutes on the lunar surface, at 1:54 p.m. EDT, Armstrong and Aldrin lift off from the moon in the ascent stage of the lunar module and dock with Columbia in lunar orbit to rejoin Collins. They also transfer their moon samples and film and jettison the lunar module ascent stage into its own lunar orbit. NASA, **Astronautics and Aeronautics, 1969**, p. 217; **Flight International**, July 2, 1969, pp. 112-114, 116.

**July 22-24** At 12:55 a.m. EDT, the three Apollo astronauts fire an SPS engine that injects the Columbia into a trans-Earth trajectory. At 12:51 p.m. EDT on July 24, the Columbia parachutes into the Pacific Ocean, 24 kilometers from the recovery ship USS Hornet. NASA, **Astronautics and Aeronautics, 1969**, pp. 222-223.

# LEARNING FROM THE

No one knows with certainty what mix of factors brought down two of the world's most sophisticated passenger jets. The final accident reports from the Lion Air and Ethiopian Airlines crashes are still being drafted. Jan Tegler looks at how the crews might have been able to save their aircraft from all that was working against them.

▲ A Boeing 737 MAX shortly after the FAA originally certified the aircraft for commercial service in March 2017.
Boeing

BY JAN TEGLER | wingsorb@aol.com


The emergencies came to light with eerily similar calls to air traffic controllers. "Flight control problem," the first officer of the doomed Lion Air jet reported after requesting permission to enter a holding pattern. "Having control problems," the first officer of an Ethiopian Airlines jet radioed four months later.

The crashes of these 737 MAX 8 jets killed 346 passengers and crew members and sparked months of investigations, public criticism of Boeing and the FAA, and analyses of actions by the captains and first officers.

In this article, we look specifically at the performance of the crews as they struggled mightily against the Maneuvering Characteristics Augmentation System, or MCAS. Boeing had developed this software to automatically compensate for the tendency for the MAX's nose to rise because of its engine placement.

With only preliminary accident reports released so far for each accident, it is too soon to identify all the lessons that these tragedies might eventually hold for air safety in the age of partial automation. But constructive observations are starting to be made, and they center not just on faulty technology and questions over FAA certification of the MAX, but also on pilot training for handling emergencies caused by automation.

### Harrowing scenario

Whether the loss of control in these accidents was indeed recoverable, as some experts contend, a long list of factors was working against the pilots. The emergencies began when one of the two angle-of-attack sensors on each jet failed, investigators say. These metal vanes pivot with the wind to measure the angle between the oncoming air, called the relative wind, and the aircraft, specifically the fuselage in the case of the MAX. Raise the nose too high, and the aircraft loses lift and stalls. That's what MCAS was programmed to watch for. When it received the faulty AoA readings, it commanded the horizontal stabilizer on the tail to rotate its leading edge upward to trim the nose down.

Compounding matters for the Lion Air captain and first officer was that they almost certainly did not know that a new piece of software called MCAS was aboard and operating in the background. Hence the mystified tone of the communications from the cockpit. Only after Lion Air crashed did Boeing and FAA inform its customers of the existence of MCAS, and even then the information dribbled out. On Nov. 6, Boeing issued a bulletin to MAX customers warning that a faulty AoA reading could trigger the aircraft's pitch system to push the airliner's nose down. FAA followed on Nov. 7 with an Emergency Air Worthiness Directive. Neither of the notices identified MCAS by name. That did not happen until Nov. 11, when Boeing sent a message to customers naming MCAS as the system that caused the Lion Air jet to dive repeatedly.

U.S. pilots were as surprised as anyone about the existence of MCAS, and some voiced their outrage to Boeing. The Dallas Morning News reported in May that members of the Allied Pilots Association, the union for American Airlines pilots, grilled Boeing representatives a few weeks after the first crash about why pilots were not informed of the existence of MCAS.

At the Nov. 27 meeting, Boeing "categorized [MCAS] as just another control law, nothing to


**Boeing 737 MAX 8**

Stephen McParlin

worry about," says Dennis Tajer, an airline pilot and chairman of the union's communication committee who attended the meeting. "Obviously, that first incident [the Lion Air crash] proves different. The second one solidified that [MCAS] is a powerful and deep system."

I was not able to obtain the MAX crew manual, but Tajer says MCAS is referred to only once, in a list of abbreviations. Boeing cautions that any "media reports that we intentionally withheld information about airplane functionality from our customers are simply untrue."

### Taking control

Matthew Menza, a former Boeing 737 production test pilot, said the responses of the pilots to the emergencies must be examined, as painful as that might be. He flew several experimental test flights on the 737 MAX 7, a version that is all but identical to the 737 MAX 8 versions that crashed, and dozens of MAX production test flights before leaving Boeing in July 2018.

In Menza's view, the pilots did not need to know the underlying cause of the problems they were experiencing to save their airliners. "It doesn't matter if it was a short circuit in a trim motor or MCAS or a problem with the wiring," he says. "The only thing that matters as a pilot is the simple situation before you. The airplane is pitching down, the airplane is pitching up. I did not tell it to do that. OK, how do we solve that?"

The solution would have been to follow the same procedures for coping with runaway trim, such as when the horizontal stabilizer trims the nose beyond what was commanded.

With me as his hypothetical first officer, Menza shows me how the procedures work. Fast action is required so that the plane does not accelerate to a speed at which it can no longer be controlled.

Our scenario starts with the aircraft flying with its autopilot and auto-throttle engaged, as was the case with the Lion Air and Ethiopian flights.

"Say you and I are flying along and the nose starts pitching down suddenly and I'm fighting it. What was that?!"

Menza in the role of captain tells me, the first officer, that he is going to disconnect the autopilot and auto throttle. "Disconnect, disconnect!" This action removes these features from the control equation. Though the following is not in the crew manual, throttles might also be moved to the flight-idle position to keep the engines from contributing to any acceleration toward the ground.

In the background, MCAS would still be operating at this point because it is separate from the autopilot.

"It's still pitching down! Jan, give me the stab trim cutout — switches now."

What he means is that I should turn off the power to the electric motor that drives the jackscrew attached to the horizontal stabilizer, the control surface that MCAS was errantly rotating upward.

"Got it!" I say.

We can now take manual control of the horizontal stabilizer by winding two large trim wheels on either side of the throttle pedestal. If a malfunctioning motor or faulty wiring had caused the

At the Nov. 27 meeting, Boeing "categorized [MCAS] as just another control law, nothing to worry about. Obviously, that first incident [the Lion Air crash] proves different. **The second one solidified that [MCAS] is a powerful and deep system."**

**— Dennis Tajer**, Allied Pilots Association and American Airlines pilot

runaway trim, we have now removed these factors from the equation. Likewise, even if we did not know that MCAS existed — a situation that pilots say Boeing and FAA should never have allowed to happen — following this protocol would have defeated its command to trim the nose down. There is no off switch for MCAS.

Turning the wheel forward trims the nose up: "Give me forward turns nose-up trim. Now give me two more turns," Menza says.

We have regained control of our hypothetical aircraft.

**Speed became the enemy**

Whether the Lion Air crew last October took any of the previous steps remains unknown. The preliminary report from the Indonesian National Transportation Safety Committee says that about three minutes after takeoff the crew experienced an episode of uncommanded "automatic nose down trim" that lasted for 10 seconds and that in response the "flight crew commanded aircraft nose up trim." About two minutes later, the crew experienced another nose-down episode. This cycle of uncommanded nose down trim and attempts by the crew to raise the nose

▼ **An angle-of-attack** sensor is the bottom piece of metal protruding from the left of this Boeing 737 MAX 8. Faulty readings from such a sensor were among the factors in two 737 MAX crashes.

Southwest Airlines


▲ **Southwest Airlines** owns 34 of Boeing's 737 MAX 8s, more than any other airline.

Southwest Airlines

continued until the crash.

The Ethiopian scenario in March was different in that the crew must have been aware of the Lion Air crash, and probably knew the procedures outlined by Boeing and the FAA to recover from such a scenario. The preliminary report shows that the captain and first officer turned off their autopilot and auto throttle and activated the stab trim cutout switch to turn off the horizontal stabilizer motor. They began manually trimming the nose.

Two events then caught the eye of Rep. Sam Graves, R-Mo., the senior Republican on the House Transportation and Infrastructure Committee and a pilot with an Airline Transport license. Graves discussed his view of the accident during a May hearing. The pilots did not take the MAX's throttles back from takeoff thrust, the report confirms, and the plane accelerated to 930 kph, far beyond the 630 kph maximum operating speed. "That fundamental error appears to have had a domino effect on all the events that followed," Graves said.

With the plane flying so fast, the captain and first officer could not physically pull up the nose with the trim wheel. The report shows that they turned back on the trim motor, but this had the effect of turning back on MCAS. The software pushed the nose down again, and the plane crashed.

Perhaps most tragically, Menza notes that at the outset of the uncommanded nose-down trim, the air speed was well within a range that would have allowed the crews to recover to stable flight and be flown manually thereafter.

"As production test pilots at 15,000 feet and 250 knots [280 kph], we would turn off the stabilizer trim motors and fly the airplane manually with the trim wheels on every flight. The airplanes were absolutely controllable until the pilots got the aircraft into a too-nose-low attitude and then the speed and dynamic pressure buildup simply became too high to overcome."

### Emphasize training

At the May hearing, Graves said the crashes "compound


▲ **A Boeing 737 MAX** trim wheel. The autopilot stab trim cutout switches are at lower left.

my concerns about quality training standards in other countries." He noted that "pilots can master the cockpit's technology, but they must be able to fall back on their training to fly the plane — not just fly a computer."

Earlier, Ethiopian Airlines CEO Tewolde Gebremariam told CNN: "It has been proved that the pilots were well-trained and they have demonstrated they were exercising all of the emergency procedures recommended by the manufacturer and approved by the regulator."

At the same hearing, FAA Acting Administrator Dan Elwell noted that in each accident, one of the two control yokes in the cockpit began shaking and the other did not, facts verified in the preliminary reports. Control yokes or "sticks" are designed to shake this way to alert pilots to pending aerodynamic stall. The stick shaker discrepancy should have been "immediately recognizable" as evidence of a false stall indication, he said. Tajer, of the pilots union, dismisses this contention as "cubicle" thinking rather than cockpit thinking.

Regardless of how the inquiries turn out, Menza stresses that airlines must be certain that their pilots understand MCAS, even if in theory the crews could have regained control of their planes without knowing it was aboard. Boeing has not yet outlined a requirement that pilots receive simulator training before the aircraft returns to flight, but Menza thinks it should be required. He adds that a MAX simulator would not be needed to practice recovery procedures — any current 737 simulator could be used.

"If we can start teaching pilots how to handle non-normal situations, coupling basic piloting skills and basic systems knowledge with proper crew resource management, the outcome of these situations can be much better."

Menza knows it can be emotionally difficult to assess the actions of flight crews who cannot speak for themselves. "Sometimes you have to put your sensitivities aside to have an honest discussion about the realities of what is affecting safety," he says. ★

# Don't forget the robots

**Sending an advance team of robots to the moon before U.S. astronauts arrive in 2024 would provide unprecedented opportunities for joint human-robotic exploration and testing. Gordon Roesler, formerly of DARPA, makes the case.**

**The Atacama Desert** in Chile has the extreme dry climate and intense sun to test potential Mars rovers.
NASA

BY GORDON ROESLER | gordonroesler@gmail.com

In almost every futuristic picture of lunar habitats, you will see robots. This makes complete sense, for it is often said, "Robots should do the jobs that are dull, dirty and dangerous." Many operations on the lunar surface will be all three of those.

Lunar regolith (soil) clings to everything and is abrasive. Pushing piles of it onto a habitat to provide shielding would be dirty, boring work that should not require an astronaut with a doctoral degree in geology. As for dangers, the most dangerous locales are also the most potentially valuable. Topping the list are the permanently shadowed regions or PSRs, the deep craters at the lunar poles that sunlight doesn't enter. These would be highly hazardous for astronauts: Once a new surface spacesuit is developed, it's unclear whether its design will permit operations in the extremely low temperatures of the PSRs. Also, the surface of the PSRs might not be the powdery regolith of the

Apollo missions, but rather unstable terrain. On top of all that, there is no ambient light. That said, the PSRs have allure because they contain water ice, an incredibly valuable resource both for sustaining human presence and for conversion into rocket propellant. We need to get samples back from the PSRs to know how much water we can count on and how easy it will be to extract.

At the moment, when U.S. astronauts return to the moon in 2024, they may not be able to enter the PSRs for safety reasons. But what if robots were available to assist the astronauts in sample collection and to demonstrate how humans and robots work together? This is an issue that NASA can fix with programmatic creativity and help from the industry.

The starting point should be that a robotic advance party cannot become a burden. The 2024 mission has an aggressive schedule. The key challenges of launch vehicle readiness, lander development, gateway development and preparation of new spacesuits are dominating the 2024 planning process. Launching robots with the 2024 lander would increase the propellant requirement unacceptably. As Neil Armstrong said in a pre-Apollo 11 press conference, "If I had one thing to take, it would be more fuel."

Instead NASA should consider incenting industry to use some of the other landers now under development to deliver some robots separately. NASA has chosen nine companies that will be eligible to compete for contracts to land instruments on the moon under its Commercial Lunar Payload Services program, or CLPS. Independently, Jeff Bezos announced in May that for the past three years Blue Origin has been developing its own lunar lander, called Blue Moon. The nine CLPS selectees advertise payload capacity from 35 kilograms, as proposed by Astrobotic of Pittsburgh, to 500 kg as proposed by Moon Express of Cape Canaveral, Florida. The Blue Moon lander would be in a different category, able to deliver 3,500-6,500 kg of payload to the lunar surface.

NASA could, for example, award a monetary prize to the company that can deliver robots to the moon ahead of the astronauts who would meet up with them. Separately from any prize, there would be numerous benefits to companies and investors that step up to this mission. They will become market leaders in the lunar business, delivering proof positive that landers and robots are reliable and efficient. They will gather data about robot performance and the resources of the moon that will empower them to make a business out of lunar resources. In fact, both kinds of data could be the value proposition — NASA could agree to provide exclusive rights to the data gathered by the human-robot team for a certain period of time. Companies that are interested in commercial lunar propellant production will recognize the value of

▲ **NASA tested its K-REX** rover in the Mojave National Preserve in Southern California to mimic a lunar mission.
NASA

this priceless, exclusive information.

The administration's position is that the new lunar activities will be "sustainable." To achieve sustainability, there is general agreement that robots will be critical to long-term, large-scale operations on the moon. But how well will they do their jobs? How easy will it be to control them? How efficient are they? These are important questions for the design of sustainable lunar complexes. NASA should view the 2024 mission as an opportunity to start answering those questions.

In addition to the mass issue, the robots need to be sent to the moon ahead of the astronauts under a separate initiative for several reasons. To avoid any danger to astronauts, the robot-carrying lander or landers must arrive first. At the same time, the robots must be near enough for useful coordinated work. When the astronauts land, they will "meet up" with the robots and go to work. This is a completely new and compelling mission architecture.

What will astronauts use the robots for? First, they can test how well they work on their own and under human control. Three operational modes can be compared for efficiency, speed of operation and accuracy: autonomous, locally teleoperated and remotely teleoperated from Earth. In autonomous mode, robots would be loosely supervised for safety. In the local mode, an astronaut in the 2024 lunar lander would perceive and react to the local environment by steering the robots and directing their robotic arms. This would ensure that the crew could direct meaningful activities, such as sample gathering, even if NASA does not have a surface spacesuit ready by 2024. In the remote mode, the robots would be


▲ **The NASA Ames K10** rover was designed for lunar sample return.
NASA

◀ **KREX-2's tools** for potential Mars exploration include a lightweight, low-power drill (blue).
NASA

**NASA canceled its** Resource Prospector project in 2018, though it says some of the rover's instruments will be tested on the moon. Commercial landers are expected to imitate some aspects.
NASA

Gordon Roesler
managed DARPA's Robotic Servicing of Geosynchronous Satellites program from 2014 to 2018. After leaving DARPA, he helped write the Commercial Lunar Propellant Architecture study and founded the Robots In Space consultancy.

teleoperated from Earth, relying on their onboard sensors to provide situational awareness. Based on my experience with humans controlling robots, my guess is that the astronaut in local control will greatly outperform the remote mode or autonomous mode. Automation would relieve her of constant attention to repetitive tasks, but will not permit her to respond to unexpected opportunities. Importantly, the robots never need approach the astronauts closely enough to represent a hazard.

These operational experiments would provide invaluable data in support of the procedures and tools needed for the sustainable lunar habitat of the future. Perhaps there will even be an opportunity for an astronaut to repair a robot or simulate repairing one.

Joint human-robot operations can also enhance the scientific yield of the 2024 mission. The rate of sample collection will be greatly increased if robots are involved. Images and samples could be obtained from locations too dangerous for astronauts to enter, such as the PSRs. Those images and samples are critical for answering lunar resource questions, such as:

- What is the surface texture, and how well can vehicles traverse it?
- What is the water ice content at the surface, and perhaps deeper?
- What are some key properties of the regolith, such as thermal conductivity, packing density, and cohesion?

Perhaps the 2024 lander could even be equipped with a chemistry lab so that some of the samples acquired by the robot could be analyzed in real time, rather than waiting for analysis back on Earth. This could be particularly important for measuring water ice content — the key resource for sustainable presence at the lunar South Pole. Without cryogenic storage for samples obtained in the PSRs, delaying analysis until samples arrive at Earth could introduce errors into water content estimates.

A robotic meet-up advance mission would greatly enhance the overall mission value but should not be allowed to delay the human mission. The landing would no longer be just about "flags and footprints," but a multifaceted mission that directly supports future sustainable lunar endeavors. It is critical for NASA to add this opportunity into its plans. Aerospace companies, large and small, will leap at the opportunity.

Given the nine CLPS awards directed toward lunar science, it only makes sense to leverage them for additional return from the 2024 and subsequent human missions. The labor to construct future lunar colonies will be dominated by robots — for site development, construction, shielding, resource production and scientific purposes. It's time to figure out how well robots can do these jobs and how best to use them. The five years before humans return to the moon is plenty of time to create and deliver some robotic pathfinders to meet up with our brave 2024 astronauts and give them a hand. ★



# AIAA Bulletin

## DIRECTORY

AIAA Headquarters / 12700 Sunrise Valley Drive, Suite 200 / Reston, VA 20191-5807 / aiaa.org

To join AIAA; to submit address changes, member inquiries, or renewals; to request journal fulfillment; or to register for an AIAA conference. Customer Service: 800.639.AIAA (U.S. only. International callers should use 703.264.7500).

All AIAA staff can be reached by email. Use the formula first name last initial@aiaa.org. Example: christinew@aiaa.org.

Addresses for Technical Committees and Section Chairs can be found on the AIAA website at aiaa.org.

Other Important Numbers: Aerospace America / Karen Small, ext. 7569 • AIAA Bulletin / Christine Williams, ext. 7575 • AIAA Foundation / Merrie Scott, ext. 7530 • Book Sales / 800.682.AIAA or 703.661.1595, Dept. 415 • Communications / John Blackstein, ext. 7532 • Continuing Education / Jason Cole, ext. 7596 • Corporate Members / Tobey Jackson, ext. 7570 • Editorial, Books and Journals / Heather Brennan, ext. 7568 • Exhibits and Sponsorship / Chris Semon, ext. 7510 • Honors and Awards / Patricia Carr, ext. 7523 • Journal Subscriptions, Member / 800.639.AIAA • Journal Subscriptions, Institutional / Online Archive Subscriptions / Michele Dominiak, ext. 7531 • Media Relations / John Blackstein, ext. 7532 • Public Policy / Steve Sidorek, ext. 7541 • Section Activities / Emily Springer, ext. 7533 • Standards, Domestic / Hilary Woehrle, ext. 7546 • Standards, International / Nick Tongson, ext. 7515 • Student Programs / Rachel Dowdy, ext. 7577 • Technical Committees / Karen Berry, ext. 7537

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


**19–22 AUGUST 2019**

## Indianapolis, Indiana

The 2019 AIAA Propulsion and Energy Forum will bring together diverse communities of professionals who work on everything from jet engines, rockets, and deep space propulsion to space habitation, electronic aircraft technologies, and small satellites. AIAA members should register by **2 August** for the best rates!

**aiaa.org/propulsionenergy**

| DATE | MEETING | LOCATION | ABSTRACT DEADLINE |
|---|---|---|---|
| **2019** | | | |
| 11–15 Aug* | 2019 AAS/AIAA Astrodynamics Specialist Conference | Portland, ME (space-flight.org) | 5 Apr 19 |
| 16–18 Aug | Rocket Testing Workshop at Purdue Zucrow Labs | Indianapolis, IN | |
| 17–18 Aug | Applied Model-Based Systems Engineering Course | Indianapolis, IN | |
| 17–18 Aug | Hypersonic Air-Breathing Propulsion: Emerging Technologies and Cycles Course | Indianapolis, IN | |
| 17–18 Aug | Integrated Performance Assessment of Boundary Layer Ingesting Aircraft and Highly Integrated Propulsion Concepts Course | Indianapolis, IN | |
| 17–18 Aug | Missile Propulsion Course | Indianapolis, IN | |
| 19–22 Aug | AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) | Indianapolis, IN | 31 Jan 19 |
| 21 Aug | Aircraft Electrified Propulsion Systems and Component Design Course | Indianapolis, IN | |
| 22–24 Aug | AIAA/IEEE Electric Aircraft Technologies Symposium (EATS) | Indianapolis, IN | 31 Jan 19 |
| 21–22 Sep* | Amelia Earhart Aerospace Summit | West Layfayette, IN (earhartsummit.org) | |
| 26–27 Sep* | CEAS-ASC Workshop 2019 on Advanced Materials for Aeroacoustics | Rome, Italy (https://www.win.tue.nl/ceas-asc) | |
| 21–25 Oct* | 70th International Astronautical Congress | Washington, DC | 28 Feb 19 |

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

## 2020

| | | | |
|---|---|---|---|
| 6 Jan | Class of 2020 AIAA Associate Fellows Induction Ceremony | Orlando, FL | |
| 6–10 Jan | AIAA SciTech Forum | Orlando, FL | 11 Jun 19 |
| 14–16 Jan* | 2nd IAA Conference on Space Situational Awareness | Washington, DC (icssa2020.com) | |
| 25–28 Jan* | Aircraft Noise and Emissions Reduction Symposium (ANERS) | Bordeaux, France (Contact: aerospace-europe2020.eu) | 31 July 19 |
| 27–30 Jan* | 66th Annual Reliability & Maintainability Symposium (RAMS®) | Palm Springs, CA (www.rams.org) | |
| 7–14 Mar* | 2020 IEEE Aerospace Conference | Big Sky, MT (aeroconf.org) | |
| 24–26 Mar* | 23rd AIAA International Space Planes and Hypersonic Systems and Technologies Conference | Montreal, Quebec, Canada | |
| 5–7 May | AIAA DEFENSE Forum | Laurel, MD | |
| 19 May | 2020 AIAA Fellows Dinner | Crystal City, VA | |
| 20 May | 2020 AIAA Aerospace Spotlight Awards Gala | Washington, DC | |
| 25–27 May* | 27th Saint Petersburg International Conference on Integrated Navigation Systems | Saint Petersburg, Russia (elektropribor.spb.ru/en/conferences/142) | |
| 15–19 Jun | AIAA AVIATION Forum | Reno, NV | |
| 23–26 Jun* | ICNPAA 2020: Mathematical Problems in Engineering, Aerospace and Sciences | Prague, Czech Republic (icnpaa.com) | |
| 24–26 Aug | AIAA Propulsion and Energy Forum | New Orleans, LA | |
| 14–18 Sep* | 32nd Congress of the International Council of the Aeronautical Sciences | Shanghai, China (icas.org) | 15 Jul 19 |
| 26–27 Sep* | CEAS-ASC Workshop 2019 on “Advanced Materials for Aeroacoustics” | Rome, Italy | |
| 12–16 Oct* | 71st International Astronautical Congress | Dubai, UAE (mbrsc.ae/iac2020) | |
| 29 Oct–1 Nov* | 37th International Communications Satellite Systems Conference (ICSSC 2019) | Okinawa, Japan (kaconf.org) | 15 May 19 |
| 16–18 Nov | ASCEND | Las Vegas, NV (ascend.events) | |

AIAA Continuing Education offerings

*Meetings cosponsored by AIAA. Cosponsorship forms can be found at aiaa.org/Co-SponsorshipOpportunities.*

# Recognizing Top Achievements – An AIAA Tradition

For over 80 years, AIAA has been committed to ensuring that aerospace professionals are recognized and celebrated for their achievements, innovations, and discoveries that make the world safer, more connected, more accessible, and more prosperous. From the major missions that reimagine how our nation utilizes air and space to the inventive new applications that enhance everyday living, aerospace professionals leverage their knowledge for the benefit of society. AIAA continues to celebrate that pioneering spirit showcasing the very best in the aerospace industry. The following are the awards presented from February 2019 to June 2019.

### Presented at the Airport Planning Design and Construction Symposium
### 20–22 February 2019, Denver, Colorado

Nashville International Airport™

**ACC/AIAA/AAE Jay Hollingsworth Speas Airport Award 2019**

**Nashville International Airport**
Accepting the Award: Robert Ramsey, Chief Operating Officer
*For creatively transforming a nearby quarry into the largest geothermal lake plate cooling system in North America to provide a sustainable source of water for the airport's terminal cooling and irrigation needs.*

### Presented at the 54th Aerospace Spotlight Awards Gala
### 15 May 2019, Washington, D.C.

**AIAA Distinguished Service Award**

**Klaus D. Dannenberg**
Deputy Executive Director (retired)
American Institute of Aeronautics and Astronautics
*For five decades of significant contributions to AIAA that created greatly enhanced value and more meaningful opportunities for the Institute's traditional and evolving constituencies.*

**AIAA Public Service Award**

**Pamela A. Melroy**
CEO, Melroy & Hollett Technology Partners
Director of Space Technology and Policy, Nova Systems
*For excellence in public service to the aerospace community in the United States and world through military and civilian service, spaceflight, engineering, and research excellence.*

**AIAA Lawrence Sperry Award**

**Katya M. Casper**
Principal Member of Technical Staff
Sandia National Laboratories
*For highly significant contributions to the fundamental understanding of boundary layer transition and fluid-structure interactions in hypersonic flows through novel diagnostics with national program impact.*

**AIAA Reed Aeronautics Award**

**Philippe R. Spalart**
Senior Technical Fellow
The Boeing Company
*For contributions in the simulation of complex turbulent flows enabling the prediction and optimization of aerodynamic characteristics of aerospace vehicles.*

**AIAA Goddard Astronautics Award**

**John L. Junkins**
University Distinguished Professor of Aerospace Engineering
Royce E. Wisenbaker '39 Chair in Innovation
Founding Director, Hagler Institute for Advanced Study
Texas A&M University
*For advances in aerospace research and education, for creating an institute for promoting scientific excellence, and for enabling contributions in spacecraft navigation, dynamics, and control*

**AIAA Foundation Educator Achievement Awards**

**Charlotte Cook**
Young Astronaut Specialist
Carver Magnet School
Little Rock, Arkansas
*For bringing STEM practices to our school, district, and community by utilizing AIAA and other resources that open students' eyes to endless possibilities.*

**Patricia Palazzolo**
Gifted Education Coordinator
Upper St. Clair High School
Upper St. Clair, Pennsylvania
*For encouraging students to pursue space- and STEM-related careers through hands-on projects and mentorship.*

**Megan L. Tucker**
STEAM Specialist
Hillsboro Charter Academy
Hillsboro, Virginia
*For inspiring a love of STEAM nationally for scholars and colleagues alike using aerospace education, Megan has a passionate mission for creating an 'Aviation Fascination'!*

### AIAA DEFENSE Forum
### 7–9 May 2019
### Laurel, Maryland

**AIAA Missile Systems Award**

**G. Satheesh Reddy**
Chairman of the Defence Research and Development Organisation
Ministry of Defence, India
*For over three decades of significant national contributions towards indigenous design, development and deployment of diversified strategic and*

*tactical missile systems, guided weapons, advanced avionics and navigation technologies in India.*

**AIAA Missile Systems Award**
**Rondell J. Wilson**
Principal Engineering Fellow
Raytheon Missile Systems
*For exemplary technical leadership and innovation that has significantly advanced the performance and capability of the world's premier Missile Defense Systems.*

## 25th AIAA/CEAS Aeroacoustics Conference (Aeroacoustics 2019)
## 20 -23 May 2019
## Delft, The Netherlands

**AIAA Aeroacoustics Award**
**William J. Devenport**
Professor and Director of the VT Stability Wind Tunnel
Virginia Polytechnic Institute and State University
*For seminal and pioneering contributions in aeroacoustics, particularly in developing new experimental techniques and to the understanding of turbulence and surface roughness noise.*

## AIAA AVIATION Forum
## 17–21 June 2019
## Dallas, TX

**2019 Wright Brothers Lecture in Aeronautics**
**Justin Paines**
Chief Test Pilot
Joby Aviation
*"Turning Flight Control on its Head for the F-35, eVTOL, and Beyond"*

**2019 AIAA Aerodynamics Award**
**Robert Gregg, III**
Chief Aerodynamicist
The Boeing Company
*In recognition of innovations in Aircraft Design through inspirational leadership and technical contributions in the field of Aerodynamic design and advanced concepts.*

**2019 AIAA Aerodynamic Measurement Technology Award**
**Marcus Aldén**
Professor
Lund University
*For wide ranging and pioneering work in developing and applying laser diagnostic techniques, including linear and non-linear approaches, for study of fundamental and practical combustion.*

**2019 AIAA Aircraft Design Award**
**Robert Parks**
Boeing Technical Fellow
Aurora Flight Sciences, A Boeing Company
*For a lifetime of novel and innovative aircraft designs including multiple prototypes and the Odysseus and eVTOL personal air vehicle.*

**2019 AIAA Chanute Flight Test Award**
**David Minto**
Technical Director (retired)
96th Test Group, Air Force Test Center
*For outstanding contributions to the art, science and technology of test flight engineering and the capabilities delivered in support of the nation's defense*

**2019 AIAA Fluid Dynamics Award**
**Hermann Fasel**
Professor
University of Arizona
*For pioneering innovation and leadership for using computational fluid dynamics as a tool for the scientific analysis of hydrodynamic instability mechanisms, transition to turbulence, and active flow control.*

**2019 AIAA Ground Testing Award**
**James Heineck**
Physical Scientist and
**Edward Schairer**
Aerospace Engineer
NASA Ames Research Center
*In recognition of outstanding contributions to the areas of optical measurement technique development and implementation, flow visualization, and high-speed photography across the NASA ground test community.*

**2019 AIAA Hap Arnold Award for Excellence in Aeronautical Program Management**
**Charles Cross**
Chief, Turbine Engine Division
Air Force Research Laboratory
*For exemplary management and technical leadership of the Versatile Affordable Advance Turbine Engines (VAATE) Program to advance turbine engine technology through focused research and development.*

**2019 AIAA Losey Atmospheric Sciences Award**
**Marcia K. Politovich**
Deputy Director for Science, Aviation Application Program (Retired)
National Center for Atmospheric Research
*For her outstanding contributions in atmospheric science research dedicated to continuous improvement in aviation safety in general and in-flight icing in particular.*

**2019 AIAA Plasmadynamics and Lasers Award**
**James A. Horkovich**
Senior Principal Engineer
AEgis Technologies
*For professional commitment and leadership, education and mentoring of scientist engineers, and distinguished contributions to science and innovation of directed energy systems.*

**2019 AIAA Theodor W. Knacke Aerodynamic Decelerator Systems Award**
**Ricardo "Koki" A. Machin**
Chief Engineer for Capsule Parachute Systems
NASA Johnson Space Center
*For excellence in the area of design, test, and certification of human rated capsule recovery parachutes enabling mankind to explore beyond the earth*

**2019 AIAA Sustained Service Award**
Director, Integration and Management Office
NASA Headquarters
*For decades of sustained service to the Institute in the areas of Membership, Technical Activities and Publications at all levels, from the Section to serving on the Board of Directors.*

# News

## SAT IOC Chair visits the Von Karman Institute for Fluid Dynamics

*Dr. Amir S. Gohardani, SAT IOC Chair*

VKI Professor, Dr. Christophe Schram, and Dr. Gohardani at the von Karman Institute for Fluid Dynamics.

The aviation sector faces many significant challenges ranging from improved transportation mobility and environmental protection. With notable objectives to reach specific air transportation goals in response to societal needs, the Advisory Council for Aeronautics Research in Europe (ACARE) recently unveiled Europe's vision for aviation as ACARE 2050. Exploration of radically new ideas is indeed a common measure for identifying potential solutions for visions such as ACARE 2050. One of these ideas specifically refers to aircraft electric propulsion, the theme for a recent lecture series offered by the von Karman Institute for Fluid Dynamics (VKI) in Brussels, Belgium. As the opening session lecturer for this lecture series with prominent speakers from academia, government entities, and industry, it was rather interesting to observe that the technological aspects of electric propulsion were not the only drivers for electric aviation. VKI, a nonprofit international educational and scientific organization, hosting three departments in aeronautics and aerospace, environmental and applied fluid dynamics, and turbomachinery and propulsion recently opened a new window into the societal impacts of electric aviation, which highlighted a myriad of underlying factors including technology, business, and sustainability that guided the environmentally friendly and efficient mobility solutions. Through this visit, the intersection between aerospace technology and society, a core function of SAT IOC was evident. Currently, 15 NATO countries among 28 contribute to the financing of VKI, a world-class institution established in 1956. SAT IOC continuously aims to enable links between the general public and their understanding of aerospace technology and the committee constantly adapts its methods to reach a larger portion of society. Visiting the VKI indeed casted additional light on the impact of experimental, computational, and theoretical research on society.

## Nominations for AIAA Directors Now Being Accepted

The AIAA Council of Directors Nominating Committee (CNC) will compile a list of potential nominees for the open Director positions on the AIAA Council of Directors. This list will include nominees who will be selected to go to the next step of competency review and interview held by the CNC. The CNC will select specific candidates for the open Director positions who will be voted on by the AIAA membership. The final slate of candidates will be publicized by December 2019 for the election that will be held January/February 2020.

Nominations are being accepted for Regional, Integration and Outreach, and Technical Group Directors for the term beginning May 2020–2023. AIAA members may nominate members qualified for the open position by submitting a nomination no later than **1800 hrs EDT, 12 July 2019**.

**Regions coordinate the activities of geographically related sections to facilitate cooperative efforts between the various geographical areas.** A Regional Director shall lead each region. The voting members who belong to that region shall elect the Regional Director for that region. The Regional Director for each group shall be a member of the Regional Engagement Activities Division (READ) as well as a delegate to the Council of Directors. The term for Regional Directors shall be three years and there shall be a limit of the Regional Director serving two consecutive terms. Nominations are being accepted for:

- Region I – North East, Director
- Region II – South East, Director
- Region VII – International, Director

**Integration and Outreach Groups coordinate the activities of related Integration and Outreach Committees to facilitate cooperative efforts between the various professional areas.** An Integration and Outreach Group Director shall lead each Integration and Outreach Group. All voting members shall elect the Integration and Outreach Directors. The Integration and Outreach Director for each group shall be a member of the Integration and Outreach Activities Division (IOD) as well as a delegate to the Council of Directors. The term for Integration and Outreach Group Directors shall be three years and there shall be a limit of the Integration and Outreach Group Director serving two consecutive terms. Nominations are being accepted for:

- Business and Management Group, Director
- Young Professional Group, Director-Elect

**Technical Groups coordinate the activities of related technical committees to facilitate cooperative efforts between the various technical disciplines.** A Technical Director shall lead each Technical Group. The voting members who belong to that group shall elect the Technical Director for that group. The Technical Director for each group shall be a member of the Technical Activities Division (TAD) as well as a delegate to the Council of Directors. The term for Technical Directors shall be three years and there shall be a limit of the Technical Director serving two consecutive terms. Nominations are being accepted for:

- Aviation Technology, Integration and Operations Group, Director
- Space and Missiles Group, Director

To nominate an AIAA member in good standing for the open positions on the AIAA Council of Directors, please submit the nominee's bio and/or CV, history of AIAA activities and/or engagement with other professional societies, and a statement from the nominee of willingness and ability to serve if elected.

Please submit nominations directly to Christopher Horton, AIAA Governance Secretary, chrish@aiaa.org, no later than 1800 hrs EDT, 12 July 2019.

## Call for Papers

**ICNPAA 2020 World Congress:** Mathematical Problems in Engineering, Sciences and Aerospace

**23–26 June 2020**

Czech Technical University (CTU) in Prague, Prague, Czech Republic

On behalf of the International Organizing Committee, it gives us great pleasure to invite you to the ICNPAA 2020 World Congress. Please visit the website (www.icnpaa.com) for all details. This is an AIAA and IFIP cosponsored event.

## MAKING AN IMPACT

# AIAA Educator Achievement Awards

Students in today's classrooms could be the next inventors, entrepreneurs and leaders who help us travel faster, father and safer both on Earth and through space. But first, they need a good teacher.

That's why AIAA created the Educator Achievement Awards in 1997. This year's honorees each received $5,000 for themselves as well as a matching $5,000 for their respective schools, a first for the Foundation, said Jim Maser, AIAA Foundation chair.

"These (teachers) are at the tip of the spear," Maser said while introducing the winners at the AIAA Aerospace Spotlight Awards Gala in May.

The winners are:

- **Charlotte Cook**, Young Astronaut Specialist at Carver Magnet School in Little Rock, Arkansas, for "bringing STEM practices to our school, district, and community by utilizing AIAA and other resources that open students' eyes to endless possibilities."
- **Patricia Palazzolo**, Gifted Education Coordinator at Upper St. Clair High School in Upper St. Clair, Pennsylvania, for "encouraging students to pursue space- and STEM-related careers through hands-on projects and mentorship."
- **Megan L. Tucker**, STEAM Specialist at Hillsboro Charter Academy in Hillsboro, Virginia, for "inspiring a love of STEAM nationally for scholars and colleagues alike using aerospace education, Megan has a passionate mission for creating an 'Aviation Fascination'!"

These premier educators talked about their students, mentors and inspiration at the awards ceremony.

"Just like Haley's comet I strive to leave behind a beautiful legacy," Cook said. "The AIAA Foundation has given me the resources to open students' minds to endless possibilities. Therefore, helping me leave a little bit of myself behind to make a difference in students' lives."

Palazzolo drew upon Shakespeare to thank the audience "for being the stuff dreams are made of, all of you, with all you do—astronautics and aeronautics—have given this teacher a supply of stuff that I've been able to use to encourage my students to pursue their dreams."

For Palazzolo, who has been teaching for 44 years, some of her students have become rocket scientists. She is now "seeing the dreams of yesterday… become the reality of today."

And it all begins in an elementary school classroom, Tucker said.

"They're going to dream of things we can't even imagine and design things we can't even dream. But it needs to start being encouraged today. I truly believe that if the student is motivated, he or she can achieve anything, and aerospace is the perfect motivation. Your attitude truly does determine your altitude."

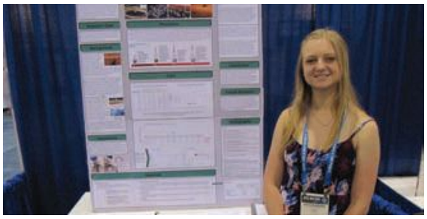
Tucker added, "teaching is ultimately about lighting the fire of lifelong learning and aerospace education is the spark."

For more information about AIAA's educational activities or to make a donation, please contact Foundation Director Merrie Scott, merries@aiaa.org or visit aiaa.org/foundation.


## AIAA "Look Up!" Award

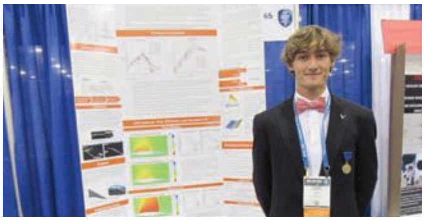
The AIAA "Look Up!" Award, presented at the 2019 Intel International Science and Engineering Fair (Intel ISEF), held 12–17 May, celebrates exceptional high school-level research to courage further study in aerospace. Winners of the AIAA "Look Up!" Award receive a cash award and one year of AIAA student membership with access to all student programs. We congratulate the 2019 winners and encourage students to Look Up! and see their future in aerospace.

**First-Place Award ($2000 award)**
*Using a Computer Program Applied to an Electromagnetic Walking Apparatus to Simulate Earth's Gravity in Space*
**MaryAlice Young**, Bishop Kenny High School, Jacksonville, FL



**Second-Place Award ($1500)**
*Implications for Biogas Energy Use via Methanogenesis in Mars Conditions*
**Alexandria Montgomery**, West Salem High School, Salem, OR

**Third-Place Award ($1000)**
*Development of Predictive Software for the Engineering & Optimization of Reliable Rocket Components*
**Chad Brown and Ryan Pearson**, Woods Cross High School, Bountiful, UT



**Fourth-Place Award ($500)**
*Design and Numerical Analysis of a Novel Co-Flow Jet System to Improve the Lift, Range, and Fuel Efficiency of a Commercial Airline Wing*
**Hans Ehrnrooth**, Pine Crest School, Ocean Ridge, FL

## 2019 Team America Rocketry Challenge

AIAA is proud to be an education partner of the Team America Rocketry Challenge (TARC), which had its National Finals Fly Off on 18 May. The winners were the team from Madison West High School of Madison, WI, and took home the top prize at the nation's largest student rocketry competition. The students from Madison West will represent the United States at the International Rocketry Challenge at the Paris International Air Show in June, facing off against teams from France, the UK, and Japan. Competitions such at TARC are a great opportunity to expose students to the challenges, fun, and comradery that underpins aerospace.



In April, Distinguished Lecturer **Charlie Vono** visited the Western Michigan University Student Branch. The students enjoyed hearing Mr. Vono's stories and were appreciative of his knowledge of the history of the SR-71 and the KC-135Q. "...I thought it was great how Mr. Vono was able to answer most questions with a detailed story. His knowledge ... ranged from general engineering principles to simple life experience. ... I sincerely hope that I remember some of what he said years from now because I really thought he gave us some great advice for life and education."—Aidan Wales, Western Michigan University class of 2021.


Student Activities Chair Jacob Russell thanking Mr. Vono.


The AIAA Athens State University Student Branch hosted a table at the university's Spring Term Transfer Day. (Left to right) Student members Danny Porter, Kathy Williams, Bethany Hammond, and Faculty Advisor Dr. Wayne McCain spoke to other students about upcoming summer classes, Dr. Robert Zubrin's new book *The Case For Space*, and the Management of Technology curriculum.

# 20 TWENTIES

## Tomorrow's Technology Leaders

# Congratulations to the universities that nominated students for this year's 20 Twenties program!

## You're supporting the future of aerospace & defense, and we appreciate you.

Nominated by professors, deans and faculty members, this year's group of 20 Twenties winners came from the following list of top universities. Winning schools are in **boldface**.

- Colorado School of Mines
- Colorado State University
- Columbia University
- **Cornell University**
- Drexel University
- Eastern Washington University
- Embry-Riddle Aeronautical University
- Florida Polytechnic University
- **Georgia Institute of Technology**
- Institute of Aeronautics and Space Studies Blida, Algeria
- Johns Hopkins University
- La Sapienza University of Rome
- Management College of Southern Africa
- **Massachusetts Institute of Technology**
- McGill University
- Ohio State University
- **Purdue University**
- Rochester Institute of Technology
- Rutgers University
- Saint Louis University
- Sharif University of Technology
- **Stanford University**
- Texas A&M University
- The Hong Kong University of Science and Technology
- Tuskegee University
- **University at Buffalo, The State University of New York**
- **University of Alabama**
- **University of Central Florida**
- **University of Colorado Boulder**
- University of Delaware
- University of Florida
- **University of Kansas**
- **University of Maryland**
- University of Michigan
- University of North Florida
- University of Petroleum and Energy Studies
- **University of South Carolina**
- University of Southern California
- **University of Texas at Austin**
- University of Virginia
- **Virginia Polytechnic Institute and State University**
- Washington University in St. Louis

**Make sure your school is involved!** Nominations are now open for the 2020 20 Twenties program.

**Visit aviation.informaexhibitions.com/20-20 to nominate your students — those who are on course to change the future of A&D.**

**For questions please contact:** Carla Sands at Carla.Sands@aviationweek.com.

In Association With:

AIAA

AVIATION WEEK NETWORK

EMBRY-RIDDLE
Aeronautical University

## Faculty Positions (all levels)
## Embry Riddle Aeronautical University, Daytona Beach Department of Aerospace Engineering

The Department of Aerospace Engineering at Embry-Riddle Aeronautical University (ERAU) in Daytona Beach, Florida has an ambitious agenda for the next five years, which is focused on expanding its graduate programs, research capabilities, facilities, and recruiting highly talented faculty. In support of this agenda, the University has invested in a new 50,000 square foot engineering building, the John Mica Engineering and Aerospace Innovation Complex (MicaPlex), housing several research laboratories and a new state-of-the-art subsonic wind tunnel, which were completed within the last two years.

The Department invites applications for three tenure-track/tenured faculty positions at the rank of Assistant, Associate, or Full Professor. Successful applicants for the Assistant rank should demonstrate a potential to establish and grow a strong research program and to excel at teaching and mentoring undergraduate and graduate students. Applicants for the Associate rank should have an exemplary record of teaching and scholarly activities including externally funded research. Appointment at the Professor rank will be considered for individuals with exceptional qualifications and national recognition. We intend to fill these positions as soon as January 2020. The preferred area of expertise is Dynamics and Control with specialization in astronautics and space applications, aircraft and spacecraft guidance, navigation, and control, and unmanned, autonomous aerial systems. However, applicants in all areas of Aerospace Engineering will be considered.

Current research thrust areas of the Department include: astrodynamics, guidance, navigation and control, unmanned and autonomous robotic systems, urban air mobility, computational fluid dynamics, aeroacoustics, rotorcraft aerodynamics, flow control, alternative propulsion, air-breathing hypersonic and rocket propulsion, aeroelasticity, composites, nanomaterials, smart materials, structural health monitoring, computational structural mechanics, and design optimization.

The Department, the largest in the nation with an enrollment of over 1500 full-time students, offers Bachelor, Master, and Ph.D. degrees, including 35 students in our PhD program. The undergraduate program has been ranked #1 by *U.S. News and World Report* for sixteen years. Since 2016, when Department's classification changed to the Ph.D.-granting category, the undergraduate program continues to rank high — #11 among the new peers — and the graduate program is ranked #29 (tied). ERAU, the world's largest, fully accredited university specializing in aviation and aerospace, offers more than 70 Baccalaureate, Master and Ph.D. degree programs in Arts & Sciences, Aviation, Business, and Engineering. ERAU's eastern campus is located at Daytona Beach and serves a diverse student body of approximately 6,000 undergraduate and 600 graduate students.

Candidates should have an earned Doctorate in Aerospace Engineering or a closely related field. Women and underrepresented minorities are especially encouraged to apply. Applicants must submit a single document that includes: (1) a cover letter, (2) a Curriculum Vitae, (3) teaching philosophy, (4) a research plan, and (5) the names and contact information of at least three references. For more information about the position and application process, please visit our careers site - **http://eraucareers.erau.edu** and click in career search to find the requisition. For full consideration, candidates are encouraged to apply before August 15th, 2019. Screening of the applications will start upon receipt and will continue until the positions are filled.



# 1919


**July 2-6** The R-34, Britain's first passenger airship, commanded by Squadron Leader G.H. Scott with a crew of 30, makes the first airship crossing of the Atlantic, from East Fortune, Scotland, to New York. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 10; Francis K. Mason and Martin Windrow, **Know Aviation**, p. 22.

**July 28** The first recorded aerial observation of fish is made at Cape May, New Jersey, by U.S. Navy aircraft in cooperation with the Bureau of Fisheries. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 10.

**July 30** The first flight across South America, from Buenos Aires, Argentina, to Valparaiso, Chile, a distance of 1,280 kilometers, is piloted by Italian Lt. Locatelli. **Aircraft Year Book, 1920**, p. 254.

**Aug. 25** The first daily commercial air service from London to Paris begins. Lt. Eric H. Lawford pilots an Airco DH.4A for Aircraft Transport and Travel Ltd. The trip is 2.5 hours. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 10; Francis K. Mason and Martin Windrow, **Know Aviation**, p. 22.

# 1944

**July 2** The prototype twin-engine Japanese Tachikawa Ki-77 experimental communications aircraft attempts to set an unofficial distance record by flying 19 865-kilometer circuits, 16,435 kilometers total, above Manchuria for 57 hours and 12 minutes. Rene J. Francillon, **Japanese Aircraft of the Pacific War**, pp. 541-542.

**July 5** America's first rocket-powered aircraft, the MX-324, is towed to an altitude of 8,000 feet by a Lockheed P-38 fighter above Harper Dry Lake, California, and released. Pilot Harry Crosby ignites the XCAL200 engine, which produces 890 newtons of thrust, and flies for four minutes before landing. The MX-324 is designed by Northrop and is a technology demonstrator for the company's forthcoming XP-79 interceptor. Ray Wagner, **American Combat Planes**, pp. 145-146.

**July 7** The first air-launched V-1 "Buzz Bomb" is released from under the wing of a Heinkel He 111H-22 with London as its target. Dropping the flying bomb from altitude gives the V-1 an extra 515 kilometers of range as compared with a ground launch. David Baker, **Flight and Flying: A Chronology**, p. 294.

**July 17** Lockheed P-38s attack targets in northern France near St-Lo with drop tanks full of napalm for the first time. David Baker, **Flight and Flying: A Chronology**, p. 294.

**July 29** Damaged while attacking the Showa steel factory in Anshan, Japan, a Boeing B-29 makes an emergency landing in Vladivostok in the Soviet Union. It is the first of several B-29s that are interned by the Soviets during the war because the country is not, as yet, at war with Japan. Stalin orders Andrei Tupolev and his design team to copy the B-29s, which will give the Soviets a much-needed heavy bomber. Less than three years later, the Tupolev Tu-4 flies for the first time, on May 19, 1947. It serves as the technological foundation of future Soviet heavy-bomber designs as well. Yefim Gordon and Vladimir Rigmant, **Tupolev Tu-4: Soviet Superfortress**, pp. 14-27.

**Aug. 4** The first mission of Aphrodite, a radio-controlled B-17 with 9,072 kilograms of TNT, is flown against German V-2 rocket sites in the Pas de Calais region of northern France. E.M. Emme, ed., **Aeronautics and Astronautics, 1944**, p. 47.

**Aug. 4** The Gloster Meteor becomes the first British jet fighter to destroy an enemy aircraft. It flies alongside a German V-1 flying bomb and tips it over with its wingtip, sending the missile crashing to the ground. E.M. Emme, ed., **Aeronautics and Astronautics, 1944**, p. 47;

**Aug. 11** A Messerschmitt Me 262 shot down by a Republic P-47 Thunderbolt fighter becomes the first jet-powered piloted aircraft to be destroyed in air combat. **The Aeroplane**, Aug. 18, 1944, p. 180.


**Aug. 12** Production of the Hawker Hurricane ends. Introduced in 1935, it became one of the most successful fighters of the war. The Royal Air Force's first closed-cockpit, retractable-undercarriage monoplane fighter, the Hurricane was largely responsible for victory in the Battle of Britain in 1940 as the RAF flew twice as many of them than its more famous stablemate, the Supermarine Spitfire. **The Aeroplane**, Aug. 11, 1944, p. 145; F.K. Mason and M. Windrow, **Know Aviation**, p. 170.

**During August 1944**
Berlin radio announces that aviator Hanna Reitsch has been awarded the Iron Cross First Class for flying a V-1 missile and solving problems that could not otherwise be solved. After the war it is learned that she had been testing a manned version of the V-1, being developed as Operation Reichenberg that never became operational. **Flight**, Aug. 3, 1944, p. 126.

**COMPILED BY** FRANK H. WINTER and ROBERT VAN DER LINDEN

# 1969

**July 1** After flying around the moon in Apollo 8, commander Frank Borman travels from New York to Moscow with his family for a nine-day goodwill tour of the Soviet Union at the invitation of the Institute for Soviet-American Relations. The itinerary includes Leningrad, Novosibirsk and the Crimea. **Washington Post**, July 1, 1969, p. A15.

**July 16-24** Apollo 11 mission. See Page 35.

**July 29** The first close-up pictures of Mars taken by NASA's Mariner 6 are transmitted back to Earth by a high-resolution camera. A total of 201 photos are taken, covering about 20 percent of the planet's surface. The closest images are taken from about 3,218 kilometers and show that Mars is heavily cratered and resembles the moon although it is relatively flat. **Flight International**, Aug. 14, 1969, pp. 262-263.

**Aug. 1** The University of California's Lick Observatory records the first hits on a laser reflector left on the moon by the Apollo 11 astronauts. This comes after about 3,000 unsuccessful attempts with Lick's 304-centimeter telescope since there is great difficulty in pinpointing the targets. In these experiments, Lick's scientists fire 500 pulses with a laser beam, each pulse lasting 15-20 billionths of a second. The pulses reach the moon in 1.3 seconds and bounce back at the same time from the reflector target. The value of these experiments is that the distance to the moon is now measured far more precisely than was previously possible. The distance between Earth and the moon is found to be 365,264.2 kilometers or 226,970.9 miles. NASA, **Astronautics and Aeronautics, 1969**, pp. 237, 259, 261; **Aviation Week**, Aug. 11, 1969, p. 31.

**Aug. 4** Scientists at the Lunar Receiving Laboratory at the Johnson Space Center in Houston open the last box of Apollo 11 lunar samples containing charcoal-gray dust and assorted rocks ranging from gravel to the size of an orange. NASA geologist Jeffrey Warner describes the rocks as "different from anything we have on Earth." Two other lab scientists, S. Ross Taylor and Oliver Schaeffer, estimate the age of the rocks from 3.1 billion to 4.5 billion years and postulate that the moon was a twin planet of Earth. **Washington Post**, Aug. 5, 1969, p. A6; Aug. 28, 1969, p. A1.

**Aug. 4-5** Mariner 7 transmits the first close-ups of the Martian south pole as it flies within 3,379 kilometers of the planet. NASA, **Aeronautics and Astronautics, 1969**, p. 265.

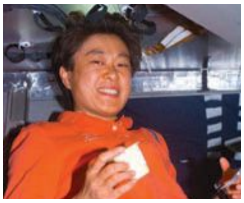
**Aug. 8-14** The Soviet Union's Zond 7 unmanned spacecraft is launched on a mission of further studies of the moon and circumlunar space, to obtain color photography of Earth and the moon from varying distances and to flight test the spacecraft systems. Earth photos are obtained on Aug. 9 while on Aug. 11, the spacecraft flies past the moon at a distance of 1,984.6 kilometers for close-up photography. **New York Times**, Aug. 15, 1969, p. 14.

**Aug. 16** A piston engine aircraft speed record that has stood for 30 years is broken when Darryl Greenamyer flying a modified Grumman F8F-2 Bearcat at Edwards Air Force Base, California, achieves a speed of 770 kph. **Aviation Week**, Aug. 25, 1969, p. 18.

**Aug. 17** Japan launches its largest rocket to date, a four-stage solid-propellant 22.8-meter-long solid-propellant Mu-3D vehicle in a suborbital test flight up to 160 kilometers in 4.5 minutes; it splashes down in the Western Pacific. **Baltimore Sun**, Aug. 18, 1969, p. A4.

**During August 1969** The month marks the 400th anniversary of Mercator's map of the world, published in the German city of Duisburg in 1569 by the Flemish cartographer Gerhard Kremer, known by his Latin name of Gerardus Mercator. The map translated Earth's sphere into a cylindrical map projection in which meridians are mapped to equally spaced vertical lines and circles of latitude (parallels) are mapped to horizontal lines. Mercator projections became standard for worldwide sea navigation and for aviation charts despite distortions of northern latitudes. **New York Times**, Aug. 17, 1969.

# 1994



**July 8** Chiaki Mukai becomes the first Japanese woman in space and Japan's first woman astronaut when she serves as a medical researcher on the space shuttle Columbia, mission STS-65. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 517, 541, 716.

**July 15** Boeing and McDonnell Douglas are awarded a $440 million federal contract to develop new airframe technologies for a potential U.S. supersonic high-speed civil transport. **NASA Release 94-118**.

**July 16-22** Fragments of the Shoemaker-Levy 9 comet strike the surface of Jupiter at 210,000 kph. The Hubble Space Telescope photographs the collision. Scientists estimate that the impact releases an equivalent of 6 trillion kilotons of TNT. NASA, **Astronautics and Aeronautics, 1991-1995**, pp. 544-545.

**Aug. 3** NASA launches a standard Pegasus booster on a modified Boeing B-52 Stratofortress to place an Advanced Photovoltaic and Electronic Experiments spacecraft into orbit. NASA, **Astronautics and Aeronautics, 1991-195**, p. 552.

# BRANDON STILTNER, 33

Guidance, navigation and control engineer, NASA's Marshall Space Flight Center

**A movie inspired Brandon Stiltner to leave his hometown in the Virginia mountains to study aerospace engineering. Now a systems engineer for technical services company Jacobs Engineering Group, Stiltner works at NASA's Marshall Space Flight Center in Alabama, analyzing flight dynamics for the Space Launch System, the heavy-lift rocket designed to transport humans to the moon and Mars.**

### How did you become an aerospace engineer?

The only industry I was exposed to as a child was coal mining. I saw the movie "October Sky" on a school field trip. Homer Hickam, the main character, grew up in a neighboring town. I thought, "He went to college, became an engineer and worked for NASA. If he could do it, so could I!" I attended community college for two years before obtaining bachelor's and master's degrees in aerospace engineering from Virginia Tech, the same school as Homer Hickam, who coincidentally was my commencement speaker. I had two internships. After my junior year, I assembled fighter jet radomes. After my senior year, I designed, built and flew unmanned aircraft for a small R&D company. It was tremendous fun, but my true passion was space exploration. After five years, I took a job with a startup that relocated me to Huntsville, Alabama. After that, I was a Missile Defense Agency contractor for two years before getting an interview at NASA Marshall Space Flight Center. Since 2015, I've been a NASA contractor. I currently work on a Space Launch System team, analyzing vehicle flight dynamics from liftoff to orbit insertion. We analyze all staging events with a high-fidelity simulation. I'm also a member of the guidance and control team for Near-Earth Asteroid Scout, a cubesat that will collect detailed images of an asteroid's surface.

### What do you think will be happening in space in 2050?

By 2050, I think our space frontier will look much different than it does today. I believe there will be a permanent base on the moon, occupied by astronauts from a partnership of nations like the International Space Station is today. I think we'll have begun sending humans to Mars, if not to the Martian surface then certainly on rendezvous-and-return missions similar to the Apollo 8 and 9 missions. I also believe that support structures, potentially including habitat modules, food, water supplies and a Mars-to-Earth return vehicle will be on Mars, awaiting the arrival of humans to the Martian surface. I believe we will have placed several robotic landers or rovers on other bodies within the solar system. In particular, I think there will be landers or rovers on Jupiter's moon Europa and Saturn's moon Titan. I also believe a mission will be underway toward our neighbors orbiting Proxima Centauri. Last but not least, I think we will see a growing presence of commercial activity in space, potentially including harvesting and mining of asteroids. ★

BY DEBRA WERNER | werner.debra@gmail.com

SCI TECH FORUM

6–10 JANUARY 2020
ORLANDO, FL

# DRIVING AEROSPACE SOLUTIONS FOR GLOBAL CHALLENGES

## REGISTRATION OPENS 9 SEPTEMBER

The AIAA SciTech Forum is the world's largest event for aerospace research, development, and technology. The 2020 forum will explore the aerospace industry's role in protecting the planet from degradation, combating climate change, and utilizing sustainable and modern energy for the betterment and prosperity of people and the planet. Start making your plans to attend!

| | STANDARD MEMBER RATE | EARLY MEMBER RATE* 9 SEP–16 DEC |
|---|---|---|
| Full Conference with Online Proceedings | ~~$1,185~~ | **$835** |
| Full-Time Graduate or PhD Student | ~~$200~~ | **$170** |
| Full-Time Undergraduate Student | ~~$95~~ | **$65** |
| Full-Time Retired Member | ~~$95~~ | **$65** |

** Prices are subject to change.*

**SIGN UP FOR ALERTS**
**aiaa.org/SciTechalerts**

AIAA
SHAPING THE FUTURE OF AEROSPACE