1. **Research Title:** Multidisciplinary nonlinear time-spectral methods for air vehicle design

2. **Individual Sponsor:**

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3. **Academic Area/Field and Education Level:** Aerospace or Mechanical Engineering / Computational Physics and Numerical Analysis (BA/BS, MS or Ph.D. level).

4. **Objectives:** To develop nonlinear time-spectral methods (e.g. harmonic balance) to include multidisciplinary coupling with sensitivities for air vehicle design optimization.

5. **Description:** Transient phenomena are foundational to air vehicle physics. It may be an intrinsic property of a system, such as a propeller wake impinging on a wing, or they may be an emergent phenomenon that manifests itself only in a multidisciplinary setting, such as flutter. In either case, it is important to account for such processes as early as possible in design to either mitigate adverse impacts to a vehicle or to formally leverage in design to the advantage of the overall vehicle. However, simulating transient processes is much more computationally expensive than steady-state processes and introduces additional challenges for calculating adjoint sensitivities for design; requiring management of both the forward and adjoint problems in time and their time-series data. Time-spectral methods (e.g. harmonic balance, nonlinear harmonics) seek to solve for a set of identified frequencies directly. As such, there is no need to march in time, which ameliorates challenges for data management, time-step resolution, length of time integration, and appropriate time-averaging for quantities of interest. The transient process must however be able to be represented by a discrete set of frequencies (e.g. flutter, turbomachinery flows, propeller airframe interaction). Of particular interest is the extension of nonlinear time-spectral methods for coupled-physics systems (e.g. fluid-structure) along with the calculation of their sensitivities for gradient-based design optimization. This topic includes several opportunities for fundamental research activity, which include:

    a. In-situ identification of relevant frequencies for coupled-physics problems.

    b. Sources of aliasing error for multidisciplinary time-spectral methods and approaches to eliminate or reduce them.

    c. Efficient implicit nonlinear time-spectral methods and their adjoint for computing design sensitivities. Efficiency here may be taken to represent memory consumption, convergence rates, preconditioning, parallelism, and scalability.

6. **Research Classification/Restrictions:** Unclassified

7. **Eligible Research Institutions:** All DAGSI Universities.

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