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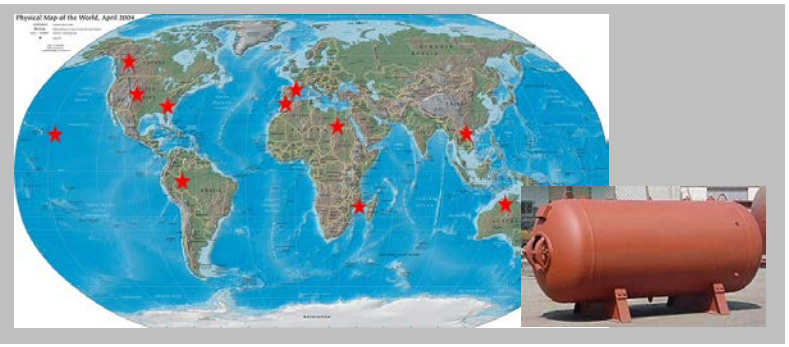

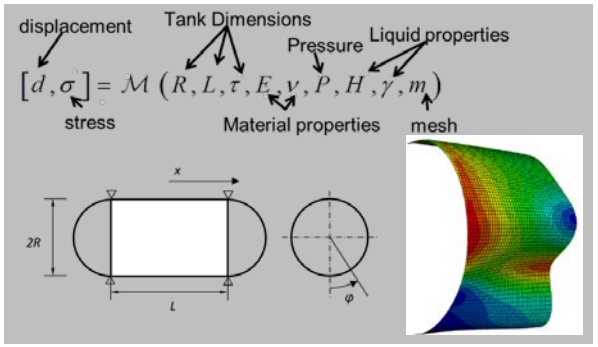

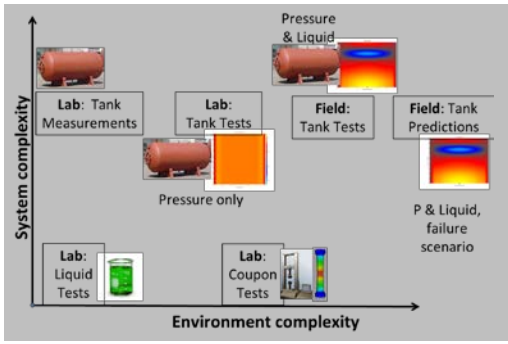

The 2014 Sandia V&V Challenge Workshop: recap, outcomes, future work

Ken Hu

VERIFICATION VALIDATION

V&V, UQ, and Credibility Processes Dept.

Sandia National Laboratories

Presented at the 2015 ASME V&V Symposium

SAND2015-3761 C

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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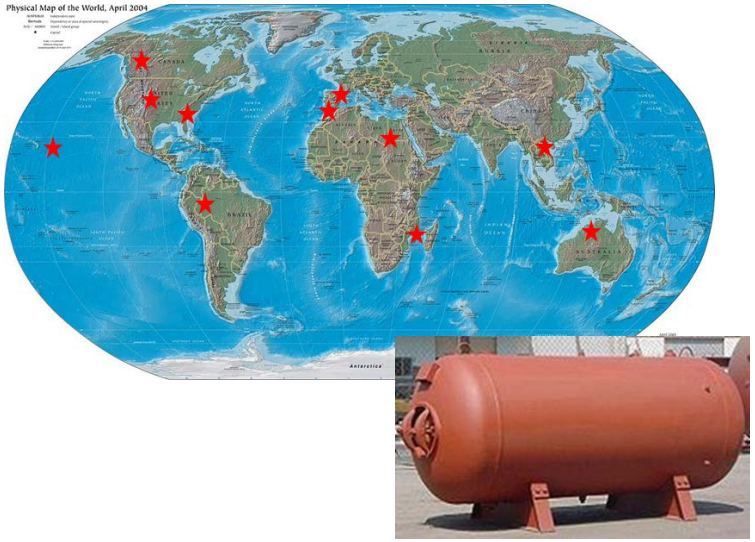
Outline

- The Challenge Problem
  - A relatable engineering project
  - A platform for methods demonstration
  - A starting point for discussions on V&V/UQ
- The responses
  - Diversity in results, approaches, methods
- Future questions
- **Soliciting discussion papers for the ASME VV&UQ Journal (Issue 3?)**

The Story of Mystery Liquid Company

Have many storage tanks, holding Mystery Liquid under pressure



During standard safety testing, one tank's measurements **exceeded a safety specification**

How should we respond?

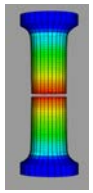
Are the tanks at risk of failure?
No tanks have actually failed, ever.

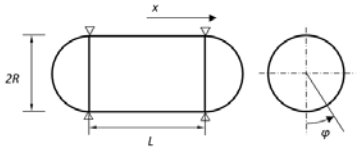
Experimental and modeling efforts are begun

displacement — Tank Dimensions — Pressure — Liquid properties

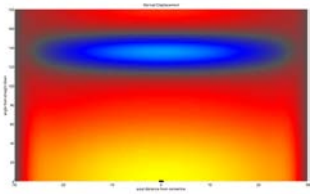
$$[d, \sigma] = \mathcal{M}\,(R, L, \tau, E, \nu, P, H, \gamma, m)$$

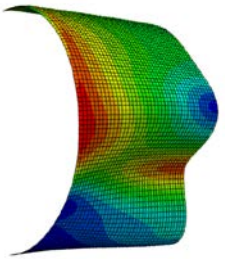
stress — Material properties — mesh





Side view

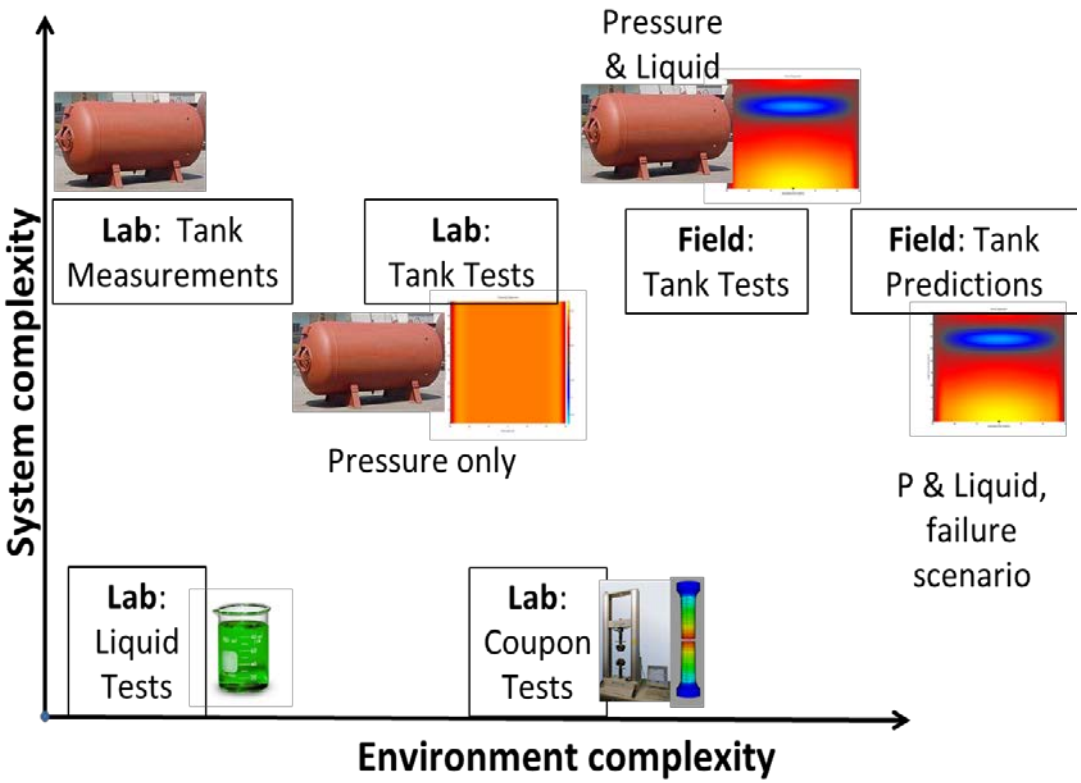




Quarter view

Supply a prediction – is it credible?

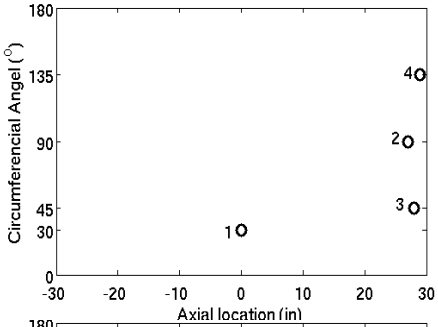
- How will evidence (data, model predictions, V&V/UQ) be integrated and used to support the final decision?



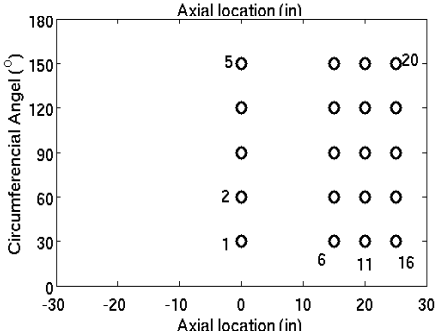
Data – summary

- Dimensions
  - Radius
  - Wall thickness
  - Length
- Material data
  - Young's modulus
  - Poisson Ratio
  - Yield stress
- Composition vs. specific weight

- Wall displacement (normal to surface)
  - Various locations
  - Various loading



Pressure Only



Pressure and Liquid

Many uncertainties / limitations

- Data quality is poor:
  - Test conditions, measurement devices, data processing, possible outliers, non-ideal choices of QoI
  - Limited types of tests, number of tests
- Mystery liquid equation of state is imperfect
- Physical specimens not representative of population

What analyses?

1) Characterize uncertainty from data
2) Treat epistemic vs. aleatoric uncertainty
3) Calibrate model parameters
4) Sensitivity analysis, Uncertainty quantification
5) Solution verification
6) Validation
7) Aggregation of uncertainty
8) Assess relevancy from hierarchy of information
9) Credibility assessment

Supply a prediction – is it credible?

Participants should:

1) Develop and communicate a strategy to use experimental data and models
2) Predict failure probability at max load and account for uncertainty
3) Assess prediction credibility

Participants

- Aniruddha Choudhary, I. Voyles, C. Roy, M. Patil (Virginia Tech), B. Oberkampf (Consultant)
- Zhimin Xi (University of Michigan – Dearborn), R. Yang (Ford)
- Lauren Beghini, P. Hough (Sandia National Labs)
- Wei Chen, W. Li, S. Chen, Z. Jiang (Northwestern)
- Josh Mullins, S. Mahadevan (Vanderbilt)
- Michael Shields (Johns Hopkins)
- Tom Paez, P. Paez, T. Hasselman (Consultants, V&V10)
- Thomas Brodrick (US NSWC Carderock)
- James Elele (US Navy)

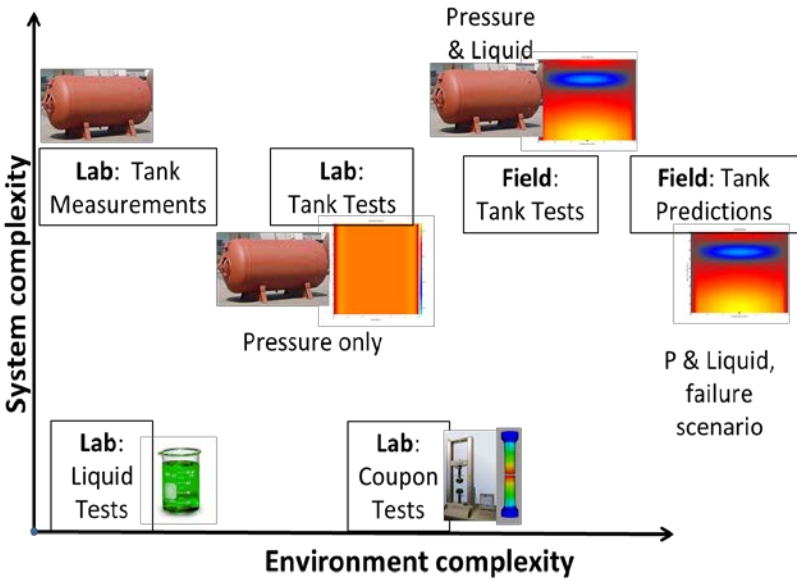
- Responded to the challenge problem
- Discussed V&V issues

The Results

- P(fail) results for groups A-F
  - (A) 0.0075, (B) 0.0068, w/ high uncertainty
  - (C) Bounded by [0, 0.0034]
  - (D) 5e-16, with 99% confidence
  - (E) 0, with low simulation credibility
  - (F) N/A, data too poor to provide a prediction
- No consensus on whether tanks are safe or whether simulations are credible

The Approaches

- Six sources of data
- "Finite element" model/code with 4 meshes



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Priorities

- Groups prioritized different aspects of the problem
  - Analysis of experimental data, use of data
  - Correcting model form error
  - Use of PCMM to organize evidence
  - Extrapolation from validation domain
  - Separation of epistemic and aleatoric uncertainty
  - Cost-benefit of analysis with and without V&V
- Most groups did not address numerical uncertainty
- Did not formally allocate computational resources

Comparisons

- Difficult to compare final results
- Strategies were not consistent

Themes

- How to model uncertainty?
  - Treatment of epistemic vs. aleatoric?
- Bayesian vs. non-Bayesian methods
- Use of surrogates
- Validation approaches
- Extrapolation vs. Rollup vs. model bias correction

Lessons

- Problem too imprecisely scoped for direct comparisons
- Even with large scope, not all aspects addressed
- Huge number of required analysis choices, assumptions
  - Simulation and V&V/UQ are hard!
- Different ideas of what to present as V&V results
- Range of time commitments
  - Off-the-shelf vs. custom methods applied

Next Questions

- How to choose the appropriate V&V strategy?
  - Balance resources vs. necessary credibility?
  - “End-to-end” analysis – all methods must be coordinated to enable “aggregation” of uncertainty
- How to evaluate these results?
- How to communicate V&V results and credibility?
- What is the responsibility of the V&V analyst?
- How to assess credibility, and influence decisions?
- Do workshops and challenge problems help?
- If V&V results are so varied, is V&V and M&S useful?

Future Work

- Envision the challenge problem as:
  - A case study – V&V training
  - A common test bed for methods, and process
- Hope to see more responses
- Continue discussions about the role of V&V in assessing credibility and supporting decisions
- **We are now soliciting discussion papers for a later issue of the ASME VV&UQ Journal**

Many thanks

- Challenge workshop participants
- V&V department and Dakota team at Sandia
- ASME committees
- V&V community
- Symposium organizers

- To learn more about the problem, workshop
  - https://share.sandia.gov/vvcw
  - Email us: vvcw@sandia.gov