# Developing Adequacy Criteria for Model Validation Based on Requirements

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Model Validation and Uncertainty Quantification Tutorial

# Model Validation History in Structural Dynamics

In the 80's

Validation = Correlation = Updating = Refinement

= "better match" between analysis and test data

In the 90's the definition of validation began to be refined.

One often-referenced definition that has emerged is:

"*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 the intended model application." [1]

Three aspects of validation

- degree to which … accurate representation (subject of this talk)
- real world (test data is our substitute)
- intended application (a decision that needs to be made)

# Approach

Here we take the approach that the model will make a blind prediction that will be compared to test results. Pre-determined bounds are set to determine if the model is valid or invalid.

George Box – “All models are wrong, but some are useful”. Here we accept that there can be systematic differences between model predictions and test and the model may still be useful.[3]

Box went on to address the crux of the matter “…that all models are wrong; the practical question is how wrong do they have to be to not be useful.”[3]

# How do we decide “the degree to which…”

- The customer for a model validation is a decision maker who wants to know, “ For the decision I must make, is the information from the model valid or not?”
- Another way to state the decision maker’s question is, “How far can the model deviate from reality and still provide information that is valid for my decision?”
- Validation requirements should be established in advance by a team
- The result of the validation will be a go/no go decision on the usefulness of the model for providing information to make the engineering decision for which the model has been generated.

# The Validation Team

- Team members can be categorized
  - Decision Maker
  - Analyst
  - Experimentalist
  - Stakeholders (mgrs, designers impacted by decision, UQ types)
- Team members must agree on the rationale that relates requirements to responses – You don’t want members saying at the end “I’m not confident that the model is valid for this”.
- Finding this agreement is hard work since it involves team members from different disciplines translating requirements into quantified numbers that can be related to responses

# Some Definitions

- *Response measures* are the quantities the model is to predict.[2] (E.G. acceleration, strain, temperature)
- *Response Features* are some mathematical operation on the response measures. (E.G.  Max acceleration, RMS acceleration, correlation coefficient)
- *Adequacy criteria* define the required maximum acceptable difference between the validation experiment and computational features.[2]

# “the intended application”

- Before deciding on response features, the validation team must be clear on the intended application for the model.
- The decision maker should be able to state the requirement in a way that the rest of the team understands.
  - the decision maker may not be a physics subject matter expert
  - the requirement may be in words, not numbers
- After the requirement is clear, then the work begins to boil it down to numerical quantities

# Response Measures

- Must be agreed by experimentalist and analyst
- May need to be considered along with “response features”
- Must correspond

# Response Features

Response features

- Must be well defined
  - Makes the decision easier
  - Well defined usually means “simple” (E.G. Max, Mean, RMS)
- Should be kept to a small number
  - Makes the decision easier
  - UQ can be propagated up from response measures
- Should be prioritized (if more than one)
  - Low priorities should have less strict adequacy criteria
- Should be related to the requirements by clear rationale
  - Do not just use a standard industry metric if it does not relate to the requirements (E.G. MAC)
  - Analyst and experimentalist should be able to get buy-in from decision maker / stakeholders

# Adequacy Criteria

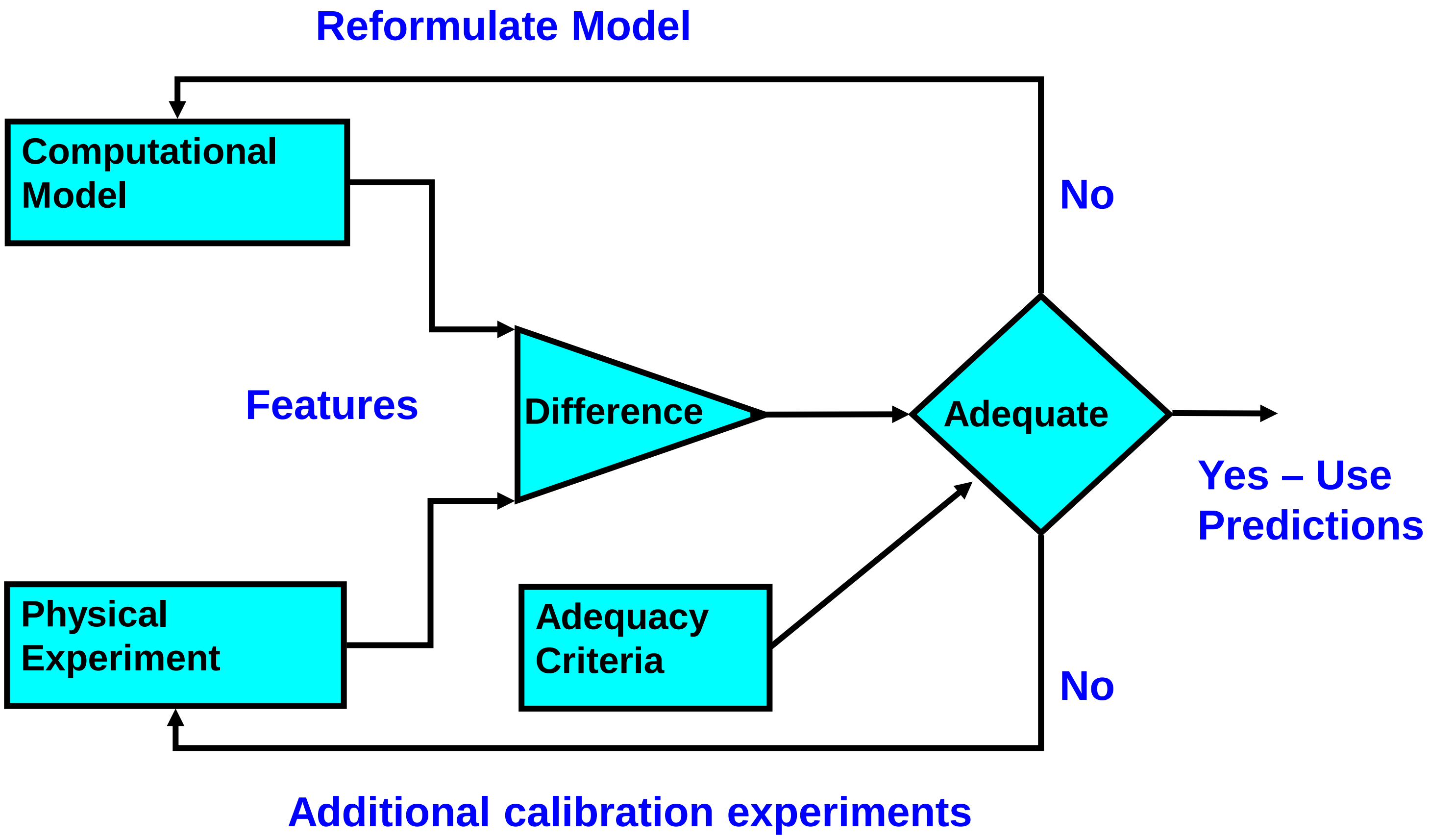
Adequacy criteria

- Must be well defined
  - Makes the decision easier
  - Well defined usually means “simple”
  - Will help the team learn how to specify good adequacy criteria
- Should not be artificially restrictive
  - Common mistake
  - Find the decision maker’s threshold of pain
- Should be related to the requirements by clear rationale
  - Do not just use a standard industry metric if it does not relate to the requirements (E.G.  Modal frequencies within 5%)
  - Team must agree

# Steps to Model Validation

- Preliminary Steps
  - Specify model use/purpose (what decision is to be made)
  - Specify response measures (what the model predicts)
  - Specify validation features and metrics and comparison domain
  - Specify calibration experiments
  - Specify validation experiments
  - Specify adequacy criteria
- Perform calibration experiments/Calibrate model parameters
- Validation
  - Perform experiment
  - Make predictions
  - Calculate metrics/compare with adequacy criterion
- Subsequent Action
  - Not valid – Reformulate model/Additional calibration
  - Valid – Make Predictions

# Model Validation Process



Reformulate Model

Computational Model

No

Features

Difference

Adequate

Yes – Use Predictions

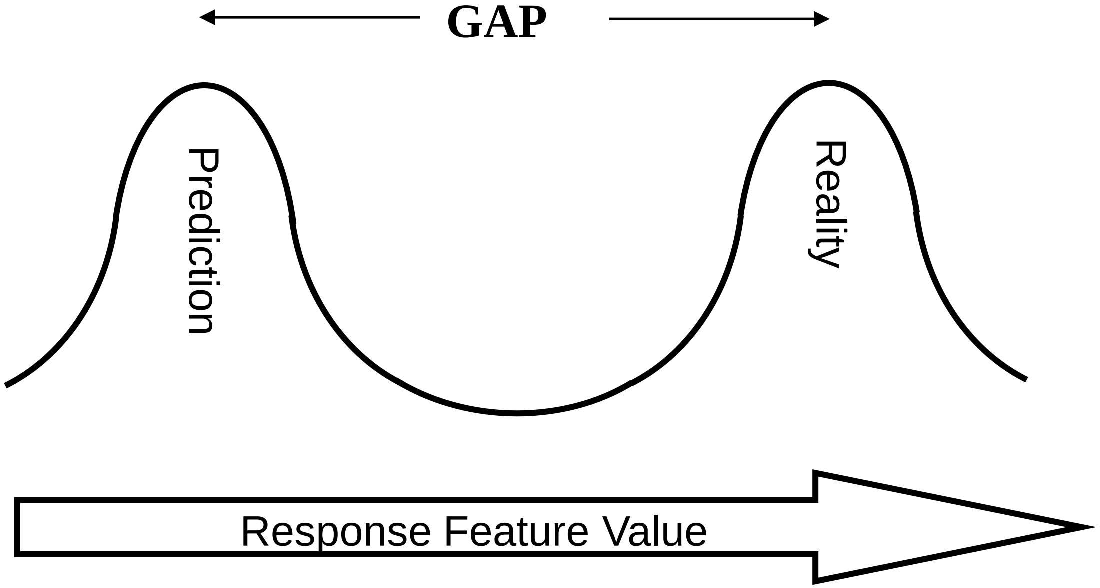
Physical Experiment

Adequacy Criteria

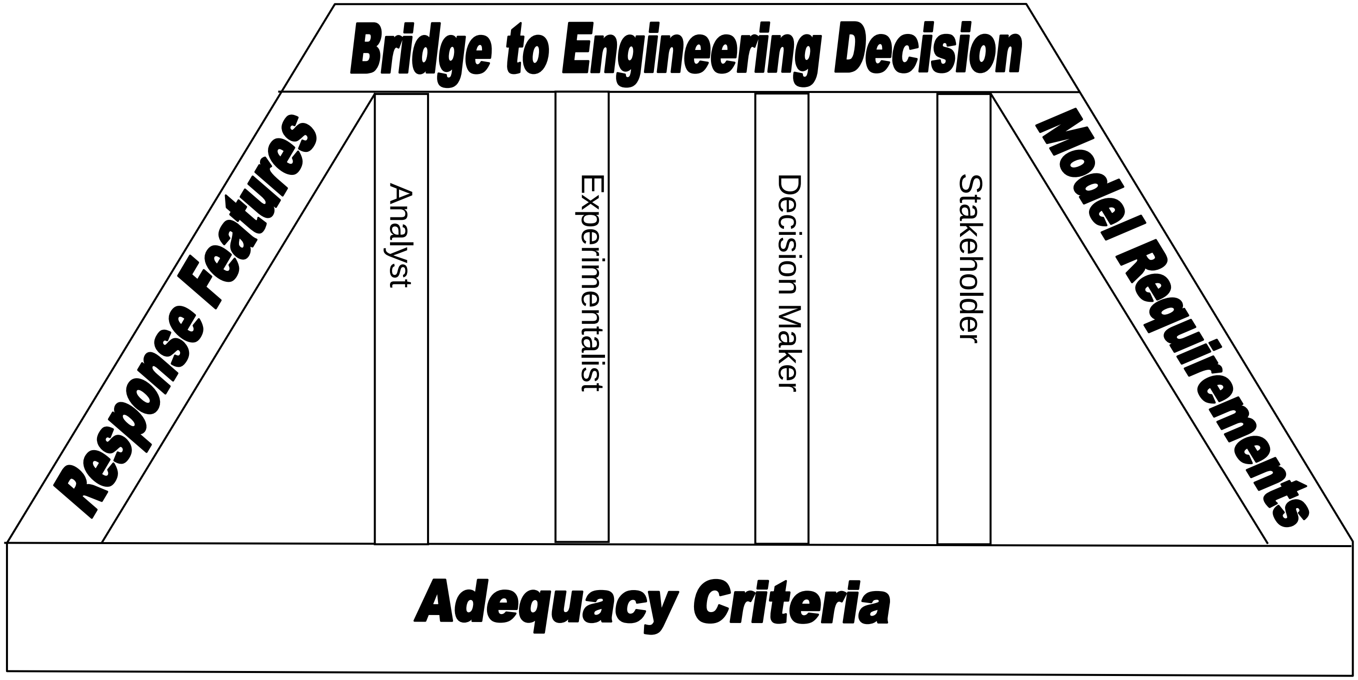
No

Additional calibration experiments

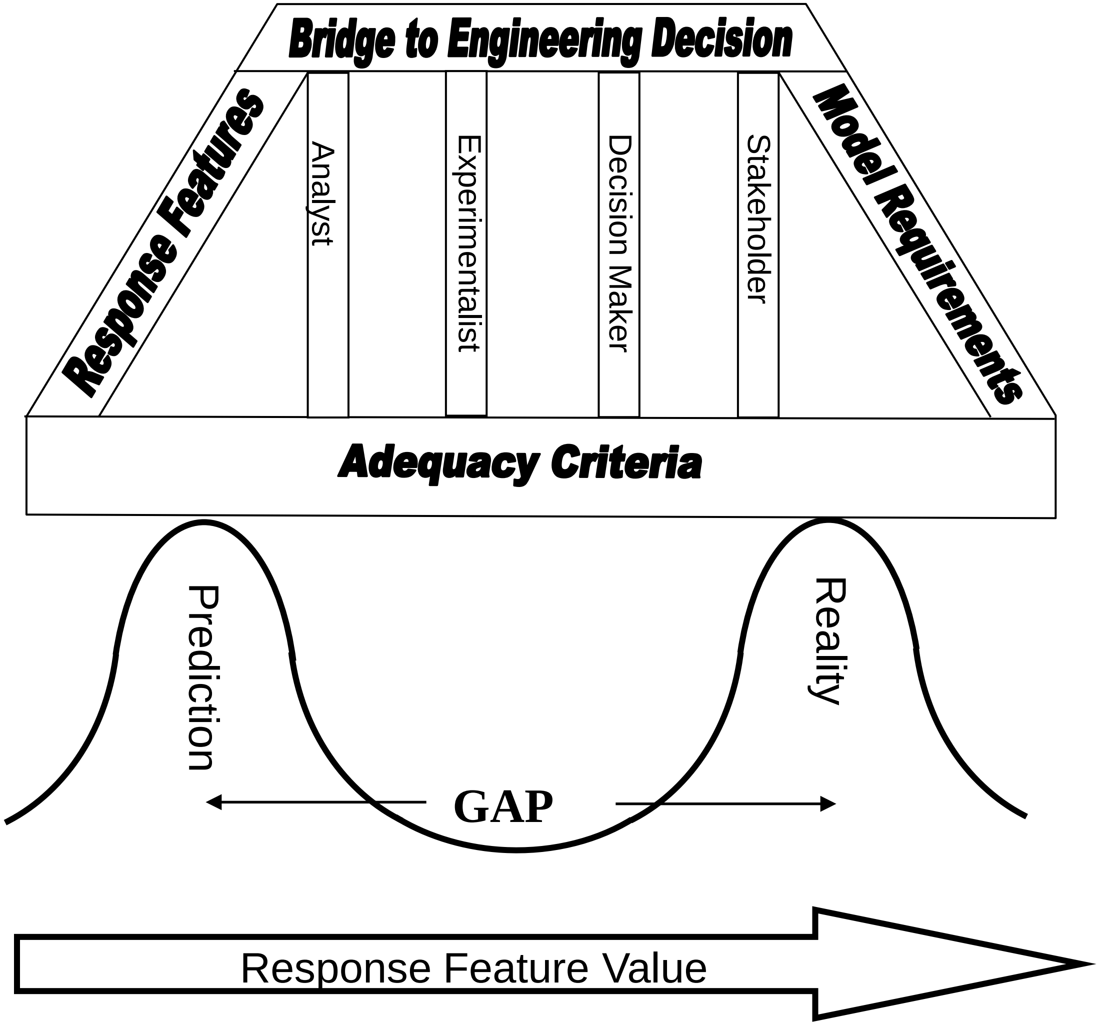
# The Gap Between Prediction and Reality



# The Bridge to Engineering Decision



# The Gap Relative to Adequacy Criterion



# References

1. AIAA (American Institute of Aeronautics and Astronautics), (1998), *Guide for the Verification and Validation of Computational Fluid Dynamics Simulations*, AIAA-G-077-1998, Reston, VA, American Institute of Aeronautics and Astronautics

2. Urbina, A., Paez, T.L.,Rutherford, B.,O'Gorman, C., Hinnerichs, T., Hunter, P., "Validation of Mathematical Models: An Overview of the Process", Proceedings of the 2005 SEM Conference and Exposition on Experimental and Applied Mechanics, Paper 210, June 2005

3. Box, George E.P., Draper, Norman R., *Empirical Model-Building and Response Surfaces*, 1987, p. 424,74, Wiley. ISBN 0471810339