Title: Introduction to Probabilistic Analysis and Uncertainty Quantification

Presenter:
Mark Andrews, Ph.D.
SmartUQ UQ Technology Steward, Madison, WI, USA.

Course Overview:
This four-hour course introduces probabilistic and Uncertainty Quantification (UQ) methods, benefits, and tools and uses case studies to illustrate these concepts. The attendees for this course would be engineers, program managers, and data scientists who are aware of probabilistic analytics and want to further investigate how UQ can maximize insight, improve design, and reduce time and resources for their projects.

Introduction to UQ
Uncertainty is an inescapable reality that can be found in nearly all types of engineering analyses. It arises from sources like measurement inaccuracies, material properties, boundary and initial conditions, and modeling approximations. UQ is a systematic process that puts error bands on the results by incorporating real world variability and probabilistic behavior into engineering and systems analysis.

Motivation for using UQ
The advantages of modeling and simulation have been recognized by several industries in the ability to model complex systems that cannot be tested. The intent of UQ is to inform decision makers of the uncertainties inherent in the simulation results so that programmatic risks can be better assessed. At a regulatory level, requirements for including robust UQ in modeling and simulation are being adopted by the Federal Aviation Agency (FAA) and the Department of Defense (DoD). By gaining a better understanding the risks, UQ offers to the industry the potential for cost savings by reducing product development cycles.

Basic Probability and Statistics
Before diving into UQ and other advance topics, this course will review basic probability and statistical methods. The review will include topics such as summary statistics, probability distributions, linear regression and Bayesian statistics. These topics are the building blocks of the more advanced UQ methods discussed later in the course.
**UQ Methods**

- Design of Experiments
- Gaussian Process
- Model Calibration
- Model Validation
- Sensitivity Analysis
- Uncertainty Propagation
- Polynomial Chaos Expansion

**Benefits**

The section will compare and discuss the benefits of using a Latin Hypercube Design (LHD) to sample the data and then build a surrogate model and perform UQ to using direct Monte Carlo sampling.

**Case Studies**

This course will illustrate UQ methods using several examples and case studies. Shown below is a high-level flowchart for a bracket in fatigue analysis case study. The walkthrough will include interpreting the results from the UQ methods.

**Final Remarks**

If time permits, there will be an open discussion on the challenges and benefits of adopting UQ to your projects and programs.