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X-PRESS

ARMSTRONG FLIGHT RESEARCH CENTER

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X-57 contributions

AFRC2022-0131-10 NASA

NASA's X-57 tests the motors spinning on all battery power. The X-57 has provided a path for industry through lessons learned and solutions to some of the complex elements of electric flight. *See page 4.*

X-66: U.S. Air Force assigns number for new flight demonstration project

By Rob Margetta
NASA Public Affairs Officer

NASA and Boeing said the aircraft produced through the agency's Sustainable Flight Demonstrator project has been designated by the U.S. Air Force as the X-66A.

The new X-plane seeks to inform a potential new generation of more sustainable single-aisle aircraft – the workhorse of passenger airlines around the world. Working with NASA, Boeing will build, test, and fly a full-scale demonstrator aircraft with extra-long, thin wings stabilized by diagonal struts, known as a Transonic Truss-Braced Wing concept.

"At NASA, our eyes are not just focused on stars but also fixated on the sky. The Sustainable Flight Demonstrator builds on NASA's world-leading efforts in aeronautics as well climate," said NASA Administrator Bill Nelson. "The X-66A will help shape the future of aviation, a new era where aircraft are greener, cleaner, and quieter, and create new possibilities for the flying public and American industry alike."

NASA illustration

The X-66A is the X-plane specifically aimed at helping the United States achieve the goal of net-zero greenhouse gas emissions by 2050. To build the X-66A, Boeing will work with NASA to modify an MD-90 aircraft, shortening the fuselage and replacing its wings and engines. The resulting demonstrator aircraft will have long, thin wings with engines mounted underneath and a set of aerodynamic trusses for support. The design, which Boeing submitted for NASA's Sustainable Flight Demonstrator project, is known as a Transonic Truss-Braced Wing.

The X-66A is the first X-plane specifically focused on helping the United States achieve the goal of net-zero aviation greenhouse gas emissions, which was articulated in the White House's U.S. Aviation Climate Action Plan.

"To reach our goal of net zero aviation emissions by 2050, we need transformative aircraft concepts like the ones we're flying on the X-66A," said Bob Pearce, associate administrator for NASA's Aeronautics Research Mission Directorate, who announced the designation at the American Institute of Aeronautics and Astronautics Aviation Forum in San Diego. "With this experimental aircraft, we're aiming high to demonstrate the kinds of energy-saving, emissions-reducing technologies the aviation industry needs."

AFRC2022-0153-12 NASA/Carla Thomas

Aaron Rumsey and Beto Hinojos carefully add weight to a 6-foot model of the Transonic Truss-Braced Wing at NASA's Armstrong Flight Research Center, in Edwards, California. The aircraft concept involves a wing braced on an aircraft using diagonal struts that also add lift and could result in significantly improved aerodynamics. Look here for more.

NASA and Boeing sought the X-plane designation shortly after the agency announced the Sustainable Flight Demonstrator project award earlier this year. The Air Force confers X-plane status for development programs that set out to create revolutionary experimental aircraft configurations. The designation is for research aircraft. With few

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Room to roam

By Laura Mitchell
NASA Armstrong Public Affairs

Each NASA facility has its own unique micro-climate and geography. At NASA's Armstrong Flight Research Center in Edwards, Calif., the high-desert climate is an interesting natural habitat for a variety of wildlife.

NASA Armstrong, housed at Edwards Air Force Base, sits on more than 300,000 acres of desert land. Part of that landscape is Rogers Dry Lake, a drainage basin that retains water with no outflow to external bodies of water like rivers, other lakes, or the ocean. This unique climate makes it an ideal location for the experimental flight testing that NASA Armstrong is known for.

It is also home to desert tortoises, bobcats, lizards, snakes, scorpions, and burrowing owls. To ensure the safety of the wildlife and the personnel, NASA biologists and the environmental office monitor the wildlife and their behavior. Mark Bratton, environmental scientist and wildlife biologist, monitors and tracks the wildlife on center and across the base in conjunction with the Air Force.

The desert tortoise is native to the Mojave Desert. The desert tortoise can live between 50 and 80 years and grow to be 10 – 14 inches. Some tortoises on base have been outfitted with radio transmitters on their shells, and other tortoises that have been relocated to different areas of the base. "The radio transmitters help us know where the adult female tortoises are so when they are ready to lay their eggs, we can take the females to holding pens were they lay/deposit their eggs in predator-proof pens. After the

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NASA

A bobcat finds shade in the Mojave Desert at NASA's Armstrong Flight Research Center in Edwards, California.

NASA

A desert tortoise, native to the Mojave Desert at NASA's Armstrong Flight Research Center in Edwards, California, goes for a walk.

News at NASA

Mars copter phones home

The 52nd flight of NASA's Ingenuity Mars Helicopter is now in the official mission logbook as a success. The flight happened on April 26, but mission controllers at NASA's Jet Propulsion Laboratory in Southern California lost contact with the helicopter as it descended toward the surface for landing.

The Ingenuity team expected the communications dropout because a hill stood between the helicopter's landing location and the Perseverance rover's position, blocking communication between the two. The rover acts as a radio relay between the helicopter and mission controllers at JPL. In anticipation of this loss of communications, the Ingenuity team had already developed re-contact plans for when the rover would drive back within range. Contact was re-established June 28 when Perseverance crested the hill and could see Ingenuity again.

Flight 52, a 1,191-foot (363-meter) and 139-second-long flight, repositioned the helicopter and took images of the Martian surface.

The target for Flight 53 is an interim airfield to the west. Then an additional westward flight will land at a new base of operations.

Paving the way

X-57 project creates paths for electric aviation

By Sarah Mann
NASA Armstrong Public Affairs

AFRC2021-0071-072 NASA/Carla Thomas

NASA's X-57 all-electric aircraft in the Mod II configuration undergoes high-voltage testing in 2021 at NASA's Armstrong Flight Research Center in Edwards, California.

NASA's X-57 Maxwell all-electric aircraft project will conclude aircraft operational activities by the end of September, with documentation and close-out activities continuing for several months afterwards. The research from the X-57 provides aviation researchers with hundreds of lessons learned, as well as revolutionary development in areas ranging from battery technology to cruise motor control design.

"NASA's goal is to drive innovation through groundbreaking research and technology development. The X-57 project team has done just that by providing foundational information to industry through lessons learned, and we're seeing the benefits borne out by American commercial aviation companies that are aiming to change the way we fly," said Brad Flick, director of NASA's Armstrong Flight Research Center in Edwards, California, where the X-57 aircraft was developed. "I'm incredibly proud of their tenacity and ingenuity as they led the way in advancing electrified propulsion. The future of electrified propulsion is possible because of their contributions."

AFRC2023-0038-125 NASA

NASA's X-57 lithium-ion batteries are installed in the aircraft in 2022.

Finalizing aircraft operations by September 2023 will not incorporate first flight of the X-57 aircraft. The project encountered several challenges to safe flight, including mechanical issues late into its lifecycle and a lack of availability of critical components required to develop experimental hardware. Given the approaching planned end of aircraft operations, the timeline would not allow the team to reach acceptable flight conditions.

Although most of the X-57's development will complete by September 2023, the team will officially conclude its work several months afterward with additional technical publications.

The primary goal of the X-57 project was to provide knowledge about the aircraft's electric-propulsion-focused design and airworthiness process with regulators. This information has already impacted and will continue to impact the development of advanced

NASA

Susanah Kowalewski prepares a cruise motor controller for testing at NASA's Glenn Research Center in Cleveland.

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NASA researchers Jeanette Le, Curt Hanson, and Erik Waite, look on as pieces of a newly installed motion simulator are tested at NASA Armstrong Flight Research Center in Edwards, California on April 26. The simulator includes virtual reality goggles depicting an aircraft cabin and city environment, as well as noise and seat motion, to simulate an air taxi ride.

AFRC2023-0072-04
NASA/Genaro Vavuris

How's the ride?

New air taxi ride simulator aims to find out

By Teresa Whiting
NASA Armstrong Public Affairs

To create a future where air taxis are a regular form of transportation, passengers need to be comfortable. That's why researchers at NASA's Armstrong Flight Research Center in Edwards, California are exploring how passengers may experience an air taxi ride by building a custom virtual reality flight simulator.

NASA is currently researching the human physiological response to motion, vibration, noise, and visual stimuli that passengers may experience during an air taxi flight, and the new simulator is a major part of that effort. It includes virtual reality goggles depicting an aircraft cabin and city environment, as well as noise and seat motion, to simulate an air taxi ride. NASA will make data collected with the simulator available to industry and other stakeholders to help shape the design of electric air taxis, locations where the aircraft will take off and land, and desired flight paths through cities.

"In the 1970s, NASA was instrumental in developing passenger ride quality metrics for jet airliner noise, seat vibration, and motion sickness through human subject testing using a unique passenger ride quality simulator located at NASA's Langley Research Center," said Curt Hanson, senior flight controls researcher for this project. "Now, NASA's Armstrong Flight Research Center is taking this technology into the 21st-century."

During an experiment, test subjects will be secured in the seat on top of a platform that can move on six axes to realistically simulate motion in an aircraft and tests will gauge their level of discomfort. They will wear a virtual reality headset and headphones to create a fully immersive experience.

As each subject virtually flies around a projected scene of downtown San Francisco, they will be asked to indicate any time they feel uncomfortable by pressing a handheld button. These discomfort cues can later be correlated with recorded visual and motion stimuli, as well as with physiological measurements, such as heart rate and breathing rate.

NASA researchers will be able to provide guidance on elements of air taxi design like seat placement and window size based on the results of these experiments. It will also help inform where the aircraft will take off, land and fly. This information will help industry and government make informed decisions to ensure a positive experience for future air taxi users.

This simulator testing is one element of NASA's Revolutionary Vertical Lift Technology (RVLT) project. Other focus areas include improving noise, safety, and efficiency for vertical lift aircraft. The research performed by the RVLT project supports NASA's Advanced Air Mobility research to integrate air taxis, drones, and cargo delivery aircraft into our sky.

Students tap NASA tech

Photo courtesy of the University of Idaho

Engineering students at the University of Idaho prepare an airplane they designed and built based on the Prandtl-D design developed by NASA's Armstrong Flight Research Center in Edwards, California. In the future, such an airplane could be used for monitoring farmland and spotting wildfires.

By Jim Skeen
NASA Armstrong Public Affairs

University of Idaho students learned real-world engineering skills during the 2022-2023 school year while advancing two NASA technologies – a tailless aircraft design using wing twists to maneuver, and a process to assemble thin-film solar panels using robotics and 3D printing.

One group of students designed, built, and flight-tested a drone using the Prandtl-D, Preliminary Research Aerodynamic Design to Lower Drag, developed at NASA's Armstrong Flight Research Center in Edwards, California. Looking like a boomerang, the Prandtl design mimics bird flight, using twists in its wingtips for maneuvering.

The students said their work is a first step in proving the commercial viability of the Prandtl-D, which could have such uses as watching over farmland and spotting wildfires.

The students set goals for their airplane of a minimum speed of 30 mph, a maximum speed of 50 mph, a carrying capacity of at least one pound, and the ability to fly for at least an hour.

Their battery-powered, 11-foot airplane made from Balsa wood, carbon fibers, and organic materials surpassed their goals, having a stall speed, the minimum speed needed for controllable flight, of 28 mph, hitting a top speed during testing of 55 mph. The airplane stayed aloft for 118 minutes, nearly doubling their goal, and carried a 1.5-pound payload that included a flight controller and a camera.

The aircraft, ground launched by a bungee cord, made nine flights, during which the team noticed vibration at the higher cruise speeds. A future team will work to address that issue.

The students shared that, "the Prandtl-D wing design is commercially viable," in a report at a recent engineering expo held at the university. "The airfoil produces an excellent platform for a wide variety of UAV applications through increased efficiency, stability, and control simplicity."

A second group of students worked with technology called PAPA, Print-Assisted Photovoltaic Assembly, or developed at NASA's Marshall Space Flight Center in Huntsville, Alabama. The students designed and demonstrated an automated assembly process for turning thin-film solar cells into larger photovoltaic arrays using two robotic arms working in tandem. NASA is eyeing the use of such thin-film cells to power spacecraft and could even use

Photo courtesy of the University of Idaho

The students designed and demonstrated an automated assembly process for turning thin-film solar cells into larger photovoltaic arrays using two robotic arms working in tandem. The technology, called Print-Assisted Photovoltaic Assembly, was developed by NASA's Marshall Space Flight Center in Huntsville, Alabama, to create an automated manufacturing process for lightweight solar arrays.

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the technology for creating solar arrays in space, enabling long-term spaceflight. The cost to build such arrays is about $450 per kilowatt while an automated process can cut the cost to $25 per kilowatt and eliminate human errors.

The students used PAPA to accomplish four tasks robotically including applying adhesive, placing the cells, printing the electronic connections between the cells, and adding a protective cover.

The students used substitute materials that mimicked the real materials but cheaper, allowing for more testing. The students had to tackle challenges such a cell breaking during placement and getting the adhesive applied consistently.

The students wanted the robotic arms to complete the assembly process without human intervention and to do it under 35 minutes. They achieved both goals, with the assembly process taking about nine minutes without any operator intervention.

The university was able to provide the hands-on engineering experiences to the students thanks to NASA's Technology Transfer University, or T2U, which connects universities with NASA-developed technologies.

"This one of the best examples of what T2U can be," said Brian Boogaard, NASA Armstrong's T2U representative. "You've got a highly motivated faculty and you have really sharp students. The students built a lot of technology, they did a lot of great documentation, great design work, and a lot of good testing. It went really well."

Students in the 2023-2024 school year will be able to pick up both projects and continue to develop the technologies, pushing them even closer to being ready for the marketplace.

"This is helping advance the art of the technology," Boogaard said. "It's also giving a bunch of students who are about to hit the workforce the ability to get their hands on this technology."

To learn more about NASA's T2U program, visit here.

Photo courtesy of the University of Idaho

Students at the University of Idaho are working with an aircraft design developed by NASA's Armstrong Flight Research Center in Edwards, California. See more here.

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exceptions, X-planes are intended to test designs and technologies that can be adopted into other aircraft designs, not serve as prototypes for full production.

"We're incredibly proud of this designation, because it means that the X-66A will be the next in a long line of experimental aircraft used to validate breakthrough designs that have transformed aviation," said Todd Citron, Boeing chief technology officer. "With the learnings gained from design, construction, and flight-testing, we'll have an opportunity to shape the future of flight and contribute to the decarbonization of aerospace."

For the X-66A, the Air Force provided the designation for an aircraft that validates technologies for a Transonic Truss-Braced Wing configuration that, when combined with other advancements in propulsion systems, materials, and systems architecture, could result in up to 30% less fuel consumption and reduced emissions when compared with today's best-in-class aircraft.

Due to their heavy usage, single-aisle aircraft today account for nearly half of worldwide aviation emissions. Creating designs and technologies for a more sustainable version of this type of aircraft has the potential for profound impact on emissions.

NASA's history with the X-plane designation dates to the 1940s, when its predecessor agency, the National Advisory Committee for Aeronautics (NACA) jointly created an experimental aircraft program with the Air Force and the U.S. Navy. The X-66A is the latest in a long line of NASA X-planes. Additionally, NASA's Armstrong Flight Research Center in Edwards, California, has provided technical expertise and support for several additional X-planes.

For the Sustainable Flight Demonstrator, NASA has a Funded Space Act Agreement with Boeing through which the agency will invest $425 million over seven years, while the company and its partners will contribute the remainder of the funding, estimated at about $725 million. NASA also will contribute technical expertise and facilities.

The Sustainable Flight Demonstrator project is an activity under NASA's Integrated Aviation Systems Program and a key element of the agency's Sustainable Flight National Partnership, which focuses on developing new sustainable aviation technologies.

Learn more about the Sustainable Flight Demonstrator here.

Wildlife ... from page 3

female lays her eggs, the adult female is returned to the wild and the eggs incubate in the pens until they hatch. Once the young hatch they are raised in predator-proof pens until they are larger and more predator resistant," said Bratton.

Bobcats have been known to venture out at Armstrong. "We know of a male and female bobcat, and three kittens. We're privileged to have the bobcats and even get to see them, since they're pretty secretive animals," said Bratton. Currently the large mammal study has been tracking some of the resident bobcats and coyotes on base. "Bobcats have different resources in different locations. Their water source might be a mile or so away from their den and another location to stalk prey," said Bratton. NASA employees have had the opportunity to witness bobcats lounging around some of the buildings and with caution, they have been able to take photos from a distance.

Snakes and lizards are also abundant around Armstrong. Bratton notes that many of the snakes are non-venomous although some like the gopher snake try to mimic the venomous snakes like the "Mojave green" rattlesnake by flattening out their head and shaking their tail in dried leaves to mimic a rattle.

The Environmental Office takes great care in managing the animals in residence at Armstrong, monitoring their behavior and locations for the safety of NASA personnel and the animals. In every case, if you see wildlife a little too up close and personal, Bratton suggests avoiding them, give them a wide berth and go on about your business.

X-57 ... from page 4

certification approaches for electric propulsion in emerging electric aircraft markets. The objective was not to develop a prototype, but to develop a test platform for technologies and design methods. And the team did just that, documenting and publishing the technology gaps and their solutions as they were discovered so that industry stakeholders could take advantage of those lessons as soon as possible.

"They did things that had never been done before, and that's never easy," Flick said. "While we prepare to finish this project later this year, I see a long list of achievements to celebrate and an industry that's better today because of their work."

The X-57 is part of NASA's commitment to supporting the U.S. climate goal of achieving net-zero greenhouse gas emissions from the aviation sector by 2050. Since 2016, the project has shared lessons learned about battery technology, electromagnetic interference, motor controller design, and so much more. NASA will continue its research into electric aircraft through other projects, including its Electrified Powertrain Flight Demonstration.

The aircraft was built by modifying an Italian Tecnam P2006T to be powered by an electric propulsion system. Using an existing aircraft design allowed the team to compare their data to that of a baseline model powered by traditional combustion engines.

X-57 successes

Early in the project, the X-57 team members found they would need significant developments in battery technology. The lithium-ion batteries installed on the aircraft warm up as they discharge energy and too much warming could result in overheating. The project worked with Electric Power Systems in North Logan, Utah to address this issue. Engineers demonstrated that the new battery system design would stay within acceptable, safe limits while powering the aircraft.

The design of the cruise motor controllers is another success of the X-57 project. These controllers convert energy stored in the aircraft's lithium-ion batteries to power its motors, which drive its propellers. The controllers use silicon carbide transistors to deliver 98% efficiency intended for high power take-off and cruise, meaning they do not generate excessive heat and can be cooled off by the air flowing through the motor. The team designed inverters to meet demanding mass and thermal requirements and are sharing these designs in technical publications so that industry can use them as a launchpad for new aircraft products. Most recently, the cruise motor controllers went through successful thermal testing.

The aircraft reached another milestone with the installation of two 400-pound lithium-ion battery packs in its cabin, followed by successful tests of its motors spinning off battery power. The motors had previously spun, but were drawing energy from either the test facility, or from the batteries when they were sitting outside of the aircraft. To reach this point, the X-57 project team repeatedly tested the batteries to ensure they could safely power the aircraft, and designed custom, lightweight cases to keep those batteries secure.

During the integration phase the team encountered electromagnetic interference that affected the operation of onboard systems and required a solution. After extensive research the team designed, developed, and installed filters that resolved the issue. The approach will be added to the technical papers and shared with industry and the electric propulsion community.

The value of the pathfinding work done on the X-57 project is well established and recognized by industry and additional research findings will continue to be published and shared with the technical community. A list of the contributions X- 57 has made to-date can be found on the technical papers site.

The X-Press is published each month for civil servants, contractors and retirees of the NASA Armstrong Flight Research Center.

Address: P.O. Box 273,
Building 4800, MS 1422
Edwards, California, 93523-0273
Phone: 661-276-3449

Editor: Jay Levine,
Logical Innovations, ext. 3459

Managing Editor: Megan Person, NASA

Chief, NASA Armstrong Office of Communications:
Kevin Rohrer, NASA