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# Survey of microwave technology development and applications at Sandia National Laboratories

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

NNSA National Nuclear Security Administration

Sandia National Laboratories

# Outline

- Introduction to Sandia National Laboratories
- Introduction to Electromagnetics: Wavelength and Media
- R&D Technology Spectrum
- Solutions using:
  - Advanced Manufacturing
  - Advanced Processing
  - Advanced Materials
- Multidisciplinary Applications
  - Miniature Synthetic Aperture Radar (miniSAR)
- Suggestions

# Sandia National Laboratories

## Mission: Meet national needs in six key areas

**–Nuclear Weapons:**
**Ensure a safe, secure, & reliable nuclear deterrent**

**–Nonproliferation:**
**Reduce proliferation of weapons of mass destruction and threat of accidents**

**–Defense Systems and Assessments:**
**Help maintain U.S. military weapon-systems superiority**

**–Homeland Security:**
**Help protect our nation against terrorism through advanced technology**

**–Energy and Infrastructure Assurance:**
**Ensure clean, abundant, and affordable energy and water**

**–Science, Technology, and Engineering:**
**Conduct R&D programs to support all national security missions**

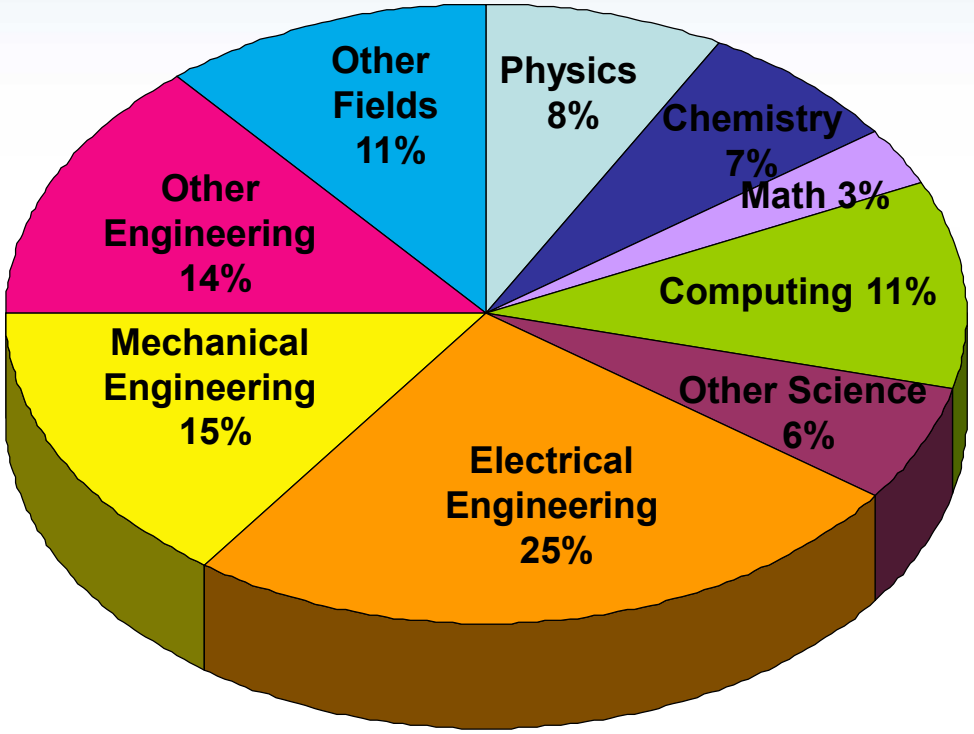
**Significant strengths in areas of:**

- Advanced Manufacturing
- Biosciences
- Chemical and Earth Sciences
- Computer Information Science
- Electronics
- Engineering
- Materials and Process Science
- Microsystems
- Modeling and Simulation
- Nanotechnology
- Pulsed Power Sciences
- Surety Sciences

# Sandia National Laboratories

- SNL is a DOE national laboratory
- Not Government
- Not Industry
- Not Academia

~ 8600 Employees
~18% of Staff hold PhDs
~30% hold Masters degrees




**Kauai Test Facility, HI**

**Tonopah Test Range, NV**

**Albuquerque, NM**

**Livermore, CA**

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*...exceptional service in the national interest.*

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# Wavelength and Media

*(uniform, isotropic, and lossless)*

$$\nabla \times \vec{E} = -j\omega\mu\vec{H}$$

$$\nabla \times \vec{H} = \vec{J} + j\omega\varepsilon\vec{E}$$

$$\nabla \cdot \vec{D} = \rho$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla^2\vec{E} + \omega^2\mu\varepsilon\vec{E} = 0$$

$$\vec{B} = \mu\vec{H}$$

$\varepsilon = \varepsilon_r\varepsilon_o$

$\mu = \mu_r\mu_o$

$$\vec{E} = \vec{E}_x(z) = E_0\cos(\omega t - \beta z + \varphi)\,\hat{i}_x$$

$$\beta = \omega\sqrt{\varepsilon_r\varepsilon_o\mu_r\mu_o}$$

$$v_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{\mu_r\mu_o\varepsilon_r\varepsilon_o}}$$

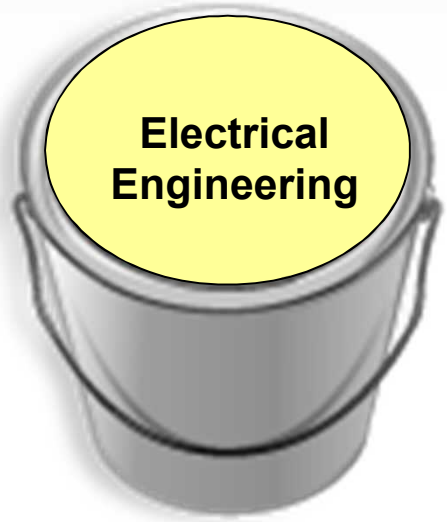
$$\lambda = \frac{2\pi}{\beta} = \frac{v_p}{f} = \frac{1}{f\sqrt{\mu_r\mu_o\varepsilon_r\varepsilon_o}}$$

$\lambda = \lambda_o/\sqrt{\mu_r\varepsilon_r}$

# Traditional Disciplines/Fundamental Research

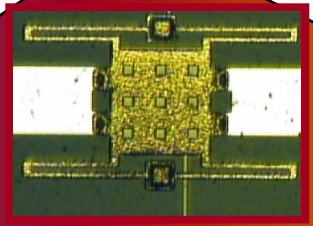

- Fluid Mechanics
- Solid Mechanics
- Heat Transfer
- Dynamics and Control
- Reliability

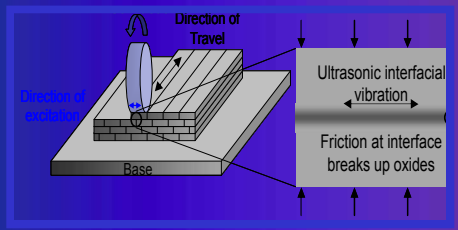

- Nanomaterials
- Polymers
- Chemistry
- Colloids
- Rheology
- Metrology
- Plastics and Metals

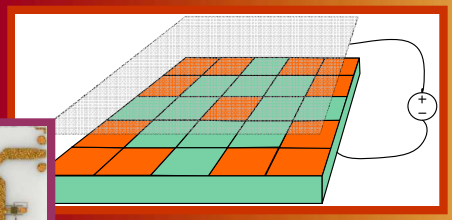


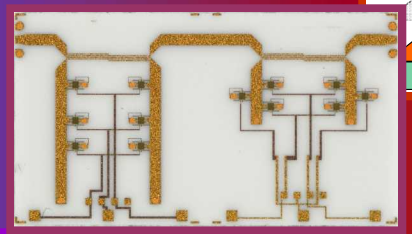

- Antennas
- Optics/Lasers
- Computers
- Fabrication
- Power
- Acoustics
- Signal Processing
- Communications

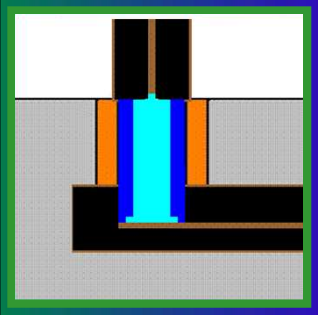
# R&D Technology Spectrum

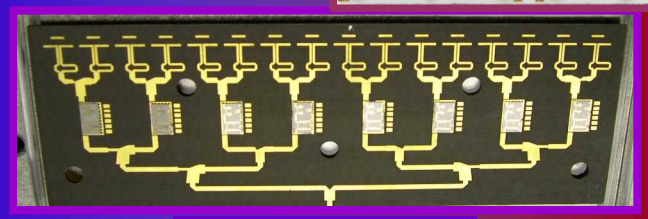


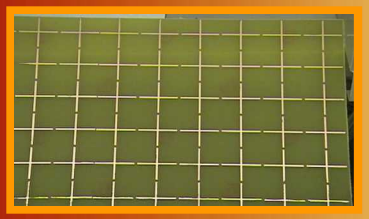


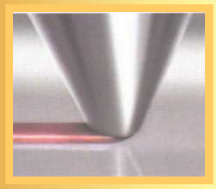



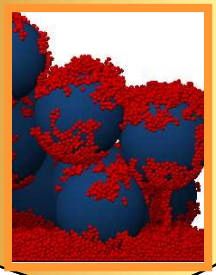












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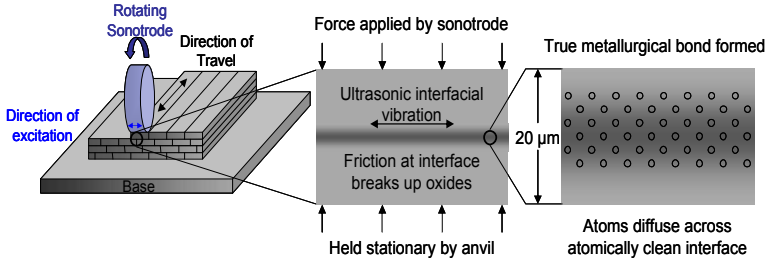
# Advanced Manufacturing

## Challenges

- Weight
- Physical Tolerances
- Thermal Issues/Heat Management
- Low temperature processes
  - Important for many RF components
  - Important for embedded MEMS devices

## New Approaches: Rapid Prototyping

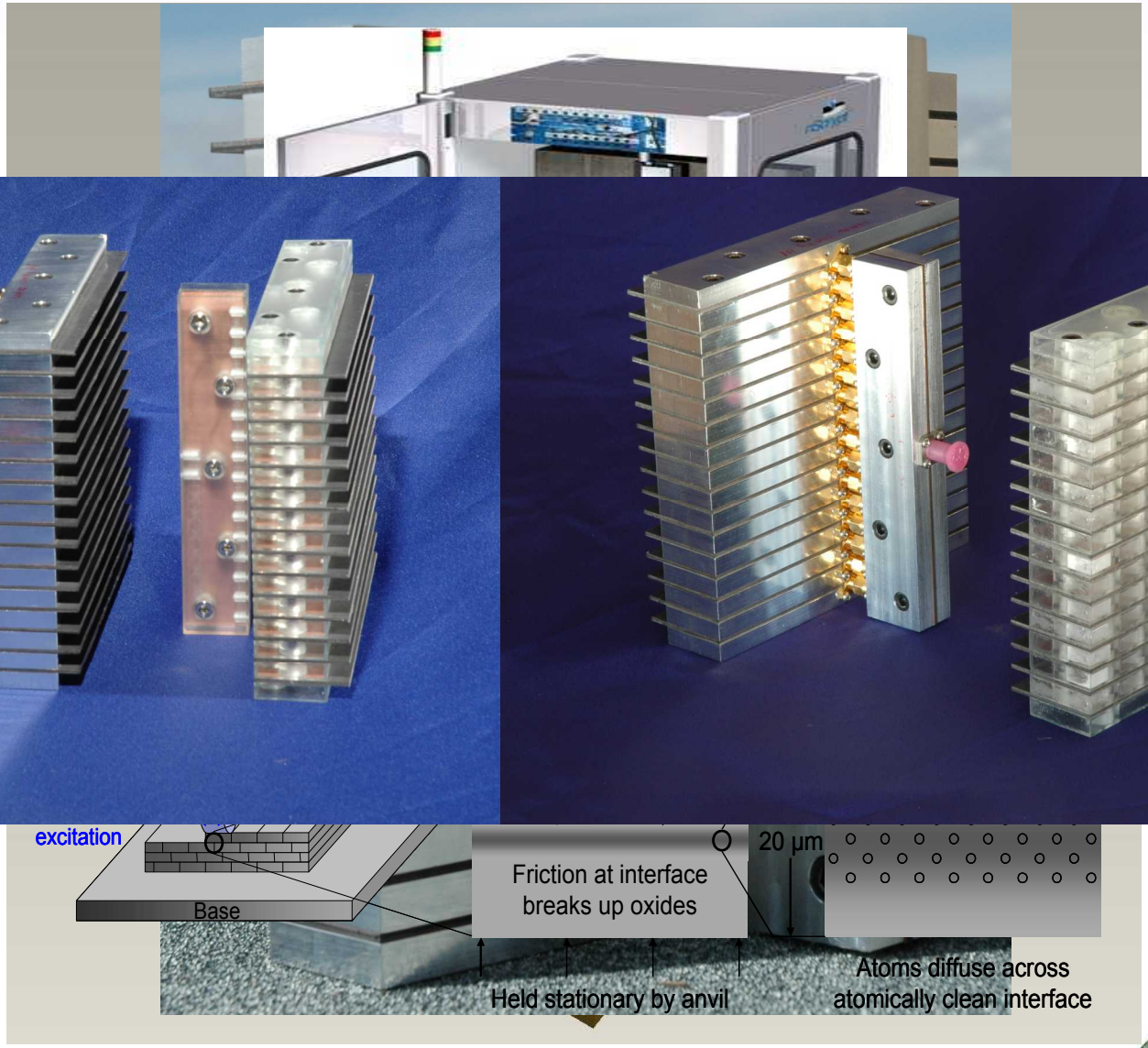
- Solidica Ultrasonic Consolidation
- Solid Free-form Fabrication
- Stereolithography




## Results

- Exploit electromagnetic dependence on geometry and media.
- Simplify and remove mechanical misalignment.
- Simplified mechanical design will facilitate RF system modeling
- Concurrent electrical and mechanical engineering R&D
- Encapsulation

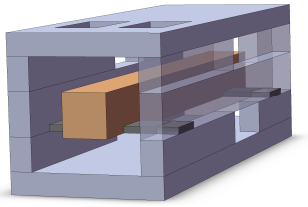
# Integrated Machining of a MEMS Antenna (IMMA)



# Advanced Processing

## Challenges
- Interconnects
- Packaging
- Losses
- 'Radation-hard'
- Bandwidth Requirements

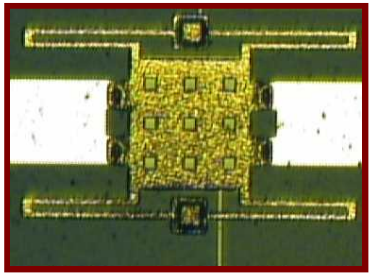
## New Approaches
- MEMS
- Monolithic Construction
- Minaturization

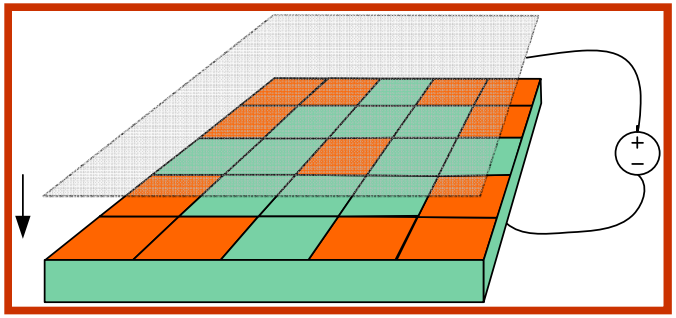


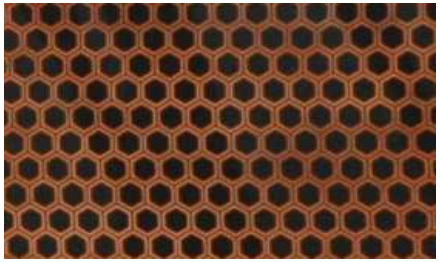
ROHM HAAS

## Results
Phase shifters
Monolithic Antenna/Receiver
Tunable Dielectrics
Frequency Selective Surfaces (FSS)
Micro-coax
Metamaterials

MEMS Switch







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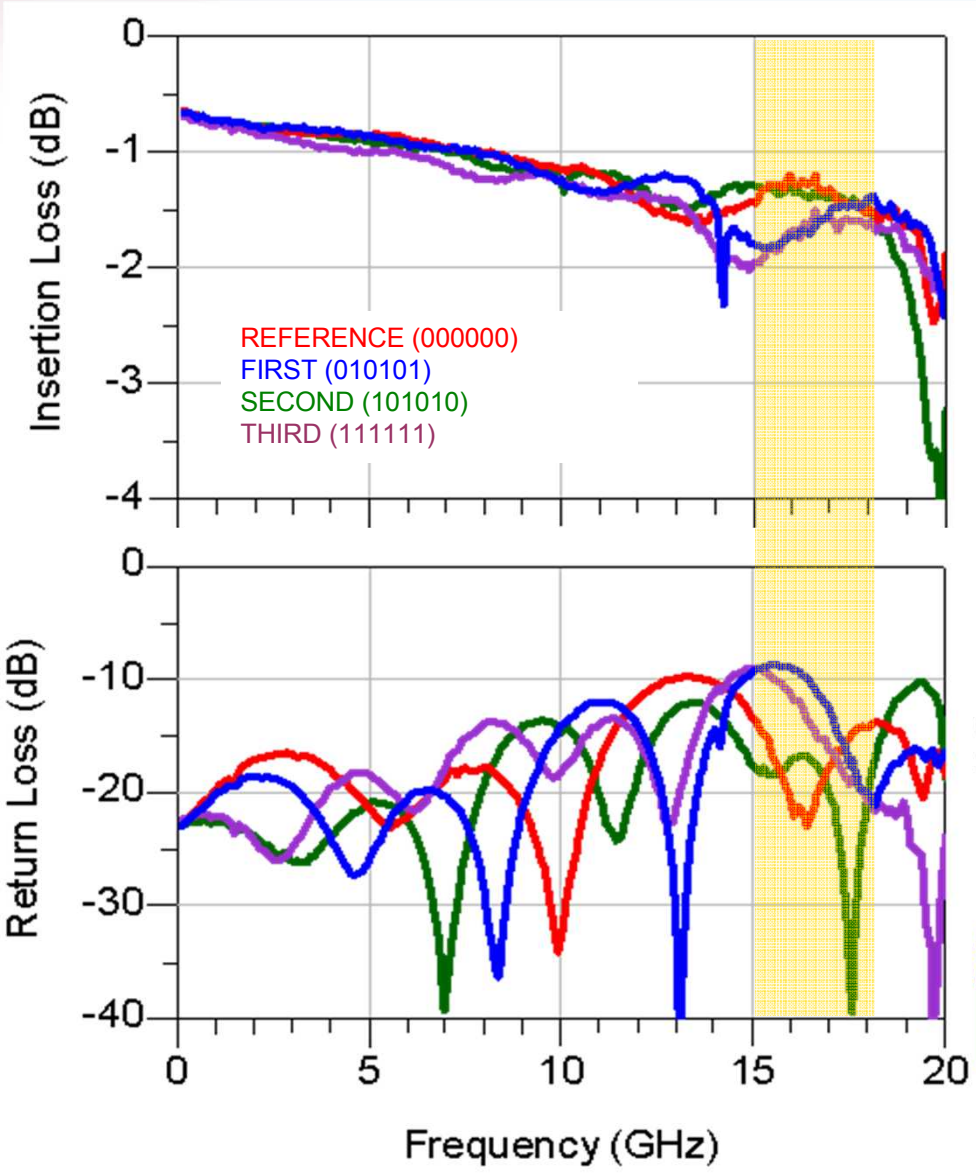
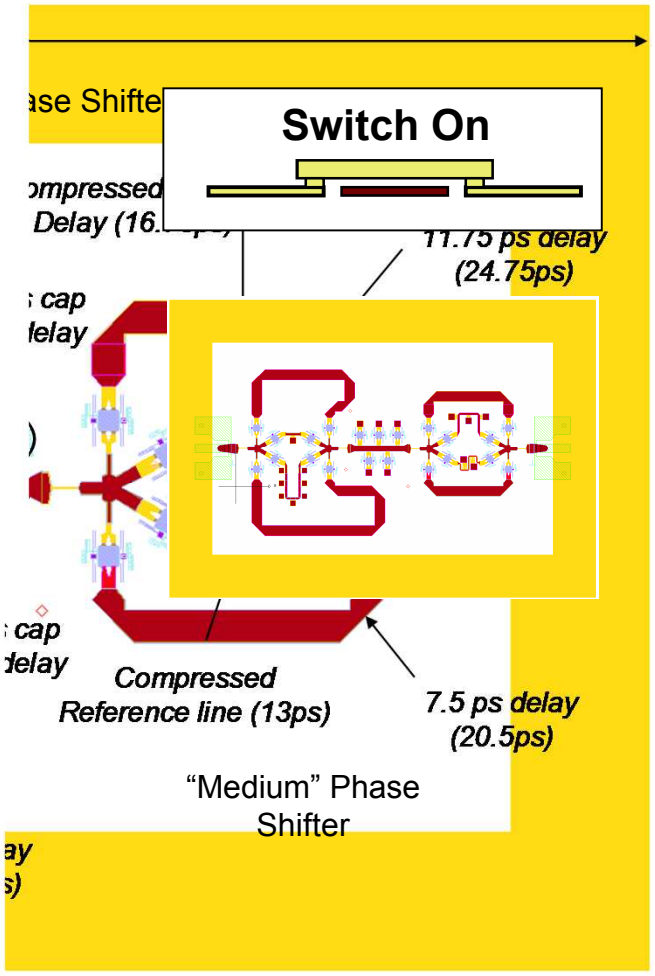
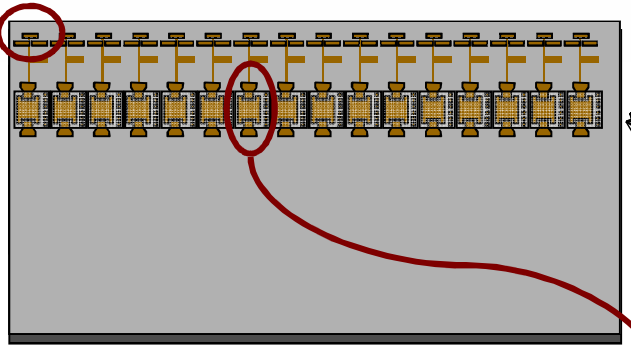
# MEMS Phase Shifter

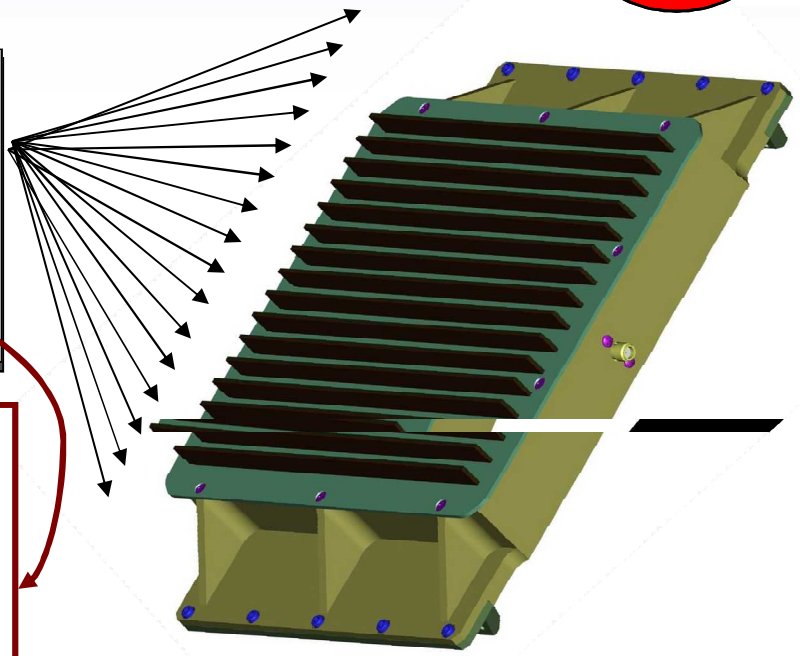


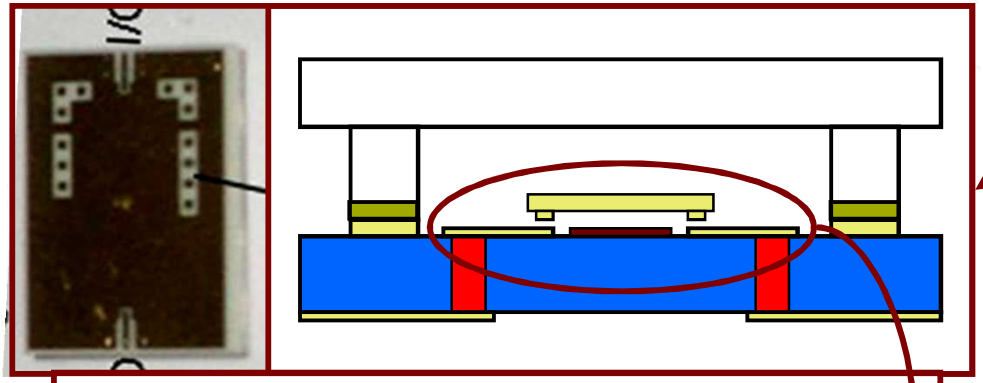



# 2-Axis Passive Electronically Steerable Array System


Quasi-Yagi antenna element

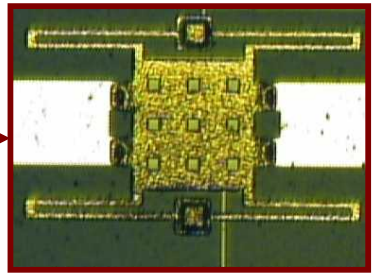




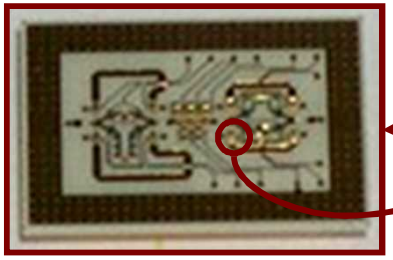


Custom packaged phase shifter

MEMS Switch



MEMS Switched-line Phase shifter



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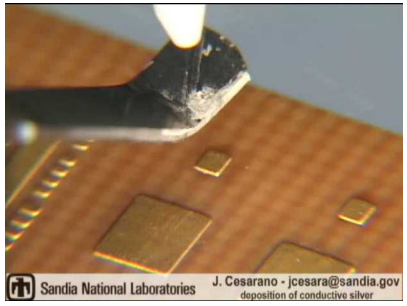
# Advanced Materials

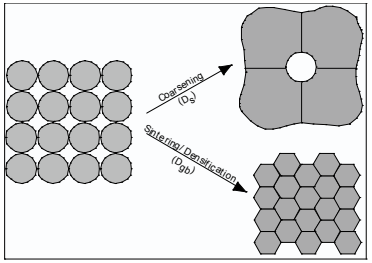
## Challenges

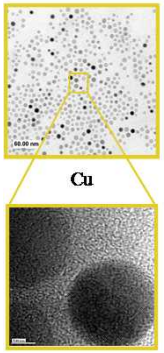
- Antenna and microelectronic substrates tend to be dissimilar
- Would like materials to be 'Designer', Tunable, and/or reconfigurable

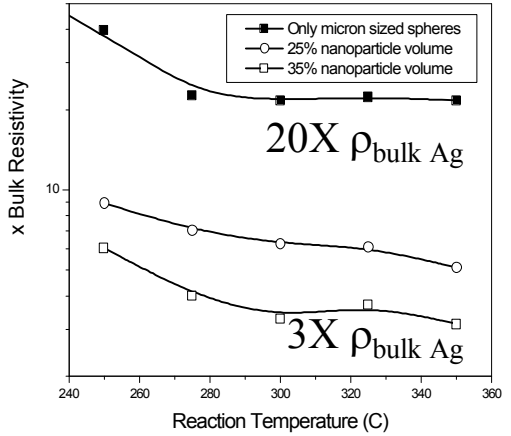
## New Approaches

- Direct-write and aerosol microspray technology
- Laminates/Composites



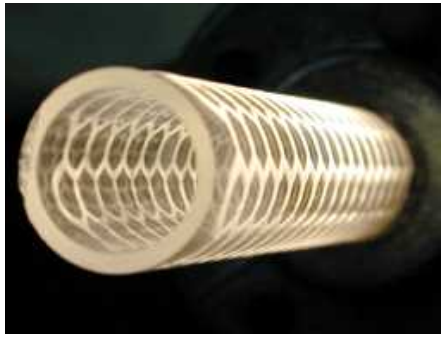



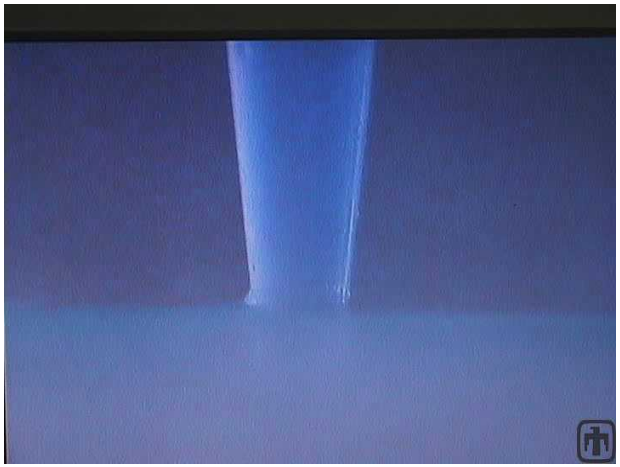



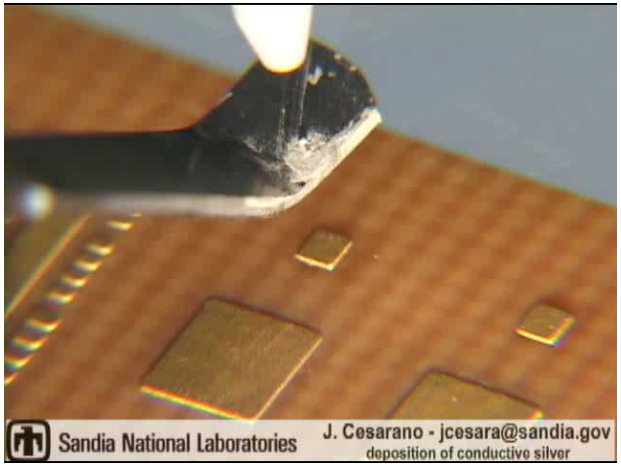

## Results:

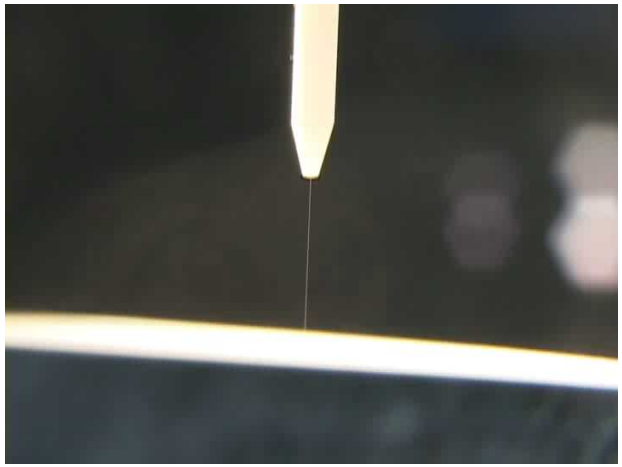
- Conformal electronics
- Flexible substrates
- 3-D printing/etching
- FSS



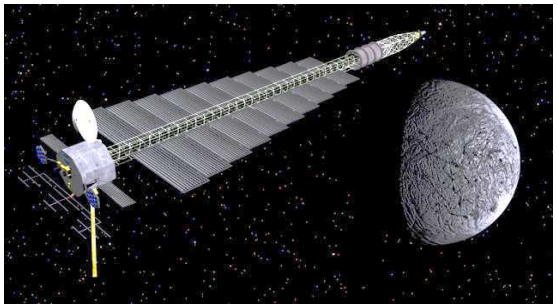
# RF Materials: From nano-particles to conformal electronics

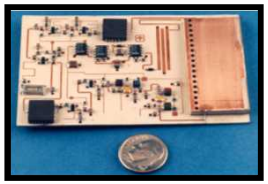





# Applications/Future Systems





- Variety of sensor and communication platforms
- Adaptive systems which sense/think/act/communicate
- Multifunction operation
- Conformal electronics
- Military and civilian applications

# SNL Synthetic Aperture Radar Roadmap

***1991***

500 lbs, 15 GHz

6-in resolution

16 km range

***1998 (Lynx)***

120 lbs, 16.7 GHz

4 -in resolution

35 km range

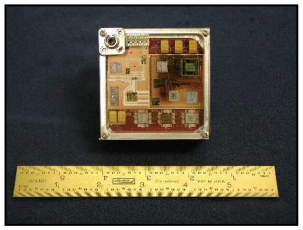
CCD & GMTI

***2005 (MiniSAR)***

25 lbs, 16.7 GHz

4-in resolution

15 km range



***2009? (MESA-SAR)***

2"x2"x1" REA

16.7 GHz, 4-in res.

~10 km range

**Sandia has been improving performance and shrinking SAR size for over two decades**

- **–MiniSAR is the current generation in this evolution**
- **–MESASAR is the next-generation**

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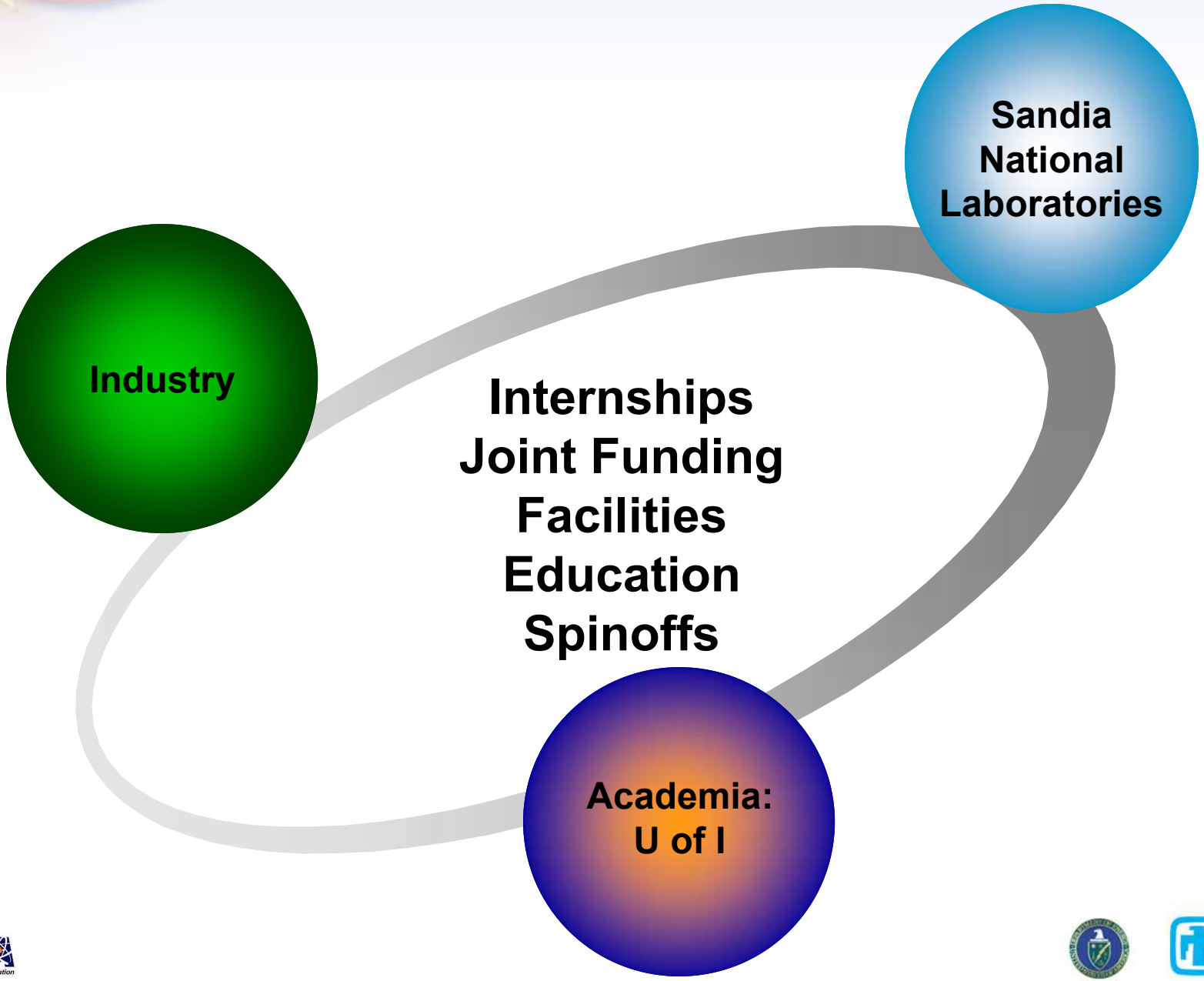
# Partnerships



# Suggestions

- Take a materials or mechanical engineering course
- Or take a EE course tangential to your area of interest
- Consider ECE 329, 450, 451, 452, 453, 520
- Load up on math courses
- Learn the fundamentals!

# Questions?

# Backup

# Test Facilities