Verification, Validation, and Uncertainty Quantification in Fluid Dynamics and Heat Transfer

A two-day Seminar held in conjunction with the 3rd ASME Verification and Validation Symposium

Presented by:
Dr. William Oberkampf and Prof. Christopher Roy

May 5-6, 2014 • Las Vegas, NV
14 Hours • 1.4 CEUs • 14 PDHs

Upon completion of this Seminar, attendees will be able to:

- Define the objectives of code verification, validation, and uncertainty quantification
- Develop procedures for code verification and software quality assurance
- Evaluate procedures for solution verification, i.e., numerical error estimation
- Design and execute validation experiments
- Perform quantitative assessments of model accuracy based on experimental measurements
- Conduct non-deterministic simulations with aleatory and epistemic uncertainties
- Identify and characterize a wide range of uncertainty sources in non-deterministic simulation
- Estimate total predictive uncertainty for informed decision making
- Perform model parameter calibration/updating
- Interpret local and global sensitivity analyses
- Recognize difficulties in implementing verification, validation, and uncertainty quantification

For more information and to register, go to www.asmeconferences.org/vvs2014/seminars.cfm
About this Seminar

Verification, Validation and Uncertainty Quantification in Fluid Dynamics and Heat Transfer

Engineering systems must increasingly rely on computational simulation for predicted performance, reliability, and safety. Computational analysts, designers, decision makers, and project managers who rely on simulation must have practical techniques and methods for assessing simulation credibility. This seminar presents modern terminology and effective procedures for verification of numerical simulations, validation of mathematical models described by partial differential or integral equations, and uncertainty quantification of nondeterministic simulations. The approaches presented in this course are applicable to a wide range of engineering and science application areas, but the emphasis is on fluid dynamics and heat transfer. The computer codes that implement the mathematical models can be developed by commercial, corporate, government, or research organizations. While the focus is on modeling and simulation, experimentalists will benefit from a detailed discussion of techniques for designing and conducting high quality validation experiments. A framework is provided for incorporating various error and uncertainty sources identified during the modeling, verification, and validation processes as to estimate the total simulation prediction uncertainty. Application examples are primarily taken from the fields of fluid dynamics and heat transfer, but the techniques and procedures apply to all application areas. The intent of the framework is to characterize the total uncertainty of a simulation for designers and decision makers.

Who Should Attend

This course benefits model developers, computational analysts, code developers, experimentalists, and software engineers. Managers directing this work and project engineers relying on computational simulations for decision-making will also find this course very beneficial. The course will discuss the responsibilities of organizations and individuals serving in various positions where computational simulation models, software, and experimental results are produced. An undergraduate or advanced degree in engineering or the physical sciences is recommended. Experience in computational simulation or experimental testing is also helpful.

Course Materials Provided

Course attendees will be provided with a copy of the book Verification and Validation in Scientific Computing, Cambridge University Press, 2010. The 780-page book provides a comprehensive and systematic development of the basic concepts, principles, and procedures for verification, validation, and uncertainty quantification for models and simulations. The book emphasizes models described by partial differential and integral equations and the simulations that result from their numerical solutions. The book also discusses experimental activities that are required for the design and execution of validation experiments, model validation and model parameter calibration. Attendees will also be provided with an electronic (PDF) file and color print copies of over 270 short course slides presented during the course.

About the Presenters

Dr. William Oberkampf

Engineering Consultant, has 43 years of experience in research and development in fluid dynamics, heat transfer, flight dynamics, and solid mechanics. He spent his entire career in both computational and experimental areas. During the last 20 years, Dr. Oberkampf emphasized research and development in methodologies and procedures for verification, validation, and uncertainty quantification in computational simulations. He has written over 177 journal articles, book chapters, conference papers, and technical reports. He has taught 42 short courses in the field of verification, validation, and uncertainty quantification. Dr. Oberkampf received his B.S. in Aerospace Engineering in 1966 from the University of Notre Dame, his M.S. in Mechanical Engineering from the University of Texas at Austin in 1968, and his Ph.D. in 1970 in Aerospace Engineering from the University of Notre Dame. Dr. Oberkampf served on the faculty of the Mechanical Engineering Department at the University of Texas at Austin for nine years. After 29 years of service in both staff member and management positions at Sandia National Laboratories, he retired as a Distinguished Member of the Technical Staff. Since this time, he has been a consultant to the National Aeronautics and Space Administration, the U.S. Air Force, various Department of Energy laboratories, and corporations in the U.S. and Europe. He is a fellow of the American Institute of Aeronautics and Astronautics.

Professor Christopher Roy

Virginia Tech, holds a B.S. in Mechanical Engineering from Duke University, an M.S. in Aerospace Engineering from Texas A&M University, and a Ph.D. in Aerospace Engineering from North Carolina State University. From 1998 to 2003, he worked as a senior member of the technical staff in the Engineering Sciences Center at Sandia National Laboratories in Albuquerque, New Mexico. From 2003 to 2007, he was an Assistant Professor in the Aerospace Engineering Department at Auburn University. In 2007, Dr. Roy joined the Aerospace and Ocean Engineering Department at Virginia Tech and currently holds the rank of full professor. He has written over 120 journal articles, books, book chapters, conference papers, and technical reports in the areas of verification, validation, and uncertainty quantification. He has taught 30 short courses in the field of verification, validation, and uncertainty quantification.
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Seminar Outline

The contents are presented in 8 lectures, organized as shown. The two-day schedule allows for ample discussion and interaction with attendees. The instructors reserve the right to modify the contents to address the audience’s needs and preferences.

May 5, 2014, Monday, 8:00 am – 5:00 pm

Lecture 1. Introduction, Background, and Motivation

Lecture 2. Terminology and Fundamental Concepts
  - Brief history of terminology
  - Present definitions and interpretations
  - Alternate definitions used by related communities
  - Additional important terms
  - Who should conduct verification, validation, and uncertainty quantification?

Lecture 3. Code Verification
  - Software engineering
  - Criteria and definitions
  - Order of accuracy
  - Order of verification procedures
  - Traditional exact solutions
  - Method of manufactured solutions
  - Approximate solution methods

Lecture 4. Solution Verification
  - Round-off error
  - Iterative convergence
  - Iterative error estimation
  - Classification of discretization error estimators
  - Reliability of discretization error estimators
  - Discretization error and uncertainty estimation
  - Solution adaption procedures

(End of Day One)
May 6, 2014, Tuesday, 8:00 am – 5:00 pm

Lecture 5. Validation Experiments
- Validation fundamentals
- Validation experiment hierarchy
- Validation experiments vs. traditional experiments
- Six characteristics of validation experiments
- Detailed example of a wind tunnel validation experiment

Lecture 6. Model Accuracy Assessment
- Definition and interpretation of validation metrics
- Various approaches to validation metrics
- Recommended characteristics for validation metrics
- Confidence interval approach
- Cumulative distribution functions approach

Lecture 7. Predictive Capability of Modeling and Simulation
- Identify all sources of uncertainty
- Characterize each source of uncertainty
- Estimate solution error in system responses of interest
- Estimate uncertainty in system responses of interest
- Update model parameters
- Conduct sensitivity analysis

Lecture 8. Final Topics
- Planning and prioritization in modeling and simulation
- Maturity assessment of modeling and simulation
- Difficulties in implementing verification, validation, and uncertainty quantification

(End of Day Two)