RQ 21-64

1. **Research Title:** Analytic Sensitivities and Machine Learning applied to Uncertainty Quantification for Multidisciplinary Systems Analysis & Design Optimization

2. **Individual Sponsor:** List the AFRL research topic sponsor's contact information
Dr. Edwin E. Forster, AFRL/RQVC
2210 Eighth St.
WPAFB, OH 45433-
edwin.forster@us.af.mil

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 a scalable and holistic UQ framework that enables the simultaneous inclusion of multi-physics and multi-fidelity models as well as experimental data at varying levels of trust is necessary to address UQ in Multidisciplinary Analysis and Design Optimization (MADO). Such a framework must leverage existing methods and develop new approaches to address increased computational expense and accuracy requirements of UQ within a design environment.

5. **Description:** Historically, Uncertainty Quantification (UQ) is performed late in the design cycle, when mitigation of deficiencies is costly or may result in a penalty to performance or capability. These late defects and faults may be critical due to unanticipated interdisciplinary couplings or due to the uncertain nature (both aleatoric and epistemic) of anticipated interdisciplinary quantities of interest. Types of uncertainty may include, but are not limited to: parameter uncertainties, such as model or design parameters, geometric or material variables, and parameters associated with environment and process control; model uncertainties, such as from physics-based models from simple to complex, empirical models based on experiments, couplings/interfaces between disciplines, and model boundary conditions; data uncertainties, including noise, measurement errors, and missing data; requirements or usage uncertainty, including uncertainty in constraints; and, uncertainties arising from simulation, including discretization errors, round-off errors, and algorithmic errors. Research opportunities exist in the general area of UQ, and in particular sensitivity analysis and machine learning applied to non-deterministic approaches. Topics of interest include

   a. methods for developing analytic sensitivities of aerospace system robustness and reliability to design parameters;
   b. methods for developing analytic sensitivities of uncertain quantities of interest with respect to distributed stochastic and statistical parameters;
   c. machine learning methods applied to multi-physics/multi-fidelity models for prediction of uncertain quantities of interest;
   d. machine learning methods applied to data fusion from models and experiments with varying levels of trust ;
   e. application of Design of Experiment techniques for modeling and simulation of failures;
   f. efficient and accurate methods for predicting rare events (in the tails of probability distributions, on the order of 1e-7 to 1e-9);
   g. the development of methods which quantify the level of confidence or credibility of a design accounting for uncertainties throughout the design process.

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

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

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