MAD MUTT

Code One

Jeff Rhodes

The X-56A was flown for the first time at the NASA Dryden Flight Research Center at Edwards AFB, California, on 26 June 2013. Lockheed Martin test pilot Mike Hartenstein sat at the ground-based left-seat console flying Fido, the nickname of the first aircraft.

"I worked on a program in the 1980s where flutter really bit us, and that program was eventually canceled," recalled Ed Burnett, the X-56A unmanned research aircraft technical program manager for the Lockheed Martin Skunk Works. "It became a personal interest of mine ever since then to kill flutter."

Flutter occurs at the point where aerodynamic forces acting on an aircraft in flight and the structural dynamic properties of the vehicle combine, or couple, to produce an often violent, harmonic vibration. The resulting vibration creates a potentially catastrophic condition that can quite literally break a wing or tail surface off an aircraft.

In simple terms, think of a flag on a pole. The wind blows at a specific speed, but the flag, with a specific set of structural properties, doesn't wave uniformly from side to side. It usually dips, or swells, or bends. When conditions are right to cause the flag to pulsate, the flag is basically experiencing induced flutter. If the wind is too strong and the grommets or stitching fail, the flag is ripped from the pole.

Flutter has been a known hazard almost from the beginning of powered flight. Even with more than a century of aircraft design experience, conditions where flutter occurs can still be hard to predict precisely. Aircraft designers traditionally have dealt with flutter by trying to avoid it—through such methods as adding structure.

By building enough stiffness into a specific structure, the natural tendency of structural dynamics and aerodynamics to couple can be prevented—even at conditions way outside an aircraft's normal operating flight envelope. But the increased stiffness also adds weight—

sometimes considerable weight—which, in turn, increases fuel use. And the end result—reduced range.

The X-56 team hopes to do something that is completely different. “The aim of the X-56A program is to mature flutter suppression technologies,” notes Burnett. “If we can suppress flutter by using the same flight control technologies used to provide vehicle stability, designers can use longer, more flexible wings and lighter weight structures. That will allow future aircraft to fly higher, faster, and farther than before.”

Long And Thin

Long, thin, high aspect ratio wings are considered key to the design of many future long-range manned and unmanned aerial vehicles and fuel-efficient transports. These future aircraft will likely bear many of the same features designed into the X-56, including a blended body, long thin swept-back wings, and very thin airfoils.

The X-56 was funded by the US Air Force Research Laboratory, or AFRL. The contractor test team hopes to demonstrate that they can accurately predict the onset of flutter, and by using the flight controls, actively suppress the aeroelastic instabilities of the aircraft.

Two types of wings will be tested on the X-56—a stiff set and a flexible set. The stiff set of wings is designed in the traditional manner with beefed up structure to avoid having flutter within the flight envelope. These are used for the initial airworthiness tests of the aircraft and any future non-flutter flight research. Flutter was deliberately designed to be deep in the flight envelope of the X-56A’s flex wing configuration. Because flutter is a natural coupling of the aerodynamics and structural dynamics, simply flying fast enough causes it to occur.

The X-56A is designed to have three different flutter modes within the flight envelope—body freedom flutter, or BFF; symmetric wing bending torsion; and anti-symmetric wing bending torsion. The active flutter controls on the X-56 are designed to suppress all three modes simultaneously.

The aircraft has external mounts that allow the wings to be removed easily and replaced with the flexible wings. The external wing attach points are covered by an aerodynamic fairing that looks like an upside down hot dog bun. Switching the wings takes about fifteen hours to complete.

“The internal structure of the wings is the same on both designs, but the flutter wings are flexible,” noted Kent Burns, the X-56A program manager. “Both sets are made of a carbon fiber internal structure of spars and ribs, but the stiff wings have very thick, highly tailored carbon fiber skins and the flex wings have very thin fiberglass and foam skins.” Three identical sets of flex wings were built, just in case one set fails in flight as a result of flutter.

The flutter wings have internal water tanks and water pumps. The weight of the water is used to simulate the fuel that would be required for long duration flight such as a long-range transport or high altitude reconnaissance aircraft. “Due to the nature of this type of research, it’s possible that we could break a wing off during testing,” Burns continued. “If that happens on this vehicle, we’ll only be spilling water instead of fuel.”

Fido And Buckeye

The two parts of the X-56 program each have a descriptor. The test program is the Multi-Utility Aeroelastic Demonstrator, or MAD, and the aircraft itself is the Multi-Utility Technology Testbed. So the team picked up the name MAD MUTT.

Following up with the canine theme, the test team had a dog tag painted on the underside of each of the two identical aircraft. Fido—from a slogan the team uses—Flutter It, Drive On—is the primary test aircraft, while Buckeye—named for the Air Force program manager's dog and the mascot of his alma mater—is the backup.

The 480-pound X-56A has a twenty-eight foot wingspan and is a little over seven feet in length. The aircraft measures nearly five feet from the ground to the top of the vertical surface of the wing tip. Construction took about eighteen months.

"We have a really good team—AFRL, NASA, the Skunk Works, and our partner, GMFI Aerospace and Defense," said Burnett. "This was the first flyable aircraft GMFI built. We learned a lot and so did they." GMFI, located in Southern California, is better known for building custom cars.

The X-56 is powered by two eighty-pound thrust JetCat P400 turbine engines, with an additional hard point in the center of the fuselage aft upper deck for mounting an additional engine or a tail like a conventional aircraft, if required.

"We didn't want propellers inducing low frequency noise into the flutter tests," added Burnett, who is also a Lockheed Martin senior technical fellow. "The jets are pretty powerful and located close together. They are also out of the airflow affecting the wings."

A forward-looking camera is installed in the aircraft's nose that allows the ground-based pilot to fly the aircraft. A small microphone is installed next to the front camera to allow the pilot to hear the aircraft, which provides significant situational awareness to the pilot and test team. The GPS and communications antennae are also located on the nose of the aircraft, which is adorned with nose art similar to the Flying Tigers of World War II.

While very much a real aircraft, the scale on the X-56 is different. The chocks are little blocks of wood and safing pins and the red Remove Before Flight streamers are actually key chain fobs. A shop-vac setup blows cooling air to the avionics bay while Fido or Buckeye is put through its preflight checks.

Test Equipment

Additional cameras located on the composite fuselage of the X-56 are pointed outward toward the wingtips to record the flutter events. A grid pattern is painted on the inside of the wingtip to provide a visual reference to measure the amplitude of the flutter.

The X-56 is capable of a maximum speed of 150 knots, but flutter onset with the flexible wings comes at about 110 knots, a speed well within the aircraft's flight envelope. The goal is to detect the onset of flutter using accelerometers on the wing structure and then to send commands to the flight controls to dampen the vibration and allow the aircraft to fly well beyond the flutter onset speed.

The aircraft also has a ballistic recovery system if the wings break during testing or if the aircraft departs controlled flight. The aircraft's landing gear was sized for impact if the aircraft had to use the emergency system parachute with the aircraft at maximum weight. If the recovery system isn't needed for a particular test, the cavity can be used for twenty-eight pounds of test payload.

The X-56A is more than just the aircraft—it's a complete research system, with a ground control station, simulation capability, a system integration lab capability, and vehicle transportation and storage equipment.

The Skunk Works developed the ground control system using commercial off-the-shelf equipment and a commercial trailer to reduce costs. The pilot and test director sit side-by-side in the front of the trailer with the test coordinator sitting behind them. The flutter and flight control test engineers sit at the consoles along the side wall. The test data conductor works in the back of the trailer along with an air conditioner that keeps both the people and the racks of equipment cool.

A second trailer is used to transport the aircraft. A third trailer, a small flatbed, is used to tow the aircraft and to swing it easily to conduct ground communications checks.

Not A New Idea

"I've been around a lot of programs over my career. We started talking about active control methods to combat flutter in the 1970s," said Jeff Beranek, the X-56 chief engineer and flutter lead. "There is a paragraph in a Lockheed research report from that period that proposed a program exactly like what we're trying to do now with X-56. The methods and technology of the era were not sufficiently mature to successfully achieve the integrated suppression we are doing today."

The X-56A program began with small independent research and development contracts in 2005. "We built five small hand-launched vehicles that had wings made of carbon fiber and Styrofoam. They were essentially designed to break to demonstrate flutter prediction capability and then ultimately demonstrate flutter suppression," said Beranek.

The relatively inexpensive and small, ten-pound, ten-foot wingspan vehicles built under the BFF program were designed to be flown to their physical limit. The miniaturization of computers in the late 1990s was the big push in moving flutter suppression studies forward. This allowed high-risk flutter suppression testing on the relatively inexpensive BFF platform. "The X-56 wouldn't be possible without the increase in computational power since the early 2000s," observed Beranek.

"But testing those aircraft showed we could predict flutter onset and perform flutter suppression," noted Burnett. "The results of the BFF research led to an AFRL contract to mature active suppression, and the building of two more BFF aircraft. Of the total of seven aircraft built, only two of the BFF vehicles survived and both of them have been used for additional research. We also conducted other studies. The combination of BFF research and those studies led to this program."

Prior to first flight, the X-56 was put through a series of static tests. Engineers used bags filled with lead shot and piled the shot bags on the wings, similar to conducting static testing from the 1930s.

The X-56 test team set up in the same hangar at Edwards AFB, California, which was used to prep the XP-59, America's first jet aircraft, in 1942. The X-56A was flown for the first time at the NASA Dryden Flight Research Center at Edwards on 26 June 2013. Lockheed Martin test pilot Mike Hartenstein sat at the left-seat console flying Fido. On the test card was a drawing of a dog wearing goggles.

The stiff wing portion of flight envelope expansion was completed in eight flights through the end of September. The flights lasted about twenty-five minutes each.

Testing with the flex wings is scheduled to begin in January 2014, and the Skunk Works portion of X-56 testing is expected to be completed early in the year. A follow-on AFRL test program is possible, but the current plan is for the entire system to be turned over to NASA after the initial flight test program is completed.

It's been said that flutter is a particularly nasty dragon that lives in one corner of the sky. "The work we're doing with the X-56A may not kill flutter completely," observed Burnett. "But we will have a much better understanding of how to tame it."