1. **Research Title:** Meta-materials for Structural Applications
2. **Individual Sponsor:**

Dr. Alex Pankonien, AFRL/RQVS
2790 D Street, Bldg 65
WPAFB, OH 45433
alexander.pankonien.1@us.af.mil

3. **Academic Area/Field and Education Level:** Mechanical, Materials, Aerospace, or Civil Engineering / Solid Mechanics or Structural Mechanics or Computational Mechanics (MS or Ph.D. level)
4. **Objectives:** Develop and validate modeling frameworks for understanding and quantifying the uncertainties, risks, and reliabilities associated with the manufacture of meta-materials (i.e. – micro-architected, hierarchical, etc.) and their utilization in morphing aerospace structural designs.
5. **Description:** Micro-architected metamaterials, materials engineered at the sub-micron scale using tessellated or hierarchically arranged nano-lattices, exist in a previously vacant region of material performance space that enable non-linear, elastic structural response(s) in metals and ceramics. Though their potential is obvious and exciting, a tremendous amount of multi-disciplinary effort remains to realize their full capability at application relevant length scales. One such application, by way of example, is compliant structures such as gross airfoil shape changes (i.e. – span-wise twisting, leading edge manipulation, etc.) or continuous control surfaces (i.e. – flaps, ailerons, stabilators, etc.). Design concepts for these applications require massive amounts of strain (>10%) along specific directions while remaining stiff enough to support transverse aerodynamic loads at near-Mach relevant airspeeds. Micro-architected materials could provide one solution to this unique design space by enabling macro-scale material design that begins at the nano-scale. Due to this expansive tailor-ability, a validated modelling framework is necessary to efficiently explore the potential design space. Because macro-scale behavior is dependent upon millions of detailed, nano-scale lattices, reduced order modelling is necessary to ensure nano-scale effects are captured at the systems level. Near term, two specific challenges are a priority: 1) creating and validating a multi-scale modelling framework to understand the macroscopic (i.e. – meter-scale) material response of nanometer-scale design variables; 2) use of that validated framework to explore the sensitivity of macro-scale material performance to nano-scale fabrication resolution and defects. This topic offers several different avenues of fundamental research:
    a. Characterization and utilization nano-/micro-meter scale material/lattice properties;
    b. Development of computational methodologies to capture the interplay between structural and material driven mechanics;
    c. Development of a multidisciplinary modelling framework that captures micron-scale behavior in reduced order models for use at sub-sequentially larger length scales;
    d. Statistically quantification of macro-scale influence of nano-scale manufacturing variabilities and associated sensitivities;
    e. Incorporation of these reduced order representations into structural design concepts to establish an application relevant feedback loop.
6. **Research Classification/Restrictions:** This research is unclassified and for public distribution.
7. **Eligible Research Institutions:** All DAGSI Universities.