

Courtesy of Lockheed Martin

This concept illustration shows what the Low-Boom Flight Demonstration aircraft could look like.



NASA/Bill White

A NASA F/A-18 took off from Kennedy Space Center Aug. 23 as part of NASA's Sonic Booms in Atmospheric Turbulence, or SonicBAT II Program. The F-18 flew at supersonic speeds while agency researchers measured the effects of low-altitude turbulence caused by the sonic booms.

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Supersonic flight at 70

Quieter era of supersonic flight is coming



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The cover image and the one in the background here were obtained during a T-38 flight using a patented process; see supersonic article for more information.

Supersonic tradition lives on at Armstrong

NASA Armstrong's first mission, when it was the National Advisory Committee for Aeronautics High-Speed Flight Facility in 1946, was to support the first U.S. Air Force experimental aircraft designed to break through the perceived sound barrier.

On the 70th anniversary of the X-1's achievement, Armstrong is helping NASA and the nation to reach new supersonic flight milestones in containing the thunderous sound, called a sonic boom, created when an aircraft exceeds Mach 1. Mach 1 is achieved at 650 to 750 mph depending on factors such as atmospheric conditions and altitude.

The development of a new experimental plane called the Low-Boom Flight Demonstrator advanced this summer to the preliminary design review to determine the general makeup of the aircraft. Also this summer was a request for proposals for completing the detailed design, construction, test and then delivery of the experimental aircraft to Armstrong for test flight.



Following the new supersonic aircraft's arrival at Armstrong, center staff will qualify and flight test the aircraft. It will then become a tool to gauge how people respond to the lower-intensity boom in different areas of the U.S. Determining a tolerable level of noise for supersonic flight is key to suggesting changes to the Federal Aviation Administration for amending current rules that do not allow overland supersonic travel. Success could lead to opening a new market for new generations of transports.

But before the new supersonic experimental aircraft flies, Armstrong is continuing work assessing how people currently perceive sonic booms. The center also has for decades supported work with government and industry partners to redirect the sound and make it less startling to people on the ground.

The Sonic Booms in Atmospheric Turbulence, or SonicBAT, in late August was the first of a number of efforts to find out how atmospheric turbulence is affected by sonic booms in humid conditions. It also was a first look at how people from other areas of the United States react to sonic booms, which was created by an Armstrong-based F/A-18 and measured by the TG-14 motorized glider, also located at the center. A year earlier, SonicBAT looked at how sonic booms were affected by dry desert conditions in flights from the center.

New innovations are part of what the center is so well known for and the latest X-plane, X-57 Maxwell, is an example of new aeronautics concepts. Set to arrive in 2018, the distributed electric powered aircraft fits into an overarching NASA plan for regional air transportation of people and cargo. Some of the technology required for that vision is underway at Armstrong in the testing of electric motors that will power the X-57. The propulsion system could open a new market for regional transportation because it would be much less expensive to operate an electric motor compared to traditional methods.

Armstrong's efforts with Unmanned Aircraft Systems Integration in the National Airspace System, or UAS in the NAS, is also intended to help open new industries for U.S. companies to operate these aircraft. Some of the uses could include deliveries, powerlines, pipelines, bridges and infrastructure inspections, crop management and help with disaster relief and recovery efforts.

Armstrong, NASA centers, industry and academia are working together to resolve technical and regulatory impediments and coordinating with the Federal Aviation Administration for this integration to happen. The first flight of Ikhana into the NAS without an escort aircraft could happen in early 2018. Ongoing NASA work with the FAA on regulations and standards will eventually lead to routine access for all classes of UAS in the NAS.

Armstrong also has developed related technology like the Automatic Ground Collision Avoidance System that is saving lives. The autonomy aspects of the system greatly reduce the possibility of a ground collision in situations that in the past resulted in the loss of life.

It is fantastic to see projects come to fruition like the human-piloted supersonic aircraft that I have been advocating for years. I also supported the development of a human-piloted Hybrid Wing Body aircraft that would have a pilot onboard to test technologies that have been validated here with The Boeing Company's subscale X-48 Blended Wing Body aircraft and could lead to a more cost-effective way to transport cargo and people.

A hybrid or blended wing body aircraft is included in NASA's New Horizons Initiative to develop aircraft that are more fuel efficient, environmentally friendly and reduce noise. There are plans for subsonic experimental airplanes that combine technologies proven through the Aeronautics Research Mission Directorate's work and are scheduled to be developed in five-year cycles.

I would like to see that schedule accelerated to reduce the time between flying one aircraft and preparing the next for flight. Regardless, it is an exciting time for aeronautics research, and we will be doing our part by advancing technology and science through flight.

David McBride

Neil A. Armstrong Flight Research Center director



Courtesy of Lockheed Martin

This concept illustration shows what the Low-Boom Flight Demonstration aircraft could look like.

Armstrong readies for supersonic demonstrator

Matt Kamlet

Armstrong Public Affairs

NASA's Quiet Supersonic Technologies project, or QueSST, has brought the agency ever closer to making the Low-Boom Flight Demonstration aircraft, or LBFD, a reality. Decades of NASA research in supersonics have gone into the unique design of NASA's next X-plane, including numerous efforts under the Commercial Supersonic Technologies project.

These efforts, a number of which are based at Armstrong, have dealt with research in several areas related to supersonic research, including the use of cutting-edge visualization technology to study shockwaves, the use of F-15s to examine methods for greater efficiency, the integration of displays to help pilots monitor the audial effects of supersonic flight and the impacts of the environment on sonic booms. Each area of research goes into realizing the goal of Commercial Supersonic Technology and of QueSST, which includes the eventual demonstration of quiet supersonic flight over land.

In April 2016, NASA's goal of developing a quiet supersonic aircraft took another step closer following a pair of successful first flights in a series demonstrating patent-pending Background Oriented Schlieren using Celestial Objects (BOSCO) technology, effectively using the sun as a background in capturing unique, measurable images of shockwaves.

The tests flown from Armstrong built on other recent NASA tests to further the art of schlieren photography. Schlieren is a technique that can make important invisible flow features visible. Although schlieren has been in use for over a century, recent research by NASA has enabled its application in flight and greatly enhanced the detail of the images that can be obtained. In this case, NASA-improved schlieren captured the visual data of shockwaves produced by a U.S. Air Force Test Pilot School's T-38 aircraft traveling at supersonic speeds.

As a result of the research, the supersonic aircraft and its



AFRC2016-0195-196

NASA/Lauren Hughes

NASA pilot Nils Larson, left, and flight test engineer and pilot Wayne Ringelberg, head for a mission debrief after flying a NASA F/A-18 at Mach 1.38 to create sonic booms as part of the SonicBAT flight series at Armstrong to study sonic boom signatures with and without the element of atmospheric turbulence.



AFRC2016-0293-30

NASA/Ken Ulbrich

Principal investigator Mike Hill (left) awaits data along with subproject manager Brett Pauer as the Air Force Test Pilot School T-38 creates visible shockwaves in front of the sun during a supersonic flight in March 2016.

shockwaves are seen with distinct clarity in front of the solar background. Observing air density changes makes the details clearer.

Visualizing these complex flow patterns of shockwaves produced by a supersonic vehicle will help NASA researchers to validate design tools used to develop the LBFD.

In May 2017, NASA also began a series of supersonic flights

to examine efforts to improve the efficiency of future supersonic aircraft.

At supersonic speeds, the force of drag that must be overcome is large. Due to the interaction of flow with the aircraft's surface, this friction drag contributes about half of the total drag at supersonic speeds. This particular series of flights will explore ways of reducing friction drag and increasing efficiency through

new and innovative methods of achieving swept wing laminar flow.

Future supersonic aircraft seeking to achieve a low boom, such as NASA's proposed LBFD, will rely on a swept wing design in order to fly at supersonic speeds without producing a loud sonic boom. The swept wing design generally produces crossflow, which is a name for air flow disturbances that run along the span of the wing, resulting in turbulent flow, increased drag and ultimately higher fuel consumption.

"Swept wings do not have much laminar flow naturally at supersonic speeds, so in order to create a smoother flow over the wing, we used distributed roughness elements, or DREs, along the leading edge of the wing," says CST subproject manager Brett Pauer. "These DREs can create small disturbances that lead to a greater extent of laminar flow."

Swept wing laminar flow technology allows NASA to consider wing designs that have low boom characteristics, yet can be more efficient.

Supersonic... from page 5

The development of advanced tools and instrumentation has also resulted from NASA's supersonic research. In December 2016, NASA pilots flew with a display that told them exactly where sonic booms were hitting the ground.

The series, which marked the second phase of the Cockpit Interactive Sonic Boom Display Avionics project, or CISBoomDA, continued from the project's first phase, where only a flight test engineer could see the display. With the ability to observe the location of their aircraft's sonic booms, pilots can better keep the loud percussive sounds from disturbing communities on the ground.

"The display is there to minimize the impact of sonic booms on the ground. Sonic booms generally don't cause damage at higher altitudes, but they can disturb people, and we want to make sure that we are good stewards to the public," said Pauer. "The use of this software allows pilots to maximize their flight, and still not bother people on the ground."

The display is able to show the sonic boom location based on tracking the aircraft's trajectory and altitude, and is founded on an algorithm designed by Ken Plotkin of Wyle Laboratories, who died in 2015.

The display will ultimately be used to help NASA proceed with supersonic research in a way that minimizes disturbance on the ground and provides practice with the future of supersonic technology for pilots such as NASA research pilot Nils Larson.

"Flying with the CISBoomDA display was really interesting," Larson stated. "It was great to have it in the cockpit, and I think it's a valuable tool for the future. As a matter of fact, I've asked to be allowed to start using the display on my proficiency flights, just so I can keep practicing with it."

Finally, NASA's supersonic research, which already spans several NASA centers, extends to other agency mission directorates.

In August 2017, NASA's Kennedy Space Center played host to the second series of Sonic Booms in



AFRC2016-0293-30

NASA/Ken Ulbrich

Flight test engineer Jacob Schaefer inspects the Cockpit Interactive Sonic Boom Display Avionics, or CISBoomDA, in a F/A-18.



AFRC2016-0293-53

NASA/Ken Ulbrich

Engineers and researchers at Armstrong monitored the flights and were able to observe sonic boom mapping from the F/A-18 from the center's mission control room.



NASA/Bill White

A NASA F/A-18 took off from Kennedy Space Center Aug. 23 as part of NASA's Sonic Booms in Atmospheric Turbulence, or SonicBAT II Program. The F-18 flew at supersonic speeds while agency researchers measured the effects of low-altitude turbulence caused by the sonic booms.

NASA image

This image of a T-38C was captured using the patent-pending Background Oriented Schlieren using Celestial Objects, or BOSCO technology and then processed with NASA-developed code to reveal shock wave structures.

Atmospheric Turbulence flights, or SonicBAT, continuing from 2016's successful supersonic research flights flown at Edwards Air Force Base.

SonicBAT helps NASA researchers better understand how low-altitude atmospheric turbulence affects sonic booms, which are produced when an aircraft flies at supersonic speeds, or faster than the speed of sound. The flight series is a key initiative in validating tools and models that will be used for the development of future quiet supersonic aircraft, which will produce a soft thump in place of the louder sonic boom.

The SonicBAT flights in Florida marked a rare opportunity for NASA's aeronautics and space operations to commingle. Kennedy showcased that center's transformation into a 21st century multiuser spaceport.

"This shows that, at NASA, we are all striving for the same thing," said SonicBAT Project Manager Brett Pauer. "We're willing to work together and help each other in any NASA mission that may be happening, whether it be space-based, which we do a lot of at our aeronautics centers, or the space centers to help us out with aeronautics. I think there's a great amount of cooperation, even more than may be expected, between NASA centers."

"One NASA is the best way to describe the cooperative spirit that makes it possible for teams to reach out across the agency and receive the kind of support SonicBAT received from Kennedy," said Peter Coen, Commercial Supersonic Technology project manager.

NASA's supersonic research is a multicenter initiative to push the boundaries of aeronautics. The Swept Wing Laminar Flow research conducted at Armstrong resulted from successful wind tunnel testing at Langley Research Center in Virginia. Subscale models of LBFD continue to undergo similar wind tunnel testing at Glenn Research Center in Ohio. The next steps that result from milestones achieved at NASA's centers throughout the country are sure to be exciting.

X-57 Maxwell

First human-piloted experimental aircraft in a decade set to arrive in 2018



NASA Langley/Advanced Concepts Lab, AMA Inc.

The background image shows one of the X-57's motors on the Airvolt electric test stand at Armstrong. The inset illustration is an artist's concept of NASA's X-57 Maxwell and the airplane's specially designed wing and electric motors. The X-57 is intended to demonstrate that electric propulsion can make planes quieter and more efficient and environmentally friendly.

AFRC2017-0269-13

NASA/Lauren Hughes

By Matt Kamlet

Armstrong Public Affairs

Just as the skies above Edwards Air Force Base are no stranger to cutting-edge aviation, Armstrong is no stranger to demonstrating this cutting-edge technology through X-planes.

With the first flight of the X-57 Maxwell expected to take place at Armstrong in early 2018, NASA will return to demonstrating the crewed flight of X-planes. In the X-57's case, NASA will demonstrate how distributed electric propulsion can reduce the energy required to cruise at high speed by up to 500 percent.

This flight demonstration is within reach following a number of milestones achieved at Armstrong. These milestones include testing of an experimental wing on a truck, developing and using a new simulator to look at the controls and handling characteristics of an electric airplane and verifying the tools that enabled NASA's aeronautical innovators to design and build the X-57.

The first area was the Hybrid Electric Integrated Systems Testbed, or HEIST, an experimental wing initially mounted on a specially modified truck. It was used for a series of research projects intended to integrate complex electric propulsion systems. The testbed functions like a wind tunnel on the ground, accelerating to as much as 73 mph to gather data. Researchers used the testbed to measure lift, drag, pitching moment and rolling moment that can validate research tools.

HEIST's first experiment was called the Leading Edge Asynchronous Propeller Technology, or LEAPTech. The experiment began in May 2015 at Armstrong and consisted of 18 electric motors powered by lithium iron phosphate batteries that are integrated into the carbon composite wing.

Those tests showed the distribution of power among the 18 motors creates more than double the lift at lower speeds than traditional systems. LEAPTech was a collaboration of Armstrong and NASA's Langley Research Center in Hampton, Virginia, and California companies Empirical Systems Aerospace (ESAero) of Pismo Beach and Joby Aviation of Santa Cruz.

Another early milestone was collecting data from baseline Tecnam P2006T flights. Because a P2006T will become the X-57 that will fly with electric propulsion technology, it was necessary to fly a baseline model, powered by traditional methods, to eventually compare data between the standard and electric-powered flights.

The arrival of X-57's fuselage to California marked another critical milestone in NASA's X-57 project, marking a point in which the electric propulsion integration and conversion of the Tecnam P2006T airframe into the X-57 was able to begin.

Upon arrival and unveiling, engineers from Armstrong and Langley, many of whom had been working on the distributed electric propulsion project for several years, got their first look at the aircraft.

"We're all really excited. We get to see in person what we've been computer modeling for so long," said Sean Clarke, principal investigator for X-57, upon watching the fuselage being uncrated for the first time. "We've been looking forward to this for years now, so there's been a lot of anticipation, and to have it out here in front of us is a relief."

Once final inspections at ESAero were complete, the aircraft was transported to Mojave, California, for modification into a fully electric airplane from the stock Tecnam configuration. Integrating electric systems through this modification will allow the team to validate the safety of the all-electric power system and two large motors in flight before a new, high-aspect ratio wing is integrated. The planned final version will feature 12 small electric propellers along the new wing's leading edge and two larger electric cruise motors out on the wing tips.

Armstrong personnel designed and fabricated a unique test stand called

X-57, page 16



ED15-0290-39

NASA/Carla Thomas

Armstrong pilots flew an Italian-built Tecnam P2006T aircraft in September 2016 to collect data to compare to a modified P2006T that is under development for the agency.



AFRC2016-0268-18

NASA/Ken Ulbrich

The Tecnam wing integration begins at Scaled Composites in California.



ED15-0137-32

NASA/Tom Tschida

Engineers work on a wing with electric motors that is part of an integrated experimental testbed. From left are Sean Clarke, Kurt Papathakis and Anthony Cash.



ED14-0318-10

NASA/Ken Ulbrich

The Subscale Prototype Technology Evaluation and Research Aircraft soon will be testing a pair of folding wings with a one-of-a-kind actuator that changes its properties when heat or cold is applied.

Folding wing is coming

By Jay Levine

X-Press editor

A subscale aircraft is set to begin a flight test series at Armstrong later this year to see if a folding wing in flight will provide performance enhancements that may increase the wing's efficiency.

The first flights on the subscale Prototype Technology Evaluation and Research Aircraft, or PTERA, will allow researchers to understand how a new technology, high energy density actuators and folding wings will change a vehicle's flight performance. This would allow the Span-Wise Adaptive Wing (SAW) to adjust in flight to the optimum position that could result in more yaw, side-to-side movement, stability and power, said Matt Moholt, NASA Armstrong's principal investigator.

The PTERA's flight performance can be compared to that of the simulations, which were used to predict system parameters and to develop control laws. The control laws are intended to be tested in later flights, he said. PTERA has full research instrumentation and permits an environment to check out the SAW equipped aircraft performance.

The wings were integrated and instrumented into the PTERA

PTERA, page 18

Armstrong wing studies

Research could lead to better wings

Jay Levine

X-Press editor

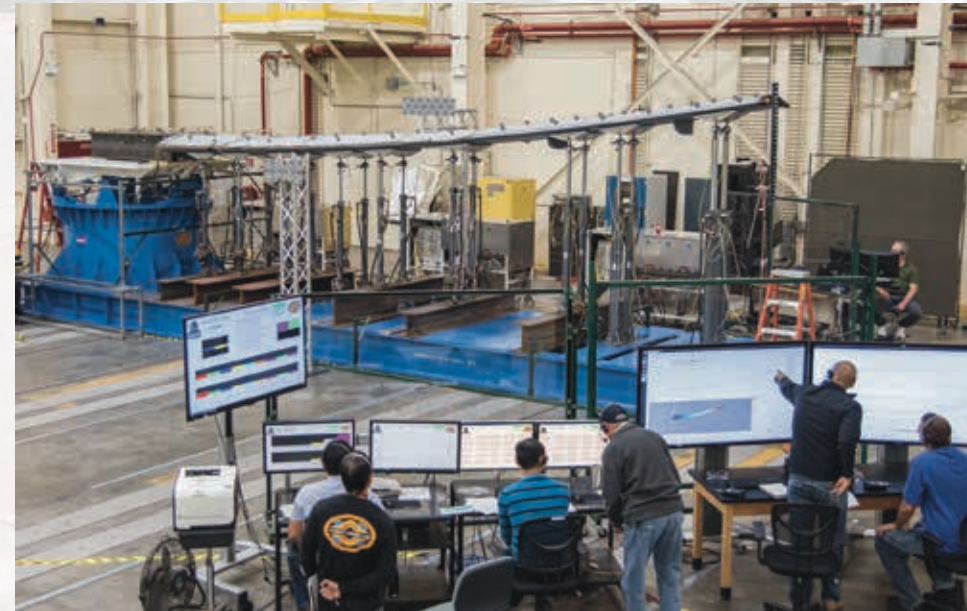
A uniquely instrumented wing will allow researchers to investigate advanced methods of monitoring flight loads, which could lead to improved flight safety.

The Passive Aeroelastic Tailored, or PAT, wing is expected to arrive later this year at Armstrong. The uniquely designed composite wing is lighter, more structurally efficient and has flexibility compared to conventional wings, said Larry Hudson, Armstrong Flight Loads Laboratory chief test engineer.

The layout of the fibers that make up the PAT wing are specially tailored and the performance of that design will be validated during these tests. Future commercial aircraft could use this wing building design to maximize structural efficiency, reduce weight and conserve fuel.

"It's called a passive tailored wing because the structural efficiency is contained within the construction of the wing, it's not an active system that is controlling the structural efficiency of the wing, it's the composite layout," Hudson explained.

The PAT wing was developed by Aurora Flight Sciences of Virginia and fabricated at the company's manufacturing plant in Mississippi. The project is funded by the Aeronautics Research Mission Directorate through the Advanced Air



AFRC2017-0259-062

NASA/Lauren Hughes

Armstrong's Flight Loads Laboratory is using a uniquely instrumented wing to investigate advanced methods of monitoring flight loads, which could lead to improved flight safety.

Transport Technology project.

Until the PAT wing arrives, loads lab staff are working on the Calibration Research Wing, or CREW, in a similar test fixture for proficiency testing. CREW will be used as a pathfinder for the PAT wing. The two wings share similar instrumentation layout and collect similar data, which is why the CREW wing is a valuable hands-on dry run to collect data, learning how to analyze data and complete calibrations.

One of the major differences in

the test architecture is the overhead loading system required to handle the significantly larger wing tip displacement inherent with the longer and more flexible PAT wing.

Another research item is the extensive use of the Fiber Optic Sensing System, or FOSS, technology. FOSS will enable faster and more economical loads calibration of the wings in the future. FOSS uses hair-like optical fibers that are

PAT wing, page 13



AFRC2017-0246-06

NASA/Lauren Hughes

James Smith and Gary Cosentino prepare the X-56A for flight. Researchers are using the aircraft to investigate if highly-flexible, lightweight wings can be controlled.

Highly flexible wings tested

By Jay Levine

X-Press editor

The subscale X-56A is scheduled for a series of research flights in November to prove enabling technology for designing aircraft with highly flexible, lightweight wings. The use of less structurally-rigid wings could be critical to future long-range, fuel-efficient airliners.

A risk reduction flight Aug. 31 from Armstrong demonstrated that past challenges experienced during takeoffs and landings are resolved, said Cheng Moua, X-56A project manager.

To mitigate the down sides of earlier flights, researchers redesigned the landing gear and braking system to improve performance, Moua explained. The flight controller was revised, extensive analysis completed and ground vibration data collected to update theoretical models to improve predictions on how the aircraft will fly.

X-56A, page 18

Hear this: 30 percent less noise

By Jelisa Beaty

Armstrong Public Affairs

The Adaptive Compliant Trailing Edge flight test project, or ACTE, is proving that a new flap design can reduce aircraft noise by as much as 30 percent on takeoff and landing.

The second phase of the project, ACTE II, which is expected to continue this fall and conclude at the end of the year, will build on the research and data collected on the flap locked in different positions in flight during the first phase. The second phase, taking place at Armstrong, also will validate the technology at higher speeds and research how the flaps impact aerodynamic forces that could improve fuel efficiency. The goal of the ACTE flight test project is to investigate the capabilities of shape-changing surfaces and determine if advanced flexible trailing-edge wing flaps can improve aircraft aerodynamic efficiency, enhance fuel economy and reduce airport noise generated during takeoffs and landings.

“ACTE has tremendous potential to increase airframe efficiencies,” said Kevin



ED15-0076-03

NASA/Ken Ulbrich

The experimental Adaptive Compliant Trailing Edge flap on NASA's modified G-III Aerodynamic Research Test Bed aircraft is expected to greatly reduce aircraft noise on takeoff and landing.

Weinert, ACTE project manager. “We have tested the flap at six positions to show we can take advantage of lightweight, efficient structures.”

In 2014, engineers replaced the traditional 19-foot aluminum flaps

for the ACTE wings on NASA's Gulfstream-III Subsonic Research Aircraft, or SCRAT. The Air Force Research Laboratory funded the flexible flaps that change shape, bend and are made of composite materials designed by FlexSys Inc.

Traditional flaps, when lowered, create gaps between the forward edge, the sides of the flaps and the wing surface. A flexed wing configuration allows a level of

ACTE, page 18



ED14-0095-128

NASA/Ken Ulbrich

NASA's G-III test bed rests on three pneumatic lifting devices or “airbags” in preparation for loads testing in NASA Armstrong's Flight Loads Lab prior to research flights.



ED13-0264-174

NASA/Ken Ulbrich

NASA aircraft technicians Leo and Juan Salazar work on installation of test instrumentation in preparation for installation of the experimental Adaptive Compliant Trailing Edge flap on NASA's modified G-III Aerodynamic Research aircraft.

By Jelisa Beaty

Armstrong Public Affairs

The latest versions of U.S. Air Force F-16 jets have a new technology greatly reducing ground collisions resulting in the loss of the pilot and the plane thanks to a system developed at Armstrong in collaboration with the Air Force Research Laboratory in Ohio.

The Automatic Ground-Collision Avoidance System, or Auto-GCAS, aircraft software is a system that activates upon detecting a collision course with the ground, said Mark Skoog, principal investigator for autonomy. The system warns a pilot, and if imminent collision with the ground is determined, it locks the pilot controls and automatically performs a recovery maneuver, returning full control back to the pilot once the aircraft has cleared the terrain.

The latest versions of the U.S. Air Force F-16 jets that are equipped with the USAF/NASA/ Lockheed Martin developed system have been more capable of avoiding ground collisions, resulting in at least six confirmed saves. The U.S. Office of the Secretary of Defense has been working with U.S. military branches that use F-16 aircraft to incorporate the software, Skoog explained.

Considering that about 75 percent of aircraft fatalities result from ground collision, such a system is needed, he said.

Skoog wants to apply the concept behind the Auto-GCAS and extend it to automatically protect unmanned aircraft systems. To that end, Armstrong is working with NASA's Langley Research Center in Virginia. Langley supplied a surrogate uninhabited aircraft system that simulates flight test techniques.

Auto-GCAS saves lives

Researcher wants to apply concepts to protect UAS



ED09-0290-8

NASA/Carla Thomas

Armstrong and the Air Force Research Laboratory used the U.S. Air Force's F-16D Automatic Collision Avoidance Technology, or ACAT, aircraft to develop and test collision avoidance technologies.



NASA/Jeff Caplan

NASA Langley's Cirrus SR-22 is testing technologies to safely integrate unmanned aircraft systems into the national airspace system.

PAT wing... from page 11

bonded to the wing's surface and can provide thousands of strain measurements to determine wing shape and distributed load.

“We will look at the limits of FOSS and how to maximize its use to help reduce the cost and schedule of loads calibration

testing,” Hudson said. Davis-Monthan Air Force Base in Arizona provided the MQ-9 (same kind of aircraft as NASA's

“With the SR-22 we were able to begin to address what the common general aviation pilot would need from such a system,” Skoog explained.

That system on the SR-22 was a warning system the pilot used to maneuver manually, he said. The system informed the pilot as to the kind of action to take to avoid a terrain collision.

Armstrong Center Innovation Funds along with FAA funding provided another avenue of study. A quad copter was used for the development of the Expandable Variable Autonomy Architecture, or (EVAA). EVAA focuses on the concept that new software does not have to be qualified for flight if it is embedded within a trusted program, which the project calls a wrapper. EVAA stands out as a potential promising approach for certifying autonomy.

EVAA could potentially create rules through a system design for UAVs on how to operate safely and in tandem with society, similar to how parents might create rules for young children.

These wrappers, or Multi-Monitor Run Time Assurance (MMRTA) systems, are trusted systems that would take over in the event of an emergency. The system operates hand-in-hand with vehicle command and control. Much like Auto-GCAS is a wrapper, the MMRTA guarantees good inflight decisions and handles problems one at a time beginning with the most critical, such as keeping the aircraft aloft, Skoog explained.

Auto-GCAS was pioneered by a partnership of the Office of the Undersecretary for Personnel and Readiness, the AFRL, Armstrong, the Air Force Test Center and Lockheed Martin.

Ikhana) wing that serves as the CREW testbed. In 2007, Ikhana was the first large aircraft to fly with FOSS at Armstrong.

UAS Integration in the NAS

**NASA is assisting
the FAA with steps to
safely incorporate
unmanned vehicles**



By Jay Levine

X-Press editor

When Unmanned Aircraft Systems (UAS) fly routinely where human-piloted aircraft do, it will have happened in part as a result of NASA's UAS Integration in the National Airspace System, or UAS in the NAS project.

"Integration of UAS into the NAS for routine flight operations is a complicated endeavor that involves development of technologies, exhaustive research through modeling and simulations and comprehensive flight testing that inform Federal Aviation Administration (FAA) technical standards and operational approvals," said Sam Kim, a UAS in the NAS subproject engineer.

A major step in the direction of incorporating large UAS into the NAS is a planned remotely piloted Ikhana aircraft flight demonstration that would fly for the first time in the NAS without an escort aircraft in 2018 from NASA's Armstrong Flight Research Center in California.

Most current UAS operations in the NAS require that a piloted chase aircraft serve as the UAS "eyes" to see and avoid other aircraft. During the 2018 flight demonstration, Ikhana will be employing its own detect and avoid (DAA) systems integrated onboard the aircraft and in the ground control station to maintain safe separation with other aircraft and avoid collisions.

The FAA is developing standards in the form of Technical Standard Orders, or TSOs, that include requirements for air-to-air radar, detect and avoid and command and control communication systems, Kim said. FAA TSOs and operational approval documentation for UAS flights in the NAS with airborne DAA are nearly ready, and the Ikhana no chase aircraft flight demonstration could show how the technology and standards fit together. Future certification and operational approval processes could be solidified with the UAS in the NAS project in partnership with industry, academia and other government agencies.

In fact, NASA researchers wrote a lot of the requirements contained in recently released documentation delineating minimum operational performance standards for detect and avoid systems and air-to-air radar for traffic surveillance. The UAS in the NAS project team has worked with the UAS community since 2011 to address the technical barriers that preclude routine UAS operations.

UAS ultimately could be used for monitoring power lines, performing cargo deliveries, surveying crops, conducting infrastructure inspections on bridges and performing emergency response and damage assessments.

The next UAS in the NAS flight test series is set to start in the fall of 2018 to support development of detect and avoid standards for medium-sized UAS, Kim said. These flights will evaluate low cost, size, weight and power airborne sensors and system modifications.

While NASA's Ikhana aircraft has been used as a key research UAS, NASA's Sensor Integrated Environmental Remote Research Aircraft, or SIERRA, from NASA's Ames Research Center in California, is set to be a star of the upcoming series. The former science platform was chosen because it is a medium-sized UAS that meets the requirements of the upcoming flight series, Kim said. It was selected for its large nose bay and payload capability, which would house the required airborne surveillance sensor and other DAA and flight test equipment.

A key test team challenge with the SIERRA UAS is its small size and the ability of pilots to see the aircraft at safe distances during air-to-air encounters. The SIERRA has a 20-foot wingspan and weighs about 500 pounds compared to the approximately 8,000 pound Ikhana that has a wingspan that measures 66 feet. These flight tests will evaluate how DAA standards developed for larger, faster UAS will need to be adapted for smaller and slower UAS.

Ames anchors the Detect and Avoid UAS in the NAS subproject, which NASA's Langley Research Center in Virginia also supports.



NASA

The SIERRA UAS is the star of a new test series. The aircraft is from NASA's Ames Research Center in California.



AFRC2016-0293-30

NASA/Carla Thomas

NASA's Ikhana remotely piloted aircraft (front right) is situated on the ramp after the UAS in the NAS Flight Test Series 4 flight, along with five flight "intruders." These intruders, which include NASA's TG-14 (front left), T-34C (front center), B-200 King Air (back left), Gulfstream-III (back center) and a Honeywell C-90 King Air (back right), fly within a pre-determined distance to Ikhana to test Detect-and-Avoid technology.

Command and Control is another UAS in the NAS subproject, one that NASA's Glenn Research Center in Ohio is leading.

The Ikhana test flight series that concluded in August included a dozen test flights that collaborated with the FAA and industry partners to continue to evolve safe separation and collision avoidance systems. The flights validated system models and demonstrated prototype technology. The team collected flight test data to evaluate systems performance and turned that over to the FAA team for their analysis.

The Ikhana conducted 241 encounters where an aircraft would broach its surrounding airspace. Ikhana cockpit displays presented the aircraft's pilots with alerts and maneuvering guidance information about how to effectively respond to the intruder if a conflict is predicted. Flight tests generated information helpful to developing UAS-related standards for use with the new Airborne Collision Avoidance System that will work with the FAA's Next Generation Transportation System.

X-57... from page 9

Airvolt to test five X-57 electric-powered cruise motors. Researchers will use Airvolt, which is made of steel and aluminum and is 13.5-foot tall, to fine tune, test and validate the motors. The tests began in September and are scheduled to end in early 2018. Once the research is complete, two motors will be integrated onto the X-57 for the initial flight tests.

Meanwhile, efforts at Langley are in full swing to validate projected models through wind tunnel testing. This testing took place while NASA's Glenn Research Center in Ohio conducted battery testing, which is key to making sure systems are in ideal conditions for flight testing.

Finally, when it comes to NASA X-planes, no amount of preparation, training or precaution is too great. These experimental aircraft, which have historically pushed the boundaries of aeronautics, feature exploratory designs and systems with which even the most experienced pilots have little actual practice.

For pilots to be as safe as possible in piloted X-plane flight demonstrations they need to gain experience well before the actual aircraft is flyable. Test pilots and engineers at Armstrong are "flying" a simulator designed to the innovative specifications of X-57.

Flight control engineers and technicians at Armstrong have designed the X-57 simulator to provide a virtual flight experience according to what the X-plane will actually feel like when it flies. This familiarizes the pilots and engineers with the system, making them more adept with reaction times and maneuvers, and helping the team develop emergency procedures.

As preparation continues for the X-57's first flight, the time draws closer to NASA's return to piloted, crewed X-plane flight demonstration, and with it, an opportunity to revolutionize aviation once again.



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NASA/Lauren Hughes

Above, Matt Redifer prepares the Airvolt electric motor test stand for a power plant that will propel the X-57 Maxwell. At right, the X-57 motor is ready for testing.



ED15-0137-64

NASA/Tom Tschida

An experimental wing, called the Hybrid Electric Integrated Systems Testbed, was mounted on a specially modified truck. The integrated experimental testbed reached speeds of up to 73 mph to create the effect of a wind tunnel on the ground.



AFRC2016-0357-1

NASA/Lauren Hughes

X-57 principal investigator Sean Clarke flies the X-57 simulator at Armstrong and examines the ideal maneuvers and reaction times for flight.



AFRC2017-0269-13

NASA/Lauren Hughes

Swept wing design could boost supersonic efficiency

Matt Kamlet

Armstrong Public Affairs

A series of supersonic flights at Armstrong is examining efforts to improve the efficiency of future supersonic aircraft.

The flights follow research developments identified during high-speed wind tunnel testing conducted at NASA's Langley Research Center in Virginia. A flight test fixture attached underneath a NASA F-15 with a model swept wing will look at different configurations based on those developments.

As NASA proceeds toward the possible development of a Low-Boom Flight Demonstration aircraft, or LBFDA, research done by the agency's Commercial Supersonic Technology project, or CST, continues to investigate ways to mitigate or minimize the disruptive sonic boom associated with supersonic flight. The agency also seeks to overcome other technical barriers to innovation in commercial supersonic flight.

One such barrier is fuel efficiency. At supersonic speeds, the force of drag that must be overcome is large. Due to the interaction of air flow with the aircraft's surface, this friction drag contributes about half of the total drag at supersonic speeds. This series of flights is exploring ways of reducing friction drag and increasing efficiency through new and innovative methods of achieving swept wing laminar flow.

As an aircraft flies, there is a thin layer of air, called the boundary layer, which exists between the surface of a wing and the fast-moving air around it. This boundary layer generally begins as a smooth, or laminar, flow, which creates minimal friction drag. However, as air flow progresses over the aircraft's



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NASA/Carla Thomas

NASA's F-15 research testbed will expose the Swept Wing Laminar Flow test article to speeds up to Mach 2, matching conditions presented during wind tunnel testing at NASA's Langley Research Center.



AFRC2016-0356-8

NASA/Ken Ulbrich

Testing different configurations of distributed roughness elements on the Swept Wing Laminar Flow test article, seen suspended above, will allow NASA researchers to observe which distributions are most efficient in extending laminar flow over a supersonic aircraft's wing.

surfaces, tiny disturbances begin to affect the boundary layer, and it eventually transitions into a more turbulent flow, which produces much more friction drag. On swept wing aircraft, this turbulence presents the aerodynamic challenge of overcoming crossflow on the wing.

Future supersonic aircraft

seeking to achieve a low-boom, such as the LBFDA, will rely on a swept wing design in order to fly at supersonic speeds without producing a loud sonic boom. The swept wing design generally produces crossflow, which is a name for airflow disturbances that run along the span of the wing, resulting in turbulent flow,

increased drag and ultimately, higher fuel consumption.

NASA believes this obstacle may be overcome through the use of an array of small dots, called distributed roughness elements, or DREs.

"Swept wings do not have much laminar flow naturally at supersonic speeds, so in order to create a smoother flow over the wing, we're putting the DREs along the leading edge of the wing," says CST subproject manager Brett Pauer. "These DREs can create small disturbances that lead to a greater extent of laminar flow."

The DREs work by alleviating the crossflow, and delaying the transition to turbulent air flow. The crossflow is essentially crowded out and is not allowed to grow. The boundary layer flow eventually does transition, but it occurs much further along the path of the wing flow and thus maintains laminar flow for a longer period of time and over more of the wing. The more laminar flow, the lower the overall drag, leading to a more efficient aircraft.

A different configuration of the DREs was recently discovered during wind tunnel testing of a wing model at Langley that is expected to work at these high-speed conditions. NASA engineers have integrated the 65-degree wing model to a NASA F-15 aircraft. The swept wing model will test several configurations of DREs along the test article's leading edge at speeds up to Mach 2, or more than 1,500 mph. Researchers are looking at how different configurations of DREs impact laminar flow.

This is being done by monitoring the flow during flight through the use of an infrared

Swept wing, page 19

X-56A... from page 11

Long, lightweight flexible wings similar to the ones on the X-56 are crucial to the design of future long-range aircraft and are especially susceptible to a destructive vibration known as flutter at lower speeds. If those vibrations are not alleviated, they could cause controllability challenges or potentially compromise the aircraft's structure.

Flutter hasn't been restrained before on an aircraft like the X-56, Moua said. Flutter suppression could lead to improved ride quality, efficiency, safety and the longevity of flexible aircraft structures, he added.

"We want to show that this kind of wing can be built and the control technology exists to suppress flutter on them," Moua said.

The flights will build up slowly as each step is meticulously executed. New techniques will be tested to collect data and make sense of it and a methodology will be developed to confirm flutter was suppressed, he said. Armstrong engineers developed a flight control system and advanced sensors to gather the information required to achieve the project's goals.

Lockheed Martin developed the small, remotely piloted aircraft for the U.S. Air Force Research Laboratory and transferred the aircraft to Armstrong for flight research. The program is funded through NASA's Advanced Air Transport Technology project and NASA's Flight Demonstration Capabilities project.



AFRC2017-0246-45

NASA/Lauren Hughes

The X-56A is scheduled for November flights to further investigate how highly-flexible, lightweight wings function.

PTERA... from page 10

at The Boeing Company, who is a partner in this effort. Boeing also performed loads calibrations and wind tunnel tests on the wing to better understand the thermal characteristics of the actuator. The actuator is a tube made of shape memory alloy – a material that has different properties depending on if it's hot or cold.

"You can attach one end of the actuator and the other end will do all the work without hydraulics or gearing," Moholt said. "You can tightly design the actuator package, which results in a durable product that is lighter and requires less maintenance. Those are some of the

ACTE... from page 12

control over how and where the wing responds to wind gusts. This design may significantly reduce a major source of airframe noise – making takeoff and landing quieter.

The first flight series for the ACTE took place in 2014 and 2015 at Armstrong, where relevant data were collected on the different flap settings and their ability to withstand the flight environment. These flaps have the potential to be retrofitted to existing airplane wings as well as incorporated into new airliners. The controls on the experimental surfaces were locked on a specific setting and were restricted to a speed of 0.75 Mach, which is approximately 570 miles per hour.

Initially, flights with ACTE flaps were in a flexed configuration

and limited to a maximum speed of 250 knots and 20,000 feet. ACTE

II showed the technology was safely demonstrated in flight at speeds similar to commercial airliners at Mach 0.85.

NASA is currently conducting data analyses to gain a better understanding of how these new wing flaps may affect aircraft fuel efficiency. The ACTE II flights will also analyze fuel flow through the engine to achieve accurate drag estimates at varied speeds, altitudes and weights, according to Weinert.

The ACTE project is in line with the goals of the Environmentally Responsible Aviation, or ERA, project under the Integrated Systems Research Program of NASA's Aeronautics Research Mission Directorate.

Wings with a twist

By Jay Levine

X-Press editor

A new method of designing aircraft wings developed at Armstrong could redefine the efficiency of future aircraft.

An increasingly complex subscale aircraft called the Preliminary Research Aerodynamic Design to Lower Drag, or Prandtl-D, is showing the value of wings designed with a literal twist. It's that twist that makes them significantly more efficient than conventional wings, said Al Bowers, Armstrong chief scientist and Prandtl program manager.

To verify the aircraft's aerodynamic loads, a Fiber Optic Sensing System was added, he said. FOSS data will be compared to pressure data gathered from sensors on the wings to verify the aircraft's efficiency. The Prandtl-D research, which has been bolstered by student interns, has resulted in a patent for the wing design method and another for propellers using the same method.

Using the Prandtl D design method and applying it to wings for other aircraft could lead to an 11-percent reduction in drag and a substantial increase in fuel economy, Bowers explained. The concept may also lead to significantly enhanced controllability that could eliminate the need for a vertical tail and could lead to new aircraft designs.

Flight data from early Prandtl-D vehicles validated the use of twist to tailor the lift distribution across the aircraft's wing – bell shaped rather than the traditional elliptical shape – leads to more efficient



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NASA/Lauren Hughes

flight. In fact, engineers estimate future aircraft could see more than a 30-percent increase in fuel economy by using the new methods of wing design and eliminating the weight of the modern aircraft tail and its flight control surfaces.

In that regard, Prandtl-D research also borrows from how birds fly. Birds turn and bank without vertical tails that are required for such maneuvers on traditional aircraft, but not on the Prandtl aircraft. The bungee launched Prandtl-D has a 25-foot wingspan and is made of carbon fiber.

Work on the Prandtl-D led to a concept for a Mars airplane. If the Preliminary Research Aerodynamic Design to Land on Mars, or



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NASA/Lauren Hughes

The Prandtl-M had a recent successful flight to verify its aerodynamics.

Prandtl-M aircraft, is successful, it could collect and transmit valuable information back to Earth. It could get to Mars by hitching a ride in multiple CubeSats that are used as ballast in the system used to transport the rovers to Mars.

Envisioned with a wingspan of 2 feet, the aircraft would be able to deploy, fly in the Martian atmosphere, glide down and land. During Prandtl-M flight over

Al Bowers, center, and a group of student interns hook up a bungee cord for a flight of the Prandtl-D 3C subscale glider aircraft.

Mars it could collect very detailed high-resolution topographic images that could tell scientists about the suitability of potential landing sites. Prandtl-M would have a range of about 20 miles.

The Prandtl-M is expected to be ready for a 1,000-foot air launch from a weather balloon later this year to verify the aerodynamics of the aircraft. Once that is complete, instrumentation will be added for flights up to 20,000 feet, also from weather balloons.

In addition, a larger version of the Prandtl-M could also be used for the Weather Hazard Alert and Awareness Technology Radiation Radiosonde (WHAATTR) Glider. Once the payload size is determined, the project will advance. It is envisioned that this reusable aircraft could economically provide more accurate and immediate information on severe weather phenomenon like hurricanes.

Swept wing... from page 17

camera mounted under the right inlet of the F-15. This will help interpret the specific DRE configurations that produce the most laminar flow. The camera will monitor flow by picking up

signatures of heat produced by air flow, indicating heat and increased friction.

If environmental noise standards are identified, met and are acceptable to the general public,

commercial supersonic flight over land, which is currently restricted, could be permitted.

"Supersonic laminar flow is something of an elusive holy grail for aerodynamicists," states

CST project manager Peter Coen. "This test, while still exploring fundamentals, is an important step toward achieving CST's fuel efficiency goals for quiet supersonic overland airliners."