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FY14 V&V Challenge Workshop

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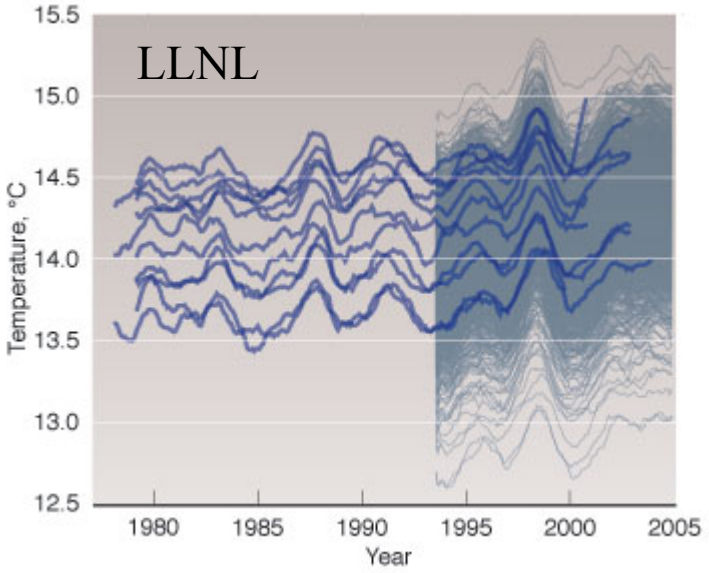
Why Do UQ?

- UQ community: focus on parametric algorithms, theory
- Applications community perspective?
  - UQ is a means to an end
  - Focus on decision making
  - Value results over algorithms
  - Value ease of interpretation over theory
- Challenge problems for two communities will share *similar ideas,* with different focus



Risk Informed Decision Making

- Use Case determines the required info:
  - Predictions → Need Modeling and Simulation
  - Variability/Uncertainty → Need UQ
  - Credibility → Need Verification & Validation (V&V)
- Challenge: find an 'end-to-end' approach
  - Simulations to decision
- UQ is an important piece
  - Parametric, Model form, numerical, etc.
  - Separation of aleatoric, epistemic uncertainty

Motivation & Vision

- V&V field is developing fast
  - PSAAP schools, ASME V&V Symposium, journals
  - Workshops help move the field forward
- **(Shared) Vision** – series of workshops
  - Range of topics: Verification, Validation, UQ
  - Range of audiences: Industry, Academia, Labs
  - Range of venues/partners: ASME, USACM, SIAM

→ **Increase awareness, interest, innovation**

V&V on One Slide

- V&V: gather evidence that predictions & UQ are credible
- Start w/ math model of some phenomenon & a use case
- Is the code implementing the math model? **Code Verification**
- Is the solution being calculated accurately? **Solution Verification**
- What are the unknowns?

  What impact do they have on predictions? **UQ**
- Do the predictions match reality? **Validation**
- What is the acceptable use of the predictions? **Decisions**

What is the State of the Art?

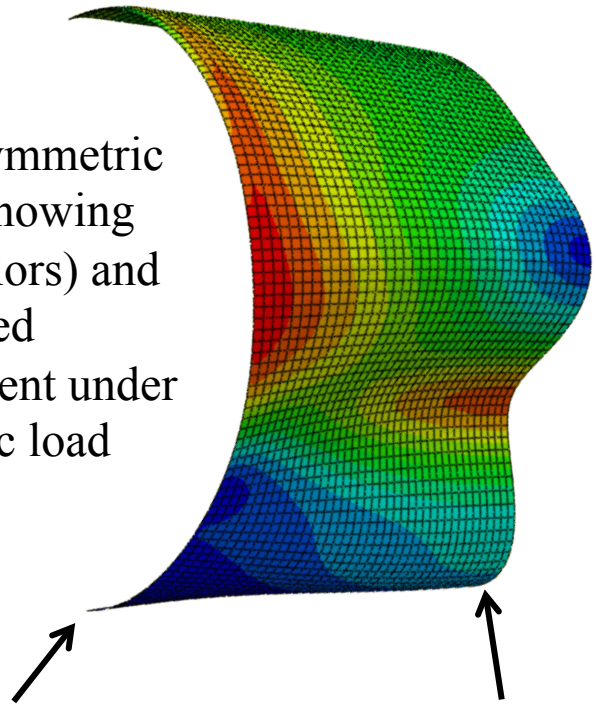
Gaps: synthesis of methods, interpretation of results

- "Aggregation" of uncertainty
  - Combine uncertainty of QoI due to multiple sources
  - Parametric, Experiment-related, Model form, Numerical
- Decision making with V&V/UQ information
- "Relevancy" of information throughout a hierarchy of analyses – Future topic

Green color = V&V/UQ feature of interest

The Problem

- Storage tank
- Pressure and liquid load
- One tank fails from tensile overload



Quarter symmetric cylinder showing Stress (colors) and exaggerated displacement under hydrostatic load

- Use test data and modeling to determine the probability of failure
- Decide whether to retire all tanks

Problem Features

- 'End-to-end' problem

  Data, models & use case

  → prediction, uncertainty, credibility

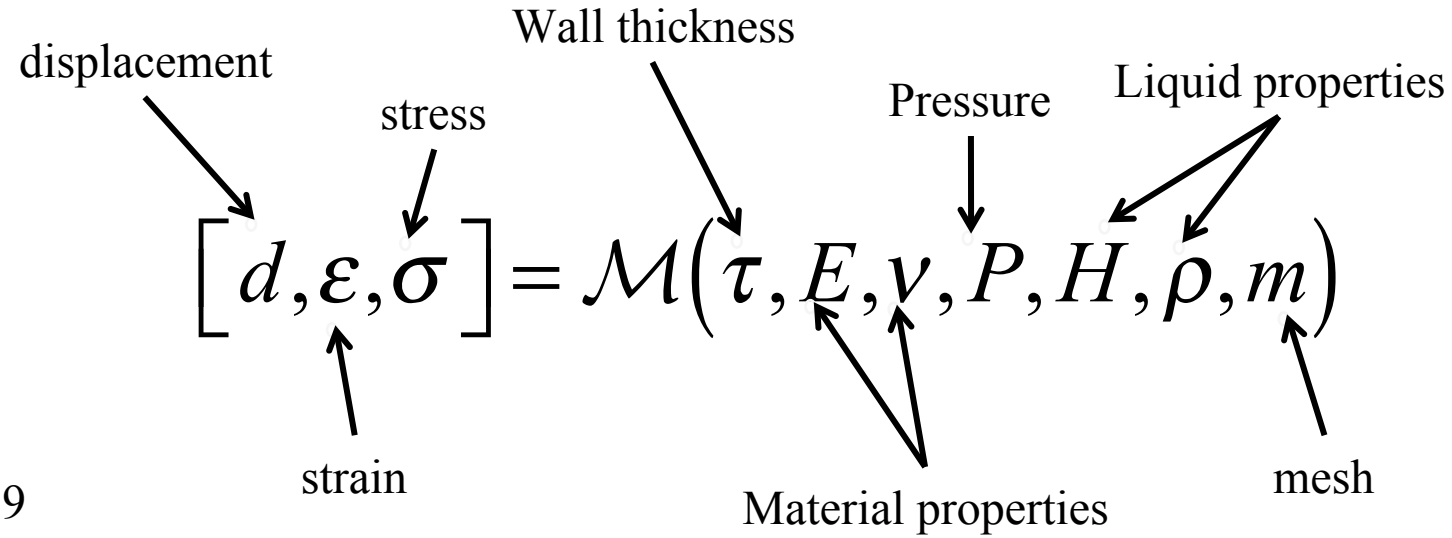
  → Decision informed by Modeling and Simulation

  – "Realistic", intuitive, and interesting story

- Topics: V&V hierarchy, calibration, solution verification, UQ, validation, aggregation
- Physics based, but no physics expertise required
- **Not a competition, no "correct" answer**

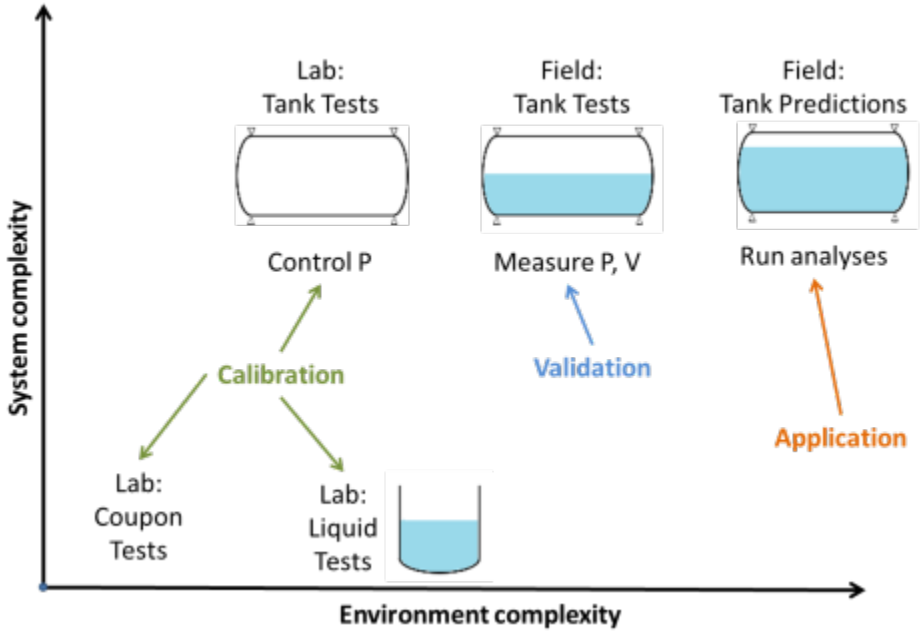
System Model Features

- Runs quickly → Not limited by methods
- Non-ideal mesh convergence (**solution verification**)
- Parameters and mesh interaction → Non-trivial **UQ**
- Modeling limitations
  - Parameter calibration w/ known **model form error**



The Story, Told w/ V&V Hierarchy

- Intended use: Probability of Failure for a range of scenarios
- Establish credibility of models → V&V Hierarchy
- Each node: improve or test the predictive capability

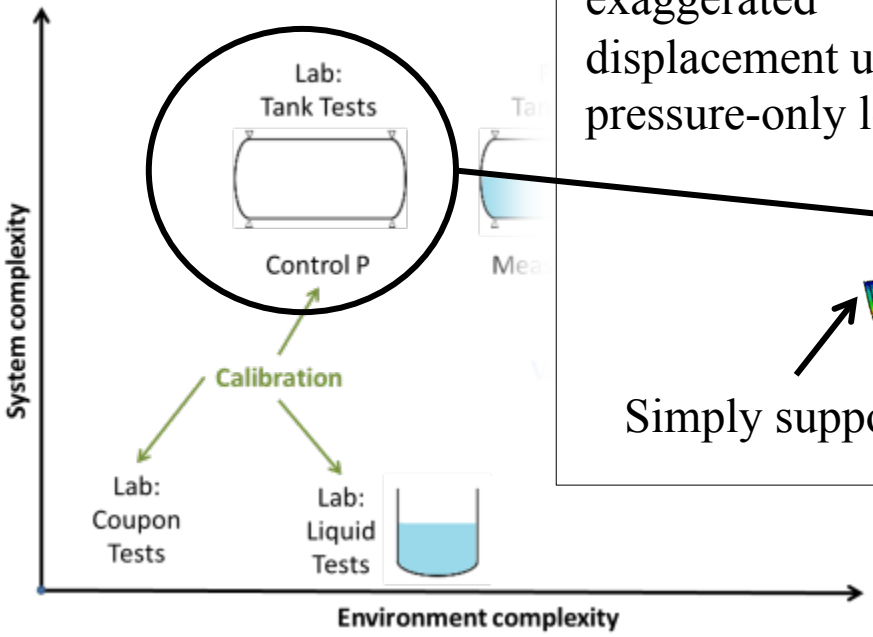


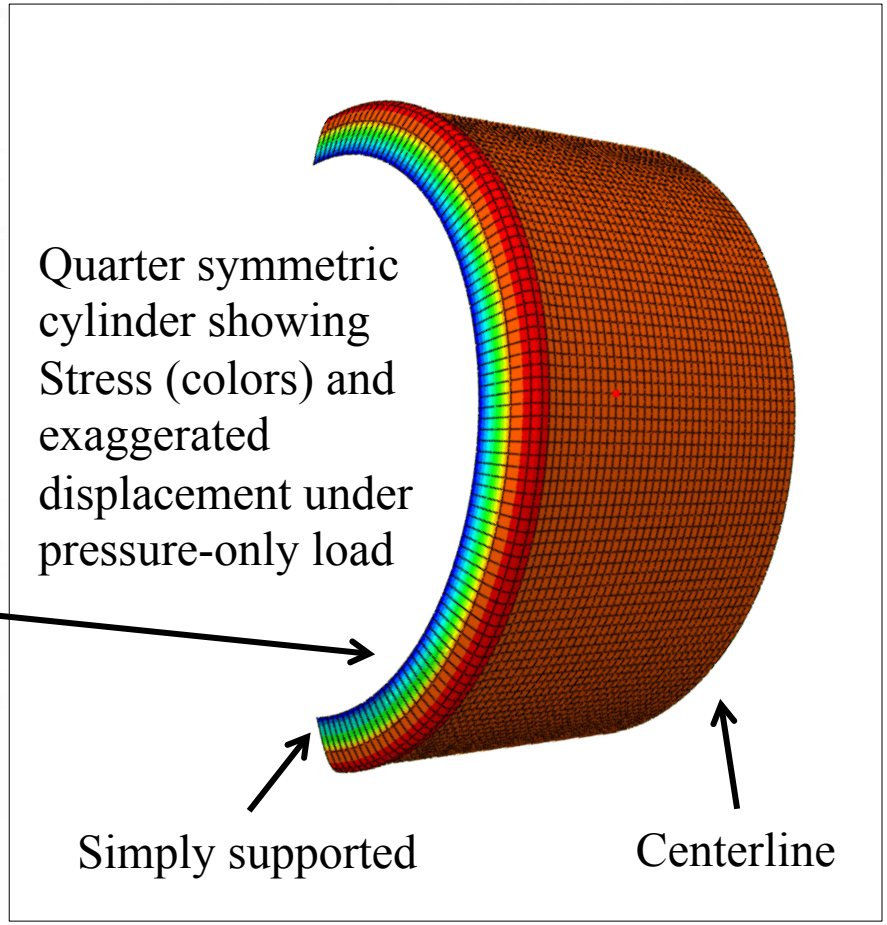
Domains: Calibration Validation Application

- System level (Full tank)
  - Combine all sources of uncertainty → **Aggregation**
  - Deal with **aleatoric & epistemic uncertainty**
- Physics level
  - Measurement limitations, Variation in materials → **Parametric uncertainty**

The Sto hy

- Intended use: Pr scenarios
- Establish credibil



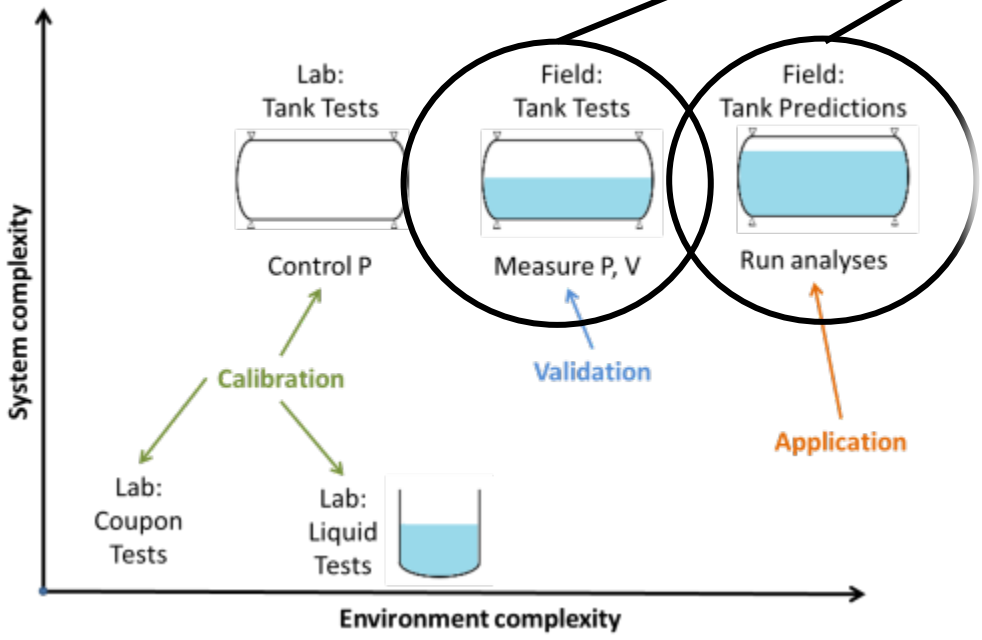


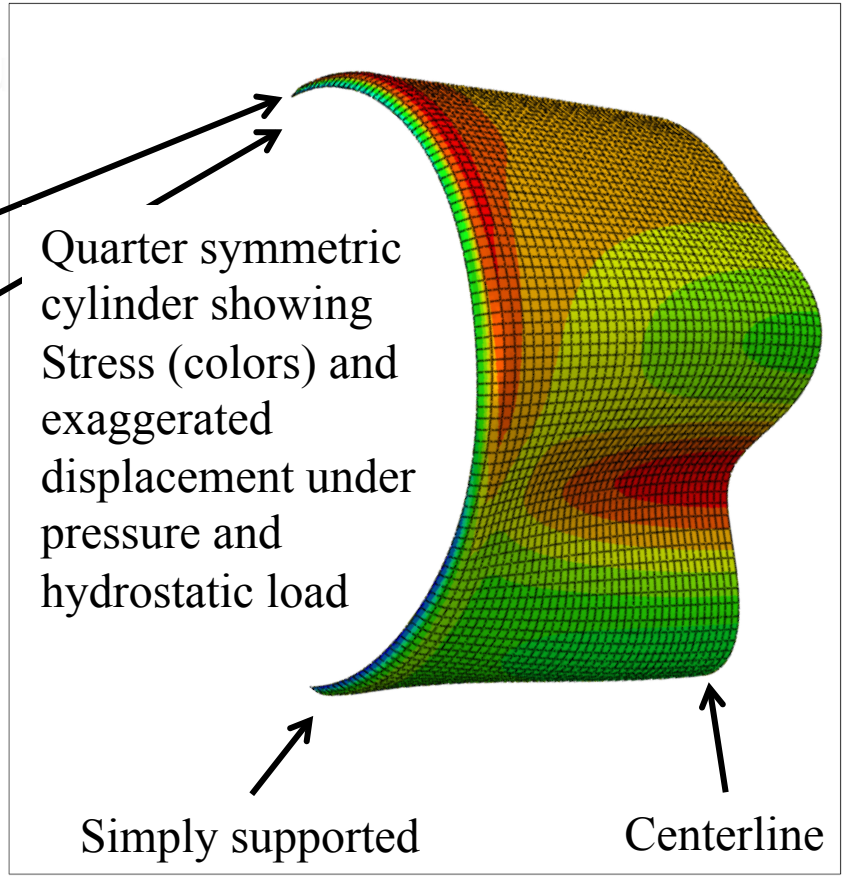
Controlled, simple test used to collect data for calibration

Domains: Calibration Validation Application

The Story, Told w/ V&V Hierarchy

- Intended use: Probability of Failu
- Establish credibility of models →





Domains: Calibration Validation Application

Uncontrolled, more complex experiments used to collect validation data

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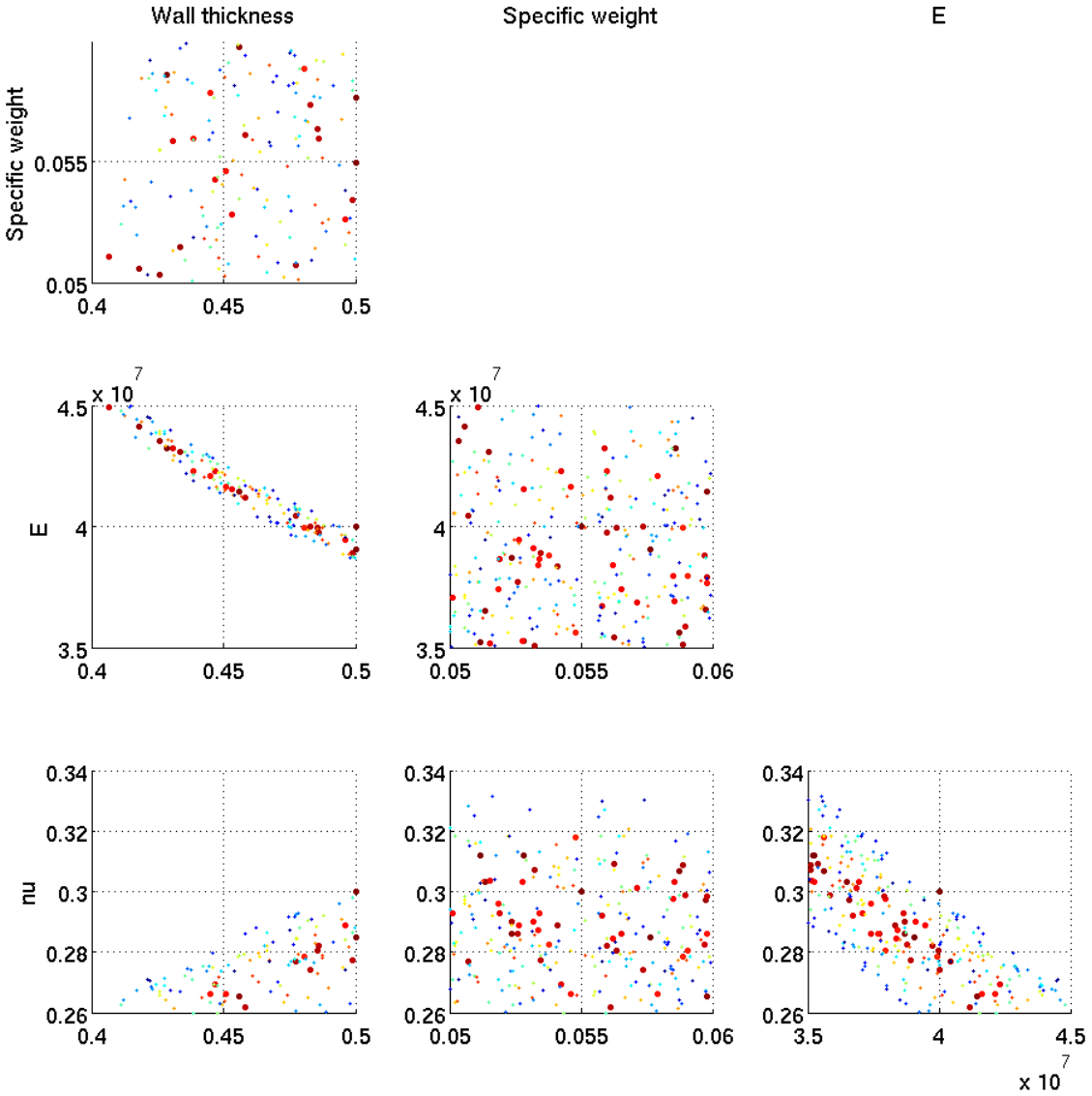
Problem Highlights

- Calibration
  - Legacy data on material parameters
  - Lab tests and controlled tank experiments
  - Physics model with multiple meshes
  - Deal with parametric & numerical uncertainty and model form error
- Validation
  - Limited, noisy data from uncontrolled experiments
  - Compare simulations and experiments
  - Handle aleatoric and epistemic uncertainty
- Experimental data generated from a “truth” model

Calibration – Mesh1



- Parameter Sampling
- Noiseless data
- Compute likelihoods

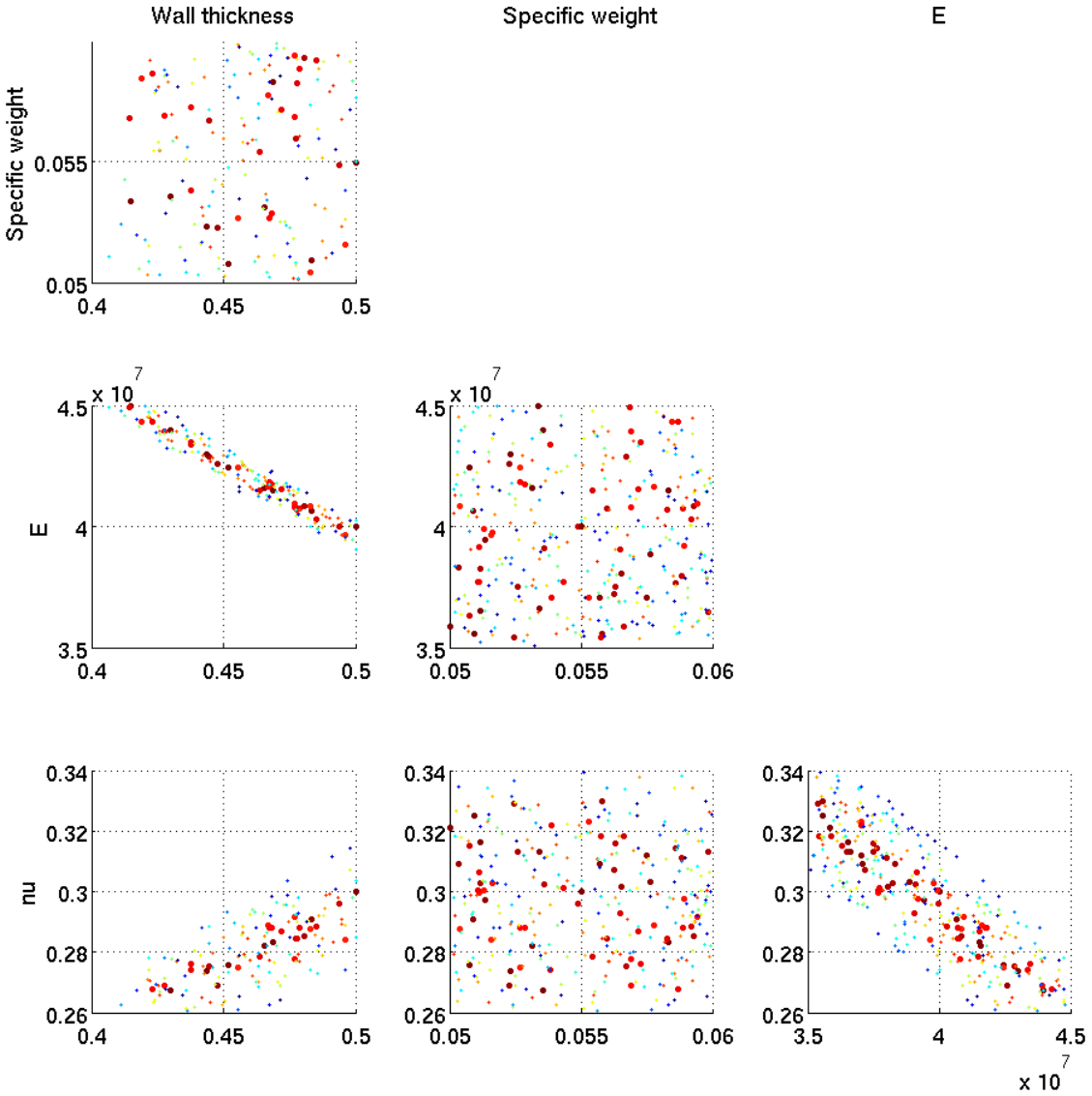
$$\sum_i \left(\mathrm{M}\ (\tau, E, \nu, P_i, \rho, m) - Data_i\right)^2$$

  - Red = high
  - Blue = lower

→ Mesh dependence

- Also – rate of convergence depends on parameter values
- How to calibrate?

Calibration – Mesh2



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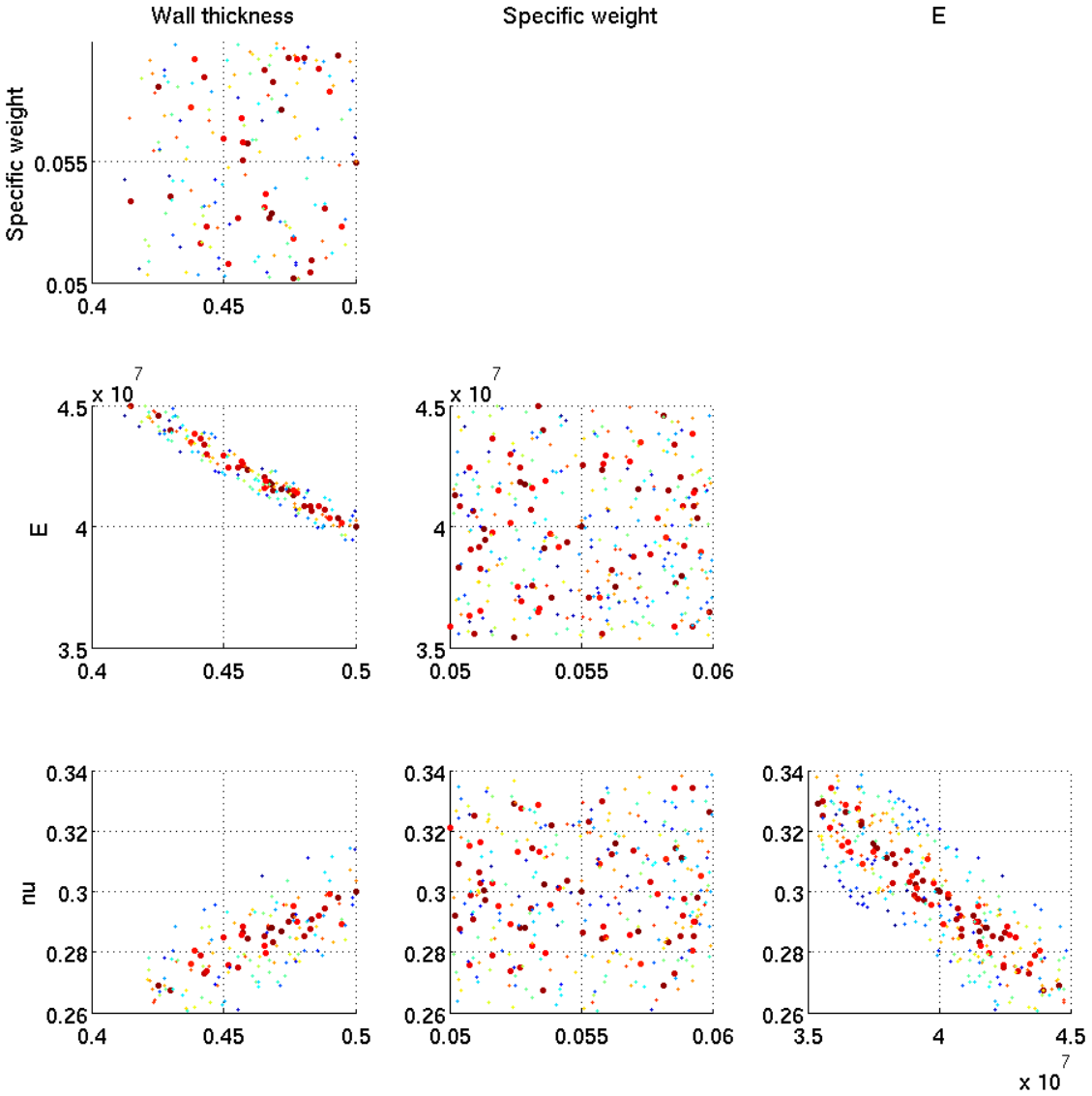
Calibration – Mesh3



- Parameter Sampling
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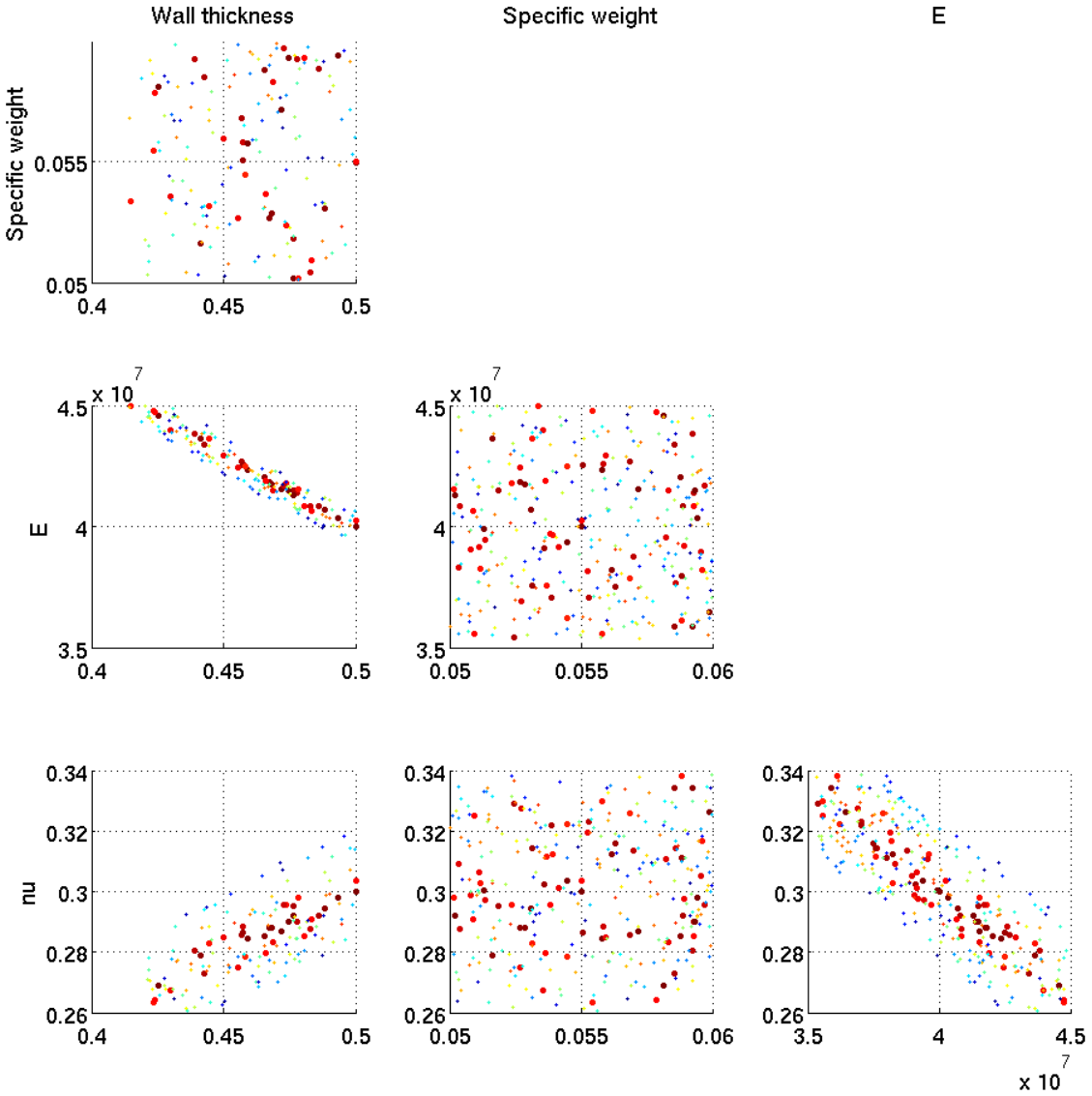
Calibration – Mesh4



- Parameter Sampling
- Noiseless data
- Compute likelihoods

$$\sum_i \left(\mathrm{M}\ (\tau, E, \nu, P_i, \rho, m) - Data_i\right)^2$$

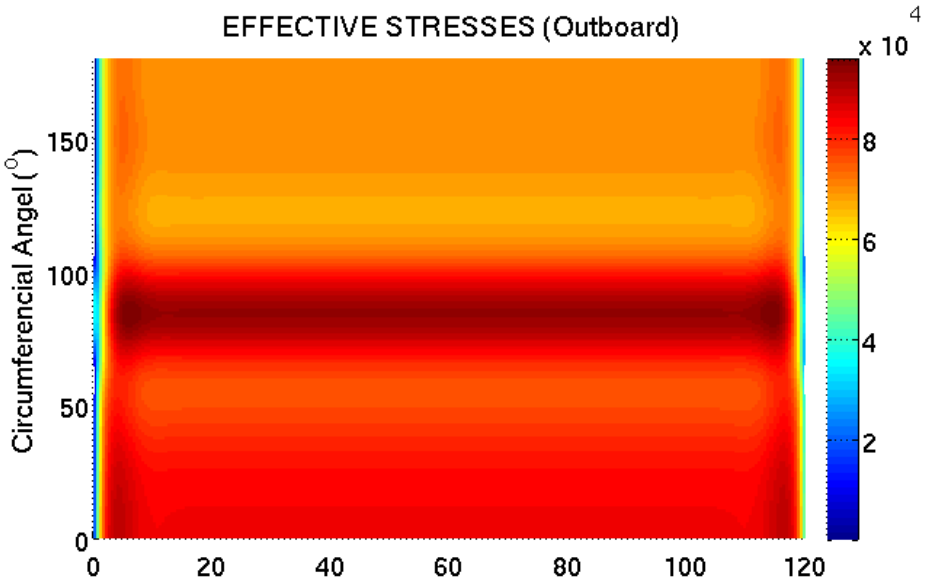
  - Red = high
  - Blue = lower

→ Mesh dependence

- Also – rate of convergence depends on parameter values
- How to calibrate?

Prediction & Decision

- Compute P (failure)
  - Based on stress
  - No data for this quantity
- Utilize
  - Available failure data
  - Aggregated uncertainty
  - Validation conclusion



- Make a decision
  - Based on predicted stresses, UQ, and credibility, as well as statistics of failure, should the tanks be retired?

Expectations

- Many choices: how to treat uncertainty, how to use data, how to assess credibility, etc
- No requirements on approaches
  - Supply references, suggestions, forum for discussion
- Not limited by # of model evaluations
  - But keep cost in mind
- Develop experience & understanding
  - Not focusing on new methods
- Targeting 40 hour commitment
  - Open ended problem – need to limit the scope!
  - NO development of physics models

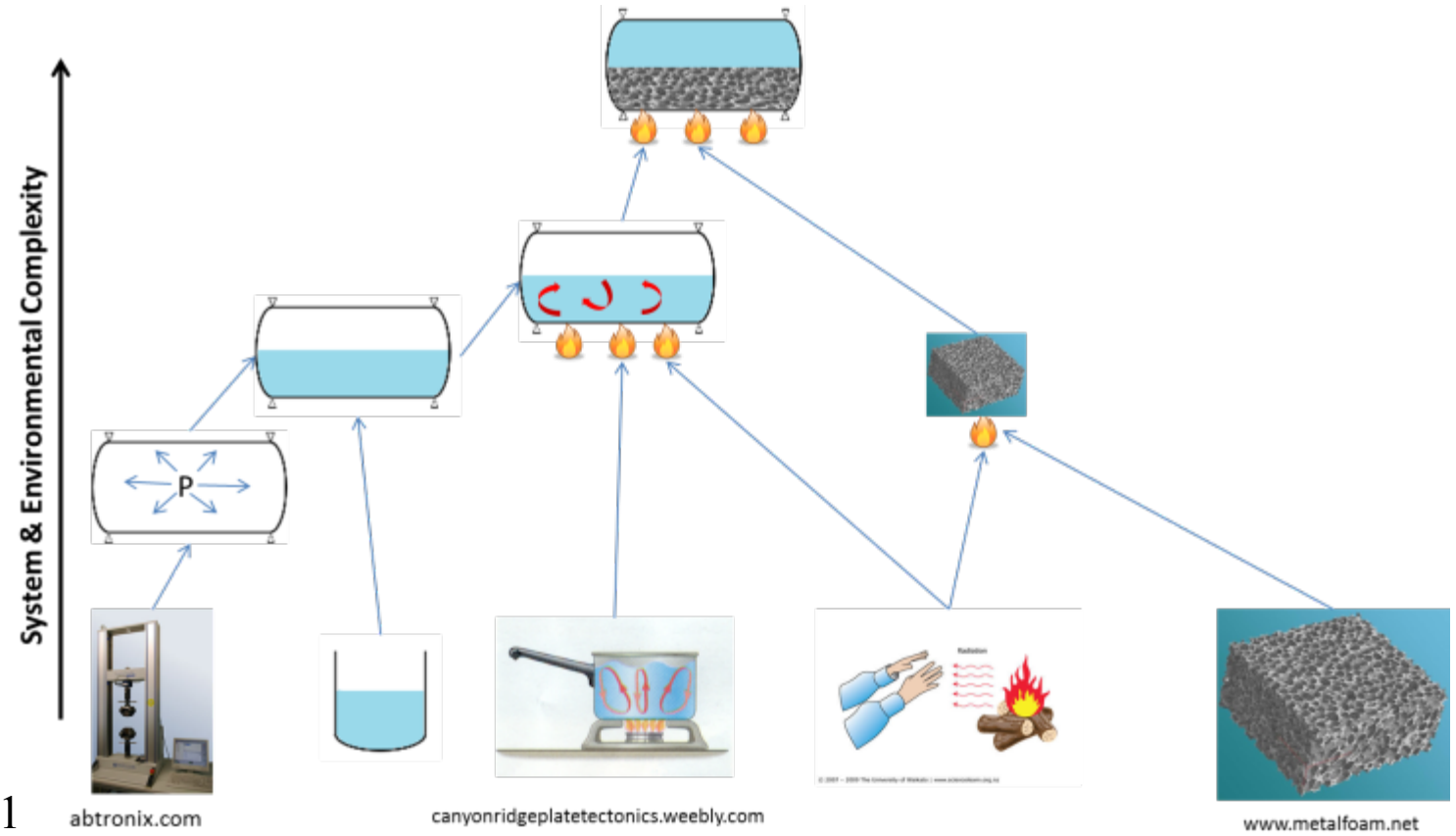
"Hidden" Features

Not explicitly asked for, to reduce problem scope

- Experiment-related uncertainty
  - Unknown experiment conditions/ Imprecise measurements
  - Propagate this to the QoI → aleatoric/epistemic issues
- **Relevancy**
  - Experimental data and simulation results from Calibration, Validation, & Application domains
    - Is all the information relevant?
    - Is the model valid (for intended use)? Is it useful?
  - Can this relevancy be quantified?
  - **How does it impact credibility?**

Context: Is this an interesting problem?

- Current V&V Hierarchy → 5 steps
  - Emphasize ideas for aggregation
- Bigger picture: Pyramid view of hierarchy



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The Workshop

- Website: https://share.sandia.gov/vvcw
- Email: vvcw@sandia.gov
  - If interested in hearing more, send an email and you will be placed on a distribution list

Timeline

- Now – Present draft problem, gather feedback
- Fall – Finalize problem, announce workshop
- Summer 2014 – ASME V&V Symposium
  - **Full or half-day plenary talks**
  - **Looking for an opportunity to publish papers**