VERIFICATION VALIDATION AND UNCERTAINTY QUANTIFICATION

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

Contacts: Lydia Stanford (stanfordl@asme.org) | Daniel Papert (papertd@asme.org)

v. 3, 2026

© 2026 by ASME Task Group on VVUQ in Engineering Education is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/

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:

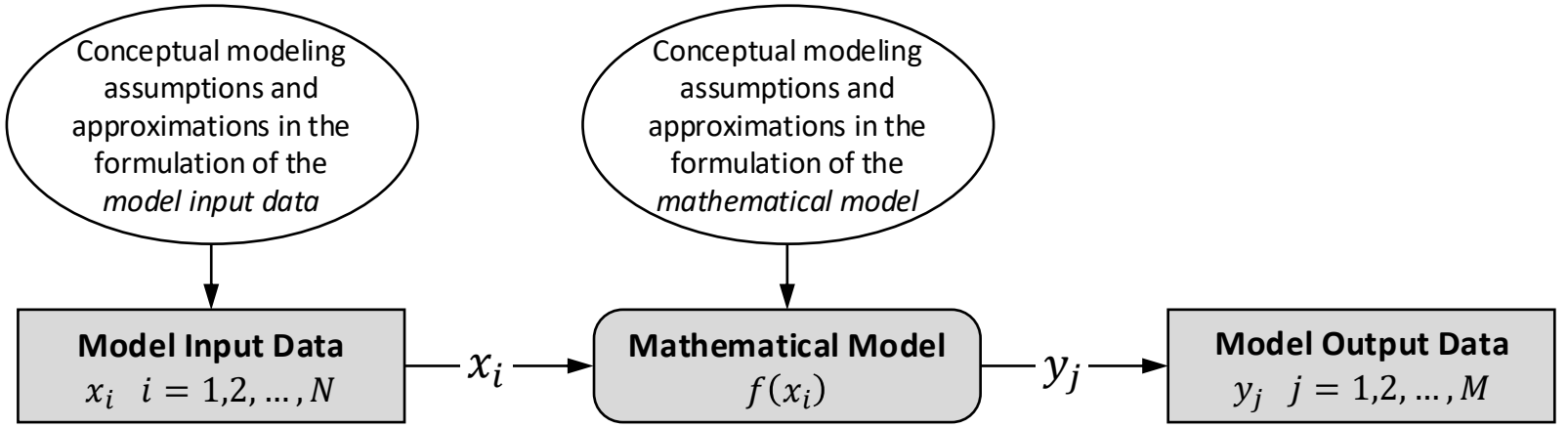


Space Shuttle Columbia Disaster



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

What do simulation models produce and how is it used?

- Simulation models are used to produce **information** about the system of interest and its responses.

- When simulation results are used in business and government:
  - Simulation is referred to as a **decision support tool**
  - The process is also referred to as **simulation-informed decision making**

- 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
  - Optimize manufacturing processes
  - Assess system safety in untestable environments such as accident scenarios or those that produce unacceptable risks to humans and the environment

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 to the mathematical model
- Physics-based accuracy is assessed by model validation:
  - **Model validation:** assessment of the accuracy of the simulation results relative to experimental measurements of system responses
- Uncertainty in the simulation results is assessed by uncertainty quantification:
  - **Uncertainty quantification:** estimation of the total uncertainty in the simulation result due to all sources of error and uncertainty in the modeling and simulation process
- 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 simulation 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 results 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 interest for the system/subsystem under considerations?
  - What are the consequences and risks involved if the simulation results are inaccurate?

References

- AIAA (2021), "Recommended Practice: Code Verification in Computational Fluid Dynamics." American Institute of Aeronautics and Astronautics, AIAA R-141-2021, Reston, VA.
- ASME (2018), "Assessing Credibility of Computational Modeling Through Verification and Validation: Application to Medical Devices," American Society of Mechanical Engineers, New York, NY, ASME V&V 40-2018, New York, NY.
- ASME (2019), "Standard for Verification and Validation in Computational Solid Mechanics." American Society of Mechanical Engineers, ASME Standard V&V 10-2019, New York, NY.
- ASME (2021), "The Role of Uncertainty Quantification in Verification and Validation of Computational Solid Mechanics Models," American Society of Mechanical Engineers, ASME VVUQ 10.2-2021, New York, NY.
- ASME (2022), "Verification, Validation, and Uncertainty Quantification Terminology in Computational Modeling and Simulation," American Society of Mechanical Engineers, ASME VVUQ 1-2022, New York, NY.
- McClarren, R. G. (2018), Uncertainty Quantification and Predictive Computational Science, Springer, Cham, Switzerland.
- NaRC (2012), "Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification." National Research Council of the National Academies, ISBN-13: 978-0-309-25634-6, Washington, DC.
- NASA (2016), "Standard for Models and Simulations." National Aeronautics and Space Administration, NASA-STD-7009A, Washington, DC.
- Oberkampf, W. L. and C. J. Roy (2025), Verification, Validation, and Uncertainty Quantification in Scientific Computing, 2nd edition, Cambridge University Press, UK.
- Roache, P. J. (2009), Fundamentals of Verification and Validation, Hermosa Publishers, Socorro, New Mexico.
- TMS (2019), Verification & Validation of Computational Models Associated with the Mechanics of Materials, The Minerals, Metals & Materials Society, ISBN 978-0-578-45369-9, Pittsburgh, PA.