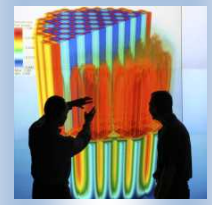
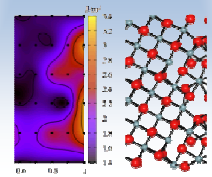




CASL
Consortium for Advanced Simulation of LWRs

SAND2012-0010C

VUQ Focus Area

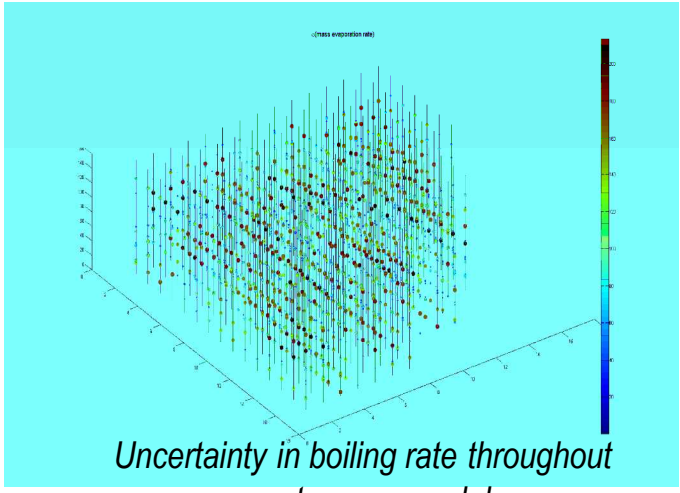
Jim Stewart
Sandia National Laboratories

Validation and Uncertainty Quantification (VUQ)

Achieving credible, science-based predictive simulation capabilities

Objectives and Strategies

- VUQ is dedicated to developing overall V&V approach
- VUQ will provide CASL with
  - Best-estimate *predictive capabilities* with reduced uncertainties
  - Capability for quantified *predictive maturity* assessments
- The Sensitivity Analysis & UQ process will guide CASL R&D investments, and aid in designing future experiments



Uncertainty in boiling rate throughout quarter core model

Requirements Drivers

- V&V and UQ methodologies and tools are needed by every Focus Area
- VUQ is the CASL "integrator;" we need:
  - Access to software and underlying math models
  - Validation data (at all physical scales)
  - Partnerships with other Focus Areas to implement uniform VUQ practices

Outcomes and Impact

- Continuous evolution towards *transformational, predictive computational simulation*
- Capability to quantify and reduce uncertainties for the CASL challenge problems
- New ways for experiments and simulations to work together, leading to predictions *with quantified confidence* of scenarios for which experimental data is not directly available

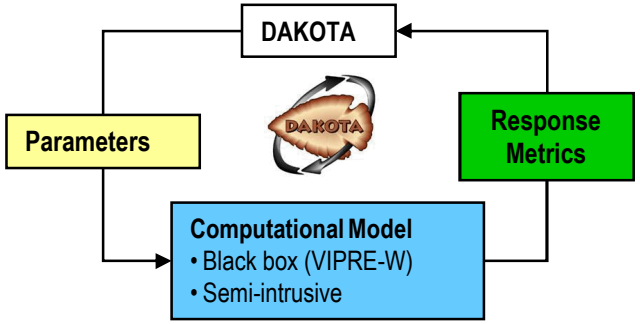
The Three "VUQ Thrusts" Emanating from First 1.5 Years of CASL

1. Enabling Sensitivity Analysis, UQ, Data Assimilation and Validation for VERA
2. Enabling Code and Solution Verification for VERA
3. Validation Data Assessments and Requirements

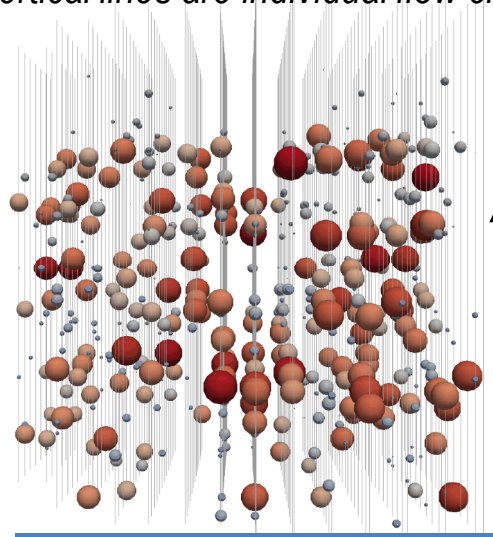
VUQ Accomplishment Highlight

Milestone VUQ.P2.03 (Enable SA/UQ Demonstrations in VERA)

- **Strategy:** Integrate SNL's *DAKOTA* UQ Toolkit with Westinghouse's VIPRE-W subchannel T/H simulator
- **Demonstration for Crud/CIPS problem (quarter-core geometry):** Assess influence of core operating parameters on mass evaporation rate
- **Results:** Affirmed well-known sensitivity (of mass evap. rate) to temperature and exposed sensitivity to pressure. Boiling model uncertainty is a key contributor.



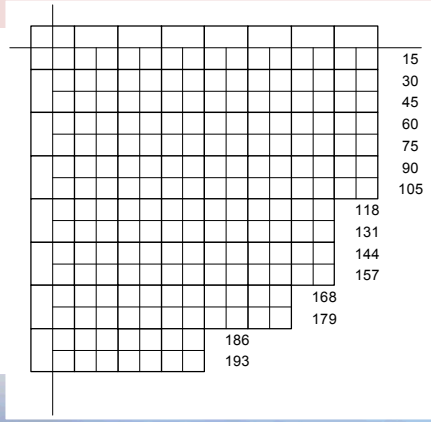
Vertical lines are individual flow channels



View inside the reactor core

Spheres denote locations where boiling occurs

- Size correlates to uncertainty
- Color correlates to mean boiling rate *(red is higher)*



VIPRE-W quarter-core geometry and axial layout
(with 193 flow channels shown, 93 nodes in axial direction (not shown))

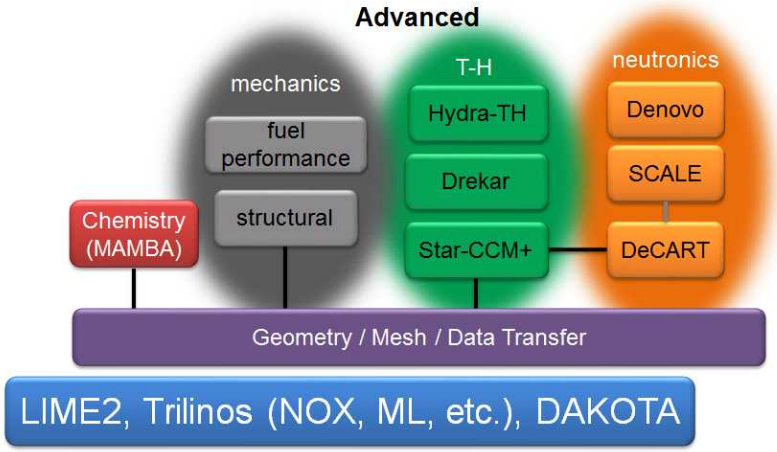
VUQ Path Forward
Thru FY12 (PoR-4, PoR-5)

Themes for FY12

- Challenge problem focus
  - Continue deployment of methods/capabilities for CIPS and GTRF
- New algorithm development/deployment
  - UQ/SA: Hybrid stochastic/deterministic methods, DAKOTA deployment for multiphysics problems, epistemic (model-form) uncertainties
  - Data assimilation: RUBENS and DAKOTA; progression of capabilities to nonlinear, multiphysics regimes
  - Verification: Continue emphasis on solution verification, including interface coupling verification
- Validation data
  - Acquisition, qualification, archiving (CASL Validation Data Committee)
- Predictive maturity assessments (PCMM)

VUQ-VERA Integration Timelines for PoR4 and PoR5

- **Baseline VERA** (ANC/VIPRE-W/BOA)
  - *L1 Milestone:* Two-way coupled (VIPRE-W/BOA) SA/UQ
  - Three-way coupled (inc. ANC) SA/UQ/DA
  - *Ramp down in PoR-5*
- **Advanced VERA**
  - Separate-effects UQ, calibration, validation for CIPS and GTRF (RUBENS, GPMSA/DAKOTA)
  - Integral-effects verification, UQ, calibration, validation for CIPS (Percept, GPMSA/DAKOTA)
  - *Ramp up in PoR-4, 5*



FY12 VUQ L1-L3 Milestones

- PoR-4
  - **L1: SA/UQ studies for CIPS using coupled VIPRE-W/BOA (Due 12/31)**
  - **L2: Separate-effects DA for CIPS using RUBENS/Denovo**
  - L3: PCMM assessment for CIPS
  - L3: Validation data plan for CIPS
  - L3: Advanced GTRF verification
  - L3: High-order validation metrics (time-independent nonlinear systems) (Due 12/31)
  - L3: UQ hybridization framework demonstration for CIPS

FY12 VUQ L1-L3 Milestones *(Cont.)*

- PoR-5
  - **L2: Multi-physics UQ hybridization framework for CIPS using Denovo/Drekar**
  - **L2: Integral-effects verification/DA/SA/UQ demo for CIPS using Denovo/Drekar *(data from Halden reactor?)***
  - L3: SA/UQ/DA studies for CIPS using coupled VIPRE-W/BOA/ANC
  - L3: Separate-effects DA/validation for CIPS using Advanced VERA (specific code modules TBD)
  - L3: Separate-effects DA/UQ for GTRF using RUBENS/Drekar
  - L3: Validation data assessment for operational reactor
  - L3: DAKOTA/LIME coupling
  - L3: Epistemic (model-form) uncertainty propagation using Drekar