RQ19-13

1. **Research Title:** *Enabling Robust and Durable Aerospace Structures for Combined, Extreme Environments*

2. **Individual Sponsor:**

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3. **Academic Area/Field and Education Level:** Experimental/Computational Mechanics (MS or Ph.D. level)

4. **Objectives:** The objective of this effort is to develop and demonstrate procedures for analyzing, designing, and forecasting the life of aerospace structures that are used in extreme, combined thermo-mechanical-acoustic environments. The emphasis is on understanding the interactions between the different phenomena and properly accounting for the interactions.

5. **Description:** The USAF has made considerable progress on advancing key elements of critical future war-fighting capabilities, such as rapid/responsive/reusable space access and sustained hypersonic flight. Significant technological breakthroughs are essential to enable the development, qualification, and deployment of robust and durable structural solutions for reliable, sustained operation in combined, extreme environments that consist of combinations of thermal, acoustic, and mechanical loading, and are characterized by large magnitudes, large spatial and temporal gradients, and nonlinear, coupled interactions. AFRL/RQ possesses world-unique facilities for investigating the response of aerospace structural concepts to these combined, extreme environments. The desire is to acquire, through an AFRL-DAGSI partnership, the equally-unique predictive, modeling, and simulation capabilities needed to both understand the structural response in these environments and how to influence it.

   We are aggressively pursuing a computational framework for enabling high fidelity simulation of structures exposed to combined extreme environments. Examples include reusable vehicles exposed to launch, sustained hypersonic velocities, and atmospheric re-entry and stealth aircraft with buried engines and ducted exhaust. Scientific challenges include the nonlinear coupling between extreme environment/loads and the structural response, evolving material attributes and interacting failure modes that define the structural limit state, and the computational framework to support a future paradigm shift towards structural scale simulation. The framework must allow the limit state and material attributes to evolve and interact with the structural response as the simulation progresses. The long-term goal of the simulation is to predict with high confidence the life of a structure subjected to a combined fluid-thermal-acoustic-mechanical-vibratory environment throughout a high-performance aerospace vehicle trajectory.

To support the long-term goal, we have challenges spanning the disciplines of mathematics, computation, and engineering. Exciting research opportunities exist in the areas of (1) computational structural scale simulation for developing the necessary algorithms and data structures required for efficient parallel computing in support of long time record simulations, (2) methods and algorithms for variable fidelity modeling including a priori and/or a posteriori error estimators with convergence indicators, (3) fluid-acoustic-thermal-structure solver integration focusing on the stability and fidelity for loosely versus fully coupled solvers, (4) multiscale coupling techniques addressing and the computational algorithms for spatial and temporal issues associated with the inclusion of fine scale features into a coarse scale model supporting high fidelity simulations, (5) novel experimental and computational techniques to characterize and predict material property evolution in extreme environments and (6) identification of representative or benchmark extreme environment structures with levels of combined loading targeted toward exercising specific phenomena for verification and validation of multi-physics simulations.

6. **Research Classification/Restrictions:** No restrictions anticipated; research is unclassified and for public distribution.

7. **Eligible Research Institutions:**

[X] **DAGSI**

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