

Preconference Course 101 • Sunday, June 6, 2010

Verification and Validation of Computational Models

Organized by the SEM Model Validation & Uncertainty Quantification Technical Division

Sunday, June 6, 2010, 8:00 AM - 6:00 PM

Instructors

John Cafeo, General Motors
François Hemez, Los Alamos National Laboratory
Randall Mayes, Sandia National Laboratories
Ramesh Rebba, General Motors
Todd Simmermacher, Sandia National Laboratories

Course Description

This short-course explains how Verification and Validation (V&V) activities are formulated for practical applications, such that analysts can leverage the support of experimental sciences to increase the levels of accuracy and confidence in the predictions of numerical simulations.

The short-course is organized to overview the state-of-the-practice to verify computer codes, assess the asymptotic convergence of discrete solutions, calculate sensitivities, propagate uncertainty, understand the effect of uncertainty on predictions, validate predictions through test-analysis correlation, and calibrate the parameters of finite element models. Applications are discussed in the disciplines of engineering mechanics and Structural Dynamics (automotive, aerospace, and mechanical engineering).

Attendees will be provided with a solid foundation to better understand the technology discussed during IMAC-XXV that relates to V&V and uncertainty quantification. Attendees will also learn how to conduct a validation assessment and what can be achieved through V&V activities.

Instructors

This short-course is organized by the SEM Technical Division on Model Validation and Uncertainty Quantification (MVUQ). The instructors are: **John Cafeo** of General Motors (john.cafeo@gm.com); **François Hemez** of Los Alamos National Laboratory (hemez@lanl.gov); **Randall Mayes** of Sandia National Laboratories (rlmayes@sandia.gov); **Ramesh Rebba** of General Motors (ramesh.rebba@gm.com), and **Todd Simmermacher** of Sandia National Laboratories (twsimme@sandia.gov). The instructors have extensive experience in all aspects of V&V, from the design of validation experiments to simulation sciences and data analysis, with applications to automotive, aerospace, and mechanical engineering.



Instructors
(clockwise from top left): John Cafeo, François Hemez, Randall Mayes, Ramesh Rebba, and Todd Simmermacher

Course Fee

The regular course fee for *Verification and Validation of Computational Models* is \$150, and the student course fee is \$75. Course fee includes box lunch, course handout material, and refreshment breaks. Lodging and additional food or materials are not included.

Who Should Attend?

Graduate students who need to learn the state-of-the-practice in V&V and how to apply V&V activities to their research. Engineers and analysts who need to defend the scientific credibility of their numerical predictions. Managers seeking to better articulate the relation between experimental and modeling and simulation efforts in their industries.

Course Outline

This short course is organized into eight one-hour lectures. A hard-copy of the course notes will be provided, together with a CD-ROM that includes the lectures and bibliographical references.

Overview of V&V

- Insights from decision analysis and design
- Workshop goals
- Math model V&V objectives
- Terminology, definitions, previous and current work
- Uncertainty analysis
- Steps to model validation

Code & Calculation Verification

- The concept of discretization, truncation error, asymptotic convergence
- Code verification test problems
- The method of manufactured solutions
- Self-convergence of numerical solutions vs. space-time discretization
- Richardson extrapolation, Grid Convergence Index, the safety factor
- When things can go wrong: wave propagation, stability, energy dissipation, artificial viscosity
- Examples

Uncertainty Quantification (For Testing and Simulation)

- Uncertainty classification: epistemic and aleatory
- Probability and other theories (evidence, etc.)
- Classical and Bayesian statistics
- Phenomenon Identification and Ranking Table (PIRT)
- Sensitivity analysis
- Design-of-experiments and input/effect screening
- Propagation of uncertainty, sampling methods
- Response surface methodology- regression, Gaussian processes

Validation Metrics + Model Bias Estimation

- Test and model correlation techniques
- Hypothesis testing methods
- Probability intervals
- Dealing with multiple outputs
- Metrics based on risk-criteria
- Reality, model output, experimental data and model bias concepts
- Experimental error quantification
- Concept of model reliability based on amount of bias
- Adequacy versus accuracy

Extraction of

Response Features

- Modal response for linear, low-frequency dynamics
- Features for transient response, shock response
- Statistical features
- What makes a good feature

Validation From a Requirements Basis

- Steps of model validation
- Metrics and adequacy criterion based on requirements approach
- Test measurement uncertainty quantification related to requirements
- Examples

Applications of FE

Model Updating

- Parameterizing FE models
- Tuning/adjusting model parameters, FE model refinement
- Structural dynamics examples

Structural Dynamic

Modeling Issues

- Time step decimation and aliasing
- Damping methods and calibration
- Uncertainty quantification for boundary conditions and loads

Closure, Group Discussion

- Short presentation of what was covered during the short-course
- What was not covered, what is missing from the short-course
- Other short-course, other resources (conferences, websites)
- Software for doing V&V?
- Feed-back from attendees, questions, expectations met/not met, final survey