Wing Shaping Concepts Using Distributed Propulsion Control For Achieving Optimal Spanwise L/D to Reduce Fuel Burn

Investigator(s): Kevin Reynolds, Nhan Nguyen, NASA ARC, Code TI; Hyun Dae Kim, James Felder, NASA GRC; James Urnes, Sr, Boeing Research and Technology, St. Louis

Purpose

The objective of this research is to conduct a multidisciplinary analysis and optimization study to demonstrate a novel concept of flexible wing shaping using distributed propulsion for reducing fuel burn. The technical challenge and potential opportunity lies in the ability to improve aerodynamic efficiency using active wing shaping control in-flight while maintaining aero-structural stability.

A key enabling concept for wing shaping is the ability to use propulsive moments from distributed propulsors mounted along the wingspan to optimize the spanwise lift distribution by modifying wing twist and shape.

Background

Since 2010, wing shaping concepts and distributed propulsion concepts have each shown potential fuel burn reductions of at least 3% over a typical mission profile. Combining the concepts into one vehicle introduces a possibly for further improvements in fuel burn reduction toward the goal of achieving an ultra-efficient, future transport aircraft.

Lightweight flexible materials on aircraft are a new paradigm shift in the design of commercial aircraft. The development of the latest Boeing 787 is a good example. Wing shaping control is currently being used on the Boeing 787, albeit based on a simple concept that can be certified in the current regulatory framework. Wing shaping concepts have been shown in previous studies to achieve as much as 3-4% fuel burn reduction on a conventional aircraft.

Distributed propulsion concepts enable a new generation of aircraft with improved propulsive efficiency. By having multiple propulsors, power-producing devices can be located separately from thrust-producing devices, allowing each device to be independently optimized for performance at a flight condition. Distributed propulsion concepts, currently used in the design of hybrid cars and diesel-electric ships, enable a new design space for aircraft. These aircraft are able to maximize range using conventional hydrocarbon fuels while achieving propulsive efficiencies 40-50% greater than conventional transports. Using a hybrid electric distributed propulsion system, Aerovironment's Global Observer demonstrated seven days of continuous flight, a testament not only to its aerodynamic design but also to its propulsive efficiency.

This study will quantify fuel burn benefits by demonstrating distributed propulsion being used for wing shaping control. This study explores the untapped potential of a novel concept to offer tremendous advantages to aeronautics both in the near-term and future utilizing current and state-of-the-art technology.