June 2015

AEROSPACE AMERICA

FIREDRONES

Unmanned craft could be the edge against wildfires, FAA permitting

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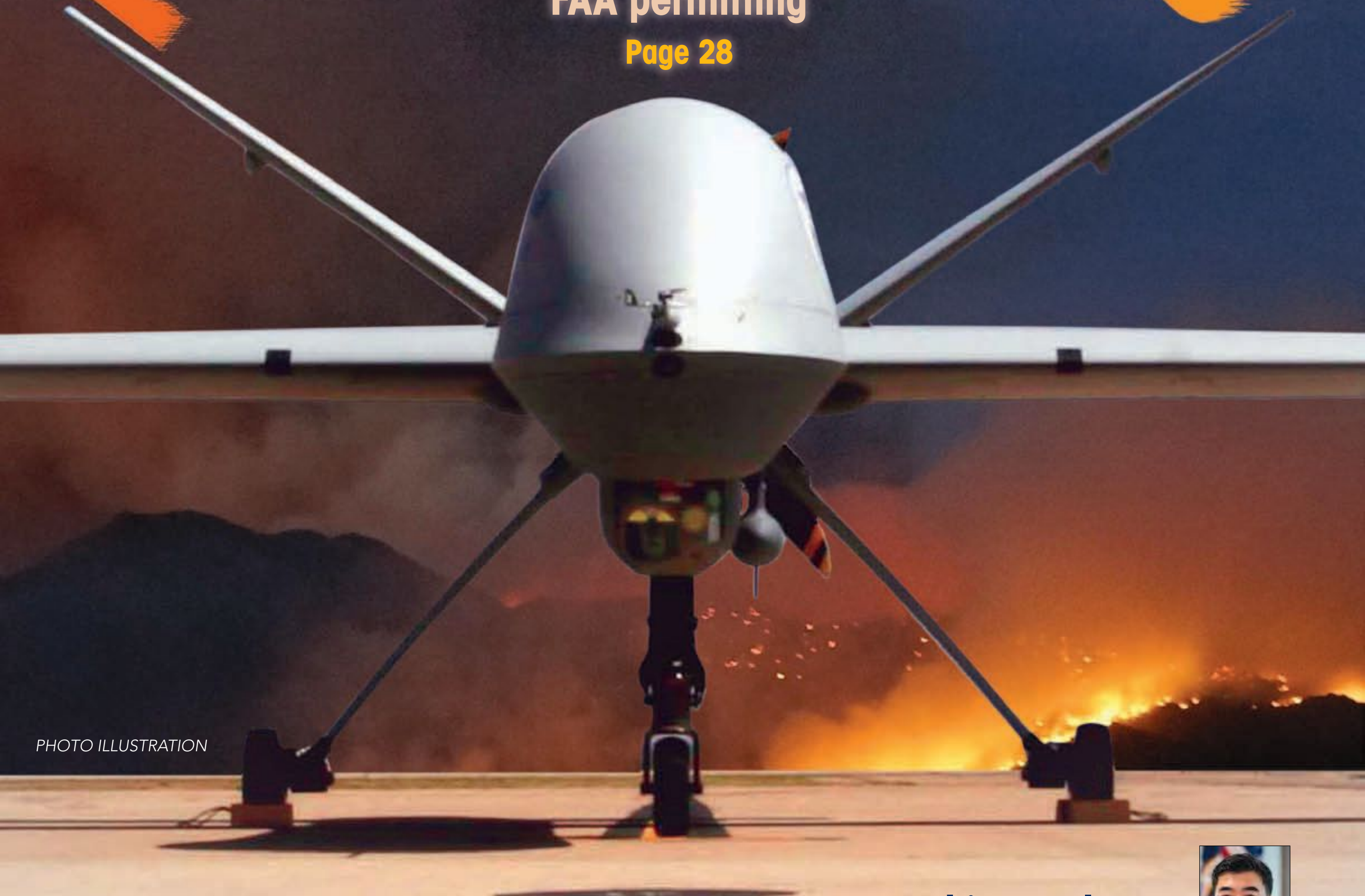

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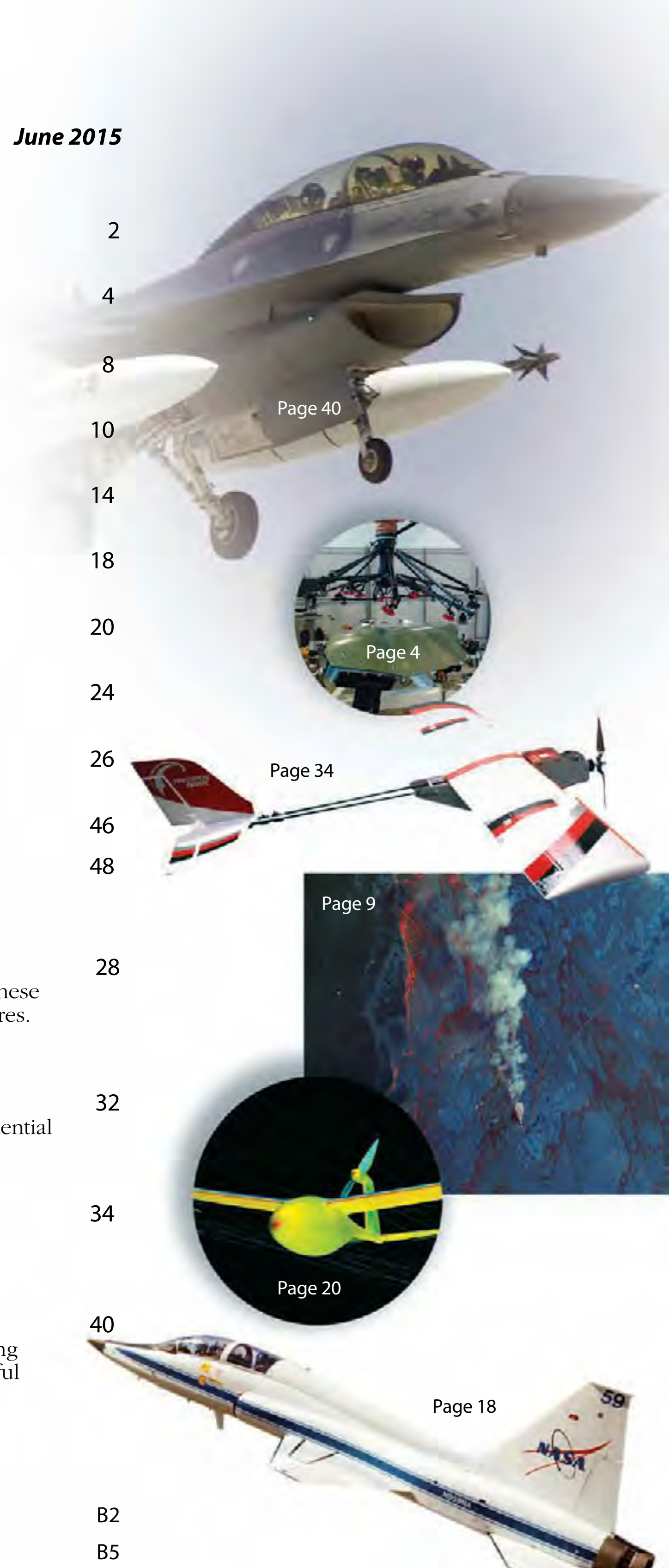

ON THE COVER
An MQ-9 Reaper on a runway with a super-imposed fire image. Photo illustration by Jane Fitzgerald

Aerospace America (ISSN 0740-722X) is published monthly by the American Institute of Aeronautics and Astronautics, Inc. at 1801 Alexander Bell Drive, Reston, Va. 20191-4344 [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 address above, attention AIAA Customer Service, 703/264-7500. Periodical postage paid at Reston, Va., and at additional mailing offices. 40,000 copies of this issue printed. This is Volume 53, No. 6

AEROSPACE AMERICA

is a publication of the American Institute of Aeronautics and Astronautics

June 2015, Vol. 53, No. 6

AIAA
Shaping the Future of Aerospace

Editor's Notebook

What would the Wright brothers do?

I haven't read David McCullough's book about the Wright brothers yet, but our review of it on page 26 got me wondering where the next aviation challenges might lie — and which of them the Wright brothers would choose to tackle if they were young professionals today.

Some of the most challenging work won't involve aerodynamic design breakthroughs like those the brothers achieved with their Flyer, and I bet the Wright Brothers would have embraced that fact and perhaps even chosen to work in areas other than aerodynamics.

Top on the list would be control of unmanned aircraft. Whether a human flies the plane or it flies autonomously by computer, better awareness of the surrounding airpsace and detailed knowledge of the terrain will be necessities. Technologists aren't yet close to achieving the awareness of a human in the cockpit, but our article, "Unmanned — not unseeing," on page 34, chronicles some of the early work in that direction. This technology will be required to clear the way for the low-altitude, consumer aircraft that NASA's Jaiwon Shin discusses in this month's conversation article on page 14.

In "Über Flight Computer," on page 40, we explore automated emergency takeover of airliners as a way to improve safety. Debra Werner reported this story before the deadly Amtrak derailment outside Philadelphia in May, but news reports about it made me wonder: If authorities are in the process of installing computers to keep train engineers from making grave mistakes like entering a corner too fast, which might have happened in this case, would it be so crazy to do something similar for airliners? The topic is a complicated one for airliners, partly because of the oft-discussed cultural reasons, but also because of legitimate questions about computing power and the concept of operations that would be required.

In "Roiling seas? No problem," on page 10, we describe work to figure out the best kind of computer-assistance to help helicopter pilots land on ships.

These issues are Wright brothers-worthy challenges, but that's not to say there aren't amazing aeronautical breakthroughs ahead, too. Should all airliners be of the tube-and-wing variety? Maybe not. Must aircraft have powerful combustion engines to carry meaningful payloads? Almost certainly not.

In this month's Case Study, "Lotus: Two aircraft in one," on page 20, the plane's designer describes an electrically-powered vertical-takeoff-and-landing aircraft whose wingtips morph into propellers for cruise. The Lotus team is not the only one vying to make an electric VTOL aircraft. A NASA team is working on a rival concept called the GL-10 or Greased Lightning, which has rotors arrayed across tiltable wings.

It's been nearly 112 years since Kitty Hawk, and there remains lots of drama ahead, from whose electric aircraft concepts will win to how aviation authorities will settle the appropriate roles of computers on airliners.

Ben Ianno tta
Editor-in-Chief

Europe seeking edge over Far East in composites manufacturing

The speed at which aerospace manufacturers, particularly in the Far East, have gained expertise in manufacturing large composite structures has forced research agencies in North America and Europe to work harder to retain their competitive edge.

The West has historically sought to develop tougher, lighter materials that are ever simpler to manufacture. Demand has been especially acute for alternatives to expensive, energy-hogging autoclaves, the electric composites-curing ovens. Western researchers are also pursuing technologies to more quickly spot faults, trim waste, reduce parts and develop more malleable structures.

A lucrative market is at stake. The research firm Lucintel estimates aerospace composites will reach total sales of $5.9 billion by 2033.

In Europe, teams of industry and academic bodies are collaborating on composites research with government funds. GKN Aerospace, for instance, is working to produce composite box structures — where the wings meet the fuselage — and winglets under a program called VIEWS, for Validation and Integration of Manufacturing Enablers for Future Wing Structures. GKN and 13 partners aim to bring these components to market within two years and shave 20 percent off the cost of producing a typical composite box structure or winglet. National and regional governments have provided about half the financial support for the $44 million (£30 million) program.

VIEWS builds on theoretical models that suggest, for example, that it may be possible to produce a lighter winglet that will require 50 percent fewer fasteners to assemble and take 25 percent less time to attach the wings to the fuselage.

Composite aircraft parts are usually made using a tape-laying process, in which sheets of pre-impregnated fiber-resin are placed layer upon layer to create a laminate in a mold. This is then cured under high pressure in an autoclave to form the final structure. That's expensive and time consuming, so European researchers are testing a curing method that would bypass the autoclave.

For the past four years, researchers have been working under a European Union-funded research program called INFUCOMP to infuse resin in the material after the dry fabrics have been assembled. This Vacuum Assisted Resin Infusion process requires only a simple set of tools to hold the part in place, while vacuum membranes are used to solidify the composite, both reducing manufacturing costs and increasing material shelf life.

Other EU-funded researchers are developing a non-invasive method for checking composites for defects. Later this year, they plan to demonstrate a scanning device that will transmit terahertz electromagnetic waves into a composite material to produce high-resolution images. Terahertz waves range from the far-infrared to the microwave region and can penetrate most non-metallic materials without contacting them. Researchers say the device, unlike some current methods, poses no health risks to system operators.

One of the largest EU-funded aerospace research programs is called the Clean Sky Joint Technology Initiative. The hope is that adding graphene, a carbon material, to resin during the manufacturing process could make composite structures more damage resistant and much lighter.

There still remain major outstanding issues for composite manufacturers to address — not the least being what to do with the material when the aircraft has reached its end of life, as burying or burning it will not be allowed in many parts of the world.

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Boeing

Composites make up more than half of the fuselage weight of the Boeing 787 Dreamliner.

Anxious months for Galileo project

By the end of June, satellites seven and eight of the European Commission's planned constellation of 30 Galileo navigation satellites are scheduled to go into service, according to the European Space Agency, which is testing and commissioning the satellites.

Next year will be crucial for Galileo and satnav services around the world. The constellation is supposed to be filled out enough by end of 2016 to provide more reliable coverage than U.S.-based GPS in high-rise cities and in northern Europe. The Galileo constellation will orbit at a higher altitude than GPS, giving each satellite a wider cone of coverage and increasing the number of satellites that smartphones or other devices can connect to.

Currently, the European Global Navigation Satellite Systems Agency says more than 60 percent of all receivers support a minimum of two constellations. More than 20 percent support all four — the United States' GPS, Europe's Galileo, Russia's GLObal NAvigation Satellite System and China's BeiDou network.

A Soyuz rocket carrying the Galileo satellites lifts off in March from Europe's Spaceport in French Guiana.

The European Commission wants to have 14 Galileo satellites deployed by 2016. That should clear the way for a range of initial services, including free public services for vehicle navigation and mobile-phone location services, an encrypted, publicly-regulated service for government users, and a search-and-rescue service. Two other services will follow: an encrypted, highly-accurate commercial service and a safety-of-life service for rail, marine and aviation network management. These services will guarantee users a minimum standard of availability and accuracy, making Galileo suitable, for instance, for air-traffic management.

According to the 2015 GNSS Market Report, about 6 percent of Europe's gross domestic product depends on satellite navigation services. Until now, those have been based on the U.S. Department of Defense's GPS. Galileo will guarantee Europe's governments and businesses a civilian-controlled satellite navigation system that will provide coverage at latitudes up to 75 degrees north, the most northerly tip of Europe, that GPS can't always cover. It will also open way for European companies to compete in market for chip sets and related software and hardware products now worth $250 billion annually, according to the Global Navigation Satellite Systems Agency.

"The program managers are under immense pressure to deliver this key European project," says David Gleave, an aviation safety technology expert in the U.K. "The longer that Europe relies on pure GPS, then the greater the foothold that U.S.-led companies will gain in the general satellite navigation and accurate timing business areas."

But the European Commission may have trouble meeting its 2016 timetable because of an errant launch last August. A Russian Fregat upper stage released satellites five and six into the wrong orbit. That left them in elliptical orbits where, at their high point, the satellites were flying 25,900 kilometers above Earth but at their low point, just 13,713 kilometers, instead of circular orbit at an altitude of 23,222 kilometers. The European Space Agency's ground staff have nudged them back into the target orbit by activating their hydrazine thrusters so that they no longer dip into the Van Allen radiation belt, which can damage sensitive on-board electronics.

With eight satellites in orbit and four more planned for launch during the rest of this year, program managers will have a much clearer understanding of how Galileo's satellite navigation network likely will perform.

"With more satellites in view, you will be able to derive a Galileo generated position for more hours of the day. This will make it possible to generate the statistics to prove how close the system performance is to the original design," says Philip Church, principal consultant with U.K. aviation consultants Helios.

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Aerospace dollars, defense fears at stake in Iran nuclear talks

Photo by Adrian Pingstone

Iran could be in the market for hundreds of new airliners if a nuclear accord lifts international sanctions on the Middle East's second-largest economy.

If negotiators from six international powers can finalize a nuclear deal with Iran by their self-imposed June 30 deadline, one of the first priorities for Iran after nuclear sanctions lift could be to re-equip its government- and privately run airlines with billions of dollars in new aircraft. But experts say revenue from new large oil exports could also enable Iran to rebuild its military, including its tactical, ballistic missile and unmanned air systems programs.

For aviation companies, Iran's population of 80 million is an enticing market for civil and military aircraft sales and new airport constructions. Iranian airlines will need between 100 and 500 new airliners over the next few years, according to industry estimates. These would replace aging airliners and help Iran meet an expected increase in international air travel once the United Nations Security Council's nuclear sanctions lift.

"Iran is poised to reinvest in a new fleet after 20 years of austerity," says Ian Lowden of the London-based aviation consultancy Infrata. "Its market position and large originating market make it one of aviation's global hot spots."

Others see dollar signs too: "Iran has incredible potential: A $500 billion economy that has been likened to Turkey with oil," according to an October 2014 report by the Sydney, Australia, based Centre for Asia Pacific Aviation.

Iran is the Middle East's second largest economy after Saudi Arabia. Yet its airlines have struggled to modernize and service their fleets in the two decades since U.S.-imposed sanctions banned American trade with Iran, including exports of spare parts and maintenance services for both Boeing and Airbus aircraft. With negotiations underway in April 2014, Boeing and Airbus were permitted to provide a few essential supplies to government-owned Iran Air — including airplane parts, manuals, drawings, service bulletins, and navigation charts and data — but no substantive supplies. Iran Air has acquired second-hand Airbus airliners since 2000 but a lack of spare parts has grounded many planes in the 50-aircraft fleet, which on average are 26 years old. The country has 75 airports but only 30 of these are regularly served, mainly by Fokker F-100s.

Iran attempted to solve the sanctions problem by building its own airliners. Ukraine and Iran signed a deal in 1995 in which Ukranian Antonov AN-140 turboprops were produced under license in Iran by the Iran Aircraft Manufacturing Industrial Co. and rebranded the IrAn-140. But the crash of the only airworthy IrAn-140 on take-off from Tehran in August 2014, which killed 39 passengers and crew, grounded the rest of the fleet.

Iran's military aircraft operators faced similar problems. The United States supplied the Shah of Iran with over 500 variants of the Northrop Grumman F-5, 79 Grumman F-14A Tomcats and 193 McDonnell Douglas F-4s of varying types during the 1970s. But after the Shah was ousted in 1979 the supply of spare parts to support these types quickly dried up. Iran's aerospace sector has focused on developing replacement parts and modifying these old planes, describing them as a new series of combat aircraft based on F-14As and F-5s, when in fact the airframes are modified rather than new. The one entirely new aircraft was supposed to be the Qaher F-313 stealth fighter unveiled to the public in February 2013. Most Western industry experts have written it off as a propaganda exercise rather than a serious attempt at a fifth-generation fighter.

But looked at differently, Iran's aerospace industry has managed to maintain a relatively large fleet of combat aircraft, transports and helicopters, and Iran in March publicly displayed a cruise missile that has gotten the attention of Israel and the United States.

"Iran's aerospace engineers have become excellent at re-engineering equipment, turning surface-to-air missiles into effective surface-to-surface weapons, for example" says Paul Beaver, a defense consultant based in London. "And they have kept a fleet of F-4s and F-14s up in the air, which is quite an achievement, given the constraints under which they have had to work."

The unveiling of the Soumar long-range cruise missile in March 2015 could mark a step-change in Iran's ability to develop and manufacture a long-range cruise missile, some industry experts say.

The missile is modeled after Russia's Raduga Kh-55, known by NATO as the AS-15 Kent, says Douglas Barrie, a senior fellow at the International Institute for Strategic Studies in London. Nevertheless, the missile "shows the technical capacity and capability that Iran has built up over the last three decades," he adds. The expertise extends beyond cruise missiles: "In the ballistic sphere, Iran has a reasonably capable domestic ballistic missile design and manufacturing infrastructure."

Many analysts are now looking at what impact an injection of funds and new components will have on the country's military aerospace sector. One theory holds that Iran will remember how its imported front-line combat aircraft were hampered by sanctions, and so it will try to develop new aircraft in partnership with allies, so that it does not have to rely on imports of spare parts.

"Iran will want to play the role of the informed customer to understand the technology, modify it and put its own weapons on it, play around with the software," Barrie says. "Developing its own combat aircraft is a big ask but Iran might do it in collaboration with China or Russia."

In the unmanned aircraft realm, analysts say lifting trade sanctions could give Iran access to more sophisticated sensors, which could accelerate its ability to make a long-endurance aircraft for both medium and high altitudes. All these factors suggest that while countries in the region might welcome a reduction in Iran's nuclear threat, they might also face an increasingly technologically-capable conventionally-armed neighbor.

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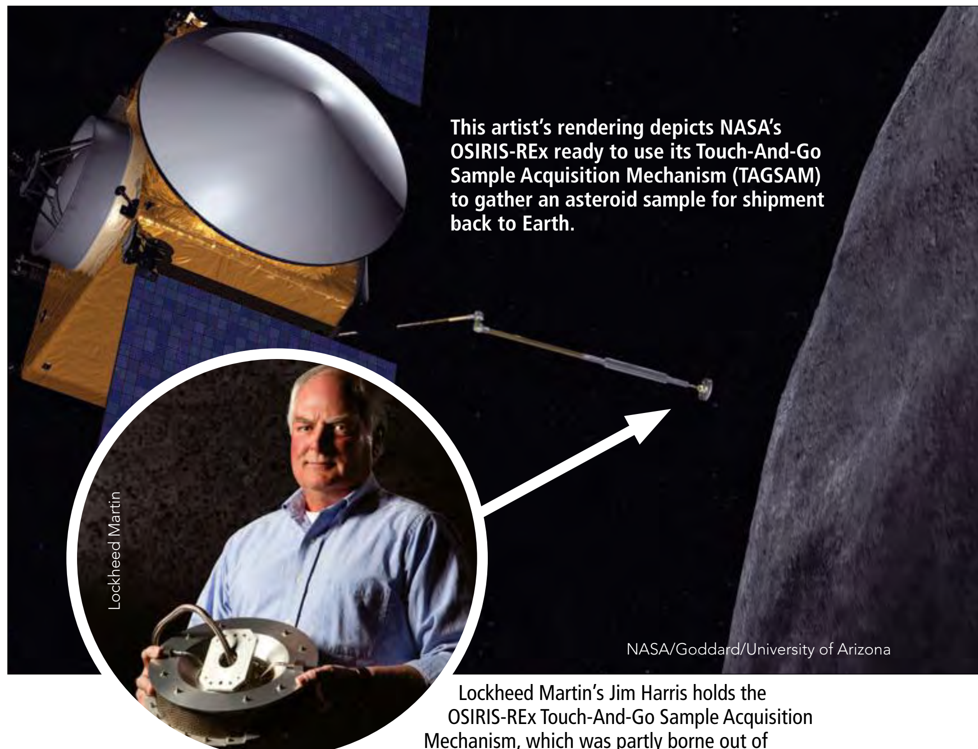
Driveway test paved way for asteroid sampler



This artist's rendering depicts NASA's OSIRIS-REx ready to use its Touch-And-Go Sample Acquisition Mechanism (TAGSAM) to gather an asteroid sample for shipment back to Earth.

NASA/Goddard/University of Arizona

Lockheed Martin

Lockheed Martin's Jim Harris holds the OSIRIS-REx Touch-And-Go Sample Acquisition Mechanism, which was partly borne out of an experiment on his driveway.

The asteroid collection device to be installed in August on the OSIRIS-REx asteroid probe has a surprising backstory.

About 10 years ago, Jim Harris, an engineer at Lockheed Martin Space Systems Co., took part in an internal review focused on ideas about how to robotically grab material from an asteroid, stow it and carry it back to Earth.

At the time, NASA had not yet selected the mission we know as OSIRIS-REx, short for the Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer.

Lockheed engineers considered a variety of sample options for OSIRIS-REx: clam shells, augers, scoops, even propellers at the end of a tube. During the search, Ben Clark, a Lockheed space scientist, gave Harris a paper that Clark had written in December 1986 as a senior staff scientist at what was then Martin Marietta. The document described how a pressurized gas might be released to lift particles off the surface of a celestial body and fluidize the particles into a gaseous mixture. Clark thought this would be a good way to quickly obtain samples for onboard analysis, or to bring back samples to Earth, without having to land on the asteriod. Harris wondered if the method might be adapted to collect regolith — surface dirt — from an asteroid for analysis back on Earth. That's when things took a creative, do-it-yourself turn.

Harris was anxious to give the method a quick trial. "It was just a question of how to do it and how much [material] could be collected," he recalls.

So one weekend, Harris and his son, Jimmy, now a mechanical engineering student at the University of Colorado, went out to his rock-and-dust driveway. His father placed the hose outlet of a home-shop air compressor into a hole at the small end of the cup, and Jimmy pressed the open end over a circle Harris had cut in a large piece of paper laid out on the driveway. When Harris flipped the switch, driveway dirt accelerated out the side holes and fell onto the paper for later measurement. The test suggested that the technique could be used to push particles into a sample container.

"My son knew his dad was a little different. At the time, he was surprised that I get paid to do this kind of stuff," Harris says.

Back at the office, Harris and his space engineering colleagues were intent on building the OSIRIS-REx's Touch-And-Go Sample Acquisition Mechanism (TAGSAM), an articulated arm with a collection head at the end. Before settling on the TAGSAM design, Harris and his co-workers built several prototype collection heads. Sampling head testing was done within a closed container to hold simulated asteroid material onboard a NASA research aircraft — christened the Vomit Comet — to simulate microgravity. Throughout the testing history of TAGSAM, in place of asteroid bits and pieces, all types of materials were used to show-off the ability of the asteroid collection apparatus.

"We've pretty much sampled just about everything you could think of," Harris said, such as lava rock, Mars simulated soil, Styrofoam peanuts, real peanuts, vermiculite, even cheese whiz.

When OSIRIS-REx sidles up to asteroid Bennu in October 2019, TAGSAM will touch the collector head to the surface and spurt out a burst of pure nitrogen gas to push surface regolith into the sampler's chamber. "It's basically over in two seconds," Harris says.

The asteriod collection device will have three separate bottles of gas for three sampling attempts. Harris is banking that if the technique worked in his driveway and on the microgravity plane, and in extensive testing at the company, all will go well at Bennu.

"Some people will be nail-biting but not me," Harris says. "It's going to work."

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U.S. intel agency to shift imagery buying plan

View of the Gulf of Mexico taken by DigitalGlobe's WorldView-2 satellite two months after the Deepwater Horizon oil spill in 2010.

The world's largest customer for commercial satellite imagery is signaling a major shift in purchasing strategy that could pose a challenge to the incumbent supplier and benefit startup companies.

The U.S. National Geospatial Intelligence Agency has been paying about $300 million a year to DigitalGlobe of Longmont, Colorado, for imagery under an annually-renewed contract called EnhancedView, which includes options that run through 2020. NGA also gets priority in decisions about where to point DigitalGlobe's satellites, and it directs some of the funds to help maintain ground stations for fast data delivery.

EnhancedView imagery typically forms the foundation for the digital maps used by troops and intelligence operatives, while government-owned spy satellites zoom in on targets to deliver detail.

Looking ahead, NGA Director Robert Cardillo says the agency is likely to turn to a more varied group of suppliers.

"We are not unhappy with EnhancedView, but we do need to be prepared to think about what's next," Cardillo said in a press briefing at the Space Symposium in Colorado Springs in April. "I would find it not impossible but hard to foresee us going down that path again."

The EnhancedView contract comes up for its annual renewal in August but Cardillo, in an email relayed by a spokesman, said he does not plan to end EnhancedView before 2020. "I see no changes to the current EnhancedView program," he said.

Eventually, though, NGA is likely to explain a goal or pose a question to vendors, rather than buying a set amount of imagery.

"We'll end up writing our requirements in such a way to say 'I don't care how you acquire the information we need. We just want to be the beneficiary,'" Cardillo said in the briefing.

NGA might, for example, ask for help in understanding changing traffic patterns at a foreign port or for daily images of the Horn of Africa, Cardillo said in the email.

NGA is positioning itself to take advantage of a crowded field of startups eager to sell imagery from simpler satellites built with miniaturized electronics and launched relatively inexpensively. Planet Labs, a San Francisco startup, aims to place 150 cubesats in orbit. Google-owned Skybox Imaging has launched two small satellites so far to capture high-definition still imagery and video. UrtheCast, a Canadian company, has mounted two cameras on the outside of the International Space Station.

"It's not just about the pixels anymore," says Keith Masback, chief executive of the U.S. Geospatial Intelligence Foundation, a not-for-profit educational group allied with the intelligence community. "Rather, NGA is looking for information." Masback is also a former director of NGA's Source Operations Group, which matches imagery to national requirements.

NGA wants to learn what the fledgling space companies can do. The agency issued a request for information in May inviting companies to share their collection plans for 2017 and beyond. Cardillo, by email, said the new strategy likely would not end NGA's work with DigitalGlobe. "I expect they will continue to be an important part of this transformation."

DigitalGlobe says it is making changes. "We are unifying our unique collection capabilities and information delivery infrastructure with new and existing sources of commercial and open-source data," says DigitalGlobe spokesman Turner Brinton. "In addition to delivering the highest resolution, most accurate and complete commercial satellite imagery, we provide a range of value-added geospatial and analytic products and services."

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Roiling seas? No problem

Landing a rotorcraft on a ship in rough seas is one of the trickiest feats in flying. Keith Button spoke to Pennsylvania State University researchers who are testing how best to split that potentially hazardous responsibility between pilot and computer.

For more than a year, Joe Horn has enlisted naval test pilots to find a potential solution to one of the hairiest tasks in flying — setting down a helicopter on the deck of a ship in rough waters.

An MH-60 Seahawk takes off from the flight deck of the amphibious assault ship USS Bonhomme Richard.

U.S. Navy

Specifically, Horn, an associate professor of aerospace engineering at Penn State, wants to pinpoint the optimal level of computer assistance for these landings. Today, only the most highly trained and skilled military pilots are allowed to perform these maneuvers, because they are done purely by hand. If Horn's Navy-funded research succeeds, the Navy will have a better handle on the best type of computer-aided pilot controls to build into future helicopters. This could make landings at sea safer, smoother, less nerve-racking and possible for a wider range of pilots. Other service branches could apply the findings to tricky landing scenarios on terra firma, such as in dust clouds or gusting winds.

Computer-assisted pilot controls are standard technology on modern airliners and widespread among fixed-wing military planes, but military helicopters have been a bastion of non-digital flying. In most helicopters, the pilot controls the aircraft with a cyclic stick, a collective stick and foot pedals that are mechanically connected to the rotors' gearboxes through a series of cables, pulleys, levers, weights, push-and-pull rods and hydraulics. Once the shift is made to computer-assisted, fly-by-wire helicopters, which is expected under the Pentagon's Future Vertical Lift program, the controls will be connected electronically to the rotor's gearboxes.

Computers could be programmed to make the aircraft respond more quickly or slowly to the pilot's movements, to accentuate or mask vibrations or G-forces, or even override the pilot's inputs in certain situations. Horn wants to define the software that would best assist pilots landing computer-assisted, fly-by-wire helicopters on ships.

Today, he says, "there's many different control movements you have to do to regulate the helicopter, and that's all fine if you're on a beautiful sunny day and you have lots of room to maneuver and you can see very well. But if you get behind a ship and you're trying to do a very high precision task of landing within a small box on a ship, it's much more difficult."

Horn has been working on this problem since he joined Penn State's faculty in 2000. In his latest research, Horn and graduate assistant Albert Zheng wrote software for different levels of computer-aided pilot controls and asked test pilots to test them on a simulator and rate which were the best.

Rotorcraft have lagged in computer assistance partly because of their complex cockpit layout and control surfaces. Pilots have found it hard to trust the computer's ability to control aircraft that require precise, continuous, coordinated adjustments to execute even a basic hover maneuver.

Among U.S. military rotorcraft, only the V-22 Osprey tilt-rotor flown by the Navy, Marine Corps and Air Force is considered a fly-by-wire aircraft. The V-22 operates in a computer-assisted mode in which the pilot maintains a set angle of pitch or roll without having to make constant adjustments for wind gusts or other factors.

The Pentagon plans to shift to fly-by-wire and computer assistance for rotorcraft under the Future Vertical Lift program, in which new helicopters will be built for each of the services. The Office of Naval Research, which is funding Horn's research, has made shipboard landings and fly-by-wire controls a priority as well.

Technologists say helicopter pilots are starting to warm to computer-assisted control. It's only a matter of time before "fly by wire is going to be seen as the way to go," says professor Daniel Schrage, director of the Center for Aerospace Systems Engineering at Georgia Institute of Technology. He says the shift is driven by the widespread use of computer-aided-flight


Pennsylvania State University

Desktop simulation: Penn State engineering professor Joe Horn, wearing glasses, monitors a helicopter-landing simulation with graduate student Albert Zheng.

technology with fixed-wing airplanes, which in his view has driven the level of acceptance among pilots to a "6, 7, 8 level," on a theoretical scale of 1 to 10.

Schrage headed a U.S. Army program in the 1980s that tested digital-optical control systems, a kind of fly-by-wire system that would use fiber optic wire instead of electrical-only connections. The idea was to weigh inclusion of the technology on the Sikorsky-Boeing RAH-66 Comanche helicopters. The Army decided not to do that due to cost considrations, but the Comanche program was cancelled anyway by the Army in 2004. In Schrage's view the Army's hesitation to invest in a fly-by-wire system for helicopters was a big mistake.

The brighter outlook for fly-by-wire could open the door to possible adoption of Horn's computer-assisted landing technology.

In April, after more than a year of evaluations, five Naval Reserve and former Navy pilots gave top marks to a level of computer-assisted control called translational rate command. This mode was the second-most-automated among the four modes defined by Horn and other researchers. The helicopter will move horizontally in the direction that the pilot moves the cyclic stick, and then stop that horizontal movement when the pilot returns the stick to center position.

In contrast, a pilot flying in the equivalent mechanical-only mode, called rate command, would move the cyclic stick in one direction to tilt the aircraft in that direction and the angle of tilt would continue to increase, along with an ever-increasing horizontal speed in that direction, until the pilot moved the stick back to center. The angle of tilt and horizontal speed would stay at those settings until the stick was moved in the opposite direction, which would require many more stick movements during a ship's deck landing — accounting for the ship's velocity, direction and rocking movements.

"We did find that we could improve the handling characteristics where they could land in a simulator on fairly high sea states, in difficult conditions, with a lot less workload and a lot more accuracy, for certain modes," Horn says. At the same time, "we found that you have to make the helicopter respond a lot more quickly than was customarily done in earlier [control] designs."

Horn plans to continue the re-

A Marine Corps MV-22 Osprey lands on the flight deck of the amphibious assault ship USS Bonhomme Richard. The Osprey is notable for its computer-assisted controls.

U.S. Navy

search in 2016, but in May he and Zheng presented a paper on their findings to date. The paper, "Investigation of Bandwidth and Disturbance Rejection Properties of a Dynamic Inversion Control Law for Ship-Based Rotorcraft," was presented at an American Helicopter Society conference.

Pilots landing on ships face a common, but dangerous, problem: The rocking motion of the deck gives false visual cues. If the pilot looks at the horizon, the aircraft seems stable, but if he or she looks at the deck, then the aircraft may seem to be rolling.

Horn and Zheng address that problem through the computer-aided controls, which allow the pilot to focus just on the direction of the helicopter's movement, not whether and how much the aircraft may be tilted.

Pilots "don't have to worry so much about stabilizing the aircraft's attitude because the controller does that for them. They just direct the velocity of the aircraft around," Horn says.

Adding levels of automation to helicopter flight controls could make it possible for a wider range of pilots to handle tricky maneuvers, Horn says.

"The really good pilot will always be able to fly these maneuvers using the mechanical controls on an aircraft. They're very well trained. But if you go into the fleet and you get thousands of pilots coming through, are you going to expect all of them to be good enough to do these really, really hard things on the aircraft? The thinking now is: 'No,'" Horn says.

Horn's test pilots flew a flight simulator with a 10 foot-by-15 foot diameter cylindrical screen, mimicking landing on a U.S. Navy FFG 7 class frigate. The simulator used the cockpit of a Bell XV-15 experimental tilt rotor aircraft, which has a cyclic control stick similar to that of an SH-60 Seahawk and a UH-60 Black Hawk.

"We really wanted to be able to have these pilots fly and switch between these different modes in kind of a seamless way, so the control algorithms become pretty complicated pretty quickly," Horn says. "Just setting up all that software to rapidly evaluate the different configurations was a big challenge."

The researchers used Simulink software to create the different permutations of control algorithms that they would test, designing and writing complicated block diagrams with the software and then linking those diagrams together. They tested 20 different variations — with a variety of parameters for responsiveness and other factors — before narrowing them down to the control schemes that the pilots tested, Horn says.

The Simulink programs were loaded into the flight simulation system, run on GenHel software, which interfaces with X-Plane flight simulation software to create the graphics viewed by the test pilots.

All five test pilots were former Navy pilots or current Navy Reserve pilots; three of them graduated from the Navy test pilot school.

"It's kind of a grueling process to go through, and we spend a whole day doing this," Horn says. "They'll fly this maneuver over and over again, and we just keep giving them different configurations — some of them bad, some of them good."

Levels of automation

Researchers needed a common language to describe the increasing levels of computer-aided flight they are testing. They came up with four levels of increasing automation, ordered here from least to highest:

- **Rate command:** Provides the pilot with the equivalent of direct mechanical control. Moving the stick away from center causes the aircraft to start rolling or pitching. Moving the stick back to center stops it, but maintains the helicopter's attitude at that tilted angle. The pilot has to move the stick in the opposite direction to roll or pitch the helicopter back down to a level position. Once the helicopter tilts, the helicopter starts moving, and the pilot has to tilt the helicopter back the other way to make the helicopter stop moving.

- **Attitude command:** This is actually a group of flight control modes. When the pilot moves the stick, the aircraft banks relative to the stick displacement — the greater the stick movement, the steeper the angle. When the pilot moves the stick back to center, the helicopter automatically rolls or pitches back to level again.

- **Translational rate command:** The pilot adjusts the angle of pitch or roll to control horizontal movement or speed. Moving the stick left automatically moves the helicopter in that direction. The larger the stick movement, the higher the speed. Moving the stick back to center halts the helicopter to a hover. The pilot no longer must stabilize the aircraft's attitude or angle of tilt. Some pilots may perceive the stability of the aircraft as sluggishness compared to mechanical controls.

- **Translational rate command with position hold:** All the capability of translation rate command, plus the pilot can make the helicopter hover above a point on the ground by leaving the stick in the center position, and the computer automatically adjusts the helicopter's position if winds knock the aircraft off that spot.

To test extreme conditions, researchers cranked up the simulation to 6 on the Beaufort Wind Scale with winds of up to 31 miles per hour and waves up to 13 feet. That translates to a ship's deck rolling by as much as 30 degrees.

The Beaufort scale ranges from zero, indicating mirror-smooth ocean, to 12, referring to hurricane-force winds and huge waves.

The test pilots rated a form of the translational rate command mode as the sweet spot for automation with the deck landings. This form — besides responding more quickly to pilot input than a typical translational rate command mode — also had the helicopter locking on to the speed and direction of the ship when it flew over the deck, leaving the pilot to concentrate on controlling the aircraft's movements relative to the deck.

Though the test pilots liked the helicopter's the translational rate command mode, researchers found they had to speed up the aircraft's responsiveness beyond current military specifications for the mode. "We found the results were very sensitive to that — how you set the speed of responsiveness," Horn says.

If the responsiveness was too slow, in some cases the pilots rated the controls as bad as the mechanical system.

Some of the Penn State researchers' ideas failed to pan out. One was a hybrid mode between attitude command and translational rate command, with the control stick smoothly shifting from one mode to the other depending on how much the pilot moved the stick. Researchers figured the hybrid mode would offer pilots both the perceived responsiveness of the attitude command and the stability of the translational rate. The hybrid mode worked. Pilots, however, rejected it because they say it was too vague; they preferred knowing that they were working in only one mode.

The ship-landing research project is scheduled to continue to 2016. Among the next steps, Horn says, the Penn State researchers will look at forms of translational rate command mode landings that can match the aircraft's speed and direction with the ship's, without any signals required from the ship.

Horn started another project last year to take helicopter deck-landing automation to the next step: the pilot would simply push a button and the aircraft would land automatically. Software would predict when the deck will be level for a touchdown.

"We add in this ship-motion prediction algorithm, so that it would take the aircraft in, and it would look at the deck motion, and try to time the final descent to landing so that you get a nice match on the deck when you settle down," Horn says.

That software would assume that some kind of signaling of the deck's motion would be sent to the aircraft. The project, however, doesn't involve figuring out how such a sensor system would work.

Keith Button
buttonkeith@gmail.com

Jaiwon Shin is NASA's longest-serving associate administrator for the Aeronautics Research Mission Directorate and the 32nd to oversee NASA Aeronautics since the agency was created in 1958.

Interview by Kyung M. Song
kyungs@aiaa.org

Airplanes guy at 'space agency'

Jaiwon Shin, associate administrator for NASA's Aeronautics Research Mission Directorate

While many of his colleagues at NASA peer into deep space and plot interplanetary travel, Jaiwon Shin is focused on the skies closer to Earth.

The South Korean native leads the smallest of NASA's four mission directorates — but still arguably the world's leading public aeronautics research and development body. Shin commands a budget of $651 million (including an extra $100 million from Congress in this fiscal year). That's less than 5 percent of NASA's total budget and equal to what Boeing spends on R&D in two months.

Nonetheless, Shin and his researchers have a big job: advancing technologies that would enable revolutionary changes in air travel. That might mean airliners that burn half the fuel or fly twice as fast as those in the air today. Or it could mean a new breed of air-transport vehicles, manned or unmanned. It could even mean preventing foul weather from stranding millions of air passengers.

*A compact man with a vigorous handshake, Shin says his job leaves little time for other passions. He's a sports car buff; he drives a 2003 Acura NSX, which is becoming a collector's item. **Kyung M. Song** spoke to Shin in his office at NASA headquarters.*

You're 55. What do you think air travel is going to be like when your grandchildren are your age?

It's hard to predict but probably even 30 years out, we will still see the current tube-and-wing [configuration]. Boeing and Airbus, they're still producing a lot [of] tube-and-wing aircraft. But we could be seeing very different segment that probably occupies a different altitude, not just always 35,000 feet and above. It could be much lower altitude. It could be autonomous aircraft, smaller unmanned aerial systems operated by companies like Amazon or Google. Who knows, maybe Pizza Hut even could operate a small UAS.

These airplanes you're talking about 30 years out, would they be largely recognizable to people today?

It could be different because what you see is small UAS with the sort of quadcopters that take off vertically and fly at a decent speed. That kind of technology could improve quite a bit in the future. One area that people are talking about is air taxi kind of idea. In huge metropolitan areas like New York and the Bay Area, it's plausible that autonomous, small air vehicles could operate like taxis. You press the button, it takes off vertically and goes to the destination and lands.

What about the flying wing design that you've talked about?

That's a different kind of large transport category. We call it hybrid wing body. That type of a configuration really promises tremendous benefit for lowering fuel consumption and also noise reduction.

Is it in the realm of the possibility in your lifetime?

I would like to think so. I need to live a little bit longer (he chuckles). But here's a little bit of dilemma that Boeing and Pratt & Whitney and GE have, in that their orders are all the way out to probably 10 years based on current configuration and certain state-of-the-art technologies. The 737 MAX is a classic example in that rather than changing the configuration, [Boeing decided on] swapping the engines with much more fuel-efficient engines and also doing some structural improvements. Airlines operate airplanes 20-plus years. So how do you insert a completely new configuration? That's a big decision.

Is that a decision for NASA to pursue?

Our role is not to really develop all the technologies to make this airplane but rather we develop the key technologies and lower the risk so that the industry can enter into that type of investment when they think the market is ready.

When you're working on the enabling technology, don't you have some vision of what kind of airplane that's going to lead to?

We have what we call generations of technologies. If we call the current technology generation N, we have N+1, N+2, N+3. So the industry knows where NASA is providing these next generation technologies.

That hybrid wing-body configuration you talked about, we classify that as N+2. It's not N+1 generation like a 737 MAX, which stays with the current configuration but employs a lot of new technologies.

So, if we're going to have some kind of a game-changing redesign of airliners, is that likely to come from NASA, or from Boeing or Airbus researchers?

We develop technologies. We're not developing airplanes. That's industry's role. We develop technologies and transfer those technologies to companies like Boeing or U.S. aviation companies in general. And then they will make their own investments. The best example [would be something] like winglets. That idea came from NASA researchers. But we didn't go out and install these winglets on the existing airplanes.

So NASA research is shared fully and completely with Boeing?

Not just Boeing but a broad spectrum of the U.S. aviation industry. We don't target a certain company to just help a certain company. That's an important point, because we have been embroiled in this World Trade Organization dispute that the European Union is subsidizing its aviation industry.

Talk about the restructuring you've initiated the last couple of years.

It was our effort to set the groundwork for NASA aeronautics to stay as world leader for conducting aeronautics R&D for the next 100 years. I believe we are still the leading public R&D organization in the world. But we don't want to be complacent. We want to [be] agile in capitalizing on what's happening even outside aerospace sectors. The tremendous advances in information, communication and automation. So we want to make sure that we are addressing the right national needs.

Give me an example of a kind of a project that might get your researchers really excited but might not be something that ranks very high as a national priority.

NASA's Jaiwon Shin

Associate administrator, Aeronautics Research Mission Directorate since February 2008

Age: *55*

Birthplace: *Seoul, South Korea*

Education: *Ph.D., Virginia Tech; masters, Cal State Long Beach; bachelor's Yonsei University, Seoul (all in mechanical engineering).*

Previously: *Deputy associate administrator, Aeronautics Research Mission Directorate (2004-2008); chief of Aeronautics Projects Office, NASA Glenn (2002-2004); chief of Aviation Safety Program office and deputy program manager for NASA's Aviation Safety Program and Airspace Systems Program (1998-2002)*

Residence: *Oakton, Virginia*

Family: *Wife, Bongok Paik*

Notable quote: *"What keeps me going are two things: my faith in God and my love for NASA."*

I don't want to see that (he laughs). I want our researchers to be excited for the national priority, not just their own interest. The new strategy is not just setting [a] new strategy but it involves cultural changes as well. For example, if you're a CFD [computational fluid dynamics] person, you're not only looking at your own discipline but you work with materials and structures and also engine disciplines and so on, and try to come up with systems-level solutions.

If the focus is really trying to align the research priorities with national priorities, where does that leave room for long-shot ideas that may or may not pan out?

National priorities are not short-term or near-term goals. National priorities could be like enabling UAS integration into NAS [National Airspace System]. Another is reducing fuel consumption from aviation. Airlines and the military combined, we are spending like $80 billion annually on fuel. And fuel consumption takes up to 40 to 50 percent of airlines' operating cost. So, reducing fuel consumption is a huge national priority. Protecting the environment around the airport, local community noise and emissions, that's another national priority.

Where do you think the line should be between public and private investment in pursuing some of these revolutionary technologies?

I think a public organization like NASA should go after really high-risk, revolutionary, game-changing ideas. The industry worries about their bottom line so sometimes they cannot justify investing heavily on this very high-risk research. That's where government research comes in. That hybrid wing body is a classic example. They're not ready to start building this aircraft as yet, but who knows? In 20 years out, that may be a really, really viable concept.

You believe the U.S. is still No. 1?

I believe so. That's not to minimize the international capabilities. Combine that with the strength that the U.S. industry has. For example, Boeing's new 787, the order on the books is well over 1,000 aircraft. Why is that? Because that aircraft consumes some 20 percent less fuels than the class it's replacing. Many of the airline executives told me that if they can save even 1 or 2 percent on fuel from their fleet, they will be going out on the street and dancing. But there are a lot of emerging challenges coming at us. Both Boeing and Airbus are projecting that there will be close to 34,000 new airplanes needed by 2033. That's why China is working to produce [a] direct competitor to the Boeing 737 class. There are a lot of countries like this. China, Russia. Japan is building regional jets to compete with Brazil and Canada. And Brazil and Canada are already very well equipped and capable of sizing up their regional jets to be more like 737s.

So do you not expect this Boeing-Airbus duopoly for large jetliners to survive?

Over time, there will be a third block. It could be combination of China, Russia, Japan, Brazil, Canada. Or, it could be India. All these countries could form another block to compete with Airbus and Boeing. Boeing actually made a comment at the AIAA SciTech [forum] back in January that they're already thinking that duopoly is over.

But this is happening at the time when the market is also expanding though.

Very good point.

What's the threat then, really, for us?

The threat is there may be enough opportunity to go around, but that will come to an end at [a] certain point. That's why we've been working on [the] hybrid wing body concept along with few other concepts as well that could reduce fuel consumption by 40 to 50 percent, not 20 percent. So, that could be one new capability or it could be supersonic flight or it could be all types of UAS.

Talk about the supersonic technology. What is the promise there?

Growth in air travel is shifting, and has been shifting, to Asia Pacific region. You're originally from Korea, too, right?

Right.

So we know how long it takes to fly to Korea from here. China alone will add about 200 million passengers between 2011 and 2016. The problem is they have to fly at least 10-plus hours to get to any place. People eventually will start demanding shorter flying time. But there are all kinds of technical barriers to that. The FAA now has a ban on civil supersonic flight over land because of the sonic boom issue. It could rattle windows and break windows. You can't fly supersonically over land, so why build a supersonic aircraft? So NASA has been working on technologies to develop the shape that will minimize the sonic boom intensity. If we successfully do that, then I think there are U.S. companies that are very much interested in building supersonic airplanes.

Is there a scientific consensus on what is acceptable or tolerable level of sonic boom?

Yeah. We tested a lot at about 85 decibel — perceived decibel level. Our researchers told me that's like your alarm clock going off next to your bedside. I actually have been in simulated chamber with that, about 85 decibels. It's very acceptable.

The Asia Pacific traffic is primarily over water, so how does a sonic jet help with that?

Our continent is huge, from L.A. to New York. It doesn't make any sense for us to operate these supersonic airplanes only from the coasts. And there aren't many populated city pairs along the coastlines that's going to make the airlines profitable for operating supersonic airplanes. Countries like China and Russia are the same situation. You have to fly over land at some point.

Aeronautics research is a tiny portion of NASA. You've said you are fine with that. But do you think that ratio is reflective of our national priorities?

I wouldn't call it tiny (he laughs). But it is a small portion of the agency budget. I think we are hovering around 4 percent now. But the space side requires a large sum of money. Developing rockets and any kind of spacecraft is several hundred million dollars. NASA is also both a developer and operator when it comes to space, whereas in aeronautics it's only a developer.

Americans might be wondering whether we can have both a manned mission to Mars and also not have all these planes canceled whenever there is a thunderstorm.

(Laughs) We are doing a lot of air traffic management research and we transferred our many tools to the FAA in the past four years, which will certainly optimize the terminal area, meaning where all the choking points are.

How diverse is you research and engineering staff at NASA?

We've come a long way, I think, compared to when I started back in 1989. The leadership here, from [NASA Administrator] Charlie Bolden on down, diversity and inclusion is a big emphasis for the agency.

Are you concerned about the quality of STEM education in this country and what that means for recruiting in the future?

I'm not concerned about the quality, but there is a little bit of trend people worry about that a lot of young students are interested in sort of becoming rich quickly.

And that's gonna not happen at NASA?

(Laughs) I'm not a millionaire. It's more of a sense of duty for the country. The challenge in science and engineering is how do you compete in this era of tremendously exciting IT and computer world [of] Google? At many of the leading institutions in this country, a big percentage of graduate student population is international students. I was one of them. I came to this country to study and get my advanced degree, but I was given an opportunity to stay in the country.

You mean that wasn't your original plan?

I thought I was going back to Korea after I finish my Ph.D. But I was given an opportunity to work at NASA, and I'm still here.

Why astronauts train in planes

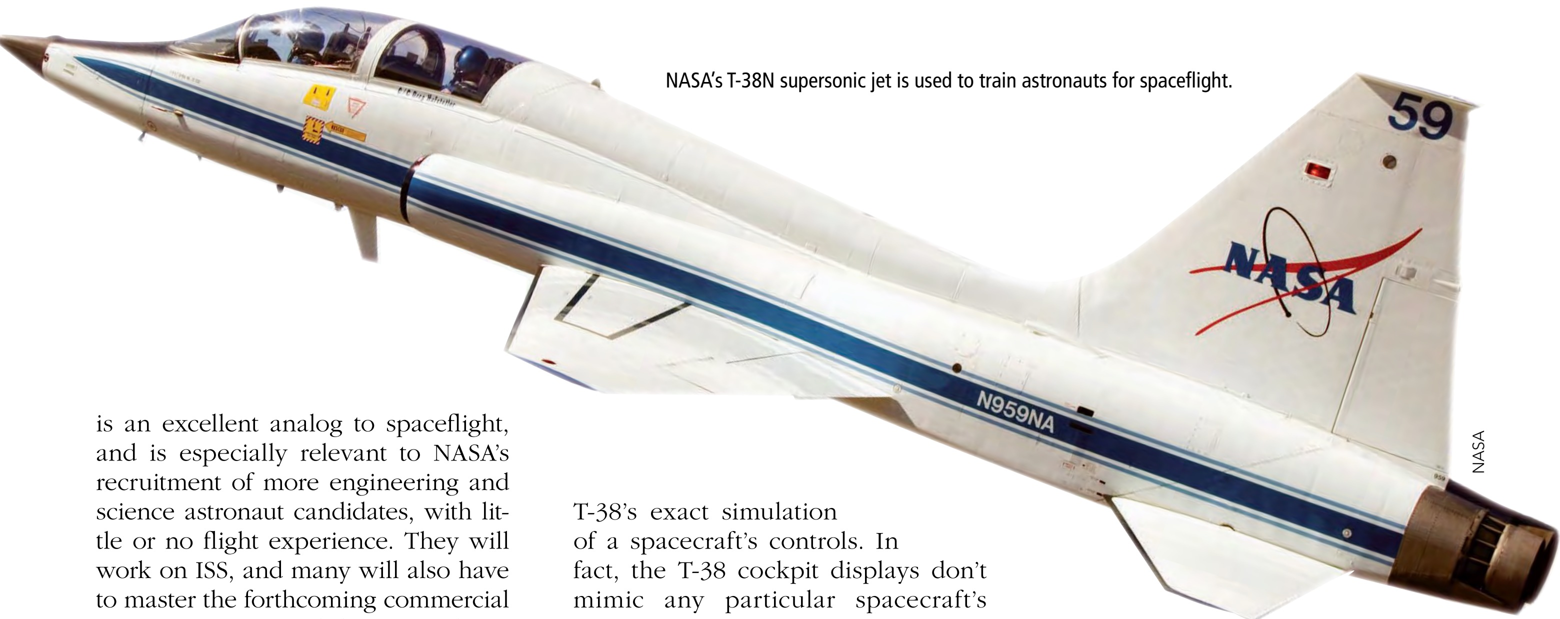
Veteran astronaut and pilot Tom Jones explains how a fleet of decades old jets continues to prepare astronauts for that moment when a spaceflight suddenly goes from smoothly on plan to a life-and-death test of teamwork.

I was a member of a National Research Council panel that in 2011 examined NASA's post-shuttle astronaut training needs. One day, Peggy Whitson, who was then NASA's chief astronaut, came to speak to us. She told us about her hair-raising, 2008 reentry after commanding Expedition 16 crew on the International Space Station. An explosive bolt failure caused her crew's Soyuz TMA-11 service module to separate late from the descent module. The flight computer, unable to fly the planned lifting reentry through the upper atmosphere, "down-moded" to a steeper and hotter ballistic reentry that subjected the crew to more than 8 Gs. Smoke entered the cabin and the crew executed the electrical fire checklist to power down most of their flight instruments. High winds in Kazakhstan then rewarded the crew with a hard landing. Whitson, a Ph.D. biochemist before she came to NASA, told us flatly that without her flight experience in NASA's T-38 jet trainers, the rapid-fire chain of emergencies might well have overwhelmed her. Instead, she stayed in the game as flight engineer and helped the Soyuz commander get the crew down safely.

Fortunately for Whitson and her astronaut colleagues, the T-38s today are still serving as the principal tools for Spaceflight Readiness Training (SFRT), despite the end of the shuttle era and constant pressure on NASA's budget. Astronauts routinely take the T-38 to altitudes above 40,000 feet and cruise close to the speed of sound to conduct aerobatic training or complete the SFRT syllabus. Such training

NASA

NASA's T-38N trainer jet cockpit displays don't look like that of any particular spacecraft. But its modern display technology is similar to those on the upgraded Soyuz capsules and new commercial space transports.



NASA's T-38N supersonic jet is used to train astronauts for spaceflight.

NASA

is an excellent analog to spaceflight, and is especially relevant to NASA's recruitment of more engineering and science astronaut candidates, with little or no flight experience. They will work on ISS, and many will also have to master the forthcoming commercial space transports and the Orion deep-space multipurpose crew module.

High-altitude classroom

Designed for training new Air Force pilots, the T-38s have front and rear cockpits with duplicate controls. NASA instructors or test-pilot-qualified astronauts fly the plane from the front cockpit, but non-test-pilot astronauts must ride in the rear, sharing duties with the front-seater. For example, I was an ex-Air Force pilot, once qualified in T38s and B-52s, when I became a shuttle astronaut. But as a mission specialist astronaut without test flying credentials, at NASA I flew in the rear cockpit, splitting hands-on flying time, navigation, and radio work with my front-seat colleague.

During the shuttle era, T-38 training honed the critical skills pilots needed to bring an orbiter to a safe landing in Florida (or California) after two or more weeks in space. There is less piloting to do in the wingless Soyuz and commercial crew transports when things go normally. But as Whitson's story shows, in spaceflight the situation can change quickly. NASA doesn't want to put its astronauts in those vehicles without having them first gain experience in dynamic flight using its fleet of T-38N Talons.

The value of Spaceflight Readiness Training does not stem from the T-38's exact simulation of a spacecraft's controls. In fact, the T-38 cockpit displays don't mimic any particular spacecraft's panel, although they use modern technology similar to those of the new commercial space transports and the upgraded Soyuz capsules.

What T-38 training does deliver is a dynamic environment that teaches astronauts to make good decisions, to coolly respond to deteriorating situations, and to operate as a team even under stress. A 2008 study by the Aircraft Operations Division and the Astronaut Office at Johnson Space Center concluded that the T-38s effectively instill discipline, prioritization, crew coordination, communication, decision-making, and space flight environment adaptation.

Prioritization and discipline, in particular, are keys to flight safety. Astronauts must identify the most critical tasks in flight and stay focused on solving them despite competing stresses and sensory distractions. Story Musgrave, my crew mate on Columbia's STS-80 mission in 1996, told a NASA interviewer that when you soar aloft in a T-38, "you're in a different world, a dynamic world — it doesn't matter whether it's a spacecraft or a T-38. It's understanding the rules, how to live within the rules."

Communication and crew coordination go hand-in-hand, as crewmembers share information and failure assessments and then work smoothly together to handle in-flight emergencies.

Decision-making in space closely mimics the fast-paced thinking needed in aviation, where multiple factors like weather, fuel state, systems malfunctions and converging traffic must be weighed quickly to accomplish the mission. While flying, there's no turning back from the consequences of your decision: Unlike in a simulator, what you decide can have a real impact on your safety or survival.

The physical sensations experienced in a T-38 — vibrations, G-forces, lowered cabin pressure and even the weight and smell of a parachute and oxygen mask — help prepare an astronaut for the unfamiliar sensory environment of spaceflight.

NASA's White Rocket

The Northrop T-38 Talon first flew in April 1959. The world's first supersonic trainer, it could reach speeds of Mach 1.3, and in 1962, a T-38A set world time-to-climb records to 3,000, 6,000, 9,000 and 12,000 meters. Pilots called it "the white rocket."

In the late 1980s, NASA began upgrading its T-38s to better meet specific astronaut training needs. The Aircraft Operations Division at NASA Johnson executed a phased aircraft

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Lotus: Two aircraft in one

A V-22 tiltrotor can take off and land vertically but it can't loiter for long. A Global Hawk can stay up for 32 hours, but it needs a runway. One of aviation's great remaining feats would be to make one aircraft that can do VTOL – vertical takeoff and landing – and also provide long endurance. Among those chasing this dream are the engineers at Joby Aviation in Santa Cruz, California. With funds from NASA, they are about to fly a subscale unmanned plane called Lotus whose wingtips can morph into propellers. The plane's chief designer, Alex Stoll, describes the innovations behind this unusual aircraft.

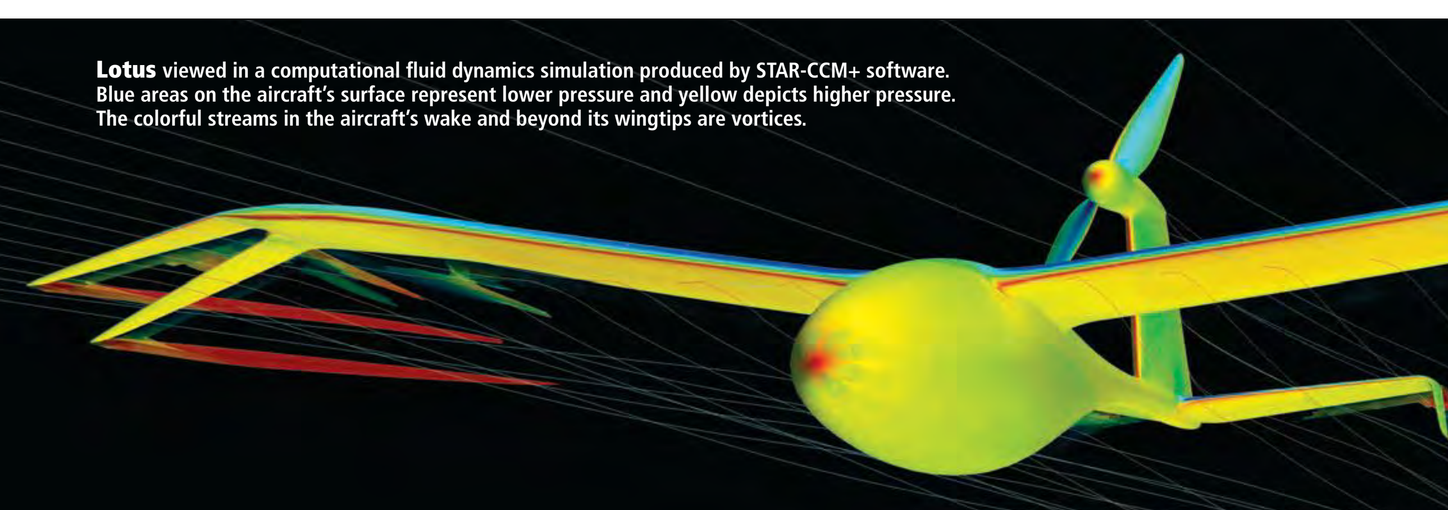
Electric propulsion sets aircraft designers free to explore many creative and innovative aircraft configurations that were never possible with traditional combustion power. We don't have to consider the constraints of combustion engines, which are large, heavy and relatively maintenance-intensive. At the same time, because this technology has only recently advanced to a level where these new configurations may be practical, we have virtually no historical data to draw on, which required conducting lots of analyses and simulations.

Such has been the case with our Lotus, a 55-pound scale prototype unmanned aircraft we've been working on at Joby Aviation in Santa Cruz since March 2013 under a NASA contract. Joby specializes in electrical vertical takeoff and landing, or VTOL, aircraft, which is the basis of our Lotus design. There are only a few locations where combustion engines can be practically located on an airframe. Once you go electric, you can propel the aircraft with small, lightweight motors connected by wire to a power source (typically a bank of lithium ion batteries) anywhere in the aircraft. Suddenly, you can place the propulsion system in locations that people haven't been able to look at before.

On the Lotus, we have a motor in each wingtip to enable our wingtip propeller configuration. The wingtip surfaces scissor into two-blade propellers during VTOL flight and fold back to become the wingtips during cruise, increasing the wing area by 21 percent. A single tail rotor provides forward propulsion. As far as we know, no one's ever done this before. This design would be impractical with traditional combustion engines, because you would have to drive the wingtips by either a complex transmission connected to a fuselage-mounted engine, or by placing an engine at each wingtip.

On top of that, instead of simply controlling the propeller revolutions per minute to vary thrust, a complicated collective pitch-control mechanism would likely be required. Our power comes from a single pack of lithium-ion battery cells like those in a Tesla car. The pack is located in the fuselage and delivers electricity via lightweight cables to each wingtip motor and to a motor at the tail rotor. We run the motors at 48 volts.

Even before Lotus, NASA engi-



Lotus viewed in a computational fluid dynamics simulation produced by STAR-CCM+ software. Blue areas on the aircraft's surface represent lower pressure and yellow depicts higher pressure. The colorful streams in the aircraft's wake and beyond its wingtips are vortices.

Joby Aviation

neers saw the potential for wings to transform into propellers as a solution to the long-endurance VTOL problem. On a traditional helicopter, the rotors are a very inefficient way to create lift at cruise speed. A better lift to drag ratio can be achieved with a fixed wing. The V-22 tiltrotor partially addresses this problem by tilting the engine nacelles up during VTOL and level for cruise, relying on a fixed wing to create lift during that mode. Since the same propellers are used for VTOL and for cruise, their design is a compromise and the maximum cruise efficiency is limited. By transforming VTOL propellers into wingtips in cruise, a separate and more efficient cruise propeller can be used.

At first, NASA suggested that we develop a concept, initially described in 2009, called Dos Samara. This design called for wingtips that would each transform during VTOL into a single-bladed rotor. We saw significant disadvantages to this approach. The thrust of this blade is not centered about the motor, resulting in substantial cyclic loading during VTOL. Also, the single blade requires a counterweight to balance the rotor. This counterweight travels through the air in opposite directions in the VTOL and cruise configurations, meaning its shape is an aerodynamic compromise, which significantly reduces efficiency in VTOL and/or cruise. By using a two-bladed propeller, we all but eliminate these two issues.

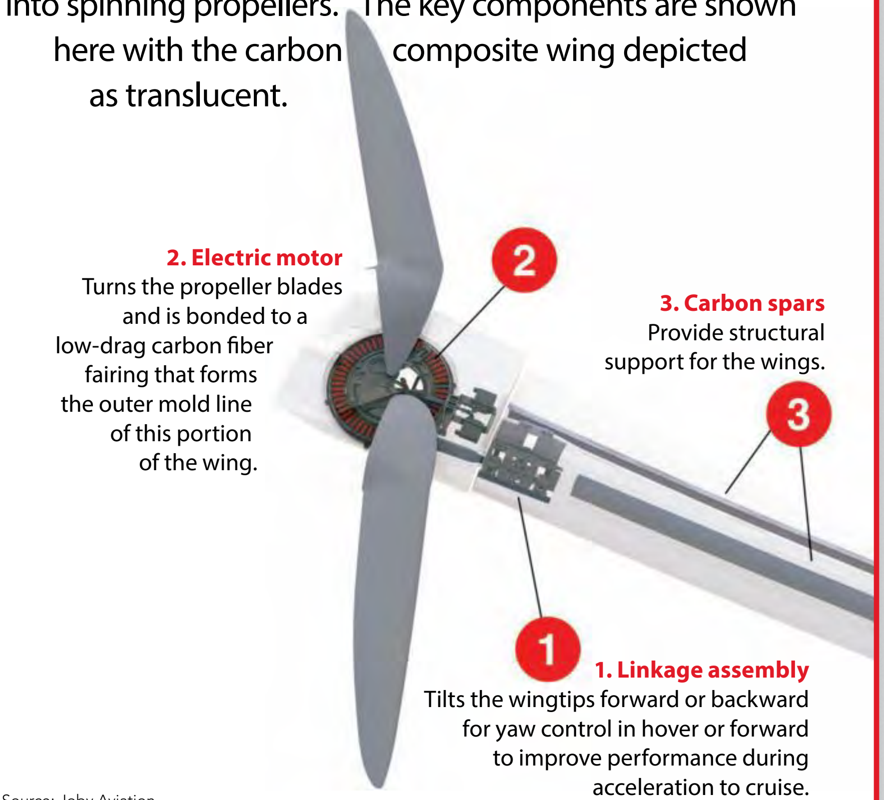
The Lotus wingtip propellers are driven by custom electric motors. The propellers are scissored closed for cruise flight by the same motors, producing a clean, low-drag wing shape. This design results in an unusual split wingtip, because it would have been impractical to split the tip and retain an aerodynamic shape for both the wingtip and the rotor blades.

NASA funded us to create Lotus, while a NASA team developed an alternate approach to the long-endurance VTOL problem. This aircraft is called the GL-10 Greased Lightning. Lotus and Greased Lightning are designed for the same mission but have completely different configurations. Greased Lightning has tiltable wings with many small, electrically driven propellers along them.

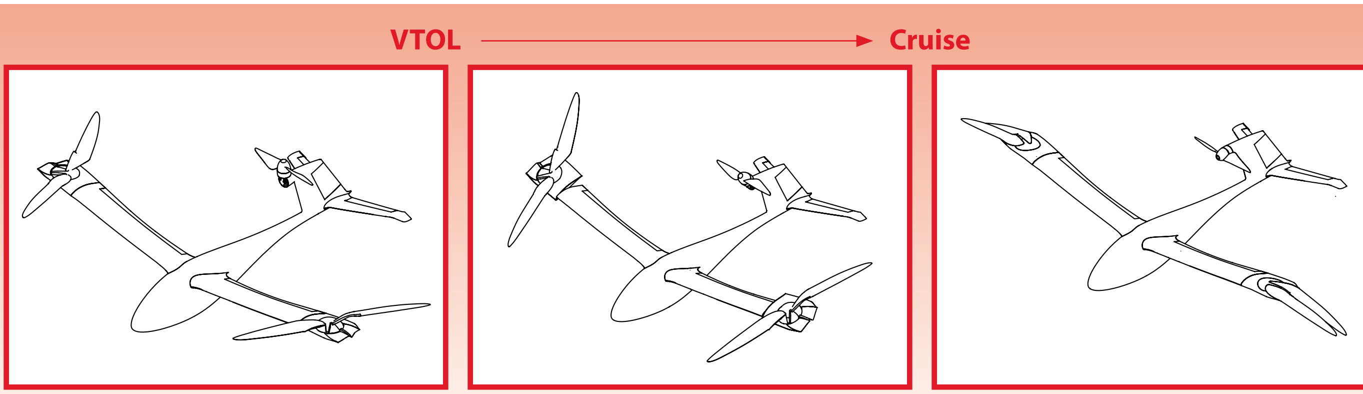
We prefer our split wingtips, which have the potential to provide better loiter performance. When we started work on Lotus in 2013, one of our first tasks was to evaluate this configuration's aerodynamic tradeoffs.This would not be like designing a new helicopter, in which design trends from earlier aircraft are largely applicable to new aircraft. We had to start from scratch. Specifically, we needed to maximize the efficiency of the wing tip surfaces, the drag produced by our split-wingtip design. We analyzed dozens of different versions of the tips using CD-adapco's computational fluid dynamics simulation software, called STAR-CCM+. We simulated different wingtip dihedrals (meaning the up-and-down angles relative to the fuselage); pitch angle, taper, twist and sweep, as well as different airfoil choices. We chose the combination that gave us the best performance in forward flight without sacrificing the performance of these surfaces when

Wingtip anatomy

Engineers needed to make the Lotus' wingtips transformable into spinning propellers. The key components are shown here with the carbon composite wing depicted as translucent.



Source: Joby Aviation



Joby Aviation

Transitioning from hover to fixed-wing flight

they're operating as propeller blades.

Our greatest challenge was to take into account this dual function. We tapered the blades so the root section has a larger chord than the tip section. When the blades are operating as a wing, the root section's longer chord produces more lift and the tip section is less important. When the blades are spinning as rotors, the tip section is actually moving through the air much faster than the root section, so the tip section is actually much more important to the performance of the rotor blade than the root section. In short, we optimized the tip section to have good performance as a rotor blade, and then optimized the root section to have good performance as a wing.

So far, we've been testing Lotus on our Ford F-150 Lightning pickup truck rigged with an instrumented test mount ahead of the cab that allows the mounting of wings, propellers or aircraft. On the tight budget of this program, this is a much more effective way to test the performance than traditional wind tunnel tests. We are planning to conduct our first flight test this year and we're currently assessing test site options.

If things go as well as our analysis suggests, we'll have some exciting decisions ahead. We may put Lotus into production at the current 55-pound size instead of, or in addition to, our planned 275-pound version that will have a hybrid powertrain in which a small gas engine produces electricity for the electric motors. It has the potential to become the first VTOL aircraft with true 24-hour endurance with a usable payload.

Alex Stoll is an aeronautical engineer at Joby Aviation and the chief designer of the Joby Lotus. He earned a Master of Science degree in aeronautics and astronautics from Stanford in 2010 and an engineering degree in 2012. He graduated from Rice University in 2008 with a Bachelor of Science degree in mechanical engineering.

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avionics upgrade program, giving this improved T-38N a weather radar, flight management computer, and primary flight instruments displayed on "glass" cathode ray tubes. To improve crew safety, NASA in 2001 began installing new Martin Baker US16LA ejection seats. These zero-zero seats [capable of a safe ejection even at zero speed and zero altitude] broadened the escape envelope and eased the dangers the old seat posed for the shortest and lightest members of the astronaut corps.

Externally, the Talon received modified engine inlets and ejector nozzles to improve high-density-altitude takeoff and cruise performance. Those modifications have reduced the T-38's supersonic capability, but that speed regime is incidental to astronaut training.

NASA began a second cockpit upgrade program in 2006. "The way we went with our upgrade was more an advanced biz-jet mentality, suited to our flying cross-country missions and dealing with bad weather," recalls Richard N. "Dick" Clark, who until last November was chief of the Aircraft Operations Division in Houston. NASA added a weather data link to complement the existing weather radar; a GPS-based flight management system; and switched to large, flat-panel displays. "It's a much more capable and effective airplane today," Clark says.

NASA has reduced the size of the T-38 fleet to match the reduction in the astronaut corps from 150 fliers 10 years ago to 50 or 55 today. NASA now maintains 18 operational jets and two spares. In the last decade, the budget for the Aircraft Operations Division has declined by half.

NASA and its aviation maintenance contractor, DynCorp International, prepare seven aircraft and two spares for daily operations. Twelve to 15 sorties launch from Ellington Field in Houston each weekday, totaling about 4,000 flight hours per year.

From Wings to Rockets

The T-38 exposes trainees who are new to aviation to spaceflight-related activities such as preflight briefings, equipment inspections, checklists, radio discipline and handling emergencies. To get its new, non-aviator astronauts up the learning curve even more quickly, NASA sends them to the Navy's flight school at Naval Air Station Pensacola in Florida for a six-week, back-seat introductory course in basic flying.

Astronaut pilots fly 12-15 hours a month to maintain front-seat proficiency, while back-seat crewmembers aim for 6 hours per month. Astronauts not assigned to a mission spend about 10 percent of their training time in the T-38, while assigned crewmembers, with many competing training demands, log just 5 percent cockpit time. The goal is to get experienced military pilots and astronaut candidates fresh to aviation to perform as a capable, qualified T-38 crew, accumulating "classroom" time aloft.


NASA

NASA has upgraded its T-38N jets with Martin Baker US16LN ejection seats to lessen danger to astronaut trainees. The seats can safely eject occupants even at zero altitude and zero airspeed.

The National Research Council panel confirmed the need for continuing Spaceflight Readiness Training. Our 2011 report, "Preparing for the High Frontier," found that SFRT provided astronauts with training "that cannot be duplicated by current...or projected alternative techniques or technologies." The NRC recommended that "to ensure continued safety and mission success, NASA should maintain a spaceflight readiness training program that includes high performance aircraft."

Retired chief astronaut Ken Cockrell, my commander on two shuttle missions, says "aviation is certainly the closest analog to the operational environment of spaceflight. There are others that we have used or evaluated: the National Outdoor Leadership School, the underwater habitat, and submarine damage control training, to name three. But exposing future spacecraft crewmembers to the aviation environment, where things happen fast, where the crew needs to think and react quickly, and where the decisions they make can mean the difference between success and failure in a personally mortal sense, is the best way to help them be successful in space."

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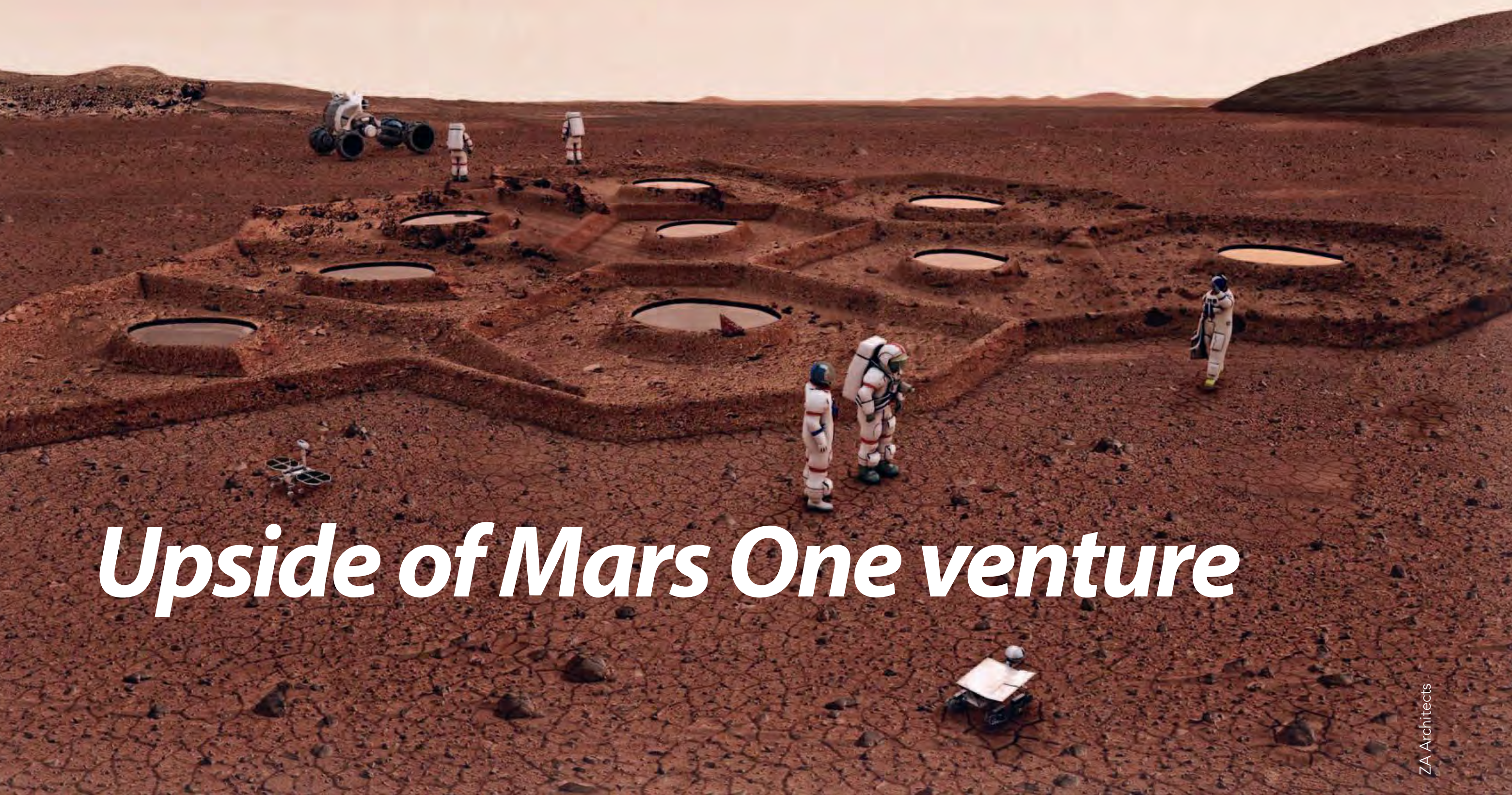
Upside of Mars One venture



A rendering by the German firm ZA Architects shows how robots may dig underground caves — similar to basalt caves on Earth — for human inhabitants on Mars.

Like many aerospace engineers just beginning their careers, I yearn for another "giant leap for mankind," specifically one on Mars. I don't mean to belittle the scientific achievements and benefits to international cooperation from the International Space Station. I also recognize the knowledge gained by NASA's space telescopes and robotic missions. But there is no achievement like sending human explorers beyond Earth's orbit, something humanity hasn't done since Apollo 17 in 1972.

Plans for exploration of the Martian surface have been in the works since at least 1952, when Wernher von Braun published "The Mars Project," the first serious technical study of how that might be done. Yet despite the mind-boggling leapfrogs in technology of the Apollo era and the founding of the Mars Society advocacy group in 1998, arguably the most public interest in sending humans to Mars was generated in the last three years by two Dutch entrepreneurs. Bas Lansdorp and Arno Wielders in 2012 announced plans for Mars One, a non-profit organization based in the Netherlands aiming to send humans on a one-way trip to Mars to establish a permanent settlement by 2027 and beam home videos for a reality TV show.

I'll leave it to others to assess the technical and financial merits of the Mars One proposal and the ethics of sending people on a one-way trip. Still, a recent exchange in my creative writing class at the University of Maryland showed me there might be important lessons in the Mars One saga, regardless of the controversy swirling around it. One of my classmates apparently heard about Mars One in the media, but when she brought up the topic in class, she confused this startup advocacy group with NASA.

I was troubled to hear such a garbled version of reality, but I realized that it was the first time I'd heard anyone outside my engineering class mention space exploration. The positive aspects of Mars One are that it has created buzz outside the science community, and its organizers have demonstrated the potential of building public support.

In just three years, Mars One says it convinced more than 200,000 people from around the globe to sign up for a flight to Mars with no return date.

It also has raised almost $800,000.

That dollar figure, of course, is nowhere enough to get to Mars. But it proves people are genuinely excited enough about the idea to put their money in it.

Imagine what might happen if NASA, with its years of technical expertise and laboratory infrastructure, could get people as excited about a Mars mission as the Mars One organizers did with its applicants.

As engineers, we tend to hide in our isolated, jargon-filled bubble, with little thought to sharing the cool stuff we do with the wider public. We have watched the nation's fervor for space exploration during the 1960s diminish to something few people today think about and even fewer people understand.

The will to explore, however, is something that everyone can comprehend and get excited about. Mars One has sparked that excitement once again by making space feel accessible to the average person. It's now up to NASA and the rest of the world's aerospace leaders to use that spark to ignite a legitimate mission to Mars.

Mars One

Mars One's timeline envisions first humans landing on Mars by 2027, 16 years after the Dutch project's founding.

Samantha Walters is a senior at the University of Maryland majoring in aerospace engineering with a focus in space systems. After graduating in August, she will work in engineering operations at the NASA Jet Propulsion Lab, where she interned for the past two summers.

Decloaking aviation's famous duo

The Wright Brothers

Reviewed by Kristin Davis


National Archives

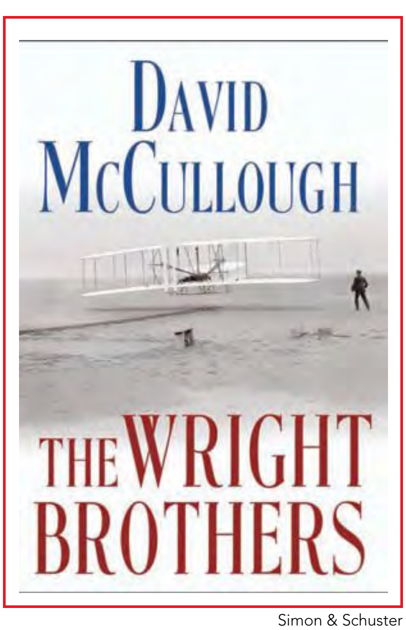
The Wright brothers test fly their aircraft — the world's first military plane — in September 1908 in Fort Myer, Virginia. The plane stayed aloft 71 seconds the first time, but crashed the second flight.

The sons of a traveling preacher, Wilbur and Orville Wright of Dayton, Ohio, preferred the shadows of obscurity, remaining enigmatic even as the world eventually came to track their every move.

"The Wright Brothers," by Pulitzer Prize-winning historian David McCullough, sweeps away any trace of that enigma. McCullough culled thousands of pages of letters, diaries, data books and other documents to paint an intimate portrait of the brothers. The book vividly illustrates how the brothers attacked one of humanity's greatest technical challenges — powered flight — not with advanced degrees or government backing but with ingenuity and grit.

The Wright brothers were never ordinary. Wilbur seemed destined for Yale when a hockey injury "changed the course of his life" and left him plagued with depression for the next three years. In high school, Orville started a print shop behind the family home with "discarded tombstone, a buggy spring and scrap metal."

Both were avid readers, especially after Wilbur's injury left him homebound and Orville was struck by typhoid in 1896. These turns of misfortune jump-started the brothers' study of aeronautics — and their dogged pursuit of what the greatest minds of their time had failed to achieve. Once they began, nothing would stop them. And there was plenty that might have. Months before Orville Wright made that first quiet flight in Kitty Hawk, North Carolina, in 1903, a highly-publicized, taxpayer-funded attempt by Samuel Langley had failed miserably.



Simon & Schuster

Many people insisted powered flight was impossible. And yet the inside story of the Wright brothers and the force of family behind them reminds us that perhaps anything is achievable with the right mindset and strategy. The odds against Orville and Wilbur seemed incalculable as they pushed through accidents, including one that claimed a life and nearly took Orville's.

The brothers were singularly driven. They wanted to study everything written in English about flight, so they wrote to the Smithsonian for a reading list. When they wanted to find a windy place to test their first glider, they wrote to the weather bureau. When the time came to motorize their invention, they consulted car engine manufacturers. Finding nothing suitable, they turned to the brilliant mechanic employed at their bicycle shop, and together the trio built their own. When the brothers shifted their flights to the farm fields outside Dayton to cut costs, they constructed a catapult to compensate for the less windy conditions. It was over those fields that they flew not feet but miles, creating at last a Flyer suitable to introduce to the world. When their own government ignored or rejected outright their overtures, they went abroad, to France and England and Germany. It was in Europe — and France in particular — that the Wright brothers became lastingly linked with the birth of the airplane.

For those in search of a human story of aviation, "The Wright Brothers" does not disappoint. The book also provides a layman's glimpse into how the Wrights, through trial and error and the study of birds and the failures of those before them, at last cracked the code of powered flight.

"Before trying to rise to any dangerous height a man ought to know that in an emergency his mind and muscles will work by instinct rather than conscious effort. There is no time to think," Wilbur Wright told a crowd of engineers in Chicago before making the first flight at Kitty Hawk.

Later, after honing the Flyer 3 that made them famous, the brothers would write: "The best dividends on the labor invested have invariably come from seeking more knowledge rather than more power."

Kristin Davis
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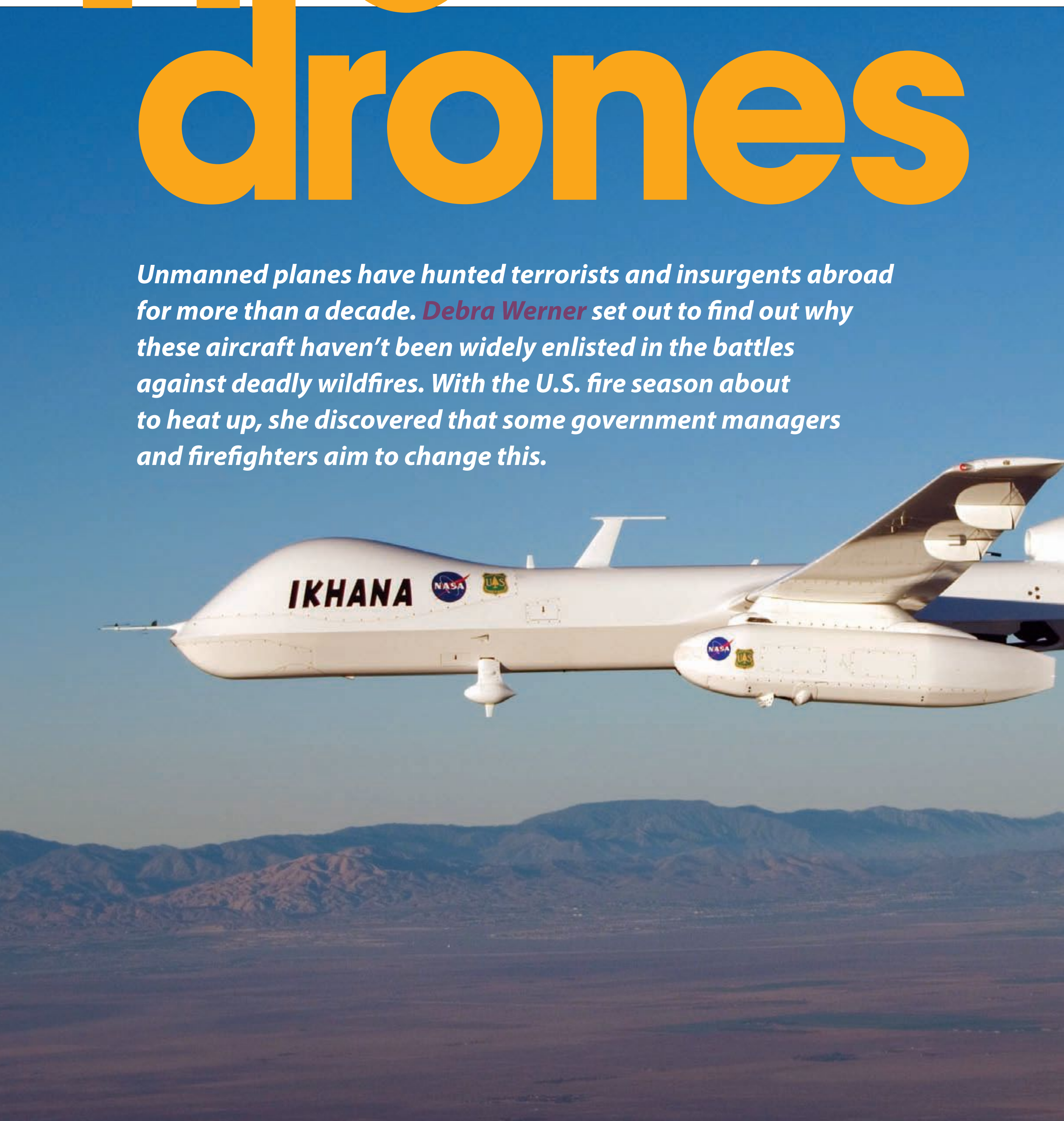
Fire drones

Unmanned planes have hunted terrorists and insurgents abroad for more than a decade. Debra Werner set out to find out why these aircraft haven't been widely enlisted in the battles against deadly wildfires. With the U.S. fire season about to heat up, she discovered that some government managers and firefighters aim to change this.



NASA has tested the ability of unmanned aircraft to map wildfires by installing a multispectral camera on its Ikhana research plane. Ikhana is a version of the MQ-9 Predator B built by General Atomics Aeronautical Systems.

NASA

Firefighters in Western Australia flew Lockheed Martin's 2.2 kilogram Indago quacopter earlier this year to gather nighttime imagery of a wildfire burning near Perth. Pictures from the craft's electro-optical and infrared cameras may have helped save as many as 100 homes, Australia officials say.

Indago is not the first unmanned aircraft tried for firefighting. Versions of the Predators built by General Atomics Aeronautical Systems have been tested, too. Between 2006 and 2009, NASA and the U.S. Forest Service flew NASA's Predator B-based Ikhana research plane over Southern California wildfires. NASA equipped Ikhana with a 16-channel multispectral camera, image processor and a satellite data link to send maps of the fire area to incident command centers on the ground. A few years later, Cal Fire, the California Department of Forestry and Fire Protection, borrowed a Predator B from the California National Guard to map the Rim Fire that ravaged Yosemite National Park in 2013.

The National Guard Predator watched the fire for 20 hours at a time from an altitude of 23,000 feet, using infrared cameras to capture detailed imagery that helped firefighters pinpoint the hottest areas, identify where vegetation already had been scorched and spot nearby brush that threatened to feed the flames, says Travis Alexander, Cal Fire battalion chief.

Firefighters in Australia and the U.S. want more eyes in the sky because wildfires are getting bigger on average, possibly due to climate change. In the U.S., for example, fires are penetrating suburban areas more so than in the past. Managers wonder if unmanned aircraft — even small ones like the quadcopter in Australia — might help them tame fires more quickly. Although the demonstrations in Australia and the U.S. have gone well, incorporating unmanned planes into regular operations is tricky. Smoky, windy skies above fires are already crowded with planes and helicopters dropping retardant, surveying the scene and directing aerial firefighting operations.

"There's a lot of potential but there's also a lot of complications because fire-

by Debra Werner
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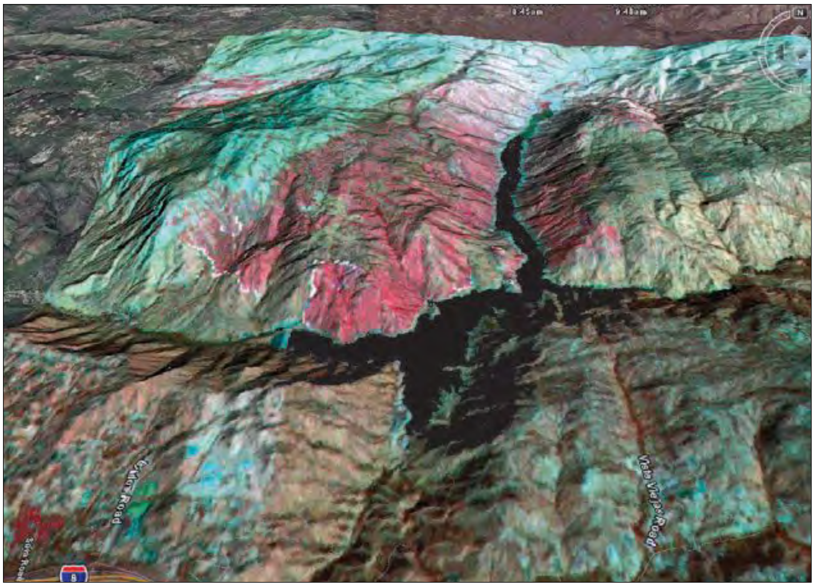


NASA

NASA's Predator B drone Ikhana took this infrared thermal image in 2007 of the Harris fire near the California-Mexico border. The black area is the El Capitan Reservoir and the reddish area indicates where the fire has burned or is still smoldering.

fighting with aircraft is very dangerous," says Jim Williams, manager of the FAA's unmanned aircraft systems integration office. "Intermixing unmanned aircraft into firefighting has to be done carefully so it does not increase the risk of an already risky operation."

Firefighters worry unmanned aircraft could get in the way of the piloted airtankers that drop retardant or cause a crash. For that reason, firefighting agencies are working with the FAA to establish rules outlining how and when these flights can be conducted. The hope is to make unmanned flights a regular part of the firefighting business. That would mean ending today's requirement to seek special permission from the FAA for each set of unmanned fire flights. There can be other complications, too. Cal Fire needed the U.S. defense secretary to sign off on its use of the California National Guard's Predator during the Rim Fire.

Lockheed Martin

Eye in the sky in minutes: **That 's the firefighting advantage Lockheed Martin sees for its vertical-takeoff-and-landing Indago VTOL Quad Rotor.**

As valuable as the quadcopters and Predator versions might prove to be, they can merely watch fires, not put them out. Firefighters do that in part by dropping thousands of gallons of retardant from large airtankers, cordoning off the fires until they burn out. For the foreseeable future, unmanned aircraft are unlikely to supplant these airtankers. Firefighters don't have the dollars to develop their own unmanned airtanker. They would have to adapt a military drone, but right now the military doesn't fly a drone capable of carrying 3,000 gallons of retardant like the Forest Service airtankers. Even the optionally-piloted KMAX helicopter, which was flown extensively in Afghanistan to transport cargo, can carry only 680 gallons at a time.

Instead, firefighters are evaluating whether unmanned aircraft built to transport cargo or capture imagery for military forces and police departments can be deployed in supporting roles, such as mapping fire areas, moving supplies, relaying communications and dropping water or retardant in smaller quantities.

One way to do that without threatening piloted aircraft would be to fly unmanned aircraft over fires when darkness or smoke prevents manned aircraft from flying near a blaze. That's what Mark Bathrick and Bradley Koeckeritz of the U.S. Interior Department are proposing. Bathrick, a former U.S. Navy aviator and test pilot, directs the department's Aviation Services Office; Koeckeritz is the unmanned aircraft specialist there.

They note that in January, the FAA and Interior Department signed a memorandum of understanding allowing Interior to use unmanned aircraft weighing 55 pounds or less and flying below 400 feet to monitor natural resources and to conduct search and rescue missions on the agency's land. Interior personnel can now fly unmanned aircraft after submitting a special type of COAs — Certificates of Waiver or Authorization — to the FAA, called a COA by notification. Unlike traditional COAs, the Interior Department's enables it to file flight plans and fly immediately without waiting for the FAA to approve the plan.

Koeckeritz and Bathrick want to establish a similar policy to test unmanned or optionally piloted planes against fires. They

“If a pilot could fly the aircraft during the day and operate it remotely at other times, that could make a substantial impact on our ability to contain and eventually extinguish fires.” **BRADLEY KOECKERITZ, United States Department of the Interior**

know that it could take years before the FAA establishes rules to allow manned and unmanned aircraft to operate in the same airspace at the same time. Hence their proposal to fly unmanned at night in the mountains or through smoke to ferry food, water, fuel, chainsaws and other supplies to firefighters. Piloted planes would be nowhere around in those situations.

On a good day, when conditions permit, manned aircraft typically support firefighters for about eight hours. “With optionally piloted aircraft, we have the potential to more than double those hours,” Koeckeritz says. “If a pilot could fly the aircraft during the day and operate it remotely at other times, that could make a substantial impact on our ability to contain and eventually extinguish fires.”

Last November, Lockheed Martin and Kaman Aerospace demonstrated that unmanned aircraft could put out a small fire. In flights conducted at the New York Unmanned Aerial System Test Site at Griffiss International Airport, the Lockheed Martin-Kaman team used an Indago to pinpoint the location of a fire. Indago transmitted the fire’s precise location to a ground station, which shared the data with the operator of a remotely-controlled K-MAX helicopter. The K-MAX conducted a series of flights, dumping more than 2,880 gallons of water on the fire in multiple drops, delivering supplies weighing more than 2,000 kilograms to four separate locations and gathering electro-optical and infrared imagery.

This year, the Interior Department would like to conduct further testing on its own property, flying one or more unmanned aircraft beyond the view of operators but within the Temporary Flight Restriction boundaries that prohibit normal air traffic near fires to protect civilian and firefighting aircraft. The unmanned aircraft, which have not yet been selected, could perform various tasks critical to firefighting, including reconnaissance, mapping and data relay.

Lockheed Martin

A K-MAX helicopter — with a safety pilot on board but solely controlled by a ground operator — douses flames in a demonstration last November by Lockheed Martin and Kaman, the K-MAX manufacturer. A 2.2-kilogram Lockheed Martin Indago quadcopter (not shown) identified hot spots for the ground operator.

If successful, this type of demonstration could pave the way for additional trials and, eventually, routine flights of unmanned aircraft to fight fires.

“When folks see the capability of unmanned aircraft and how they can help protect the landscape, save money and potentially lives, I believe they will want to use them,” Bathrick says.

New risk: Passengers love Wi-Fi, but cybersecurity experts see it as a possible avenue into an aircraft's computers.

Don't fear cyber disclosure

Airlines should welcome, not squelch, responsible disclosure about potential security loopholes as a defense against future attacks

VIEWPOINT
by Tim Erlin
terlin@tripwire.com

Americans have become accustomed to seemingly-ceaseless warnings about potential cyberattacks that could breach electronic medical records, steal bank and credit-card information, and disrupt the nation's electric power grid.

The aviation industry, however, has largely escaped scrutiny about its security vulnerabilities. Airlines arguably have been more resistant than retailers, insurers and financial institutions in accepting public disclosure of security flaws as a tool for preventing future breaches. Indeed, the advocacy group Electronic Frontier Foundation said a cybersecurity researcher was detained in April by FBI agents after his United Airlines flight landed in Syracuse, New York, because he tweeted a joke on board about hackers deploying oxygen masks.

That case highlights a tension between regulators and information-security professionals about whether publicly exposing potential paths for cyberattacks helps reduce the risk of future strikes or actually paves the way for more attacks.

The aviation industry — with the lives of of passengers at stake — is particularly sensitive to acknowledging security weaknesses, lest hackers exploit them. Yet awareness is growing that airlines and federal agencies must better prepare for such attacks.

The title of a recent Government Accountability Office (GAO) report captured this urgency: "Air traffic control: FAA needs a more comprehensive approach to address cybersecurity as agency transitions to NextGen." Modern aircraft, the GAO notes, are increasingly connected to the Internet, bringing risk of "unauthorized remote access to aircraft avionics systems."

Security researchers already have demonstrated theoretical attacks on aircraft and aircraft systems, such as accessing flight control systems via the in-flight entertainment system. Rather than acknowledging the security gaps and developing a plan to fix them, regulators and airlines seem more intent on squelching the information. Nonetheless, many industries have come to realize that suppressing security research leads to less effective response and patching. Very simply, the reality of eventual public disclosure puts pressure on vendors to develop and deploy fixes.

The threats targeting aviation

Given all the technologies that enable modern air travel, it might seem that one of the aviation industry's highest priorities would be to defend against highly-sophisticated attacks. But in reality, lack of attention to basic, best-practices guidelines is the biggest danger.

That's especially true as once-closed networks are modernized and connected to other networks. While there is not a direct link between air traffic control and the Internet today, the distance between these systems continues to decrease. An example of this intersection of old and new is the recent introduction of Wi-Fi on planes, which some researchers say creates an easier avenue for attackers to someday hack an airliner's flight control system, either by masquerading as an innocent passenger or by working remotely from the ground. While some steps, like a basic firewall, have been put in place to separate these systems, attackers have been circumventing firewalls in other industries for many years.

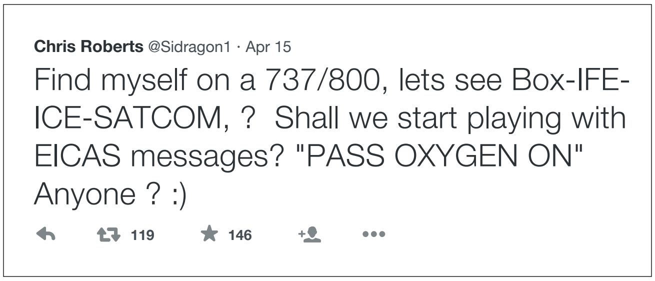
If those vulnerabilities are ever exploited in a real attack, the consequences could be catastrophic.

The risk isn't limited to aircraft alone. The aviation sector as a whole has to worry about how to collectively manage information security issues in adjacent parts of the business. Threats to air traffic control and passenger reservation and transaction systems are numerous.

With the air traffic control systems, the primary concern is flight safety. The GAO questioned the FAA's strategy for cybersecurity around NextGen, the GPS-based replacement for today's radar-based air-traffic control system. NextGen is another example of new technology being introduced into a field that has traditionally been closed. The number of people who are familiar with and have access to radar equipment is relatively small, but millions of people use GPS on a daily basis.

Then there is the major risk of financial fraud. Airlines, booking agents and ultimately consumers use a limited number of Global Distribution Systems to book tickets and manage reservations around the globe. Because an airline's GDS network handles transactions not just between banks and airlines but consumers as well, the threat model is substantially broader than with say, air-traffic control systems. Though GDS systems are harder to secure in one sense — their scope means they present a bigger attack surface — they also are easier to secure because security architects can use much of the host company's existing IT technology.

On the air-traffic control side, it's worth noting that the impact of an individual security incident can be vast. Someone who is intent on causing a significant air traffic incident has different motivations than someone who is trying to steal money. These two attackers will take different risks and typically have different resources.



The tweet that got cybersecurity advocate Chris Roberts detained by the FBI.

Building a threat model

Effective aviation cybersecurity requires organizations to build threat models that describe the attacks that could compromise safety or put customer data and financial information at risk. A reasonable threat model is the first step toward establishing sufficient defenses. Security managers should begin by attempting to understand who the potential threat actors are, and what they might want to accomplish. Once this is understood, it's possible to build layers of defense designed to thwart the most likely attack scenarios.

A starting point must be a willingness to disclose information about potential cyberattacks through responsible partnerships between researchers and the various affected vendors. Such partnerships allow researchers to discover new vulnerabilities, report them to affected vendors first, then ultimately publish them publicly after enough time has elapsed for the vendor to address the issue. Most security researchers believe this is the best approach for minimizing the risk of publication and maximizing the effectiveness of response. This approach has produced measurable gains in other industries, and should be used in aviation as well.

Tim Erlin is director of IT security and risk strategy at Tripwire, a security software and consulting firm. He is a member of the Information Systems Security Association and frequently advises corporations and government agencies on cloud-security management.

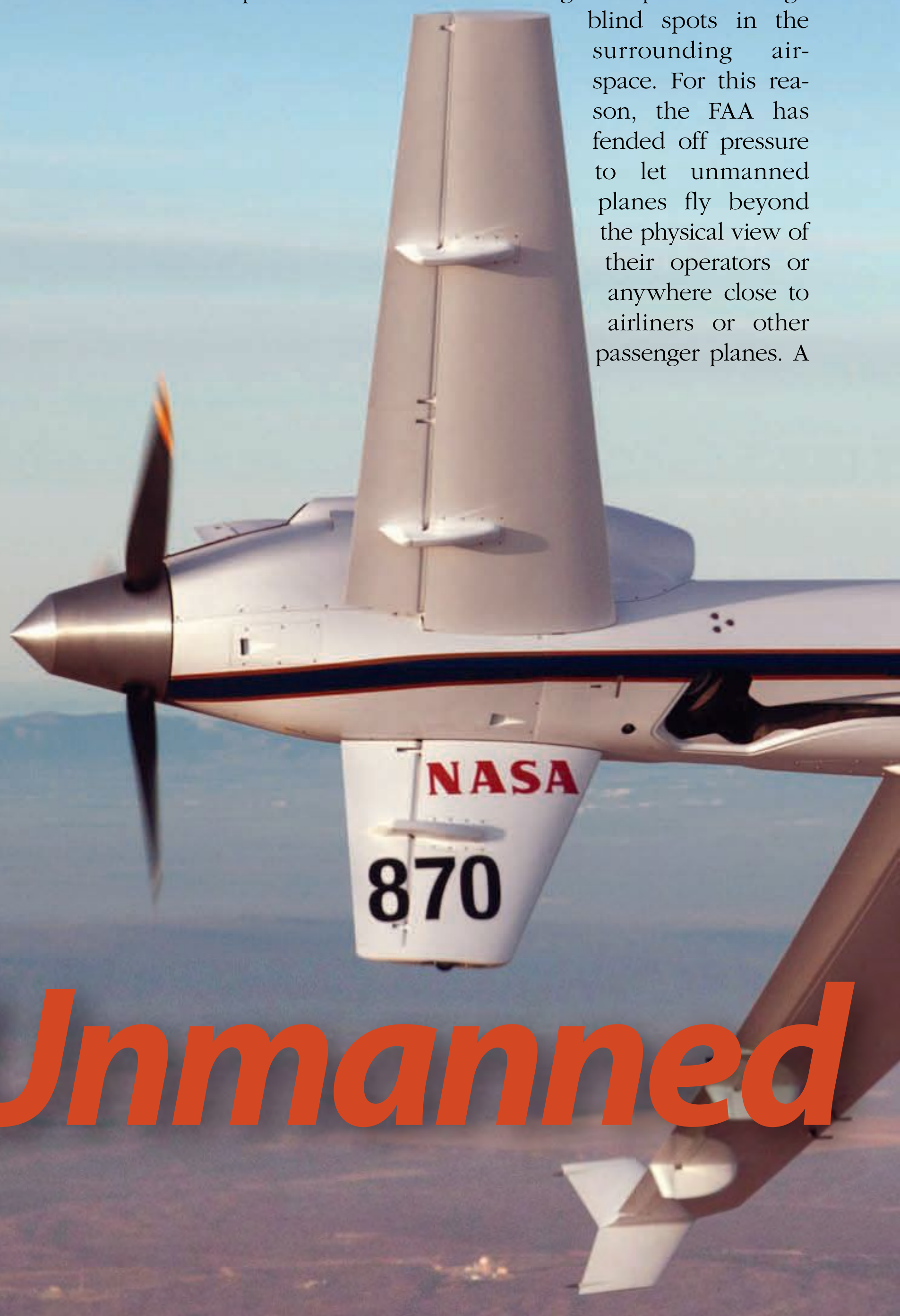
Unmanned

The specter of an unmanned aircraft flying blind to the surrounding airspace and colliding with a passenger plane has prompted the FAA to restrict where these craft can fly. Henry Kenyon examines technical solutions to the sense-and-avoid problem.

by Henry Kenyon
hkenyon@hotmail.com

A pilot controlling NASA's Ikhana unmanned research plane from a ground station saw an icon pop up on his display indicating another aircraft approaching on a collision course. He modified his flight path and avoided the other plane. If he hadn't done so, software on the plane would have made the evasive maneuver for him. This test, described to Aerospace America by participants, is one in a series carried out beginning last November by the FAA, NASA and General Atomics Aeronautical Systems at NASA's Armstrong Flight Research Center in California.

The encounters targeted a glaring shortcoming of today's unmanned planes: Even the most sophisticated of them leave their ground pilots with huge blind spots in the surrounding airspace. For this reason, the FAA has fended off pressure to let unmanned planes fly beyond the physical view of their operators or anywhere close to airliners or other passenger planes. A



plethora of close calls back up the FAA's concerns. FAA reported 175 incidents of unmanned aircraft entering restricted airspace in 2014, 25 of which resulted in near-collisions between an unmanned plane and another aircraft.

The job for Ikhana last November was to demonstrate a possible solution. General Atomics equipped this research version of the MQ-9 Predator B with an experimental radar to scan the surrounding test range; an antenna to receive GPS-locations that might be broadcast by other aircraft; and a transponder to interrogate their collision-avoidance transponders. The tests demonstrated redundancy — if a nearby plane wasn't broadcasting GPS coordinates or didn't have a collision transponder, it would still be de-

NASA's Ikhana unmanned research plane is equipped to test several methods to detect surrounding air traffic.

NASA

not unseeing

General Atomics

General Atomics, which manufactures the Predator and Reaper unmanned aircraft, is testing a prototype sense-and-avoid technology that allows unmanned aerial vehicles to avoid collisions in the sky.

tected by the radars. If the radar were blocked by ground clutter, the pilot would be alerted by the GPS or collision avoidance detections. NASA officials probably had this kind of experiment in mind in 2006 when they acquired the MQ-9 and named it Ikhana, the Choctaw word for intelligence.

Putting sense-and-avoid equipment on a Cessna-sized unmanned plane like Ikhana is one thing. Figuring out how to do that on a smaller unmanned aircraft such as the 44-pound Boeing Insitu ScanEagle or even tiny quadcopters — the kind that are driving much of the commercial interest in drones — will be quite another.

Current anti-collision technology is "too large and heavy" for small unmanned planes, defined as under 55 pounds, FAA says in its proposed rules released in February. Until "this equipment is miniaturized," ground operators must physically watch their craft at all times, a process called see and avoid, or file paperwork with the FAA requesting exemptions.

Existing FAA regulations restrict operations in a way that executives like W. Hulsey Smith, CEO of Aero Kinetics in Fort Worth, Texas, find onerous. The rules allow firms to request waivers to operate in civilian airspace for limited and very specific purposes such as cinematography.

"You're not allowed to operate over personnel or property that can be damaged by the systems. You're not allowed to operate in environments that are not prescribed in your COA [Certificate of Waiver or Authorization]," says Smith, whose company makes small unmanned aircraft.

FAA shows signs of bending on the sense-and-avoid question, but only a little. In May, it announced a research initiative to explore expanding unmanned flights in some cases. BNSF Railroad will examine how unmanned planes might be commanded to fly beyond the view of their operators to inspect railroad tracks and bridges in rural or isolated areas. Drone maker PrecisionHawk of Raleigh, North Carolina, will explore flying unmanned planes outside the pilot's view in rural areas to monitor crops and guide application of water, fertilizer and pesticides. CNN will look at how unmanned planes might be used for news gathering in urban areas, although still with visual line of sight between plane and operator. The FAA expects each participant to introduce new sensor and navigation technologies, but how those technologies fit into existing regulations will be worked out during safety assessments, says FAA spokeswoman Alison Duquette.

Even if that research pans out, industry experts say the only way to fully open the airspace to legions of small drones will be to equip them to spot air traffic. A host of companies, including General Atomics, have taken up the miniaturization challenge. Success could help clear the way for unmanned aircraft to satisfy the exploding demand for agricultural flights, surveillance and scientific missions, consumer package-delivery and even movie stunts. As things stand, operators can only do those things legally through the FAA's exemption process.

Today, military and government-operated unmanned planes are equipped with video cameras, but these are meant for watching people or vehicles on the ground, not for spotting other planes. The growing numbers of smaller craft flown by hobbyists, businesses and law enforcement agencies have smaller cameras that deliver even less situational awareness.

ONBOARD OR ON GROUND?

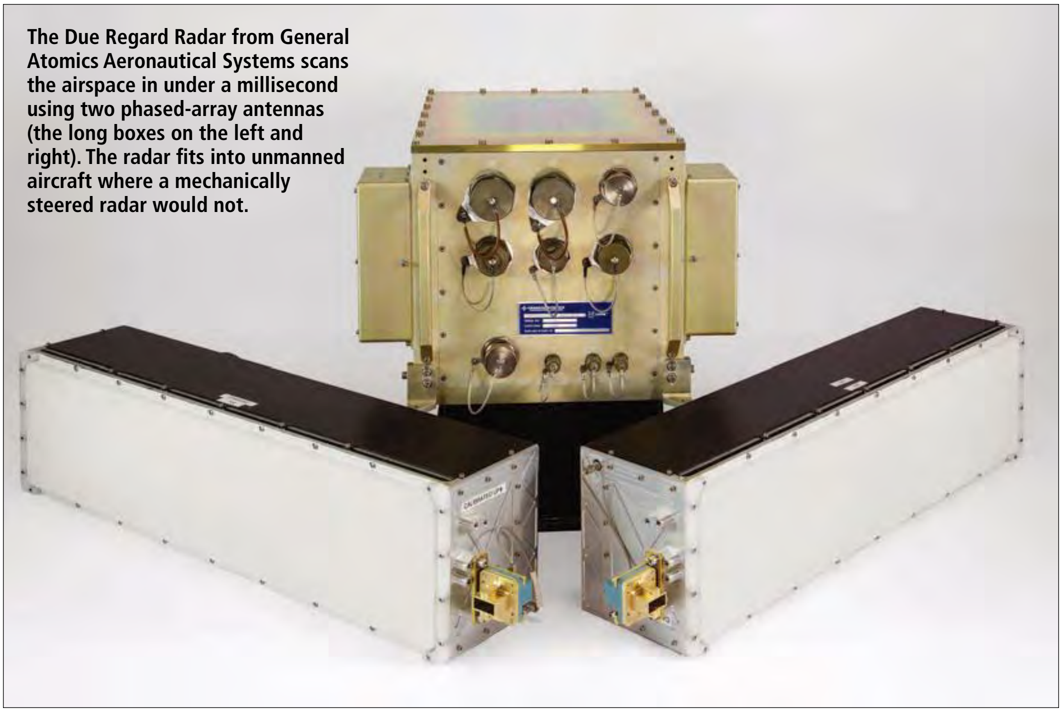
So far, industry and government engineers are working on two main types of sense-and-avoid technologies: 1. Ground radars, which transmit radio waves into the airspace to detect planes, and 2. Electronics that can be installed on unmanned planes to sense other aircraft.

An advantage of the ground approach is its reliance on existing FAA radars, meaning there is no need to modify the aircraft, says Paul Schaeffer, program manager for sense-and-avoid technology at the Air Force Research Laboratory at Wright-Patterson Air Force Base in Ohio. But Schaeffer also notes a disadvantage: Without an on-board radar or other sense-and-avoid electronics, the plane can only fly where there is radar coverage. This may be adequate for flights over urban areas or well-traveled flight corridors, but not for rural Alaska and other remote regions.

Today, when the military wants to fly unmanned aircraft through commercial airspace, the FAA requires the plane's operator to follow it with conventional planes or station human observers along its flight path. The Air Force avoided this requirement in one location by erecting ground radars to create a safe corridor between Cannon Air Force Base in New Mexico and nearby restricted military airspace. Pilots can see the locations of other aircraft on their navigation screens as they steer their craft through the corridor. The FAA approved these radars and displays in April 2014.

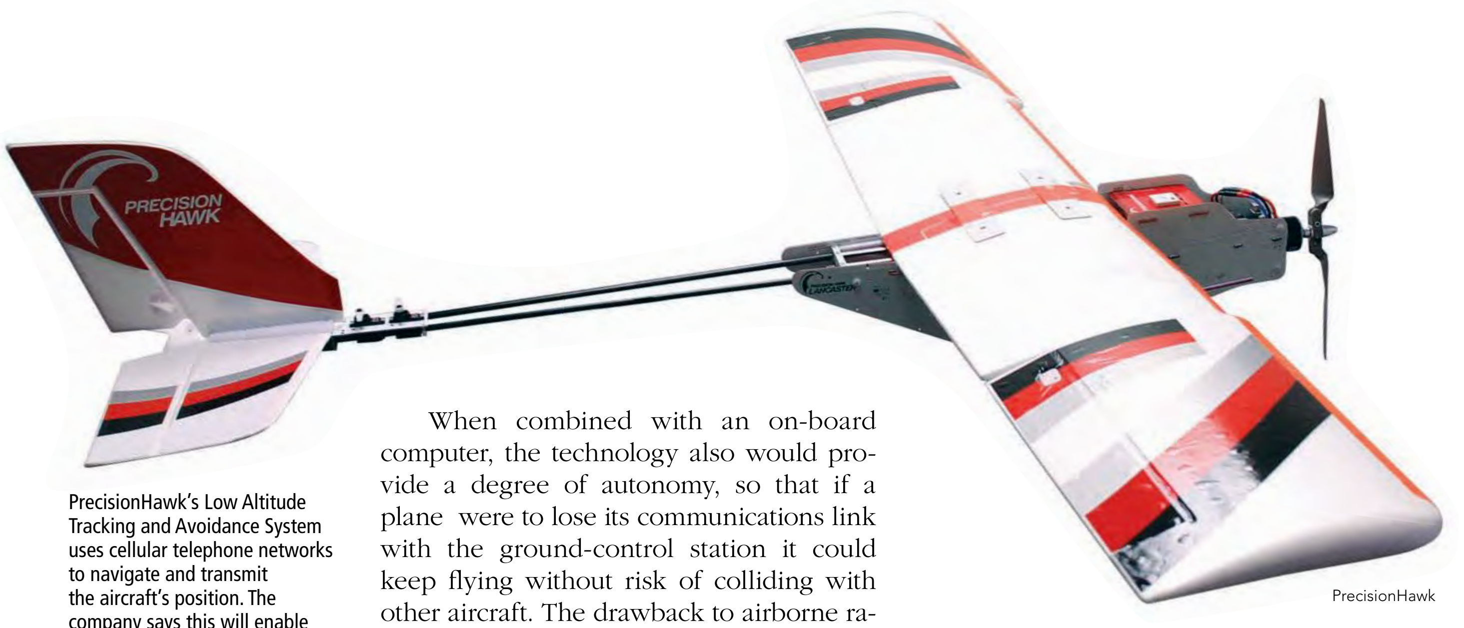
Still, ground radars will always be constrained by their limited ranges. Schaeffer would rather install cameras or radars on planes and display the views to pilots on the ground.

"This solution is elegant in that it provides the ability to fly wherever required, untethered by earthbound radar coverage limitations as the sensors go where the aircraft goes," Schaeffer says.



The Due Regard Radar from General Atomics Aeronautical Systems scans the airspace in under a millisecond using two phased-array antennas (the long boxes on the left and right). The radar fits into unmanned aircraft where a mechanically steered radar would not.

General Atomics



PrecisionHawk

PrecisionHawk's Low Altitude Tracking and Avoidance System uses cellular telephone networks to navigate and transmit the aircraft's position. The company says this will enable small unmanned aircraft to safely fly in commercial airspace.

When combined with an on-board computer, the technology also would provide a degree of autonomy, so that if a plane were to lose its communications link with the ground-control station it could keep flying without risk of colliding with other aircraft. The drawback to airborne radars is that they perform poorly at very low altitudes — 550 feet or below — due to the "clutter" or interference from objects such as power lines and buildings.

AIRBORNE RADAR

General Atomics wants to scale down the airborne equipment it tested at Armstrong into a version for smaller aircraft like the ScanEagle with its 10-foot wingspan, which poses size, weight and power challenges. This work focuses on the larger half of the small drone category, not very small aircraft such as quadcopters. The version tested on the MQ-9 drew 1,800 watts, and program manager Ramon Estrada says a 650-watt version will be required for smaller aircraft, something he says is achievable. Ultimately, his team wants to shrink the mass and volume by half, and combine the equipment in one box.

The company calls the technology a Due Regard Radar in reference to the FAA requirement that all aircraft must maintain a safe separation or "due regard" to avoid collisions. Two electronically scanned radar arrays sweep across an area and focus on a target in a fraction of a millisecond, Estrada explains. The equipment contains more than radar electronics. The package tested on NASA's Ikhana includes a radio to broadcast GPS coordinates and receive them from other planes. The FAA, under its NextGen air-traffic-control system, has ordered that all planes flying in U.S. airspace, including small unmanned ones, must have Automatic Dependent Surveillance-Broadcast radios by 2020.

The radar is a smaller and less powerful version of the radars aboard larger traditionally-piloted military aircraft. Currently, Due Regard Radar consists of three boxes: two with antenna arrays and one unit housing the radar's electronics. The primary engineering challenges are power and weight, Estrada says. The radar's range is limited to 30 nautical miles or less — depending on the size of the object. But Estrada notes that should be enough buffer to avoid a collision. The radar is useful for detecting "non-compliant" targets — small aircraft not equipped with ADS-B or Traffic Collision Avoidance Transponders or wildlife such as large birds.

The drone's flight computer collects the airborne radar data and aircraft position information and fuses it using software developed by Honeywell. This single picture of the local airspace is then transmitted to the ground and shown to the pilot via the ground control system's Conflict Prediction and Display system.

If another plane is detected, FAA-funded software called ACAS-Xu, for Airborne Collision Avoidance System for Unmanned Aircraft, warns the pilot to evade, either by climbing, descending or turning away. The message is stored in the flight computer, and if the pilot fails to respond, the aircraft automatically takes evasive action. The pilot can also manually override this auto-evade function, if necessary, explains Brandon Suarez, the General Atomics lead project engineer for sense and avoid.

ACAS-Xu can be programmed to maintain a set distance from other aircraft. "We don't want to trigger anyone else's collision avoidance system," Suarez says.

Work on the radar system began in 2010, when the company's Pentagon customers asked for on-board sensors to operate their unmanned aircraft in commercial airspace.

General Atomics plans to conduct an additional series of flight tests this year on its own Predator B test aircraft, with follow-on tests set for early 2016 aboard NASA's Ikhana.

SMALL AIRCRAFT

Unlike their larger counterparts, small unmanned aircraft represent a new challenge because until very recently, their size made it difficult to fit them with radar or other types of sensors for sense-and-avoid systems. Small drones, from hand-launched hobbyist toys to aircraft used for law enforcement and scientific research, are supposed to be flown under tight limits, but some operators ignore the rules. The FAA restricts craft weighing less than 55 pounds to flying under 500 feet in daylight and in line of sight of their operators. The FAA, NASA and private industries are working on new technologies for the smallest unmanned aircraft to potentially allow them to fly beyond the view of their operators.

Experts from the University of North Dakota, NASA, Mitre and Rockwell Collins are trying to miniaturize ADS-B transponders to fit into unmanned aircraft including the ScanEagle, says Al Palmer, the university's director of unmanned aircraft systems research.

Operators would control the drones from smartphones, laptops or tablets, and they would see the locations of ADS-B equipped aircraft in their vicinities, Palmer explains.

"All you need is a video screen," he says.

The university and its partners are working with Appareo Systems, a Fargo, North Dakota-based electronics firm, to make ADS-B or a similar type of sense-and-avoid electronics small enough to fit inside small drones.

The University of North Dakota and Mitre engineers have test flown prototype miniaturized electronics on a piloted NASA test aircraft standing in for a drone. Rockwell Collins is helping to develop a command and control system that will allow operators to see a picture of the airspace around the plane that extends beyond line of sight, Palmer explains.

LOW ALTITUDES

At the same time, a growing number of agricultural and oil exploration firms are getting FAA exemptions to use small unmanned aircraft to monitor crops and conduct geological surveys. Those often fly at very low altitudes, usually no higher than 500 feet, which makes them a potential collision hazard near airports for passenger planes that are taking off and landing.

PrecisionHawk, one of the companies in the new FAA initiative, wants to avoid the challenge of squeezing lots of new communications equipment on aircraft by using cellular telephone networks to send and receive guidance and navigation data. PrecisionHawk's Low Altitude Tracking and Avoidance System, or LATAS, uses software and a navigation chip installed in the aircraft's flight control computer to connect to a ground controller's tablet computer or smartphone via a commercial cellular network. The aircraft operator would view detailed digital maps depicting fixed obstacles such as power lines. The obstacles could be geofenced in advance, meaning the operator would be alerted if the craft approaches a boundary, and if the craft crossed the "fence" it could be programmed to turn around or automatically land, says Tyler Collins, PrecisionHawk's director of business development and the developer of LATAS.

Besides geofencing, LATAS will also allow pilots to file flight plans with the FAA from their laptops or smartphones, which fits with requirements to include all types of drones into the overarching national airspace monitoring system taking shape.

The technology is still in the testing and development phase. Over the next six months PrecisionHawk will test and validate cellular networks across the U.S. and Canada to ensure that LATAS-using drones can operate across most of North America. PrecisionHawk is also working with NASA to ensure that the system fits into next generation airspace navigation plans.

However the regulatory process plays out, unmanned aircraft are swiftly joining the nation's skies. Technologies that allow their safe operation in commercial airspace will open new markets across the economy, notes Aero Kinetics CEO W. Hulsey Smith. "We have not seen any single industry in the United States that could not benefit from some sort of application of small unmanned aircraft systems," he says.

The U.S. Air Force so far has updated the software on 482 F-16 fighter jets with Automatic Ground Collision Avoidance System developed in part by Lockheed Martin.

NASA

by Debra Werner
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Deep inside a U.S. F-16 fighter jet, computer software constantly compares the aircraft's path to the terrain depicted in digital maps uploaded from the National Geospatial Intelligence Agency. If the software decides the plane is about to crash into the side of a mountain or valley floor, a digital beep warns the pilot through his or her headset. If the pilot fails to change course, the software takes over, rolling the wings level and ascending with a force of 5 to 6 Gs per second until the jet clears the terrain.

The hope is that by then, a pilot who might have lost consciousness due to the high G forces of a tight turn will be conscious again. The Office of the Secretary of Defense credits the Automatic Ground Collision Avoidance System, which was developed by NASA, Lockheed Martin Skunk Works and the Air Force Research Lab, with saving at least two pilots and two F-16s since the Air Force began installing it in 2010.

The F-16's collision avoidance software is a long way from the velvet-voiced, misanthropic HAL 9000 computer depicted in author Arthur C. Clarke's 1968 classic, "2001: A Space Odyssey." The new software cannot land the plane nor do anything more complicated than direct it away from the ground.

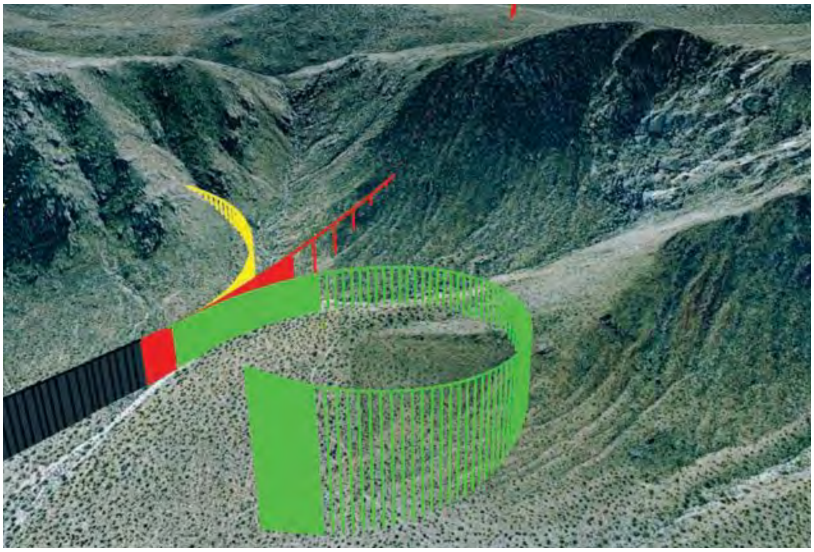
Über flight computer

The Germanwings crash has shone fresh light on the possibility of taking over an airliner via computer, if necessary, in an emergency. Debra Werner reports that despite interesting technical work, an all-powerful flight computer appears to be a long way off — perhaps for good reason.

Despite its limits, the new collision avoidance technology is one of the innovations aviation experts cite most often when asked about possible technical solutions for cases like the Germanwings crash in March or EgyptAir in 1999, in which pilots intentionally crashed their planes. The Germanwings crash has prompted experts to take a close look the F-16 technology. Yet so far, the deeper they look, the more challenges they see, prompting even one advocate to say that such a system is at best years away.

Putting the equivalent of the F-16's collision avoidance system on commercial airliners would be "a slam dunk technology-wise," says Richard "Pat" Anderson, director of Embry-Riddle Aeronautical University's Eagle Flight Research Center in Daytona Beach, Florida.

NASA engineers have begun to modify collision avoidance software to determine when an airliner comes dangerously close to hitting the ground and to include airports in its digital maps so the warning does not go off with each landing. They have not yet begun the more difficult task of redesigning autopilot systems to enable passenger planes to make aggressive, evasive maneuvers rather than the slow, steady ascent and descent they currently favor. Even then, it would take years to prove to the FAA that the new technology wouldn't cause more problems than it solves. Anderson knows it would take


NASA

With technology NASA is testing, a drone operator would see visual aids superimposed on the terrain ahead. The current flight path is shown in black; red and yellow indicate collision courses with the terrain; green shows the only safe course.

years to prove to the FAA that these modifications were worthwhile, but he still sees great potential for them to contribute.

Advocates like Anderson nonetheless may find it difficult to swing the discussion in their direction. One expert at NASA – which studies automated flight – says programing in a collision avoidance feature would definitely be doable, but he questions the value.

"Automatic Ground Collision Avoidance System technology could be adapted to work on a single airliner," says Mark Skoog, chief engineer for collision avoidance technology at NASA's Armstrong Flight Research Center. To be widely used, however, that system would need to make its way through the airworthiness review and certification process, which could be an uphill battle since engineers would need to prove to the FAA that giving increased authority to autopilots could not do more harm than good.

Plus, a mentally-ill pilot could take down an airliner in many more ways than steering it into the French Alps, as in the Germanwings flight. He or she could dump the plane's fuel or shut off power to its engine.

"This is a slippery slope," Anderson acknowledges. "When you've identified that the human is trying to do something bad, then you have to let the computer lock out the pilot and land somewhere by itself, which is not out of the realm of scientific possibility right now. It's more of a political issue than a technology issue."

If there is any common consensus among experts, it is this: the Germanwings scenario would be all but impossible to prevent by technology alone. Even the most advanced autopilot system could not solve the entire problem. It would have to be paired with policies to protect passengers from pilots who become incapacitated by physical or mental illness.

"We all know how difficult it is to protect any machine against an attacker," says David Mindell, an aeronautics and astronautics professor at MIT. "But to protect it against a user who turns into an attacker, that's extraordinarily difficult."

Locking out the pilot

In 2010, Lockheed Martin began updating the software on F-16 fighters with the Automatic Ground Collision Avoidance System, and so far has installed 482 of them. Advocates had to convince the pilots who dominate the Air Force leadership that the system would help them, not steal their authority. Designers knew they had to avoid impeding a pilot's ability to carry out a mission. Accuracy was paramount, because pilots will become frustrated by false alarms and simply turn the system off. In flight, Air Force pilots have discovered they can still "push as hard as they want," Anderson says. "The airplane knows exactly where the ground is and how at the last second to pull out if the pilot doesn't do it."

Anderson is confident that in the commercial passenger realm, flight control software on airliners could someday be programmed to do even more than avoid collisions. It could take control of the aircraft for good if it determined that a pilot's actions threatened flight safety.

In such a scenario, "the flight control computer will have to have the final say," Anderson says. The airplane would take charge and broadcast a message, saying, "I've taken control of this airplane and I'm going to land at Frankfurt at 10:30."

Experts are wrestling with the question of whether ceding control to an über computer might actually add danger, as Arthur C. Clarke seemed to suggest with his depiction of the HAL 9000.

"These days, we tend to think technology can solve problems," says Amy Pritchett, an associate professor of aerospace engineering at the Georgia Institute of Technology. "But the technology itself adds failure modes, cost, safety concerns and security concerns."

She points to Air France flight 447, an Airbus A330 that crashed into the Atlantic Ocean off Brazil in 2009 after ice crystals lodged in the Pitot tubes that gauge airspeed near the nose of the craft. When airspeed data no longer matched airspeed data from static-pressure sensors on board the aircraft, the plane's autopilot system switched off, leaving the flight crew to sort matters. That confusion was a contributing factor in the accident, according to the July 2012 report by BEA, the French air accident investigation agency.

What's interesting, Pritchett says, is that Flight 447 was not the only time the Pitot tubes froze. In at least two prior incidents, ice clogged the tubes of Airbus aircraft, causing incorrect airspeed measurements. In those cases, pilots realized their airspeed indicators were not working properly, turned off the autopilot and flew the aircraft manually until their airspeed sensors worked again.

That's just one example of the limit of autopilots on today's aircraft. "We still have not gotten to the point where autonomous decision making, processing and computational capability can match the sensing and computational capability of the human brain," says retired Air Force Lt. Gen. David Deptula, who ran the service's intelligence, surveillance and reconnaissance shop from 2006 to 2010, during a spike in drone patrols in Iraq and later in Afghanistan.

"You can't anticipate everything that could happen and artificial intelligence only knows what it's been programmed to know," adds Deptula, now dean of the Air Force Association's Mitchell Institute for Aerospace Studies.

An analysis of flight data recorders shows that autopilot systems malfunction in about 20 percent of all flights. Many of those malfunctions are small. For example, a pilot might need to turn off autopilot for a minute while the co-pilot resets a circuit breaker.

"The times when autopilot fails and pilots step in far outnumber the times a pilot intentionally or unintentionally flies an airplane into the ground," Pritchett says.

Remote control

The Germanwings crash also prompted public discussion of whether someone on the ground could take control of an aircraft to prevent a collision. Some aviation experts scoff at the idea.

"I don't think people have thought that through," Mindell of MIT says. "Who gets to decide when to take over? What do you do when communication links are broken? How do you secure communication links?"

The modified DROID unmanned aircraft was used in developing an autonomous ground collision avoidance system that is being integrated into the U.S. Air Force's fleet of F-16 fighter jets.

NASA

A human factors engineer at Rockwell Collins' Advanced Technology Center in Cedar Rapids, Iowa, tests a simulator for use in a NASA study about the viability of a single pilot controlling an airliner.

Rockwell Collins

Even before the Germanwings crash, however, the possibility of remote control came up frequently when engineers discussed whether it would be safe to let airlines fly large passenger planes with a single pilot. Researchers at the NASA Ames Research Center since 2012 have been studying whether single pilot operations would be feasible. Last May, NASA picked Rockwell Collins to lead a team of industry and university partners to study issues related to a single-pilot cockpit, including ways to reduce the pilot's workload through automation and ground support.

The Germanwings accident underscores the need for improved autonomous systems and remote operations for when a lone pilot is granted control of a passenger plane, says Michael Clamann, postdoctoral associate at Duke University Pratt School of Engineering's Humans and Autonomy Lab. Eliminating onboard co-pilots is probably years away, Clamann says, but could save carriers billions of dollars annually.

But before then, engineers need to improve the safety of autonomous flight control systems and the security of communication links between the air and the ground. The improved communication links would be needed to avoid hacking and because airlines are likely to want a pilot on the ground who could intervene should the airborne pilot suffer a heart attack, stroke or even food poisoning.

"If you move to single-pilot operations, you are inherently asking for some kind of alternative control of the plane," Clamann says. In theory, he says, the same type of remote operation needed for single pilot flights could save passengers from a pilot intentionally trying to crash a jetliner.

Remote control systems, like the ones used by the U.S. Defense Department to operate unmanned aircraft, are not yet safe enough for passenger jets. In June 2014, a Washington Post investigation revealed that military drones around the world crashed 400 times between September 11, 2001 and December 2013.

"That's a crash approximately every three weeks in a fairly small fleet," Pritchett says. "If a fairly small fleet is crashing every three weeks, imagine what would happen with the huge volume of air transport flights."

Approximately one quarter of the crashes counted by the Post involved lost communications links between the aircraft and the ground stations. Maintaining secure and reliable communications links could pose similar problems for remote operators of passenger jets. A danger is that someone seeking to divert a plane could jam communications or provide faulty navigation information.

"One really scary notion is being able to play with the GPS signal by sending false signals or modulating the signal so that what the ground controllers think is happening in the sky is not what's actually happening," Pritchett says. "The notion of being able to control aircraft from the ground to prevent a bad act in the air, has some fairly obvious flaws in terms of someone sabotaging that ground control takeover mechanism."

To prevent sabotage, airlines would need to ensure ground control facilities were extremely secure, much safer even than existing air traffic control centers. In September 2014, thousands of flights into and out of Chicago airports were diverted when a contract employee allegedly set fire inside an air traffic control facility in Aurora, Illinois.

"That Air Traffic Control center was already considered a secure facility," Pritchett says. "Imagine the level of hardening we would need on a facility where a number of airplanes could be flown in a way that could lock a pilot out."

Human solutions

Rather than turning to remote operations or autonomous flight to prevent rare pilot suicides, airlines are gravitating toward non-technical solutions.

The Germanwings co-pilot was given the controls when the pilot left the cockpit to use the restroom, and so an obvious step was to require two crew members in the cockpit at all times. Air Canada, Air Berlin and Norwegian Air Shuttle quickly announced plans to do so. Under FAA regulations, U.S. carriers already were required to have two people on the flight deck. For planes with a two-member cockpit crew, that means whenever one of the pilots leaves the cockpit, a flight attendant or other crew member must enter the cockpit and remain there until the pilot returns, although it is unclear how a non-pilot could save the plane.

The Germanwings crash also sparked calls for better mental-health screening of pilots. Soon after the March crash, Lufthansa, the parent company of Germanwings, confirmed news reports that the co-pilot of the A320 had informed the company in 2009 about an episode of severe depression. Airlines and government aviation authorities began reviewing procedures to screen pilots. In the U.S., air transport pilots under the age of 40 receive annual medical evaluations, which are designed to spot physical and mental problems. Pilots 40 and older must renew their medical certificates with a trip to the doctor every six months.

"The system needs to acknowledge that pilots have inner lives and they're human beings and not machines," Mindell says. "I think the American system has been better at that than the European system."

As an example, Mindell points to the FAA's decision in 2010 to begin allowing pilots who receive a special medical certificate to continue flying even if they take medication to treat depression. "That was a step toward acknowledging pilots are human beings like everyone else," Mindell says.

Screening is important, Pritchett says, but it raises additional questions. If a pilot reports severe depression, for example, do you prevent the pilot from flying, or would that discourage further reporting? No system can identify every dangerously ill pilot, nor can autonomous control technologies completely replace human pilots. Automated systems might help save lives, though, if the F-16 is any indication.

"No Air Force pilots looked on automatic collision avoidance technology with favor 25 or 30 years ago," Skoog says. "We are stunned by the way it has been accepted."

Out of the

25 Years Ago, June 1990

June 1 West Germany's Rosat satellite is launched by a U.S. Delta 2 rocket from Cape Canaveral, Florida. Rosat, named after the famous German scientist Wilhelm Roentgen, who discovered X-rays in 1895, is designed to take photos in extreme ultraviolet light to gather data on intergalactic gases, black holes and other objects on the edge of the universe. Flight International, June 13-19, 1990, p. 29.

June 7 Europe's first test firing of a liquid-hydrogen-fueled ramjet is made at MBB's site at Munich, Germany, toward the development of the Sänger space plane, although the Sänger is later canceled. The Sänger design, named in honor of the early Austrian pioneer of the space plane concept, Eugen Sänger, is a two-stage vehicle in which the first stage is initially propelled by a turbojet and then a turbo-ramjet to bring it up to Mach 6.6. The reusable Horus upper stage then takes off with its cryogenic rocket engine. Flight International, September 19-25, 1990, p. 26.

Also in June 1990 Sabena becomes the first civilian airlines to use satellite communications data for air traffic control during scheduled operations in a trial experiment with the Inmarsat satellite. Sabena's Airbus A310-300 is used in the test. Flight International, June 20-26, 1990, p. 5.

50 Years Ago, June 1965

June 3-7 The Gemini 4 mission is carried out, using a two-stage Titan 2 booster that carries astronauts James McDivitt and Edward White. Their spacecraft achieves 62 Earth orbits in 97 hours 56 minutes at 17,567-mph at an apogee of 174.8-miles and perigee of 100-miles. During the second orbit, White, equipped with a tether, emerges from the spacecraft for a space walk. The astronauts also perform medical and scientific experiments during the flight. Their capsule reenters the Earth's atmosphere on June 7 and is recovered in the Atlantic Ocean by a helicopter and taken to the recovery ship, the carrier USS Wasp. The New York Times, June 9, 1965, pp. 1, 22.

June 8 The USSR launches its 3,179-pound Luna 6 space probe toward the Moon. But the probe misses the Moon by almost 100,000 miles. due to an unsuccessful mid-course maneuver when an engine used to adjust the spacecraft's trajectory cannot be switched off. Tass releases, June 8, 1965, and June 10, 1965.

June 10 The first computer landing of an airliner is made with fare-paying passengers aboard, when a British European Airways Trident touches down in London. The Trident is the first civil aviation aircraft certified to use the automatic-landing system known as Autoflare that was developed by Smith & Sons, Ltd., a British aviation engineering company, in partnership with Hawker Siddeley Aviation Co. The New York Times, June 11, 1965.

June 12 Canada's solid-propellant Black Brant 5B sounding rocket makes its first launch at Fort Churchill, Manitoba, Canada. Missiles & Rockets, June 28, 1965, p. 11.

June 14 The Early Bird communications satellite successfully transmits, on an experimental basis, an electrocardiogram of a passenger on the S.S. France ocean liner, 2,000 miles at sea, to his physician in Paris. The Washington Post, June 15, 1965, p. A14.

14 June Carl Norden, the Dutch-born inventor of the famous bombsight named after him, dies at age 55 in Zurich, Switzerland. He emigrated to the United States in 1904, and in 1920, started work on the Norden U.S. Navy bombsight that was was produced in 1927. It was an analog computer and was further developed and used by Army Air Force B-17s and other bombers during World War II. The New York Times, June 16, 1965, p. 43.

June 15 In a surprise appearance, the Soviet Union's An-22 aircraft, the world's largest plane, lands at the International Air Show at Le Bourget, France. The AN-22 is said to be able to carry 720 passengers or 80 tons of cargo and weighs 250 tons with maximum cargo. Designed by Oleg Antonov and called the Antaeus, the aircraft is powered by four turboprop engines, each with twin propellers. The range with maximum load is 3,100 miles at a cruising speed of 420-mph. Aviation Week, June 21, 1965, p. 24.

June 16 Dr. Werner R. Kirchner, of Aerojet-General Corp., receives the James H. Wyld Propulsion Award from

the American Institute of Aeronautics and Astronautics (AIAA). He is cited for "outstanding contributions to solid rocketry," including his development of the thrust-vector control and thrust reverser that made possible the use of large, solid-propellant rocket motors in ballistic missiles such as the Polaris. The New York Times, June 17, 1965.

June 21 The 1.5-million-pound thrust F-1 rocket engine completes its 1,000th test firing. A cluster of five of the engines is to provide 7.5-million pounds of thrust for the first stage of the Saturn 5 to take men to the Moon. Marshall Space Flight Center Release 65-154.

June 27 Six scientist-astronauts selected for the Apollo manned Moon-landing program are announced. They are: Owen Garriott, associate professor of physics; Edward Gibson, senior research scientist; Duane E. Graveline, fight surgeon; Lt. Cmdr. Joseph Kerwin, USN, staff flight surgeon; Frank Michel, assistant professor of space sciences; and Harrison Schmitt, astrogeologist. The Washington Post, June 27, 1965.

June 28 The Early Bird 1 communications satellite begins commercial operations when President Lyndon Johnson formally inaugurates telephone service via the satellite in a 25-minute, six-nation conference call with European leaders. The New York Times, June 29, 1965, p. 12.

75 Years Ago, June 1940

June 10 Italy enters the war on the side of the Axis powers. Upon Italy's entry in the conflict, the British Overseas Airways Corp. services to Italy are eliminated and all British Empire air services are suspended. Interavia, June 14, 1940, p. 11.

June 12 The first production-built helicopter, the Focke Achgelis Fa 223 Drache, completes its initial flight. It is powered by a single 1,000-hp BMW Bramo radial engine that drives two rotors mounted outboard of the fuselage. Only 20 are built. David Baker, Flight and Flying: A Chronology, p. 253.

June 18-19 The first large-scale air raid on Great Britain is undertaken by a hundred or more German Heinkel 111 bombers. Although they mainly attack RAF air stations, some of the bombs fall on two-story houses in a working-class district of Cambridgeshire, killing about a dozen civilians. The air station attacks are unsuccessful—six of the bombers are shot down by Spitfire fighters and one by antiaircraft gunfire. Flight, June 27, 1940, p. 559.

June 26 Congress authorizes construction of the NACA's third research lab near Cleveland, Ohio. Initially called the Aircraft Engine Research Lab, in 1948 it is renamed the Lewis Flight Propulsion Lab after George W. Lewis, who served as the NACA's director of aeronautical research from 1924 to 1947. Upon the founding of NASA in 1958, it is transferred into this organization and becomes the Lewis Research Center. E.M. Emme, ed., Aeronautics and Astronautics 1915-60, pp. 40, 99.

June 28 Italian Air Marshal Italo Balbo is allegedly killed in an aerial engagement with British aircraft over Tobruk, Libya. Born in 1896, Balbo was an early leader in Benito Mussolini's Fascist movement and through political means gained his role in the Italian Air Ministry. It is claimed by some that Balbo was actually murdered on Mussolini's orders because he represented a political threat to his leadership. Interavia, June 29, 1940, p. 1.

100 Years Ago, June 1915

June 7 The German Zeppelin L.Z. 37 is shot down by an incendiary bullet later known as the Brock bullet, after its inventor, British scientist Frank Brock. Brock bullets are used thereafter and bring down 12 of the 17 Zeppelins shot down. Alan St. H. Brock, A History of Fireworks, p. 26.

June 8 Pioneering American aviator Glenn Curtiss is awarded a patent for his development of the stepped fuselage for flying boats. This revolutionary invention places a step approximately halfway along the underside of the fuselage to help break the surface tension of the water, allowing the aircraft to take off more easily. David Baker, Flight and Flying: A Chronology, p. 78.

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AIAA Bulletin

Members of AIAA's University of Texas (UT) in Austin's Student Chapter, along with members of UT's Sigma Gamma Tau, volunteered at the 14th Annual Women in Engineering Program, known as Introduce a Girl to Engineering Day (Girl Day) where over 1,600 elementary and middle school students were introduced to engineering. (See the full article on page **B9**.)

JUNE 2015

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

Addresses for Technical Committees and Section Chairs can be found on the AIAA Web site at **http://www.aiaa.org**.

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.

Event & Course Schedule

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
2015			
4 Jun	Aerospace Today ... and Tomorrow—An Executive Symposium	Williamsburg, VA	
16–19 Jun†	7th International Conference on Recent Advances in Space Technologies – RAST 2015	Istanbul, Turkey (Contact: Capt. M. Serhan Yildiz, +90 212 6632490/4365, syildiz@hho.edu.tr or rast2015@rast.org.tr)	
20–21 Jun	Optimal Design in Multidisciplinary Systems	Dallas, TX	
20–21 Jun	FUN3D Training Workshop	Dallas, TX	
22–26 Jun	AIAA AVIATION 2015 (AIAA Aviation and Aeronautics Forum and Exposition) **Featuring:** 21st AIAA/CEAS Aeroacoustics Conference 31st AIAA Aerodynamic Measurement Technology and Ground Testing Conference 33rd AIAA Applied Aerodynamics Conference AIAA Atmospheric Flight Mechanics Conference 7th AIAA Atmospheric and Space Environments Conference 15th AIAA Aviation Technology, Integration, and Operations Conference AIAA Balloon Systems Conference AIAA Complex Aerospace Systems Exchange 22nd AIAA Computational Fluid Dynamics Conference AIAA Flight Testing Conference 45th AIAA Fluid Dynamics Conference 22nd AIAA Lighter-Than-Air Systems Technology Conference 16th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference AIAA Modeling and Simulation Technologies Conference 46th AIAA Plasmadynamics and Lasers Conference 45th AIAA Thermophysics Conference	Dallas, TX	13 Nov 14
28 Jun–2 Jul†	International Forum on Aeroelasticity and Structural Dynamics (IFASD)	Saint Petersburg, Russia (Contact: Dr. Svetlana Kuzmina, +7 495 556-4072, kuzmina@tsagi.ru, www.ifasd2015.com)	
6–9 Jul	20th AIAA International Space Planes and Hypersonic Systems and Technologies Conference	Glasgow, Scotland	8 Dec14
12–16 Jul†	International Conference on Environmental Systems	Bellevue, WA (Contact: Andrew Jackson, 806.834.6575, Andrew.jackson@ttu.edu, www.depts.ttu.edu/ceweb/ices)	
25–26 Jul	The Application of Green Propulsion for Future Space	Orlando, FL	
25–26 Jul	Advanced High Speed Air Breathing Propulsion	Orlando, FL	
27–29 Jul	AIAA Propulsion and Energy 2015 (AIAA Propulsion and Energy Forum and Exposition) **Featuring:** 51st AIAA/SAE/ASEE Joint Propulsion Conference 13th International Energy Conversion Engineering Conference	Orlando, FL	7 Jan 15
30–31 Jul	Business Management for Engineers	Orlando, FL	
30–31 Jul	Hybrid Rocket Propulsion	Orlando, FL	
9–13 Aug†	2015 AAS/AIAA Astrodynamics Specialist Conference	Vail, CO (Contact: Dr. W. Todd Cerven, william.t.cerven@aero.org, www.space-flight.org/docs/2015_astro/2015_astro.html)	
29–30 Aug	Introduction to Space Systems	Pasadena, CA	
31 Aug–2 Sep	AIAA SPACE 2015 (AIAA Space and Astronautics Forum and Exposition)	Pasadena, CA	10 Feb 15
7–10 Sept†	33rd AIAA International Communications Satellite Systems Conference and Exhibition (ICSSC-2015)	Gold Coast, Australia (Contact: Geri Geschke, +61 7 3414 0700, Geri.geschke@emsolutions.com.au, www.satcomspace.org)	1 Apr 15
13–17 Sept†	34th Digital Avionics Systems Conference	Prague, Czech Republic (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, www.dasconline.org)	
22–25 Sept†	3AF/AIAA Aircraft Noise and Emissions Reduction Symposium	La Rochelle, France (www.aners2015.com)	30 Apr 15
23–24 Sept†	19th Workshop of the Aeroacoustics Specialists' Committee of CEAS and 5th Scientific Workshop of the European X-Noise EV Network	La Rochelle, France (www.aners2015.com)	

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
12–16 Oct†	**66th International Astronautical Congress**	Jerusalem, Israel (Contact: www.iac2015.org)	
27–29 Oct†	**Flight Software Workshop**	Laurel, MD (Contact: http://www.flightsoftware.org)	
2016			
2–3 Jan	**2nd AIAA CFD Aeroelastic Prediction Workshop**	San Diego, CA	
4–8 Jan	**AIAA SciTech 2016 (AIAA Science and Technology Forum and Exposition)** Featuring: 24th AIAA/AHS Adaptive Structures Conference; 54th AIAA Aerospace Sciences Meeting; AIAA Atmospheric Flight Mechanics Conference; 15th Dynamics Specialists Conference; AIAA Guidance, Navigation, and Control Conference; AIAA Information Systems—Infotech@Aerospace Conference; AIAA Modeling and Simulation Technologies Conference; 18th AIAA Non-Deterministic Approaches Conference; 57th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference; 9th Symposium on Space Resource Utilization; 3rd AIAA Spacecraft Structures Conference; 34th Wind Energy Symposium	San Diego, CA	**2 Jun 15**

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
25-28 Jan†	**Annual Reliability and Maintainability Symposium (RAMS)**	Tucson, AZ (Contact: Sean Carter, seancarter67@gmail.com, www.rams.org)	
14–18†	**26th AAS/AIAA Space Flight Mechanics Meeting**	Napa, CA (Contact: Ryan Russell, 512.471.4190, ryan.russell@utexas.edu, www.space-flight.org/docs/2016_winter/2016_winter.html)	
5–12 Mar†	**2016 IEEE Aerospace Conference**	Big Sky, MT (Contact: Erik Nilsen, 818.354.4441, Erik.n.nilsen@jpl.nasa.gov, www.aeroconf.org)	
16–20 May	**SpaceOps 2016: 14th International Conference on Space Operations**	Daejeon, Korea	**30 Jul 15**
13–17 Jun	**AIAA AVIATION 2016 (AIAA Aviation and Aeronautics Forum and Exposition)** **Featuring:** **32nd AIAA Aerodynamic Measurement Technology and Ground Testing Conference** **34th AIAA Applied Aerodynamics Conference** **AIAA Atmospheric Flight Mechanics Conference** **8th AIAA Atmospheric and Space Environments Conference** **16th AIAA Aviation Technology, Integration, and Operations Conference** **AIAA Flight Testing Conference** **8th AIAA Flow Control Conference** **46th AIAA Fluid Dynamics Conference** **17th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference** **AIAA Modeling and Simulation Technologies Conference** **47th AIAA Plasmadynamics and Lasers Conference** **46th AIAA Thermophysics Conference**	Washington, DC	
5–8 Jul†	**ICNPAA 2016 Mathematical Problems in Engineering, Aerospace and Sciences**	University of La Rochelle, France (Contact: Prof. Seenith Sivasundaram, 386.761.9829, seenithi@gmail.com, www.icnpaa.com)	
25–27 Jul	**AIAA Propulsion and Energy 2016 (AIAA Propulsion and Energy Forum and Exposition)** **Featuring:** **52nd AIAA/SAE/ASEE Joint Propulsion Conference** **14th International Energy Conversion Engineering Conference**	Salt Lake City, UT	
12–15 Sep	**AIAA SPACE 2016 (AIAA Space and Astronautics Forum and Exposition)** **Featuring:** **AIAA SPACE Conference** **AIAA/AAS Astrodynamics Specialist Conference** **AIAA Complex Aerospace Systems Exchange**	Long Beach, CA	
25–30 Sept†	**30th Congress of the International Council of the Aeronautical Sciences (ICAS 2016)**	Daejeon, South Korea (Contact: www.icas.org)	**15 Jul 15**

For more information on meetings listed above, visit our website at www.aiaa.org/calendar or call 800.639.AIAA or 703.264.7500 (outside U.S.).
†Meetings cosponsored by AIAA. Cosponsorship forms can be found at https://www.aiaa.org/Co-SponsorshipOpportunities/.
AIAA Continuing Education courses.

From the **Corner** Office

NECESSARY CHANGES ARE CREATING POSITIVE RESULTS

Sandy H. Magnus, Executive Director

The AIAA 2014–2015 Annual Report, Charting a Course for Success*, is available online, and I hope that each of you has taken, or will take, the time to read it. If the whole report hasn't yet made it onto your summer reading list—or you are sitting on a beach reading* Aerospace America *without Internet access—I submit to you my Executive Director's Report, which I've adapted for this column. It describes highlights of the past 12 months (it's been a busy year!) and where we are on our continuing journey to evolve AIAA into a stronger, more adaptable, more cohesive organization. Jim Albaugh summed it up aptly in his President's Report, which I urge you to read and which we will reprint here in a future issue, "The difficult decisions that we've made, and changes we have implemented, have positioned us well for growth and we are optimistic about our future."*

As you know, in 2014, AIAA adopted its Strategic Plan predicated on three strategic imperatives: develop and expand our community; strengthen our existing community; and deliver exceptional results—those three imperatives have contributed greatly to a year of positive growth and change at AIAA. In a relatively short amount of time, we've come a long way in realigning the AIAA staff and organizational structure to serve the evolving needs of our members—both individual and corporate—and the aerospace industry writ large. This type of evolution is necessary if the Institute is to grow and remain relevant and responsive. Shaping the Future of Aerospace isn't just our tagline; it's what we at AIAA are doing every day through our forums, publications, committees, honors and awards, member services, advocacy, and outreach. We have more work to do to refine and implement our Strategic Plan fully—it will take all of us working together to ensure our long-term success. It also will involve a continued culture of change. As Jim Albaugh's President's Report makes clear, we need to take steps to ensure our governance structure allows us to be nimble, proactive, and quickly able to recognize and react to new trends in our industry to be relevant to our members.

I am delighted to share with you that the changes we've made during the past two years have borne fruit. In the report's detailed Financials section, Bill Seymore, our secretary/treasurer shares that our budget returned to the black in fiscal year 2014. This promising financial news was due, in large part, to prudent stewardship of the Institute's endowment portfolio, which allowed for continued investments in AIAA's growth and sustainability. This news, along with improved revenues and economies of scale provided by our forums, reduced and realigned staff, and other factors, have us optimistic about our financial stability. We are emerging from the turbulence of the past few years, and are hoping for smoother sailing ahead for AIAA.

That said, adherence to the strategic imperatives; making hard, but necessary choices, about staff and the organizational chart; and having successful events and publications will not sustain our growth unless you, our members, continue to invest your time and energy in AIAA as fully as possible. While your professional obligations often limit the time you can spend on AIAA activities, the hours you volunteer are valuable ones. If you are active, involved, and engaged, thank you. If you are seeking new and different engagement opportunities, you may be interested in our Diversity Working Group, our STEM Working Group, or the renewed AIAA Foundation. If your inner advocate needs to speak out, the Public Policy Committee continues to be our voice on Capitol Hill and in the states. You can help make lawmakers and policymakers aware of the pressures facing the aerospace community and work with them to better ensure our industry's present and future success. Be it diversity, advocacy, or working with the next generation of aerospace professionals—AIAA needs your time and talent, which I hope you will invest liberally.

As I mentioned earlier, the past year saw the successful transition to—and completion of—our first full cycle of forums. While the switch from our old format to the new was not always an easy path, it is proving to be a successful one. The five forums in the past 12 months buzzed with collaboration, energy, and excitement. Combining multiple technical conferences and tracks under one roof has allowed us to bring together a much wider array of professionals, ensuring maximum exposure for attendees to new concepts, ideas, research, and subject areas. Additionally, the new forums allow us to maximize content delivery and draw even better speakers and panelists—making them more relevant not only to attendees, but also to the media and the public at large. The transition, of course, has not been without its challenges and lessons learned. But we have solicited and studied your feedback, implementing the necessary changes to make 2015 and beyond even more relevant, and an even better return on your investment. The forums have injected new energy into the Institute, the membership, and the aerospace community, and have allowed us to help you shape the future of aerospace more readily than we could have even two short years ago.

AIAA also continues to be a champion for aerospace, both on Capitol Hill and in a growing number of states. As the Public Policy section of this report details, our members are actively engaged with federal and state lawmakers on a wide variety of issues, including the ongoing threats posed by both "Open Access" legislation and the continued government travel regulations, which hinder attendance at our forums. To address those and other problems, our members continue to recommend sensible policies and stronger support for the aerospace industry and research and development enterprise in the United States.

I am excited about AIAA finishing strong in 2015. This year began with a bang at AIAA SciTech and every indication is that the rest of the year will be just as solid. Two things are certain: First, the Institute will continue to identify and implement the changes and improvements necessary to make your AIAA membership valuable and relevant to both you and to the entire aerospace profession. Second, as you, our members, continue to become more fully involved in the Institute's activities—regions and sections, committees, student branches, honors and awards—we will keep moving forward. I look forward to continuing our work together toward our common goals of growth, success, and prosperity—for our industry, our profession, and our Institute.

To submit articles to the *AIAA Bulletin*, contact your Section, Committee, Honors and Awards, Events, Precollege, or Student staff liaison. They will review and forward the information to the *AIAA Bulletin* Editor. See the AIAA Directory on page **B1** for contact information.

PREMIER AWARDS PRESENTED AT AIAA AEROSPACE SPOTLIGHT AWARDS GALA

AIAA presented its highest awards at the Aerospace Spotlight Awards Gala on 6 May, at the Ronald Reagan Building and International Trade Center, Washington, DC. Inside the building's soaring atrium, nearly 500 assembled guests heard similar messages from honorees and awardees, all firmly establishing that the world's aerospace workforce is one large community—with all of the weight that word brings. The AIAA Aerospace Spotlight Awards Gala, an annual, black-tie event, celebrates what AIAA Executive Director Sandra Magnus called "the best in aerospace." And what a celebration it was—from the presentation of the newly elected class of 2015 Fellows and Honorary Fellows, to the presentation of all of the evening's awards, the atrium ballroom rocked with enthusiastic applause as our community's best and brightest were recognized.

For more information about the AIAA Honors and Awards program, contact Carol Stewart at carols@aiaa.org or at 703.264.7623.

Class of 2015 Honorary Fellows (from left to right): Kyle T. Alfriend, Ben T. Zinn, Wanda M. Austin, Frederik J. Abbink.

Randall Walden of the Air Force Rapid Capabilities Office (left) and Daniel Hart of Boeing Defense, Space and Security (right) accepting the 2015 AIAA Foundation Award for Excellence on behalf of the X-37B Orbital Test Vehicle Team. At center is AIAA Foundation President Michael Griffin (left) and AIAA President James Albaugh (right).

Class of 2015 Fellows: front row (left to right): David Eames, Wayne Goodman, Michimasa Fujino, Alison Flatau, Debra Facktor-Lepore, Glenn Lightsey, John Crassidis, David Miller, James Walker. Back row (left to right): Allen Arrington, Lawrence Brase, Jayanth Kudva, Thomas Beutner, Eric Evans, Timothy Lieuwen, Eli Livne, Alton Romig, Paul McManamon, Robert Smith, Zhi Wang, Ashok Srivastava.

2015 AIAA Distinguished Service Awardee, Roy V. Harris Jr. (right), formerly of NASA Langley Research Center, with AIAA President James Albaugh (left).

Alan R. Mulally (center) after accepting the Daniel Guggenheim Medal with AIAA President James Albaugh (left) and Bruce Mahone of SAE International (right). AIAA, ASME, AHS International, and SAE International jointly sponsor the Medal.

Accepting the 2015 AIAA Public Service Award on behalf of Congressman Ralph Hall (Texas-4th, retired) was Janet Poppleton, Hall's former Chief of Staff.

AIAA President James Albaugh (right) with 2015 AIAA Reed Aeronautics Awardee Ramesh Agarwal (left) of Washington University in St Louis.

Christopher Scolese of NASA Goddard Space Center (at center) accepts the AIAA National Capital Section Barry M. Goldwater Educator Award. Also shown are Martin Frederick (right) of the AIAA National Capital Section and AIAA President James Albaugh (left).

ESA Director General and 2015 AIAA Goddard Astronautics Awardee Jean-Jacques Dordain (left) with AIAA President James Albaugh (right).

AIAA Foundation Educator Achievement Awardees with AIAA Executive Director Sandy Magnus. Left to right: Mohamad Barbarji, West Point High School, West Point, VA; Gary Garber, Boston University Academy, Boston, MA; Kaci Heins, Northland Preparatory Academy, Flagstaff, AZ; Sandra Magnus; Paul Wiedorn, Wilde Lake High School, Columbia, MD; and Heather L. Stewart, Paxton School, Paxton, FL.

2015 International Cooperation Award recipients Russell M. Cummings of the U.S. Air Force Academy (left) and Andreas Schuette of DLR—German Aerospace Center (center) with AIAA President James Albuagh (right).

CALL FOR BOARD OF DIRECTORS NOMINATIONS

The 2015–2016 AIAA Nominating Committee will meet in early September to review nominees and select candidates to participate in the Board of Directors (BoD) Election to fill the following vacancies by election in 2016:

- Vice President-Elect, Member Services
- Vice President-Elect, Technical Activities
- Director–Technical, Information Systems Group
- Director–Technical, Propulsion and Energy Group
- Director–Region IV
- Director–Region V
- Director–Region VII
- Director–At-Large
- Director–International

AIAA BoD Duties Highlights
Details to keep in mind when running for the Board of Directors:

- Volunteer Board service (commitment to attend 3–4 meetings per year in person)
- Need employer time and travel commitment
- Support Institute mission and vision
- Provide strategic discussion and input when required
- Duty to protect assets and exercise fiduciary prudence
- Serve in BoD leadership or support capacity as required
- Be vigilant of the aerospace landscape and identify business opportunities for the Institute
- Support AIAA Executive Director and staff as appropriate

AIAA members may submit themselves or other members qualified for the chosen position as nominees by submitting a nomination through the AIAA website (go to **www.aiaa.org**, log in, and select Board of Director Nomination from the left-hand navigation bar) no later than **21 August 2015**. Nominations will open 9 June 2015.

Bill Seymore
AIAA Corporate Secretary/Treasurer

AIAA FOUNDATION CLASSROOM GRANT PROGRAM

The AIAA Foundation believes that one of the most significant ways to inspire students and advance the future of aerospace is to fund grants that allow teachers to supplement their lesson plans with hands-on math and science activities.

One of our classroom grant recipients, **Douglas Ferguson** of Martin Sortun Elementary in Kent, WA, used his AIAA Foundation grant to provide resources to support his school's after-school program: The Academy of 21st Century Learning. The Academy uses hands-on programs such as LEGO NXT robotics to promote STEM education.

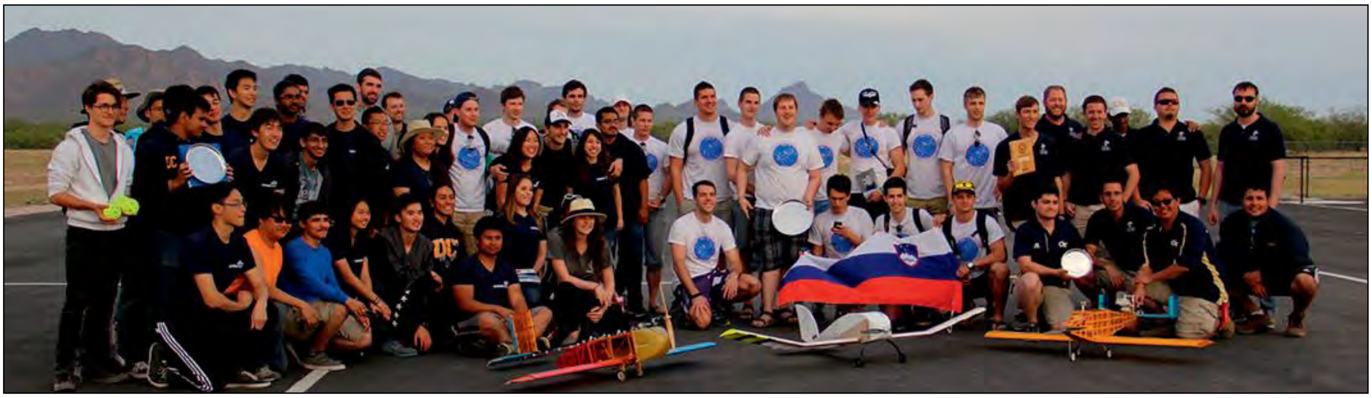
Mr. Ferguson and Martin Sortun Elementary are transforming classroom instruction and growing their small after-school program into an all new STEM Academy for grades 5 and 6. The Academy makes STEM accessible and interesting for students through fun, real-world projects like programming a robot, and creates confidence and academic enjoyment. This program also allows students to collaborate, fostering social skills and new friendships as the school culture embraces STEM as cool.

Community involvement has provided connections, perspective, and smaller adult-to-student ratios. Involved parents have strengthened the school–home partnerships, and Boeing professionals have spoken first-hand about STEM, and former students have become powerful mentors. The volunteers inspire, motivate, and prepare students for STEM-related careers.

Martin Sortun Elementary has expanded STEM education into the 5th-grade curriculum. Highly engaged students excitedly anticipate their classroom's turn to apply standards-based content through hands-on, robotics-based experiments. These experiments attach purpose to the science and improve student understanding. The school has also seen similar levels of excitement and improved learning from the application and use of robotics during after-school programs.

"Thank you again for AIAA's support of our STEM programs. And thank you, in general, for your support of public education. Making a difference in the life of a child is a gift that keeps on giving, but you've made a difference in the lives of many children across the country. So thank you, we appreciate your efforts to improve education and better the lives of our students."—Douglas Ferguson

The AIAA Foundation is committed to providing financial support to educational aerospace programs by devoting resources to the education of both practicing and future professionals. If you would like to make a donation to the AIAA Foundation 2015 Annual Fund, it will support students and educators at the K–12 and university levels by providing funding of classroom grants, scholarships, design competitions, and student conferences. Please visit **www.aiaafoundation.org**.



DBF 2015 winners: First place went to the University of Ljubljana (middle), the first time an international team has won DBF; second place went to University of California, Irvine (left); and third place went to Georgia Institute of Technology (right). The Best Paper Award, sponsored by the Design Engineering Technical Committee for the highest report score, went to Georgia Institute of Technology.

DESIGN/BUILD/FLY COMPETITION ATTRACTS ENGINEERING STUDENTS FROM AROUND THE WORLD

Hannah Thoreson, AIAA Communications, and Stephen Brock, AIAA Membership

The 19th annual Design/Build/Fly (DBF) Competition was held 10-12 April at TIMPA Airfield near Tucson, AZ. Sponsored in conjunction with Raytheon Missile Systems and Cessna Aircraft, the annual contest is held by the AIAA Foundation in either Tucson or Wichita during alternating years. This year's contest welcomed over 650 students from 25 U.S. states, as well as from 15 other countries.

The students arrived at the competition with their aircraft in pieces and had to assemble their projects onsite. The teams competed in four separate missions: three in the air and one on the ground. This competition was the culmination of months of dedicated work to design a plane that could meet this year's challenges and prepare a technical report outlining their design and testing processes.

In the end, the day truly belonged to the international students, as many of them ranked very highly in the competition. The University of Ljubljana from Slovenia had a large presence on the airfield with 21 students in attendance. They also led all teams in overall score. Tel Aviv University and Beihang University also placed very highly. There was even one student who made the long voyage from Cairo to represent an entire team that had been unable to secure visas. She was able to successfully pass the technical inspection and complete the ground mission.

The AIAA Foundation thanks all of the students and volunteers who contributed to making DBF 2015 one of this year's most successful programs. We look forward to the 2016 event in Wichita.

AIAA SOUTHWEST TEXAS SECTION AND UT'S AIAA STUDENT CHAPTER HOLD INTRODUCE A GIRL TO ENGINEERING DAY

On 28 February, in celebration of Engineering Week, the AIAA Southwest Texas (SWTX) Section partnered with University of Texas's (UT) AIAA Student Chapter members and Sigma Gamma Tau student members to participate in UT Austin's 14th Annual Women in Engineering Program, known as Introduce a Girl to Engineering Day (Girl Day). Over 1,660 1st–8th grade girls from across the state took part in the event at UT. With the assistance of 952 volunteers, 96 activities were facilitated that included booths and demos hosted by 113 student organizations, corporate partners, community organizations, schools and college/university partners. AIAA South Central Regional Director Jayant Ramakrishnan and SWTX Section Chair Joan Labay-Marquez were proud to be a part of this remarkable international event.

Thanks to the leadership provided by Zach Basset, vice president of the AIAA student chapter, and Shivani Patel, vice president of Sigma Gamma Tau's student chapter, dozens of enthusiastic AIAA student members volunteered their time, talents, and resources to inspire and engage girls, their parents, and teachers, with hands-on engineering. Participants learned about the concepts of Newton's Law of Motion, friction, jet propulsion, and air resistance by designing and constructing their own balloon-powered rocket car using empty water bottles and a variety of materials. AIAA student chapter members encouraged the future engineers and offered them innovative ideas to help them overcome design challenges and improve the aerodynamics of their vehicle. One of the most popular areas was the Design Station where the girls explored their creativity and imbued the arts in their design. The SWTX section is looking forward to making this an annual section STEAM event.

DAYTON-CINCINNATI SECTION HOLDS AEROSPACE SCIENCES SYMPOSIUM

Eric Swenson and Ryan Schmit, 2015 DCASS Executive Chairs

For four decades, the AIAA Dayton-Cincinnati Aerospace Sciences Symposium (DCASS) has provided a unique venue for technical interchange with members of our regional aerospace community. The 40th AIAA Dayton-Cincinnati Aerospace Sciences Symposium was held on 4 March at the Sinclair Conference Center in Dayton. This year's symposium showcased cutting-edge research with a one-day program with technical presentations across multiple areas of aerospace science and technology.

Over 240 people attended the 2015 Aerospace Sciences Symposium, which included 142 technical presentations in 35 parallel morning and afternoon sessions. The keynote session included opening remarks and an award presentation by special guest Sivaram Gogineni, AIAA Region III Director. The invited keynote speaker was Michael Drake, Technical Fellow of Aircraft Configuration Design, The Boeing Company, and he spoke about "Technology and Innovation in the 787 Dreamliner," which addressed many of the design and technical challenges that had to be overcome in creating one of Boeing's greatest aircraft.

2015 DCASS Organizing Committee: (from left to right) Maj James Rutledge, Beth Huelskamp, Travis Michalak, Michael Drake (keynote), Marcus Rumpfkeil, Ryan Schmit, Lance Chenault, Eric Swenson, Levi Elston, Sivaram Gogineni, and Tim Leger.

The symposium's technical program attracted a broad range of technical content and best presentation awards were evaluated in 14 different categories including Acoustic and Aeroelasticity, Unmanned Vehicles, Human Factors, CFD, Combustion Co-Winners, Experimental Methods, Flow Control, Fluid Dynamics, Materials, Optimization & Uncertainty, Space, Structures, Thermal & Heat Transfer, and Image & Diagnostics. Once again this year's DCASS hosted an Art-in-Science Competition that included 20 different entries with 1st, 2nd, 3rd place photo awards and best video submission award. These award winners were recognized at the 2015 AIAA Dayton-Cincinnati Section Awards Banquet on 21 May 2015.

CALL FOR PAPERS FOR JOURNAL OF GUIDANCE, CONTROL, AND DYNAMICS

SPECIAL ISSUE ON "COMPUTATIONAL GUIDANCE AND CONTROL

The *Journal of Guidance, Control, and Dynamics* (*JGCD*) is devoted to the advancement of the science and technology of guidance, control, and dynamics through the dissemination of original archival papers disclosing significant technical knowledge, exploratory developments, design criteria, and applications in aeronautics, astronautics, celestial mechanics, and related fields. The journal publishes qualified papers on dynamics, stability, guidance, control, navigation, optimization, electronics, avionics, and information processing related to aeronautical, astronautical, and marine systems.

A clear trend in the field of aerospace guidance and control has emerged in recent years in what we call "Computational Guidance and Control" (CG&C). In contrast to traditional guidance and control, CG&C has the following identifying trademarks: 1) Guidance and control laws and controllers of fixed structures are replaced by algorithms. 2) The generation of guidance and control commands relies extensively on onboard computation. The extensive onboard computation requirement is in fact the defining difference between CG&C and other branches of computational engineering and sciences. 3) The process of determining guidance and control commands may be model-based or data-based, and does not require significant pre-mission planning, gain tuning, or extensive offline design of nominal references.

This special issue on CG&C intends to bring recognition to this significant trend in aerospace guidance and control and afford it a proper descriptive term. Even with the great strides made in recent years in CG&C, much remains a work in progress. This special issue of *JGCD* will provide a focused forum to disseminate the latest research work in CG&C, and further stimulate interest in this area of great potential. Original research papers that meet the afore-listed CG&C descriptions (with special consideration given to onboard applications) are sought in, but not exclusive to, the following topics:

- Control (model predictive control, computational optimal control, control allocation, etc.)
- Guidance (all flight phases, powered or unpowered, space or atmospheric flight)
- Autonomous mission and trajectory planning and optimization
- Modeling of system dynamics and problem formulations promoting computational benefits
- Air traffic management applications (with focus on onboard applications)
- Embedded computation implementations for real-time guidance and control
- CG&C verification and validation

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

Deadline: Submissions are due by **31 October 2015**.
Contact Email: Ping Lu, *JGCD* Editor-in-Chief (plu@iastate.edu)
Guest Editors: Panagiotis Tsiotras (tsiotras@gatech.edu) and Mehran Mesbahi (mesbahi@uw.edu)

CALL FOR NOMINATIONS

Nominations are being accepted for the following awards, and must be received at AIAA Headquarters no later than **1 July**. Awards are presented annually, unless other indicated.

AIAA members in good standing may serve as a nominator and are highly urged to carefully read award guidelines (https://www.aiaa.org/Secondary.aspx?id=2915). You may submit nominations online or download the nomination form after logging into www.aiaa.org with their user name and password.

Aerospace Design Engineering Award recognizes design engineers who have made outstanding technical, educational, or creative achievements that exemplifies the quality and elements of design engineering. (Presented even years)

Aerospace Guidance, Navigation, and Control Award recognizes important contributions in the field of guidance, navigation, and control. (Presented even years)

Aerospace Software Engineering Award honors outstanding technical and/or management contributions to aeronautical or astronautical software engineering. (Presented odd years)

Children's Literature Award is presented for an outstanding, significant, and original contribution in aeronautics and astronautics. (Presented odd years)

de Florez Award for Flight Simulation is presented for an outstanding individual achievement in the application of flight simulation to aerospace training, research, and development.

Excellence in Aerospace Standardization Award honors contributions by individuals that advance the health of the aerospace community by enabling cooperation, competition, & growth through the standardization process. (Presented odd years)

Faculty Advisor Award is presented to the faculty advisor of a chartered AIAA Student Branch, who in the opinion of student branch members, and the AIAA Student Activities Committee, has made outstanding contributions as a student branch faculty advisor, as evidenced by the record of his/her student branch in local, regional, and national activities.

Gardner-Lasser History Literature Award is presented for the best original contribution to the field of aeronautical or astronautical historical nonfiction literature published in the last five years dealing with the science, technology, and/or impact of aeronautics and astronautics on society.

History Manuscript Award is presented for the best historical manuscript dealing with the science, technology, and/or impact or aeronautics and astronautics on society.

Information Systems Award is presented for technical and/or management contributions in space and aeronautics computer and sensing aspects of information technology and science. (Presented odd years)

Intelligent Systems Award recognizes important fundamental contributions to intelligent systems technologies and applications that advance the capabilities of aerospace systems. (Presented even years)

Lawrence Sperry Award is presented for a notable contribution made by a young person to the advancement of aeronautics or astronautics. The nominee must be under 35 years of age on **December 31** of the year preceding the presentation.

Mechanics and Control of Flight Award honors an outstanding recent technical or scientific contribution in the mechanics, guidance, or control of flight in space or the atmosphere.

Pendray Aerospace Literature Award is presented for an outstanding contribution or contributions to aeronautical and astronautical literature in the relatively recent past.

Structures, Structural Dynamics and Materials Award is presented for an outstanding sustained technical or scientific contribution in aerospace structures, structural dynamics, or materials. (Presented even years)

Survivability Award honors outstanding achievement or contribution in design, analysis implementation, and/or education of survivability in an aerospace system. (Presented even years)

Summerfield Book Award is presented to the author of the best book recently published by AIAA. Criteria for the selection include quality and professional acceptance as evidenced by impact on the field, citations, classroom adoptions and sales.

Sustained Service Award recognizes sustained, significant service and contributions to AIAA by members of the Institute. A maximum of 20 awards are presented each year.

For more information on AIAA's awards program, contact Carol Stewart, Manager, AIAA Honors and Awards, carols@aiaa.org or 703.264.7623.

AIAA NORTHWEST FLORIDA SECTION PARTIPATES IN OKALOOSA SCIENCE FAIR

Mike Sytsma

The AIAA Northwest Florida (NWF) section continued its tradition of endowing special awards on Okaloosa science fair students whose projects show excellence in aerospace-related topics. On 4 February, the Okaloosa County Regional Science Fair was held at the Fort Walton Beach Fairgrounds.

Six AIAA members volunteered as special award judges: Eugene Toma, Tim Eymann, Thomas Webb, Chiung Hung, Brian Sytsma and Mike Sytsma. Mike Sytsma was responsible for organizing the judges and the logistics of the awards. They judged both the junior and senior divisions and awarded four awards to entrants who had the best aerospace-related projects.

Eugene Toma presented the awards to the students at a ceremony held 17 February at the Emerald Coast Convention Center.

Recognized for projects that showed excellence in aerospace-related topics. (L–R): Senior Division, 2nd place: Daniel Bobbitt, Go with the flow; Junior Division, 2nd place: Matthew VandenBoom, How does the size and location of a model rocket's fins affect its stability?; Junior Division, 1st place: Logan Thursby, Hands free driving; and Senior Division, 1st place: Camille Miles, Triple the fun in the sun!

On 26 March, the AIAA Niagara Frontier Section hosted a dinner meeting and lecture. Speakers included Robert Brady, retired CEO of Moog Inc., and Dr. Renso Caporali, retired CEO of Grumman Aerospace. In a fascinating 45-minute panel discussion, they spoke about their careers in the aerospace industry—from their greatest challenges to advice for young engineers today. The meeting began with the recognition of 75-year IAS and AIAA member Walter Brewer, and 66-year ARS and AIAA member John Sennef.

L–R: Bob Brady, retired CEO of Moog Inc. (speaker); John Sennef, 66-year member, flew P-47s over Europe in World War II before becoming Bell rocket engineer, worked on Bell Agena, and Lunar Module Ascent engine; Renso Caporali, retired CEO of Grumman Aerospace, AIAA Honorary Fellow (speaker); Walt Brewer, 75-year member, worked at Curtiss-Wright on P-40 prior to World War II, then Cornell Aeronautical Laboratory, retired as vice president of The Aerospace Corp.

OBITUARIES

AIAA Fellow Morkovin Died in October 2014

Mark V. Morkovin died 18 October 2014.

Professor Morkovin began his teaching career at Illinois Institute of Technology (IIT) in 1967, and established a strong reputation of fluid dynamics research in Armour College of Engineering Mechanical, Materials and Aerospace Engineering Department. His legacy continues through the IIT Fluid Dynamics Research Center, and the Mark V. Morkovin windtunnel was named for him. He conceived the Morkovin Hypothesis—first discussed in the article, "Effects of compressibility on turbulent flows," *Mecanique de la Turbulence* (1962, pp. 367–380). The hypothesis states: "that for moderate Mach numbers compressibility effects did not influence the dynamic behavior of turbulence directly, and the principal effect of high speeds was felt through the change in fluid properties."

Professor Morkovin made significant contributions to two projects that are on exhibit at the Smithsonian Institution: the first transonic and supersonic airplane, the X-1; and the first maneuverable re-entry vehicle. He was elected as a member of the National Academy of Engineering for contributions to the understanding of instability, transition, and turbulence through outstanding research and distinguished written reviews of the field. Professor Morkovin was awarded the AIAA Fluid Dynamics Award (1976): For outstanding personal contributions in basic and applied research on transition and turbulent flow, and for many years of service as a stimulating and stabilizing influence on research in this field.

Associate Fellow Greenwood Died in March

William R. Greenwood, 84, died 9 March 2015.

Mr. Greenwood was an engineering graduate of Purdue University. He also earned graduate degrees in engineering from Massachusetts Institute of Technology and in business from Ohio State University.

Mr. Greenwood started his career in the U.S. Air Force, serving for five years on active duty, and several more years in the Air Force Reserve. His duty included three years as an engineering officer at Wright-Patterson Air Force Base in Dayton, OH. He then worked seven years at RCA as a group leader and engineering scientist on military electronics projects.

Before his retirement in 1993, he was employed at Raytheon Company for 29 years. At Raytheon, he was a Principal Engineer working on missile systems at facilities in Bedford, Wayland, and Tewksbury. He was a Life Senior Member of IEEE, and an Associate Fellow of AIAA.

AIAA Senior Member Roderick Died in April

Norman F. Roderick, former chair of the Chemical and Nuclear Engineering Department in the School of Engineering, died 6 April.

Dr. Roderick graduated from the United States Air Force Academy and received his master's and Ph.D. in aerospace engineering from the University of Michigan. He worked at the rocket test track at Holloman AFB, was a faculty member of the Department of Aeronautics at the U.S. Air Force Academy, and then was a faculty member of Chemical and Nuclear Engineering (ChNE) at the University of New Mexico for more than 30 years. Roderick led the nuclear engineering program through a particularly difficult time during the 1980s and 1990s and also served as interim chair of the ChNE department on a number of occasions.

Dr. Roderick was an AIAA Senior Member, a member of both the American Nuclear Society and the American Physical Society, and a fellow of IEEE. He had a long, successful career in research and consulting in the Air Force, at UNM, Los Alamos National Lab and at Numberex, specializing in high-density plasma physics.

AIAA Senior Member Pieronek Died in April

Catherine F. Pieronek, associate dean for academic affairs and director of the Women's Engineering Program at the University of Notre Dame, died 9 April. She was 52 years old.

Ms. Pieronek graduated from Notre Dame in 1984 and earned a master's degree in aerospace engineering from the University of California at Los Angeles in 1987. She worked as a senior systems engineer at TRW, where she helped develop both the Data Relay System on NASA's Compton Gamma Ray Observatory and the Chandra satellite.

She returned to Notre Dame in 1992 to pursue a law degree and served as editor-in-chief of the *Journal of College and University Law*. After earning her law degree in 1995, Ms. Pieronek became director of alumni relations for the Notre Dame Law School and editor of its quarterly publication. She became a nationally recognized expert in Title IX issues,.

In 2002, Ms. Pieronek joined Notre Dame's College of Engineering, serving as its associate dean and establishing the women's engineering program to increase the retention rate of women from the first through sophomore years.

Last year Ms. Pieronek was named a fellow of the Society of Women Engineers, cited for having had a lasting and positive impact on engineering education, and for illuminating public discourse on gender equity in fields. She had been a member of AIAA since 1981.

AIAA Space and Astronautics Forum and Exposition

Setting a Course for the Future

31 August–2 September 2015
Pasadena Convention Center
Pasadena, California

Organizing Committee—The New Face of SPACE
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Complete list of organizers at ***aiaa-space.org/Organizers***

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AIAA SPACE 2015 combines the best aspects of technical conferences with insights from respected leaders, providing a single integrated forum for navigating the key challenges and opportunities affecting the future direction of global space policy, capabilities, planning, research and development, funding, security, environmental issues, and international markets.

What's Unique about AIAA SPACE 2015?

AIAA SPACE 2015 features more than 350 technical papers, ITAR sessions, and the best papers from researchers around the world, ensuring that you'll find the latest scientific and technical research that will advance your capabilities to improve or develop new space assets, find business solutions, and achieve your goals.

Plenary and Forum 360 Sessions

Plenary and Forum 360 panelists will walk you through recent accomplishments, discover how those successes have been applied to today's programs, and explore future possibilities, in the areas of:

- Planetary Exploration
- Human Spaceflight
- Robotic Planetary Exploration
- Commercially Viable Business Opportunities
- Cybersecurity
- Earth Science and Remote Sensing

New! Interactive Sessions

- ***20-Year Vision Workshop***—This is your opportunity to share your vision for the future! Participants will join small group roundtables with a facilitator and a designated topic. As a group, you will discuss what your desired future state is in 20 years. From that future state, your group will outline a vision statement and a summary of the mission and activities necessary to achieve your vision.

- ***Lightning Networking Workshop***—Think, Plan, Act! The engaging lightning pitches from some of the most creative thinkers at AIAA SPACE 2015 will get you thinking. From there, join the open collaboration session to meet the presenters, make new connections, and plan how you can act on what you've learned!

Technical Program

The technical program contains more than 350 technical papers from about 100 government, academic, and private institutions in 21 countries reporting on the latest in space research, and offering scores of opportunities for collaboration and discussion on high-impact topics.

- Atmospheric and Space Environments
- Emerging Commercial Space
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- National Security Space
- Reinventing Space
- Small Satellites
- Space and Earth Science
- Space Exploration
- Space Exploration and Operations
- Space Habitation, Colonization, and Infrastructure
- Space History, Society, and Policy
- Space Logistics and Supportability
- Space Robotics and Automation
- Space Systems
- Space Systems Engineering and Space Economics
- Space Transportation and Launch Systems

Search, browse, and create your own personal agenda at **http://aiaa-msp15.abstractcentral.com/itin.jsp**.

Courses and Workshops

Register for an AIAA short course and gain access to all forum activities.

Introduction to Space Systems (Instructor: Mike Gruntman, Ph.D., Department of Astronautical Engineering, University of Southern California, Viterbi School of Engineering)
This introductory course is designed for engineers and managers—of diverse background and varying levels of experience—who are involved in planning, designing, building, launching, and operating space systems and spacecraft subsystems and components. The course will facilitate integration of engineers and managers new to the space field into space-related projects.

Rising Leaders in Aerospace

Young aerospace leaders, age 35 and under, participate with others in a multidimensional program featuring a leadership exchange/speed mentoring, panel session, Q&A with top industry leaders, and multiple opportunities for networking. These exciting and energetic activities will provide access to top aerospace leaders and their perspectives, with subject matter relevant to your career stage.

von Kármán Lectureship in Astronautics

For Laser Guide Star Adaptive Optics: A Revolution for Ground-Based Astronomy
Robert Q. Fugate, Manager and Owner, Arctelum, LLC, Senior Research Advisor, Emeritus, New Mexico Tech, Former Senior Scientist, Air Force Research Laboratory, Kirtland AFB

New! 1st Annual Sweet Space--An Evening of Astronaut Stories from the Cosmic Frontier

Enjoy a private reception with astronauts, hear about their experiences from their missions in space, take photos, get autographs, and enjoy some tasty treats. This event is a fundraiser for the AIAA Foundation and the Association of Space Explorers, two organizations that support educational programs and scholarships in science, technology, engineering and mathematics.

Exposition

Take your place among our exhibitors and sponsors. Contact Tobey Jackson, tobeyj@aiaa.org; Paul doCarmo, pauld@aiaa.org; or Chris Grady, chrisg@aiaa.org

(Exhibitors, as of 5/15): AIAA San Gabriel Valley Section • Airborne Systems • ATA Engineering, Inc. • Bastion Technologies • California Space Enterprise Center • Crean & Associates • Esterline Power Systems • KamaticsRWG • Lockheed Martin Corporation • MDA US Systems, LLC • RT Logic • Students for the Exploration and Development of Space (SEDS) • Wheelift

Plan Your Trip

AIAA has made accommodations for a block of rooms at the Hilton Pasadena and the Sheraton Pasadena.

Hilton Pasadena: Room rates at the Hilton Pasadena are $169 for a standard room (single or double occupancy). Government rates are $138. Applicable taxes will apply. These rooms will be held for AIAA until **29 July 2015** or until the room block is full, then released for use by the general public. **Conference rate reservations**: http://www.hilton.com/en/hi/groups/personalized/P/PASPHHF-AIOAA-20150827/index.jhtml?WT.mc_id=POG. **Government rate reservations**: http://www.hilton.com/en/hi/groups/personalized/P/PASPHHF-AIAAGV-20150827/index.jhtml?WT.mc_id=POG

Sheraton Pasadena: Room rates at the Sheraton Pasadena are $179 for a standard room (single or double occupancy). Government rates are $138. Applicable taxes will apply. These rooms will be held for AIAA until **15 August 2015** or until the room block is full, then released for use by the general public. **Conference rate reservations**: https://www.starwoodmeeting.com/Book/SpaceForum. **Government rate reservations**: https://www.starwoodmeeting.com/Book/SpaceForumGovernmentBlock

Any issues making reservations, please contact Melissa Mulrine at melissam@aiaa.org.

Registration

AIAA members will pay $911 when they pay by 17 August 2015. The member rate is $1150 after that date. The full conference rate is $1381. ***It pays to become an AIAA member!*** Student and other rates can be found at **aiaa-space.org/register**.

Upcoming AIAA Continuing Education Courses

Courses at AIAA Aviation and Aeronautics Forum 2015 (AIAA AVIATION 2015)
www.aiaa-aviation.org/ContinuingEd

20–21 June 2015

Optimal Design in Multidisciplinary Systems (Instructors: Joaquim R. R. A. Martins and Jaroslaw Sobieski, Ph.D)

When you are designing or evaluating a complicated engineering system such as an aircraft or a launch vehicle, can you effectively reconcile the multitude of conflicting requirements, interactions, and objectives? This course introduces you to methods and tools that have been developed over the years for the design optimization of engineering systems.

You will be presented with a review of the state-of-the-art methods for design optimization that exploit the modern computer technology for applications with large numbers of variables, and design constraints. You will learn how to evaluate sensitivity of the design to variables, initial requirements, and constraints, and how to select the best approach among the many that are currently available.

The last part of the course will take you to system-level applications where the primary problem is in harmonizing the local disciplinary requirements and design goals to attain the objectives required of the entire system, and where performance depends on the interactions and synergy of all its parts. In addition to imparting skills immediately applicable, the course will give you a perspective on emerging methods and development trends.

Key Topics
- Multidisciplinary design-components, challenges, and opportunities
- Optimization methods
- Sensitivity analysis
- Decomposition architectures in multidisciplinary design
- Surrogate modeling in design
- Soft computing methods in optimal design

FUN3D Training Workshop

Please note that FUN3D is export-controlled software and may only be provided to U.S. persons.

This workshop will provide participants with guidance on how to install and execute the NASA Langley Research Center FUN3D computational fluid dynamics software for common aerospace applications. The objective of this workshop is to provide engineers and scientists with sufficient instructions to apply a large-scale Navier-Stokes solver to their analysis and design applications of interest. Detailed instructions will be provided for topics including analysis of steady and unsteady flow, boundary conditions, application to dynamic and overset mesh simulations, adaptive gridding, aerospace computations, geometry parameterization, and adjoint-based design optimization.

Courses at AIAA Propulsion and Energy Forum 2015
www.aiaa-propulsionenergy.org/ContinuingEd

25–26 July 2015

The Application of Green Propulsion for Future Space (Instructors: Alan Frankel and Timothee Pourpoint)

Liquid propulsion systems are critical to launch vehicle and spacecraft performance and mission success. This two-day course, taught by a team of government, industry, and international experts, will cover propulsion fundamentals and topics of interest in launch vehicle and spacecraft propulsion, non-toxic propulsion drivers, propellants and figures of merit, applications of non-toxic propulsion, flight experience, and advances in smallsat propulsion. Lessons learned from development and flight of components and systems will be discussed.

Key Topics
- History of Hydrazine/Hypergols
- What is Green and what drives Green movement
- Green Propellants
- Flight and Near Term Flight Experience
- Applications of Green – What drives propulsion decisions
- Challenges for Green Propulsion

Advanced High Speed Air-Breathing Propulsion (Instructors: Dora E. Musielak, Venkat Tangirala, Bob Moehlenkamp)

Revolutionary methods of high speed air-breathing propulsion are needed to extend the flight regime of aircraft, missiles, and improve Earth-to-orbit spacecraft. Advanced High Speed Air-Breathing Propulsion will introduce students to the design and development processes of high speed propulsion, including ramjet/scramjets and TBCC concepts. The course will present a comprehensive overview of the state of the art, including highlights of current high speed propulsion programs in the world. An introduction to multidisciplinary design optimization (MDO) will help students appreciate the challenges of developing this breakthrough propulsion technology.

The instructors are actively engaged in high-speed propulsion R&D. They will discuss the challenges, and development trends and future of the propulsion technologies needed to make truly high speed flight a reality. This course is sponsored by the AIAA High Speed Air Breathing Propulsion Technical Committee (HSABP TC).

Key Topics
- Mission requirements
- Combined cycle propulsion concepts
- Ramjet/scramjet inlet design

- Ram/scramjet combustion structural design
- Fuels and thermal management engine/airframe integration, TBCC integration
- Advanced materials
- CFD modeling and simulation of high speed reacting flow
- Propulsion multidisciplinary design optimization (MDO)
- High speed propulsion ground and flight testing

30–31 July 2015

Business Management for Engineers (Instructors: Alan C. Tribble and Alan Breitbart)

This course will help individuals with a technical background master the business principles that guide the leadership of an engineering-oriented company. The course will prepare students for the transition from the role of a technical contributor to that of a business leader.

Key Topics
- Basic principles—Economics and free markets
- Project execution—Technical performance measures and earned value management
- Business management—Business finance concepts used to evaluate a product or business
- Developing and presenting a business case—Articulating a value proposition and presenting a business message
- Initiating and planning a program—Understanding what needs to be managed and how to manage it
- Business development—Growing an idea into a business
- Globalization—Navigating import/export regulations and expanding internationally

Hybrid Rocket Propulsion (Instructor: Dr. Joe Majdalani)

This course reviews the fundamentals of hybrid rocket propulsion with special emphasis on application-based design and system integration, propellant selection, flow field and regression rate modeling, solid fuel pyrolysis, scaling effects, transient behavior, and combustion instability. Advantages and disadvantages of both conventional and unconventional vortex hybrid configurations are examined and discussed.

Key Topics
- Introduction, classification, challenges, and advantages of hybrids
- Similarity and scaling effects in hybrid rocket motors
- Flowfield modeling of classical and non-classical hybrid rockets
- Solid fuel pyrolysis phenomena and regression rate: Mechanisms & measurement techniques
- Combustion instability and transient behavior in hybrid rocket motors
- Metals, other energetic additives, and special binders used in solid fuels for hybrid rocket applications

Courses at AIAA Space and Astronautics Forum 2015 (AIAA SPACE 2015)
www.aiaa-space.org/ContinuingEd

29–30 August 2015

Introduction to Space Systems (Instructor: Dr. Mike Gruntman)

This course provides a broad overview of the concepts and technologies of modern space systems that combine engineering, science, and external phenomena. We concentrate on scientific and engineering foundations of spacecraft systems and interactions among various satellite subsystems. These fundamentals form an indispensable basis for system engineering. The basic nomenclature, vocabulary, and concepts will make it possible to interact with understanding with various subsystem specialists.

Key Topics
- Space environment and interactions
- Orbital mechanics and space mission geometry
- Overview of space mission design and applications
- Space propulsion and launch systems
- Attitude determination and control
- Communications, power, and thermal control subsystems