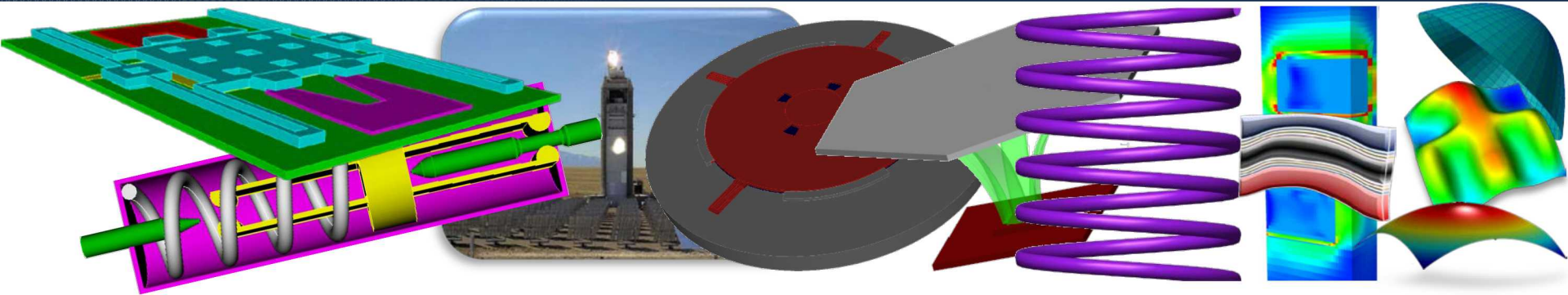


Exceptional service in the national interest



Uncertainty-enabled Design of Electromagnetic Reflectors with Integrated Shape Control

Drs. Jordan E. Massad & Eric A. Shields

Raleigh, NC
July 18, 2017

Sandia National Laboratories
Albuquerque, NM



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Industrial Mathematical & Statistical Modeling Workshop for Graduate Students

Sandia National Laboratories



- **Core Purpose:** help secure a peaceful and free world through technology.
- Provide objective, multidisciplinary technical assessments for complex problems.
- Focus on solutions with large science and technology content.
- Create prototypes for production and operation by industry.



U.S. DEPARTMENT OF
ENERGY

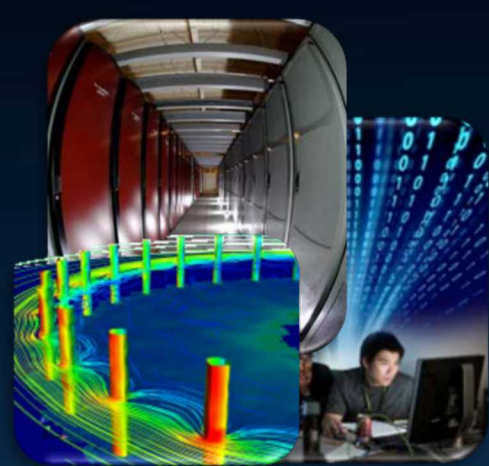


Scope & Complexity of National Security

SNL Applies both
BREADTH & **DEPTH** to
solving our nation's most
challenging
problems.



Research Disciplines Drive Capabilities



**High Performance
Computing**

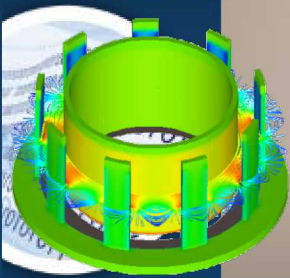


Science & Technology Products

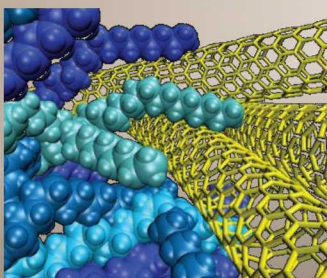


**Renewable Systems &
Energy Infrastructure**

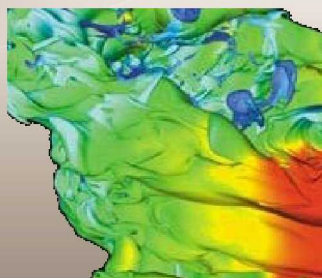
**Computer
Sciences**



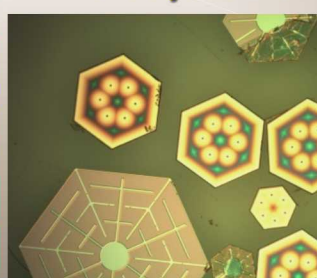
Materials



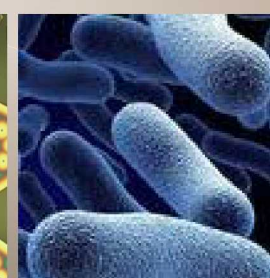
**Engineering
Sciences**



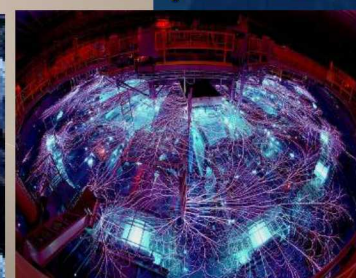
**Nanodevices &
Microsystems**



Bioscience



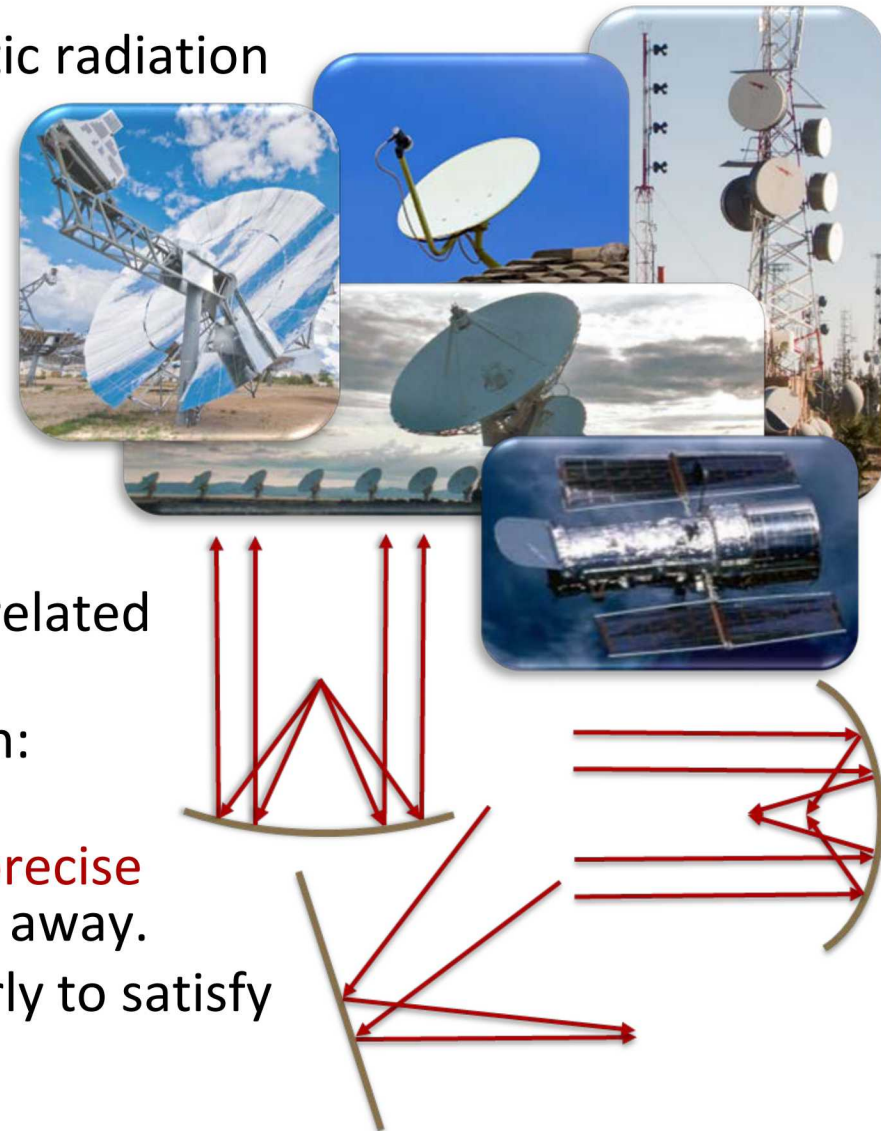
**High Energy
Density Science**



Research Disciplines

Electromagnetic Reflectors

- Surfaces that reflect electromagnetic radiation (often radio and visible light).
- Typically in antennas, receivers, and telescopes:
 - satellite TV receivers,
 - communications systems,
 - solar concentrators,
 - radio observatories,
 - reflecting telescopes...
- Reflected signal pattern is directly related to *reflector shape*.
- Paraboloidal reflectors are common: shape allows sharp focus.
- Some applications demand highly *precise shapes*, especially when looking far away.
- Many reflectors are rigid, particularly to satisfy small shape tolerances.





Shape Matters: An Infamous Example

The Hubble Space Telescope

2400 mm Mirror



Degraded Images



Culprit: **0.0022 mm** shape error.

Solution: correct for shape error in orbit 3 years later!

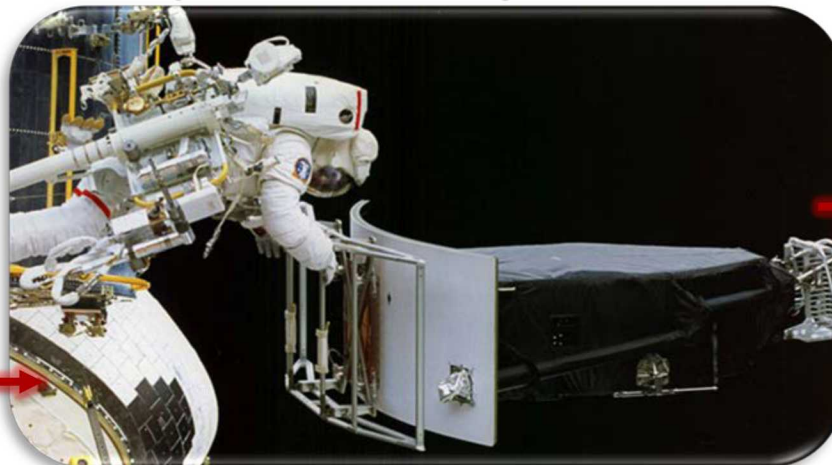
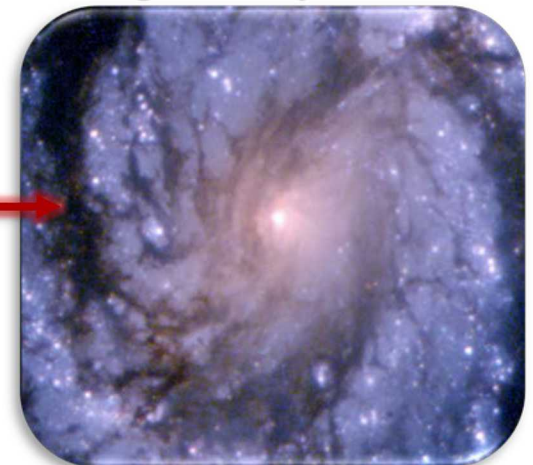


Image Quality Restored

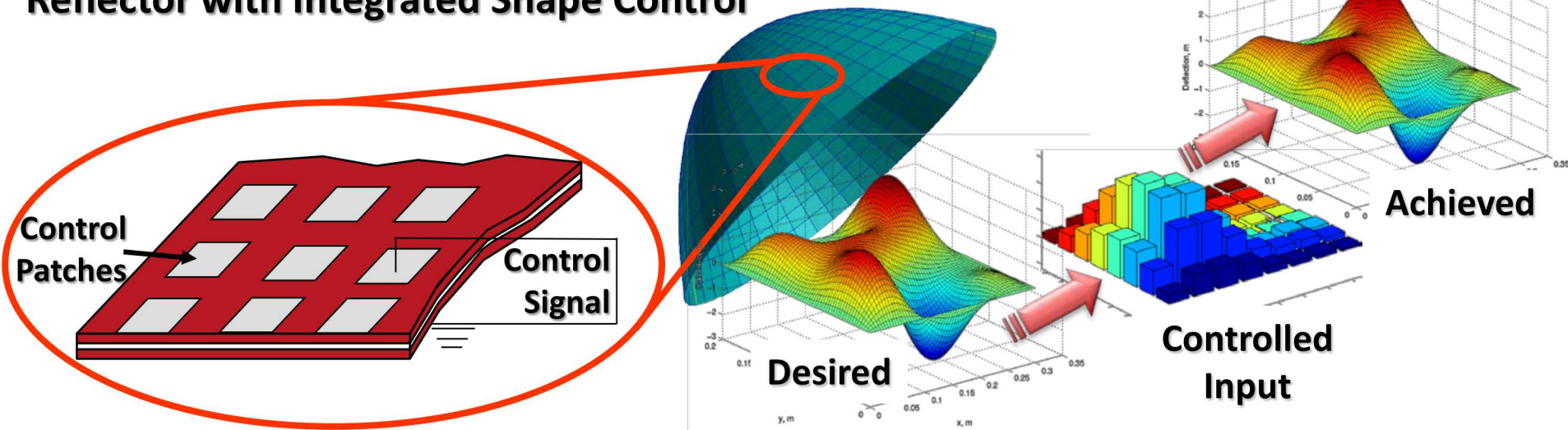


Shape-controlled Reflectors?

- Reflector shape control is possible using various methods.
- For typical rigid reflectors, options and amount of control are limited and controlling mechanism can be bulky.
- Shape errors can be mitigated using additional hardware.

More control, larger deflections, smaller footprint, less overhead?

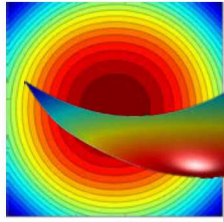
Reflector with Integrated Shape Control



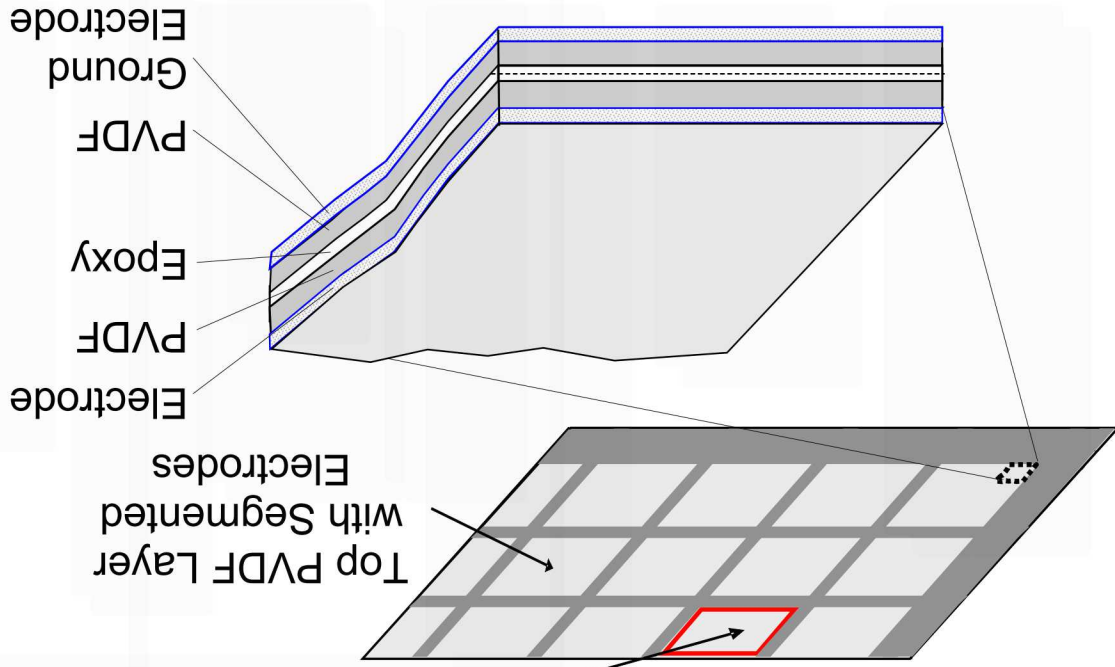
Sandia Smart Laminate Concept

Thin, Square, Active Membrane

- Natural actuation into paraboloid
- Improved flexibility, when corner-supported,
- Large deflections possible.



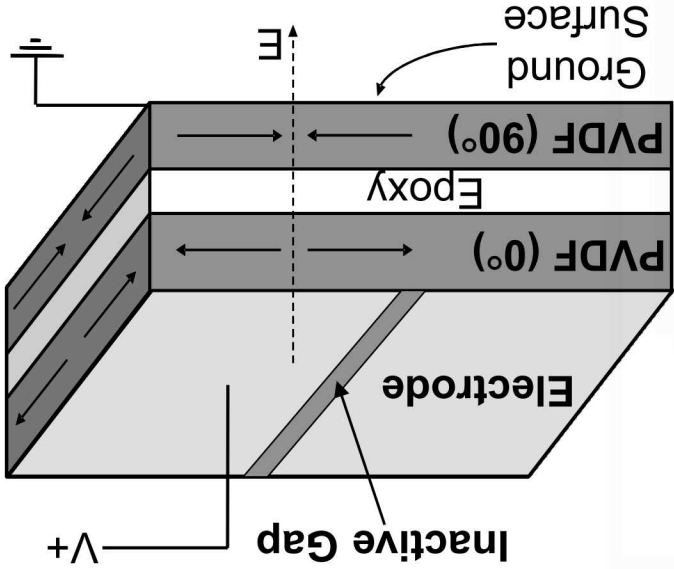
Electrode



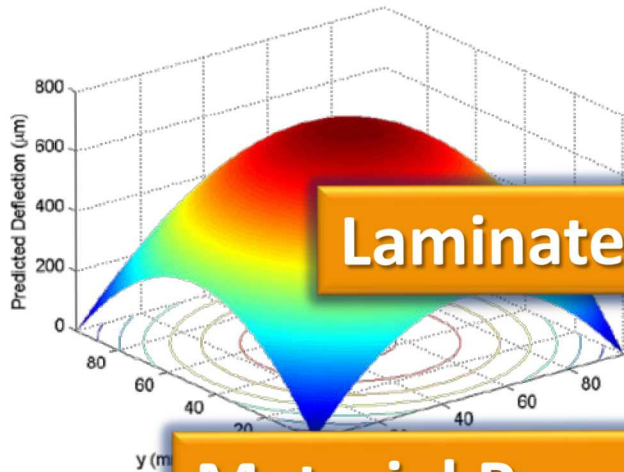
(bottom).

How it Deforms: Bimorph Action

- PVDF layers have opposing poling directions.
- Positive field induces simultaneous expansion (top) and contraction



What Determines Reflector Shape?



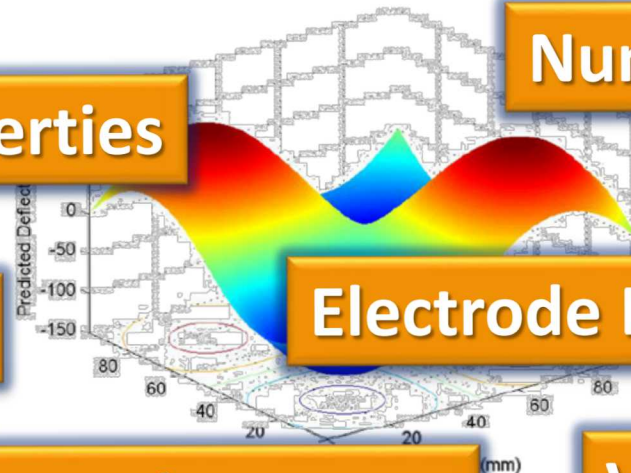
Laminate Dimensions

Boundary Conditions

Material Properties

Number of Electrodes

Layer Thicknesses



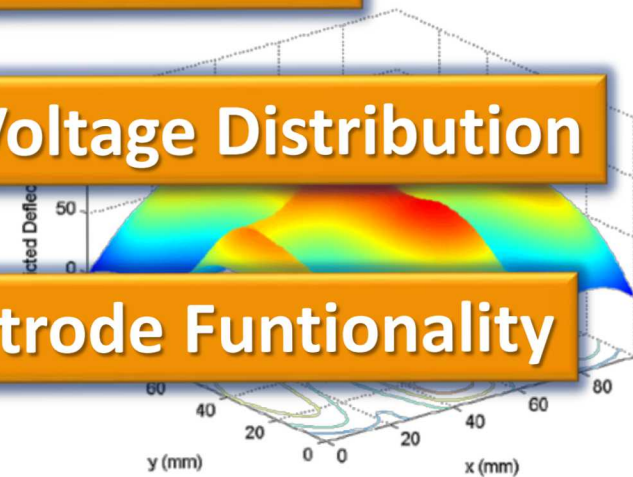
Electrode Dimensions

Electrode Pattern

Voltage Distribution

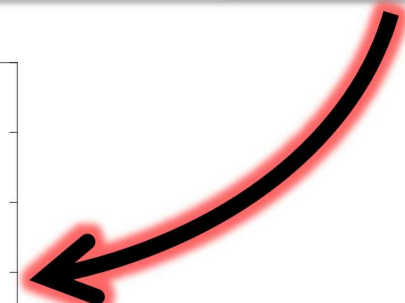
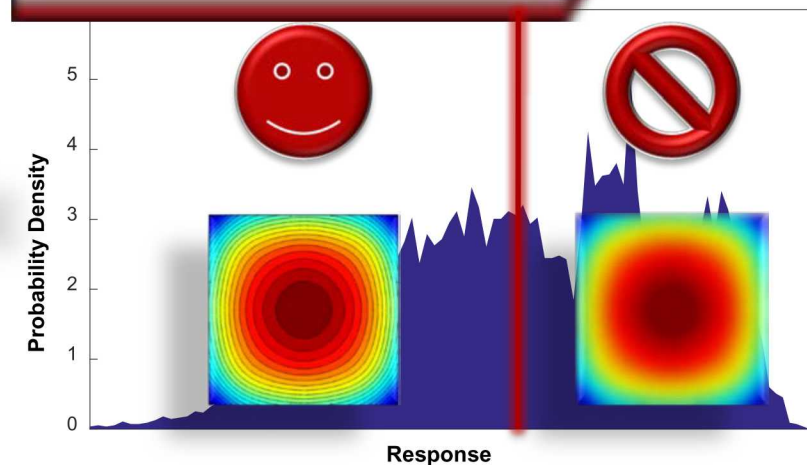
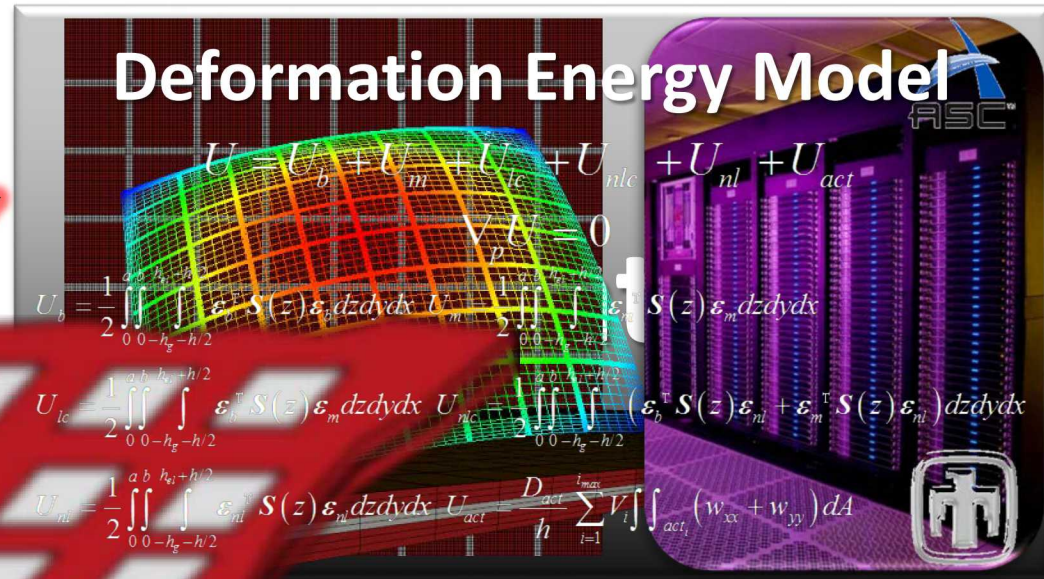
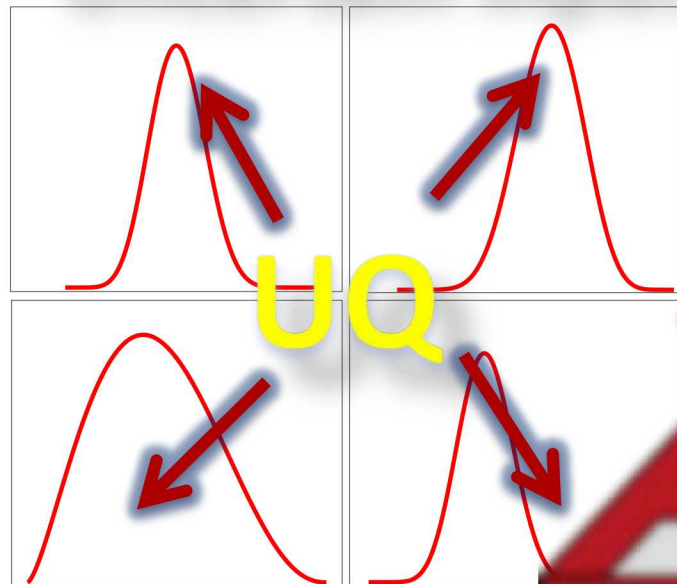
Electrode Functionality

*What if there is
variation & uncertainty?*



Impact of Uncertainty

Uncertain Input



What Sandia Wants to Know

How do variations affect smart laminate reflector operation & performance?

- Questions to address include:
 - What is an estimate of shape with an arbitrary electrode pattern and voltage distribution?
 - What is a statistical description of shape error given an uncertain design and uncertain conditions?

Addressing this problem can help us explore feasible, robust, shape-controlled reflector designs.

- Cat: can you determine a corner-supported design that maintains low shape errors despite uncertainty?
- Cat's Meow: can you accommodate uncertain boundary conditions?