# Perspectives on Uncertainty Quantification for the NNSA Mission

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on assignment to the

**National Nuclear Security Administration**

**United States Department of Energy**

**Washington, DC**

# Mission of the National Nuclear Security Administration

- Maintain a safe, secure, and reliable US nuclear stockpile

- Develop scientific understanding necessary to assess and certify weapons without underground nuclear testing

- Support a variety of threat reduction activities that rely on the capabilities and skills developed in the nuclear weapons program.

# Complex scientific and engineering issues are pervasive across the mission space of NNSA



Design

Test

Manufacture

**NNSA is responsible for stewardship of nuclear weapons over their lifetime**

**Simulation, computing and experimental science play crucial roles in every aspect of this mission space**

Delivery Countermeasures
Normal and Abnormal
Environments

"Button to Boom"
Initiation Yield

Dismantle

Nuclear threat reduction goes beyond the U.S. stockpile:

• Nonproliferation
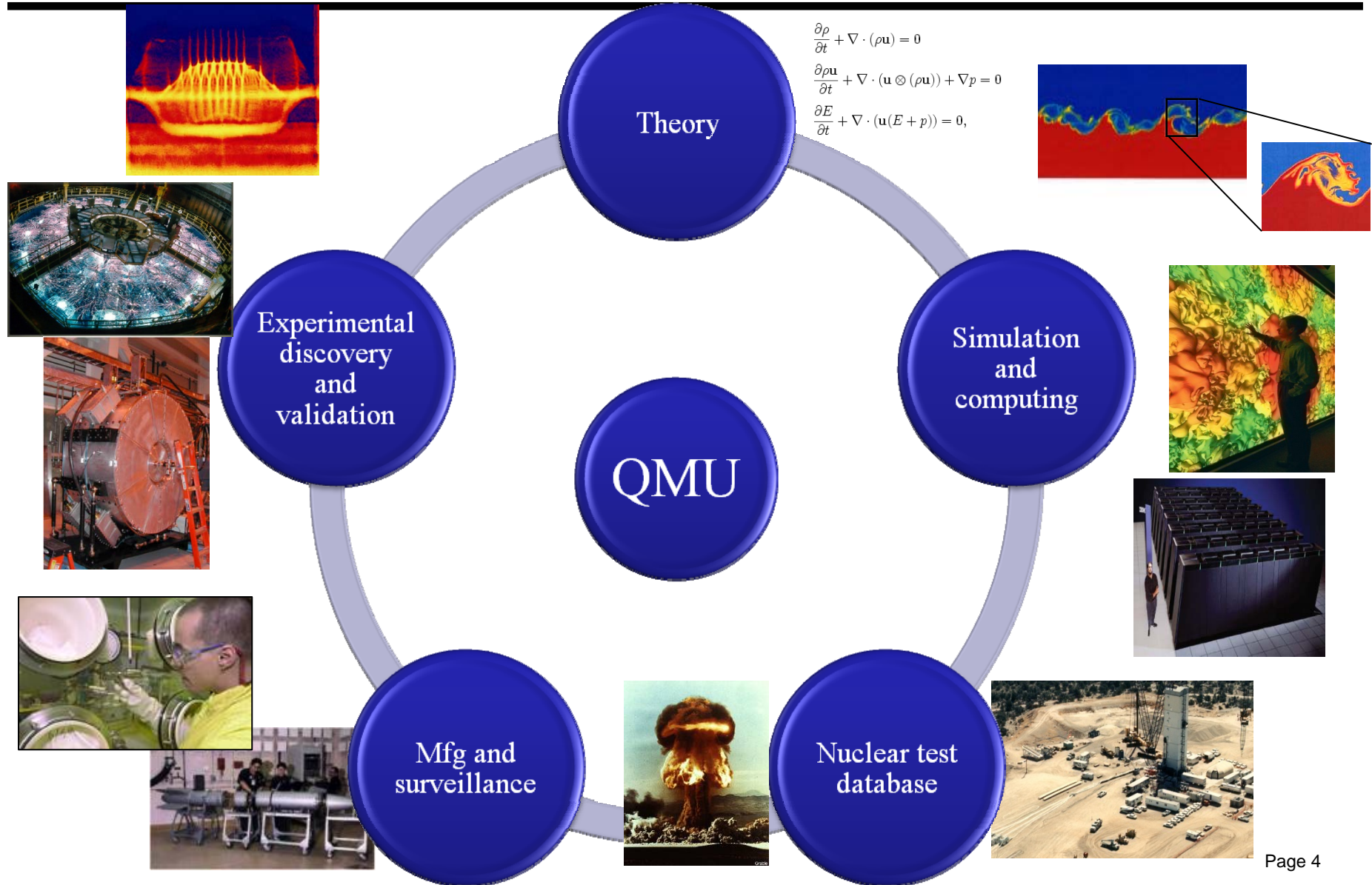
• Nuclear forensics

• Counterterrorism

# Uncertainties arise in all areas of the NNSA science and engineering programs

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

$$\frac{\partial \rho \mathbf{u}}{\partial t} + \nabla \cdot (\mathbf{u} \otimes (\rho \mathbf{u})) + \nabla p = 0$$

$$\frac{\partial E}{\partial t} + \nabla \cdot (\mathbf{u}(E + p)) = 0,$$

Theory

Experimental discovery and validation

Simulation and computing

QMU

Mfg and surveillance

Nuclear test database

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**Domain of applicability**

**Theory**

**Effects of Experimental Regimes**

**Uncertainties in physics models and parameters**

**Effects of Surrogate Materials**

Experimental discovery and validation

**Aggregating all uncertainties for high-consequence decisions**

Simulation and computing

**Propagation of Uncertainties**

**Uncertainties in Experimental Conditions**

**QMU**

**How Good is Good Enough?**

**Numerical Resolution and Convergence**

**Unexpected Observations**

**Ambiguities in Historical Data**

**Effects of Material Aging**

**Test-to-test Variability**

Mfg. and database

**Unit-to-unit Variability**

**Uncertainties in integral measurements and derived quantities**

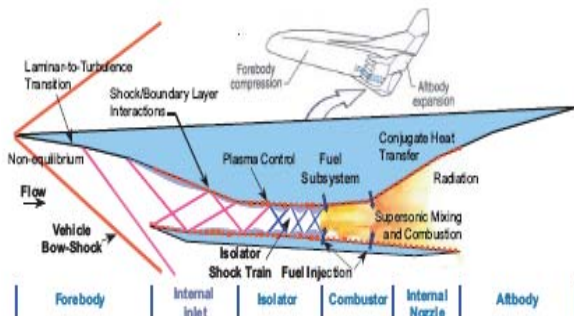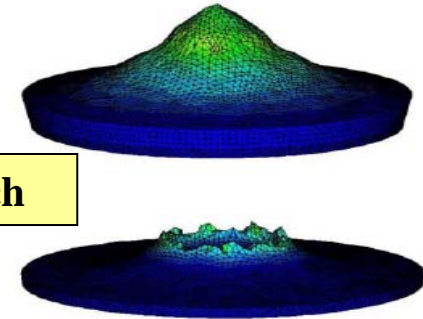# Predictive Science Academic Alliance Program (PSAAP)

- **Focus on a multi-scale, multi-disciplinary, unclassified application of NNSA interest**

- **Demonstrate validated simulation capability for prediction**

- **New methodologies:**
  - **Verification**
  - **Validation**
  - **Uncertainty quantification**
  - **Tight integration of experiment and simulation**
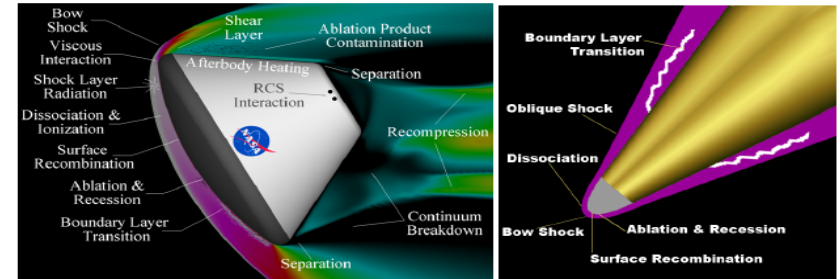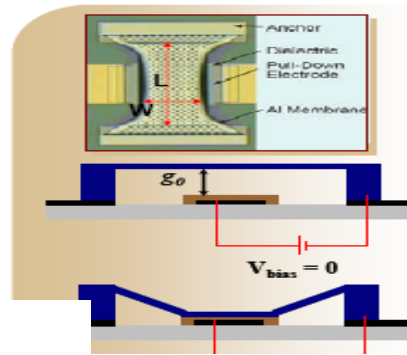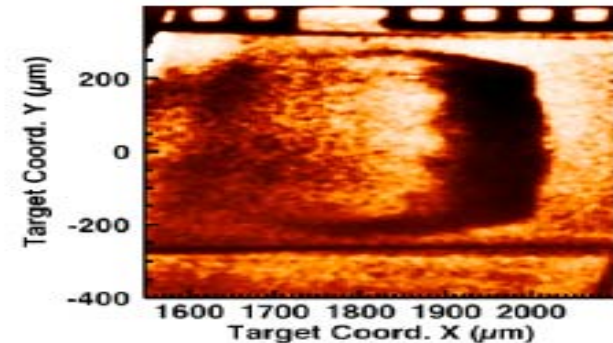


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