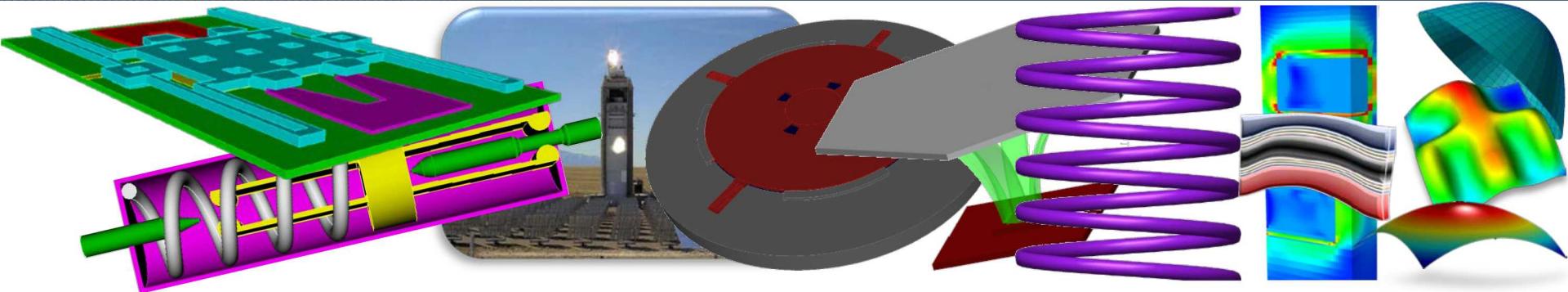


*Exceptional service in the national interest*



# Uncertainty-enabled Design of Electromagnetic Reflectors with Integrated Shape Control

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Raleigh, NC

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Sandia National Laboratories

Albuquerque, NM



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# 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.

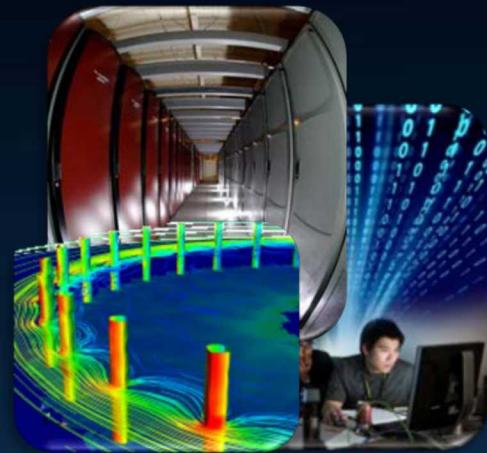


# Scope & Complexity of National Security

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**

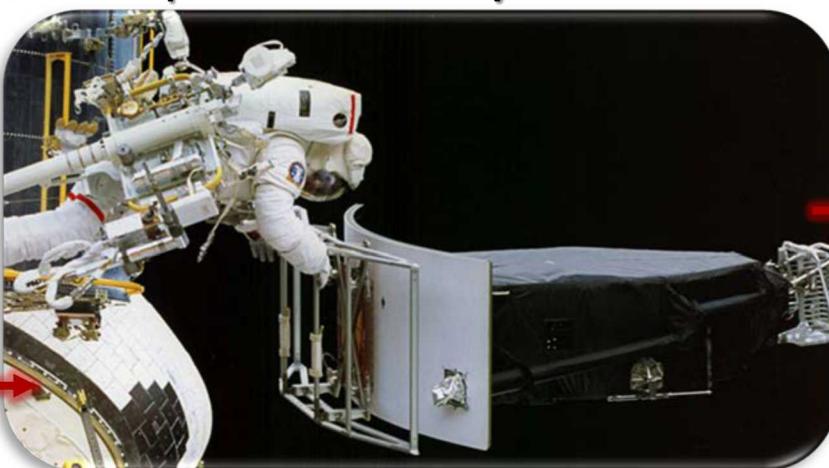


**Degraded Images**

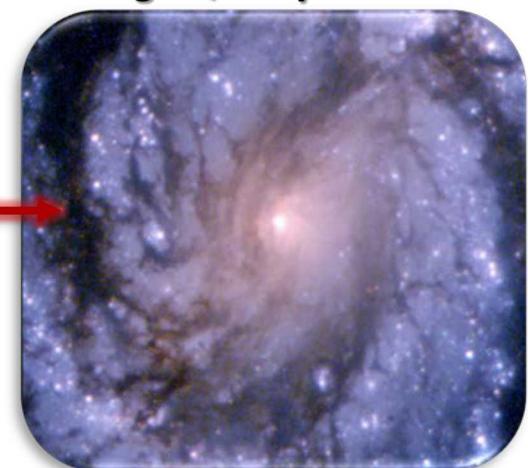


**Culprit: 0.0022 mm shape error.**

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



**Image Quality Restored**

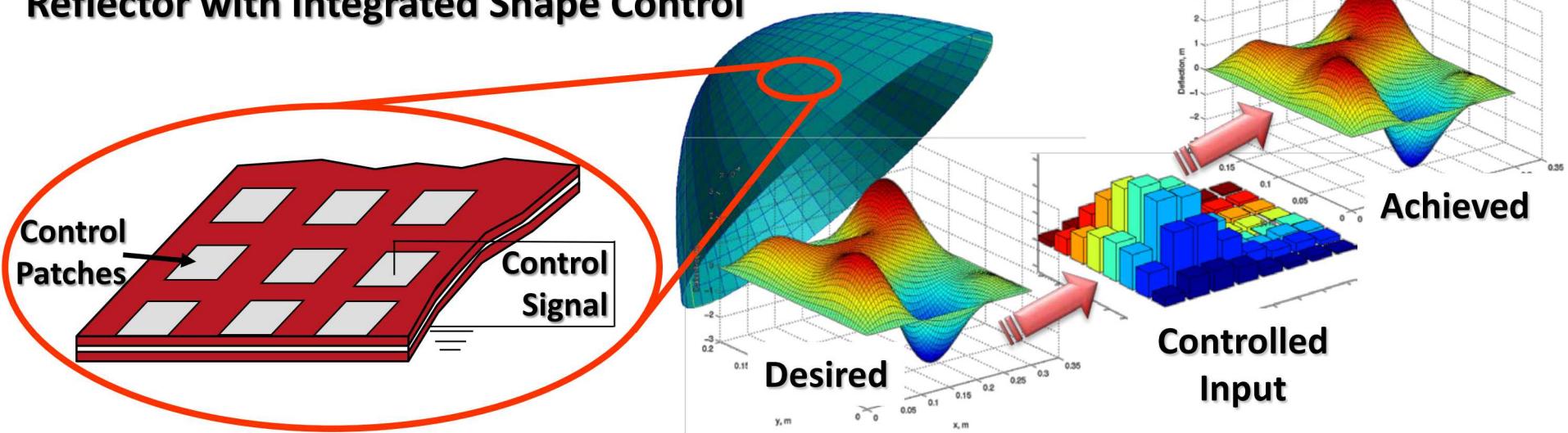


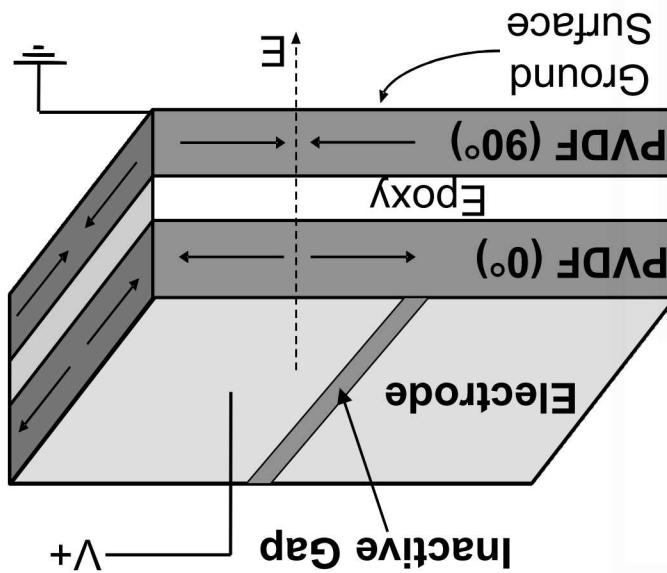
# Shape-controlled Reflectors?

- 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?*

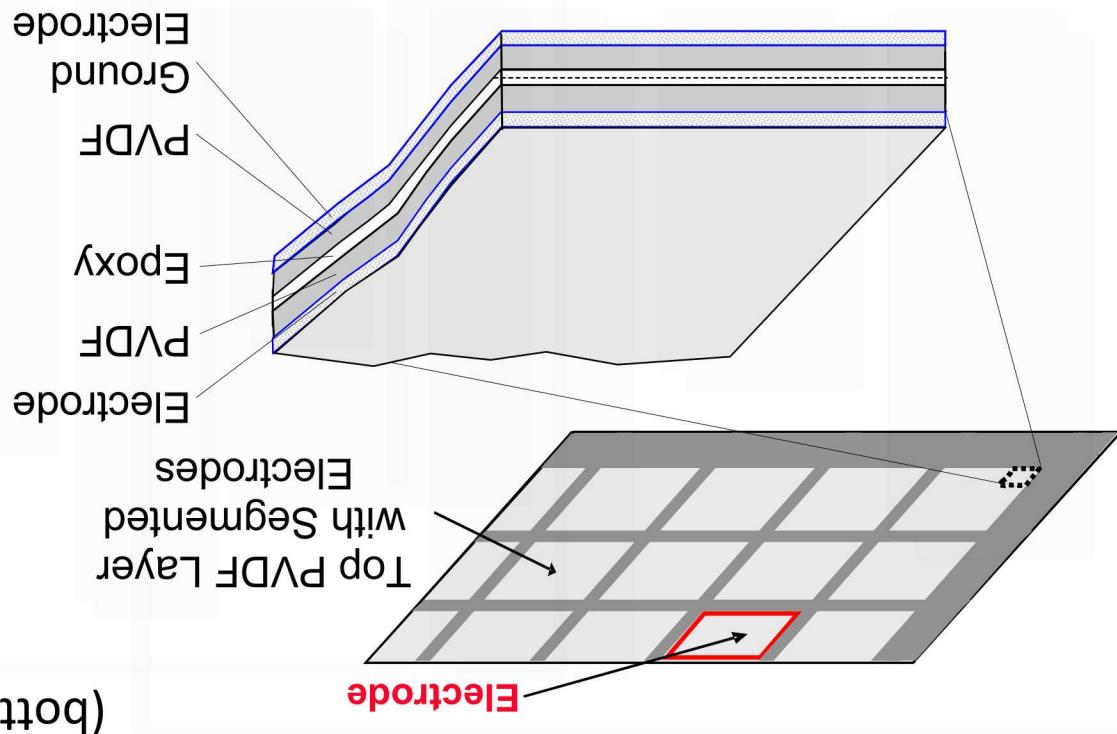
## Reflector with Integrated Shape Control





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

### How it Deforms: Bimorph Action

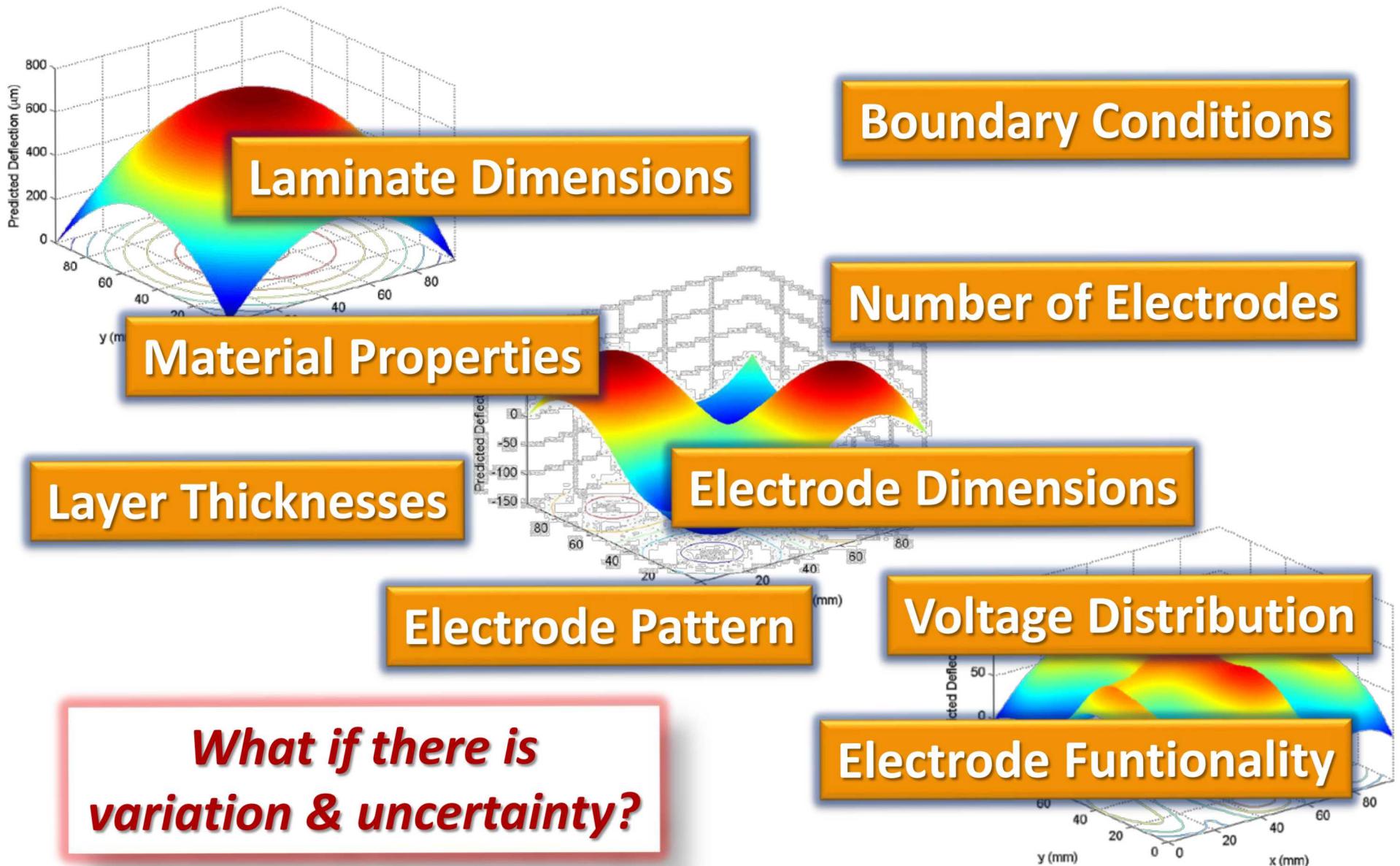


- Natural actuation into paraboloid when corner-supported,
- Improved flexibility,
- Large deflections possible.

### Thin, Square, Active Membrane

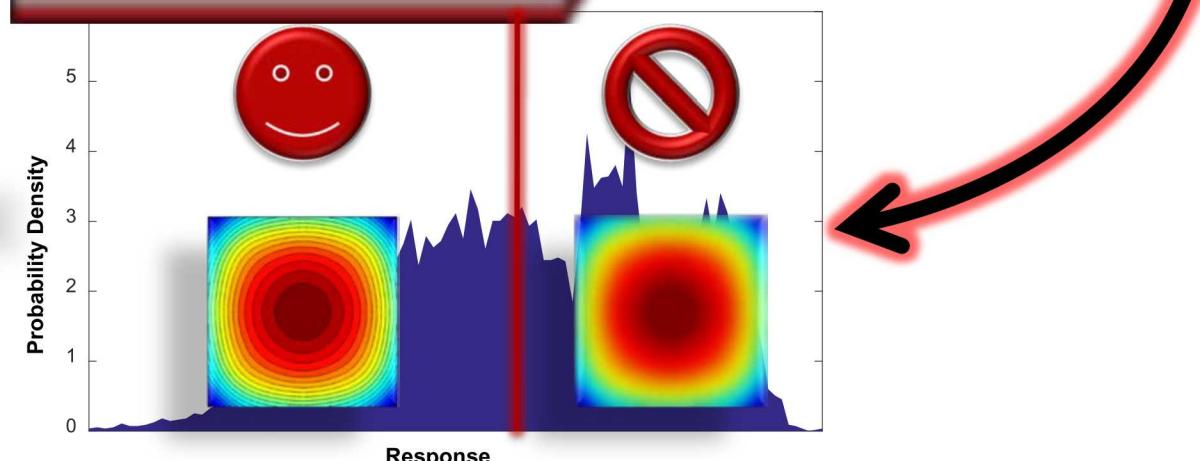
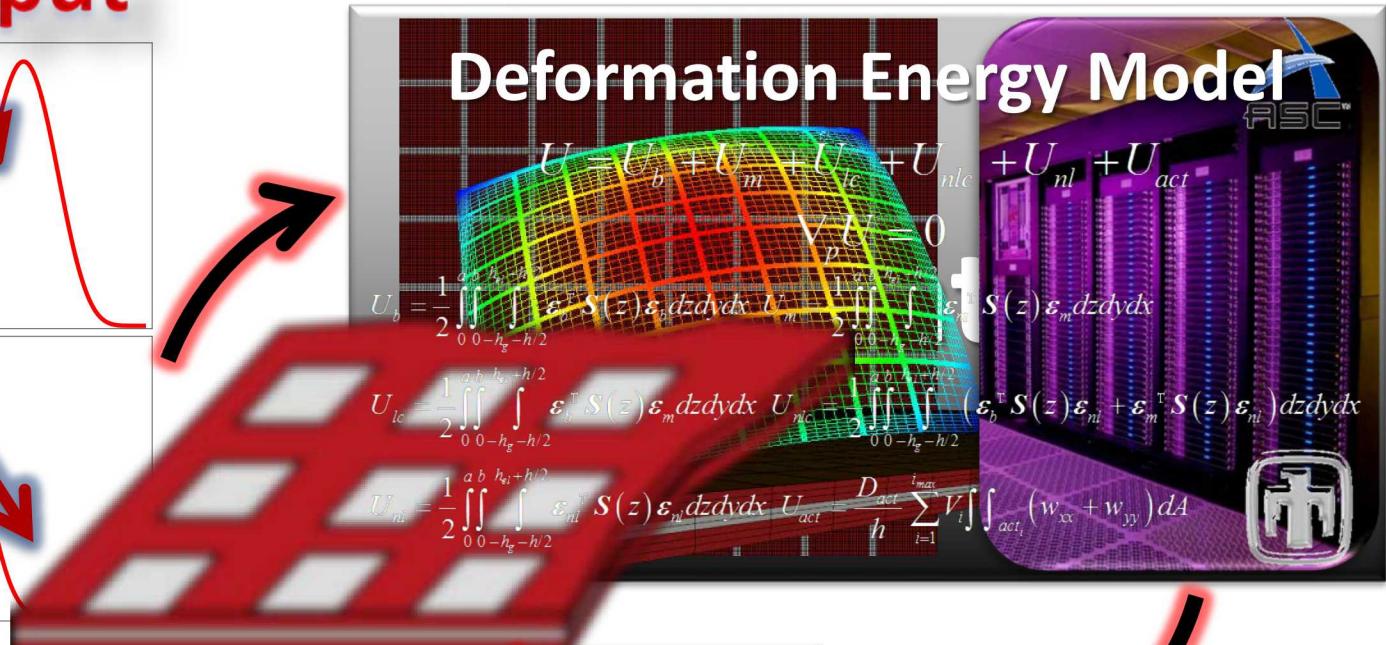
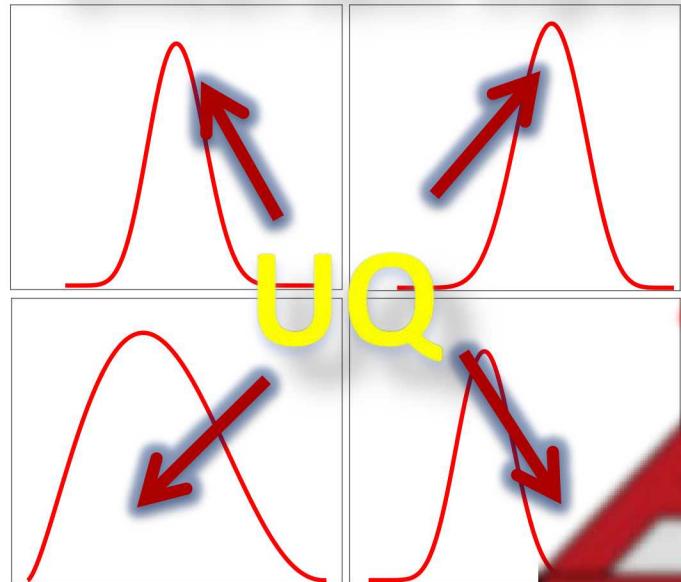
# Sandia Smart Laminate Concept

# What Determines Reflector Shape?



# Impact of Uncertainty

## Uncertain Input



## Probabilistic Output

# 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?