VERIFICATION VALIDATION AND UNCERTAINTY QUANTIFICATION

Introduction to VVUQ | Part 3
Validation

Task Group on VVUQ Concepts in Engineering Education

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

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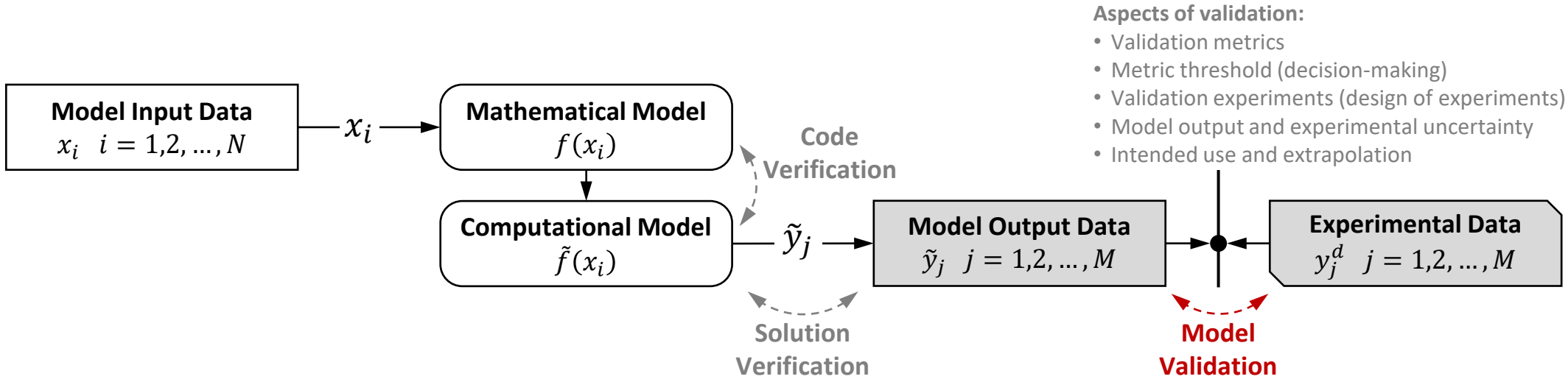
V. 1, February 11, 2025

Outline

- What is validation and why do we care?
- How is validation performed?
- What is prediction?
- How does validation inform the model's *predictive capability*?

What is validation and why do we care?

- Computational modeling and simulation are used to aid the decision-making process
  - e.g., Predicting traffic flow in a city: an inaccurate model could lead to bad decisions, like building unnecessary roads.
- **Validation** compares the model to real-world observations (data) to ensure it captures essential features (physical phenomena) of the real system.
- Validation data should reflect the situations that the model should handle (its 'intended use').
  - e.g., Validating the traffic model using rush hour data rather than a quiet Sunday morning



How is validation performed?

- **Create model:** build a computational model for a specific context of use
- **Verification:** assess numerical errors (see previous module)
- **Collect measurements:** conduct validation experiments (preferred) or collect historical data
- **Quantify uncertainty:** estimate for both model outputs and measurements
- **Validation assessment/model error estimation:** compare model outputs to measurements via
  - qualitative assessment by expert judgment
  - quantitative assessment using mathematical validation metrics

- Note: There is often a hierarchy of validation in real-world complex systems
  - validation of individual components or subsystems
  - validation of the entire system

What is prediction?

- **Prediction** involves producing model outputs for which corresponding measured data is not used in developing the model (validation) or is unavailable (intended use)

- **Validation domain**: A model is validated against experimental results at a specific set of input conditions ('validation points') that form the *validation domain*.

- **Intended use domain**: Predictions in the *intended use domain* (model inputs) may be interpolative or extrapolative with respect to the *validation domain*.

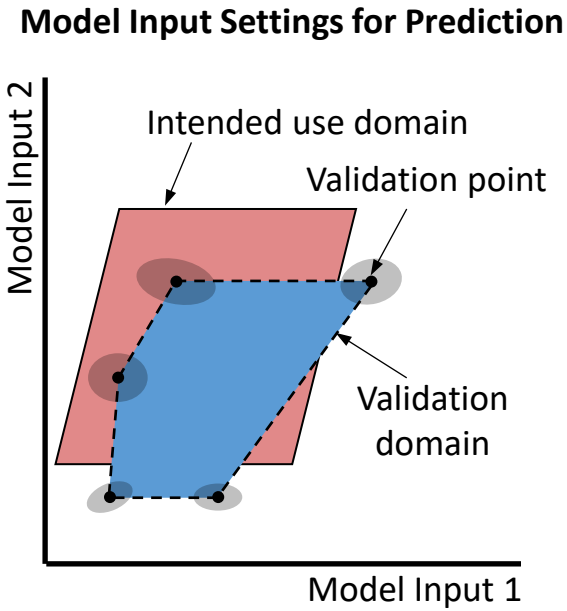


Image credit: adapted from V&V 10

How does validation inform the model's predictive capability?

- **Predictive capability** is an evaluation of model *accuracy* and *credibility* (trustworthiness) that is based on
  - quantitative validation assessment at sufficiently many validation points
  - the model's intended-use domain relative to the validation domain
  - "error bounds" due to uncertainty and error in the model and measurements
  - acceptable quality process (standardization, peer review, training, etc.)

- A model's **adequacy** involves other programmatic requirements such as
  - implementation for a practical application
  - cost, maintenance, and ease of use considerations
  - determination if the predictive capability is adequate for the intended use of the model

References

- ASME (2022), "Verification, Validation, and Uncertainty Quantification Terminology in Computational Modeling and Simulation," American Society of Mechanical Engineers, ASME VVUQ 1-2022.
- 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 (2009), "Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer." American Society of Mechanical Engineers, ASME Standard V&V 20-2009(R2021), New York, NY.
- Oberkampf, W. L. and C. J. Roy (2010), Verification and Validation in Scientific Computing, Cambridge University Press, UK.
- 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.