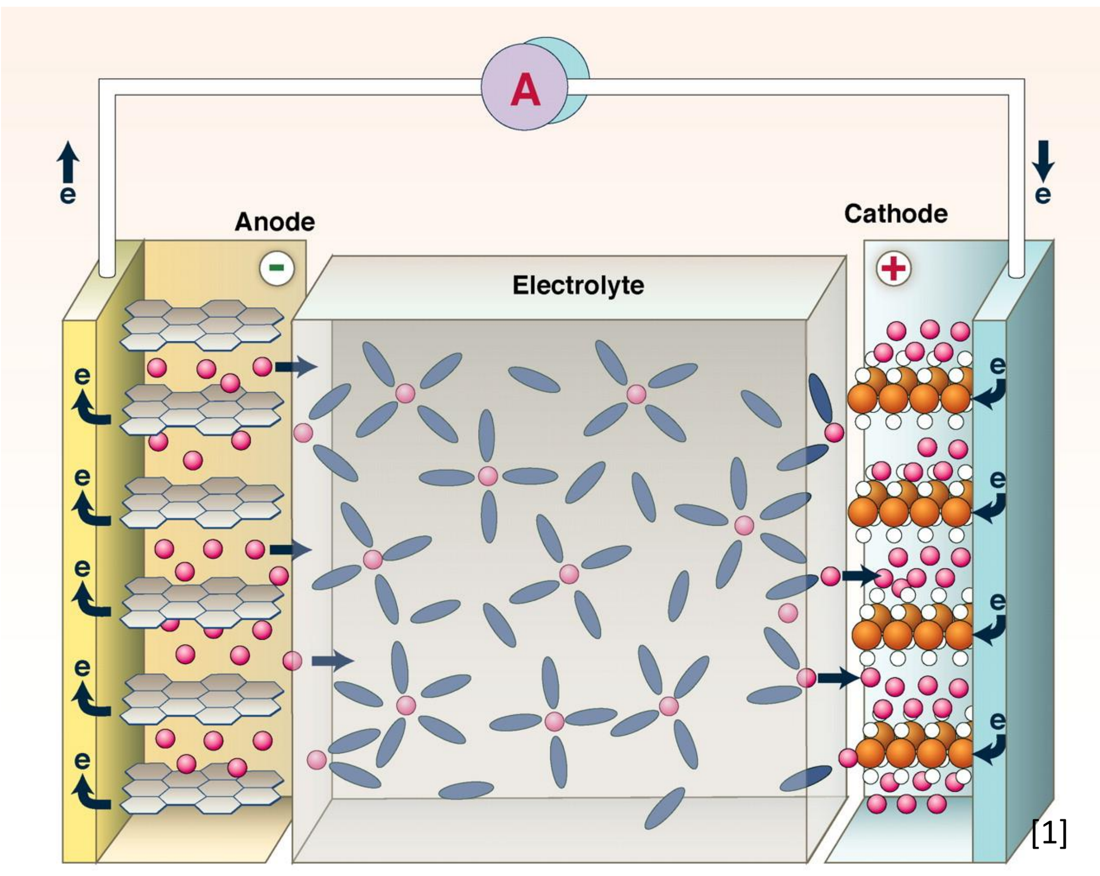
SAND2017-7367D

Exceptional service in the national interest

Sandia National Laboratories



Quick Facts about Thermal Batteries [2]

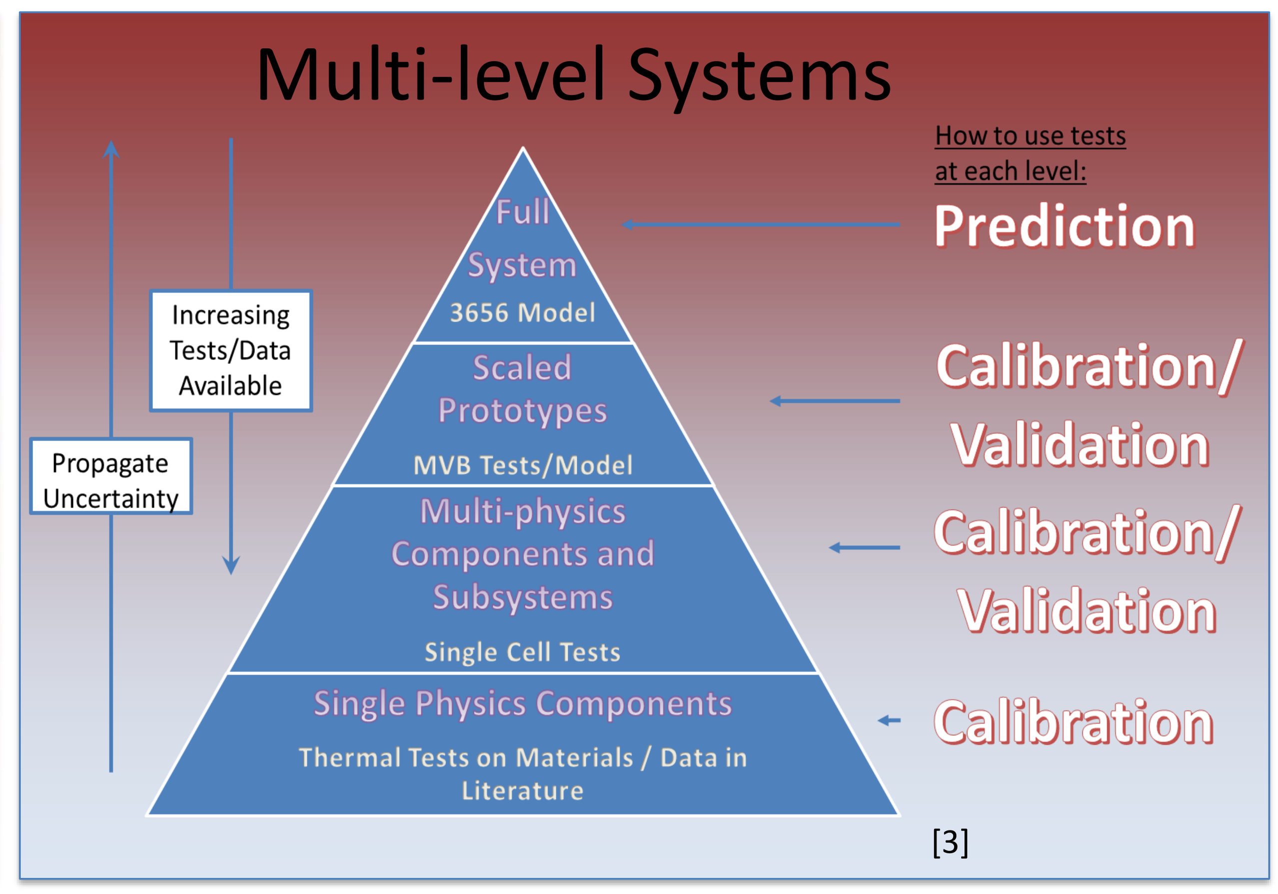
History: Developed by Georg Otto Erb, a German scientist, during World War II. USA's information about the battery was garnered via interrogation of Erb after the war.

Components: solid salt electrolyte, anode, cathode, separator

How it Works: Pyrotechnics are used to produce heat and melt the salt electrolyte, which activates the battery. This is why these batteries are often called molten salt batteries.

Advantages: Long shelf life, doesn't lose charge, inert (safe to handle), reliable

Disadvantages: 1 time use only, short activated life



Quantifying and Reducing the Uncertainty in Thermal Battery Predicted Performance

PhD Student
Major: Civil Engineering
Expected Graduation: May 2019

Kyle D. Neal
Vanderbilt University

Manager: Walter R. Witkowski
Mentors: Joshua G. Mullins & Benjamin B. Schroeder
Organization: 1544 – V&V, UQ, Credibility Processes

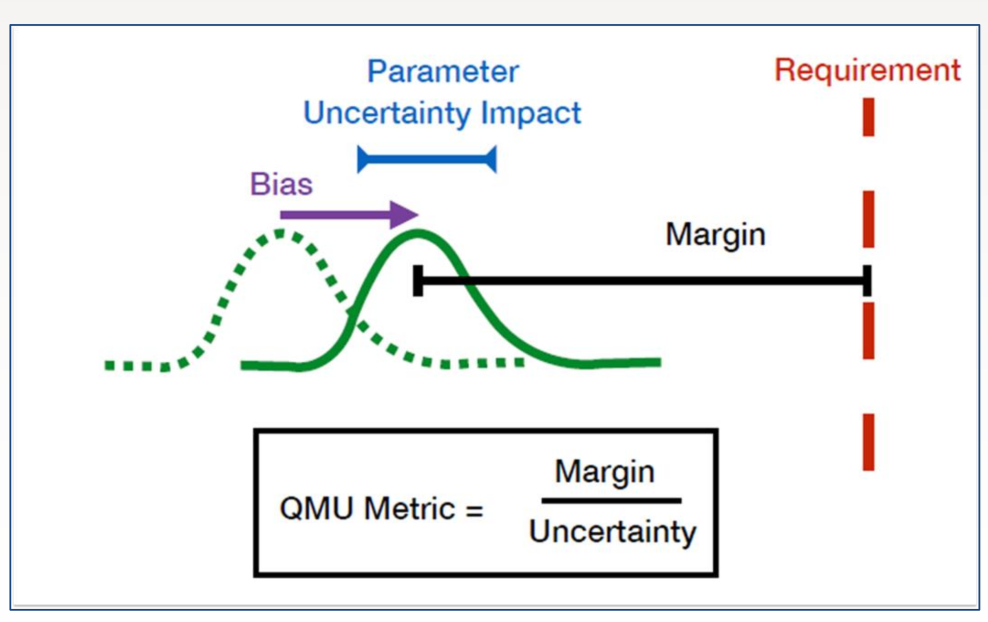
Performance Requirements

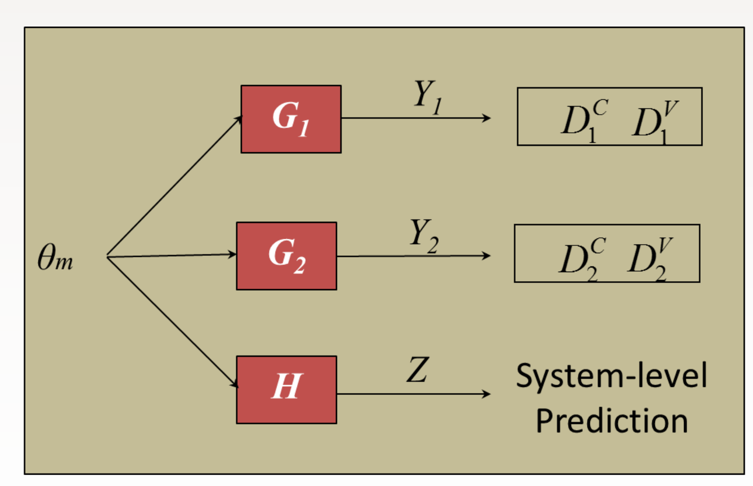
Rise Time (s)
- Time needed for battery to become active

Lifetime (s)
- Time that battery will remain active

Maximum Temperature (°C)
- The anode and cathode are subject to high temperatures

Uncertain QoIs



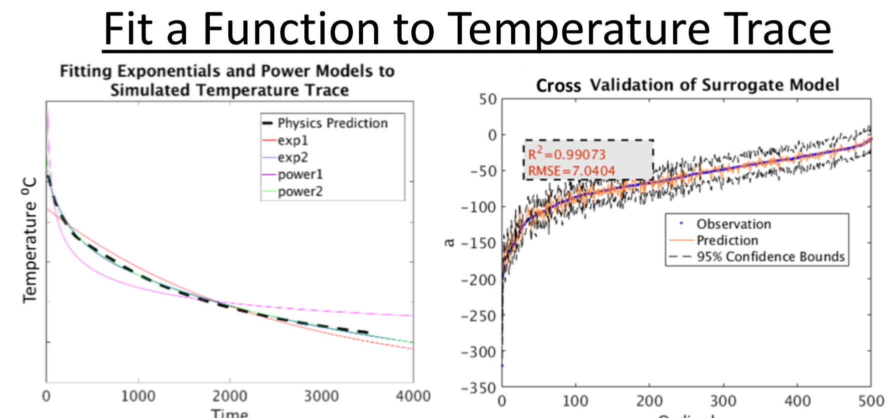


Use available test data to reduce uncertainty in the prediction

Method

1. Replace expensive physics models with surrogate models (Gaussian Process)
   a) Sensitivity analysis to reduce number of model parameters
   b) Fit a function to the temperature trace
   c) Train surrogate with function coefficients as outputs
2. Use available experimental data for calibration/validation
3. Aggregate uncertainties via Roll-up
4. Propagate updated model parameters through the system model – predict QoI

Fit a Function to Temperature Trace



exp1	exp2	power1	power2
Y = a*exp(b*x)	Y = a*exp(b*x)+c*exp(d*x)	Y = a*x^b	Y = a*x^b+c

Future Work

Consider Multiple Lower Levels:
- Thus far I have only considered one lower level. When multiple lower levels are considered this should further reduce uncertainty in the predicted QoI.

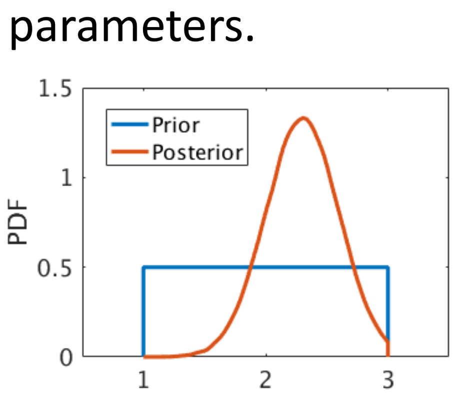
Resource Allocation and Test Design:
- How many and what type of tests should be performed at each level? (Inverse Problem)

Calibration

Use experimental observations to reduce uncertainty in model parameters.

Bayes' Theorem:

$$P(\theta|D) = \frac{P(D|\theta)\,P(\theta)}{P(D)}$$



Validation

How well does the model represent reality? Characterize the bias in the model using experimental observations.

Rollup

The quality of the calibration is dependent on having an accurate model. In Rollup, calibration and validation results are combined through a weighted sum of the prior and posterior distributions.

References

[1] Dunn, B., Kamath, H., & Tarascon, J. M. (2011). Electrical energy storage for the grid: a battery of choices. Science, 334(6058), 928-935.

[2] Mohamed, Hanim (2014). Thermal Batteries in Missiles. <https://www.slideshare.net/Hanim_Mohamed/thermal-battery-in-missiles>

[3] Rider, J., Kamm, J. R., Weirs, V. G., & Cacui, D. G. (2010). Verification, validation and Uncertainty Quantification Workflow in CASL.

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND No. 2011-XXXXP

VERIFICATION VALIDATION