Insights that may be helpful in constructing future paradigms of Model Validation

Vicente Romero

Model Validation and Uncertainty Quantification Dept.

Sandia National Laboratories

Albuquerque, NM

CSRI Workshop on Mathematical Methods for V&V

Aug. 14-17, 2007, Tamaya Resort, Albuquerque

LOCKHEED MARTIN

Sandia National Laboratories

Foreword

Standard definition: "Model Validation is the process of determining the degree to which a computer model is an accurate representation of the real world from the perspective of an intended use of the model."

- Definition does not provide guidance on what constitutes a validated model, or what are the steps of the model validation process.
- The following insights are based on many years of M&S at component, subsystem, and system level applications, and incorporation of V&V, UQ, QMU into engineering projects.
- *Tremendous opportunity and fertile ground still exist for fundamental and applied research in the areas of model conditioning, validation, and optimal extrapolation for Best Estimate Plus Uncertainty predictions….these are all at the frontier of prediction science. Progress in prediction will depend on advancing these.*

In particular, contemporary Model Val. paradigms have not completely resolved these important questions:

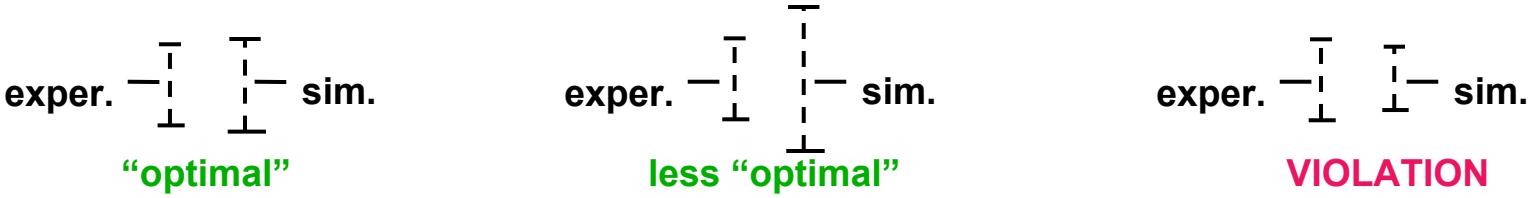
- What constitutes a validated model?
- What are the essential criteria that allows one to defensibly make the claim that they are using a validated model in an analysis?
- What is the value-added information product from the model validation activity?
- What, ultimately, does the validation process involve?

Issues/Constraints for application of Validation in Engineering Projects

- **Non-Uniqueness of model accuracy "requirements"**
  - In parsing error budgets from the system level down to subsystem, component, and constitutive models that are to be validated, an infinite no. of combinations of error budgets at lower levels will add to the same total-error allowance at the system level.
  - Therefore, accuracy "requirements" as criteria for validation of models below the system level suffer from a substantial degree of arbitrariness:
    - Material property models
    - Constitutive models (including failure models)
    - Component models
    - Subsystem models
  - Difficult to defend acceptance or (especially) rejection of models based on arbitrary "rqmnts."
  - There are other problems with hypothesis tests for model accuracy as a validation approach.

Issues/Constraints for application of Validation in Engineering Projects

- **Validate with respect to what, then?**
  - **Validate that reality lies within the model's predictions at the validation points in the parameter space.**
  - **Specifically, validate that the matched set {model form + uncer. representation} adequately bounds the *total experimental uncertainty* within which we can establish that reality lies.**

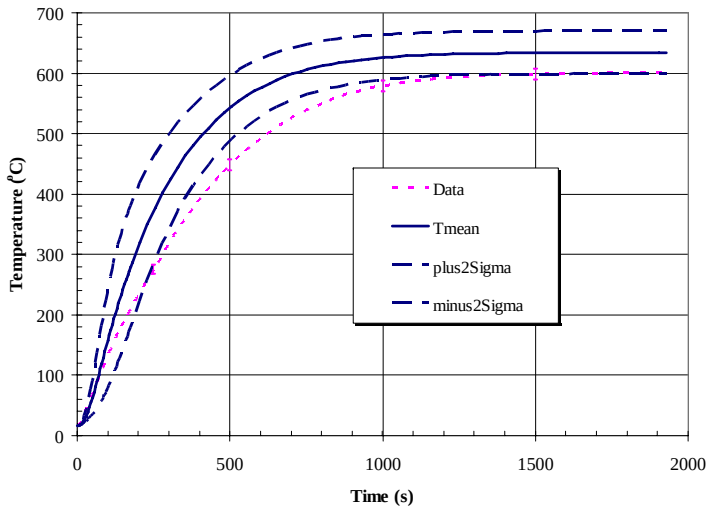


Issues/Constraints for application of Validation in Engineering Projects

CAUTION:

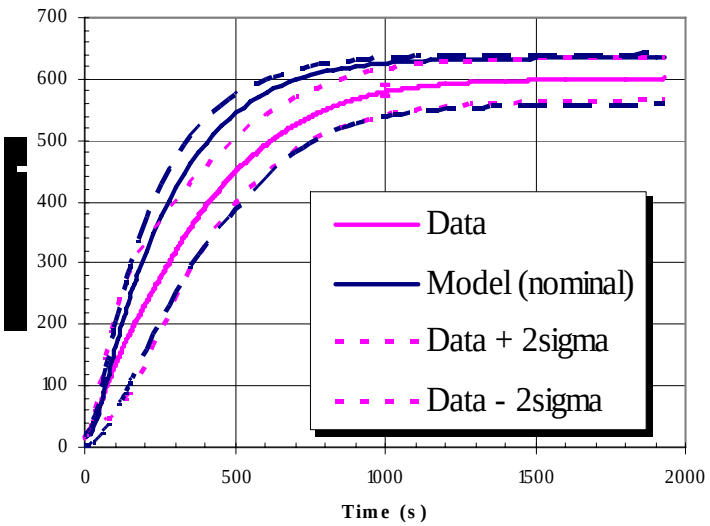
- **Be careful about what is taken as Total Experimental Uncertainty**

What I typically see…



Uncer. on experimental inputs is propagated through the model and applied to sim. "error bars"

What should be as well…



Uncer. on experimental inputs should be propagated through model and be also convolved with experimental result variability and measurement uncertainty**

Issues/Constraints for application of Validation in Engineering Projects

➡ One does not validate a 'model' in the sense of e.g. a given finite-element model; one validates that the matched set {FE model + uncertainty representation} envelopes our best perception of where reality lies.

- Uncertainty representation in the model can be in terms of:
  - Parameter uncertainty and/or an uncertainty "layer" functions
  - Uncertainty representation should be in a form that allows *transportation* to conditions for which a smooth, continuous parametric mapping does *not* exist between the validation and application parameter spaces, e.g., in regards to
    - Geometry, Boundary Conditions, etc.
  - This is the "*morphing constraint*" with respect to extrapolation.
  - This constraint—a non-existent parametric map between the two spaces—is at play in most engineering projects.
    - This also prevents mapping of program rqmts. (from the application domain) to accuracy rqmts. in the validation domain.
    - Precludes rigorous extrapolation of conclusion 'validated model' and any associated confidence from the validation domain to the application domain.

Issues/Constraints for application of Validation in Engineering Projects

➡ **So, work to a Model Accreditation and Best Estimate + Uncertainty paradigm for extrapolative predictions.**

BEPU implies:

- **Model Conditioning (of which calibration is a narrow special case)**
  - **This is the mapping of experimental uncertainty, and any correction for model bias (that is discernable outside the resolution lower-limit allowed by the precision of the experiments), to suitable parameters and/or added uncer. layers of the model.**
  - **required only when the uncertainties (incl. "*intrinsic uncertainties*") in the model do not envelope the total exper. uncer. – –often the case**

  uncertainty repres. = a-priori model uncer.
  + mapped uncer. from any model cndtng.

- **Techniques for "optimal" extrapolation**