Flight Controller Software Protects Lightweight Flexible Aircraft

NASA Technology

Since its founding in 1958, NASA has made profound contributions to aviation, including advancing our understanding of flight mechanics—the study of forces that affect aircraft in flight—and devising ways to improve aircraft performance.

In keeping with that tradition, in the late 1980s the agency participated in the development of what's known as Robust Control theory. Put simply, the theory aims to provide automated stability to a structure in response to various external forces. An important resulting application is called gain scheduling, whereby electronic controllers are programmed to apply those split-second changes.

Gain scheduling has proven very important for airplanes, which are susceptible to conditions such as turbulence and other gust disturbances that can damage wings and other critical components. In response to data picked up by onboard sensors, automated controllers are able to direct ailerons (hinged control surfaces attached to wings), rudders, and elevators to shift the plane's trajectory and prevent structural damage and otherwise improve flight quality for passengers.

In the early 2000s a new type of airliner was drawn up called a lightweight flexible aircraft. True to its name, the plane's body and wings would be made of lighter materials—carbon fiber instead of metal, for example—resulting in drastic reductions of fuel needed for transport and longer flight distances. But reducing a wing's heft also increased susceptibility to a dangerous condition called flutter: uncontrollable vibrations that can cause a wing to break apart.

For lightweight flexible aircraft technology to become viable, NASA advanced what's called Linear Parameter-Varying Control (LPV) theory to account for the aeroelastic conditions that bring about flutter. Now the agency needed new gain scheduling tools capable of applying the theory so that controllers could be programmed to prevent the dangerous occurrence.

In the short term, researchers at Armstrong Flight Research Center would use the technology to synthesize flight control algorithms for an unmanned, lightweight flexible aircraft called the X-56A Multi-Use Technology Testbed (MUTT). Developed by Lockheed Martin initially for the Air Force Research Laboratory, the X-56A MUTT's successful deployment of flutter suppression algorithms would be an important step toward making lightweight flexible aircraft technically feasible.

Technology Transfer

Founded in the early 1990s, MUSYN Inc. was among the first companies to build on NASA's Robust Control theory research and develop a software program, aptly named the Robust Control Toolbox (distributed by MathWorks), to help manufacturers design controllers

Using MUSYN's LPVTools software toolkit, NASA is synthesizing flight control algorithms for an unmanned, lightweight flexible aircraft called the X-56A Multi-Use Technology Testbed (MUTT). The agency's work with MUTT is an important step toward making such aircraft, which are prone to flutter, technically feasible.

for their aircraft at specific flight conditions. In the late 1990s, when NASA's new theories on flutter suppression arrived on the scene, the firm once again began working on a complementary set of software tools. Development languished until 2010, when the agency put out a call for such a software program to be created.

The company's proposal was met with approval, and later that year NASA and the Minneapolis, Minnesota-based company entered into a Small Business Innovation Research (SBIR) Phase I contract, followed by Phase II funding the following year. "It was an opportunity to finish what we had started," says MUSYN CEO Gary Balas.

Much of MUSYN's work over that two-year period centered on building on the software and theory developed for the Robust Control Toolbox, and overcoming its limitation: It can analyze the flight conditions of speed, altitude, and angle of attack only one point at a time. "That means you'd have to look separately at conditions during takeoff, landing, and cruise altitude, and everything in between," Balas says. "It makes it difficult for flight control engineers to both analyze and synthesize controllers for an aircraft that flutters at different places and times during flight."

By 2013 MUSYN had overcome that roadblock with its LPVTools software toolkit. The application is able to synthesize flight control algorithms and set a controller's gain schedule for not just a single point in time, but the entire duration of an airplane's flight.

Benefits

With lightweight flexible aircraft on the horizon, it's hard to underestimate the importance of having the LPVTools software toolkit, says Armstrong engineer Marty Brenner, who played a key role in developing both the Robust Control and LPV theories. "Flutter and instability can happen very quickly with this type of aircraft, so it's critical that we have an advanced tool to deal with the problem adequately."

Two pilots operate the X-56A MUTT from a ground control station.

Brenner is one of the researchers who will be using LPVTools to experiment with flutter suppression algorithms in the X-56A MUTT's flight controller. Having overseen MUSYN's work during the SBIR contract, he's confident the technology will perform well. "The company has really improved on the original algorithms while also developing a solid software infrastructure to handle complex models," he says. "It's topnotch."

The software was made commercially available in 2014, and aircraft manufacturers designing similar lightweight flexible aircraft will want to use the software, says MUSYN's Balas. But the application is more than just a flutter prevention tool. Farming equipment companies, for example, can utilize the software to set controls for engines and active suspensions. "Even a bulldozer's blades can be programmed for precision grading and digging work," he says. "Farming today is incredibly automated. You don't get out there with just an ox and a tiller anymore."

Industrial plants that employ robots and companies that develop unmanned aerial vehicles such as drones can also benefit from the programming technology. In agriculture, drones are employed to measure water, growth density, and other variables in crop fields. "Like aircraft, they need cues to handle air disturbances and other threats," Balas explains.

The sky's literally the limit with the technology, and Balas gives credit to NASA for helping make it possible.

"The agency's hand in applying the Robust Control theory helped guide the software development in the first place," he says. "Also, the SBIR funding was invaluable for a small company like ours. The project otherwise might have sat on the shelf for years, but now it's here and available to the commercial community. NASA has been invaluable." ❖