“Essentially all models are wrong, but some are useful,”
George E.P. Box, Industrial Statistician
Lecture 1 Introduction

- What is validation, verification and uncertainty quantification?
- Why do we care?
- Motivation: Etrema Products, Inc., SolidDrive
  http://www.etrema-usa.com/
Terfenol-D Transducer

- Schematic of Terfenol-D transducer in the SolidDrive
- Terfenol-D rod can be modeled as a rod with elastic and damped boundary conditions.
- For uniform input fields, spring equation with nonlinear inputs provides “good” approximation of rod dynamics.
- What is nonlinear and hysteretic behavior of \( f(H,u) \)?
Magnetomechanical Material Behavior

- Material depends on both magnetic fields and stresses
- Consider application of periodic field followed by application of positive and negative stresses.
- Data from Pitman, 1990.
- Note: the source and conditions under which data was collected are crucial in the context of validation, verification and uncertainty quantification!!!
Model Development

Question: Which model is better??
Model Development

Original data: (Craik and Wood 1970)

Questions:
1. Are scales accurate?
2. Is data accurate?
3. What is source of loss in upper loop?
Model Development

Experimental Data

Notes:
1. Numerical implementation of Model 1 is inaccurate (verification)
2. Neither model is “true” representation of physical device (validation)
Modeling Issues

Reality

Model Validation

Computer Simulation

Analysis

Conceptual Model

Model Qualification

Programming

Model Verification

Computer Model
Verification: The process of determining that a model implementation accurately represents the developer’s conceptual description of the model and the solution to the model.

Note: Verification deals with mathematics.
**Validation Process**

- **Real World**
  - **Conceptual Model**
    - **Computational Model**
      - **Computational Solution**

- **‘Correct’ Answer Provided by Experimental Data**
  - Benchmark cases
  - System analysis
  - Statistical analysis

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**Validation:** The process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended model users.

**Note:** Validation deals with physics and statistics

**Reference:** Oberkampf, Trucano and Hirsch 2004
Validation Metrics

- **'Viewgraph' Norm**
- **Deterministic**
- **Experimental Uncertainty**
- **Numerical Error**
- **Nondeterministic Computation**
Validation Metrics: Example

Metric 1:

Data

Model
Validation Metrics: Example

Metric 2:
Difficulties with Using Existing Experimental Data for Validation

1. Incomplete documentation of experimental conditions
   • Boundary and initial conditions
   • Material properties
   • Geometry of the system
2. Limited documentation of measurement errors
   • Lack of experimental uncertainty estimates

Note: It is critical that modelers, numerical analysts, and experimentalists work together

Reference: Oberkampf, Trucano and Hirsch 2004
Background of Validation and Verification

• Validation and verification began to be formalized during the ASCI (Accelerated Strategic Computing Initiative) Program to replace physical nuclear testing by computer experiments.

• A large body of validation and verification research has been performed at Sandia National Lab.