Aeroelasticity and Aeroservoelastic Control

Lead Center: LaRC

Participating Center(s): AFRC

Scope Title
Aeroelasticity and Aeroservoelasticity for Advanced Configurations

Scope Description
The technical discipline of aeroelasticity is a critical ingredient necessary in the design process of a flight vehicle for maintaining optimal performance while ensuring freedom from aeroelastic and aeroservoelastic instabilities. This discipline requires a thorough understanding of the complex interactions between a flexible structure and the steady and unsteady aerodynamic forces acting on the structure, with interactive control systems for flight vehicle performance and stability. These fundamental aeronautics work is focused on active/adaptive aerostructural control for lightweight flexible structures, specifically related to load distribution, flutter prediction and suppression, gust load prediction and alleviation, and aeroservoelasticity for Ultra-Efficient and Supersonic Commercial Vehicles.

The program’s work on aeroservoelasticity includes conduct of broad-based research and technology development to obtain a fundamental understanding of aeroelastic and unsteady aerodynamic phenomena experienced by aerospace vehicles in subsonic, transonic, supersonic, and hypersonic speed regimes.

The program content includes theoretical aeroelasticity, experimental aeroelasticity, and advanced aeroservoelastic concepts. Of interest are:

- Aeroelastic, aeroservoelastic, and unsteady aerodynamic analyses at the appropriate level of fidelity for the problem at hand.
- Aeroelastic, aeroservoelastic, and unsteady aerodynamic experiments to validate methodologies and to gain valuable insights available only through testing.
- Development of computational fluid dynamic (CFD), computational aeroelastic, and computational aeroservoelastic analysis tools that advance the state of the art in aeroservoelasticity through novel and creative application of aeroelastic knowledge.

Specific subjects to be considered include:

- Development of aerostructural control design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Development of efficient methods to generate mathematical models of wind tunnel models and flight vehicles for performing aeroservoelastic studies.
- Development of CFD-based methods (reduced-order models) for aeroservoelastic models and simulation that can be used to predict gust loads, ride quality issues, flight dynamics stability, and aerostructural control issues.
- Development of novel aeroservoelastic sensing and control approaches, including active/adaptive control concepts and architectures that employ smart materials embedded in the structure and aerodynamic sensing and control schemes for suppressing aeroelastic instabilities and improving performance.
- Development of techniques that support simulations, ground testing, wind tunnel tests, and flight experiments for aerostructural control of aeroservoelastic phenomena.

**Expected TRL or TRL Range at completion of the Project**

3 to 5

**Primary Technology Taxonomy**

**Level 1**

TX 15 Flight Vehicle Systems

**Level 2**

TX 15.1 Aerosciences

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

- Hardware
- Software

**Desired Deliverables Description**

This subtopic seeks technologies for

- Development of CFD, computational aeroelastic, and computational aeroservoelastic analysis tools that advance the state of the art in aeroservoelasticity through novel and creative application of aeroelastic knowledge.
- Development of aerostructural control design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Development of efficient methods to generate mathematical models of wind tunnel models and flight vehicles for performing aeroservoelastic studies.
- Development of CFD-based methods (reduced-order models) for aeroservoelastic models and simulation that can be used to predict gust loads, ride quality issues, flight dynamics stability, and aerostructural control issues.
- Development of novel aeroservoelastic sensing and control approaches, including active/adaptive control concepts and architectures that employ smart materials embedded in the structure and aerodynamic sensing and control schemes for suppressing aeroelastic instabilities and improving performance.
- Development of techniques that support simulations, ground testing, wind tunnel tests, and flight experiments for aerostructural control of aeroservoelastic phenomena.

**Expected Phase I and Phase II Deliverables:**

**Phase I:** Develop the infrastructure for the analysis tool(s), methods, methodologies, and/or simulation/test techniques, then demonstrate/verify feasibility via prototype or proof of concept.

**Phase II:** Complete development of the Phase 1 effort, demonstrating/verifying the tool(s), methods, methodologies, and/or simulation/test techniques via model(s)/structure(s) of appropriate complexity and interest to NASA.
State of the Art and Critical Gaps

Aeroelastic prediction and testing methods must evolve and expand together with new and emerging aircraft, structural, and material concepts. The use of lightweight flexible structures, the development of new airframes (truss-braced wings, blended-wing bodies, etc.), and the intentional exploitation of aeroelastic response phenomena require a comprehensive understanding of the aeroelasticity involved if they are to succeed. Both enhancements to current methodologies/codes and new methodologies/codes that enable evaluation and understanding of new concepts are needed to keep pace with the state of the art in vehicle technology and to fill critical gaps in understanding those vehicles. Code development and performance prediction typically lag vehicle conceptual development, so while the most popular computational methods in use today, which were developed under Small Business Innovation Research (SBIR) awards, work well for yesterday's configurations, they will have to be modified or rethought entirely to capture the behavior of today's and tomorrow's evolutionary and revolutionary vehicles.

Relevance / Science Traceability

Predicting the aeroelastic response of emerging evolutionary and revolutionary vehicle concepts is not an easy task. Aeroelastic prediction and testing methods must evolve and expand with the concepts themselves, which include new vehicle configurations, new structures, and new materials. The use of lightweight flexible structures, the development of new airframes (truss-braced wings, blended-wing bodies, etc.), and the intentional exploitation of aeroelastic response phenomena require a comprehensive understanding of the aeroelasticity involved if they are to succeed. The Boeing 787, for example, has the most flexible wing of any transport built thanks to composites and aggressive aeroelastic optimization of the structure. Some specific NASA programs/projects/topics that will greatly benefit from the expansion of aeroelastic knowledge, tools, and test techniques are under the Aeronautics Research Mission Directorate (ARMD), including (a) the Advanced Air Vehicles Program (AAVP), specifically, the Aerosciences Evaluation and Test Capabilities (AETC) project, the Advanced Air Transportation Technologies (AATT) project with the Performance Adaptive Aeroelastic Wing (PAAW) and Passive Aeroelastically-Tailored Wing (PATW) subprojects, and the Commercial Supersonic Technology (CST) project; (b) the Transformative Aeronautics Concepts Program (TACP), specifically, the Convergent Aeronautics Solutions (CAS) project and the Transformational Tools and Technologies (TTT) project; (c) the Integrated Aviation Systems Program (IASP), specifically, the Flight Demonstrations and Capabilities (FDC) project; (d) N+3; (e) the X-56A flight project; and (f) the work with new ultra-efficient and supersonic commercial vehicles.

References

Links to program/project websites:

1. ARMD's Advanced Air Vehicles Program (AAVP): https://www.nasa.gov/aeroresearch/programs/aavp
2. ARMD's Transformative Aeronautics Concepts Program: https://www.nasa.gov/aeroresearch/programs/tacp
3. ARMD's Flight Demonstrations and Capabilities (FDC) project under the Integrated Aviation Systems Program (IASP): https://www.nasa.gov/aeroresearch/programs/iasp/fdc

Information related to evolutionary and revolutionary flight vehicle concepts/configurations that are on the drawing board or already being tested:

3. Joined Wing: https://www.nasa.gov/centers/langley/multimedia/iotw-tdt-wing.html