Q&A 10
NASA's Bridenstine on lunar planning

URBAN AIR MOBILITY 14
Coping with complexity

NASA'S NEW FRONTIERS 28
Next probe goes to Titan or to comet

AEROSPACE AMERICA

In 1921, an Army pilot dropped insecticide on crops, starting a dashing new profession that might or might not survive the age of drones.

PAGE 20

TOMORROW'S CROP DUSTERS

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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

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PAGE 28

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PAGES 9, 36

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PAGE 20

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PAGE 64

DEPARTMENTS

▲ **The moon is visible** just above the Earth's limb in this photo shot from the International Space Station, whose solar array can be glimpsed at the left. NASA

The audacity of 2024

Over the next 16 months, we'll learn whether setting a bold, but probably unrealistic, date of 2024 for a U.S. return to the moon was folly or a stroke of genius by the Trump administration.

In the genius column, this aggressive schedule could be the only way to push the lunar hardware to the point of "too big to cancel" before a new administration has a chance to rethink NASA's entire strategy on Inauguration Day in January 2021 or 2025.

In the folly column, the 2024 goal could backfire as follows: Rushing could increase the odds of a critical test failure. An ambivalent audience in Congress or a corner of the executive branch might balk at supplying tax dollars to try again. An example of this is the X-33 single-stage-to-orbit demonstrator that was supposed to clear the technical path for a successor to the space shuttle. The wall of its liquid hydrogen tank peeled apart after a 1999 ground test. That turned out to be the coup de grâce for the program, and the X-33 never flew.

This is the point in the conversation when someone invariably declares, "That's why we test." True, but there are reasons everyone does high-fives when requirements are met or exceeded. One of them is that it's harder to defund success. In fact, that knowledge could be what drives the infamously risk-adverse culture within U.S. government space programs. Huge risks tend to be unacceptable until we perceive that our way of life is at stake. That's why the pace of American aerospace innovation during World War II and the Cold War amazes us today.

In the folly column could be an overestimation of the ability to shift that culture without such a driver. It's understandable to want NASA to return to the "light this candle" culture of the 1960s and to be more like the Russian managers who put the Soyuz rockets back to work just eight weeks after a harrowing launch abort. Desire is easy. Change is harder. It's not at all clear that top-down pressure from the political leadership can accomplish this. Today, careers, the lives of colleagues and dollars are at stake, but not the future of the nation.

For sure, Election Day 2020 will be a good moment to take stock of the Trump administration's performance on many fronts, including the proposed lunar return, even if that won't be a voting issue for most citizens. Where matters stand could well determine whether Americans touch the moon again.

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

Aiming for small, "tough" constellations

Thank you for the article "Controlling space" in the April 2019 Aerospace America.

In the September 2007 issue of the Armed Forces Journal, I wrote an article that covered some of same issues that you raised. In my article, "America's brittle space systems," my point of departure was Stephen Budiansky's 2004 book, "Air Power," in which he asserted that "this new kind of air power (using the third dimension of space and the fourth dimension of information warfare) could indeed operate against an enemy force with impunity."

I pointed out that the system described by Budiansky, although exceedingly powerful and destructive, was inherently brittle by virtue of the brittleness of the space systems upon which it depended. The brittleness of our space elements was a consequence of decisions made long ago. For reasons of utility and economy, the space elements were developed according to what I called a "big iron" architectural philosophy, producing big, expensive satellites that were launched from big, soft platforms and were controlled by big, complex, soft centers.

I suggested that future developments should aim for proliferated and dispersed constellations of small space elements, launched from dispersed sites, and controlled from dispersed ground elements. These could be combined into "tough," as opposed to "brittle," systems that could deploy with, and be operated by, an expeditionary force in a theater of operations.

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Scar Tissue

Society today and into the future is crucially dependent on a successful and safe aerospace industry. To retain strategic and technological preeminence, and truly lead from a position of strength, adjustments in our risk tolerance will be mandated. It is clear that our industry is moving rapidly, necessitating speed, agility, and faster implementation. No segment of aerospace is untouched. We can see an emerging private enterprise space arena and the development of autonomous air mobility. Potential adversaries are taking aim at our technological advantage. Transportation technologies are developing quickly to move people around the globe at higher speed, and with less environmental impact. We have a directive to return Americans to the moon in 2024. To remain truly nimble, it is clear that our tolerance of risk and failure must be recalibrated to better account for our society's desired outcomes.

Our current acquisition and risk approaches must adjust to meet these rapid advances. Systems and approaches must be modernized and implemented to meet the timescale of the evolving demands. What does this mean in practice? From an acquisition standpoint, we need a shift in culture to allow us to build new capabilities with less than ideal performance and to be able to implement an initial level of performance that meets the near-term need, recognizing that we can improve performance in future iterations. For example, can we ultimately view our technology-laden aerospace systems in the same way we view our technology-laden mobile phones? Meaning, when we lose or break a mobile phone, we quickly replace it. If a technology-laden CubeSat fails, can we simply launch another from the assembly line, and then do the failure investigation in parallel, rather than impeding progress pending a mishap investigation. Of course, a fair question remains — how does this altering of tolerance and thought affect safety and risk? That answer is totally dependent on situation and application. At all costs, we must prioritize the protection of human life — in aircraft, spacecraft, or on the battlefield.

From a commercial, private enterprise perspective, success in the market place is at least partially driven by timeliness. Yes, the product must work and be viable; however, time-to-market is an extremely important factor. For national defense there is a different risk acceptance calculation to meet the threat — the "benefit" of protecting our way of life. For space exploration there is another and different risk calculation. The farther humans venture beyond Earth orbit, the less we know, the more we learn about living and operating in new environments, and the more we learn about our home spaceship, Earth. The urgency in space exploration arises from the leadership learning how to go beyond current human limits while establishing the "rules of the road" in space.

> ... we must not allow the scar tissue of past failures to hold us back from meeting the complex challenges of the future.

We are obligated to question what we do, how we do it, and, most importantly, why each step matters. The conscious questioning, professional debate, and thoughtful implementation will transport us to better and more efficient ways to meet our needs. Status quo thinking often leads to stagnation. We must learn from our failures, recognize the lessons, and, *crucially,* communicate all to our colleagues. Only then can we say we are truly preparing the next generation. And, ***we must not allow the scar tissue of past failures to hold us back from meeting the complex challenges of the future.*** We must test our ideas, not only talk about them. We must understand what is possible, along with limitations and constraints. Finally, we must work to critically evaluate and eliminate non-value-added activities that so frequently find their way into our processes.

If we wish to stay relevant, the industry, and AIAA, must choose balanced risk over scar tissue — only then will it be poised to remain at the forefront of aerospace. We owe it to society, our investors, and our industry's future workforce to broaden our minds. ★

Dan Dumbacher, AIAA Executive Director

Do you have a puzzler to suggest? Email us at **aeropuzzler@aiaa.org**

Photo illustration

Icy runway

Q. You've been asked to review a new horror movie. In the closing scene, a passenger jet is ready for takeoff at the head of a runway that's very wide and completely covered in ice. The zombies are slipping and sliding toward the plane, so the pilot has no choice but to open the throttle. Will the plane take off?

Submitted by Jeff Eldredge, professor of mechanical and aerospace engineering at the University of California, Los Angeles.

Draft a response of 250 words or fewer and email it by midnight Eastern time June 6 to aeropuzzler@aiaa.org.

FROM THE MAY ISSUE

CALL FOR HELP: We challenged you to tell us why the engineer among a group of castaways implored the person with a VHF radio to wait for a forecast temperature inversion before expending the last bit of battery power on a mayday call.

Your responses were reviewed by space systems consultant Chris Hoeber and Dave Jenn of the Naval Postgraduate School in California. Here is the top submission:

WINNING RESPONSE: VHF radio waves are a part of the electromagnetic spectrum. All EM waves bend when they move from a denser to a less dense substance. This is known as refraction. Refraction is responsible for rainbows, mirages, halos and sundogs. When the weather is calm and there is a strong temperature inversion, a layer of high-density cold air is blanketed above by a layer of low-density hot air. This forms an ideal condition for VHF signals to refract and be transmitted over large distances (1,000-3,000 miles). This is called tropospheric ducting, and the engineer hopes to tap into this phenomenon. Under ideal weather, VHF signals do not refract substantially to be transmitted over a longer distance. Stranded on a tropical island, it is less likely that the pilot can signal for help using the VHF radio. Instead, if they wait for tomorrow, the temperature inversion will benefit them. The VHF signal can then travel for a long distance. This will increase their chances of their mayday call being picked up by someone.

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

Webb telescope poised for "final integration"

BY AMANDA MILLER | agmiller@outlook.com

▲ The components of NASA's James Webb Space Telescope in a clean room at Northrop Grumman in Redondo Beach, Calif.
Northrop Grumman

To this point, NASA and Northrop Grumman have steered the massive James Webb Space Telescope through development in two halves. Engineers had to do that, partly because in space the two halves must function at opposite temperature extremes. No facility could replicate near absolute zero on one side of the spacecraft and sunlight on the other.

A big moment for Webb will come in the weeks ahead when, depending on results of thermal tests, Northrop Grumman joins the optical half, including 1 the honeycomb primary mirror, to 2 the spacecraft element. 3 The yellow bar on the ceiling of the company's Redondo Beach, California, facility will lift the optics, called OTIS for Optical Telescope and Integrated Science instrument module, precisely into position. Technicians and engineers will then bolt OTIS to the spacecraft element and connect numerous power wires, cryocooler lines and data cables in a final integration process that should take about 11 hours, followed by lots of testing.

Folded up inside the spacecraft element is a tennis-court-sized sunshield consisting of five layers of polymer that will open to block solar radiation and chill anything on the other side to nearly absolute zero. Keeping the optics cold will empower Webb to detect infrared light from the early universe, once the three petals of its 6.5-meter primary mirror come together in space.

Smooth integration of those halves would mark a rebound from a test failure last March. Hardware bolting together the sunshield fell out during a high-decibel noise test that mimicked the roar that Webb will face as its Ariane 5 rocket lifts off and accelerates toward space. That issue and other setbacks caused NASA to slip the launch from January 2020 to March 2021.

Bolting the sunshield was tricky due to the need to protect the sunshield layers, the thinnest of which are 0.03-millimeter thick, from risk of tearing.

"One thing about Webb I try to emphasize all of the time is that everything we do is a first," says Scott Willoughby, Northrop Grumman's Webb program manager.

The fix to the bolt problem worked as planned during a repeat of the high-decibel testing late last year, and during vibration testing early this year.

The bolt problem and other issues added $800 million to Webb's price tag, bringing the estimated total mission cost, since design and development began in 1996, to $9.7 billion.

Once Webb is fully assembled and ready for launch, it'll be laid down horizontally in a container for shipping through the Panama Canal to the Guiana Space Center in Kourou, French Guiana. ★

NASA

JIM BRIDENSTINE

POSITIONS: NASA administrator since April 2018; represented Oklahoma in the U.S. House of Representatives, 2013-April 2018; major in Oklahoma Air National Guard, 2015-April 2018; pilot in U.S. Navy, 1998-2007, and U.S. Navy Reserve, 2010-2015, earning the rank of lieutenant commander in 2012.

NOTABLE: First congressman to become NASA administrator; introduced American Space Renaissance Act while in Congress, which never passed in full but had some of its provisions passed as part of the 2017 National Defense Authorization Act; piloted MC-12 reconnaissance planes for Oklahoma Air National Guard; flew counterdrug missions in Central and South America in Navy Reserve; piloted E2-C Hawkeyes during wars in Iraq and Afghanistan while in the Navy.

AGE: 44

RESIDENCES: Tulsa, Oklahoma; Arlington, Virginia

EDUCATION: Bachelor of Science from Rice University, where he majored in psychology, business and economics; Master of Business Administration from Cornell University.

Scan this QR code to read the complete transcript online.

Shooting for the moon

NASA Administrator Jim Bridenstine and his agency have just five years to accomplish what Americans haven't done since 1972. Landing on the moon in 2024 will require many different pieces of the mission architecture to come together, from the heavy-lift Space Launch System rocket that's still in development to the Gateway, a proposed reusable command and service module. At the same time, NASA can't forget that the mission won't just be about going to the moon in 2024, but also forward to Mars. NASA must accomplish all this without losing sight of its other responsibilities, including gathering data about Earth for climate scientists. Just over a year into his tenure as administrator, Bridenstine spoke with me by phone from his office about NASA's new era of space exploration.

— Cat Hofacker

IN HIS WORDS

2024 moon landing "technologically achievable"

We have to make sure that we hit our milestones and we don't make mistakes and we don't have setbacks. To make sure that we don't have setbacks, we need to build redundancy into the architecture as much as possible. So instead of one lander, maybe we have two landers that can go from the Gateway down to the surface of the moon. Those are the kind of things that we're looking at to ensure success for the 2024 moon landing. In order to accelerate as fast as possible, one of my first initiatives even before the 2024 directive was given was to create what we call the Commercial Lunar Payloads Services program. CLPS [pronounced "clips"] is what we call it, and so we were turning to commercial industry and saying, "If NASA had a payload, who can deliver it and for what cost?" In other words, the access to the moon for small payloads is not going to be by NASA purchasing, owning and operating its own hardware, but instead buying a service from commercial industry.

High risk but high return

We do understand that through the Commercial Lunar Payloads Services program there will be failures. I want to make sure that gets known. There will be failures. In other words, not everybody who attempts to land on the moon is going to be successful. I see CLPS as kind of a venture capital effort. It's high risk, but it's very high return, and it's low cost. So, low cost, high risk, but a very high return for successful missions. That was an initial program that we put together to help inform us how we would get humans to the surface of the moon eventually, and when those humans are on the surface of the moon, what are they going to be doing? What are the most interesting parts of the moon scientifically that we can investigate? Remember, we had an effort to land on the moon in 2028; so in order to get to 2024 what we're doing is we're taking some of those investments that we were going to make in '25, '26, '27 and '28 and we're pushing them forward to today.

Commercializing space

The reason we want to commercialize low Earth orbit in general is so that we can have more resources to go where there isn't yet a commercial industry. In low Earth orbit we have an interest in being one customer of many customers, which drives down our costs. We also have an interest in having numerous providers that are competing on cost and innovation, and we are rapidly approaching that in low Earth orbit. And what does that mean for us? That means that we can use the resources that are remaining to do things for which there isn't yet a commercial market, namely go to the moon and on to Mars. Again, we want to, at the same time, work to commercialize activities in cislunar space and then of course at Mars as well. So the reason we commercialize is so that we can use the taxpayers' resources to do the things that only NASA can do. We don't want to do things that commercial industry can already do.

There are people who say that you can get to Mars without using the moon. I think that's crazy; I think it's unsafe; I think it would be inappropriate. ... We saw what happened on Apollo 13: Our astronauts made it home safely. Why? Because they were going to the moon. If they were headed to Mars, it would have been the end of the story for them.

Overcoming political challenges

I feel pretty confident. I think most people understand the history. The history is that since 1972, which was the last time we landed on the moon, there have been many attempts to get back to the moon, and all of the attempts have failed. Not because of technological challenges, but they have failed because of political challenges. The goal here is to make sure that we are not doing the things that make this politically problematic, which have been tried in the past. So we need strong bipartisan support in order to achieve the end state. It's how President Kennedy was able to achieve the moon landing back in the 1960s. He had strong bipartisan support. Lyndon Johnson, Richard Nixon continued that bipartisan support that ultimately resulted in a moon landing on July 20, 1969. We just have to make sure that we're doing all the right things to make this as apolitical and bipartisan as possible.

The path to Mars

As we are headed toward the moon, we want to build technology and capability that is replicable at Mars, and that's what we're doing. There are people who say that you can get to Mars without using the moon. I think that's crazy; I think it's unsafe; I think it would be inappropriate. What we learned during the Apollo program is that the moon is the path to Mars. We saw what happened on Apollo 13: Our astronauts made it home safely. Why? Because they were going to the moon. If they were headed to Mars, it would have been the end of the story for them. The moon is the proving ground; it's the place where we can learn. It's the place where we can ultimately understand how to utilize the resources of another world to live and work and ultimately apply all of what we learn at the moon, where it's only three days away, as opposed to Mars, which is a seven-month journey plus a two-year stay.

The allure of Mars

Number one, we now know that there are complex organic compounds on the surface of Mars. So the building blocks for life exist on Mars. That doesn't mean that there is life on Mars. We don't know, but those complex organic compounds do not exist on the moon. They exist on Mars; they exist on Earth. It might be an indicator of something, and I think it's important that NASA continue to investigate. In the last year we also learned, because of the Mars Curiosity rover, which discovered the complex organic compounds, but we also learned that the methane cycles on Mars are commensurate with the seasons of Mars, so that's a big discovery. Doesn't guarantee that there's life, but the probability has gone up. And then not related to NASA specifically, but an orbiter of Mars from a different country discovered that there's liquid water 12 kilometers below the surface of Mars.

Maintaining urgency for Mars

Yes, I'm concerned about that. The answer is we need leadership, but remember, the goal here is to put that first human on the moon since 1972 in 2024, to have a sustainable lunar program by 2028 and then to do all of the things we need to do to learn how to live and work on another world, and then go to Mars. There's a lot of things that have to be invented in order to go to Mars. The moon is the proving ground, but if 10 years from now we don't have active leadership attempting to make that next great leap, it will be a problem. But I can tell you right now this administration is very motivated and highly focused on achieving the moon landing and making sure that the technologies we develop are applicable for an eventual Mars landing.

America leading the way

We lead because we bring the preponderance of the assets and a preponderance of the capabilities, and without our leadership, quite frankly, it just won't happen. We are very open, and we want international partnerships, 100%. This is about American leadership, and we want them to be with us when we go to the moon, but the reality is America is going to lead. That's who we are, that's what we do, it's what we've done in the past and it's what we're doing now. Absolutely this is an effort internationally that we want to lead on. If you just look at the International Space Station, for example, the United States of America provides 77% of the resources

▲ **Jim Bridenstine**, second from right, appears on a panel with former NASA administrators at AIAA's 2018 Space Forum. From left, former administrators Dick Truly, Dan Goldin, Sean O'Keefe, Mike Griffin and Charlie Bolden, Bridenstine, and space historian Roger Launius, who moderated the discussion.
AIAA

for the International Space Station, and there are 15 different nations that participate in the International Space Station from an operational perspective. So while we are one of 15, we bring the preponderance of the capability and the preponderance of the assets. So it's up to us to lead. We can either choose to lead, or we're just not going to go, but we have to lead. Certainly we want to lead with a coalition of international partners to achieve even more spectacular outcomes.

Recent achievements

In November, we landed InSight on Mars, which was the eighth time in human history that we've landed on Mars. The United States of America is the only country that's ever done it. InSight is going to give us great information and data about the formation of Mars and, really, how planets in general form. It's going to have the ability to understand Mars quakes and asteroid impacts on Mars. Another big accomplishment was entering orbit around Bennu with OSIRIS-REx. The idea that we can actually orbit an object as small as Bennu, characterize it for a period of years and then bring a sample home from that asteroid in deep space, that will be a first for humanity. Another big accomplishment was flying by Ultima Thule in the Kuiper belt, which is 4 billion miles from Earth. This was the first time we've ever had the ability to get good scientific data and characterize an object that is that far from Earth. Even more impressive is the fact that it was from the same New Horizons mission that gave us beautiful images of Pluto back in 2015. Another big accomplishment was launching a Commercial Crew to the International Space Station with the [SpaceX] Crew Dragon. Even though it was uncrewed, it was a demonstration of what Commercial Crew will bring.

Strong on Earth science

Understanding the water cycle is a critical piece of what we do. Water, of course, is the most potent greenhouse gas in the atmosphere, and so by measuring it we can get a good understanding of the climate, as a matter of fact. ICESat is a mission that helps us understand and characterize the ice at the poles of the Earth and how that ice is changing. It helps us measure the thickness of the ice, and then you combine that with imagery that helps us understand the mass of the ice in the horizontal, I guess the mass, like the land, how much of the Earth is it covering at the poles. GRACE Follow-On is helping us understand how water moves around the Earth just by measuring gravity, so what we find is that the gravity of the Earth is not uniform, nor is it stable. It's constantly changing, and that gravity change is based on where water is accumulating. We're also actively sensing water vapor in different parts of the electromagnetic spectrum, and of course we do that because number one, we want to understand the changing climate, but number two, we want to be able to predict weather. Understanding weather prediction is a key component as well. Understanding carbon dioxide is a big mission for us. We have the Orbital Carbon Observatory 2 on orbit right now helping us gather information on carbon dioxide. We have Orbital Carbon Observatory 3, which will be launching this year to the International Space Station to help us gather even more information from a carbon dioxide perspective. We also have GeoCarb that will be a geostationary hosted payload on a communication satellite in GEO stationary orbit. GeoCarb is going to give us great information on not just carbon dioxide, but methane and other greenhouse gases that are over the Western Hemisphere. So NASA is focused on Earth science. Our Earth science budget request is very strong, and we continue to study the Earth in ways that only NASA can do.

Leading in climate study

What you'll find is that our budget requests for Earth science is higher than five of the enacted budgets under President Obama. So we have a strong Earth science budget that I think keeps NASA right where it needs to be and of course, again, if you look at how we compare to the rest of the world. If you add up all of the nations of the European Space Agency, Canada, Japan, Russia — all of our partners on the International Space Station — you add up all of their climate science budgets and ours alone is still higher than all of theirs. I would say that the United States is very strong when it comes to studying the climate.

Climate change is "very real"

When I was in the House of Representatives, I was on the Armed Services Committee and there was an amendment to have the Department of Defense understand climate and how it affects our national security posture. There were a lot of Republicans against it and a lot of Democrats for that amendment. I broke with my party and supported that amendment. Why? Because here's what we know: The Arctic ice is melting. As a Navy pilot, I can tell you that the Navy is having to defend territory it never used to have to defend, and the ocean is open in ways that the ocean didn't used to be open, especially when we talk about the Arctic. So climate change is very real; it has a national security kind of posture. My position on that, that was my position on it in the House of Representatives. It's my position on it today. I have a history of being in favor of trying to understand the changing climate. ★

For Vahana, a study in coping with complexity

Urban air mobility concepts tend to be odd-looking airframes covered with propellers. The innovations promise maneuverability and energy efficiency, but they also bring aerodynamic complexities. How does one control such an aircraft? Keith Button spoke to the designers of Vahana, the Airbus urban air mobility demonstrator, to find out.

BY KEITH BUTTON | buttonkeith@gmail.com

envision erecting in suburban neighborhoods and atop city buildings.

For reasons of economics, the aircraft probably will need to do all this autonomously, which is where the modeling comes in. Flight control software can execute complex maneuvers in a variety of wind and weather conditions only if it has an accurate aerodynamic model to work from.

This is the story of how one company, Airbus, addressed that challenge in building and flying its all-electric, self-piloted urban air mobility demonstrator, Vahana. Since 2018, the company has been flying the single-passenger seat demonstrator without anyone aboard in a series of test flights at PUR, the Pendleton Unmanned Aerial Systems Range in Oregon, where the company leases a hangar. The flights could clear the way for development of an operational version that would carry multiple passengers.

In 2016, when engineers at A³, the Silicon Valley, California, arm of Airbus, received the aircraft design from colleagues, they realized the blueprint was so complex that they could not fully model it with computational fluid dynamics software due to the time and expense, says aerodynamics engineer Monica Syal, a member of the modeling team. Shooting for maximum energy efficiency and safety, designers had created a one-seat passenger cabin with four swiveling wings mounted to it, each with two "fans," in Vahana parlance, consisting of three rotor blades each. Tilting the wings forward for horizontal flight meant Vahana could achieve a flight speed of 185 kph and demonstrate the ability to turn a 90-minute ground commute into, say, a 15-minute hop. All this would require a mix of 22 different actuators, some mechanical and others electric-motor driven. Two actuators co-located with each of the eight fans adjust the fan speed and rotor pitch; another actuator tilts the front wings and another tilts the rear set. Two more move the elevators on the front wings, and two adjust the position of the ailerons on the rear wings.

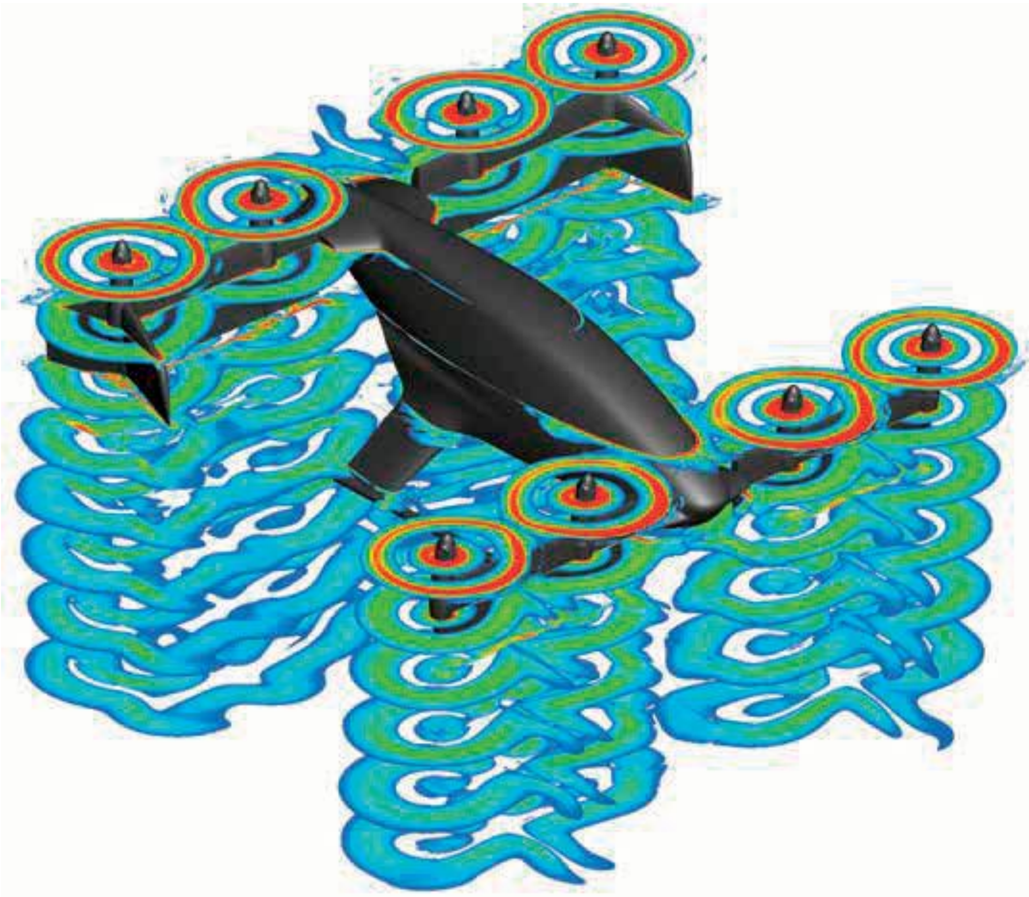
▲ Vahana, an all-electric, self-piloted urban air mobility demonstrator.
Airbus

Aircraft companies around the world are throwing the old design book away in an attempt to gain an edge in the potentially lucrative urban commuter market. With the advent of lithium ion batteries, designers no longer need to pair rotors to bulky combustion engines whose size and weight crimp design options. Multiple rotors can now be distributed across the airframe to maximize thrust, lift or energy efficiency, and wings can be reconceived.

This design flexibility is exciting to engineers, but it also presents aerodynamic modeling and hardware challenges, especially given all that an urban air mobility aircraft must do. They will need to whisk passengers safely over neighborhoods and to and from vertiports, the landing pads that planners

If a conventional CFD modeling approach were applied, the CFD would capture the flow physics precisely, but doing so would require approximately 1,000 computations run on expensive high-performance-computing clusters, each run taking two to four days. It would have taken years to complete.

Syal and the other two engineers on her team knew they needed a different tack. Instead of relying entirely on CFD, they decided to first model the main aerodynamic components of the aircraft with medium-fidelity aerodynamics software and turn to CFD only to verify their results. The medium-fidelity software makes certain assumptions to reduce the computational complexity while still producing a reasonably accurate model. With this software, they calculated what the optimal actuator



◀ Vahana engineers turned to CFD software called ROSITA, for ROtorcraft Software ITAly, to verify the results of the medium-fidelity aerodynamics software.
Airbus/Vahana

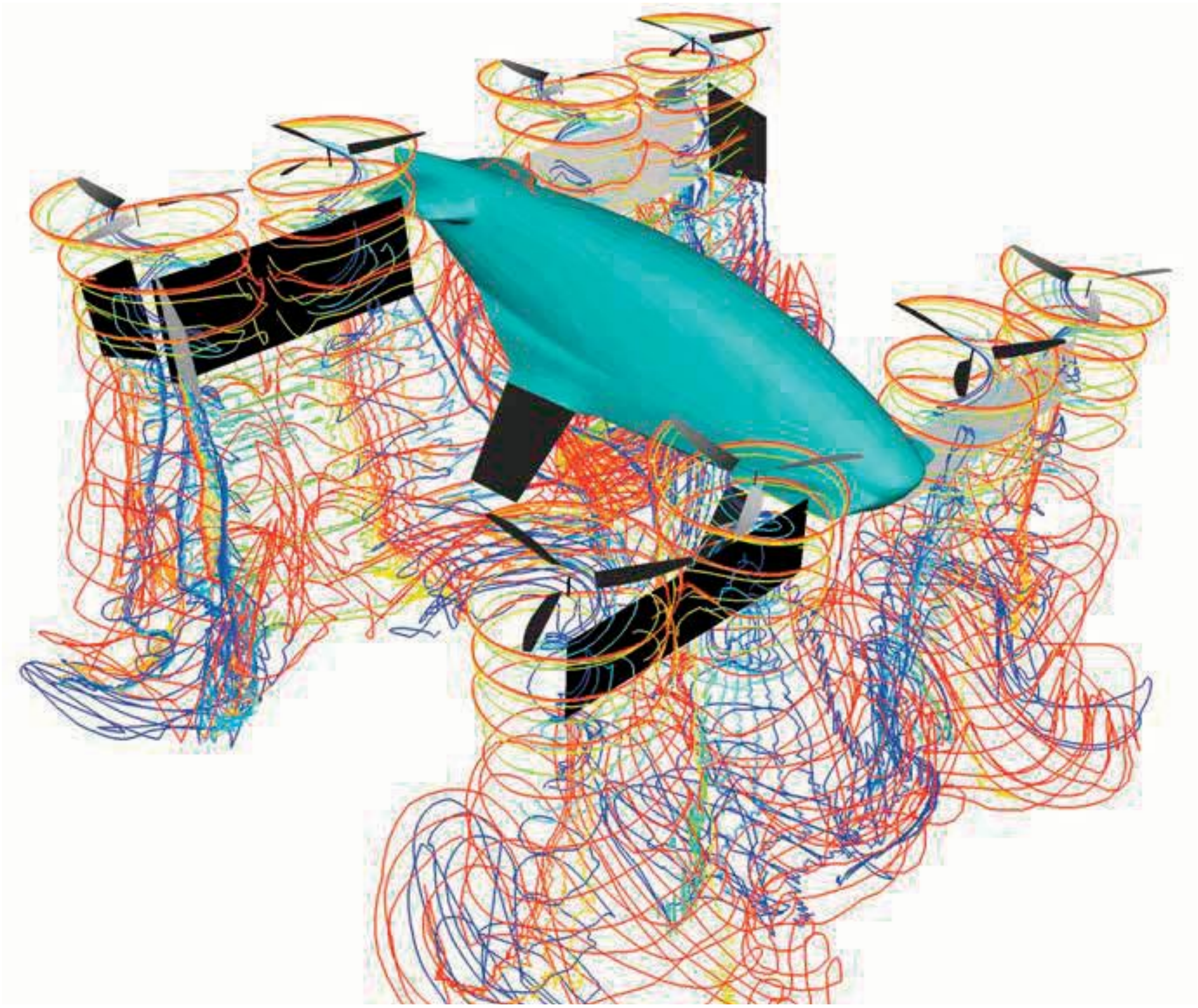
settings would be at hover, at 50 meters per second forward airspeed, and at every 5-meter-per-second increment in between, during the transition between vertical and horizontal flight. As the aircraft moves from full hover to forward flight, the wings must gradually tilt forward, from pointing straight up to flat. During the transition, as the wings are partially tilted forward and fans begin to provide some forward propulsion, the fan-wing combinations set up complicated aerodynamic forces. At a moderate speed when the wings are a third of the way tilted forward, for example, the wings would create significant drag and stall conditions along areas of the wings where no airflow was provided by the fans. But at the same time, on areas of the wings where the fans were blowing, the wings would be producing lift.

This all had to be modeled accurately for the flight control software. The optimal settings were those that would conserve the most electricity while still empowering Vahana to stay in control during unpredictable flight conditions, such as wind gusts or the loss of a fan. Each of more than 1,000 calculations by the medium-fidelity software took 30 to 60 minutes to compute on a desktop computer.

Syal's team checked the medium-fidelity aerodynamics models for various flight speeds by running the results through the CFD software. The CFD program confirmed their models in hover, low-speed transition and near-cruise flight. For the middle of the transition phase, the CFD software found that the medium-fidelity models hadn't fully accounted for how strongly the wake from the front set of wings and fans would affect the rear wings and fans. But when the engineers tested the aerodynamics model

Vahana's novel design also challenged the engineers working on its hardware. The fans had to perform the roles of helicopter rotors — providing vertical lift plus control of pitch, roll and yaw — and also provide forward propulsion like an airplane's propellers.

Each Vahana fan has two actuators (not visible).
Airbus



by flying a quarter-scale Vahana model, they found that the model worked well.

After three months of work, the team in December 2016 completed its first aerodynamic model of Vahana. The model was loaded into the flight control software that guides the 22 actuators to produce lift or thrust through the hover, transition and cruise phases. The engineers tested the model on a computer-simulated Vahana, then by test flying the quarter-scale Vahana starting in 2017 at a site in Hollister, California. Since then, Syal and her team have continued to refine their model with data from flights of subscale Vahanas and a full-scale Vahana in Pendleton. The company has a second full-scale Vahana that it has yet to fly.

▲ The wake of Vahana's fans in hover is visible in this image created by medium-fidelity software called CHARM, short for Comprehensive Hierarchical Aeromechanics Rotorcraft Model.
Airbus/Vahana

Reinventing the actuator

Driving the complexity was that, in vertical mode, the fans had to provide vertical lift plus control of pitch, roll and yaw, and then in forward flight, propulsion like an airplane's propellers. Designers had determined early on that the fan rotors would have to be able to vary their pitch, meaning the angle at which they cut through the air, to lift the aircraft in hover mode and to propel it during forward flight. Fixed-pitch rotors would draw too much electricity when maximizing thrust, says Evan Frank, a mechanical engineer in charge of propulsion for the aircraft.

Most helicopters and turbo-prop airplanes control their blade pitch with hydraulic pumps and hoses powered the aircraft's combustion engines. But hydraulically powered rotor pitch actuators would have been impractical for the Vahana.

"You can just imagine the complexity of running eight sets of hydraulics out to the wings," Frank says. "It would drive the takeoff mass of the vehicle up significantly."

Frank and his team created electro-mechanical actuators, one for each fan, to control the pitch of the three rotors on each fan. Each actuator is 10-by-10-by-20 centimeters, weighs about 1.5 kilograms and is mounted behind the motor that spins the fan. Inside each, an electric motor drives a series of gears and a ball screw that controls the position of a rod that changes the pitch of the rotors. As the aerodynamic models for the Vahana were tested and tuned, engineers refined what they call the schedule for how the rotors would be pitched at various flight speeds. In hover, when the fans are pointed straight up, the actuator pitches the rotors to nearly zero degrees, meaning the rotors cut through the air at a minimal angle. This maximizes thrust, which is essential given that the wings are not contributing lift. After the transition to horizontal flight, when the maximum cruise speed of 185 kph is attained, the fans point straight ahead and the actuator pitches each rotor to a 25-degree angle relative to the air flow so that it chops lots of air. All told, this produces less total thrust than during hover but maximizes forward propulsion. In between hover and cruise, the rotor pitch changes on a continuum that coincides with the forward speed of the aircraft at every 5-meter-per-second increase in forward speed, as does the wing tilt.

Engineers had another challenge. To control the aircraft properly, they had to be sure that each fan would produce the expected level of thrust. While each unit was manufactured within acceptable tolerances, tiny differences in the width or weight of the rotors, for example, would mean that the thrust of one fan at a given RPM might differ by as much as 15% from another fan at the same RPM. That could mean disaster for the software trying to control the Vahana's flight.

To ensure that each fan produced the same amount of thrust at a given RPM, Frank and his team had to devise a method for testing and adjusting the fans and their associated motors and actuators before they were bolted onto the wings. Engineers decided to bolt these fan units one at a time to a welded-steel frame and measure each unit's thrust at various RPMs and rotor pitch angles. They then adjusted the software controlling the actuators to produce the same thrust at a given RPM as another fan's zero-degree setting, for example, at the same RPM. More tests were done to make sure the adjustments worked. After the fan units were tested and adjusted, they were bolted onto the aircraft.

Airbus has moved the Vahana program out of A³ and into the urban air mobility unit that it launched last year to develop UAM vehicles, vertiport concepts and air traffic management ideas. Syal and Frank and their teams plan to fly the Vahana through a complete transition to cruise flight, which begins at 167 kph, later this year. ★

▼ A full-scale version of Vahana is prepared for shipping to the Pendleton Unmanned Aerial Systems Range in Oregon.
Airbus/Vahana

COVER STORY

THE FARMER'S AIR FORCE

Crop dusting with conventionally piloted aircraft is approaching its centennial. Now, with the challenge posed by drones, Jan Tegler looks at what could be in store for the next 100 years.

BY JAN TEGLER | wingsorb@aol.com

Credit the catalpa sphinx caterpillar for helping to launch a global industry.

On an August day in Ohio back in 1921, a U.S. Army pilot took off from an airfield near Dayton, his Curtiss JN-4 Jenny fitted with a small makeshift hopper (a metal container) and a release mechanism. The Jenny dropped low over an orchard, spreading powdered lead arsenate insecticide in an attempt to kill the caterpillars that were happily munching on the leaves of the catalpa trees, a hardwood used for railroad ties and fence posts.

It worked, and the technique caught on quickly with American farmers. On call to strike at insects, parasites and bacteria, crop dusters gained the nickname, the "Farmer's Air Force."

Today crop dusting is known as aerial application in the agricultural industry, and it's one of the keys to modern productivity. "Ag" pilots flying a range of turbine and piston aircraft and helicopters skim 10 to 15 feet above fields. They swoop and pirouette to fly precise parallel lines over crops spraying protection chemicals, fertilizers and seed in one of the most demanding and potentially dangerous forms of aviation.

With the centennial of crop dusting approaching, aerial application pilots tell me they feel more relevant, capable and safer than ever in the vocation's storied history. They could soon start feeling the pinch from a 21st-century competitor, however. Drone makers currently offer a range of small unmanned aircraft for aerial application but anticipate their wares could gradually displace ag pilots and their aircraft, although opinions vary about the feasibility of that.

In some concepts, rotorcraft drones would rise vertically from the perimeters of the fields they treat, spraying in precise patterns feet above crops, never venturing far from the remote pilots or automated support systems that accompany them. With no pilot aboard, drone makers say their aircraft are safer than manned aerial applicators. They also claim that drones can be more cost-effective and productive.

Drones might also be a solution to the looming pilot shortage that aerial application, like the rest of aviation, will face in coming years says Rafi Yoeli, CEO of Tactical Robotics Ltd., a drone maker in Yavne, Israel. "We're looking at manned agricultural aircraft and helicopters and asking, what will happen to application for large fields that require a lot of material?"

The company's Ag Cormorant prototype is a turbine engine-powered rotorcraft with enclosed

Tactical Robotics' Ag Cormorant prototype takes off and lands vertically with enclosed rotors.

Tactical Robotics

▲ **The Ag Cormorant** flies autonomously for aerial application.

Tactical Robotics

rotors that takes off and lands vertically. Capable of carrying a 500-liter load, it is designed to fly autonomously for aerial application. With its size and power, it's intended for large-scale applications and, as far as I could learn, is larger than any of the drones that are being flown for aerial application. Yoeli thinks that in five to seven years Tactical Robotics can "start earning money with this aircraft."

Ag Cormorant is the result of a partnership announced in March between Tactical Robotics and Tel Aviv-based Adama Ltd. (a subsidiary of China National Chemical Corp.), which produces crop protection products for aerial and ground applications. The Ag Cormorant prototype first flew in February and is an adaptation of Tactical Robotics' Cormorant prototype that made its initial flight in 2015. The Cormorant was designed for military and border security tasks.

Yoeli says Ag Cormorant is "aiming directly" at manned agricultural aircraft and helicopters "with everything it takes to actually replace a human pilot" and "provide the same level of safety."

According to the U.S National Transportation Safety Board, there were 52 accidents in the U.S. involving aerial applicators in 2018 with eight fatalities, up one from 2017's seven fatalities. The FAA's most recent annual general aviation and air carrier activity survey shows that ag pilots flew 1.1 million hours in 2017. Using these numbers, the National Agricultural Aviation Association calculates 6.2 accidents per 100,000 flight hours for aerial applicators with a fatal accident rate per 100,000 flight hours of 0.65. That compares favorably with the FAA's fatal accident rate for general aviation in 2016 (the most recent data) of 0.89 per 100,000 flight hours. Accident statistics for a drone like the Ag Cormorant don't exist yet.

Size matters

Aerial application accelerated after World War II, spurred by development of a variety of insecticides,

> "FARMERS RELY ON PLANT NUTRIENT AND PEST CONTROL PRODUCTS BEING DISPERSED [AS] QUICKLY, EFFICIENTLY AND EFFECTIVELY AS POSSIBLE. WE HAVE THE BIGGEST, FASTEST AIRPLANE THAT HAULS THE BIGGEST LOAD WITH THE WIDEST SPRAY SWATH."
>
> — **Jim Hirsch**, Air Tractor

▲ **Yamaha Precision** Agriculture operates 10 RMAX helicopters under FAA waivers in Napa, Calif.

Yamaha Precision Agriculture

fungicides and herbicides and a swift increase in the average size of farms. Hopper size steadily increased to accommodate larger dry and wet loads — all the way up to the 3,028-liter hopper found on today's piloted Air Tractor 802 planes.

Jim Hirsch is the president of Olney, Texas-based Air Tractor, the world's leading producer of aerial application planes. He told me that his firm's newest model, the AT-1002, will carry even more, up to 3,875 liters, once it completes FAA certification.

"It's about acres [hectares] per minute," Hirsch says. "Farmers rely on plant nutrient and pest control products being dispersed [as] quickly, efficiently and effectively as possible. We have the biggest, fastest airplane that hauls the biggest load with the widest spray swath."

In the U.S., aerial application drones "are generally small currently and have very limited capability" says Steven Thomson, engineering programs and projects leader for the National Institute of Food and Agriculture, part of the U.S. Agriculture Department. With a background in aerial application crop protection materials as well as unmanned aerial systems, he views drones as "supplemental" to manned aircraft in the near to midterm.

Regulated under Part 107 of the FAA's Federal Aviation Regulations, unmanned aircraft in the U.S. can fly no higher than 400 feet, no faster than 161 kph and must weigh less than 25 kilograms total. The weight restriction in particular severely limits their potential for aerial application.

Yamaha's RMAX remotely piloted helicopter is the largest unmanned aerial application aircraft flying in the U.S., though significantly smaller than the Ag Cormorant. Brad Anderson, unmanned systems division manager for Yamaha Precision Agriculture, leads a three-person team, operating 10 RMAX helicopters under special FAA waivers in Napa, California. Yamaha's waivers exempt the RMAX from FAA airworthiness requirements, exempt it from the requirement that the remote pilot have a commercial pilot's license as ag pilots do and allows it to fly at its 64-kilogram weight. Since 2016 Anderson's team has worked with a small group of vineyards, spraying fungicide for mildew prevention on wine grape crops.

Measuring 3.5-meters long (with rotor) and 1-meter tall, the RMAX is powered by a 2-cylinder gasoline engine. It carries a 16-liter payload. Anderson tells me over 2,000 are at work in Japan. "Forty percent of rice paddies are sprayed now by a Yamaha remotely piloted helicopter," Anderson says. But he adds that drone regulation and the aviation and agriculture environment are different in Japan. Air traffic is far less dense and the rice paddies are smaller than America's farm fields. Further, the Japan

▲ **Yamaha's RMAX** remotely piloted helicopter is the largest unmanned aerial application aircraft flying in the U.S.

Yamaha Precision Agriculture

Civil Aviation Bureau doesn't require certification of the RMAX.

While still focused on traditional aerial application planes, Air Tractor has made a foray into unmanned aircraft, Hirsch says. In May 2016, Air Tractor acquired Hangar 78 UAV, maker of the Yield Defender, a small autonomous quadcopter fitted with an infrared camera to shoot photos and videos of crops. But Hirsch notes that certification for large unmanned aerial application aircraft capable of carrying loads comparable to manned ag aircraft in the U.S. is "out of sight now, maybe 10 years away or more."

The Ag Cormorant, yet to be certified or even tested, will carry up to 500 liters of wet or dry chemicals. Ag pilots ask: How could an unmanned aircraft capable of carrying just one-sixth of the load of the manned AT-802 match its efficiency? Yoeli has an answer: By employing an entirely different concept of operations.

"Imagine how this would change if instead of flying back and forth to a remote field to reload, these aircraft could, whenever necessary, land on a truck that's less than a minute away and be off again after a 20-second auto-refill to continue working. That's how Ag Cormorant will operate, so the 'optimal design load' for our case is no more than 500 kilograms," he says.

Conventionally piloted aerial application

Pilots say their well-oiled operations are still more efficient than anything the drone world has conjured. Consider Downstown Aero Crop Service Inc. in the cranberry and blueberry country of New Jersey. Downstown operates six ag planes, including three Air Tractor-602s that each carry a 2,271-liter load. Four pilots and ground crew treat a variety of crops but primarily spray fungicide, insecticide and fertilizer on 1,500 hectares of cranberry and blueberry bogs.

In season, aerial application begins before dawn with Downstown's aircraft flying to an 823-meter gravel runway in the midst of the bogs. There, pesticide-licensed ground crews mix fungicide to strictly enforced proportions. When the aircraft arrive, fungicide is pumped from mixing tanks into the hopper/tanks immediately in front of the Air Tractor's cockpit. Simultaneously, a farm foreman gives the pilots computer thumb drives containing GPS coordinates for the bogs they will spray. The pilots insert the drives into GPS units in the aircraft and take off.

In "less than 90 seconds" the planes are over the cranberry or blueberry bogs, says Curt Nixholm, the company's co-owner. Pilots descend and manually turn on their spray booms as they pass the perimeters at a little over 209 kph. Yoeli says Ag Cormorant will fly at 111 kph over fields and slower for application to orchards. A light bar mounted ahead of the AT-602's cockpit using data supplied by the airplane's GPS helps pilots line up for the parallel lines they will fly across the bogs. Their spray booms are calibrated prior to flights with pressures and nozzles adjusted to spray chemicals at the droplet size and rates called for on fungicide labels — usually 38 liters per half hectare — a rate that would rapidly empty the 500-liter Ag Cormorant.

The average flight lasts about 20 minutes per aircraft and the planes return to the landing strip. Nixholm says his AT-602s can refuel and take on more chemicals in three to five minutes. Yoeli estimates that the Ag Cormorant can be refilled in 20 seconds. Over a five-hour span, Nixholm's planes will average 20 loads each. Carrying less than a quarter of the load the AT-602 carries, an Ag Cormorant would have to haul and apply more than 80 loads to achieve the same output.

The skill of ag pilots, averaging 19 years of experience according to the National Agricultural Aviation Association, allows them to spray accurately, minimizing drift — a byproduct of the aerodynamic vortices (swirling air) generated by the wingtips, propellers and rotors of ag aircraft and helicopters. Drift can result in damage to crops, wildlife and humans adjacent to fields being sprayed. Consequently U.S.-based aerial applicators are monitored for violations by the Environmental Protection Agency.

Nixholm and other ag pilots observe that drift patterns from unmanned aerial application aircraft have never been measured or studied. Yoeli says that the Ag Cormorant produces "zero vortices," adding, "all we have is two cones of fast-moving air downward because our rotors are enclosed inside the fuselage." But he admits that his claims are "based on estimates and simulations." No aerial application testing of the Ag Cormorant has been done.

Robotic aerial application

Tactical Robotics CEO Yoeli describes aerial application with the Ag Cormorant as a robotic partnership. The autonomous drone pairs with a specialized "robotic truck" that automatically reloads the drone with chemicals and refuels it. One human supervisor will be required to operate the system. Once the drone has finished spraying a field, it lands on the robot truck, the supervisor drives it to the next field, and it takes off once more to autonomously spray.

Geo-fencing — a virtual GPS-defined perimeter for a real-world geographic area — along with electronic fencing, "poles in the ground around the perimeter of a field with some electronics," will contain the Ag Cormorant within the boundaries of the area it sprays, Yoeli explains. Software yet to be created may also be used. Confining the AG Cormorant is vital because it eliminates the regulation and management needed to allow drones to fly in airspace between fields as manned aircraft do, Yoeli says. "We think this is a limitation that will exist for all unmanned agricultural aircraft."

▼ Conventionally piloted aerial application aircraft have bigger hoppers (containers) than unmanned aircraft.

Downtown Aero Crop Service

"IMAGINE HOW THIS WOULD CHANGE IF INSTEAD OF FLYING BACK AND FORTH TO A REMOTE FIELD TO RELOAD, THESE AIRCRAFT COULD, WHENEVER NECESSARY, LAND ON A TRUCK THAT'S LESS THAN A MINUTE AWAY AND BE OFF AGAIN AFTER A 20-SECOND AUTO-REFILL TO CONTINUE WORKING." — **Rafi Yoeli**, Tactical Robotics Ltd.

Yoeli says that Ag Cormorant will be more productive than manned ag aircraft because it will be able to spray by night as well as by day. But ag pilots already work at night in the U.S. Bruce Hubler, chief pilot for Valley Air in Caldwell, Idaho, says his operation has been spraying seed crops at night with aircraft-mounted flood lights "since at least 1969."

Four years ago, Hubler and Valley Air began using night-vision goggles to spray after dark. "They actually increase your depth perception," Hubler tells me. "I can see obstacles like power wires at night better than I can during the day." He notes that aerial applicators in Southern California are also using the goggles now.

Hubler believes that drones can complement manned aerial application, appropriate for treating small corners of fields and crops near housing, buildings or forests — any area an ag aircraft struggles to spray safely and effectively. He also says that development of unmanned aerial applicators should come from within the existing community of aerial applicators. Hubler says he's signed a nondisclosure agreement with a drone maker to develop "a cost-effective unmanned sprayer" capable of carrying 189 liters of chemicals — about one-tenth of the capacity of the average ag airplane.

It's realistic, he observes, noting that the unmanned aircraft offered for aerial application so far cannot legally spray many chemicals at the rates specified by their labels because they lack capacity and booms capable of meeting the requirements.

Yoeli concedes that the Ag Cormorant may not be able to spray chemicals at the volume manned ag aircraft can but explains that another factor governs the 500-liter capacity of the Tactical Robotics drone — the Missile Technology Control Regime.

The U.S. State Department describes the regime as "an informal political understanding among states that seek to limit the proliferation of missiles and missile technology." Thirty-five countries adhere to the understanding, but the State Department says the regime "is not a treaty and does not impose any legally binding obligations on partners."

Nevertheless, Yoeli says the Missile Technology Control Regime "places severe limits on the export of unmanned aircraft that can carry more than 500 Kg for more than 300 kilometers." The restriction may be lifted in the future, he predicts, "but for now it's an export-limiting factor."

Cost and safety

Air Tractor's Hirsch says the cost associated with developing unmanned aircraft capable of performing aerial application at scale along with the absence of any regulatory, legal or insurance framework are what's keeping his company from creating its own aerial application drone.

"Buying an airplane like ours is $1 million to $1.7 million," Hirsch says. "It'll fly for decades, and we think the cost of a similarly capable drone would be significantly higher today."

For comparison, Yamaha advertises the comparatively small RMAX for a price between $80,000 and $120,000.

The much larger, more capable Ag Cormorant has no price at this point. Yoeli says that its cost will be competitive with manned ag aircraft because it doesn't carry a salaried pilot who must be insured and requires just one supervisor. That's not to say it will be inexpensive.

"Admittedly a large investment is necessary," Yoeli says, "both on the aircraft itself and the specialized truck, avionics and operation to achieve the fully automated robotic application that we have in mind."

The Agriculture Department's Thomson notes that while manned ag aircraft have a measurable safety record, no metric exists for a drone capable of carrying potentially poisonous chemicals. He adds that there is no data for the economics and efficiency of unmanned aerial application drones able to operate at the same scale as manned ag aircraft. Thomson thinks aerial application drones are most relevant for specialty crops or smaller fields.

"Ag aircraft will be there in the areas where they're used as the predominant force for aerial spraying for years to come," he concludes. ★

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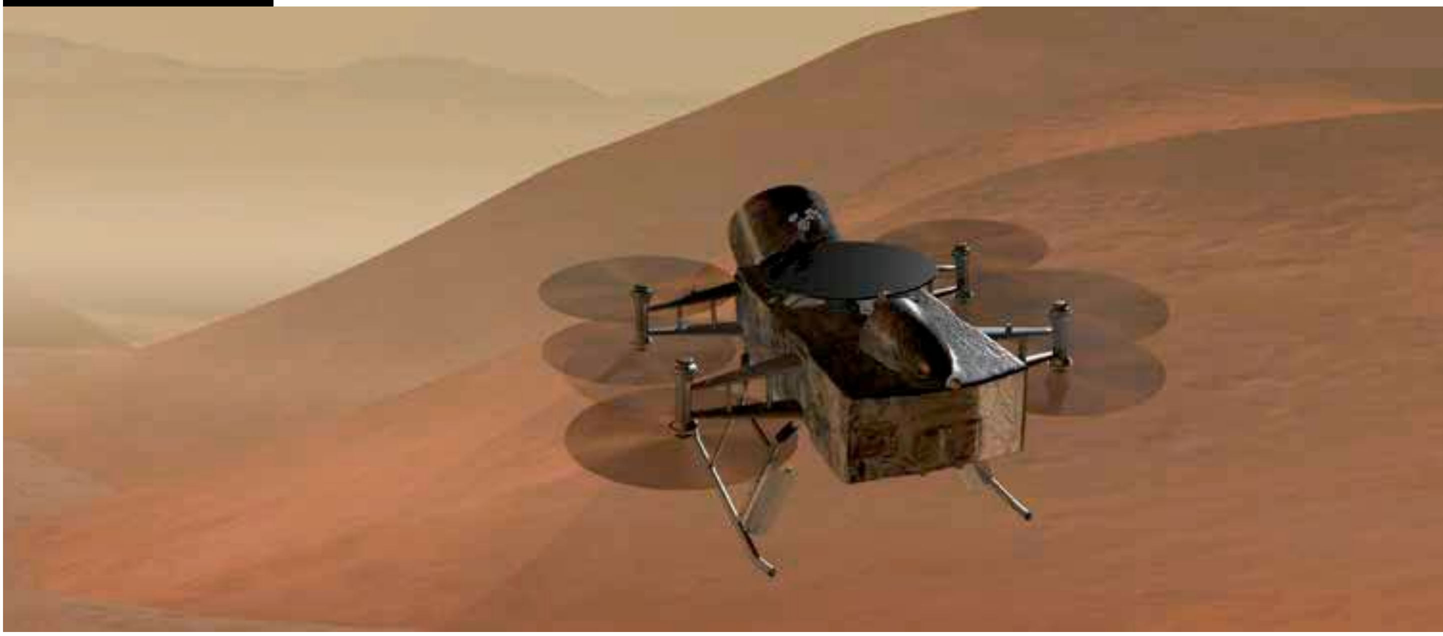


DECISION T·I·M·E

NASA'S NEW FRONTIERS

SUS ⋯⋯⋯⋯ CAESAR

NASA has limited dollars for exploring the solar system with robotic spacecraft, and it can take a decade to get such a probe to its destination. Careers are made or stalled when NASA selects a proposed mission, which is why the agency's latest New Frontiers competition is such a high-stakes affair. Adam Hadhazy spoke to the finalists vying for the prize.

BY ADAM HADHAZY | adamhadhazy@gmail.com

Where to: a comet or Saturn's icy moon Titan? That's the question NASA managers will need to answer in July 2019 when they select the next mission in the agency's New Frontiers series.

For planetary scientists, comets are tantalizing ancient messengers from the early solar system, while Titan is on the short list of places in our solar system that, though a long shot, could harbor life of some form. The decision is not an easy one.

"'Agonizing' falls far short of describing this" decision, says NASA's Curt Niebur, lead program scientist for New Frontiers. "The teams pour all of their talent and passion into this work, and they produce amazing missions. Picking only one is the worst part of my otherwise great job."

Whoever wins will have the challenge of continuing what has been a great run for New Frontiers since the initiative's founding in 2002. Its first three probes have achieved household name status among those who follow planetary science. New Horizons flew by Pluto in 2015 and is now flying by other mysterious Kuiper Belt objects. Juno began orbiting Jupiter in 2016, and OSIRIS-REx in 2020 will attempt a sample return from the asteroid Bennu.

For the fourth round, NASA in 2017 down-selected from an initial field of a dozen entrants, choosing CAESAR (Comet Astrobiology Exploration Sample Return) and Dragonfly, a rotorcraft inspired by consumer drones. CAESAR intends to bring back to Earth the first-ever sample of a comet's icy main body, critical for measuring the relative amounts of the primordial ingredients that went into making our solar system. Dragonfly, as the name implies, would flit about Titan, seeking clues about the emergence of life, both here on Earth and potentially elsewhere.

"The science content of both missions [is] extremely compelling," says Niebur.

The winner will proceed toward a flight no later than 2025 under a cost cap of $850 million. Once the launch vehicle and mission operations are factored in, NASA expects the tab to come to about $1 billion. The CAESAR and Dragonfly teams each received $4 million after the down selection to refine their concepts.

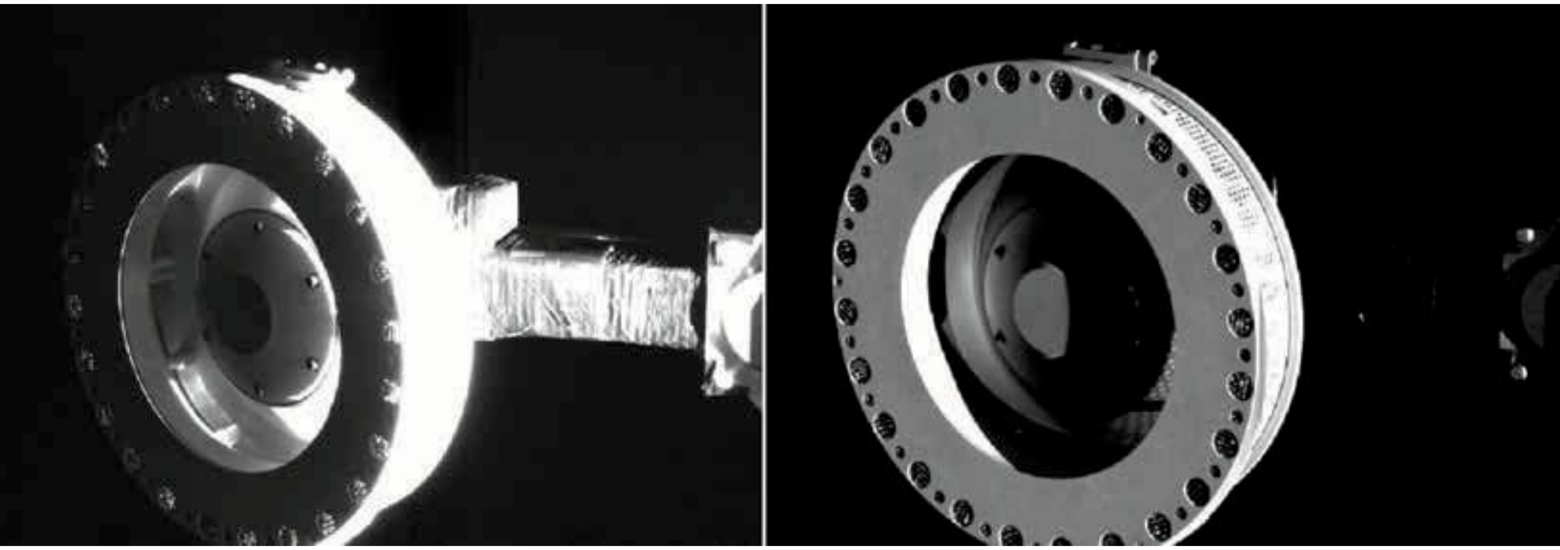
Like beverage cups, NASA's solar system exploration missions come in three sizes: small, medium and large. The smaller Discovery missions have budgets in the range of $600 million–$700 million, fly at a rate of up to a few per decade and focus on answering narrower sets of questions; arguably the most famous Discovery mission was the planet-hunting Kepler space telescope. On the large end, Flagship missions' budgets run upward of $2 billion and thus fly the least frequently. The next two Flagships are the Mars 2020 rover and the Europa Clipper.

Two review boards — one for science, the other covering technical, management and cost aspects — consisting of about 70 people are evaluating CAESAR and Dragonfly. The boards will soon submit their findings to NASA.

Here's a preview of the two proposals vying to be the next New Frontiers mission.

▼ The OSIRIS-REx Touch-and-Go Sample Acquisition Mechanism, or TAGSAM, sampling head is extended from the spacecraft in two views. The CAESAR team built a new sample collection device that was modeled on the TAGSAM.

NASA/Goddard/University of Arizona



Hail CAESAR

▲ **A camera on the European Space Agency's** Rosetta probe took this close-up view of a flat region of Comet 67P/Churyumov-Gerasimenko, which would be the CAESAR probe's destination as well.

ESA/Rosetta

In essence, comets are icy dirtballs left over from the solar system's formation 4.5 billion years ago, a fact that makes them scientific motherlodes.

"Comets represent the most primitive solar system material that's available to us for sample return," says Steven Squyres, a professor of astronomy at Cornell University and the principal investigator of CAESAR. "They're the best-preserved examples of the stuff from which the solar system was made. By sampling them, we can see into the past." Also, unlike asteroids, comets do not fall to Earth constantly as meteorites, and even if they did, their ices — made of water and other materials — would be burned off in the process. The only way to touch their constituents is to go to them.

Although multiple spacecraft have visited comets and observed them up close, these observations yield comparatively little information compared to bringing a portion of the cosmic body back home for analysis.

"When you do a sample return mission," says Squyres, "the instrumentation of your mission is essentially the combined scientific power of all the world's laboratories for decades to come." He points out that the best science ever done with the moon rocks retrieved half a century ago by Apollo astronauts is happening now, in modern labs. "Samples are a scientific gift that keeps on giving," says Squyres.

The only comet return mission to date is NASA's Stardust probe, which in 2006 returned about a milligram of cometary material, consisting of dust grains from Comet Wild-2's coma, or luminous atmosphere.

Building on Stardust's success, CAESAR's goal is to gather and return to Earth on the order of 80 to 800 grams of volatiles (frozen gases and ices) directly from a comet's nucleus. "Our motto is, 'it's all about the sample,'" says Squyres.

To avoid complications, the CAESAR team selected Comet 67P/Churyumov–Gerasimenko, one of the best-characterized space rocks in the entire solar system. The European Space Agency's Rosetta probe extensively mapped and studied 67P from 2014 to 2016. Its Philae lander module snapped high-resolution images mere meters from the surface before touching down. "One of the real keys to reducing risk," says Squyres, "is to know in advance what your target is like." Making the case, the team behind OSIRIS-REx is having to reconceive its sample return procedure because the target asteroid, Bennu, has surprised scientists by possessing a rough, rugged, boulder-strewn surface; remote radar surveying of Bennu from Earth had inaccurately suggested a smooth, easy-to-sample landscape.

Familiarity and risk reduction extend to the CAESAR spacecraft design as well, which leans on proven heritage components. The bus will be based on Northrop Grumman's GEOStar-3 communications satellites; the solar electric propulsion system, from NASA's Dawn spacecraft that journeyed through the asteroid belt; the sample return capsule, developed by JAXA, the Japan Aerospace Exploration

Agency, for its asteroid sample return missions; the sample retrieving arm, developed by NASA for the Mars 2020 rover. The CAESAR team did build a new sample acquisition device that goes at the end of the arm but drew heavily on OSIRIS-REx's, whose sampling head will emit a blast of nitrogen onto Bennu to stir up dust and pebbles. This material will be collected by a vacuum pump during the five-second touch-and-go maneuver.

Where CAESAR necessarily innovates is in sample preservation. Comet material cannot be simply hermetically sealed after capture, because putting volatiles and nonvolatiles in a confined space could trigger sample-damaging chemistry that wouldn't naturally occur on a comet. Prior asteroid sample return schemes have therefore let the samples vent to space en route back to Earth. CAESAR's designers had to hatch a plan so as to not lose the precious volatiles. That plan involves gently warming the sample to minus 30 degrees Celsius (minus 22 degrees Fahrenheit) — about the temperature Comet 67P's surface naturally reaches during its closest sun approaches. Doing so releases the comet's volatiles, but these are directly captured in a separate, chilled, 5-liter tank. This container is then sealed shut, while the mostly dried, solid sample innocuously vents to space. "This is the key innovation that distinguishes CAESAR from any prior attempts to do comet sample return," says Squyres.

The final obstacle will be to keep the comet material suitably cold through the capsule's entry, descent and landing, when friction with the atmosphere flame-broils a heat shield up to 3,000 degrees Celsius. Part of the solution will be to surround the sample container with aluminum housings filled with dodecane, a hydrocarbon that has a melting temperature of about minus 10 degrees Celsius (14 degrees Fahrenheit). During entry, heat will be pumped behind the heat shield, the frozen dodecane melts, plateauing the temperature at a sample-preserving level. Closer to the ground, the heat shield will drop from the capsule while it's coasting down via parachute. This prevents the capsule from coming to rest on the ground with a foundry-hot shield attached. Overall, these tactics buy a capsule retrieval team an ample four to five hours before any sample alteration would take place.

The capsule's landing zone will be the Utah Test and Training Range, some 130 kilometers east of Salt Lake City (and the same site employed for Stardust's sample return and OSIRIS-REx's, come 2023). Upon retrieval, the capsule will be airlifted into a cold storage vehicle — nicknamed the ice cream truck — for delivery to a planned dedicated CAESAR facility at NASA's Johnson Space Center in Texas.

Should the mission be greenlit, CAESAR would launch in 2024 and have to travel beyond the orbit of Jupiter to make its rendezvous with 67P come 2029. Out there, the comet will be far enough from the sun's warmth to be ideally stable and quiet for performing an astronomical biopsy. The CAESAR spacecraft wouldn't then return to Earth's vicinity until November 2038. It would be a long wait, but Squyres argues well worth it.

"We're talking groundbreaking science for decades to come," says Squyres.

Flight of the Dragonfly

In many respects, Saturn's moon Titan is a cold, bizarro version of our planet. Though the only other body in the solar system known to have liquid bodies on its surface, Titan's seas and rivers are not aqueous; instead, they're filled by tar-like hydrocarbons, replenished by seasonal, un-Earthly rains. Geologically, Titan has familiar features like mountains and dunes. Yet all have formed in an environment three times colder than Antarctica. The world further intrigues because it is thought to possess a global ocean of water, sloshing around under an icy surface shell. The proverbial cherry on top: Titan's rich chemical inventory, with organic (carbon-containing), "prebiotic" molecules, the building blocks of life, strewn about its surface.

Scientists know all this from the Cassini orbiter and Huygens lander. These spacecraft arrived in the Saturnian system in 2004.

Cassini mapped and remotely sensed Titan, while Huygens parachuted through Titan's thick, hazy atmosphere in January 2005, touching down and snapping pictures on the surface for 90 minutes; it still stands as the most distant landing humankind has accomplished.

Dragonfly would visit scores of sites on Titan, offering an unprecedented look at extraterrestrial conditions conducive to biology. Admittedly an extreme longshot, Titan might already host alien life, a tantalizing prospect Dragonfly could assess.

"Titan is just this incredibly unique opportunity to be able to really study in detail prebiotic chemistry and habitability," says Elizabeth Turtle, a planetary scientist at the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland, and the principal investigator of Dragonfly. "It's an environment where we have all the ingredients we need for life as we know it."

Dragonfly would be an octocopter with a top-and-bottom pair of rotors at its four corners. It would make leapfrog-style jaunts between potentially scores of landing sites of interest, spread tens of kilometers apart. Space agencies have never before attempted to fly a probe in another world's atmosphere. Yet the technology is now at a place where this horizon-expanding search strategy and design looks feasible.

"The drone revolution has enabled all this autonomous flight and rotorcraft technology," says Turtle.

The first technology demonstration of an extraterrestrial science drone is slated to be a small, 2-kilogram helicopter accompanying NASA's Mars 2020 rover, scheduled to land on the red planet in February 2021. Compared to that Martian drone, Dragonfly would be a beast, standing about a meter tall and weighing a few hundred kilograms. If that sounds

▼ **The Dragonfly probe** is seen in various stages of its operations on Titan in an artist's concept. From left, the images represent entry, descent, surface activities and flight.

Johns Hopkins Applied Physics Laboratory

Flight control and navigation demonstrated at a Dragonfly field test.

Johns Hopkins Applied Physics Laboratory

"As a human being, if you put some wings on your arms, had an oxygen source, and a really good sweater, you'd be able to fly on Titan."

— **Elizabeth Turtle**, Johns Hopkins Applied Physics Laboratory

too heavy to fly on Earth, that's the point; Titan has only one-seventh of Earth's gravity and its atmosphere is denser, with about 60% greater pressure. "It is a lot easier to fly on Titan than on Earth," says Turtle. "As a human being, if you put some wings on your arms, had an oxygen source, and a really good sweater, you'd be able to fly on Titan."

Much of Dragonfly's curb weight is expected to be from the battery. As a rough, high-end estimate, designers assumed a 140-kilogram unit, about a quarter of the size of a Tesla electric car's battery pack. The battery would recharge by drawing power from a Multi-Mission Radioisotope Thermoelectric Generator, or MMRTG. NASA has access to enough plutonium fuel to construct two more MMRTGs after the generator already committed to the Mars 2020 rover.

If selected for New Frontiers Four, Dragonfly would launch in 2025, reaching Titan nine years later. The probe would bring science instruments including spectrometers for detailed chemical analysis, a meteorology package, a seismic sensor and — of course — cameras. The intended landing zone is Titan's equatorial dunes, at a similar latitude as Huygens' site. These sand seas offer a safe, mostly rock- and gully-free place to put Dragonfly through its paces before visiting more exotic Titanian environments. One such destination could be outflows from cryovolcanoes, possibly recently active, which spew a cold slurry of water and hydrocarbons, versus Earth's molten lava. Outflows could offer key insights into if and how the organics-laden surface of Titan interacts with the moon's internal water ocean.

Overall, Titan's astrobiological appeal is immense. "We want to understand how chemistry progresses to the point of biology," says Turtle. "With the drone revolution and all this information we have from Cassini, the timing is really perfect to go and study Titan's chemistry and implications for the development of life."★

AIAA/IEEE ELECTRIC AIRCRAFT TECHNOLOGIES SYMPOSIUM

22–24 AUGUST 2019 | INDIANAPOLIS, INDIANA

Building upon a successful event in 2018, the 2019 Electric Aircraft Technologies Symposium will look at progress over the past year and continue the discussion about the aerospace industry goals for future aircraft. To accommodate rapid growth in emerging markets and ensure sustainability of air travel, one approach being explored is using nontraditional aircraft propulsion: electric, turboelectric, or hybrid-electric powertrains. AIAA and IEEE crafted this unique symposium to bring the aerospace engineers and the electrical engineers together to discuss these topics and their challenges.

The 2019 symposium will focus on electric aircraft technology across three general areas: electric-power-enabled aircraft configurations and systems requirements, enabling technologies for electric aircraft propulsion, and electric aircraft system integration and controls.

TOPIC AREA 1

Aircraft Configurations and Systems Requirements

- System feasibility studies
- Electric-enabled innovative aircraft design and propulsion concepts
- Electrical powertrain performance requirements
- Safety, critical failure modes, certification
- Lifecycle energy, operational cost, and emission analysis

TOPIC AREA 2

Enabling Technologies and Components

- Machines and drives integration for optimum performance
- Conventional, cryogenic, and superconducting
- Energy storage devices and systems
- Electric machine and gas turbine integration
- New material solutions or applications
- Novel thermal management solutions

TOPIC AREA 3

System Integration and Controls

- Electric powertrain architectures
- Fault isolation and reconfigurable systems
- Energy management systems
- Integrated electro-thermal systems
- System modeling tools
- Monitoring and diagnostics
- Verification and testing

Detailed Agenda

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PITCHING TO

NASA and the Pentagon want to be more open to innovative ideas from entrepreneurs and business development managers, and they are creating in-person opportunities to hear from them. The catch is that it can be nerve-wracking to try to convince members of an audience to buy a product, invest in it or just believe in it. Amanda Miller shares advice from veteran pitchers.

BY AMANDA MILLER | agmiller@outlook.com

▲ **NASA iTech hosted** Ignite the Night at the Space Symposium in Colorado. The NASA program gives young companies, academics and government agencies a chance to pitch their ideas.
Space Foundation

“I don’t know if you heard recently, in the news? There was an incident in an Antarctic isolation study. One crew member stabbed another crew member.”

The audience quieted down, and entrepreneur Alires Almon had our undivided attention.

She was one of about a dozen small-business executives who gathered in Denver to make elevator pitches at last November’s Innovation and Opportunity Conference, a first-of-its-kind, NASA-sponsored event that I attended, where government agencies were put in contact with new players and vice versa.

Almon was pitching her company’s idea for a computer-based method to predict human behavior.

She continued: What precipitated the stabbing? The victim hadn’t hoarded food or slacked on chores. “They stabbed ’em because they were telling the ending of books that they were reading.”

The new method would have diffused the tension to “more of a verbal argument, or better yet, prevented it altogether.”

Within a couple of minutes, we all knew what her company, Deep Space Predictive, is all about: empowering teams of space explorers to get along and manage any disputes peacefully.

This was Almon’s debut pitching the idea publicly, but she was able to draw on her experience in public speaking in other contexts. Not everyone adapts as easily to the art of the pitch.

The crop of aerospace entrepreneurs I’ve met at industry events over the past year mostly uttered variations on “nerve-wracking” to describe the experience of pitching their ideas in front of an audience of investors or government acquisition officers. Here are some lessons from them, along with advice from pitch insiders.

Business case

A frequent pitfall for aerospace startups is focusing on the technology while giving “zero thought to actual business,” says Rachel Cheetham, the Rocky Mountain regional director for the U.S. Defense Department’s NSIN, for National Security Innovation Network. “You come in with a high TRL” — technology readiness level — “but your business readiness is nothing.”

Traditionally, the military has learned about industry capabilities through informal conversations in centralized offices, followed by official paperwork submitted in response to requests for information or broad agency announcements. The 4-year-old innovation office provides new avenues.

NSIN, which changed its name in May from MD5, puts on pitching contests, among other events such as collegiate “hackathons,” and tracks tech startups with the aid of regional portfolio managers such as Cheetham. She may connect a company with investors; help find a place to build a prototype; or go back to military units, such as those at the Air Force bases in Colorado Springs, to get ideas for product improvement.

Cheetham headed up a pitch contest in Denver last October. On hand to present, judge and watch were several hundred people drawn from the service branches, the intelligence agencies, and the research and private investment communities. The winner got $5,000, but the real prize was getting to pitch in front of that crowd.

Of 30 companies that submitted videotaped pitches, five got to make live presentations.

The five finalists in October got through because they made a business case — they could "clearly articulate the value proposition," Cheetham says.

Group goal

A subscriber to the pitching school of thought that "all exposure is good exposure," Michael Hurowitz took the podium as one of NSIN's final five in Denver to describe how a constellation of microwave-detecting, three-unit-long cubesats could map temperatures and precipitation around the world, amounting to a new source of weather data for the airlines and others.

Hurowitz is chief technology officer and senior vice president of engineering for Orbital Micro Systems of Boulder, Colorado, and one of seven co-founders from the local science community. The staff of 15's first technology-demonstrator cubesat went into orbit on a resupply flight to the International Space Station in April and is waiting to deploy, probably in July, depending on astronaut schedules.

Hurowitz thinks more doors will open in terms of customer interest once that first satellite starts sending home data. "There's a high bar in this industry to be taken seriously," he says.

When he travels to conferences for business, Hurowitz prioritizes events that bring together people from other industries outside the space sector. Besides aviation, agriculture is another industry that Orbital Micro wants to grow.

Hurowitz says he most values the chance to present in front of a group like at the NSIN pitch contest:

"Now people know who you are, and if they think you have something to talk about, they can come find you," he says.

Talk it out

The Air Force hosts its own technology accelerator for small businesses in Colorado Springs apart from NSIN. The day before we talked for this story, co-founder and CEO Rod Goossen of Denver-area startup RoGo Fire had pitched there.

An avionics engineer, Goossen got the idea to start a company after something his brother, a wildland firefighter, said following the Yarnell Hill Fire that trapped and killed 19 firefighters in Arizona in 2013.

"I said, 'How could this happen?'" Goossen recalls. "He said, 'We're still using paper maps, compasses and two-way radios.'"

RoGo Fire's founders want to relay real-time information to wildland firefighters by satellite — data including weather, texts, firefighters' own whereabouts, that of others, and of equipment. He and two partners, including his brother, have moved the business into a coworking space to work on an early iteration that will plug into an off-the-shelf tablet. The facility caters to companies making things out of electronic components.

▲ **Devaki Raj, CEO and** founder of CrowdAI, pitches her company to an audience of small-business people, venture capitalists and airmen in New York at Air Force Pitch Day. The Air Force created the event to find small businesses to work with on national security in air, space and cyberspace.

U.S. Air Force/Tech. Sgt. Anthony Nelson Jr.

Aside from a possible National Guard activation, the military doesn't fight wildfires, but Goossen was glad he got to pitch for the Air Force accelerator anyway. It turns out a system like RoGo Fire could be useful in a combat scenario.

As the CEO and technical expert, Goossen does all the pitches.

"It's taken some work. I think it's come to me easier than it would come to many people. But still, I'm in no way saying I'm great or even good at it," he confesses.

Even things like nonverbal gestures factor into the delivery style.

"It's absolutely necessary for any pitch to be practiced in front of a nonintimidating crowd," he advises.

Head start

The University of Colorado-Boulder plans to get engineering students up to speed on pitching by

▶ **Alires Almon of** Deep Space Predictive practices her pitch.

Alyson McClaran

> "It's absolutely necessary for any pitch to be practiced in front of a nonintimidating crowd."
>
> — Rod Goossen, CEO and co-founder of startup RoGo Fire

offering a minor in engineering entrepreneurship starting in the fall.

The "problem-rich environment" of the space sector promises lots of opportunities for future entrepreneurs, says Kyle Judah, director of entrepreneurship in the university's College of Engineering and Applied Science, who was wooed away from MIT.

One new class will guide students through the "venture-building process" from an idea through production of a working prototype — a lot like what the venture world calls a "startup weekend," Judah says, but stretched over a whole semester and providing "a much better idea of, 'Is this viable or not?'

"The majority of ventures that start in a classroom, or on a campus, will never translate into an industry," Judah says. "It's about helping develop the entrepreneurial mindset and skill set to do it."

Part of the university's strategy has been to host startup weekends on campus. One was a privately run, pitch-intensive, space-themed startup weekend held last October. Entrepreneurially spirited students, alongside executives from a few small companies around Colorado, divided into teams and made pitches all weekend, aiming for the first-place prize of an invitation to pitch at the Satellite 2019 conference in Washington, D.C., in May.

BUSINESS BOOSTER

The Space Foundation in Colorado Springs, Colorado, has created a series of free video webinars aimed at helping space entrepreneurs. Among the 15 videos are "The Future of Space Commerce," "Intellectual Property in the Aerospace Industry," "Space Law" and "Growing Your Business." The videos were made with a grant from the U.S. Commerce Department's Minority Business Development Agency.

To get warmed up, the actual and aspiring entrepreneurs had to improvise a pitch from a set of ideas that people randomly yelled out.

Many ways to win

The weekend culminated in a round of pitches made for a panel of judges, all experts in entrepreneurship or members of the space industry.

CU Boulder engineering physics major Kathy Vega stood up to make her final pitch. Several competing ideas were made up largely to practice the business-building process, but not Vega's.

"As a student studying engineering, I've had the opportunity to work on cubesat missions," she told the judges. "I spent hours and hours just sourcing the supplies and materials we needed for our cubesat. In fact, one time I was looking for a hinge. [Hinges] are very important for building solar panels on cubesats. It took me weeks just to find a supplier for this hinge and then a couple more weeks to get on the phone with someone so I could get a [price] quote.

"Our solution is to create one central marketplace for cubesat products. This center would have all the information you need on all the parts you need — so hundreds of hours of engineering labor in just a few hours of point and click.

NASA and Pentagon officials watch presentations at NASA's pitch event.
Space Foundation

"And this isn't just useful for those creating the cubesat, but it'll be a great value for the current suppliers of cubesat parts because we would be able to generate new leads for these suppliers as well as create new customers.

"After speaking with some suppliers, right now the best way to do this is driving from conference to conference or calling up different places to try to sell their product," Vega said.

She didn't win — other teams scored higher on teambuilding aspects that weekend — but the judges deemed her idea the most likely to be a real business one day, and one of them stayed on as a mentor.

Cross the "t" in customer

In the weeks leading up to her March testimony on human space exploration before the National Space Council, Wanda Sigur tells me she's made pitches over the years and heard a lot of them — "That's pretty much the nature of the game, of course."

An independent consultant and adviser for space startups since 2017, when she retired from Lockheed Martin Space Systems as a civil space programs vice president and general manager, she tells me the story of a recent pitch gone wrong.

A startup company wanted $30 million from investors to build a production facility. The company had demonstrated a product, and the executives had customers in mind: "They were focused on large primes, but they had no letters of intent, no commitments — nothing," Sigur says. A pitch asking for such a "big chunk of money" as $30 million, without documented customer interest, "left folks a bit cold."

To get good investors onboard, Sigur tells entrepreneurs they should demonstrate credibility and a history of turning an idea into a product; and show that they've assessed risk, cost, customers and the competition.

PITCHES ARE TRENDING

"Pitch Days are new fast tracks for startups to work with the Air Force," says Will Roper, assistant secretary of the Air Force for acquisition, technology and logistics, in remarks on the U.S. Air Force's website for its first Air Force Pitch Day in March. The Air Force posted topics online in November and invited finalists to make 15-minute pitches at a competition in New York. The 51 winning companies got a combined $3.5 million in award money the same day.

Wild pitch

As a civilian working for various Defense Department offices over the years, including eight years at the U.S. Missile Defense Agency, Shane Deichman made internal pitches for technologies that he wanted to develop, and he heard contractors make pitches.

One pitch in particular was memorable. "We had one major defense prime — one of the big top five primes — their guy came in and proceeded to lecture us," Deichman recalls. The beef had to do with perceived corporate bias in the proposal process.

"I thought, 'You're one of the most massive defense primes in the history of the world, and you're coming in and lecturing us?'" says Deichman, who now heads business development for Teledyne Brown Engineering. "The best pitches always have a little bit of give and take. They really are a conversation, a two-way dialog." ★

NASA's single-aisle turboelectric aircraft with aft boundary-layer propulsor, or STARC-ABL, concept.

NASA

Flying electric

Aerospace innovators should look to history as they seek to carve a place in the market for electric aircraft amid enormous societal stakes. Today's aircraft have significant carbon footprints; more passengers than ever want to travel by air; and the supply of fossil fuels in the world is finite. Amir S. Gohardani explains.

BY AMIR S. GOHARDANI

A New York Times reporter was about to witness something spectacular. Stooped over a table in a laboratory in Menlo Park, New Jersey, Thomas Alva Edison observed the makeshift filament of a lamp. Moments earlier, he had tested its vacuum and asked his assistant to seal it. As the dynamo bled power to the lamp, the reflection of light started shining in Edison's blue eyes, according to the reporter's account from 1879.

Many recognize Edison as the first inventor of incandescent light. Yet, Edison was not the first person to create it. In fact, he studied the work of many other prominent inventors and researchers to accomplish his unique breakthrough. Unlike previous electric lamp designs, Edison's solution required less power and lasted longer. The current state of affairs with electric aircraft bears some resemblance to the development of incandescent light. If all-electric aviation for large numbers of passenger transport ever happens, it will not occur overnight. Small feats of invention will be needed along the way to achieve an optimal solution.

Rethinking transportation

As exciting as aerial electrification is, air travel is not the only contender for future transportation. Emerging trends of electrification are sweeping through the transportation sector with identified targets such as surface vehicles, trains and ships. But what could be the key underlying reason for such trends? A possible answer is the urgency for rethinking transportation due to its environmental impact and the chance that fossil fuels will run out.

According to the U.S. Bureau of Transportation Statistics, transportation became the largest source of carbon dioxide emissions in the United States in 2016 and continued to be the largest emitter of this greenhouse gas in 2017. The transportation sector relies on petroleum for 92.2% of its energy requirements and accounted for 70.6% of U.S. petroleum consumption in 2017, the highest level since 2009.

Overcoming these energy-supply and environmental hurdles is about to become even more challenging, given expectations of increasing demand for air travel. The FAA forecasts that the number of domestic passengers in the U.S. will grow by 1.8% each year through 2039. The solution won't be as simple as introducing additional aircraft to meet the demand. Since the first powered, heavier-than-air machine achieved controlled, sustained flight, this sector has gradually reduced noise and emissions, while achieving new fuel efficiency levels. There is an opportunity for even more progress by developing electrified aerial platforms, a catch-all phrase covering everything from hybrid aircraft to today's power-hungry Airbus 380s and Boeing 787s to all-electric aircraft.

Despite their potential advantages, however, electric aircraft also face hindrances. Critics of electric aviation commonly highlight its shortcomings and confinement to platforms solely suitable for a small number of airborne passengers or short aircraft range. Moreover, visions for all-electric aircraft capable of transporting a large number of air travelers are occasionally brushed off as dreamlike concepts unlikely to materialize. These criticisms are not simply rooted in blind pessimism. They often stem from genuine insights into the deficiencies of supporting technologies that will need to be addressed before electric aviation can expand. These are the smaller inventions akin to those that ultimately empowered Edison to impress the New York Times reporter with his incandescent lamp.

Usually, one of the distinct characteristics of electric aircraft is the employment of electric motors instead of internal combustion engines. All-electric concepts, which unlike hybrids aren't aided by combustion engines, have in recent years demonstrated their benefits in terms of noise and hazardous-emission reductions mostly for unmanned applications and aircraft with small numbers of passengers. Currently, they also show limited promises for someday carrying a larger number of passengers. Now, designers are increasingly exploring a host of innovations under the all-electric banner, including solar cells, fuel cells, ultra-capacitors, better batteries and motors. A power-by-wire concept, for instance, provides many benefits, including moving aircraft flight surfaces electrically, minimizing or eliminating hydraulic systems with their flammable liquids and specific temperature and pressure requirements.

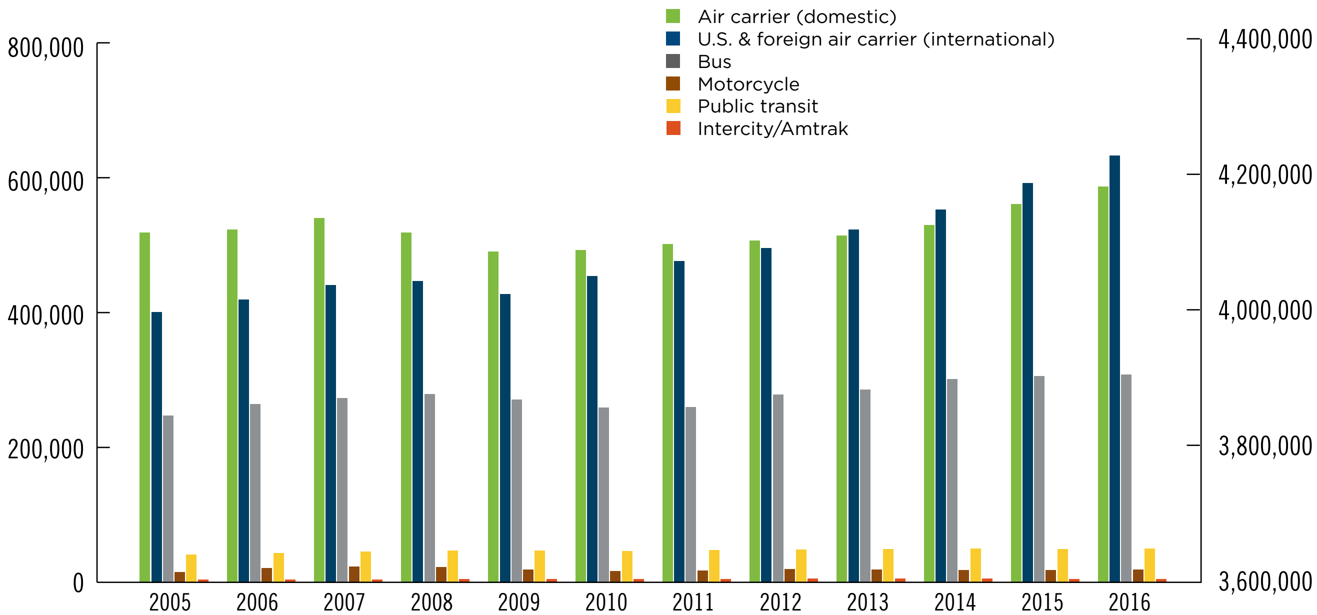
▲ **The Airbus A380,** top, and the Boeing 787, bottom, have numerous electrical components.

Airbus and Boeing

Nonetheless, due to the typical impractical weight per power unit of some all-electric architectures, a distinct conflict arises when the all-electric aircraft vision is applied to a larger airframe with increased gross weight. Still to be solved is the complexity of combining the hydraulic and pneumatic power systems with the electrical system, while maintaining safe flight. The air transportation industry has taken steps in that direction with what are known as MEAs, or More Electric Aircraft, the architectures of the Airbus 380 and Boeing 787 being prime examples. On the Airbus A380, the horizontal stabilizer backup

U.S. passengers like to fly

The number of passenger miles traveled in the U.S. between 2005 and 2016 shows that flying's popularity continues to climb.



Source: U.S. Transportation Department

and thrust reverser actuation function electrically. On the 787, electrical system features include environmental control systems and electro-hydraulic pumps for actuation.

Going forward, engineers will need to identify remedies to raise technical readiness levels and assess the optimized capabilities of safe electric aviation. A leaf out of the history books reveals that such efforts typically consist of various phases of technology life cycles. The trials ahead for electric aircraft do not translate only to inadequacies of battery technology or limited payload, range and endurance. In essence, they are not even exclusively technology driven. Environmental policies, legislative aspects and business incentives favoring more environmentally friendly transportation solutions are all important elements affecting future electric aviation.

Through a macroscopic lens, the transportation sector can either choose to ignore its impact on the environment entirely or to reinvent itself with more environmental friendly footprints. Based on current environmental challenges and global access to finite sources of fossil fuels, the second alternative is likely to gain momentum only if its value proposition is aligned with regulating governmental bodies or if it is embraced by the business sector due to distinct incentives.

It can be argued that current electrification endeavors are part of an S-curve of technological progress, a graph that shows the rate of progress over time. The progress starts slowly (the bottom edge of the standing S) in an embryonic, new invention period; the middle part marks rapid growth in the technology improvement period, and the upper part marks a mature technology period. This final phase exemplifies a period when the technology performance parameter reaches its physical limit. Based on the technical achievements of one technology, the S-curve of the same or an adjacent technical field can be juxtaposed next to it, and work on the electric aircraft can therefore begin at a higher embryonic or technical readiness level.

Electric aviation

During World War II, or more exactly, on Feb. 2, 1943, power engineer Lee Kilgore and his colleagues filed a patent application on behalf of Westinghouse Electric Corp. titled "Electrical Airplane Propulsion." Kilgore and a number of fellow inventors highlighted weight obstacles associated with electric power transmission that left electric airplanes in the realm of impracticability. They unveiled their notable achievement of weight-reduction per horsepower. Decades after this patent application, the aerospace industry still struggles with weight aspects of electric aircraft. Now more than ever, energy storage onboard electrified platforms is of paramount importance. In pace with the adoption of additional electrical components, such as electric motors, in support of electric aircraft architectures, an uptick in energy demand is also noted. This demand stems from operating additional electrical systems to minimize mechanical and pneumatic means to the extent possible.

Over time, increasing the size of electric generators has consequentially required increasing the size of engine nacelles and electric motors. Higher energy density storage advancements are unceasingly being investigated to enable better usage of electric power distribution. Distinctly, batteries still signify one of the technical challenges of electric aviation. Electric aircraft featuring battery technologies are specifically impacted as batteries remain as payloads and are not burnt away as jet fuel. Moreover, the energy density of existing batteries is not yet comparable to that of jet fuel. Despite the higher efficiency of electric motors — compared to fuel engines — all-electric concepts and demonstration aircraft continue to battle with their shortcomings in terms of aircraft range and transportation of large numbers of passengers. Yet, there is hope. The glimmer of hope rests with prominent researchers, educators, engineers and those who seek to address the shortcomings of electric aviation. Whether the issues are low energy-density storage, limitations with respect to electronic parts or excessive weight per power unit, and other topics, an abundant number of organizations seek solutions, including the U.S. Defense Department, FAA, NASA, and other educational, research and government institutions.

NASA has spearheaded a significant share of research into electric aircraft. The agency is investigating hybrid electric aircraft to gain further insight into the capabilities of such concepts. Following the success of NASA's Environmentally Responsible Aviation project, the agency has revived its exploratory opportunities for aircraft fuel savings, noise reductions, and reductions in emissions of carbon and nitrogen pollutants, with specific considerations for on-demand mobility and safety. Even so, NASA is not the only entity seeking electrically enhanced propulsion systems or hybrid-electric solutions. As a matter of fact, for a portion of the industrial sector, the path to all-electric aircraft that can transport larger numbers of passengers starts with hybrid-electric architectures. This is particularly an intermediate solution as currently the technical readiness levels of supporting technologies limit all-electric aviation to short-range flight and a small number of passengers. Hybrid-electric aircraft architecture could bring some advantages. For example, hybrid gas-electric propulsion enables heavier payload, new mission capabilities including duration and durability, as well as noise, emission and operational cost reductions.

Future electric aviation and transportation

As different organizations investigate energy storage, component characteristics, propulsion-airframe integration aspects, energy conversion technologies and a myriad of supporting measures to enable electric aviation, the industry is carefully tracking the two key alternatives electrification technologies are likely to affect aerial transportation. Whether an evolutionary transformation aligned with further development of electric aircraft or a revolutionary transformation that advocates electric propulsion, the electrification process is not solely a function of technology. On the contrary, environmental, political, sustainable, legal and business incentives also bear weight in the evolutionary or revolutionary shifts of electrified aerial platforms, whether hybrid or all-electric. Societal solutions are best viewed from a holistic perspective. Therefore, more electric aircraft or all-electric aircraft should be viewed based on their overall impact on society. Moreover, enabling technologies should also be considered based on the environmental impact they have throughout their entire lifecycle. For example, if an enabling technology consistently results in excessive carbon dioxide emissions in its manufacturing process, the severity of its environmental footprint might overshadow a potential positive environmental impact it might have on an electric aircraft.

As the transportation sector explores new modes of transport, all options should remain on the table. Electric aviation might be a viable solution for future societies. Whether all-electric aircraft platforms for a larger number of passengers ever will be possible or hybrid-electric aircraft would be more suitable for a large number of passengers needs to be investigated. But the transportation sector should not treat one specific mode of transport as a threat to the others. Rather, different modes of transport should be considered as complementing each other for meeting U.S. passenger transport demands. For instance, if trains can assist passengers on shorter routes or assist the aviation sector to access airports, such synergistic effects should be considered. Finally, in a throwback to Edison's incandescent light, the global aviation industry is likely to benefit from the equivalent likes of inventors Joseph Swan and Humphrey Davy, who made significant contributions to incandescent light. The Edisons of electric aviation could emerge from the incremental research contributions of independent entities repeatedly targeting the shortcomings of electric aircraft in anticipation of sustainable breakthroughs. ★

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

Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2019			
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)	
15–16 Jun	Practical Design Methods for Aircraft and Rotorcraft Flight Control for Manned and UAV Applications with Hands-On Training Using CONDUIT®	Dallas, TX	
15–16 Jun	Designing Unmanned Aircraft Systems	Dallas, TX	
15–16 Jun	Hypersonic Flight: Propulsion Requirements and Vehicle Design	Dallas, TX	
15–16 Jun	OpenFOAM Foundations: The Open Source CFD Toolbox	Dallas, TX	
16 Jun	Principles of Electric VTOL	Dallas, TX	
16 Jun	Workshop for Integrated Propeller Prediction (WIPP)	Dallas, TX	
16 Jun	Workshop for Multifidelity Modeling in Support of Design and Uncertainty Quantification	Dallas, TX	
17–21 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition)	Dallas, TX	7 Nov 18
17–21 Jun*	International Conference on Icing of Aircraft, Engines, and Structures	Minneapolis, MN	
25–27 Jun*	2nd Cognitive Communications for Aerospace Applications (CCAA) Workshop	Cleveland, OH (ieee.org/CCAA)	
11–15 Aug*	2019 AAS/AIAA Astrodynamics Specialist Conference	Portland, ME (space-flight.org)	5 Apr 19
16–18 Aug	Rocket Testing Workshop at Purdue Zucrow Labs	Indianapolis, IN	
17–18 Aug	Applied Model-Based Systems Engineering Course	Indianapolis, IN	
17–18 Aug	Hypersonic Air-Breathing Propulsion: Emerging Technologies and Cycles Course	Indianapolis, IN	
17–18 Aug	Integrated Performance Assessment of Boundary Layer Ingesting Aircraft and Highly Integrated Propulsion Concepts Course	Indianapolis, IN	
17–18 Aug	Missile Propulsion Course	Indianapolis, IN	
19–22 Aug	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition)	Indianapolis, IN	31 Jan 19
21 Aug	Aircraft Electrified Propulsion Systems and Component Design Course	Indianapolis, IN	
22–24 Aug	AIAA/IEEE Electric Aircraft Technologies Symposium (EATS)	Indianapolis, IN	31 Jan 19
21–22 Sep*	Amelia Earhart Aerospace Summit	West Layfayette, IN (earhartsummit.org)	
26–27 Sep*	CEAS-ASC Workshop 2019 on Advanced Materials for Aeroacoustics	Rome, Italy (https://www.win.tue.nl/ceas-asc)	
21–25 Oct*	70th International Astronautical Congress	Washington, DC	28 Feb 19

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

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

AIAA Continuing Education offerings

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

2019 AIAA Aerospace Spotlight Awards Gala

AIAA presented its most prestigious awards at the AIAA Aerospace Spotlight Awards Gala on 15 May, at the Ronald Reagan Building and International Trade Center in Washington, DC. The Class of 2019 AIAA Fellows and AIAA Honorary Fellows were also recognized at the event.

For more information about the AIAA Honors and Awards Program, contact Patricia Carr at patriciac@aiaa.org or 703.264.7523.

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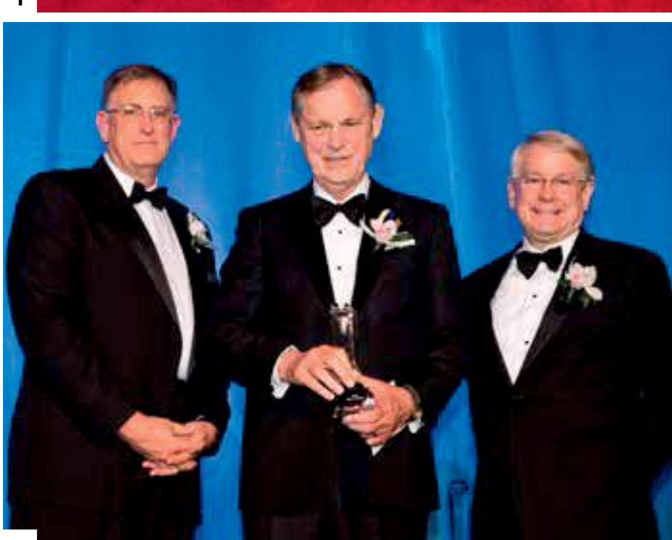

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1 Class of 2019 AIAA Fellows and Honorary Fellows (not pictured: AIAA Honorary Fellow Dennis Muilenburg, and AIAA Fellows Mark Pasquale and XinGuo Zhang).

2 AIAA Executive Director Dan Dumbacher (left) and President John Langford (right) with John L. Junkins, recipient of the 2019 AIAA Goddard Astronautics Award.

3 AIAA Executive Director Dan Dumbacher (left) and President John Langford (right) with Philippe R. Spalart, recipient of the 2019 AIAA Reed Aeronautics Award.

4 AIAA Executive Director Dan Dumbacher (left) and President John Langford (right) with Klaus D. Dannenberg, recipient of the 2019 AIAA Distinguished Service Award.

5 AIAA Executive Director Dan Dumbacher (left) and President John Langford (right) with Pamela A. Melroy, recipient of the 2019 AIAA Public Service Award.

6 AIAA Executive Director Dan Dumbacher (left) and President John Langford (right) with Katya M. Casper, recipient of the 2019 AIAA Lawrence Sperry Award.

7 (Left to right) AIAA Foundation Chair Jim Maser with the 2019 AIAA Foundation Educator Achievement Award recipients — Charlotte Cook, Patricia Palazzolo, and Megan Tucker — and President John Langford and AIAA Executive Director Dan Dumbacher.

7

MAKING AN IMPACT

AIAA Student Design/Build/Fly Competition

AIAA's Design/Build/Fly (DBF) Competition encourages excellence in aerospace engineering skills at the undergraduate and graduate levels by challenging teams to design and fabricate a radio-controlled aircraft, submit a written report about the aircraft's design, and fly their aircraft over a defined course while carrying a payload and landing it without damage.

In April, at the 23rd annual DBF, 77 teams comprising 785 students had designed a multi-purpose aircraft to support carrier operations. Ninety-six flights took place at the Tucson International Modelplex Park Association (TIMPA) Airfield and the team representing Slovenia's University of Ljubljana won the event. The other top scoring teams were from Georgia Tech and Austria's FH Joanneum of Applied Sciences.

Thank you to our sponsors: Primary: Raytheon and Textron Aviation; Gold: Lockheed Martin, AeroVironment, Aurora Flight Sciences, General Atomics and MathWorks; Silver: Honeywell; and Bronze: FlightStream. Get involved at next year's DBF in April 2020 in Wichita, KS!

The AIAA Foundation supports DBF in an effort to advance aerospace and to ensure the next generation of aerospace professionals is equipped as they prepare to enter the workforce. More information on DBF can be found at **aiaa.org/dbf**. For information on how your organization can engage with and sponsor this event, please contact merries@aiaa.org.

2019 AIAA Regional Student Conferences

AIAA sponsors student conferences in each AIAA region for student members at both the undergraduate and graduate levels. Students are judged on technical content and clarity of communication by professional members from industry. The conferences provide a venue for students to share AIAA experiences, participate in social activities, connect with industry professionals, and exchange ideas about current topics in aerospace engineering. Since 2018, Lockheed Martin Corporation's generous donation to the AIAA Foundation has supported the Regional Student Conferences and the International Student Conference.

The first-place winners in each category are invited to present their papers at the AIAA Foundation International Student Conference held in conjunction with the 2020 AIAA SciTech Forum in Orlando, Florida, 6–10 January.

Undergraduate Category Winners

Region I: Volumetric Origami-based Deployable Modular Space Structures with Tailorable Stiffness, James H. Lynch and Jordan R. Raney, University of Pennsylvania

Region II: Airfoil Lift Calculation Using Wind Tunnel Wall Pressures, Sreevishnu Oruganti and Shreyas Narsipur, North Carolina State University

Region III: Active Flow Control in a Compact High-Speed Inlet/Diffuser Model, Collin O'Neill, Ohio State University

Region IV: Thermodynamic Calculations of Boiling Liquid Expanding Vapor Explosions (BLEVE), Joshua R. McElrath and Adonios N. Karpetis, Texas A&M University

Region V: Aerodynamic Analysis and Simulation of Degraded Flight Configurations of the A-10 Thunderbolt II, Reese Fairchild, Matthew Green, and Thomas R. Yechout, United States Air Force Academy

Region VI: Effects of Electric Field on Primary Electron Trajectories in Miniature Gridded Ion Thrusters, Juan-Pablo Almanza-Soto, University of California, Los Angeles

Masters Category Winners

Region I: Trim Analysis for an Electric Rotorcraft Utilizing a Moving Mass Control Scheme,Robert Brown, University of Maryland

Region II: Design and Testing of a Fault-tolerant Space Suit, J. Sublett, Georgia Institute of Technology

Region III: Lagrangian Coherent Structures in Optimal Vortex Ring Formation, Braxton N. Harter and James W. Gregory, Ohio State University

Region IV: Spectral Proper Orthogonal Decomposition Analysis of Shock-Wave/Boundary-Layer Interactions, Stephanie M. Cottier and Christopher S. Combs, University of Texas at San Antonio

Region V: Simulating a Vortex-Driven Cloud Feature on Uranus, Kevin Farmer, Saint Louis University

Region VI: Band Gap Optimization of Topological Waveguides, Tim Gormley, University of Washington

Team Category Winners

Region I: Design and Intergration of a High-Powered Model Rocket – I, Kyle F. Foster, Peter D. Dohn, Colin Y. Cooper, Amanda Dings, Jacob H. Fennick, Eve M. George, Nicholas J. Lapierre, and Ty F. Moquin, Worcester Polytechnic Institute

Region II: Implementation and Verification of a Versatile GN&C and Flight Software Architecture for an Active Control Launch System, Kunal S. Gangolli, Athreya Gundamraj, Wyatt Hoppa, and Shrivathsav Seshan, Georgia Institute of Technology

Region III: Specialized Terrestrial Rotorcraft Explorer, T. Hutchinson, N. Marquand, J. Springer, T. Swedes, S. Tandon, and J. Zyck, Purdue University

Region IV: N/A

Region V: Automatic Detection of Auroral Substorms from a CubeSat Platform Using Machine Learning, Valerie Lesser, Christopher Peercy, Vishranth Siva, and Colin Sullivan, University of Colorado Boulder

Region VI: Construction of Facility for Rotating Detonation Engine Research, Chinmay S. Upadhye, Andrew C. Jacob, Andrew J. Milligan, and Kevin Chau, University of Washington

Please visit the AIAA Regional Student Conferences website for more information (aiaa.org/home/get-involved/students-educators/student-conferences).

News

Wang Presented Hampton Roads Section Inaugural Laurence D. Leavitt Lecture

AIAA Hampton Roads Section (HRS) 2019 Engineer of the Year, **Dr. Li Wang**, presented the HRS Inaugural Laurence D. Leavitt Lecture on 7 March, at NASA Langley. Dr. Wang is a Senior Research Engineer at the National Institute of Aerospace (NIA) and physically works at the Computational AeroSciences Branch at NASA Langley. Dr. Wang has been leading research on the development of a practical and efficient design optimization tool for rotorcraft aeromechanics. She has created an integrated methodology to couple state-of-art computational fluid dynamics and comprehensive rotorcraft analysis, and to enable multidisciplinary sensitivity analysis for high-fidelity design optimization. Dr. Wang presented an overview of the multidisciplinary analysis and design optimization framework applied to rotorcraft applications. Prior to the lecture, Bobby Berrier presented a special tribute to Laurence D. Leavitt, for whom this annual lecture will be named henceforth.

TOP: HRS Vice-Chair, Dr. Tyler Hudson (left), thanks Dr. Li after the lecture with a Certificate of Appreciation.
BOTTOM: Dr. Li Wang talks to the audience about the design optimization tool for rotorcraft aeromechanics.

IAC Kickoff Reception Held on Capitol Hill

AIAA, in collaboration with eight sister societies, sponsored a congressional reception on 30 April for the 70th International Astronautical Congress (IAC 2019), which will be held 21–25 October in Washington, DC.

The reception, which included NASA Administrator Jim Bridenstine and Congressman Brian Babin (R-TX), House Aerospace Caucus co-chair and Ranking Member of the House Space and Aeronautics Subcommittee, allowed lawmakers and their staff to hear more about upcoming IAC 2019 programming being developed for them, including additional Hill briefings that will take place in the next few months.

AIAA Utah Section Supports Local Robotics Team

Intergalactic Bionic Porcupines with the Robot Game Trophy and Champions Award

The Intergalactic Bionic Porcupines First Lego League (FLL) robotics team received the Utah State Champion's recognition and is going to the FIRST World Robotics Festival in Houston this April to represent the state of Utah and as one of the representatives of the United States. FLL is for kids ages 9-14 and teaches them STEM activities such as building and programming a robot and presenting original project research. Over 270 teams participate in FLL in Utah and 32,000 across the world.

This year's FLL theme was improving long duration spaceflight. The robot game missions imitated space-related activities such as asteroid deflection, rescuing an astronaut, and crossing a simulated Mars crater. The team builds their autonomous robot using the EV3 Lego processor, which is programmed in a version of LabView. The EV3 Lego processor drives attachments of Lego Technic parts built by the kids to perform the robot game missions. In researching their project, the team met with astronauts, attended the Small Sat Conference at Utah State University, and spoke with NASA experts. The team prepared original research for their project by making and testing bricks and tools from simulated Mars soil (provided by University of Central Florida). Working with the University of Utah and Salt Lake Community College, the team manufactured and evaluated the strength of bricks and tools made from Mars simulated soil using 3D printing technology and various binders.

The team is sponsored by the AIAA Utah Section and is excited to be the FLL team representing Utah at the 2019 World Festival, which takes place in April. To achieve this distinction, the team had a best-in-state score of 283 out of 400 points in the robot game, displayed an innovative robot design concept, and were recognized for an outstanding project at the Southern Utah Championship on 16 February 2019.

In May the AIAA Foundation presented the first Dr. Hassan A. Hassan Graduate Awards in Aerospace Engineering to **Jonathan T. McCready** and **Joshua Glazer**. The $5,000 Hassan Graduate Award is designed to entice top North Carolina State University (NCSU) aerospace engineering seniors, who also are AIAA members, to earn their graduate degree (M.S. or Ph.D.) in aerospace engineering at NCSU. More information about the award can be found at: aiaa.org/home/get-involved/honors-awards/awards/student-awards.

Obituaries

AIAA Fellow Madelung Died in December 2018

Professor Gero Madelung, Honorary President of the RAeS Munich Branch e.V., died on 13 December 2018, aged 90.

Madelung studied aeronautics at the technical university in Stuttgart and Clarkson College. Under his uncle Willy Messerschmitt's supervision, Madelung began his career as an aeronautical engineer and project manager for the HA200 at Messerschmitt AG, Entwicklungsring Süd (EWR) in Spain and later in Egypt on the HA300.

He worked in the United States for GEC and later was appointed Chief Technical Officer at Messerschmitt AG, contributing to the creation of MBB through the merger of the companies Bölkow, Blohm and Messerschmitt. He continued his practical aeronautical activities as the project leader of the VJ101 VTOL project. He was the first Managing Director of Panavia GmbH, having significant influence on the development of the Tornado multi-national aircraft program. He later returned to MBB as President and Chief Executive.

At the end of his industrial career he transferred his knowledge and experience in aeronautics to academia, becoming the inaugural professor at the Institute of Aircraft Design at the Technical University Munich. He was chairman of the "Messerschmitt Stiftung," a foundation which supports the conservation of cultural assets and monuments. Under his leadership, and in cooperation with EADS (later Airbus), he encouraged the founding of the Messerschmitt Flying Museum, housing airworthy Messerschmitt aircraft at Manching.

Madelung was made an Honorary Fellow of the Royal Aeronautical Society in recognition of his many contributions to international aeronautics and supported the society as a member of the Medals and Awards International Adjudication Panel. He was a founding member of the RAeS Munich Branch in 1991, when Munich became a center of aerospace excellence in Germany with companies such as MBB/DASA and MTU together with the multinational agencies Panavia, NAMMA/NETMA, Eurofighter, Eurojet and Eurocopter. This international environment attracted staff from the UK, the European partner companies, and elsewhere to work in the heart of Bavaria. The branch, under his leadership and with active support from the new committee and membership, became a focus for encouraging friendship and networking within the aerospace and academic communities. With his active support it also became a German-registered "gemeinnütziger Verein," which is an official German registered nonprofit charity organization.

In addition to these countless demanding professional and volunteer positions and activities he was an active glider pilot, still flying far into old age.

Madelung was awarded the highest honors in aeronautics from Germany and also internationally. An AIAA Fellow, he also gave the Wright Brothers Lecture in Aeronautics in 1977, entitled Characteristics of Fighter Aircraft.

AIAA Associate Fellow Haloulakos Died in January

Dr. Vassilios Elias "Bill" Haloulakos died on 13 January. He was 88 years old.

Born in Sparta, Greece, he came to the United States as a member of the Greek Air Force Academy training at Lackland Air Force Base. There he met his wife (Victoria Villarreal Haloulakos), a civil servant with the U.S. Air Force, and later he became a U.S. citizen. He received his Bachelor's (BSME), Master's (MSAE) and Doctorate (ENGR.D) degrees from the University of Southern California's Viterbi School of Engineering. He was studying for his master's in 1962 along with Neil Armstrong before Armstrong was chosen for the astronaut program.

As a rocket scientist, aerospace engineer, and university lecturer Haloulakos was a major player/significant contributor in a golden era of aeronautics and aviation—the Jet Age, Space Race, and Cold War—with a stellar career from the late 1950s through the late 1990s at McDonnell Douglas Space Systems

Company, Huntington Beach, CA. He worked with U.S. astronauts and on a couple of occasions with Soviet cosmonauts. Among the projects Haloulakos is associated with are the Gemini and Apollo manned space missions, Sky Lab, Upstage anti-ballistic missile interceptor, DC-10 jet airliner, NERVA (Nuclear Engine Rocket Vehicle Application), and the DC-X Clipper reusable single stage rocket.

Haloulakos served as president of various technical societies throughout the 1970s and 1980s, and was the author of two books (Mathematics, The Layman and Daily Life and Rocket Propulsion Fundamentals and Mission Analysis). In addition he published over 100 scientific & technical papers in his field, and his research has now been donated to Brigham Young University. His teaching career included university instructor in physics & mathematics, academic decathlon advisor, and as a docent at the Gene Autry Museum of Western Heritage. He viewed himself as a lifetime learner who stayed young by learning something new each day.

AIAA Fellow Hakkinen Died in March 2019

Raimo J. Hakkinen, 93, passed away on 7 March 2019.

Hakkinen, born in Finland, received a Diploma in Aeronautical Engineering from the Helsinki University of Technology in 1948, a Master of Science (1950) in Aeronautics and a Doctor of Philosophy in Aeronautics (1954) from Caltech. He received a Doctor of Science in Technology (honorary) from Helsinki University of Technology in 1998.

Hakkinen served in the Finnish Air Force in 1944. An avid sail plane pilot, he was co-designer of the Harakka II training glider in 1946 while a member of the student flying club at Helsinki University of Technology. He went on to serve as head of the technical office of the Finnish Aeronautical Association in 1948, an instructor at Tampere Technology College, and as a design engineer in the aircraft division of Valmet Corporation in 1949.

Newly married, he moved to the U.S. in 1949 to begin his studies at Caltech. Hakkinen was subsequently a research staff member at Massachusetts Institute of Technology before joining Douglas Aircraft Company in Santa Monica, CA, as an aerodynamics engineer in 1956. He was a visiting associate professor in aerospace and astronautics at MIT from 1963 until 1964, when he became chief scientist in the physical science department at Douglas. Hakkinen went on to become chief scientist for flight sciences at McDonnell Douglas in St. Louis in 1970, and then director of research - flight science in 1982, retiring from that position in 1990.

Following retirement from McDonnell Douglas, he joined Washington University in St. Louis as a professor in mechanical engineering and as director of the fluid mechanics laboratory. His AIAA efforts over the years included member of the Fluid Dynamics Technical Committee, the Honors and Awards Committee, the Technical Activities Committee, and as a director at large.

1919

June 1 The U.S. Aerial Forest Patrol is established to scout for forest fires. By 1922, Canada also operates a forest patrol service with airplanes. **Aircraft Year Book, 1920**, p. 253; **Flight**, Feb. 9, 1922, p. 90.

June 14-15 British Capt. John Alcock and Lt. Arthur Whitten Brown make the world's first nonstop flight across the Atlantic, flying a modified Vickers Vimy bomber powered by two Vickers-Vimy Rolls 400 engines, from St. John's, Newfoundland, to Galway Bog, Ireland. They cover a distance of 3,115 kilometers in 15 hours, 57 minutes at an average speed of 190 kph (118 mph) and average altitude of 4,000 feet (1,200 meters). The Vimy is 13 meters long and has a wingspan of 20 meters. Alcock and Brown are knighted on June 21. **Flight**, June 19, 1919, pp. 801-804 and June 26, 1919, p. 830; Charles H. Gibbs-Smith, **Aviation**, p. 180.

1944

June 3 Operation Cover begins in the Pas de Calais area of northern France. Three hundred and thirty-eight heavy Allied bombers attack enemy coastal defenses as a deception raid to draw enemy forces from the planned Allied invasion point at Normandy. K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 360.

June 6 D-Day landings in Normandy, France, commence with airdrops of three airborne divisions. Allied air force operations also heavily support the operation, which is the biggest amphibious assault in history and entails 5,000 sorties. The aircraft, flown from their bases in Britain, conduct tactical attacks. In all, 1,729 8th Air Force heavy bombers drop 3,262,236 kilograms of bombs during D-Day and suffer only three losses, one to a collision and the others to ground fire. German opposition is light, due in part to Operation Cover. F.K. Mason and M. Windrow, **Know Aviation**, p. 48; K.C. Carter and R. Mueller, compilers, **The Army Air Forces in World War II**, p. 363.

June 7 Following the D-Day landings, Allied engineers construct their first beachhead airstrip at Asnelles, on the Normandy coast, for Allied fighters' emergency use. F.K. Mason and M. Windrow, **Know Aviation**, p. 48.

June 13 Germany launches its first operational V-1s, or flying bombs, from France against southern England. The first hits Swanscombe, Kent, at 4:18 a.m. Four of the 11 bombs hit London. F.K. Mason and M. Windrow, **Know Aviation**, p. 48.

June 13 A top-secret German A-4 (V-2) rocket, with components of a Wasserfall missile radio guidance system aboard, is test-flown from Peenemunde and accidentally lands on Swedish soil. Swedish authorities gather up some of the pieces and send them to London for analysis. This provides British air intelligence with valuable information on the weapon, although it misleads them to believe the rocket is radio-guided. F.I. Ordway III and M.R. Sharpe, **The Rocket Team**, pp. 148-153.

June 14-15 A V-1 is shot down for the first time by a fighter aircraft, a Royal Air Force Mosquito flown by Flight Lt. J.G. Musgrave. F.K. Mason and M. Windrow, **Know Aviation**, p. 49.

June 15 Boeing B-29 Superfortresses stationed at new bases in Chengdu, China, make their first attack on Japan, raiding iron and steel mills at Yawata, Kyushu. The aircraft belong to the U.S. Army Air Forces' 20th Bomber Command. Peter Bowers, **Boeing Aircraft Since 1916**, p. 323.

June 24-25 The Luftwaffe makes its first use of the double aircraft, or Mistel, composite. This initially consists of a piloted Messerschmitt Bf 109G-14 mounted on an unmanned Junkers 88A-4. The Junkers, stripped of its pilot seats and related equipment, carries a hollow charge warhead of 3,800 kilograms of high explosives. The combination planes are flown toward the target, and the lower plane is dropped while the upper plane is flown to safety. In the first night, five Mistels attack Allied ships in the Seine Bay in France. All five miss their targets. William Green, **Warplanes of the Third Reich**, pp. 477-482.

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1969

June 3 The first flight of the world's largest passenger aircraft, a Boeing 747, is flown by Boeing pilot Don Knutson from Seattle-Tacoma Airport in Washington state to Le Bourget Airport in Paris for the 28th Paris Air Show. During the nine-hour, eight-minute flight, the plane averages 917 kph and a maximum of 1,055 kph. **New York Times**, June 4, 1969, p. 74.

Alan Wilson

June 3 A flyable replica of a Vickers Vimy, the famous British World War I heavy bomber biplane that also set several records for long-distance flights is flown from Wisley, England, to Le Bourget Airport in Paris for the Paris Air Show. **Flight International**, June 12, 1969, p, 953.

June 5 The Soviet Union's Tu-144 supersonic aircraft exceeds Mach 1 for the first time during a flight test. **Interavia Air Letter**, April 9, 1969, p. 5.

June 10 The Manned Orbiting Laboratory, or MOL, the United States' second project to put a man into space, is canceled by the Department of Defense for budgetary reasons. The U.S. Air Force has been responsible for the program. It entailed using modified Gemini-B spacecraft launched into 482-kilometer orbits by two-man crews. Each MOL craft was designed for a 30-day working life, with missions to investigate how manned spacecraft could further America's defense programs. **Flight International**, June 19, 1969, p. 1034, and June 26, 1969, pp. 1070-1071; **Washington Star**, June 21, 1969, p. A5.

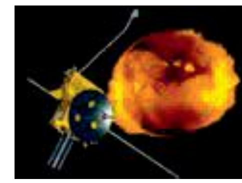
June 10 The X-15 No. 1 rocket research aircraft is turned over to the National Air and Space Museum of the Smithsonian in Washington, D.C. The joint NASA/U.S. Air Force X-15 program established several world aviation records, some of which still stand, including an altitude record of 107,960 meters and a speed record of 7,274 kph (Mach 6.7). The X-15 was powered by a Thiokol Chemical Corp. XLR-99 rocket engine with 222,411 newtons of thrust. **New York Times**, June 15, 1969, p. 70; Frank H. Winter, **America's First Rocket Company: Reaction Motors, Inc.**, pp. 191-210.

June 21 NASA launches its 179-kilogram Explorer 41, or IMP 5, for Interplanetary Monitoring Platform, by a Thrust-Augmented Improved Thor-Delta from Vandenberg Air Force Base, California. The spacecraft's instruments measure energetic particles, magnetic fields and plasma in space. In August 1972, it records important data on one of the most potent solar proton events of the Space Age. NASA, **Astronautics and Aeronautics, 1969**, p. 185.

June 25 Hermann Oberth, considered one of the founding fathers of modern rocketry and astronautics, celebrates his 75th birthday and in a news conference in Salzburg, Austria. Oberth is especially acclaimed for his milestone book, "Die Rakete zu den Planetenräumen (By Rocket into Planetary Space)," published in Germany in 1923 in which he presented details of his concept of a liquid propellant manned space rocket. Wernher von Braun, director of NASA's Marshall Space Flight Center in Alabama, says that Oberth's ideas on rocketry in 1923 remain "valid to date." **New York Times**, June 29, 1969, p. 3.

June 28 NASA's Biosatellite-3 spacecraft is launched to provide information on the effects of prolonged weightlessness on a high form of life. The payload is a 6.3-kilogram male pig-tailed monkey. The mission is planned for 30 days, although, after only 8.8 days in orbit, the flight is terminated because of the subject's deteriorating health. The monkey, named Bonny, dies on July 8, one day after the biological capsule's recovery from the Pacific. **Aviation Week**, July 7, 1969, p. 27.

1994



June 12 The European Space Agency's Ulysses spacecraft reaches the south pole of the sun after a three-year journey. It was launched from the space shuttle Discovery in October 1990 and traveled around Jupiter in order to enter an orbit that will take the craft around both poles. Ulysses will gather data on the sun's magnetic field, solar flares, and gamma and gravity waves. NASA, **Astronautics and Aeronautics, 1994**, p. 532.

June 28 The planet Venus is still geologically active, says Suzanne Smrekar, a geophysicist at NASA's Jet Propulsion Laboratory. Her research is based on altimetry and gravity data collected by the Magellan spacecraft, which went into orbit around Venus in August 1990 and mapped about 98% of its surface. Smrekar says that the data indicates there are at least two hot spots on Venus. NASA, **Release 94-105**.

ISTVÁN LÖRINCZ, 31

Chief business officer and co-founder of Morpheus Space

During his childhood in Transylvania, Romania, István Lörincz had a flash of insight that set the initial trajectory for his career. He went on to attend universities in Romania, the Netherlands and Germany before co-founding Morpheus Space, a satellite propulsion spinoff of the University of Dresden. In February, Morpheus demonstrated the first electric propulsion for a single-unit cubesat, measuring only 10 centimeters on a side.

How did you become an engineer?

During the last weekend I spent with my late father, we built a large kite. While trying to make it take off in our backyard, I dreamed about flying myself. In that moment, even though I was only 12, I knew my life would be oriented toward the sky. A couple of years later, I became a paraglider pilot, achieving my dream of flying. My passion for aviation shifted toward the stars at the Polytechnic University of Bucharest thanks to a professor who was passionate about rocket science. Although the university did not offer rocket science lectures or degrees, this professor organized secret evening lectures for a few students. Through his passion and mentorship, I stepped into the world of space propulsion technologies and designed my first plasma rocket. I carried on the search for breakthrough space propulsion technologies, earning a master's degree in space systems engineering at Delft University of Technology and a Ph.D. at the Technical University of Dresden, before co-founding Morpheus Space. My main responsibilities within the company are the market launch, business development and, most importantly, I am the interface between our clients and our team.

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

Any optimistic image of our world set three decades in the future must contain flying cars. But setting aside our dreams of not sitting in traffic jams all day, the upcoming decades will need to contain a few important turning points for our global civilization. One is acceptance that knowledge must be treated as an indivisible entity and not fragmented into an ever-increasing number of fields. Another turning point will be when a space infrastructure is firmly established. We are now seeing the beginnings of a new era, where we start to think broadly about space as a resource. Space-based technologies will offer significant solutions to a number of serious global issues like nutrition, disaster management and climate. I expect that the overall life quality will rise due to these new solutions. It is also very exciting to think about space tourism, which looks as if it could be realized sooner than flying cars.

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