Aircraft of the Future

Enabling engineers to model, simulate, analyze, and develop control laws so that future flexible vehicles can fly safely, comfortably, and efficiently.

Top photo: X-56A taxiing on the ground (Credit: NASA Photo / Ken Ulbrich). Bottom image: This artist's rendering shows a notional concept for a future supersonic commercial aircraft that potentially could go into service in the years 2030 to 2035 (Credit: The Boeing Company). Right Page: Artist Concept of NASA's X-56A MUTT aircraft (Credit: AFRL / Lockheed).

Lightweight flexible aircraft may be the next generation of vehicles that fly in our airspace. They can reduce the cost of air travel and extend aircraft flight distances because there is less wing structure compared to conventional fixed wing aircraft, making them lighter and more energy-efficient. More energy efficient aircraft will lead to reduced greenhouse gases which is important as air travel consumes around 1.5 billion barrels of Jet A-1 fuel annually and contributes 4-9% of the CO2 produced. However, with less structure the wings will bend and twist more easily in flight, which may result in uncontrollable vibrations called flutter, a destructive phenomenon that can cause the wings to break apart.

NASA Collaboration

Under a NASA **Small Business Innovation Research Program (SBIR)** contract from Dryden Flight Research Center, MUSYN Inc. has developed innovative modeling, simulation and control design tools for analyzing and suppressing flutter and gust loads for flexible aircraft. With a planned commercial

MUSYN's LPVTools provides a unifying software framework that will transform how industry approaches flight control design and analysis, for flexible aircraft as well as intelligent ground vehicles, transportation systems, medical systems, and industrial machinery and processes.

release in 2014, this tool will allow engineers to model, simulate, analyze, and develop control laws so that future flexible vehicles can fly safely, comfortably, and efficiently.

Filling the Gap

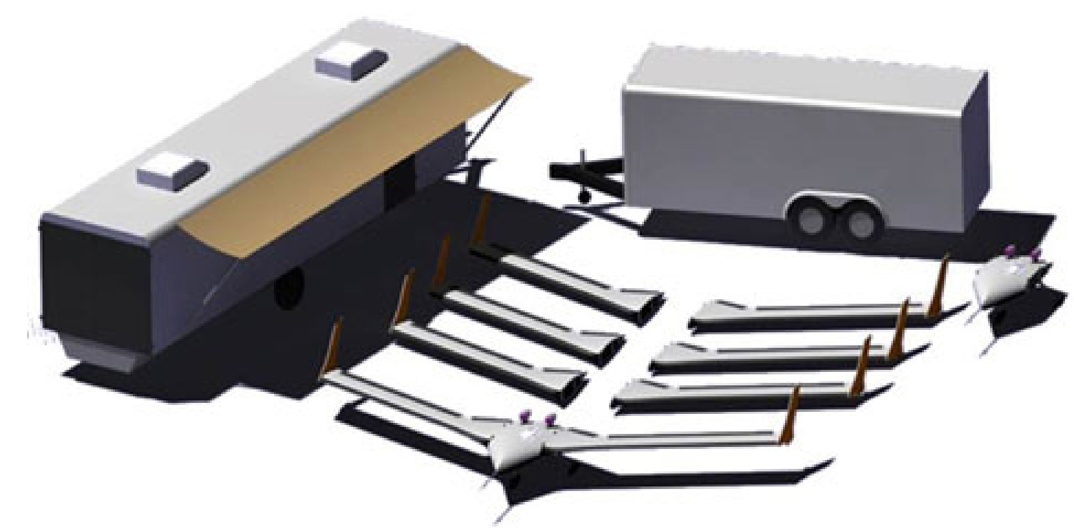
MUSYN developed LPVTools, a Linear Parameter-Varying (LPV) Control software toolkit, to study active control techniques for flutter suppression and gust load alleviation in a 2010 NASA SBIR Phase I contract. The LPV framework was initially developed in the late 1980s to analyze ubiquitous gain-scheduled controllers. Gain-scheduling has long been the traditional flight control design approach for aerospace vehicles as it allows the control of a system which cannot comply with a single operating point. Using multiple controllers, each set for a specific operating point, allows control across the region. Some of the first applications of the LPV framework were for general aircraft flight control and it has since been applied in a wide array of fields, including automotive, space, robotics, and computing systems. The LPV paradigm has been expanded to include algorithms for modeling, analysis, control design, system identification and fault detection. Despite the successes of the LPV paradigm in the aerospace industry, the field has lacked access to LPV software tools. MUSYN's LPVTools will fill this gap. The LPVTools software is being used to synthesize flight control algorithms for the X-56A with flight tests planned in 2014.

Innovative Partnerships

Due to the success of their Phase I contract, a follow on Phase II was awarded to expand the existing toolkit to be used on NASA Aeronautics' X-56A Multi Utility Technology Testbed (MUTT) and towards applications for general aerospace vehicles. The MUTT is a new experimental aircraft being developed by the Air Force Research Laboratory and Lockheed Martin to study aeroelastic phenomena in flexible aircraft. It is a small jet powered unmanned aircraft, at just 7.5-foot-long with a 28-foot wingspan. The wings of the MUTT aircraft can be made very flexible, allowing the aircraft to experience flutter and as a result provide the necessary data for the development of the LPVTools software.

Taking Control

One goal of the X-56A MUTT project is to study the effectiveness of using ordinary aircraft control surfaces to lessen the effects of flutter and gust disturbances by incorporating flutter suppression algorithms into the flight control system. The X-56A provides a challenging platform due to its very flexible wings. Very flexible aircraft have flutter modes within the frequency bandwidth of the flight control system, which requires the flexible modes to be actively controlled in flight. Failure to control these flutter modes can lead to oscillations that can destroy a vehicle. Current aircraft



Artist's rendering of X-56A MUTT package, consisting of the aircraft with three additional wing sets and a second fuselage/mid-body (center), flanked by the ground control station on the left and the air vehicle storage/transport trailer on the right. (AFRL/Lockheed image)

flight control systems are designed independently from flutter suppression and gust load alleviation systems.

MUSYN's LPVTools is a modeling, analysis and control design tool that will synthesize flight control algorithms that will operate in real-time onboard the X-56A to minimize the flutter motion of the aircraft by commanding the aircraft's control surfaces. A successful experimental demonstration of flutter suppression algorithms onboard the X-56A is an important step toward making lightweight flexible aircraft technically feasible.

Flying into the Future

Technologies for improved control law analysis and synthesis will offer clear advantages for a number of aerospace systems, including military fixed-wing aircraft and helicopters, Uninhabited Aerial Systems (UAVs), launch platforms, re-entry vehicles, spacecraft, and commercial aircraft. The performance and safety of future lightweight, environmentally friendly engineered systems (e.g. wind turbines, ground vehicles, trains, etc.) will require advanced control systems which directly handle flexible dynamics. LPV control techniques have already been demonstrated for the control of aircraft, launch vehicles, automotive suspensions, trucks, missiles and underwater vehicles. MUSYN's LPVTools provides a unifying software framework that will transform how industry approaches flight control design and analysis, for flexible aircraft as well as intelligent ground vehicles, transportation systems, medical systems, and industrial machinery and processes.

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