Materials and Structural Concepts for Aeroelastically-Tailored Aircraft Wings

The Fixed Wing and High Speed projects are focused on development of enabling technologies and advanced concepts for subsonic and supersonic cruise transport category aircraft, respectively, demonstrated to TRL 4-6 in the 2025 time frame. Both projects require simultaneous reduction of weight and drag to achieve their respective performance objectives. For subsonic transport aircraft, lift-induced drag is approximately 40% of the total drag at cruise and can be directly addressed via increased wing aspect ratio. For supersonic flight, speed requirements dictate highly swept wings with a very thin airfoil section. Both of these wing geometries, with higher aspect ratio or thinner airfoil section, result in more flexible structure that can exhibit aeroelastic instability and thus require more complicated aeroelastic design, analysis and control. The traditional solution to these aeroelastic issues has been primarily to stiffen the wing by adding additional structure, thus creating a weight penalty. Solutions that favorably modify the aeroelastic response of thin or high aspect ratio wings with no or little weight increase are needed. Furthermore, maneuverability of the vehicle is dependent upon the control authority achievable by wing-located control surfaces in traditional aircraft designs, and possibly actively tailorable portions of wings in more integrated aircraft designs. Designing the wing to have desired aeroelastic characteristics makes the wing amenable to minimal-input active control solutions to further modify the aeroelastic response. Using a building block approach in this research topic, the current solicitation focuses on materials and structural concepts for aeroelastically-tailored aircraft wings, while the more complex aeroservoelastic solution will be the subject of a future solicitation.

This solicitation topic seeks innovative materials and/or structural concepts and technologies for lightweight wings with aeroelastic tailoring, such as tailored bending and torsional stiffness as an example. Proposals should involve novel materials, processes and structural concepts with significant potential to improve the structural efficiency and reduce specific weight. Laboratory scale approaches may be proposed for proof of concept, but must be scalable to application across a broad range of fixed wing aircraft sizes and speeds.

Tailored stiffness may include spatial or temporal variations in stiffness achieved by a combination of passive stiffness tailoring of anisotropic or functionally graded materials, novel structural topologies, or active integrated elements to change structural and/or material properties. The use of existing design and analysis tools and techniques to the greatest extent possible is encouraged, as it is not the intent of this solicitation to develop new computational tools. Specifically, the following concepts and technologies are sought:
- Materials and processing routes to fabricate engineered materials with tailored material properties along all three axes.

- Aeroelastically-tailored structural concepts by which desired static or dynamic aeroelastic responses can be achieved.

Phase I: Identify candidate material systems and structural concepts that enable aeroelastic tailoring of wing structure for reduced weight, for example, variable bending and torsional stiffness. Assess the feasibility and benefits of the proposed concept, including scale-up, necessary material property quantification, and design trade studies. The studies must include quantification of expected structural weight benefits. Identify limiting factors and recommendations for further technology development to address the shortfalls. For novel material systems and structural concepts requiring development, conduct initial proof of concept computational studies and/or element tests.

Phase II: Perform scale-up of materials and processes as necessary, and produce a detailed structural design and hardware build of a subscale wing suitable for laboratory testing to assess structural performance of the concept. Structural testing of the subscale wing will be performed subsequently by NASA and is beyond the scope of the Phase II effort.