

Introduction to VVUQ | Part 1 Simulation Credibility Assessment

Task Group on VVUQ Concepts in Engineering Education

ASME Codes & Standards | Committee on Verification, Validation, and Uncertainty Quantification

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Outline

- Why do we care?
- Structure of a simulation model
- How is a simulation model assessed?
- How is simulation credibility assessed?
- Context of use of the simulation

Why do we care?

- "All models are wrong some are useful." Prof. George E. P. Box
- Why is this true?
 - All models rely on assumptions and approximations in the formulation of the model
 - All models require input data to describe the system of interest and its surroundings, which are approximate or possibly not measurable
 - All models require numerical solution, which results in numerical errors
- Infamous system failures due to erroneous modeling:

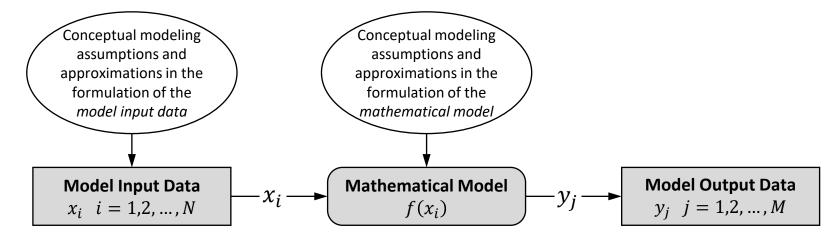


Space Shuttle Columbia Disaster



Fukushima Nuclear Disaster

Structure of a simulation model



Examples of model input data:

- System mass
- System geometry
- Thermal conductivity
- Young's modulus
- System initial conditions
- External loading
- Magnetic field intensity
- Acoustic environment

Examples of mathematical models:

- Nonlinear algebraic equation
- Ordinary differential equation
- Partial differential equation
- Integral equation

Examples of model output data:

- System thermal response
- System deflection
- Local stress and strain
- Vibrational modes of a structure
- Fluid lift and drag
- Electrical current
- Magnetic field strength
- Acoustic response

How is a simulation model assessed?

- Simulation models are used to produce **information** about the system of interest and its response.
- Examples how this information can be used:
 - Design of new systems or modification of existing systems
 - Optimization of system design to increase performance, reliability, and safety
 - Reduce development time and physical testing of the final system
 - Assess system safety in untestable accident environments
- Simulation models are assessed for:
 - Accuracy and uncertainty in the simulation result
 - Credibility and applicability of the simulation result to the issue at hand
 - Time and cost to develop a simulation model vs physical testing of the system
 - Are the approximations and assumptions in construction of the model consistent with the **context of use** of the model?

How is simulation credibility assessed?

- Numerical accuracy is assessed by simulation verification:
 - **Simulation verification:** assessment of the accuracy of the numerical solution relative to the exact solution of the mathematical model
- Physics-based accuracy is assessed by model validation:
 - **Model validation:** assessment of the accuracy of the simulation result relative to experimental measurements of the system responses
- Uncertainty in the simulation result is assessed by uncertainty quantification:
 - **Uncertainty quantification:** estimation of the total uncertainty in the simulation result due to all sources of error and uncertainty
- These assessments are collectively referred to as VVUQ
- Note: These concepts of verification and validation are distinctly different from the systems engineering concepts of V&V

Context of use of the simulation

- Context of use: the relationship between the applicability and accuracy of the model relative to the requirements for the intended use of the model
- Examples of issues related to the context of use:
 - Are the assumptions and approximations of the formulation of the model consistent with the intended use of the model?
 - Is the accuracy and uncertainty of the simulation result sufficient for the needs of the intended use of the model?
 - Are the VVUQ assessment activities sufficient to insure credibility for the intended use of the model?
 - Are the conditions of model validation sufficiently relevant to the actual conditions of the system of interest?
 - What are the consequences and risks involved if the simulation result is inaccurate?

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