A1.01  Aerodynamic and Structural Efficiency - Integration of Flight Control with Aircraft Multidisciplinary Design Optimization

Lead Center: ARC

Participating Center(s): AFRC, LaRC

Scope Title:

Integration of Flight Control with Aircraft Multidisciplinary Design Optimization

Scope Description:

Successful design tools for advanced aircraft concepts typically require close interaction among the various design disciplines involved: aerodynamics, structures, propulsion, flight control, etc. This is particularly true for advanced modern transports such as the Boeing 787 and nontraditional aircraft concepts currently being studied at NASA, such as the Transonic Truss-Braced Wing or the blended wing body, where the level of coupling across the various disciplines can be very complex. It has been shown that substantial benefits could be realized by including many of these disciplines within a single multidisciplinary design optimization (MDO) process, rather than optimizing each discipline in isolation. Furthermore, nontraditional flight control design philosophies are becoming increasingly more common as the aircraft industry is responding to the new urban air mobility (UAM) market. The NASA X-57, for example, could employ many modes of flight control distributed throughout the aircraft enabled by distributed electric propulsion. Thus, integration of flight control into an aircraft MDO process can produce more advanced aircraft design capabilities through improved and integrated methods and tools.

This subtopic seeks proposals that develop new methods and tools that enable the inclusion of flight control in an aircraft MDO process. The proposed control approach should directly contribute to aircraft overall design objectives, such as fuel burn, aircraft takeoff gross weight, or other aircraft performance metrics. The resulting tightly coupled MDO environment should be capable of handling the interactions among relevant disciplines, such as structures, aerodynamics, flight control (including the control effector design parameters and actuator weight/power), and propulsion. Design variables may include structural details (e.g., skin thickness, structural layout, and materials), aerodynamic details (planform shape, jig twist, and airfoil shape distributions), control law details (type, objective function, and control gains), control effector and sensor design parameters (size, layout, locations, and quantity), propulsion design parameters (thrust distribution, integrated allocation, and scheduling), etc. The control law may be parameterized in such a way that the resulting parameters are suitable to a numerical optimizer. Control design tools may utilize advanced distributed sensors such as fiber optic shape sensors or surface pressure sensors to achieve improved aircraft design objectives.

Appropriate design constraints should be imposed within the integrated MDO tool to ensure proper aerodynamic
limits, such as stall and buffet; structural limits, such as maneuver and gust load response and flutter margins; as well as control-centric constraints, such as stability margins, control actuator power and authority, position and rate limits, and sensor and actuator requirements that dictate controllability and observability.

Applications of these integrated MDO approaches could be implemented for realistic and relevant aircraft configurations to demonstrate the impact of the proposed methods. Performance gains should be actively derived from the system response to a control policy such as cruise-drag optimization, gust load alleviation, flutter suppression, flight-propulsion control, and multiobjective flight control. To integrate flight control into an MDO environment with a large number of design variables and constraints, new tools that would enable increased computational efficiency, such as adjoint-based optimization, are of interest using appropriate-fidelity aircraft models capable of capturing nonlinear aerodynamics. The proposed tools could be stand-alone or added capabilities to available open-sourced NASA MDO environments.

This subtopic does not seek proposals that propose vehicle conceptual design and analysis studies or control methods that have no clear transition paths to commercial applications.

**Expected TRL or TRL Range at completion of the Project:** 2 to 5

**Primary Technology Taxonomy:**
- Level 1: TX 15 Flight Vehicle Systems
- Level 2: TX 15.6 Vehicle Concepts

**Desired Deliverables of Phase I and Phase II:**

- Research
- Analysis
- Software
- Prototype
- Hardware

**Desired Deliverables Description:**

For Phase I, the deliverables include flight control integrated MDO methods and tools.

For Phase II, the deliverables include more mature and validated flight control integrated MDO methods and tools which are to be integrated with open-sourced NASA MDO environments.

**State of the Art and Critical Gaps:**

Increasingly, more advanced aircraft concepts utilize innovative flight control design philosophies, such as the modern Boeing 787 with trailing edge variable camber, and Airbus A350 with adaptive drooped hinge flaps, as well as a wide variety of UAM aircraft design concepts with distributed electric propulsion. The current state of the art in research does not usually consider integration of flight control systems into an aircraft MDO process. Some low-level research effort of addressing flight control integration in an MDO process exists within the Aeronautics Research Mission Directorate (ARMD) Advanced Air Transport Technology (AATT) Project, but the effort does not consider a wide range of integration of flight control systems including actuators, sensors, and flight control laws. This critical research gap area could be filled by this subtopic.

**Relevance / Science Traceability:**

Under the NASA Advanced Air Vehicle Program (AAVP), the AATT Project is conducting research in distributed electric propulsion and adaptive wing technologies. Both of these research elements could benefit from this subtopic. Also, under the NASA AAVP, the Revolutionary Vertical Lift Technologies (RVLT) Project is conducting research in the area of UAM aircraft using distributed electric propulsion for electrical vertical takeoff and landing (eVTOL). This subtopic could complement the research conducted under the RVLT Project.
References:

NASA Aeronautics Research Mission Directorate (ARMD), https://www.nasa.gov/aeroresearch

Advanced Air Vehicles Program (AAVP), https://www.nasa.gov/aeroresearch/programs/aavp

Advanced Air Transport Technology (AATT) project, https://www.nasa.gov/aeroresearch/programs/aavp/aatt

Revolutionary Vertical Lift Technology (RVLT) project, https://www.nasa.gov/aeroresearch/programs/aavp/rvlt