



## Verification and Validation in Scientific Computing (MC133)

*A two-day Seminar held in conjunction with the ASME V&V Symposium*

*Presented by:*

Dr. William Oberkamp and Prof. Christopher Roy

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15 Hours • 1.5 CEUs • 15 PDHs

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

- Define the objectives of verification, validation, and uncertainty quantification
- Implement procedures for code verification and software quality assurance
- Implement procedures for solution verification, i.e., numerical error estimation
- Plan and design validation experiments
- Explain procedures for model accuracy assessment
- Explain the concepts and procedures for non-deterministic simulation
- Identify sources of uncertainty, such as aleatory and epistemic uncertainties
- Recognize the goals of model parameter calibration/updating
- Interpret local and global sensitivity analyses
- Recognize the practical difficulties in implementing VVUQ technologies

For more information and to register, go to <http://go.asme.org/mc133>

## About this Seminar

### ***Verification and Validation in Scientific Computing***

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, and uncertainty quantification of nondeterministic simulations. The techniques presented in this course are applicable to a wide range of engineering and science applications, including fluid dynamics, heat transfer, solid mechanics, and structural dynamics. The mathematical models are assumed to be given in terms of partial differential or integral equations, formulated as initial and boundary value problems. The computer codes that implement the mathematical models can be developed by commercial, corporate, government, or research organizations. A framework is provided for incorporating a wide range error and uncertainty sources identified during the modeling, verification, and validation processes with the goal of estimating the total prediction uncertainty of the simulation. While the focus of the course is on modeling and simulation, experimentalists will benefit from a detailed discussion of techniques for designing and conducting high quality validation experiments. Application examples are primarily taken from the fields of fluid dynamics and heat transfer, but the techniques and procedures apply to all application areas in engineering and science. The course closely follows the course instructors' book, *Verification and Validation in Scientific Computing*, Cambridge University Press (2010).

## 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 software, mathematical models, and simulation results are produced. An undergraduate or advanced degree in engineering or the physical sciences is recommended. Training and 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. For more information, see the Cambridge University Press website. 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 Oberkamp***,

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. Oberkamp 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 44 short courses in the field of verification, validation, and uncertainty quantification. Dr. Oberkamp 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 Aerospace Engineering from the University of Notre Dame. Dr. Oberkamp 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 32 short courses in the field of verification, validation, and uncertainty quantification.



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## AGENDA

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.

### Day One: 8:00 am – 5:00 pm

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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
- Traditional exact solutions
- Method of manufactured solutions
- Approximate solution methods

Lecture 4. Solution Verification

- Round-off error
- Iterative convergence
- Iterative error estimation
- Discretization error estimation
- Reliability of discretization error estimators
- Discretization error and uncertainty estimation
- Solution adaptation procedures

*(End of Day One)*

**Day Two: 8:00 am – 5:00 pm**

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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

- What are validation metrics?
- Various approaches to validation metrics
- Recommended characteristics for validation metrics
- Confidence interval approach
- Cumulative distribution function 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 total uncertainty in system responses of interest
- Procedures for updating model parameters
- Types of sensitivity analysis

Lecture 8. Final Topics

- Planning and prioritization in modeling and simulation
- Maturity assessment of modeling and simulation
- Practical difficulties in implementing VVUQ technologies

*(End of Day Two)*