AIR SAFETY 14
Containing blade-outs

OPINION 44
Why blockchain is powerful

SPACEFLIGHT 28
Dream Chaser attempts a comeback

AEROSPACE AMERICA

TRY THIS MONTH'S AEROPUZZLER
PG 11

Fighting for the future

U.S. Army seeks to accelerate Future Vertical Lift PAGE 18

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AIAA
Shaping the Future of Aerospace

On the cover: Bell's (top) and Sikorsky-Boeing's Future Vertical Lift demonstrators

Image credits: Bell and Sikorsky-Boeing

AEROSPACE AMERICA

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IN THIS ISSUE

Keith Button

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

PAGE 14

Amanda Miller

Amanda is a freelance reporter and editor based near Denver with 20 years of experience at weekly and daily publications.

PAGE 28

Jan Tegler

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

PAGE 18

Debra Werner

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

PAGES 9, 36, 64

DEPARTMENTS

Fast action on vertical lift

▲ A U.S. Army medical evacuation helicopter lands at an outpost in Afghanistan.
U.S. Army

I enjoy our Looking Back section because it reminds me that nations can act quickly in the technology realm when they choose to. One hundred years ago in June, with World War I raging, Britain inaugurated the first strategic bombing force and Germany chose to rush the Fokker D.5 monoplane into production as the D.8 and start flying it before the end of the war. One could pick parallel examples from 1943, as the allies, Germany and Japan fought to decide how the world would be ordered.

Looking Back offers a juxtaposition to our cover story, in which we describe the near decade of research that has gone into the U.S. Future Vertical Lift initiative, work that is just now culminating with flights of demonstration aircraft and a desire among some to accelerate the initiative toward production.

The story captures how the U.S. military branches are thoughtfully analyzing their alternatives in the rotorcraft realm before committing to a multibillion-dollar joint program. That's reassuring in one sense, because it means the U.S. government is not running entirely on instinct when it comes to spending tax dollars. There has indeed been time to be thoughtful, given that the U.S., while at war, is not locked in an existential fight.

The question is how much time one needs to make a wise choice. The alternatives to committing to next-generation rotorcraft were probably the same a few years ago and could have been resolved then. Time, as they say, is money, and that's really what's at play here, even given the Trump administration's determination to boost annual defense spending by billions.

For whatever reason, advocates of rotorcraft often seem to have trouble carving a place in the portfolio of newly designed aircraft. In the realm of fighter aircraft, by contrast, advocates name their aircraft by generations, giving an air of inevitability that surely there will be a sixth-generation U.S. fighter, and a seventh, and so on.

The struggle to get on with building next-generation rotorcraft surprises me, given the dangerous jobs that these aircraft and their pilots do, from evacuating the wounded, to delivering supplies, to inserting and extracting special operators, to conducting reconnaissance and rescuing people at sea.

Let's assume that if the next war comes, it is one marked mainly by dueling hypersonic weapons and sixth-generation fighter jets vying for air superiority at 30,000 feet. Even then, it's almost certain that closer to the ground, piloted and unmanned rotorcraft will be doing the same kinds of hard work they do today. The question is whether their crews will be doing those things in next-generation versions that fly faster and farther than their forebears. ★

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

GENERATION STEM

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FLIGHT PATH

To the Future

For many years, this column has been called "From the Corner Office." As our new governance structure becomes a reality, and as we, your new president and new executive director, present AIAA's new Strategic Plan, it seemed the perfect time for a new name—one that better represents our vision for this column. In the months to come you will hear from diverse voices from across the Institute whose views will help inform the Institute's "Flight Path" to future growth and continued success. Please let us know if there are issues you would like discussed or topics we should explore.

This year has been a busy one for AIAA's volunteer leaders and one of transition at Headquarters. Our multiyear move to the Institute's new governance model is well underway. We continue to work with the Board of Trustees and Council of Directors to tweak the structure while experimenting with how new concepts that benefit our membership will work in reality. And if the annual meetings in May were any indication, the hard work is paying off.

The Council is truly hitting its stride, focusing on the integration of its operations, experimenting with leveraging engagement, building stronger communities, and aligning its operations with the larger institutional plan. The restructured Technical Activities Division and Regional Engagement Activities Division and new Integration and Outreach Division are quickly getting up to speed and they are to be commended.

After much hard work and deliberation, the Board—with input from the Council and AIAA staff—has developed an ambitious but achievable three-year vision—our new Strategic Plan for 2018–2021. The plan's guiding principle is our new mission statement: **AIAA exists to help aerospace professionals and their organizations succeed.** It's simple and to the point, and it's what the aerospace community needs. The Board outlined three core strategies that will guide us as we work to achieve the strategic goals. All the goals and their objectives align with one or more of these core strategies: 1) Use the appropriate data in the analysis of decisions; 2) Be the leader in curated aerospace content; and 3) Be the thought leader in technology and capability advancement. In other words, double down on our strengths and address our weaknesses head on. And we will do that through three main goals in areas that support the mission—assure financial sustainability; increase member loyalty and investment in their professional success; and ensure that AIAA's capacity will be sufficient to meet the needs of our members. It's a tall order to address, but it is critical to our success. You'll hear more detail about the Strategic Plan, and your role in it, in the months to come. The plan is available at: **aiaa.org/StrategicPlan.**

As the team addresses the Strategic Plan, volunteers and staff are hard at work exploring new ideas that will operationalize the Board-directed priorities to ensure success. We will be reaching out to you, the members, for your input on initiatives that you find most valuable to ensure your professional success.

What does this all mean from a practical standpoint? What changes will members see over the coming months? AIAA has always worked to support aerospace professionals. The typical career arc is evolving, and AIAA will continue to evolve to support its members at every stage of their career from student to retiree and every point in between. A big part of that will be integrating and connecting the work of the AIAA Foundation and the Institute—all for the greater good. You will see a focus on increasing the membership, making the forums more engaging with the famous AIAA technical content, and building the AIAA online presence to support this pivot.

Diversity and inclusion is essential in both the aerospace workforce and the Institute. Broadening our base, and ensuring that we communicate and act from our core values in a way that supports that goal, will be key to achieving the strategic goals. To that end, the Diversity Working Group was elevated to a Board-directed committee as a sign of AIAA's commitment to address these issues at the highest level of the organization and to integrate those outputs into the very fabric of our mission.

Why are we doing all this? AIAA has an audacious vision. It's based on what we as an Institute believe about ourselves, about you and what binds our global community in a way that few other industries can boast: that exploration is the essence of the human spirit. AIAA is the technical society for aeronautics and astronautics—it is our legacy and our differentiator. As the industry grows increasingly complex and interconnected with adjacent technologies, our legacy must integrate this broader thinking—systems, platforms, and mission oriented—into our operational and intellectual framework. To remain relevant and be the thought leaders of the future, we must embrace emerging and adjacent technical areas that will influence the direction of aerospace, lest we be influenced by them in ways that may not be ideal for our own industry's future.

We have much work to do between now and 2021 and the Strategic Plan will be a regular topic of this column. AIAA needs you to succeed. Join us on this journey; participation is power! ★

John S. Langford and Daniel L. Dumbacher

Satellites lend confidence to report of Antarctic ice loss

BY AMANDA MILLER | agmiller@outlook.com

▲ An iceberg with a melt pond in the Bellingshausen Sea in Antarctica.
Andrew Shepherd/University of Leeds

By the late 1990s, scientists had reason to believe that the ice sheets covering Antarctica and Greenland, which hold more than 99 percent of the world's fresh water, were on balance shedding more ice than they were accumulating. Data was gathered mainly by planting stakes in the ice to measure snowfall (input), then attempting to gauge how much ice was lost (output) where glaciers emptied into the sea.

Jay Zwally, NASA's chief scientist for the study of Earth's frozen places, figures that the estimates of the balance of this input and output at the time were accurate to within 25 to 30 percent.

A June paper in the journal Nature, "Mass Balance of the Antarctic Ice Sheet from 1992 to 2017," shows how satellite altimetry and gravity measurements have given scientists newfound confidence in their ability to chronicle the melting of ice sheets with precision.

Zwally thinks the accuracy has now been narrowed to within about 5 percent.

That accuracy is important, given the paper's alarming conclusion that from 2012 to 2017, Antarctica on balance shed ice at an annual rate that was three times higher than the average annual rate of loss for the prior two decades. The authors also estimate that sea level rose 7.6 millimeters over the course of the 25 years of data. NASA, in a press release, noted that if all the ice on Antarctica melted, sea level would rise by 190 feet (58 meters).

Mass measurements from the Gravity Recovery and Climate Experiment, a joint satellite project by the U.S. and Germany, "dominated" the findings, says Erik Ivins, a senior research scientist at the NASA-funded Jet Propulsion Laboratory in California. He is co-lead on the Ice Sheet Mass Balance Inter-comparison Exercise, or IMBIE, an international effort to apply various kinds of satellite data to the task of measuring ice cover and its impact on sea level. The IMBIE team wrote the Nature paper.

The first pair of GRACE satellites, launched in 2002, passed microwave range-finding signals between each other and proved it was possible to track changes in the mass of terrain features over time. As the lead satellite approached a more massive feature such as an ice sheet, the gravity from the feature pulled the satellite slightly farther ahead, until the trailing satellite, 137 miles (220 kilometers) behind, felt the gravity of the land mass and caught up. The original GRACE stopped working in 2017, and GRACE Follow-On was launched in May. Its microwave range-finder was undergoing its planned checkout phase in June, with a laser range-finder also onboard for testing.

Among the altimetry readings, the European Space Agency's CryoSat-2 was "extremely important, as it is specifically designed for Antarctica and Greenland," says NASA's Ivins, referring to a satellite that bounces radar waves off the ice.

For part of the study period, the scientists also analyzed data from NASA's Ice, Cloud and Land Elevation Satellite, or ICESat. From 2003 until 2009, it measured the ice height by bouncing laser light off the surface to produce more accurate readings than is possible with radar, whose signals can penetrate ice. For ICESat-2, scheduled for launch in September, NASA has increased the laser pulses from 40 per second to 10,000 per second, or every 71 centimeters along the Earth, and bolstered the configuration to three pairs of laser beams. Without a laser altimeter in orbit, NASA has been gathering altimetry readings by aircraft in a project called Operation IceBridge. ★

NOAA searches for solution to GOES-17 camera issue

BY DEBRA WERNER | dlpwerner@gmail.com

NOAA

▲ Engineers install the main camera on the GOES-S (now GOES-17) satellite. With that satellite in orbit, its main camera, the Advanced Baseline Imager, isn't working in the middle of the night over the United States.

NOAA, NASA and industry experts are digging into the intricacies of loop heat pipes as they try to figure out why the main camera on the newest U.S. geosynchronous weather satellite isn't working during the middle of the night over the U.S.

The team's task is to identify the cause and whether anything can be done remotely to correct the problem on the school bus-sized GOES-17 satellite, which is in geosynchronous orbit 35,000 kilometers over the equator.

At stake is whether the satellite can take over the imaging duties from an older NOAA satellite that currently watches the western half of the Americas and much of the Pacific Ocean from the GOES West position. Without a solution, the satellite won't be able to determine the altitude of water vapor and winds for a 12-hour period each day, and NOAA will need to continue to rely on GOES-15, launched in 2010, and GOES-16 launched in 2016.

Also at stake is the fate of GOES -T and -U, satellites that will be renamed GOES-18 and -19 once they reach geostationary orbit; they are slated to carry the same type of cameras built by Harris Corp. in Fort Wayne, Indiana.

Officials are mystified by the problem, because the camera, called the Advanced Baseline Imager, is nearly identical to those that are working properly on GOES-16 and the Japanese Himawari weather satellites.

"It was a shock when we ran into this problem," NOAA's Pamela Sullivan told reporters in a May briefing. Sullivan, an astronautical engineer, is directing the roll out of NOAA's new Geostationary Operational Environmental Satellites, GOES-16, -17, -18 and -19.

The rollout seemed to be going well with the launch of GOES-16 (known as GOES-R during its NASA-managed construction) in 2016 and its subsequent commissioning. The problem with GOES-17, formerly GOES-S, was discovered during the commissioning phase following its March launch.

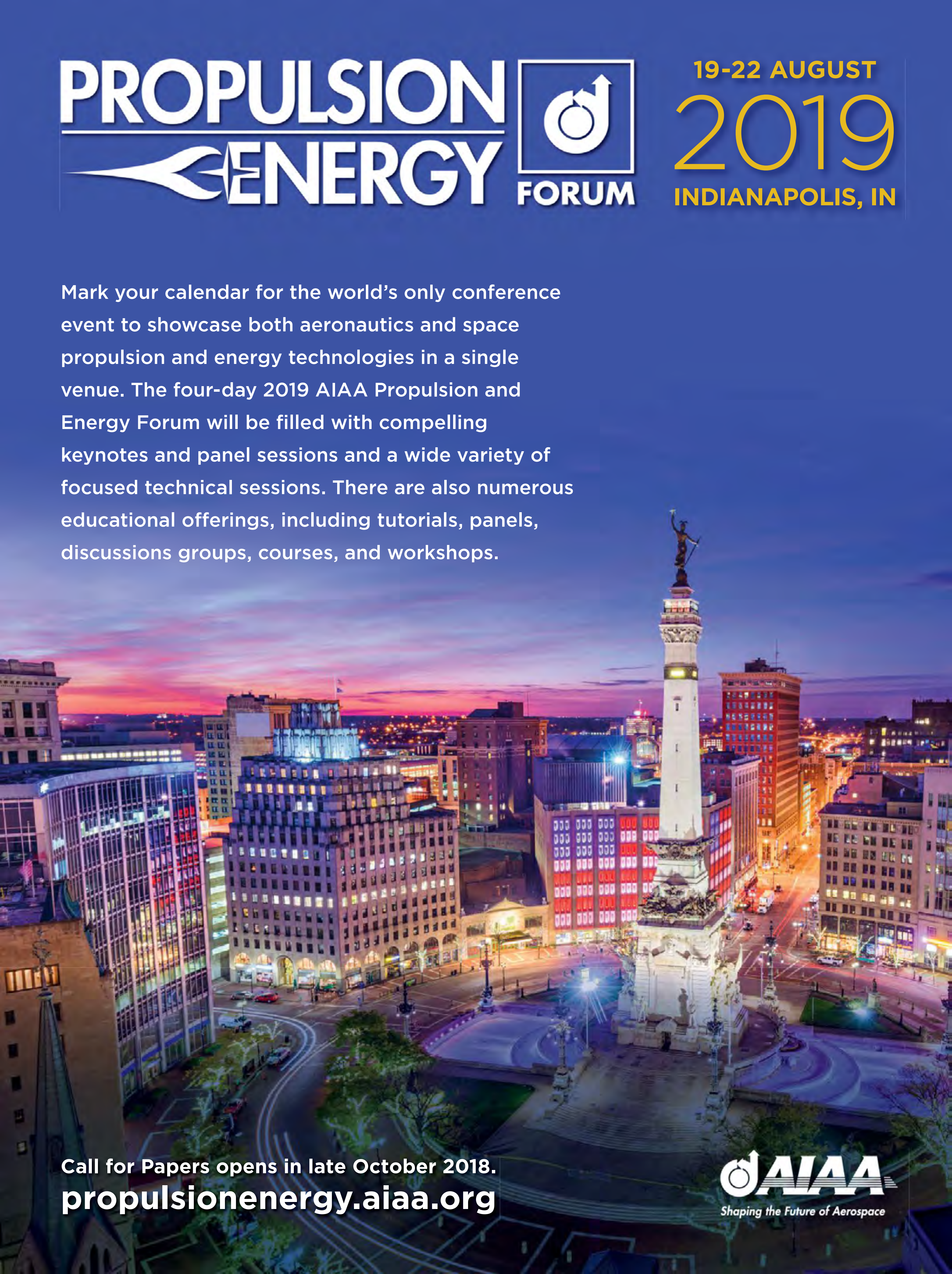
ABI's thermal control system is not cooling the imager's 13 infrared and near infrared detectors to the required temperature of minus 213 degrees Celsius, just 60 degrees above absolute zero. During the night when the camera is pointing at the U.S., the sun is directly behind Earth and some sunlight shines directly into the lens, heating it up. Cooling is necessary so that infrared energy from the atmosphere stands out when it reaches the detectors that must convert the faint infrared energy into electrical signals and measurements.

Far from giving up on ABI, though, experts are devising tests to try to figure out what's causing the problem and strategies for solving it aboard GOES-17. The team is comparing data gathered in tests prior to launch with the performance of the instrument in orbit, and to the performance of ABIs flying on GOES-16 and the Japanese Meteorological Agency's Himawari-8 and -9 satellites. The team also is devising tests to conduct on GOES-17 in orbit and on two additional ABIs Harris built for NOAA's next two geostationary satellites, GOES-T and GOES-U.

The loop heat pipes contain liquid propylene that is supposed to cool the cryocooler that contains the detectors. Heat should be absorbed by the liquid propylene, turning it to vapor that flows through a radiator that sheds the heat to the cold of space. The vapor cools back into liquid to continue the cycle. The loop heat device is passive, meaning it requires no mechanical pumps or moving parts.

The cryocooler is overheating because the loop heat pipes are not transferring heat to the radiator, said Sullivan. "The thermal load increases [each day] to a point where we are not able to cool the detectors down," Sullivan said during the press briefing. The team must "understand the loop heat pipe behavior and isolate the cause of the problem," Sullivan said in a written response to my questions.

ABI manufacturer Harris confirmed the problem but declined an interview request. "We are working closely with NOAA, NASA and other industry experts to troubleshoot," Harris spokeswoman Kristin Jones said by email. ★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A fruit fly as big as a Cessna

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ABOUT THE AEROPUZZLER

Your task is to boil a complex concept into a maximum of 250 words that anyone could understand (without equations or drawings, please). Email your response to aeropuzzler@aiaa.org by midnight EDT July 16 for a chance to have it published in the next issue. Include your city or town and a phone number (we won't publish it).

ANSWER

ICEBOATS

We asked if an iceboat can go faster than the wind. Physicist Ryan M. Wilson, an assistant professor at the U.S. Naval Academy, helped us review your responses for accuracy and clarity. Here is the winner:

"Those iceboats can achieve speeds much greater than 18 mph. As wind flows over the sail, the sail will generate two forces, lift and drag. Lift is perpendicular to the wind direction while the drag is aligned with the wind. The magnitude of the lift on a moving sail, a small component of which propels the boat forward, increases as the relative wind velocity increases over the sail. For example, with the boat standing still but pointed perpendicular to the wind, the sail will fill (producing lift and drag) from the wind flowing over the sail at 18 mph. As the boat starts to move, the magnitude of the relative wind (the true wind at 18 mph plus the speed of the boat) will increase. The apparent angle of the relative wind will also change as the boat increases speed. The relative wind will appear to move from the side of the boat toward the front. The boat will keep increasing in speed until the drag and friction of the boat equals the forward component of the lift from the sail. The point at which this happens depends on the shape of the sail, the angle of the sail to the wind, the friction between the runners and the ice, and the streamlining of the boat. An iceboat such as these can achieve speeds two, three and more times the velocity of the true wind through which they sail."

Mark Hunter

Niceville, Florida
mark.hunter.mark@gmail.com
Hunter is a sailor with a Ph.D. in mechanical engineering.

Safran

Open rotor innovator

The European Union's Clean Sky program is funding Paris-based Safran to create an airplane engine that would be lighter than conventional jet engines, burn less fuel and release fewer carbon emissions. Safran's Jerome Bonini oversees research, testing and development of the Open Rotor concept: an engine without a casing that includes two exposed sets of counter-rotating blades behind the gas turbine. The safety of the design was a top concern for Bonini and his team even before the fatal fan blade accident in April on a Southwest Airlines plane that involved an engine built by CFM International, the joint venture of Safran Aircraft Engines and GE Aviation. Bonini thinks the Open Rotor's composite fan blades, which are like those on today's CFM LEAP (Leading Edge Aviation Propulsion) engines, could prove to be more durable than titanium blades like the one that broke in the April accident. I spoke with Bonini on the phone and followed up by email to learn the latest about the Open Rotor project.

— Tom Risen

JEROME BONINI

POSITIONS: Vice president of research and technology at Safran overseeing Open Rotor program since 2017; chief engineer of Safran's M88-4E fighter jet engine from 2010 to 2014; head of flight tests and director of Safran engine test location in Istres, France, from 2006 to 2010; joined Safran (previously Snecma) in 1997 as an engineer in the engine design office; research engineer at the French Nuclear Safety Authority from 1994 to 1997.

NOTABLE: As a chief engineer for Safran, Bonini oversaw the creation of the M88-4E engines on Rafale fighter jets built by France-based Dassault Aviation. This experience, he says, is driving his current work designing and testing the open rotor engine. Working closely with the airframe designers on the M88-4E gave him experience for his next position as general manager of Safran's propulsive system design office overseeing teams that coordinated design with GE Aviation for the LEAP engine built by CFM. "You need experience to imagine the future," he recalls of these past engine design projects. Bonini's team conducted open air ground tests of the open rotor engine in 2017.

AGE: 49

RESIDENCE: Paris

EDUCATION: Master of Science from the University of Bordeaux in France; doctorate from Arts et Métiers ParisTech with a research focus on composite materials.

FAVORITE QUOTE: "Your task is not to foresee the future, but to enable it."

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IN HIS WORDS

Reducing fuel burn

The open rotor saves 30 percent fuel burn compared to CFM56 turbofan engines. The main objective of Clean Sky programs is to reduce the environmental impact of aviation. During the next four years we will continue to work on Open Rotor with this funding. It is partially funded by the European community. All the Clean Sky projects aim to achieve by 2050 to reduce [European Union carbon dioxide emissions] by 75 percent compared to the beginning of this century.

Post-test inspection

The engine was very good on the test bed [in 2017]. We will disassemble each part to check that the behavior of each part is what we expect. If there is some start of degradation, we will correct for the next version.

Bird strike test

We have composite blades — the way the propeller blade cracks is different from a metallic blade. These blades are more robust than metallic blades. We can imagine a different way to monitor them and to replace blades before failure. The main event we have to demonstrate is the bird strike event. We intend to perform it in the next two years in Villaroche where we have a dedicated test bed for ingestion test of fine blades.

Timetable

Regarding the flight test, that should be 2024-2025. We expect the beginning of the development in 2030 and an entry into service in 2035.

Possible interest from airlines

It will depend on what the market will need in 15 years and on the airframer decision to change or not the architecture of the future aircraft. You have to do a breakthrough; 10 to 15 years is not too much time to convince them that the Open Rotor is the right option. We have new technologies which can help them to reduce fuel burn for the next short- and medium-range aircraft. And if they want to have the same gain in terms of fuel burn they made with the last generation, they have to think differently.

More thrust, less drag without engine casing weight

If the diameter of the fan is very large, you can reduce significantly the fuel consumption of the engine. Bypass ratio is a major lever to increase the engine's efficiency. With the open rotor concept, you can increase the diameter of the fan and bypass ratio without penalties of drag and weight of casings.

Lighter than titanium

The 3D woven innovation enables us to make stronger and lighter parts and plays a key role in improving the performance of the new LEAP commercial airplane engine. We make the fan blades and case for the LEAP engine family using a 3D-woven composite and the resin transfer molding, RTM, process. Composite materials are a sea change in the aerospace industry. Their combination of strength and lightness makes a significant contribution to improving engine efficiency. These 3D-woven RTM composite blades are a 500-kilograms-per-airplane weight savings over conventional blades. The next step will be to expand use of these materials to aircraft engine parts subject to greater stress, such as compressors.

Safran

▲ A Safran Open Rotor demonstrator.

Explaining counter-rotation

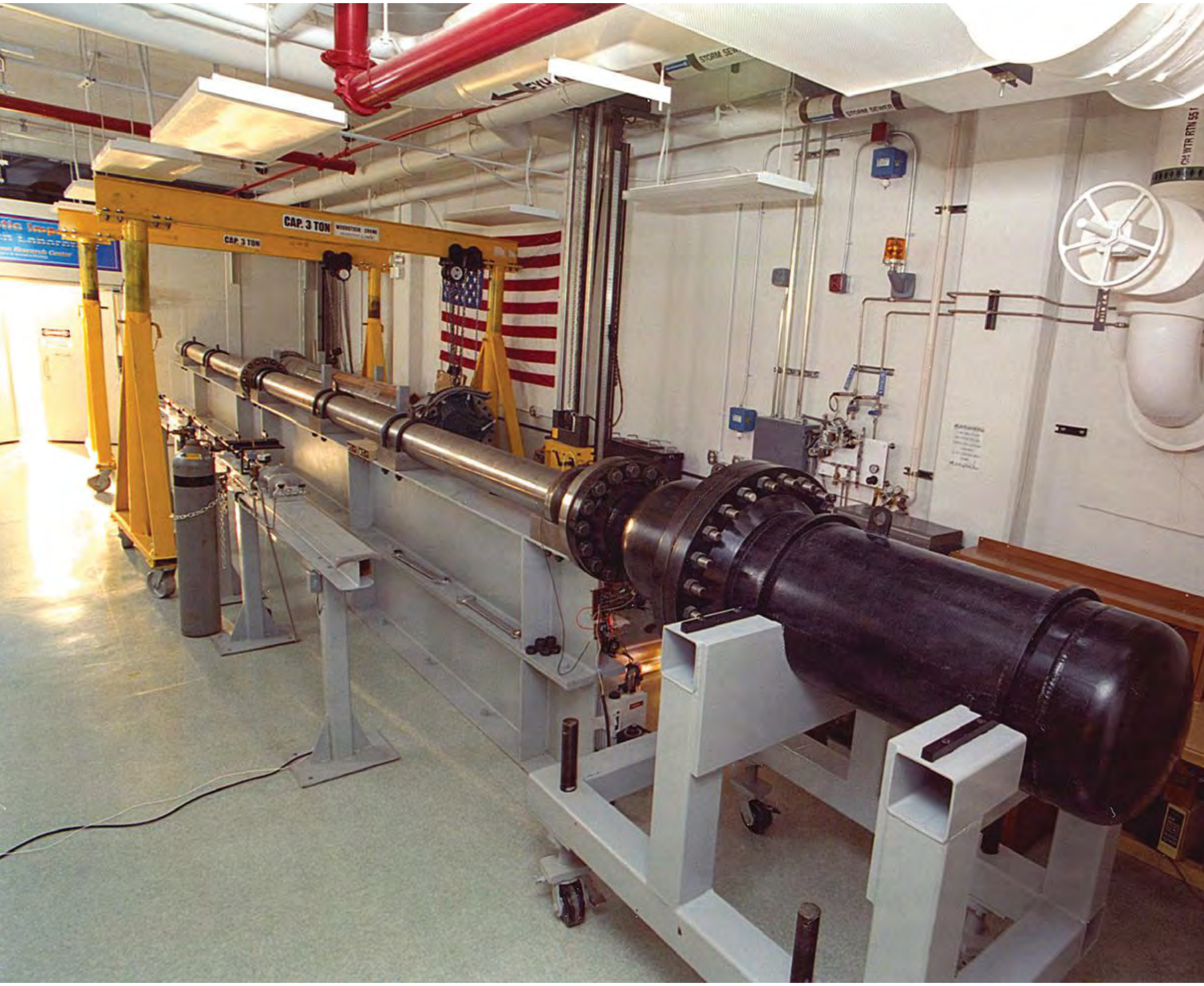
[The blades] are counter-rotating to reduce the speed of each set of blades. By having two rotating stages, you can put a static one to redirect the air after rotation. They make sure the air flow is going straight.

Aerodynamic shapes for wings, fuselage to match open rotor engine

These engines can be adapted to be installed under the wings, but it would be best to have them farther back on the aircraft. We have to work very close with a framer to have the best integration. If you increase the size of the aircraft a lot and keep the engines under the wings, you have a problem with your landing systems. You have the problem of weight also, of the aircraft itself, and if you want to reduce this impact, you have to think about the integration of large bypass ratio engines differently. Airbus has also one of these concepts where the engine is embedded at the rear of the fuselage. You have also a NASA boundary layer ingestion concept.

Public perception

This concept is different. You have to make people confident in this concept and that's the reason why we talk a lot about this concept today. Even with 10, 15 years, it's a good challenge for us to prepare people to have an engine with no casing at the rear of the aircraft and a large engine. The aircraft would be larger, so the engine is larger. That's not so different. ★



Containing a blade-out

NASA has long been working with the FAA and the aviation industry to improve technologies for containing broken fan blades and preventing damage like that which killed a Southwest Airlines passenger. Keith Button looks at a research project that could help prevent future tragedies.

BY KEITH BUTTON | buttonkeith@gmail.com

NASA

▲ **This 12-meter-long** gas gun at the Ballistics Impact Lab at NASA's Glenn Research Center fires projectiles (such as broken fan blades) into materials from aircraft.

When a fan blade snaps off inside a turbofan engine, as happened on a Southwest Airlines flight in April, a ring of metal or composites must keep the broken blade inside the engine. The engine rapidly winds down, shaking violently like a supersized clothes washer with an unbalanced load.

The broken blade stayed inside the engine in the Southwest incident, as it was supposed to do, but other debris nevertheless pierced the cabin of the Boeing 737-700, depressurizing the cabin and killing a passenger.

Even before the Southwest accident, researchers at NASA Glenn Research Center's Ballistics Impact Lab in Ohio, were assessing the ability of new materials to withstand projectile impacts, including from broken blades, and chronicling the amazingly rapid progression of events when there is damage.

The work has been playing out under a five-year High Energy Dynamic Impact project that wraps up in September 2019, with funding from the Advanced Composite Consortium, which includes NASA, FAA, aircraft and engine manufacturers, and universities.

The archives of these test results will be fed into computer models to help airplane and engine designers more accurately predict the performance of their designs for blade-out containment and fuselage protection. The testing should also give the FAA more confidence in the accuracy of the models, which in some cases might substitute for certification testing.

With most materials, the ability to hold up under certain types of loading is predictable and well-known. But predicting the results of an impact, even on materials with well-known properties, is extremely complicated, says Mike Pereira, head of the Ballistics Impact Lab.

"It's surprisingly difficult to predict penetration, even in simple metals," Pereira says. "If you were trying to predict if a metal projectile will penetrate a flat panel of aluminum, your prediction is probably not going to be accurate."

Once a material is damaged, it's also difficult to predict whether it will maintain its strength and still do the job that designers intended it to do, Pereira says. Adding to the challenge, composite materials can be considered as miniature structures: Some have fibers running in different directions in each layer, for example. This structure makes it difficult to predict whether or how far damage will propagate through the material.

Pereira and his team get at these and other questions by firing gas-powered guns at materials. They have about a dozen gun barrels, ranging from 46 centimeters to 12 meters long and from 1.6 millimeters to 40.6 centimeters wide.

In addition to pieces of fan blades, the ballistics lab has shot sharp and blunt objects for impact testing, ranging from ice crystals to artificial birds made of gelatin containing micro-balloons to create specific desired densities.

Aircraft engine designers hire the ballistics lab to test their blade-out containment designs. The lab's cost of testing a blade-out projectile is typically a few thousand dollars. "We test concepts relatively inexpensively and do multiple tests within a week, whereas a whole blade-out is a really expensive proposition. You destroy an engine," Pereira says. To simulate a blade out, the containment ring, or containment case, is removed from an engine. These rings are typically about 60 centimeters wide, and they circle the fan blades. Safety regulations require that the case be wide enough to cover 15 degrees fore and aft from the center hub of the fan blades.

Until the 1970s, these rings were solid metal designed to withstand and deflect blade-out shrapnel so it wouldn't penetrate the cowling, which is the outer shell of the engine, also called the nacelle. This metal "hard-wall" approach makes the engine heavy, so engine makers started developing cases that would permit broken blades to poke through the interior walls into an outer layer of Kevlar, inside the cowling. These "soft-wall" containment cases reduced the weight of the engine.

Today, more engine designers are adopting composite cases. The CFM56-7B engine — the engine on Southwest Flight 1380 that broke apart after a blade out, killing a passenger — has a hard-wall metal containment design. The Honeywell HTF7500 engine on Gulfstream G280 business jets is an example of a composite soft-wall containment design, and its composite and fabric materials were tested in Pereira's lab.

The hard-wall and soft-wall designs each have pros and cons. With a soft-wall, the Kevlar must have room to stretch when impacted, and that means there must be adequate room for this expansion between the ring and the cowling. Designing in this empty space makes the engine's diameter a bit larger, and that increases drag. The advantage is that the broken-off fan blade is captured away from the flow path, where other blades are spinning, so there are fewer secondary impacts with those blades.

With a hard-wall design, like that of the CFM56-7B, the containment wall must be strong enough to prevent the blade from penetrating it. That means the cowling doesn't have to be as large, so it can have a more streamlined design. But its disadvantage is that the initial broken blade can't get out of the flow path completely, so it typically stays in the engine as the engine winds down, hitting the other blades.

Some soft-wall designs also have a metal interior wall that blunts the fan-blade projectile as it

Competing technical approaches

Engine designers have adopted different strategies for containing blade-outs. Some engines attempt to contain broken blades with “soft walls” that slow and grab the blades. Other designs have rigid hard walls that broken blades cannot penetrate.

ENGINE		CONTAINMENT	FLOWN ON
	**CFM56-7B**	**Metal hard wall**	**Boeing 737**
	**Honeywell AS907 (also known as HTF7000)**	**Metallic soft wall (aluminum honeycomb surrounded by aramid-fiber wrap)**	**Gulfstream G280**
	**General Electric GEnx***	**Composite hard wall**	**Boeing 787 Dreamliner**
	**Honeywell HTF7500E****	**Composite soft wall**	**Embraer Legacy 500/450**
	**Williams International FJ44-4A****	**Composite hard wall**	**Cessna Citation CJ4**

* Containment material was tested at NASA Glenn Research Center’s Ballistics Impact Lab.
** Containment materials and containment cases were tested at the Ballistics Impact Lab.
Source: Staff research, Ballistics Impact Lab

passes through. Another factor for how the cases are designed is the type of fan blades: Hard-wall composite designs usually won’t work with solid titanium fan blades, only with hollow titanium or composite blades.

To test a soft-wall containment case, the lab researchers fire the broken fan blade into the inside of the ring. Then, they simulate the vibrations caused by the unbalanced fan as the engine winds down. “As it’s spooling down, it goes through different resonances, and you can get very large vibrations,” Pereira says. As with an unbalanced car tire that vibrates violently at certain speeds and not at others, the engine goes through extreme swings in vibration loads at certain points as it slows.

When the engine is under power, the fan blade tips are spinning at supersonic velocities, so the lab researchers fire the broken fan blade into the containment wall at a velocity of about 300 meters per second, Pereira says.

To control the position of the projectile as it leaves the gun barrel, the lab researchers support it in a sabot — a device resembling an aluminum can that fits snugly into the gun barrel and slides through it when the gun is fired, stopping short at the end of the barrel as the projectile flies out. The projectile is typically positioned and supported in the sabot with foam. The researchers fire the gun by releasing pressurized helium or nitrogen into it through a burst valve — a layer of mylar that breaks

▲ **National Transportation Safety** Board investigators examine a CFM-56-7B engine on the Southwest Airlines' plane that made an emergency landing in Philadelphia in April.

NTSB video

when heated by a wire, releasing the pressurized gas all at once.

The researchers must then attach the damaged ring to an apparatus on the floor of their lab to simulate the vibrational loads of a blade-out. The damaged ring is bolted flat to a cross-shaped support that has a post in the middle. Four hydraulic actuators extend from the post to connect to the ring at evenly spaced locations Each actuator pushes or pulls with up to 11,000 kilograms of force.

The hydraulic actuators generate the same shear and orbital loading and displacement on the ring as in a blade-out, but not at the same frequency, Pereira says. The hydraulic actuators take 1 second to accomplish what the engine in wind-down mode would experience in a half a millisecond, so it takes several hours to simulate a 30-second wind down.

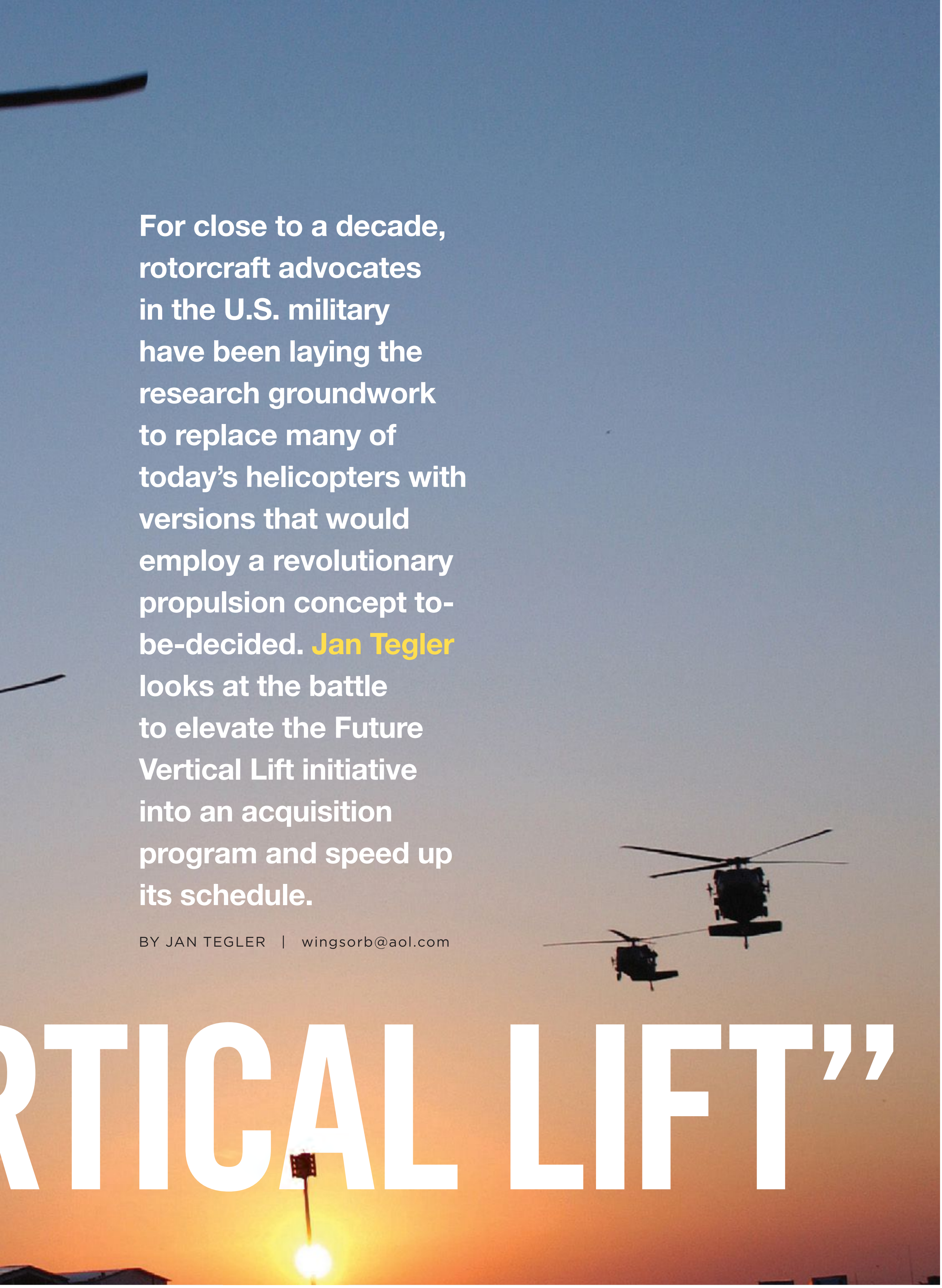
The containment case passes the vibrational load test if no new cracks form or grow from the initial blade penetration damage. "That kind of loading, if the case isn't designed properly, it can generate cracks that propagate around the whole engine case," Pereira says. "If that happened, that would allow the part of the engine to separate, and we can't have that."

The FAA requires that no part of the detached fan blade penetrate the outer wall of the cowling in a blade-out, nor can blades that may break off the turbine or compressor parts of the engine, Pereira says. Farther into the flow path, where the turbine and compressor blades are, the FAA doesn't require certification testing for blade-outs — only analysis based on previous test data — because the containment wall is stronger and thicker.

Under the High Energy Dynamic Impact project, the ballistics lab has been testing blunt and sharp projectiles fired into flat plates of materials that someday might be approved for fan cases. The materials could also protect fuselages as the FAA would require in designs for planes with open-rotor engines — jet engines without a cowling covering the propulsion blades. Following the flat-plate tests, the researchers began testing materials that have structural features, such as ribs, or variations in thickness, added to them. So far, the lab has performed 200 to 300 impact tests, Pereira says.

The idea is to build a database from impact tests on materials with increasing structural complexity. The data should improve the accuracy of a NASA computer model, Pereira says. A group of companies have started to exercise the model, finding bugs and examining how they can put it to use. These "alpha users" include Pratt & Whitney and Lockheed Martin's Sikorsky. As the computer modeling of impacts on materials becomes more accurate and capable of predicting the performance of materials, it will help both designers and regulators. ★

FIGHTING FOR "FUTURE VER



For close to a decade, rotorcraft advocates in the U.S. military have been laying the research groundwork to replace many of today's helicopters with versions that would employ a revolutionary propulsion concept to-be-decided. Jan Tegler looks at the battle to elevate the Future Vertical Lift initiative into an acquisition program and speed up its schedule.

BY JAN TEGLER | wingsorb@aol.com

RTICAL LIFT”

Army Chief Warrant Officer 3 Joseph Priester was jolted awake at 4 a.m. by the sound of rocket and mortar fire. He sprinted to his OH-58D Kiowa Warrior, a lightly armed reconnaissance helicopter, and took off with his co-pilot from Forward Operating Base Salerno in eastern Afghanistan. They didn't have to fly far. A group of 30 insurgents about 2 kilometers from the base had launched an attack on the coalition base. At one point, Priester landed in the middle of the fight to pick up a wounded American soldier — his left-seater remaining behind so that the two-seat Kiowa Warrior could transport the wounded man back to the base.

Priester's response to the 2008 attack was emblematic of many of the missions flown by U.S. helicopter crews in the wars in Iraq and Afghanistan. Many could be accomplished by short dashes by light-lift, maneuverable helicopters. Now, however, recognition is growing in the Pentagon that range and speed could turn out to be paramount in the next conflicts.

For years, the Pentagon has been laying the technological groundwork for the possible creation of multibillion-dollar acquisition program called Future Vertical Lift. Preliminary plans call for the Army to manage development of FVL variants for itself, the Marines and Navy, with the designs founded on a revolutionary propulsion concept still-to-be-decided. The overarching goal would be to double the range and speed of today's helicopters by rolling out conventionally piloted and unmanned versions in the mid 2030s, a schedule that the Army and allies in Congress want to accelerate.

At the moment, FVL remains a modestly funded research effort, although in June the Army released a draft solicitation to industry to get feedback on a Future Reconnaissance Aircraft Competitive Prototype under the FVL initiative. According to this solicitation, the Army wants to have prototypes of an armed reconnaissance rotorcraft (one of two FVL aircraft types it is prioritizing) flying by 2023 in an effort to choose a design to enter service within a decade. The White House is proposing to spend $125 million on FVL and related efforts in fiscal 2019, a request that is making it through the congressional appropriations and authorization process with minimal adjustments up or down.

The FVL initiative appears to be at a crossroads. On one path is a multiservice, multibillion-dollar, joint acquisition program. On the other lies something short of that. The Army, Marine Corps and Navy are in the midst of analyzing their rotorcraft alternatives for the years ahead in an Analysis of Alternatives, or AoA, that will spill into 2019 and largely determine the path for FVL.

Brig. Gen. Walter T. Rugen, who manages the FVL initiative from Joint Base Lewis McChord in Washington state, expresses confidence that the path will be a bold one, with some questions still to be addressed. "We've moved on from the 'why' question. We're not

U.S. Army

▲ **A U.S. Army OH-58D** Kiowa Warrior helicopter returns to the flight line after completing a mission as an HH-60 Black Hawk medevac helicopter flies off for another mission in Afghanistan, where many missions could be flown with light-lift, maneuverable helicopters.

having to justify why we need Future Vertical Lift. It's how we do it," he said in a phone interview.

I spoke with Rugen, Marine Corps leaders, a member of Congress, former Army helicopter pilots and defense analysts to take the pulse of FVL about this critical crossroads.

Schedule

On the question of timing, the plan to roll out FVL aircraft in the 2030s has not set well with Army aviation advocates in the Pentagon or on Capitol Hill.

One of them is Rep. Anthony Brown, D-Md., a former Army OH-58 pilot whose state is home to the Army's Aberdeen Proving Ground, where rotorcraft research could aid FVL, and Naval Air Systems Command, or NAVAIR, which manages rotorcraft acquisitions for the Navy and Marine Corps.

Brown says he was surprised when he was briefed about the timeline by the Army. Plans still call for releasing the FVL request for proposals in 2021, which is itself a two-year slip from the plan as it stood in the fiscal 2017 budget. That release would put the first FVL aircraft in the hands of pilots in the mid-2030s.

"I must say my first impression was 'Man, this is going to take a long time,'" Brown says.

Earlier this year, the House authorization subcommittee that Brown sits on told the Army to "weigh speeding modernization and fielding" of weapons including FVL.

Rugen, who manages the FVL initiative from Joint Base Lewis McChord in Washington state, tells me "we have to go faster," which would mean flying operational FVL aircraft within a decade rather than the mid-2030s. He says accelerating FVL "is being pushed at the highest levels, so we enjoy that priority."

Rugen leads the Cross Functional Team that has been assembled to ensure that all relevant subject matter experts are included in the FVL initiative. He sounds cognizant of the complexities and speckled history of other attempts at large programs serving multiple agencies.

"We're focused on accelerating this capability as much as we can, balancing the risks," he says of FVL.

For one, he and others shun the "joint" in reference to the structure of the FVL program. "If we had a joint program we'd have a joint program office and all that stuff. We don't have that," he said.

On the question of timing, the answers I received from NAVAIR's PMA-276 office, which manages the Marine Corps light-attack helicopters, are strikingly different from those of the Army.

"The Marine Corps need is currently unchanged," PMA-276 said when I asked whether the Marines also would like to see FVL rotorcraft delivered sooner than the mid-2030s.

Also, the Marine Corps explained that the "driving factor" in its planning is an aircraft that can carry six to eight passengers and match the V-22 tiltrotors in range and speed to escort them.

An open question remains how these divergent visions of timing would translate into budget planning, once the services finish analyzing their rotorcraft futures early next year.

Richard Aboulafia, who analyzes military aviation spending for the Teal Group in Virginia, cautions that the Army has only a "small window of time" to get an FVL program funded and moving forward. That's because the Trump administration spike in defense spending would peak in 2019.

If FVL is elevated to an acquisition program, the stakes would be enormous. Early plans call for producing a family of aircraft to replace such stalwarts as the Army's UH-60 Black Hawk, the Marine Corps UH-1Y Venom utility helicopter and the AH-1Z Viper attack helicopter. The new aircraft must exceed the performance of those flown by near-peer competitors, meaning China and Russia, which would mean flying about twice as fast and far as most of today's rotorcraft.

The foundational propulsion technology has yet to be chosen. Two concepts are facing off against each other under a related demonstration initiative, called the Joint Multi-Role Demonstrator program, with funding tracing back to 2013. Vying are the V-280 Valor tiltrotor built by Bell of Fort Worth, Texas, and the SB-1 Defiant, an unusual helicopter built by Sikorsky and Boeing. The SB-1 team says it is "fighting hard"

▼ **Sikorsky is positioning its S-97 Raider** as a candidate for the Future Vertical Lift "Light" variant. The S-97 was developed for the U.S. Army's canceled Armed Aerial Scout program.

Sikorsky

Future Vertical Lift demonstrators

The V-280 Valor and the SB-1 Defiant are competing to become the U.S. military's next-generation rotorcraft, developed through the Army's Future Vertical Lift initiative. The Valor design was partly inspired by the larger V-22 Osprey tiltrotors. The SB-1's two coaxial rotor blades are mounted one above the other and rotate in opposite directions.

Source: Staff research, manufacturers

Manufacturer Bell
Engines GE T-64 on Joint Multi-Role-Technology Demonstrator
First flight Dec. 17, 2017
Weight Declined to provide
Airframe Composites/metal

Manufacturer Sikorsky-Boeing
Engine Honeywell T55
First flight Late 2018
Weight 13,600 kilograms (30,000 pounds)
Airframe Composites/metal

IT'S IN THE NAME

The "280" in the name V-280 Valor highlights the 280-knot (519 kph) cruise speed Bell says this tiltrotor will be able to achieve. First flown in December 2017, the V-280 has logged about 30 flight hours and reached 190 knots (352 kph) in level-flight at this writing.

to fly for the first time by the end of this year.

The two concepts could not be more different. The Valor design was partly inspired by the larger V-22 Osprey tiltrotors. The main difference is that the V-22's engines tilt entirely when transitioning between horizontal and vertical flight, whereas just the gearbox on each Valor engine tilts. "V-22 is the number one in-demand VTOL aircraft within DoD because of its speed and range," says Keith Flail, Bell's vice president for advanced tilt-rotor system. "We're taking all the knowledge from the Osprey — over 400,000 flight hours — and we've applied that to Valor, a clean- sheet design with today's technology."

SB-1 gets at the range and speed problem another way. Its two coaxial rotor blades are mounted one above the other, and they rotate in opposite directions to prevent clockwise or counterclockwise torque on the fuselage. This strategy eliminates the need for a tail rotor (sometimes called an anti-torque rotor) and frees up space for a pusher prop to add speed and maneuverability. The design is based on Sikorsky's experimental X2 that the company flew in 2008. "Not only does our X2 technology preserve all of the best characteristics of traditional single or double-rotor aircraft like the Chinook, Black Hawk and Apache, it betters them in some ways. Yet it can still achieve speeds well north of 200 knots to get to the expanded battle space the government appears to be looking at," says Rich Koucheravy, Sikorsky's business development director.

At the moment, it's not clear whether one or both of these approaches will be chosen as the way forward for FVL. The Marine Corps light-attack helicopter office, PMA-276, says the analysis-of-alternatives is "reviewing multiple aircraft concepts, not just those used for the full scale technology demonstrators."

Perhaps complicating budget matters, FVL is one of six modernization priorities the Army has identified across all domains: air, land, space, cyberspace, electromagnetic spectrum, information and the cognitive dimension. All require significant expenditures.

Speed = Reach

The joint requirements for the FVL aircraft have yet to be written, but the demonstrators are targeting a cruise speed of 230 knots or 425 kph and a range of up to 800 nautical miles or 1,481 kilometers.

Rugen rattles off the broad brushstrokes of what rotorcraft experts want: "We're looking for sweeping improvements in our lethality, agility, survivability, sustainability and what we call reach."

"Reach" alludes to a different kind of fight from the counterinsurgency war that Priester, the Kiowa Warrior pilot, was thrown into. In future conflicts, the air superiority that U.S. forces have enjoyed could be contested, Rugen says. In that case, dotting the battlefield with forward operating bases and refueling points for rotorcraft won't be practical. Missions would have to cover greater distances, whether for attack, reconnaissance, transport,

medevac or special operations.

Speed and range will “get them to the fight rapidly” Rugen explains. Penetrating sophisticated enemy defenses would be done by teaming rotorcraft with an “ecosystem of unmanned aircraft and modular missiles.”

The question is which concept — the coaxial SB-1, the V-280 tiltrotor or perhaps another idea — would be best suited.

Maneuverability

Army helicopter pilot Chief Warrant Officer 4 Michael LaGrave, an ex-Kiowa Warrior pilot, says tilt-rotor aircraft “lack the agility at low speed” of traditional helicopters, noting that the Army is the only service which does not operate the Osprey.

Bell officials are aware of this perception, and the company has invited current Army aviators to fly its V-280 simulator. Bell’s Flail says the V-22 is in fact “incredibly agile” at low speed. “We’ve been able to do a lot of things with this next-generation tiltrotor to have even greater agility at low speeds,” he says. “As we go through the envelope expansion we will demonstrate that.”

Sikorsky and Boeing think they have an edge with an aircraft that traces its heritage to previous helicopters. Looking at the initial FVL description, “we realized that while the Army did want the extended range and speed of a fast vertical lift platform, it did not appear they were willing to sacrifice much in terms of low speed hover and performance in the objective area,” says Sikorsky’s Koucheravy.

That’s why Sikorsky and Boeing based their SB-1 Defiant design on the X2, which was a compound helicopter, meaning it combined the propulsion of rotors and propellers.

Cost

The Army wants this new generation of rotorcraft to cost about the same to operate and maintain as

▲ **The Bell V-280 Valor** demonstrator flew for the first time in December 2017.

the latest variants in its fleet, from the UH-60V Black Hawks to AH-64E Apaches.

"I'll echo what Gen. [James] McConville our vice chief of staff said," says Rugen. "We're looking at the price point that we have now for procurement and flight hours as our targets."

Aboulafia of Teal Group doesn't think it's realistic to think that the FVL aircraft will cost the same as today's versions.

"I don't think you can get this incredible capability for the same or anything like the same price," he says.

Given the costs, funding uncertainty of FVL and the history of joint programs, Aboulafia is skeptical about the future of FVL. He thinks it makes little sense to try to compress diverse demands into one program. "Rather than building one giant mega-cathedral, how about just a small village church?"

If he were the Army or Marines, he'd think about a "fallback" option of continuing with "upgrades or existing new-build helicopters."

"I tell everybody who will listen," Aboulafia quips, "be prepared for a future of 'Black Hawk-N' models, 'Apache-G' models or 'Chinook-Q' models, take your pick."

Aboulafia notes that the Army is continuing to make incremental upgrades to its existing fleet. The service continues to buy the latest version of the Apache, the AH-64E and the UH-60M while upgrading UH-60L Black Hawks with a digital cockpit as UH-60Vs. The Army also has an Improved Turbine Engine program underway to replace the engines in its Black Hawks and Apaches with more powerful, fuel-efficient turbines. Meanwhile, the Marine Corps is continuing to procure the UH-1Y Venom and AH-1Z Viper utility and attack helicopters.

Prioritizing designs

FVL rotorcraft are classified under six "capability sets" that encompass the variety of roles Army and Marine helicopters fulfill, from light attack and reconnaissance to airborne assault and heavy lift.

In March, Army aviation leaders, including Rugen, indicated the service would focus on two FVL variants — a light future reconnaissance attack aircraft (the subject of the draft solicitation) and a long-range assault aircraft similar to the medium-lift SB-1 Defiant or V-280 Valor rotorcraft now progressing through JMR-TD.

I had heard speculation that the Army wants an armed scout to be the first FVL variant fielded. I asked Rugen if that was the plan, and he says that's "yet to be determined."

Sikorsky thinks that's a real possibility and is offering its S-97 Raider for the future reconnaissance role. Not part of the current demonstration program, Raider was developed for the Army's Armed Aerial Scout program (canceled in late 2013) to replace the OH-58D. The S-97 has the same coaxial rotor configuration as the SB-1 Defiant.

It remains unclear how the Marine Corps would fit into the FVL initiative, given the statement from PMA-276 that it still likes the 2030s date and that the "driving factor" is not a light FVL but one capable of carrying 6 to 8 passengers and escorting V-22s.

Asked about that, Rugen says the Army shares "significant" interest in a light FVL with U.S. Special Operations Command and the Coast Guard.

Aboulafia of Teal Group contends that Bell's tilt-rotor V-280 is more suited for the type of missions the Marine Corps performs while Sikorsky-Boeing's SB-1 may be more appropriate for Army missions. If FVL is to go forward, "each service should pick one of the aircraft now in development for JMR TD and get going." ★

Staff reporter Tom Risen contributed to this report.

TECHNICAL TOPICS TO INCLUDE:

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Shaping the Future of Aerospace

DREAMI

Sierra Nevada Corp.'s Dream Chaser test vehicle is hoisted by helicopter to its Nov. 11, 2017, free-flight test at Edwards Air Force Base, Calif.
NASA

NG BIG

If all goes as Sierra Nevada Corp. hopes, you'll soon be hearing a lot more about Dream Chaser, the spacecraft with a history of ups and downs. Amanda Miller toured the new Colorado facility where the first spaceflight version of Dream Chaser will be built. Miller went in expecting to learn about a spaceship and came out with a sense that a comeback could be at hand.

BY AMANDA MILLER | agmiller@outlook.com

THE YEAR WAS 2014. Mark Sirangelo had already made all the mistakes known to entrepreneurs, "some multiple times, just to make sure how bad I could be."

As head of Sierra Nevada Corp.'s Space Systems division in Colorado, Sirangelo knew NASA was going to call between 8 and 9 a.m. The company that builds satellites and intelligence cameras and modifies aircraft for the military was vying against SpaceX and Boeing Co. for the right to ferry astronauts to and from the International Space Station in a privately owned spacecraft.

Sirangelo had good reasons to be confident about the call, but also a nagging concern. His 200-person team had proposed the only contender that could land on a runway, as the space shuttle fleet had done before its retirement. Not only that, much of Dream Chaser's design had come from NASA itself. Still, a landing gear malfunction after a helicopter drop test the year before had caused the test version of Dream Chaser to skid off the runway at Edwards Air Force Base, California. The landing wasn't a requirement of that particular test, and the one-and-only Dream Chaser test vehicle survived to glide again. Even so, the incident probably hadn't helped the company's cause.

When the phone call came, the program officer's words were a lot like the ones Sirangelo wanted to hear, "with one or two really big, important exceptions," he says. The officer was sorry to say Dream Chaser was not among the two concepts selected to deliver astronauts back and forth.

And the Space Systems division descended into one of the periodic dark chapters in its corporate history.

This is the story of how the Dream Chaser team has climbed out of this pit, with a multibillion-dollar NASA contract on the books and international business in view. Soon, full-scale production will begin on the Dream Chaser Cargo System, while SNC continues to work out the details of a United Nations science mission — the U.N.'s first-ever mission to space.

It's a business fairytale with sci-fi overtones that can't help but conjure comparisons to a certain mythical beast: the fabled Egyptian phoenix bird that rose from the flames.

If you've poured your heart into a project, only to lose a bid, or you're staring down the barrel of a business setback that's going to hurt a lot of people,

▼ **The Dream Chaser test vehicle** touches down at Edwards Air Force Base in California after being dropped from a helicopter at an altitude of 12,400 feet.

NASA

keep in mind Dream Chaser's fall, its pending rise, and what that all could symbolize — if everything goes as planned. Ascent and re-entry, after all, are still unproved.

I met with Sirangelo as he counted down his days running the division after nearly a decade in the role. Longer, if you include his time as CEO of the startup SpaceDev, which SNC acquired.

Lesson 1: Take the long view

Our backstory begins in 2001, before Sirangelo had joined SNC. He was at the annual Space Symposium in Colorado Springs where he was being inducted into the Space Technology Hall of Fame as CEO of a company that designed an infrared missile sensor that was developed for medical research.

That symposium reconnected Sirangelo with some people he'd known as a U.S. Army officer when he advised at the Pentagon. Those former colleagues were on the board of "this very small company in San Diego called SpaceDev" that was trying to break into the space industry. They invited him to consult and soon asked him to be CEO and chairman, which he accepted. "And we were in a garage — literally a garage."

Around 2004 or 2005, in the course of working on a business plan, the small team at SpaceDev recognized that the space shuttle's days were likely numbered. They asked themselves: "If we were going to rebuild the shuttle now, how would it be different?" Sirangelo recalls.

A lot had changed since the space shuttle was designed in the late 1960s and 1970s. The shuttle orbiters were built big to launch elements of a future space station, scientific spacecraft (most famously the Hubble Space Telescope) and spy satellites. By the mid-2000s, space station assembly was well underway, and national security satellites were traveling on unmanned rockets.

"We thought there needed to be a [space shuttle] 2.0, and there were no plans for a 2.0," Sirangelo says.

He knew that lots of promising NASA research got relegated to files, never resulting in a product.

"I said, 'Well, maybe we should go look.'"

Lesson 2: Give "life support" when necessary

NASA had studied an idea for a spacecraft smaller than the space shuttle, known as the HL-20, back in the 1980s to take astronauts to a then-envisioned Space Station Freedom.

In name, the HL-20 alluded to a prior NASA spaceplane design called the HL-10. But the HL-20 was really based on spy photos of a Soviet spaceplane, says John Martin, an engineer at NASA's Langley Research Center in Virginia who became the point person there for Dream Chaser, sharing all the data and insights that NASA's engineers had acquired.

▼ **Sierra Nevada Corp.** technicians work on connecting the Dream Chaser test vehicle to a helicopter for its free-flight test.

NASA

> **"We could offer them a turn-key mission where we launch from wherever, do whatever mission they want, and then land in their country, for roughly the price of a satellite launch."**
>
> — **Steve Lindsey**, head of Dream Chaser's design, development, testing and operations for Sierra Nevada Corp.

The HL-20's lifting-body design — lift is generated by the spacecraft's body instead of wings — meant it could land on a runway.

Students from North Carolina State University and North Carolina A&T State University built a full-size research model of the HL-20 for Langley in 1990 to help envision the layout for a 10-member crew.

Several years of study ultimately went into the HL-20 at Langley, but the idea was later axed. Estimates had ranged from $3 billion to $6 billion to build it.

"So we came in, in 2005, and said … 'Why not start out with something that had 10 years of good work, that wasn't killed because it was a failure — it was killed for budget reasons and other reasons?'" Sirangelo says.

"And we actually have kept the same shape of the vehicle, through all its turns — it's called the outer mold line — I mean, within small tolerances. They did it right. They did it well. We changed a lot of other things, but we kept the basic design and shape because it works pretty well."

Just as SpaceDev rescued the HL-20 mockup from impending destruction — "because it wasn't being useful for anything, it was going to be destroyed," Sirangelo says — NASA made what ended up being its own historic maneuver.

NASA started a program in 2005 called COTS, short for Commercial Orbital Transportation Services, allocating an initial $500 million for it. This was the U.S. government's first step toward seeding commercial space enterprises. The idea of COTS was to get companies working on concepts for carrying cargo and/or crew as a service, rather than NASA picking a company to build a spacecraft to its precise specifications and taking ownership of it.

COTS was effectively a first phase for companies, such as the young SpaceDev, to demonstrate that they could take on space transportation. The company submitted proposals twice and was turned down twice. "We found ourselves being that close to being funded with a reasonable amount of money, a couple hundred million dollars, and we didn't get it — which created, as you can imagine, a lot of disappointment."

SpaceX's reusable Dragon capsule got a funding boost under COTS, as did then-Orbital Science Corp.'s expendable Cygnus capsules, which burn up, along with ISS trash, on re-entry. Cygnus got picked in a second round of proposals, after the now-defunct Rocketplane Kistler company, initially selected — although in bankruptcy at the time — couldn't fulfill its contract.

"We found ourselves having lost two competitions within a year-and-a-half, both of which we thought we should've won," Sirangelo says. "And that led to a very dark period" in which "everyone thought, 'Well, you had your crazy idea. You tried. You came really close. It's over.'"

But COTS had forced the Dream Chaser team to get real. They had defined the project. They had found partners. They didn't want to give up.

"So we kept it on life support for a couple of years on our own," Sirangelo says, investing the company's money to continue some of the work — "to prove to ourselves we could actually build and fly the vehicle."

Lesson 3: Ride the ups and downs

Meanwhile, a fortunate meeting over a contract had connected Sirangelo with Nevada-based Sierra Nevada Corp.'s owners, Eren and Fatih Ozmen. SNC acquired SpaceDev and brought Dream Chaser into the fold.

"At that time, it was enormously innovative to understand that building a successful space program didn't necessarily have to start from scratch," says SNC's CEO and owner Fatih Ozmen. "It was exciting to us that there was no one else building anything like it, even with 30 years of shuttle legacy proving that the design works."

Then the announcement came down in 2010: The space shuttle fleet would be permanently grounded. NASA soon started its series of Commercial Crew Development contracts as a successor to COTS. Contracts would be awarded to companies for work devising concepts to take astronauts to and from the International Space Station in privately owned spacecraft that would meet NASA's strict safety criteria.

"We submitted, and this whole long, dark period shut off, and we won the biggest of the contracts," Sirangelo says. "And all our craziness began to look not so crazy."

SNC won four Commercial Crew Development contracts in all, for a total of $363.1 million, to design and build the Dream Chaser test vehicle, the same craft that ran off the runway in the unmanned test at Edwards in 2013 and that complet-

ed its last test flight in November 2017.

The earlier landing-gear malfunction was traced to a possible clog in the hydraulics. Dream Chaser had sat locked behind the gates at Edwards throughout a three-week government shutdown.

"One of the things no one had ever anticipated was a three-week stand-down, because of a government shutdown, and one of the things that probably happened was that the hydraulic fluid had settled and might have picked up some metal particles from not being rotated or circulated," Sirangelo says.

When Dream Chaser finally glided in to land, one landing gear deployed two seconds too late.

And the kicker?

No landing gear like that — an aircraft landing gear just for the test — was ever going to space.

Maybe the accident would've happened anyway — maybe not. One thing it showed: The ship could protect its contents.

"Nothing inside the cabin was destroyed, even though the vehicle had a traumatic ending. The computers actually turned back on and worked," Sirangelo says.

"Much to our chagrin, the gear actually did come down. It just came down late."

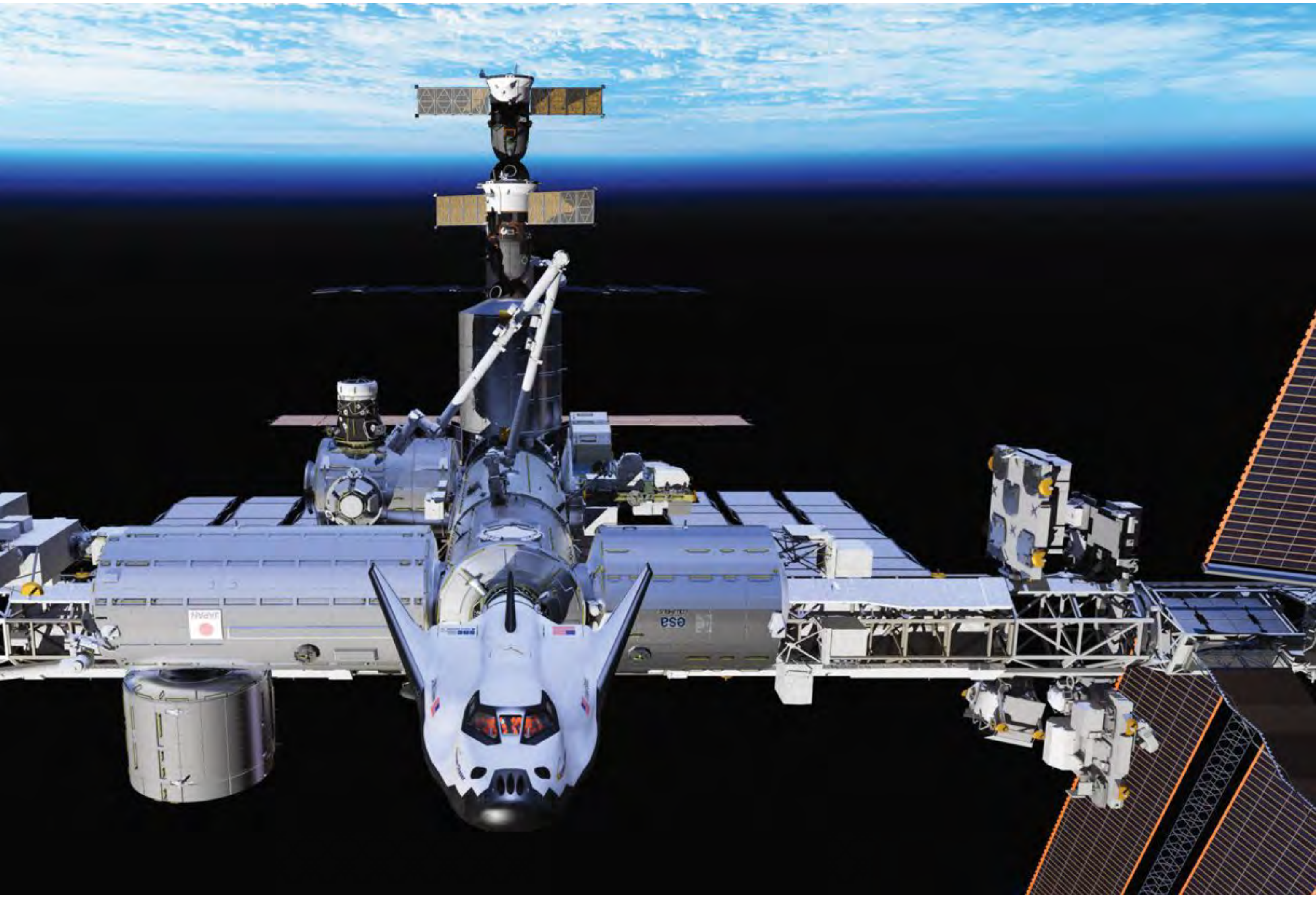
Lesson 4: Orchestrate the comeback

SNC officially protested the eventual Commercial Crew loss in 2014, arguing among other things that the value of promising to have the vehicles approved for human flight by NASA, by 2017, wasn't clear in the request for proposals. SNC had declined to make that guarantee.

However, the congressional Government Accountability Office, which judges bid protests, ruled only that the decision was up to NASA. SpaceX and Boeing got their $2.6 billion and $4.2 billion contracts, though neither achieved the human flight certification in the promised timeframe. (Now a new GAO report from May 2018 estimates that goal will slip as late as December 2019 for SpaceX and February 2020 for Boeing.)

"It was a very devastating loss for us because by that time we had geared up our team," Sirangelo says. It hurt to let so many people go.

"Then we made what was a fairly fateful choice — and probably the key to all of this — was we said,



▼ **The Dream Chaser** Space System — Sierra Nevada Corp.'s name for a potential crewed version — docks with the International Space Station in an artist's conceptual image.
Sierra Nevada Corp.

Sierra Nevada Corp.

▲ **Sierra Nevada Corp. owners** Fatih Ozmen, CEO, left, and Eren Ozmen, president, show the Dream Chaser test vehicle to U.S. Vice President Mike Pence. Dream Chaser was on display at the Space Symposium in Colorado Springs in 2018.

'No, we're not done.' And on the craziness scale of everything crazy that we did, this was off the scales."

NASA soon announced another round of commercial funding — to deliver cargo this time.

An intense, four-month redesign of Dream Chaser ensued. A team of about 100 turned the design into an autonomous cargo system.

This time, SNC, Orbital ATK (now Northrop Grumman Innovation Systems) and SpaceX each won contracts for a minimum of six resupply missions to the space station. Not making the cut were Lockheed Martin's proposed Jupiter module, described as having the flexibility to also haul things deeper into space, and a cargo version of Boeing's Starliner personnel capsule, which was already in development for Commercial Crew.

This time when the call came, Sirangelo recalls a couple of small but big differences — like the addition of a "happy" and omission of a "not," as in "We're happy to tell you you've been selected."

SNC has tried to hire back all the old Dream Chaser people it could from before the 2014 Commercial Crew setback. About 80 percent have said yes, and SNC has brought on a total of about 400 workers in the past year due largely to the cargo contract. Many of the staff went out to this year's Space Symposium, to the outdoor display, and got a portrait with Dream Chaser, and took their families to see it — the original Dream Chaser test vehicle, now partly modified for autonomous flight, on its last mission before retirement in a glass case at the entry to the new spaceship factory.

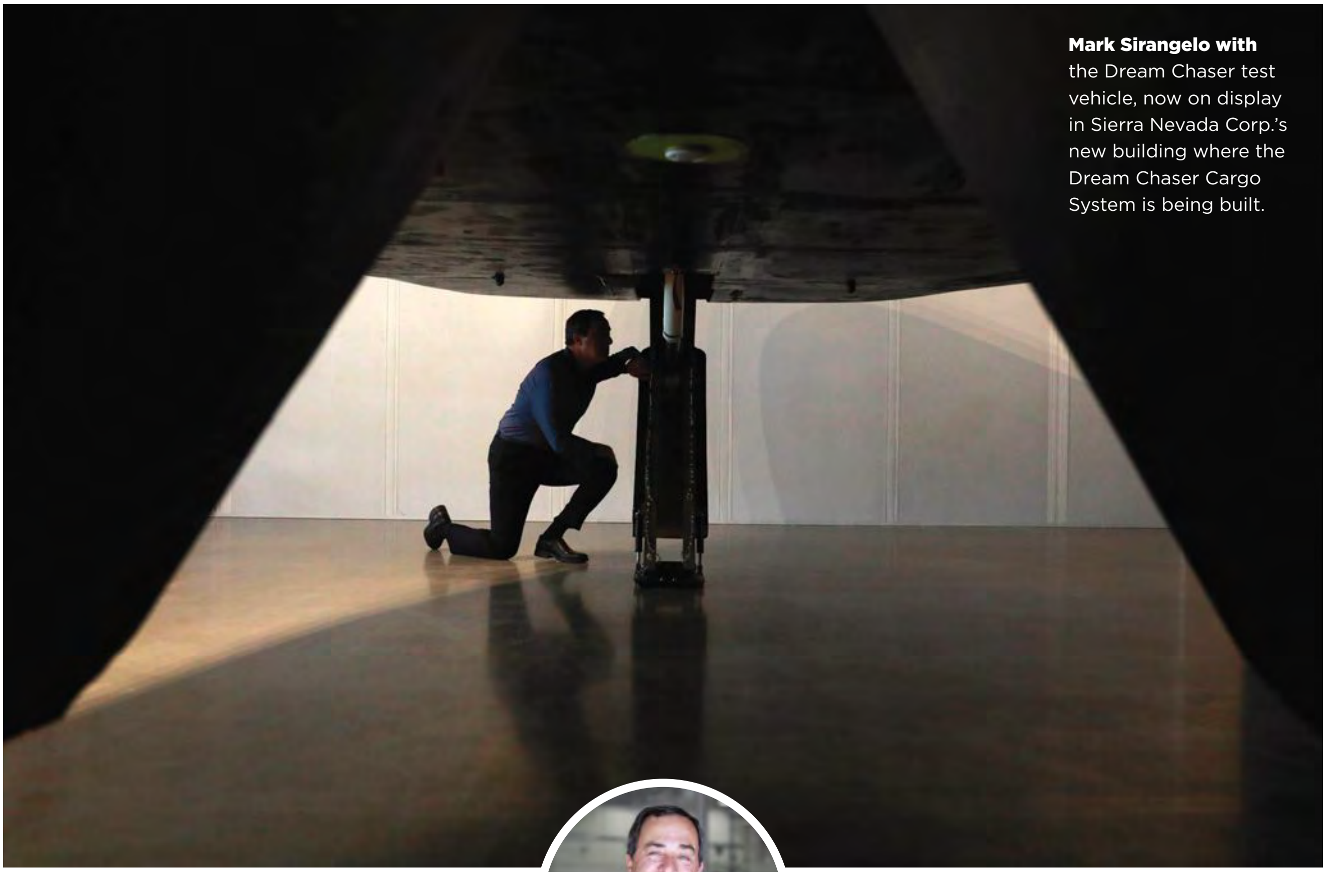
Now the first Dream Chaser Cargo System, as this version is known, complete with an external module that will burn up on re-entry, must be readied for the 2020 cargo mission to the space station. And it's getting company. It's about to be built on a brand-new manufacturing floor side by side with SNC's pitch for the Lunar Orbital Platform-Gateway, the space station planned as a staging area for exploring the moon.

"So the story has a happy ending, as you know," Sirangelo says. He'd been at the helm of the Dream Chaser project since Day 1.

Lesson 5: Go global

The test vehicle now having completed two free-flight helicopter drop tests from over 12,000 feet, Dream Chaser's next mission is going to space — a full-fledged cargo resupply trip set for 2020 in the new ship.

Engineers at NASA Langley helped analyze Dream Chaser's thermal properties, putting 10-inch-long cast ceramic models through wind tunnel tests simulating ascent and re-entry. SNC predicts Dream Chaser will reach 1.5 G's, or 1.5 times the force of gravity, on re-entry, "considerably less than the 4-8 G's for existing capsule-based systems."



Mark Sirangelo with the Dream Chaser test vehicle, now on display in Sierra Nevada Corp.'s new building where the Dream Chaser Cargo System is being built.

Alyson McClaran

Martin, the engineer at Langley, has moved on to other programs, but he's still rooting for another version of Dream Chaser, one that will carry people to space and back someday.

"That dream has never gone away," he assures me. "Cargo is just a stepping stone to get there."

A former space shuttle pilot and shuttle mission commander, Steve Lindsey now leads all of Dream Chaser's design, development, testing and operations for SNC.

Speaking with reporters at the Space Symposium, including Aerospace America's Tom Risen, Lindsey explained why the cargo version doesn't have windows — namely to save 400 pounds and thus carry 400 more pounds of cargo; and how Dream Chaser's non-toxic propulsion system — he couldn't elaborate on the fuels aside from "nothing exotic" — make it a candidate to land anywhere in the world that a 737 airliner can.

"There's a lot of international interest in landing outside the U.S. with this," Lindsey says — such as if a country wants to do a mission but doesn't have the resources to get a whole space program up and running.

"We could offer them a turn-key mission where we launch from wherever, do whatever mission they want, and then land in their country, for roughly the price of a satellite launch," Lindsey says.

"We submitted, and this whole long, dark period shut off, and we won the biggest of contracts. And all of our craziness began to look not so crazy."

— Mark Sirangelo, departing head of Sierra Nevada's Space Systems Division

"If you think about that, now you open up the whole world."

Meanwhile the reality of a cargo Dream Chaser going into service in 2020 gave rise to an idea that is beginning to involve dozens of countries in space research for the first time.

"It dawned on us," Sirangelo says, "we own the vehicle." NASA wants six resupply missions, and a single Dream Chaser is being designed for 15 or more. NASA doesn't have to be the only customer.

SNC in 2016 reached a first-of-its kind agreement with the United Nations' Office of Outer Space Affairs for a science mission that will carry 20 to 30 experiments for countries that have never had a presence in space. The current plan is to launch aboard a Dream Chaser flight by the mid-2020s.

Dream Chaser — it's a good name. The name goes back to SpaceDev. "In all truth, we had thought we might change it at some point, because it was sort of a fun name. … Don't we all want to chase our dreams?" Sirangelo says.

"But at the end of the day, what we really are doing is showing that maybe the impossible is possible. That you could take this idea and a couple of dozen people in a garage in California and say, 'We want to build a replacement for the space shuttle.'

"And then go do it." ★

MISSION-CRITICA

The U.S. Defense Department relies on data from civil, military and allied weather satellites to develop forecasts for troops carrying out a range of operations.

U.S. Defense Department

AL FORECASTING

The U.S. Air Force is in the midst of upending its decades-old approach of gathering life-and-death weather data for commanders and troops with limousine-sized satellites. Smaller is in for this next generation, and privately operated constellations could play a prominent role too. Debra Werner went looking for what could come after the Defense Meteorological Satellite Program.

BY DEBRA WERNER | werner.debra@gmail.com

The U.S. Air Force launched the DMSP-19 polar-orbiting satellite in 2014, confident that it would stream temperature and humidity data well beyond its planned five-year-minimum lifespan. Most of the satellite's predecessors in the Defense Meteorological Satellite Program had exceeded their design lives since the 1970s. If anything did go wrong, the Air Force had a backup, DMSP-20, in storage and ready for launching in a pinch.

These polar orbiters are especially important to the far-flung U.S. military, because they amass global coverage twice a day as they circle from pole to pole. They also deliver finer resolution imagery and data than is possible from geosynchronous satellites orbiting thousands of kilometers in space, and they watch the high latitudes that those geosynchronous satellites cannot see. From this and civilian data, the Air Force creates forecasts for the Army and its own forces, while sharing DMSP data with the Navy, which has its own forecasters.

Enter Congress, where lawmakers knew that the Air Force would sooner or later be requesting hundreds of millions of dollars to replace the DMSP satellites with modern versions. The thinking went: Why sink $40 million a year to keep DMSP-20 and its 1990s-era technology in climate-controlled storage? Congress zeroed funding for DMSP in 2016, including the storage plan, and the legislation instructed the Air Force to shut down the program.

It only took a few months for things to go terribly wrong. DMSP-19 stopped responding to operators due to a power failure within its command and control system. The Air Force rejected the idea of going back to Congress to request funding to launch DMSP-20, because some officials feared that the satellite might experience the same kind of power failure. Today, DMSP-20 is a museum piece, and the U.S. military is left to rely on DMSP-17 launched in 2006 and DMSP-18 launched in 2009.

The loss of DMSP-19 injected a sense of urgency into deliberations over what should come after the DMSP constellation, and it underscored the risk of relying so heavily on the fate of a single satellite. Instead of buying modern versions of the limousine-sized DMSP satellites, the Air Force will disaggregate the next weather sensors onto a handful of smaller satellites. These satellites won't meet all of the military's weather needs, so the Air Force is weighing a role for commercially operated weather satellites, plus the help of allies, as always.

Unlike NOAA, which spends billions of dollars annually on weather satellites, the Air Force plans to spend just under $800 million to $1 billion over five years on these new weather satellites and sensors.

Being realistic

As important as the DMSP satellites have been, they have never been the whole forecasting story for the U.S. military. Much of the time, the military is happy to rely on data from NOAA satellites and those operated by U.S. allies. But when special operators are preparing to come ashore under cover of night, for instance, they need exceptional detail about tides and atmospheric conditions, and they need the information to come through a secure network that won't break down even momentarily.

"The National Weather Service has great stuff, but they are not built for wartime," says retired Adm. David Titley, who was the Navy's top oceanographer and later NOAA's chief operating officer. The bottom line is "the Department of Defense weather capability absolutely, positively has to work when somebody is shooting at you."

If money were not an issue, the Defense Department would run an entire weather forecasting apparatus, from sensors in orbit to networks to move the data around. "But we have to be realistic," says Ralph Stoffler, the Air Force director of weather and deputy chief of staff for operations, who oversees weather policies, plans and programs for the Army and Air Force. The Naval Meteorology and Oceanography Command at Stennis Space Center in Mississippi performs a similar role for the Navy.

"A combination of a core capability that DoD owns with leveraging access to information provided by key allies and coalition partners is the way DoD is meeting its needs of assurance to the data and reducing costs at the same time," Stoffler says.

"THE NATIONAL WEATHER SERVICE HAS GREAT STUFF, BUT THEY ARE NOT BUILT FOR WARTIME." THE BOTTOM LINE IS "THE DEPARTMENT OF DEFENSE WEATHER CAPABILITY ABSOLUTELY, POSITIVELY HAS TO WORK WHEN SOMEBODY IS SHOOTING AT YOU." — Retired Adm. David Titley

For now, the DMSP constellation remains that core capability. These satellites cross the equator at different locations on each orbit, but always in the early morning on the descending side of their orbits. The satellites gather atmospheric temperature and humidity observations, the fuel for weather models. Forecasters pair this DMSP data with observations from NOAA and Eumetsat, the European Organization for the Exploitation of Meteorological Satellites. Eumetsat satellites cross the equator in the midmorning and NOAA polar orbiters cross the equator in the afternoon. Those three orbits combined supply the vast majority of data for numerical weather models.

With DMSP's end now inevitable, the Defense Department has drafted a two-pronged replacement plan. For the near-term, the Air Force Operationally Responsive Space Office at Kirtland Air Force Base in New Mexico, which changed its name in December to the Space Rapid Capabilities Office, is soliciting bids for a small polar-orbiting satellite. If all goes as planned, the Air Force will spend about $189 million to build, launch and operate this satellite, to be called Operationally Responsive Space-8. It must fill "U.S. Strategic Command's urgent need for Space-Based Environmental Monitoring capability gaps for cloud characterization and theater weather imagery" and "provide weather data support to U.S. Central Command and U.S. Pacific Command," Col. Shahnaz Punjani, Space Rapid Capabilities Office director, said in a written response to questions.

ORS-8 would be a stopgap, a low-cost experimental satellite without extensive backup systems to keep it working for many years. Longer term, the Air Force is planning to buy two kinds of satellites. Ball Aerospace is developing Weather System Follow-on Microwave, a satellite to monitor ocean wind speed and direction, tropical cyclone intensity and energetic charged particles under a $93.7 million contract awarded in November 2017. The fixed-price contract includes options for two low Earth orbit satellites.

Plans are also in the works to buy at least one imaging satellite that would observe clouds and monitor weather around the world for at least five years. With an estimated $450 million on the line, companies are jockeying for position ahead of the competition to build a single Weather System Follow-on Electro Optical Infrared satellite, although the contract may include an option for a second satellite, according to the request for information published last November.

For WSF-E, Harris Corp. thinks an updated version of its Advanced Very High Resolution Radiometer would be the best choice for its sensor. When the Air Force was looking for technologies for future weather satellites in 2013, it gave Harris $12.7 million to update the design of AVHRR, a cross-track scanner that has flown on 19 NOAA Polar Orbiting Environmental Satellites since 1978. The updated version, called the Enhanced AVHRR, would reveal cloud cover and monitor temperature. It would do this by measuring heat reflected by Earth's surface, bodies of water and cloud tops with a 20-centimeter telescope that scans from horizon to horizon, measuring visible near infrared and thermal infrared energy across nine channels covering wavelengths from 0.5 to 11.8 micrometers. The result would be imagery with 1-kilometer resolution. The sensor's onboard passive radiant cooler must keep the thermal infrared detectors at 105 degrees Kelvin. In flight,

▲ **The U.S. Air Force** plans to put weather sensors on a group of smaller satellites rather than buy modern versions of the Defense Meteorological Satellite Program satellites, above.

Lockheed Martin

Enhanced AVHRR would calibrate itself with a warm calibration target onboard and a view of deep space.

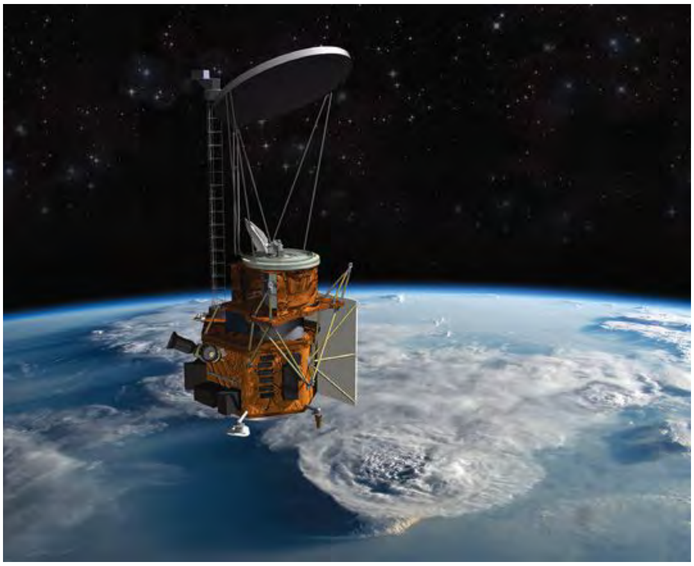
"It's affordable, small and flexible," says Eric Webster, Harris Environmental Solutions vice president for business development. Since AVHRR is roughly the size of a roll-on suitcase, the Air Force could fly it alone on a small military satellite or send it into orbit as a hosted payload on a commercial satellite, Webster says.

Raytheon thinks its Visible Infrared Imaging Radiometer Suite, or VIIRS (pronounced VEERZ), first flown on the NASA-NOAA Polar orbiting Partnership satellite in 2011, would be a better choice. VIIRS gathers sea, land and atmospheric imagery and data with a rotating telescope that captures light from Earth in 22 spectral bands. Other optics then direct the light into the sensor's aft optics assembly and through a beam-splitter, which sends visible and infrared wavelengths to four focal planes cooled to cryogenic temperatures to ensure sensitivity.

VIIRS was conceived as part of the National Polar-orbiting Operational Environmental Satellite System, or NPOESS, program, a failed effort to develop a single constellation of polar orbiters for military and civilian forecasters. NPOESS was started in 1994 by the Clinton administration and backed by Congress as a plan to save money. Instead, costs spiraled out of control due to the complexity and sheer number of instruments on each satellite, prompting the Obama administration to cancel NPOESS in 2010.

From its start in NPOESS, VIIRS was focused on meeting NASA, NOAA and Defense Department requirements. VIIRS is particularly useful for military operations because it can reveal fog over the ocean, pinpoint ships traveling at night and show airborne dust against a desert backdrop, says Shawn Cochran, acting chief scientist for Raytheon's Joint Polar Satellite System Common Ground System. The Joint Polar Satellite System is a constellation established after the collapse of NPOESS. The Defense Department already receives VIIRS data from the NASA-NOAA Suomi NPP satellite and

Measuring ocean winds



The U.S. military sees a special need to predict wind speed and direction, given the impact those factors can have on vessels, aircraft and other mission-critical factors.

Under a contract awarded by the U.S. Air Force last November, Ball Aerospace of Colorado aims to prove that the company can provide the wind capability affordably by adapting satellite technologies flown on civilian spacecraft.

If Ball gets the greenlight to start fabrication, it will deliver up to two Weather System Follow-on-Microwave, or WSF-M, satellites, including a wind-sensing microwave instrument for each and installation of a charged particle sensor supplied by the Air Force as a hosted payload for each. The total award if the Air Force exercises options for two satellites is $457.9 million.

Ball plans to customize each satellite on the Ball Configurable Platform, the company's standardized design for a satellite frame or bus. This design also forms the core of the NASA-NOAA Suomi National Polar-orbiting Partnership satellite launched in 2011 and the NOAA-20 weather satellite (formerly Joint Polar Satellite System-1) launched in November.

The Microwave Imagers will be modified versions of the Global Precipitation Measurement Microwave Imager, or GMI, which rides on a NASA-JAXA (Japan Aerospace Exploration Agency) satellite launched in 2014.

For the military application, Ball is enlarging GMI's rapidly rotating main reflector by about 50 percent. Making this flat antenna larger will improve its spatial resolution. Ball also is eliminating two higher-frequency channels and adding digital polarimetric receivers to three channels. These receivers pick up microwaves in two orientations, the vertical and horizontal. "It's like putting on a pair of polarized sunglasses," says Ball's Cory Springer, director for weather and environment. With that information, meteorologists can derive wind speed and direction. With the two instruments, WSF-M will measure ocean surface winds, tropical cyclone intensity and energetic charged particles that can interfere with environmental sensors. In addition, WSF-M will offer the Air Force a backup method for observing sea ice and measuring, for example, how thick it is, a task currently performed by the Air Force's Defense Meteorological Satellite Program satellites. — Debra Werner

Weather data flows from allies' satellites

The U.S. Defense Department relies on its Defense Meteorological Satellite Program satellites and data from allies for its weather forecasts.

Sources: NOAA, European Space Agency, Eumetsat

NOAA-20 launched in November 2017. If the military wants VIIRS to fly in its preferred early morning orbit, it could buy the instrument from Raytheon's hot production line, says Wallis Laughrey, Raytheon Space Systems vice president.

Dealing with a gap

There is a risk that the remaining DMSP satellites could fail before anything new flies, since the youngest one is nearly 9 years old. "If all goes well, ORS-8 will launch in time," says Stoffler, the retired Air Force colonel who oversees weather matters for the Army and Air Force. "If ORS-8 doesn't come online when we expect it to, there could be a gap that we have to deal with. One of the ways of dealing with that gap is commercial data."

"While the military may continue to build and control some weather satellites for security reasons, much lower-cost weather data from the commercial sector could be cost-effective for the majority of weather forecasting needs."

— retired Navy Adm. Conrad Lautenbacher, former NOAA administrator who leads GeoOptics

So, the Air Force is investigating a role for commercial satellites in plugging the gap. A handful of U.S. companies, including Spire of San Francisco, Planet-IQ of Colorado, and GeoOptics of California, are building small satellites with a variety of sensors to gather weather data for the Air Force, NOAA and commercial customers. Spire, alone, has launched hundreds of the radio occultation nanosatellites. These monitor temperature and water vapor by measuring how the atmosphere refracts transmissions from GPS satellites as they pass behind Earth from the vantage point of the spacecraft, the technique proved by 70-kilogram satellites in the U.S.-Taiwanese COSMIC constellation launched in 2006. COSMIC stands for Constellation Observing System for Meteorology Ionosphere and Climate.

"The more complex and larger the satellite, the longer it takes to design, build, and launch," says retired Navy Adm. Conrad Lautenbacher, a former NOAA administrator who leads GeoOptics. "While certainly the military may continue to build and control some weather satellites for security reasons, much lower-cost commercial weather data from the commercial sector could be cost-effective for the majority of weather forecasting needs."

Congress is encouraging the Defense Department to test the idea that commercial weather sensors could supply data at a fraction of the cost of military satellites. In 2017 and 2018, Congress gave the Defense Department money to start buying commercial weather data to assess its impact on weather models. That trial runs until October but Stoffler already sees promise in miniature satellites and commercial data sources.

DMSP-20

The Defense Meteorological Satellite Program-20 satellite is on display at the U.S. Air Force Space and Missile Systems Center at Los Angeles Air Force Base.

"One of the things we've been trying to do, frankly, is get away from large satellites," he says. "As you saw with DMSP-19, if one small component fails, you lose access to that particular satellite, which means all seven sensors are lost immediately. As we go down the path of microsatellites, cubesats and disaggregation, we'll be able to maintain a good secure constellation and replacing individual satellites should be considerably less expensive." ★

U.S. weighs solutions for geosynchronous gap

IN A COUPLE OF YEARS, the U.S. military will face another hole in its weather satellite coverage, with no American or allied satellites in geostationary orbit over the U.S. Central Command area of responsibility, which spans from the Middle East to Central and South Asia, including Iraq and Afghanistan. U.S. civil geostationary satellites focus primarily on the continental United States and surrounding oceans. Europe, which has been operating satellites over the Middle East and sharing data with the U.S. military, plans to stop covering the region when its current satellite Meteosat 8 runs out of fuel in late 2020 or early 2021.

At that point, the United Nations' World Meteorological Organization will turn to Russian and Chinese geostationary weather satellites for information. That's not an option for the Defense Department. Congress directed the Defense Department in a report accompanying the 2016 National Defense Authorization Act not to rely on Russian or Chinese weather satellite data, which military experts call a no-brainer.

"We can't put ourselves in a position of being hostage," says retired U.S. Navy Adm. David Titley, a professor of meteorology at Pennsylvania State University and the founding director of its Center for Solutions to Weather and Climate Risk. "It would not be at all surprising if a [Russian or Chinese] satellite had technical difficulties when the Defense Department needed it the most."

Instead, the Pentagon might borrow one of NOAA's backup geostationary weather satellites or look for commercial data sources. "Most of the commercial companies recognize that our area of interest is over the U.S. Central Command area of responsibility," says Ralph Stoffler, the Air Force director of weather and deputy chief of staff for operations, who oversees weather policies, plans and programs for the Army and Air Force. "I believe even if we have a perceived gap, the commercial viability will help us cover that."

— Debra Werner

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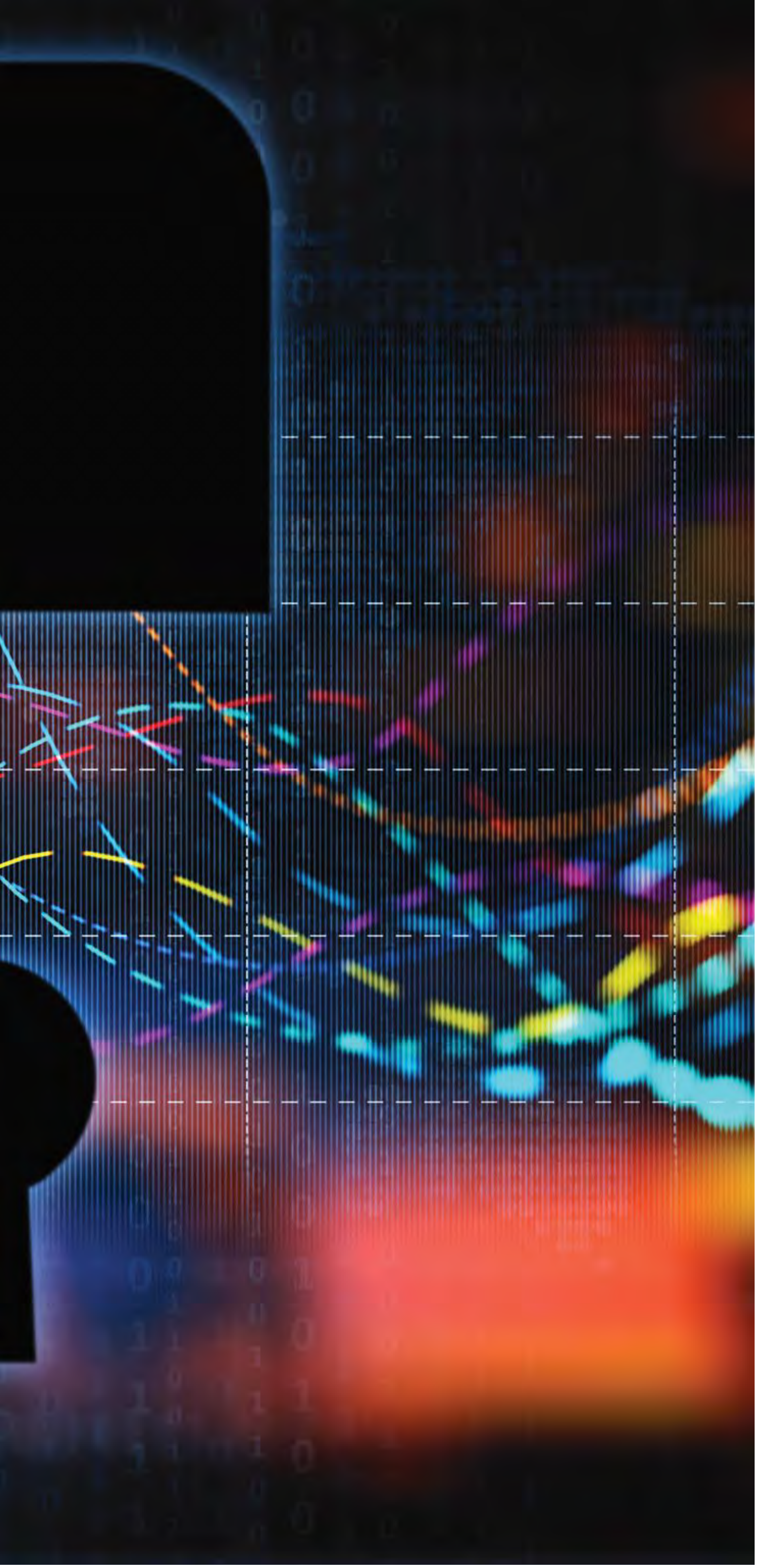
OPINION

ALL ABOARD THE BLOCKCHAIN TRAIN

A digital transformation is underway in the aerospace industry toward blockchain information technology, a secure method of storing and sharing high volumes of data. Companies that want to compete effectively in a transformed industry should embrace the technology quickly but in a systematic way. Blockchain researcher and contractor Sam Adhikari explains.



As manufacturing, operations and maintenance become increasingly complex in the aviation and space sectors, a digital transformation is underway in the aerospace industry toward blockchain technology, an open source digital architecture for related data and their histories. The technology's roots can be traced to the late 1990s, when software designers began conceiving of online cryptocurrencies, the most famous of which is bitcoin. The term blockchain refers to the fact that data is stored in numerous blocks, typically on multiple servers, sometimes on the public internet, but, in the aerospace world, increasingly within a private intranet of authorized users. The data is refreshed automatically at a frequency set by the network's designers. MRO, short for maintenance, repair and overhaul, has been a catalyst for blockchain, but the possible aerospace applications are unlimited, ranging from MRO to collaborative design and simulations, to supply chain management, flight records, airline e-ticketing and loyalty programs, and protection against GPS spoofing.

A blockchain network registers aerospace components in a digital ledger accompanied by relevant data. Consider an example from MRO in aviation: Suppose a part malfunctions or big data predictive analytics points to this part as the root cause of a failure. Maintenance technicians can extract relevant information from the blockchain ledger and take appropriate corrective measures. In fact, all relevant parties can be authorized to access this ledger, which means the information is stored seamlessly across manufacturers, airlines and MRO service providers. This enables all MRO stakeholders to view documentation on the entire maintenance cycle of a single component.

It does not stop there. A blockchain network can include a feature called smart contracts, which are agreements between artificial intelligence software and its human programmers defining the diagnostic and corrective measures that should be taken automatically when a set of specific factors are present in the blockchain ledgers. In combination with big data analytics, blockchain and smart contracts are transforming the civilian and military aerospace industry.

Blockchain technology is a natural match for the civilian and defense aerospace industry.

But several issues need to be kept in mind. While blockchain is real and promise of the future, experts continue to mature it. The return on investment must bring business value and integrate with other data and a company's information technology governance document. A successful, enterprise-level digital transformation will have several components, and blockchain is just one of them. It is better to embrace this technology early and make sure legacy systems become compatible with this technology that provides promise for transparency, audit trail and strong security.

Advantage: Security

That said, the strengths are numerous. A blockchain network is virtually immutable, meaning the data residing within it cannot be changed without the knowledge of the collaborative parties. Even if a hacker managed to penetrate one block, the overall integrity of the data would remain intact, because the data is distributed among thousands of blocks containing cryptographically protected ledgers. These blocks are typically spread among multiple servers, with the blocks "chained" together securely with the latest cybersecurity technologies. The result is an incorruptible, distributed digital ledger that records virtually everything of value. The data in the blocks is digitally sealed with the cryptography, making it almost impossible to alter or manipulate. The blockchain network intermittently verifies the data, so that any outlying data would be detected quickly and rooted out. The verified data is visible to every node in the distributed network, and that transparency is extremely beneficial when different companies work together in the realm of aviation and space operations.

Easy auditing

Digital transactions forming the basic building blocks in a blockchain implementation can be tracked and audited all along the supply chain to MRO services with cyberconfidence. The data and business rules validation can be automated, minimizing need for manual reconciliation and exception handling. This reduces cost immensely. Because of greater transparency and visibility across the supply chain, manufacturing, after market, and maintenance operations, the overall aerospace operations improve immensely. Manufacturing, operational, and regulatory reports are detailed, integrated, verifiable, and immutable because of the decentralized blockchain technology. The digital ledger technology guarantees against single points of failure. Computer programs can be embedded in the blockchain network to generate smart contracts automating supply chain, manufacturing, and maintenance operational decision-making.

▲ **Companies involved** in maintenance, repair and overhaul of aircraft say blockchain could track aircraft parts from manufacture through repairs and replacement.

Use cases

Complex design of space and aviation systems is facilitated by the blockchain digital transformation technologies because many entities can collaborate closely during product development. Because of the built-in trust in the immutable data technology, shared blockchain ledgers can achieve rapid consensus among many participating parties. This is a fascinating advance over the current collaborative systems that lack historical version management and immutable record keeping for future reference in case of design failures and system malfunctions. In blockchain technology the distributed digital ledger leaves behind a transparent version and unchangeable history of original design, changes made, simulation data, test results, and a certification of record covering the sources of all components and the overall and subsystems.

Design-to-manufacturing time is reduced immensely and the product quality is augmented due to trust and transparency. In case of manufacturing disruption, all the involved parties can view the digitally secured distributed digital ledger and make the corrective decision at a lightning speed and accuracy.

Airbus

In computational fluid dynamics, CFD , aerospace engineering entities are using blockchain to work collaboratively to reduce aviation-related drag and improve fuel efficieny, rocket payload shrouds and more. CFD simulation results are kept in chained blocks over the distributed networks for artificial intelligence-based adaptive and reinforced learning. Optimizing instruction codes in a blockchain development environment can automatically generate the best results.

In MRO implementations, the reliability, cost reduction and time to recover are dramatically changing the aviation and space industry. The biggest benefit comes in the form of an enhanced, forward-looking knowledge base that forms the biggest component of artificial intelligence-driven, smart, next generation aerospace and defense systems.

Then there is GPS spoofing. This is a cyberintrusion technique that sends fake signals to systems that use GPS data for navigation. It is difficult to detect these false signals, creating a risk that aircraft drift off course into dangerous environments or perhaps even collide. A blocked or jammed GPS satellite signal is relatively easy to detect almost instantaneously by trigger alarms built into the system. Aerospace companies are using blockchain digital ledgers for maintaining backup records of GPS-related information in cases where anti-spoofing systems indicate the incoming GPS data is manipulated and unreliable.

Aviation and flight records are increasingly kept in distributed immutable blockchain ledgers to increase aviation safety. Aviation-related anomaly data is fed into predictive analytics tools to avoid collisions and other disasters. The data comes from various heterogeneous networks and increasingly are kept in blockchain ledgers to make sure they are not manipulated in a central location. In many cases, the blockchain ledgers are used for back-up and source-of-data validation against cyberspoofing and other intrusions.

Aviation and space companies using blockchain technology

Lufthansa Industry Solutions has started the Blockchain for Aviation (BC4A) initiative to bring together software developers, manufacturers, MRO service providers, logistics providers and regulators, according to the Lufthansa Industry Solutions website. In November 2017, General Electric filed multiple patents to implement systems for tracking flight records, aircraft maintenance records, parts acquisition, and other information related to an aircraft's operational lifecycle. IATA reportedly is in the process of evaluating blockchain digital ledgers for a payment network for aviation that could save close to $8 billion for airlines. Airbus wants to leverage blockchain technology in supply chain tracking and purchasing, according to its website. The company formed a blockchain working group to search and deploy blockchain applications. In December 2017, Boeing filed a patent on blockchain to implement a prevention mechanism in case of GPS spoofing events.

At the end of the day, the blockchain digital transformation is inevitable because of the security, immutable record keeping, and collaboration required to bring complex aerospace systems to market and operate them efficiently and safely. According to Accenture, blockchain is set to disrupt the aviation industry within the next one or two years. The technology would lower cost, increase reliability and improve convenience. Those in the industry should seize the day when it comes to the blockchain digital transformation. ★

Sam Adhikari is the vice president for operations and research at Sysoft Corp., a big-data analytics company headquartered in Whitehouse Station, New Jersey. He is also a researcher at Stanford University and a certified information systems auditor, CISA. Adhikari is an associate fellow of AIAA and the chair of the institute's Aerospace Cybersecurity Working Group. He is a past chair of the AIAA Software Technical Committee and currently a member of the Intelligent Systems Technical Committee.

sadhikari@sysoft.com and sadhikar@stanford.edu

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DIRECTORY

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

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

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

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

Calendar

Notes About the Calendar

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2018			
3–6 Jul†	ICNPAA-2018 - Mathematical Problems in Engineering, Aerospace and Sciences	Yerevan, Armenia (www.icnpaa.com)	
7–8 Jul	Emerging Concepts in High Speed Air-Breathing Propulsion Course	Cincinnati, OH	
7–8 Jul	Fundamentals of Gas Turbine Engine Aerothermodynamics, Performance, and Systems Integration Course	Cincinnati, OH	
7–8 Jul	Liquid Atomization, Spray, and Fuel Injection in Aircraft Gas Turbine Engines Course	Cincinnati, OH	
7–8 Jul	Liquid Rocket Engines: Fundamentals, Green Propellants, and Emerging Technologies Course	Cincinnati, OH	
7–8 Jul	Propulsion of Flapping-wing Micro Air Vehicles (FMAVS) Course	Cincinnati, OH	
7–8 Jul	AIAA Complex Aerospace Systems Exchange (CASE) Workshop	Cincinnati, OH	
7–8 Jul	4th Propulsion Aerodynamics Workshop	Cincinnati, OH	
8 Jul	Enabling Technologies and Analysis Methods for More-, Hybrid-, and All-Electric Aircraft Course	Cincinnati, OH	
9–11 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – Joint Propulsion Conference – International Energy Conversion Engineering Conference	Cincinnati, OH	4 Jan 18
12–13 Jul	AIAA/IEEE Electric Aircraft Technologies Symposium	Cincinnati, OH (aiaa.org/eats)	15 Feb 18
5–7 Aug†	North Carolina Drone Summit and Flight Expo (NC Drone SAFE)	Greensboro, NC (www.ncdronesummit.com/)	
19–23 Aug†	2018 AAS/AIAA Astrodynamics Specialist Conference	Snowbird, UT (www.space-flight.org)	
6–7 Sep†	22nd Workshop of the CEAS-ASC: Future Aircraft Design and Noise Impact	Amsterdam, The Netherlands (nlr.org/ceas-asc-2018-workshop)	
15–16 Sep	Integrating Program Management and Systems Engineering Course	Orlando, FL	
16 Sep	Advancing Propulsion for Hypersonic Flight Course	Orlando, FL	
16 Sep	Space Standards and Architectures Course	Orlando, FL	
17–19 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition) Featuring: – Complex Aerospace Systems Exchange – International Space Planes and Hypersonic Systems and Technologies Conference	Orlando, FL	8 Feb 18
1–5 Oct†	69th International Astronautical Congress	Bremen, Germany	
10–11 Oct†	International Symposium for Personal and Commercial Spaceflight	Las Cruces, NM	
5–8 Nov†	ITC 2018	Glendale, AZ (www.telemetry.org)	

AIAA Continuing Education offerings

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

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2019			
7 Jan	AIAA Associate Fellows Awards Ceremony and Dinner	San Diego, CA	
7–11 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition)	San Diego, CA	11 Jun 18
13–17 Jan†	29th AAS/AIAA Space Flight Mechanics Meeting	Ka'anapali, HI	14 Sep 18
28–31 Jan†	65th Reliability and Maintainability Symposium (RAMS 2019)	Orlando, FL (www.rams.org)	
2–9 Mar†	2019 IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
3–5 Apr†	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (www.eurognc19.polimi.it)	
7–9 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum)	Laurel, MD	
14 May	AIAA Fellows Dinner	Crystal City, VA	
15 May	AIAA Aerospace Spotlight Awards Gala	Washington, DC	
20–23 May†	25th AIAA/CEAS Aeroacoustics Conference (Aeroacoustics 2019)	Delft, The Netherlands	1 Oct 18
27–29 May†	26th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (www.elektropribor.spb.ru/icins2019/en)	
10–13 Jun†	18th International Forum on Aeroelasticity and Structural Dynamics	Savannah, GA (http://ifasd2019.utcdayton.com)	
12–14 Jun†	The Sixth International Conference on Tethers in Space (TiS2019)	Madrid Spain (http://eventos.uc3m.es/go/TiS2019)	
17–21 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition)	Dallas, TX	
19–23 Aug	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition)	Indianapolis, IN	
21–25 Oct†	70th International Astronautical Congress	Washington, DC	

Recognizing Top Achievements - An AIAA Tradition

For over 80 years, AIAA has been committed to ensuring that aerospace professionals are recognized and celebrated for their achievements, innovations, and discoveries that make the world safer, more connected, more accessible, and more prosperous. AIAA celebrates the following individuals or teams who were recognized between February and June 2018.

Presented at the Airport Planning Design and Construction Symposium, 28 February–2 March 2018, Denver, Colorado

ACC/AIAA/AAE Jay Hollingsworth Speas Airport Award

Gerald R. Ford International Airport Authority, Grand Rapids, Michigan
Accepting the Award: Roy D. Hawkins, R.L.A., Planning Engineer, and Casey Ries, P.E., Redondo Beach, California
For an innovative and sustainable stormwater and deicing treatment system that provides an example to other airports in meeting operational, regulatory and community needs.
Nominated by: Bryan C. Wagner, Wayne County Airport Authority

Presented at the 54th Aerospace Spotlight Awards Gala 2 May 2018, Washington, D.C.

AIAA Distinguished Service Award

Mary L. Snitch
Senior Manager, Global S&T Engagement
Lockheed Martin Corporation
For two decades of significant contributions to AIAA, ranging from tireless advocacy for funding, to national and international influence on aerospace policy, to substantial impact on organizational and management improvements.
Nominated by: Robie Samanta Roy, Lockheed Martin Corporation

AIAA Public Service Award

George C. Nield
Associate Administrator
Federal Aviation Administration (retired)
For his dedicated service to our nation's space programs, and his ongoing efforts to encourage, facilitate, and promote commercial space transportation.
Nominated by: Pat Hynes, New Mexico Space Grant Consortium

AIAA Lawrence Sperry Award

Michael D. West
Engineering Manager
Australian Department of Defence
For significant contributions to AIAA and the Australian aerospace sector through policy, education, and innovative scientific research activities.
Nominated by: Arnab Dasgupta, AIAA Sydney Australia Section

AIAA Reed Aeronautics Award

Mark Drela
Professor
Massachusetts Institute of Technology
For unique sustained contributions to a broad range of path-breaking aircraft designs and for development of widely used aircraft design software.
Nominated by: Robert Liebeck, The Boeing Company

AIAA Goddard Astronautics Award

Gwynne E. Shotwell
President and Chief Operating Officer
SpaceX
For extraordinary leadership and vision in the field of space exploration and groundbreaking contributions to aerospace technology.
Nominated by: Timothy Hughes, SpaceX

Daniel Guggenheim Medal

Paul M. Bevilaqua
Manager, Advanced Development Programs
Lockheed Martin Corporation (retired)
For the conception and demonstration of the multi-cycle propulsion system and other technologies enabling the production of the F-35 supersonic V/STOL Strike Fighters.
Nominated by: Steven Weiner, Sikorsky Aircraft

Presented at the AIAA AVIATION Forum, 25–29 June 2018, Atlanta, Georgia

AIAA/SAE William Littlewood Memorial Lecture

Highly Efficient Civil Aviation Now via Operations—AAR & Challenges

Raj Nangia
Honorary Research Fellow
University of Bristol
Bristol, United Kingdom

AIAA Aeroacoustics Award

Tim Colonius
Frank and Ora Lee Marble Professor of Mechanical Engineering
California Institute of Technology
For outstanding contributions to theoretical and computational aeroacoustics for the prediction and control of noise and his absolute commitment to educating the next generation.

AIAA Aerodynamics Award

Kenneth C. Hall
Julian Francis Abele Professor of Mechanical Engineering and Materials Science
Duke University
For seminal contributions in the development of novel unsteady aerodynamic theories and analysis methods for internal and external flows.

AIAA Aircraft Design Award

Airbus A380 Design Team
For their work designing the unique double-deck Airbus 380, the next step in the development of very large commercial transport for long-range, high-density routes.

AIAA Fluid Dynamics Award

Helen Reed
Regents Professor in Aerospace Engineering
Texas A&M University
For lifetime achievements in the fundamental understanding, modeling, and control of boundary-layer laminar-to-turbulent transition for aerospace vehicles from subsonic to hypersonic.

AIAA Ground Testing Award

Norbert Ulbrich
Senior Aerodynamicist
Jacobs Technology, Inc.
In recognition of outstanding contributions to ground testing, balance calibration methods, and wind tunnel measurement corrections over many decades of dedicated service.

AIAA Hap Arnold Award for Excellence in Aeronautical Program Management

Jeff Babione
Vice President and General Manager, Advanced Development Programs
Lockheed Martin Aeronautics Company
For exemplary leadership and program management contributions to Lockheed Martin Aeronautics F-16, F-22 and F-35 programs.

AIAA Losey Atmospheric Sciences Award

Roland Bowles
NASA Langley Research Center (retired)
For his outstanding scholarship and leadership that has led to a better understanding and mitigation of aviation hazards (wind shear, convection-induced turbulence, and wake turbulence).

AIAA Multidisciplinary Design Optimization Award

Evin J. Cramer
Former Technical Fellow
The Boeing Company
For seminal contributions to formulation and solution of MDO problems, and for exceptional advocacy in promoting industrial adoption of MDO methods and tools.

AIAA Piper General Aviation Award

Norman Crabill
NASA Langley Research Center (retired)
For a lifetime of general aviation technical contributions and advocacy including lightning protection, weather datalink, and current work on active ride improvement.

AIAA Plasmadynamics and Lasers Award

Martin Gundersen
Lloyd F. Hunt Chair in Electrical Power Engineering and Professor of Electrical Engineering-Electrophysics, Chemical Engineering and Materials Science, and Physics and Astronomy
University of Southern California
For development of high-voltage pulse power technology, studies of non-equilibrium nanosecond pulse plasmas, and their applications for plasma assisted combustion, pollution control, quantum electronics, and biology.

AIAA Thermophysics Award

Iain D. Boyd
James E. Knott Professor of Engineering
University of Michigan
For contributions to the development and application of detailed physical models and advanced computational methods for numerical simulation of gas flows in thermochemical nonequilibrium.

Learn more about the AIAA Honors and Awards program at aiaa.org/HonorsAndAwards

Helen L. Reed Wins 2018 Yvonne C. Brill Lectureship in Aerospace Engineering

AIAA Fellow Dr. Helen L. Reed, Regents Professor at Texas A&M University, is the recipient of the third Yvonne C. Brill Lectureship in Aerospace Engineering. Reed will present her lecture, "Student Design-Build-Fly Micro- and Nano-Satellites," on 2 October, in conjunction with the National Academy of Engineering's Annual Meeting in Washington, DC.

Notably, Dr. Reed has contributed to the discipline through her Satellite Design Programs: first at Arizona State University (ASUSat Lab) and then when her Lab moved with her to Texas A&M and became AggieSat Lab. She found effective ways to create interdisciplinary teams of undergraduate and graduate students, with industry and government affiliates, to engage in design-build-fly of operational small satellites while advancing new technologies that feed into national initiatives and learning industry practices within the university environment. Involving more than 1,000 students over the years, her team has launched four small satellites with the U.S. Air Force and NASA and partnered on other projects. Her students have joined space-oriented businesses and the national laboratories.

Dr. Reed is also an acknowledged national and international expert in laminar-to-turbulent transition. Her technical expertise is reflected in comprehensive pioneering contributions that integrate perceptive discernment of the fundamental physics of transitional flows with best-in-class simulations revealing key phenomenological details. Her work has not only provided essential fundamental insight into complex fluid dynamic processes, but also strongly influenced the development of aerospace systems. As lead computational person, Dr. Reed has teamed throughout her career with experimentalists to achieve a high degree of closure between theory and experiment. She has developed stability and transition tools that include linear stability theory, nonlinear parabolized stability equations, and direct numerical simulation of the Navier-Stokes equations. Her tools have supported and validated meaningful ground and flight experiments aimed at understanding the physics of transition and maturing drag reducing technologies.

Dr. Reed also has been honored with the 2018 AIAA Fluid Dynamics Award for "lifetime achievements in the fundamental understanding, modeling, and control of boundary-layer laminar-to-turbulent transition for aerospace vehicles from subsonic to hypersonic," the 2016 American Society of Mechanical Engineers (ASME) Kate Gleason Award for "lifetime achievements in the fundamental understanding and control of boundary layer transition for high-efficiency aerospace vehicles, and in pioneering small satellite design and implementation," and the 2007 J. Leland Atwood Award for important contributions to space systems engineering and space systems design education. She holds both the title of Presidential Professor for Teaching Excellence and the Edward "Pete" Aldridge '60 Professorship at Texas A&M. As well as being an AIAA Fellow, she is also a Fellow of ASME and the American Physical Society.

AIAA, with the participation and support of NAE, created the Yvonne C. Brill Lectureship in Aerospace Engineering to honor the memory of the late, pioneering rocket scientist, AIAA Honorary Fellow and NAE Member, Yvonne C. Brill. Brill was best known for developing a revolutionary propulsion system that remains the industry standard for geostationary satellite station-keeping.

FREE LECTURE ON STUDENT DESIGN-BUILD-FLY MICRO- AND NANO-SATELLITES

AIAA Fellow Dr. Helen L. Reed will be presenting the 2018 Yvonne C. Brill Lecture in Aerospace Engineering, "Student Design-Build-Fly Micro- and Nano-Satellites," on Tuesday, 2 October 2018. This lecture will be held in conjunction with the National Academy of Engineering's Annual Meeting in Washington, D.C.

To RSVP to this free lecture or for more information about the Yvonne C. Brill Lecture in Aerospace Engineering, please contact **awards@aiaa.org.**

AIAA Shaping the Future of Aerospace

NATIONAL ACADEMY OF ENGINEERING

A Night to Remember: Jumping from Space 1.0 to Space 2.0

On 3 May, Professor Russell Boyce, director, University of New South Wales (UNSW) Canberra Space, hosted an "Intimate Cocktail Evening with the Stars of 'Mission Control'" for a select group of Australian space academics, researchers, and professional, including members from the AIAA Sydney Section. The reception was organized to welcome Charlie Duke, former NASA Apollo 16 astronaut, and Gerry Griffin, former Apollo Mission Control Flight Director and former director, NASA Johnson Center, to Canberra. The special guests had arrived in Canberra as part of a national public-speaking tour of Australia sponsored by UNSW Canberra Space, as the major partner, and also supported by the Australian National University, represented by astrophysicist Dr. Lisa Harvey-Smith. Dr. Harvey-Smith facilitated an informative and entertaining panel discussion with Boyce, Griffin, and Duke. The discussion drew out highlights from their space mission training and operations experiences to inform and entertain the audience, jumping the audience from the Space 1.0 era of the NASA Apollo program to the Space 2.0 era small satellite program currently in progress at UNSW Canberra.

(L to R) Dr. Harvey-Smith with Gerry Griffin, Charlie Duke and Russell Boyce.

Dr. Harvey-Smith inspects one of the cubesat engineering models from Dr. Boyce's small satellite space missions program at UNSW Canberra Space.

Photographs by courtesy of UNSW Canberra.

AIAA Managing Director of Products and Programs Megan Scheidt was presented with the SpaceOps Distinguished Service Medal at SpaceOps 2018 on 1 June in Marseille, France. She received the award: "In appreciation of over a decade of extraordinary contributions to the SpaceOps Organization, in particular shaping and optimizing the role of the newly established SpaceOps Secretariat." AIAA has worked with the SpaceOps organization for 14 years and Scheidt served as the first SpaceOps Secretariat and then as AIAA manager directly responsible for support to SpaceOps.

Call for Papers: Special Issue on "Multi-Core Architectures in Avionics Systems"

The *Journal of Aerospace Information Systems* (*JAIS*) intends to publish a special issue on multi-core architectures in avionics systems. With the growth of the cyber layer in aircraft and the paradigm shift from federated and distributed on-board systems architectures to Integrated Modular Avionics (IMA), there is an increasing demand on higher throughput computing architectures. This is further elevated with optimization efforts to reduce the total number of high-speed computers within an airplane to comply with space, weight, and power (SWAP) requirements and to achieve a better maintainability. Well-known platforms will not be able to satisfy the ever-increasing requirements on SWAP and processing performance. Thus, for new functionality higher performing systems must be implemented using alternative and emerging architectures. Multi-core technology, now being state of the art in standard Information & Communications Technology (ICT), seems to be the most promising path to improve computational capabilities in avionics systems. However, there are still many challenges associated with transition to multi-core architectures.

Topics of interest to this special issue aim toward a focused forum to disseminate the latest research about multi-core architectures in avionics systems. Original research papers are sought in, but not exclusive to, the following topics:

- Multi-core processors for avionics applications
- Certification of multi-core based platforms
- Model-driven development for multi-core systems
- Parallelization of multi-core applications
- ARINC 653 and multi-core
- Worst Case Execution Time (WCET) in multi-core systems
- Virtualization for multi-core avionics systems
- Quality of service (QoS) in multi-core architectures
- Mixed-criticality on multi-core architectures
- Methods and tools related to the usage of multi-core in avionics

Submissions deadline: 21 December 2018. Anticipated publication date: April 2019. Submittal guidelines can be found at: **arc.aiaa.org/loi/jais**.
Guest Editors: Umut Durak, German Aerospace Center (DLR), umut.durak@dlr.de; Falco Bapp, Karlsruhe Institute of Technology (KIT), falco.bapp@kit.edu.

New AIAA Foundation Daedalus 88 Scholarship Awarded

The inaugural AIAA Foundation Daedalus 88 Undergraduate Scholarship has been awarded to **Samuel Zorek**, who is studying for dual undergraduate degrees in Mechanical Engineering and Policy Studies at Rice University, Houston, TX.

The $10,000 scholarship is intended to promote and support student entrepreneurship in aerospace. It is funded through a generous donation by AIAA President John Langford, and will be awarded annually. In 1988, Langford and 39 fellow MIT students recreated the flight of Daedalus (the first reference in Western literature to man flying under his own initiative). The Daedalus Project ultimately set records in distance and for human-powered voyage with a 72-mile flight between the Greek islands of Crete and Santorini.

For the past two decades, the AIAA Foundation has awarded more than 750 scholarships and graduate awards to students. For more information, please go to the AIAA Foundation's scholarship website, aiaa.org/Scholarships.

Paul Park Appointed as New Editor-In-Chief of Library of Flight

On 12 June 2018, AIAA President John Langford formally appointed **Paul Park** as the new editor-in-chief of the Library of Flight book series, succeeding **Edward "Ned" Allen**. The Library of Flight encompasses a wide variety of general-interest and reference books, including case studies. Subjects include the history and economics of aerospace as well as design, development, and management of aircraft and space programs.

Mr. Park currently is an adjunct faculty member at the University of Texas at Arlington in the Mechanical and Aerospace Engineering Department, following a 40-year career as an aerospace engineer employed by Boeing, General Dynamics/Lockheed, Bell Helicopter, and Orbital ATK. He holds engineering degrees from the University of Pennsylvania, Princeton University, and Stanford University.

An ad hoc search committee was appointed by the Publications Committee chair, John Daily, to evaluate applicants for the position. Mr. Park was chosen from among an exceptional field of candidates and will serve as the second editor-in-chief for the series, following the long and productive tenure of Dr. Allen, who served as the editor beginning in 2006 when the series was officially launched.

Mr. Park's enduring interest in the history of aerospace and his commitment to education attracted him to the position. His goals for the series include encouraging more titles on recent aerospace developments, including topics such as computers in aerospace design, the space station, the Hubble telescope, and Mars rovers. He would also like to continue promoting works that cover the human history of aircraft and space program development that have always been part of the Library of Flight, including the leaders, personalities, conflicts, and key technical contributors to the industry.

Mr. Park is committed to the hard work of acquiring and developing manuscripts for the series. His long career in aerospace and his interest in educating the broader public about the industry will contribute to the continued success of the Library of Flight.

AIAA "Look Up!" Award

The AIAA "Look Up!" Award, presented at the Intel International Science and Engineering Fair (Intel ISEF), celebrates exceptional high school-level research to encourage further study in aerospace. Winners of the AIAA "Look Up!" Award receive a cash award and one year of AIAA student membership with access to all student programs. We congratulate the 2018 winners:

Frederik Dunschen (Friedensschule Munster, Munster, Germany) was awarded first place for Designing and Building a Continuously Spinning but Controllable Flying Object at this year's Intel International Science and Engineering Fair, a program of Society for Science & the Public and the world's largest international pre-college science competition.

Robert Gabriel Tacescu (Clovis North High School, Fresno, CA) won second place for his design, Safecopter: Developing a Collision Avoidance and Mapping System Based on an Array of Time-of-Flight 3D Cameras. The student designed a modular collision detection, avoidance, and mapping system that makes flying a multicopter in autonomous or tele-operated mode safe and responsive to the changing environment. The system used an array of time-of-flight 3D cameras for point cloud data with full 360° view.

Keshav Vedula (CREC Academy of Aerospace and Engineering, Windsor, CT) won third place for his research: Undulated Leading-Edge Airfoils in Low to Medium Reynolds Number Regime. The student studied airfoils with undulating leading-edges, which have been shown to improve stall characteristics in certain airflow regimes. His research project featured two NACA 2415 airfoils: a traditional design, and an experimental design with a sinusoidal leading-edge that mimics the tubercle protuberances on the leading-edge of humpback whale fins. Wind tunnel testing was conducted in the transitional regime with 3D-printed prototypes; coefficients of lift and drag were calculated for both airfoils at varying angles of attack. A numerical study using Computational Fluid Dynamics was also performed.

AIAA encourages all students to Look Up! and see their future in aerospace.

Greater Huntsville Section Celebrates Rosie the Riveter Day During Women's History Month

By Ken Philippart

The AIAA Greater Huntsville Section participated in a ceremony to honor women's contributions to winning World War II on Rosie the Riveter Day in Birmingham, AL, on 21 March. The invitation was extended on behalf of the American Rosie the Riveter Association (ARRA) and included a ribbon cutting for a Rosie the Riveter Rose Garden containing three newly-created rose bushes, *Rosa Floribunda Rosie the Riveter.* The Memorial Rose Garden project is a national campaign to plant a Rosie the Riveter Memorial Rose Garden in each congressional district in the United States by August 2020, the 75th anniversary of the end of World War II.

There were four Rosies in attendance:

• Mabel Myrick who worked in the War Department and has been an ARRA officer for more than 12 years

• Jackie Ramsbacher who worked in a factory in Mississippi sewing clothing for the military and trained as a B-29 electrician

• Mary Louise Hodges, who answered telephones for the Red Cross during the war

• Dr. Fran Carter who was a riveter working on B-29 bombers and subsequently founded the ARRA

The AIAA Greater Huntsville Section was honored to hear each Rosie relay her personal experiences from the war. The event was an especially fitting way to recognize their unsung but vital contributions to the war effort during Women's History Month.

ABOVE: Mary Louise Hodges, Mabel Myrick, Jackie Ramsbacher, and Dr. Fran Carter cut the ribbon while Leanne Messer holds a picture of the namesake rose bush, Rosa Floribunda Rosie the Riveter. Images courtesy of Lisa Philippart.

AIAA SSTC-STTC STEM Teacher Grant Program Brings Successful and Diverse Projects

John Bloomer, Space Systems Technical Committee

Since 2010, the AIAA Space Systems Technical Committee (SSTC) and Space Transportation Technical Committee (STTC) have partnered to award grants to K–12 STEM teachers through a nationwide competitive process, providing STEM resources to stimulate student imagination and confidence. For the 2017–2018 school year, three $500 grants were awarded, made possible through donations from NASA Alumni League JSC Chapter, Analytical Mechanics Associates, Inc., and San Fernando Engineers' Council. This year's winning teachers brought forward diverse projects in watershed science, robotics, and flying drones, giving students motivation and foundational skills.

Barbara Adcock, Powhatan County Public Schools, Powhatan, VA – Ms. Adcock's fourth grade students engaged in multi-day Meaningful Watershed Educational Experiences to learn about Virginia's natural resources, the Chesapeake Bay Watershed, and how what they do affects their environment. The students took part in a series of eight stations: making observations, sketches and listing the living things within a biocube placed in the forest floor or in the creek; taking part in a simulation of a water molecule's cycle through the watershed; learning to use a dichotomous key to identify native trees and plants; using maps and discussion to understand why the Chesapeake Bay watershed is important to them and why what they do impacts it; examining a soil sample using an auger, and investigating which types of soil hold more water; calculating the rate of flow of a local creek; determining the health of the creek by collecting and identifying the macro invertebrates; and examining samples of rocks and minerals mined in Virginia and determining how they are used. The students used critical thinking and problem-solving skills to delve deeper into their environment. High school students planned and supervised the stations.

Dr. LaBombard-Daniels' classes learning computer science fundamentals by programming Sphero robots.

Barbara Adcock's Powhatan County students conducting science activities.

Dr. Jennifer LaBombard-Daniels, John Kerr Elementary School, Winchester, VA – Dr. LaBombard-Daniels' K–4 students exercised three LEGO WeDo 2.0 Core robotics sets to develop and test water-run LEGO models in preparation for participation in the First LEGO League Jr. Challenge. They learned how to use a Smarthub controller together with motors and multiple sensors using programming software. The accompanying eLearning program helped teachers to become confident users of the WeDo 2.0 Core Set and thus made for a very successful EXPO. Students' hands-on activities were augmented by the WeDo 2.0 Curriculum Pack, which addresses topics in engineering, earth science, space science, and life science. The local county recognized the project's potential and extended it to all the area elementary schools.

Douglas Ferguson, Martin Sortun Elementary, Kent, WA – Mr. Ferguson's K–6 students utilized Flybrix and Parrot drone kits to learn basic programming skills, conduct science experiments using several types of drone sensors, apply the engineering design process to their work, and use mathematics learned in class to analyze and interpret recorded data. The Flybrix drone uses LEGO bricks to design and build the drone, so the engineering process here focused on the physical structure. The Parrot drone is pre-built, but fully programmable so students focused on applying block-based programming to solve flight problems and challenges. Both types of drones required learning the basics of drone flight, while also building into the more advanced capabilities representing real-world application of content they are learning in a school setting. The students got hands-on experience relevant to grade level standards in multiple areas: motion and energy transfer; programming; engineering design process; basic measurement; consideration of variables; and geometry.

Obituaries

AIAA Fellow Lukasiewicz Died in March

Julius ("Luke" or "Julek") Lukasiewicz, D.Sc. (Engineering) died on 31 March.

Lukasiewicz believed in "living life to the fullest" and did just that for every one of his 98 years, engaging with the world around him as a student, soldier, engineer, author, professor, photographer, husband, father and grandfather, and dear friend to many not only in Ottawa but all over the world.

Born in Poland in 1919, he began studying engineering at the Warsaw Polytechnic Institute in fall 1938, having scored the highest grade on the entrance exam, but his education was interrupted by the war. Lukasiewicz served in the Polish Forces in France and England, and then resumed his study of mechanical and aeronautical engineering at Imperial College in London. Unable to return to Communist-controlled Poland after the war, he and his wife chose to immigrate to Canada in 1948, where he joined the National Research Council. One of his signature achievements while at the NRC was co-designing the world's first Mach 4.5 trisonic wind tunnel. The wind tunnel continues to operate today, having completed over 50,000 tests since its inception.

From 1958 to 1968, Lukasiewicz was the Chief of the von Kármán Gas Dynamics Facility at the Arnold Engineering Development Center in Tullahoma, TN, where he supervised critical aerodynamic testing for the Mercury and Gemini manned space flights and the Apollo moon shot. In 1966 he was awarded the degree of Doctor of Science (Engineering) by the University of London on the strength of his body of work in the field of fluid mechanics. In 1968, Lukasiewicz was recruited to become the Associate Dean for Research and Graduate Studies at the College of Engineering at Virginia Tech, where he taught until 1971 when he moved back to Ottawa.

From 1971 until his retirement in 1997, he was a professor at Carleton University, where he taught mechanical and aerospace engineering and founded the groundbreaking interdisciplinary program "Technology, Society and Environment."

Lukasiewicz started taking photographs in 1932 when he was 12 years old, recording more than 75,000 images in his lifetime, the vast majority with one of his many Leica cameras. He began exhibiting his photographs in 2007 at age 88. He was also the author of countless articles and numerous books, including The Ignorance Explosion: Understanding Industrial Civilization and Experimental Methods of Hypersonics.

Continued on page 60

Continued from page 59

AIAA Associate Fellow Rivir Died in May

Dr. Richard B. Rivir, age 79, died on 3 May.

After graduating from Purdue University with a Bachelor of Science in Aeronautics and Astronautics Engineering in 1960, Dr. Rivir began his career as an aerospace engineer in the Propulsion Laboratory, Wright-Patterson AFB, OH. He earned a Master of Science in Astronautical and Aeronautical Engineering in 1968 and a Ph.D. in Astronautical and Aeronautical Engineering in 1976, both from the Ohio State University.

Throughout his career, Dr. Rivir worked in the areas of electric propulsion, plans, advanced propulsion and turbines. He also served on special projects that included the design and testing of the aerodynamics for the first Airborne Laser Laboratory and the Compressor Research Facility. Additionally, he led AFOSR's Gas Turbine Aero Thermal effort for the Propulsion Directorate for over 20 years, and was a consultant and advisor for the Department of Energy and several NASA committees for space and propulsion.

During his career, Dr. Rivir earned many awards and honors, including the S.D. Heron Award, Aero Propulsion and Power Directorate (1988 and 1995); the Outstanding Engineer and Scientist Award, Affiliate Societies Council (1999); and the 2002 AIAA Air Breathing Propulsion Award. Dr. Rivir was an AFRL Fellow and a Fellow of the American Society of Mechanical Engineers. He served as the final Chief Scientist for the Propulsion Directorate from 2010 to 2012.

AIAA Associate Fellow Coleman Died in May

Dr. Hugh W. Coleman, 71, passed away 15 May 2018.

Dr. Coleman received his B.S. in Mechanical Engineering from Mississippi State University (MSU), and his M.S. and Ph.D. in Mechanical Engineering from Stanford University. Beginning in 1978 Dr. Coleman served as Assistant, Associate, and Distinguished Professor in MSU's Mechanical Engineering Department. In 1991 he moved to the University of Alabama in Huntsville (UAH) where he served as Professor in Mechanical and Aerospace Engineering until he retired in 2011. He was a Giles Distinguished Professor at MSU and held the Eminent Scholar Chair in Propulsion at UAH for two terms.

He and Dr. W. Glenn Steel co-authored Experimentation, Validation, and Uncertainty Analysis for Engineers (4th Edition, 2018) and conducted more than 100 related workshops to a range of national and international corporate and governmental offices. He is also the co-author of Mathematics for Mechanical Engineers (2000) and author and co-author of numerous journal articles, technical papers, and book chapters. He is an American Society of Mechanical Engineers Fellow and an AIAA Associate Fellow.

AIAA Fellow Bird Died in May

Professor Graeme Austin Bird died on 26 May at age 88.

Professor Bird was an internationally renowned Australian scientist and aeronautical engineer whose 60-year plus contributions have revolutionized the field of rarefied gas dynamics. He pioneered the Direct Simulation Monte Carlo (DSMC) Method, a gas flow simulation technique that became the principal tool for solving a wide range of aerospace problems. DSMC calculations have provided aerodynamic and aerothermodynamic design data for numerous space vehicles and missions, and have assisted in the design of vacuum systems, including those for semiconductor manufacture. The method was introduced by Professor Bird over 50 years ago and it has been the subject of three monographs and over 160 articles that he published. His third monograph, entitled *The DSMC Method*, was published in 2013, at the age of 83.

Professor Bird attended the University of Sydney where he obtained the following degrees: B.Sc. (1951), B.E. (1953), M.E. (1959), and Ph.D. (1963). He served as a Scientific Officer with the Australian Defence Scientific Service (1953–1959) and was subsequently affiliated with the University of Sydney for the rest of his career, first as a Senior Lecture in Aeronautical Engineering (1960–1964), then as the Lawrence Hargrave Professor of Aeronautical Engineering and head of the Department (1964–1990), and Professor Emeritus from 1990. For almost 40 years, he worked in close collaboration with and as a consultant to NASA and held many temporary appointments at prominent institutions around the world.

He was a Fellow of AIAA, the Australian Academy of Technological Sciences and Engineering, the Australian Institution of Engineers, and the Royal Aeronautical Society. He was also a Foreign Associate of the U.S. National Academy of Engineering.

In 1988, he received the NASA Medal of Exceptional Scientific Achievement for his unusually significant contributions to the space program and for developing the first realistic method for analyzing rarefied flow effects over entry vehicles. He was also awarded the 1988 AIAA Thermophysics Award for sustained and significant contributions to the development of the DSMC method for simulating real gas flows for re-entry and space applications, and furthering understanding of translational, chemical and radiation nonequilibrium effects. His contributions continue to be acknowledged by a biennial lecture given in his honor at the International Symposium on Rarefied Gas Dynamics. In June 2017, he was awarded the Order of Australia, which recognizes Australian citizens and other persons for achievement or for meritorious service

An important legacy of Professor Bird's has been the knowledge and experience he has so generously shared with individuals around the world, particularly young researchers and scholars. In Australia, his contribution to academia principally took the form of his leadership of the Department of Aeronautical Engineering at Sydney University where he taught a generation of scientists and aeronautical engineers. His dedication to his alma mater, teaching, and research provides lasting examples of a life well lived characterized by commitment and service.

TECHNISCHE UNIVERSITÄT DARMSTADT

Technische Universität Darmstadt invites applications for

Professor of Fluid Mechanics (W3) (Code. No. 226)

in the Department of Mechanical Engineering beginning in Winter Semester 2018/19.

The successful applicant will represent the chair of "Fluid Mechanics" in research and teaching. We are looking for a nationally and internationally highly qualified person combining an excellent knowledge base and an extensive experience in the field of fluid mechanics. The applicant must have demonstrated significant independent research achievements and implemented innovative methods in practice.

The applicant will be responsible for teaching the compulsory course "Fluid Mechanics" as required in the Bachelor's Degree programme of the Department of Mechanical Engineering. In the Master's Degree programme the applicant will teach various advanced subjects in fluid mechanics.

The research focus is on experimental fluid mechanics, e. g. in the area of aero- and gas dynamics or multiphase flows. Modern laboratories, measuring technologies, wind tunnels as well as the airfield of TU Darmstadt are available. The successful candidate is expected to collaborate in current and planned joint projects.

The candidate is expected to demonstrate a strong commitment to national and international collaborative research and to undertaking interdisciplinary projects with other departments and research groups.

Candidates must hold a Ph.D. or equivalent in engineering or natural sciences with suitable pedagogical qualifications, an excellent knowledge of German and English, as well as the willingness to participate in academic self-government.

The position is tenured with a remuneration package commensurate with experience and qualifications, following the German "Besoldung" and subject to negociations between the applicant and the university directorate. The regulations for employment are specified under §§ 61 and 62 HHG (Hessisches Hochschulgesetz).

The Technische Universität Darmstadt intends to increase the number of female faculty members and encourages female candidates to apply. In case of equal qualifications applicants with a degree of disability of at least 50 or equal will be given preference.

The Technische Universität Darmstadt is certified as a family-friendly university and offers a dual career program.

Applications must include a CV, a list of publications, an overview of previous teaching responsibilities (including teaching evaluations) and a description of research activities in one single document. Please address your application including the identification number 226 to: The Dean of the Department of Mechanical Engineering, Technische Universität Darmstadt, Otto Bernd Str. 2, 64287 Darmstadt, Germany.

Application deadline: August 15, 2018

1918

July 9 Maj. James McCudden of the Royal Air Force is fatally injured in a plane crash after his engine fails on takeoff and he chooses to turn back to the airfield. A champion of the SE.5 biplane fighter, McCudden tallied 57 victories over the Germans. He is the RAF's fourth leading ace. David Baker, **Flight and Flying: A Chronology**, p. 113.

July 28 Royal Air Force Maj. A.S.C. MacLaren pilots a Handley Page 0/400 on the first flight from England to Egypt, departing from Cranwell and arriving at Heliopolis. Francis K. Mason and Martin Windrow, **Know Aviation**, p. 21.

Aug. 10 Germany's third leading ace, Lt. Erich Lowenhardt, is killed in a flying accident when his Fokker D.VII is struck midair by the D.VII from one of his squadron mates. Lowenhardt had 53 victories. David Baker, **Flight and Flying: A Chronology**, p. 115.

Aug. 17 The U.S. Army Martin MB-1 bomber makes its first flight and subsequently becomes the Air Service's first standard bomber although it is not flown in combat. The Post Office Department flies it with modifications. E.M. Emme, editor, **Aeronautics and Astronautics, 1915-60**, p. 8.

1943

July 4 The first transatlantic "skytrain," comprised of a fully loaded glider towed by a Douglas C-47, arrives safely in the United Kingdom. The 5,600-kilometer flight is completed in stages in 28 hours. The cargo of the Waco-designed CG-4A glider, which left from Montreal, includes vaccines for Russia, and radio, aircraft and motor parts. **Aero Digest**, August 1943, p. 419.

July 5 The Westinghouse 19A completes its first 100-hour endurance test and becomes the Navy's first turbojet. E.M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 45.

July 6 The U.S. War Department announces that the well-known aviator Jacqueline Cochran has been named director of female pilots in the Army Air Forces and special assistant to Maj. Gen. Barney M. Giles, assistant chief of staff for operations. **American Aviation Daily**, July 6, 1943, p. 18.

July 11 The U.S. Senate's War Investigating Committee issues a controversial 30-page report on its investigation of airplane engine failures in Army Air Force operations. The report also addresses manpower difficulties in aircraft plants, labor wastages, and aluminum sheet and other shortages. Some American aviation industry leaders protest, charging that it kindles disputes and may undermine morale; others say the criticisms are warranted and the report is needed. **Aviation**, July 1943, p. 290; **American Aviation Daily**, July 9, 1943, p. 35.

July 18 The U.S. Navy K-74 blimp, used for anti-submarine patrols, is shot down by gunfire from a German submarine that surfaced off the Florida coast; it is the only American airship to be destroyed by enemy fire during the war. **The Aeroplane**, Aug. 6, 1943, p. 152.

July 19 Development of the Gorgon air-to-air, Westinghouse turbojet-powered, radio-controlled missile begins at the Naval Aircraft Factory. However, since the turbojet is not available, and nitric acid-aniline liquid-propellant rocket engines are ready, the program is expanded to cover turbojet, ramjet, pulsejet and rocket-powered missiles. The first Gorgon is tested in 1946. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 45; F.I. Ordway III and R.C. Wakeford, **International Missile and Spacecraft Guide,** pp. 180-181.

July 24 "Window" or "chaff," small pieces of aluminum to deflect radar waves and jam enemy radar, are dropped for the first time in combat by the British Royal Air Force during massive attacks on Hamburg, Germany. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 45.

Aug. 25 Germany's Hs-293 rocket-powered remote-controlled missile begins operations against British anti-submarine ships in the Bay of Biscay. The missile is carried by a Dornier Do-217. Upon release from the plane, a flare light or electric candle at the rear of the missile is lit while the bombardier of the release plane uses a joystick to guide the missile to its target by radio link to a servo-mechanism operating the control surfaces. F.I. Ordway III and R.C. Wakeford, **International Missile and Spacecraft Guide**, p. 111.

Aug. 31 The Grumman F6F Hellcat fighter flies its first combat mission, from the USS Yorktown aircraft carrier against Japanese positions on Marcus Island in the Pacific theater. Rene Francillon, **Grumman Aircraft Since 1933**, p. 206.

1968

July 4 NASA launches its 190-kilogram Explorer 38 into a near-circular orbit. The spacecraft is to measure the intensity and direction of radio signals from cosmic sources not normally observable from Earth. It is also expected to provide the first low-frequency radio map of the Milky Way and data on low-frequency signals from the planet Jupiter and the sun. **Flight International**, July 1968, p. 112; **New York Times**, July 5, 1968, p. 26.

July 5 The Soviet Union launches the eighth in its series of Molniya communication satellites into a highly elliptical orbit to improve telephone and telegraphic radio communications and TV transmissions from Moscow to stations in the Orbita system in north Russia, Siberia, the Far East and Central Asia. **Flight International**, July 18, 1968, p. 112.

July 7 Sir Roy Hardy Dobson, a British aviation pioneer, dies at Greater Manchester. He joined the A.V. Roe Co., one of the world's first aircraft builders, as a fitter in 1914 and became a test pilot. (A.V. Roe became known as Avro.) Dobson became managing director in 1941 and it was largely on his initiative that the Avro Lancaster heavy bomber was put into production. More than 7,000 were built. **The Aeroplane**, July 17, 1968, p. 35; Stephen Skinner, **Hawker Siddeley Aviation and Dynamics: 1960-77**, Appendix 1.

July 12 The last U.S. Navy flying boat, the SP-5B Martin Marlin, is retired from active service and turned over to the Smithsonian Institution at a ceremony at the U.S. Naval Air Station at Patuxtent, Maryland. Built by the Glenn L. Martin Co. of Maryland, the Martin Marlin is a twin-piston-engined flying boat that became operational in 1951; the Navy flew it on naval patrols. **Astronautics and Aeronautics, 1968**, p. 160.

July 13 The General Dynamics FB-111A strategic bomber version of the F-111 Ardvark makes its first flight at Carswell Air Force Base, Texas, reaching an altitude of 20,000 feet (6,096 meters) and 1,062 kph. It is equipped with computers for the pilots to automatically alter flight missions. **Washington Post**, July 14, 1968, p. A5.

July 23 France's first Sea Dragon 3 upper atmospheric rocket is launched from the Landes Test Center at Biscarosse, southwestern France, near Bordeaux. Designed and built by Sud-Aviation, the two-stage solid-propellant rocket reaches an altitude of 562 kilometers. **Flight International**, Aug. 22, 1968, p. 311.

July 31 Britain's Princess Margaret inaugurates Seaspeed's Saunders-Roe SR.N4 hovercraft, named the Princess Margaret; it starts Airspeed's cross-channel passenger and car ferry hovercraft service between England and France the following day. In 1971 the hovercraft is featured in the James Bond film "Diamonds Are Forever." **The Aeroplane**, Aug. 7. 1968, p. 27; **"Seaspeed" file, NASM**.

Aug. 2 The Ryan XV-5B Vertifan aircraft makes its first vertical and hovering flights at NASA's Ames Research Center in California's Silicon Valley to test the vehicle's airworthiness. The aircraft reaches 20 feet and remains stationary in the air for a minute. NASA, **Astronautics and Aeronautics, 1968**, p. 177.

Aug. 16 Two new missiles, the Poseidon and Minuteman 3, are launched for the first time and within a few hours of each other from Cape Kennedy, Florida. When operational, both missiles are to carry multiple independent re-entry vehicle, or MIRV, advanced nuclear warheads. **Flight International**, August 1968, p. 350.

Aug. 16 Essa 7 is launched into a sun-synchronous orbit and is the seventh meteorological satellite in the Tiros Operational Satellite system of the Environmental Science Services Administration. The satellite was designed to record daytime Earth-cloud pictures on a global basis. NASA, **Astronautics and Aeronautics, 1968**, pp. 191-193.

Aug. 18 The Concorde supersonic transport airliner moves under its own power for the first time in taxiing tests at Toulouse, France, in which all four of the aircraft's engines are operated. The jet taxis up to 200 kmh. **The Aeroplane**, Aug. 21, 1968, p. 34; **Aviation Week**, Sept. 2, 1968, p. 32.

1993

Aug. 18 The DC-X, or Delta Clipper, completes its first test at the White Sands Missile Range in New Mexico. The Clipper is an experimental vehicle to test the validity of a single-stage-to-orbit concept that promises to make spaceflight cheaper. It has four throttleable Pratt & Whitney RL10A-5 liquid hydrogen/oxygen rockets. In the test, the vehicle climbs, hovers, then touches down vertically within a minute. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 414; **Aviation Week**, Aug. 23, 1993, p. 26.

Aug. 28 The spacecraft Galileo makes a close encounter with the asteroid Ida and discovers the first known moon of an asteroid. **Aerospace America**, September 2001, pp. 29-33.

JAIME SINGER, 30

NASA Jet Propulsion Laboratory, InSight instrument deployment lead

Jaime Singer didn't realize she was interested in engineering until her junior year of high school in Colorado Springs, Colorado, when her math teacher passed around a sign-up sheet for a summer program. That program combined with a movie she saw the following year helped chart Singer's course toward the NASA Jet Propulsion Laboratory in California, where she will oversee the two- to three-month deployment phase of the Mars InSight lander, which is scheduled to land in November. InSight, or Interior Exploration using Seismic Investigations, Geodesy and Heat Transport, carries two instruments: a seismometer to detect tectonic activity and a probe to investigate the planet's heat source.

How did you become an aerospace engineer?

When my teacher invited us to a four-day program at the University of Colorado College of Engineering, I thought, "What the heck?" We saw all different types of engineering. It began to feel like a fit. I didn't have any idea what type of engineer I wanted to be until my senior year physics class watched "Apollo 13." There is a scene when the operations team on the ground is trying to help the astronauts fix the problem with the air filter. They throw all this stuff on a table and say, "Here's what we have. We've got to make it work." I wanted to do that. I went to the University of Colorado to study aerospace engineering and worked with the Colorado Space Grant Consortium doing student balloon satellite projects. I went on a trip with other students to JPL to present our work. I didn't know much about JPL at the time, because I was still pretty new to the idea of engineering. They showed us the Mars Exploration Rover in the in-situ instrument laboratory and it hit me. People at JPL built and were operating rovers on Mars. I wanted to do that. I debated whether to stay at Boulder to get a master's or a Ph.D., but once I heard from people at JPL who wanted to hire me, I didn't want to risk it. I went to JPL and got my master's in mechanical engineering at the University of Southern California in parallel with working.

Imagine the world in 2050. What do you think will be happening in space?

I hope that by 2050 we are exploring more beyond our solar system. There's a lot of really interesting stuff still to do at Mars and at Europa. But I also think we've learned a lot from the Kepler mission in terms of where we might find other possible Earths. So it would be great to do several missions that follow along that science and see what is happening beyond our solar system. And I hope we continue to have funding to do science that informs us more about Earth and the world that we live in. ★

BY DEBRA WERNER | werner.debra@gmail.com