SAND2006-4903P

Science, Technology and Engineering Strategic Management Unit

Presented to the

Sandia Corporation Board of Directors

Missions Committee

Richard H. Stulen, Ph.D.

Vice President and Chief Technology Officer

Science and Technology and Research Foundations

Sandia National Laboratories

July 25, 2006

LOCKHEED MARTIN

Sandia National Laboratories

Science, Technology and Engineering Strategic Management Unit

- **Overview – *who we are***
  - **Guiding Principles**
  - **Recent accomplishments**
    - Nurturing the Core
    - Enabling the Programs

- **Challenges, Strategy and Initiatives – *influencing and preparing for the future***

Sandia National Laboratories

Guiding principles for ST&E

- **Ensure that the fundamental science and engineering core is vibrant and pushing the forefront of knowledge**

- **Enable the programs by effective application of that science base**
  - **responding to current needs**
  - **anticipating the future**

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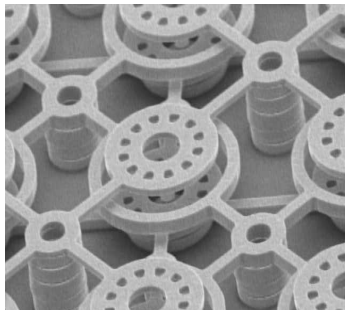
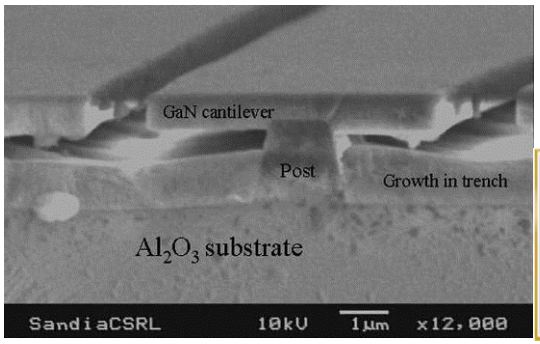
Dual nature of relationship between science and Sandia's mission

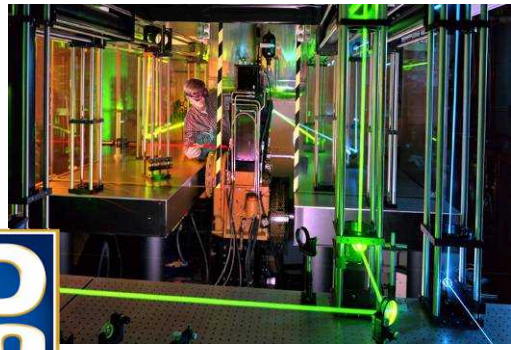


Science underpins and enables technology for Sandia's missions,

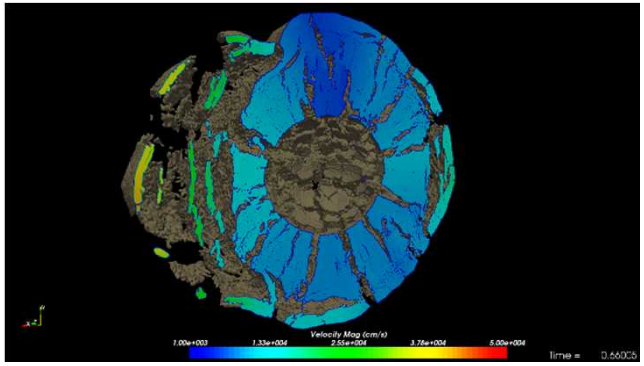
AND

Facilities and equipment for mission needs enable world-class science that pushes the frontiers of knowledge

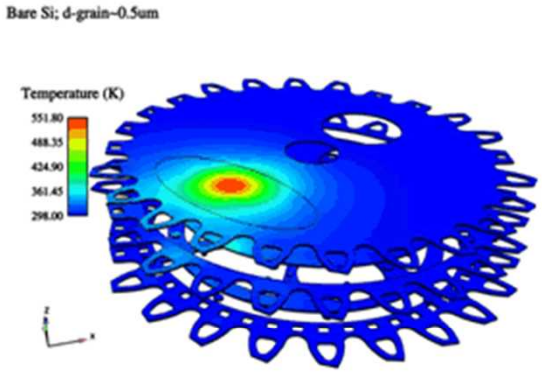




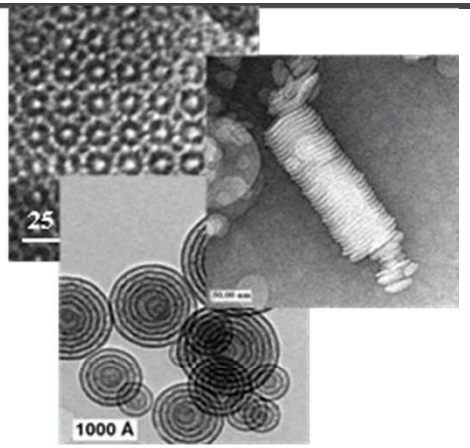
ST&E Research Foundations



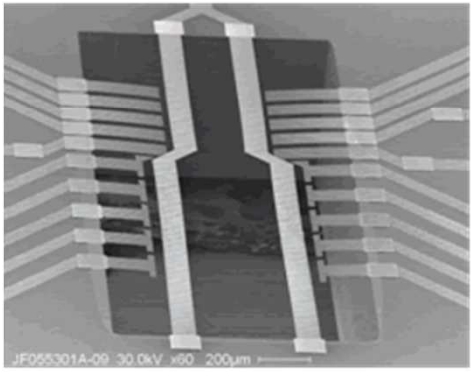
Computational and Information Sciences



Engineering Sciences

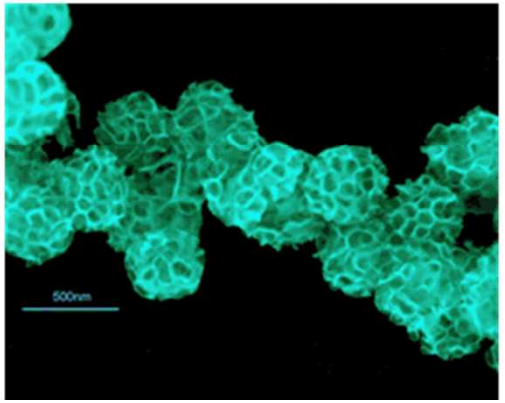


Materials Science and Technology



Microelectronics and Photonics

Pulsed Power



Bioscience and Technology

Sandia National Laboratories

Overview – *who we are*

Recent Accomplishments:
Nurturing the Core

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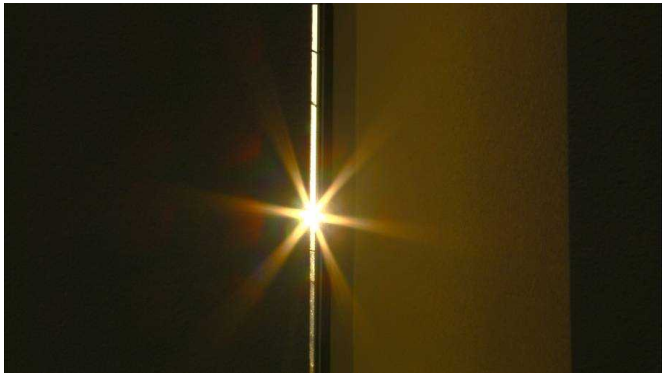
Center for Integrated Nanotechnologies (CINT) core facility has started operations

Core facility, Sandia

Gateway facility, LANL



- BES-funded user facility
- Focused on the integration challenges unique to nanotechnology
- Joint with LANL
- Core dedication on August 23, 2006

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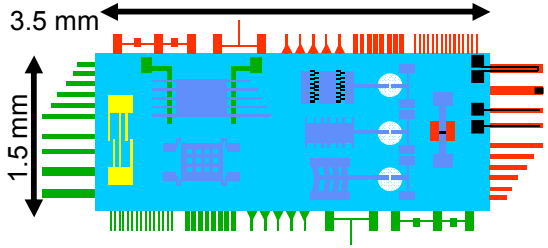
Differentiating tools: Discovery platforms™

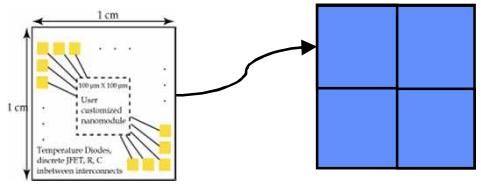
Standardized modular, *micro-laboratories* for CINT user community. Designed and batch fabricated at Sandia to:

- Integrate nano and micro length scales
- Study the physical/chemical properties of nanoscale materials and devices

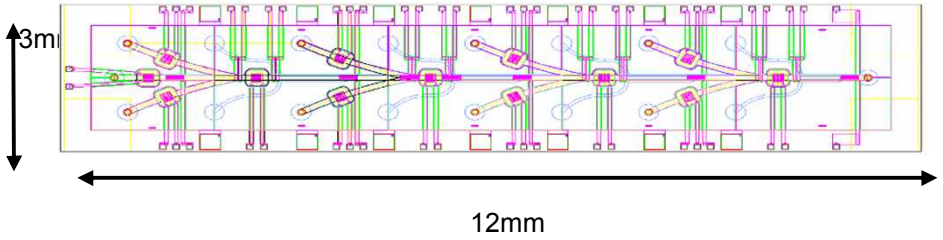
Cantilever Array Platform



Electrical Transport & Optical Spectroscopy Platform



Microfluidic Synthesis Platform



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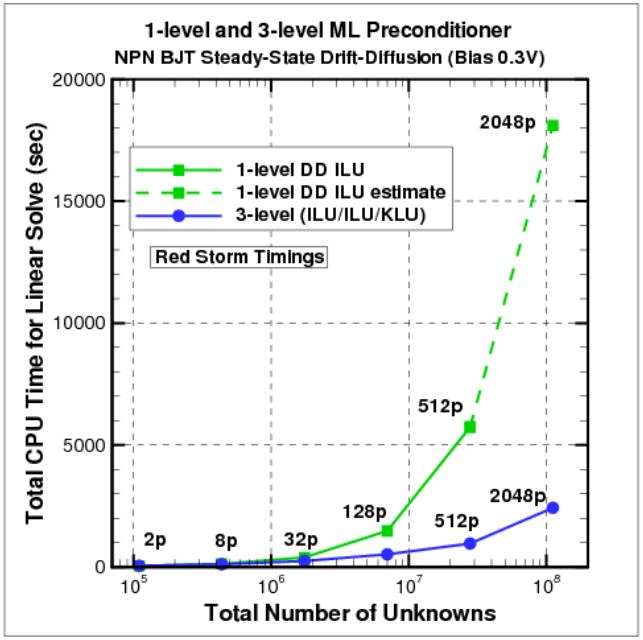
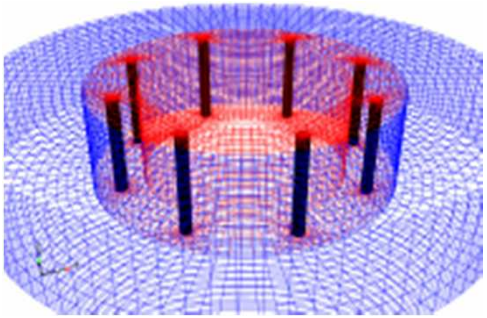
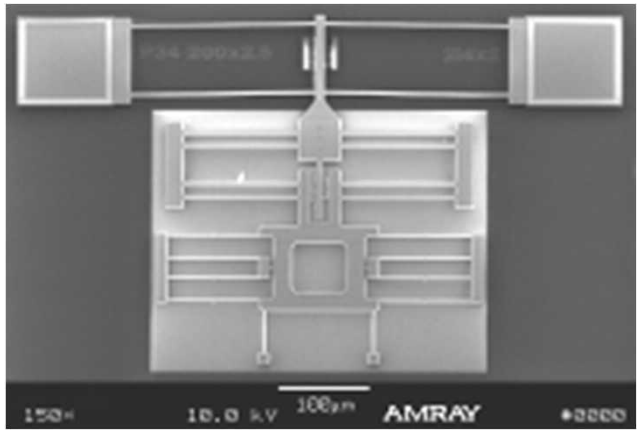
Scalable Solvers Enable Fast Solutions on Massively Parallel Computers

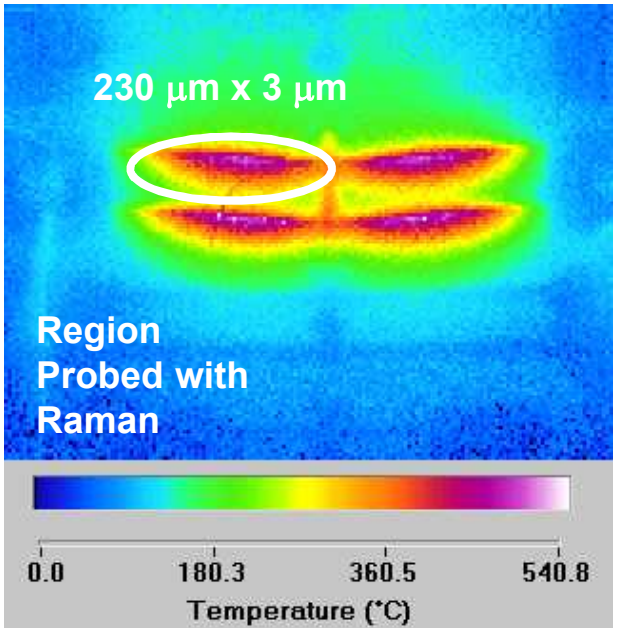




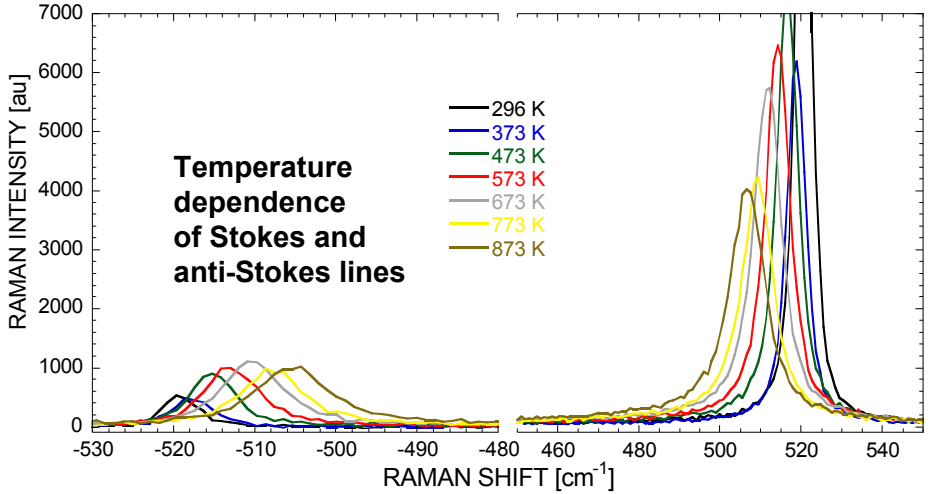
- TRILINOS provides a framework for scalable solvers.
  - R&D100 in 2004
  - v6.0 released in 2006
- Solvers and algorithms developed to enable large shock physics and MHD simulations – calculations on parallel machines with millions of unknowns and 10,000 processors possible
- Mesh optimization and improved solvers have been critical to calculations supporting ZR design refinements

Engineering Sciences is developing the tools needed to understand microsystems





- Spatially resolved Raman thermometry at the micron scale
- Enables study of non-continuum thermal transport phenomena



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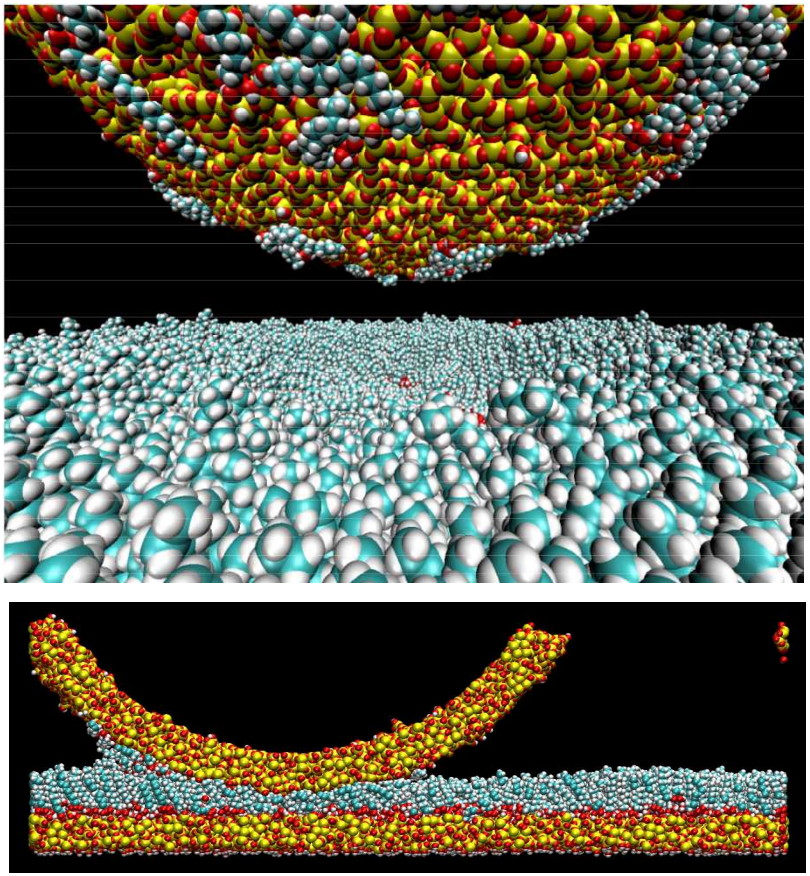
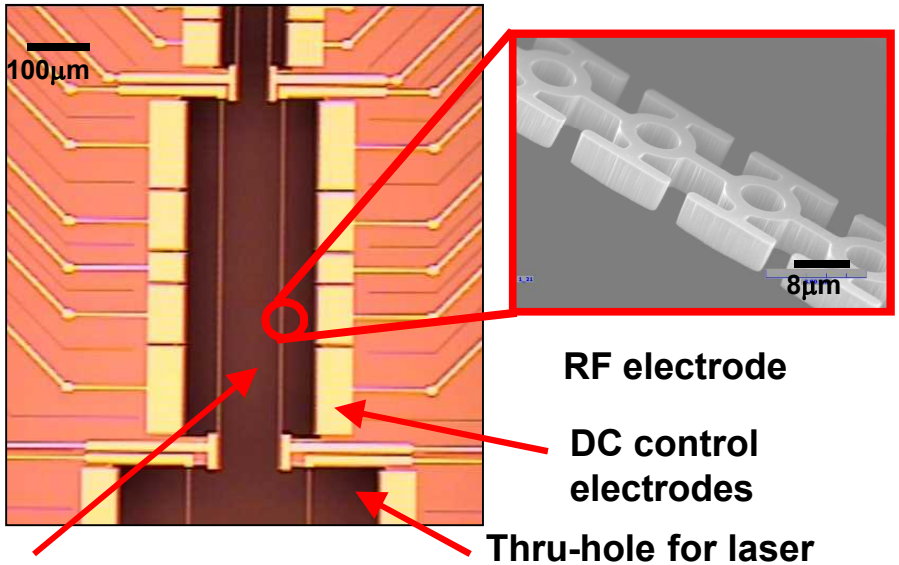
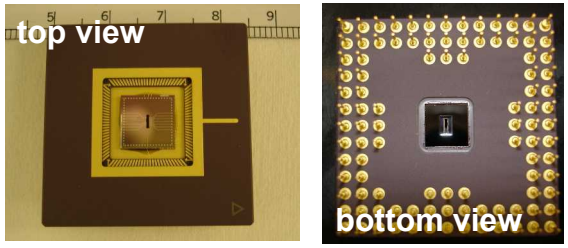
Modeling of microsystem coatings leads to understanding of tribological behavior



- Atomic force microscope tip simulations performed to study tribological properties (such as friction) of microsystem coatings
- Even low applied stresses can lead to tip fouling and damage of a self assembled monolayer (SAM) coating on a microsystem surface.
- Fundamental understanding important for predicting long-term behavior of microsystems

Sandia is at the forefront of microfabrication for quantum computing



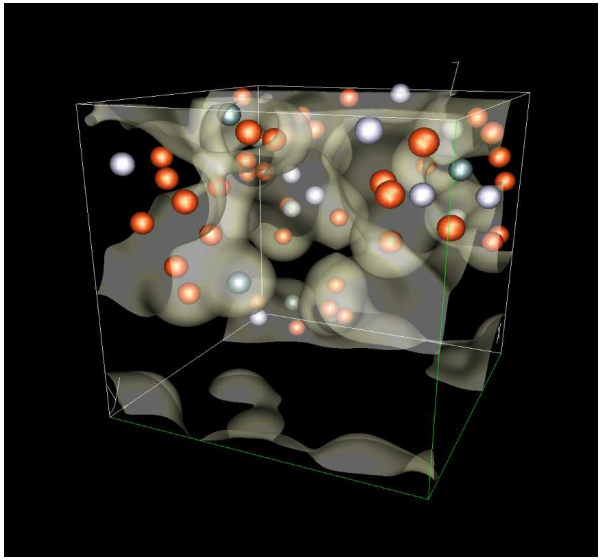


Packaged 3D ion trap chip with thru-chip and thru-package optical access

- Fabricating ion traps to create Qubits (quantum bits)
- Traps currently being tested by 4 labs around the world
- Could enable exponential speed-up versus classical computing

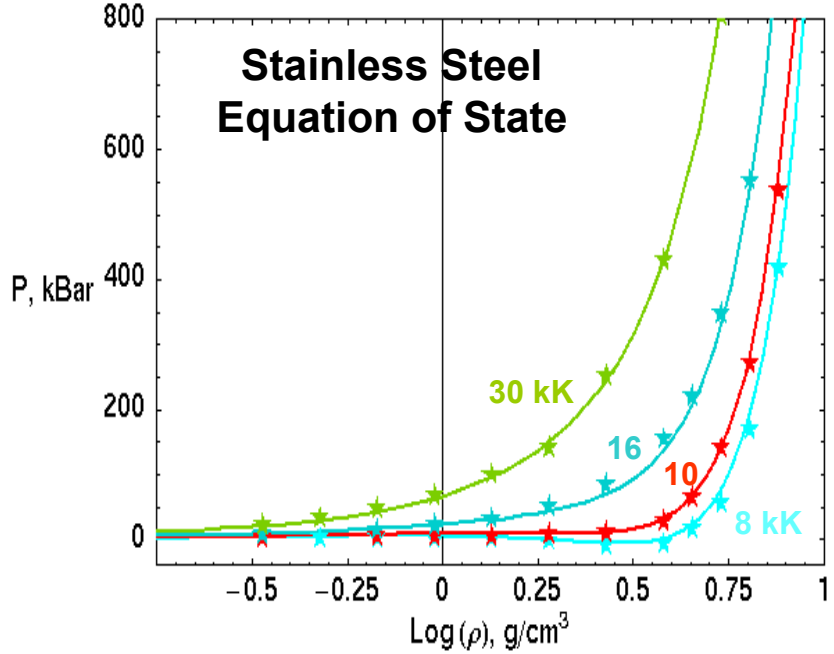
Density function theory simulations are used to model materials under extreme conditions

Stainless Steel (Fe, Cr, Ni)



Pressure

Energy



- Density function theory simulations foundational for a wide-range equation of state and transport properties models
- High energy density physics applications – magnetically launched flyer plates, z-pinches, multi-physics armor (Army Research Lab), melt experiments (National Ignition Campaign), etc

Pulsed Power

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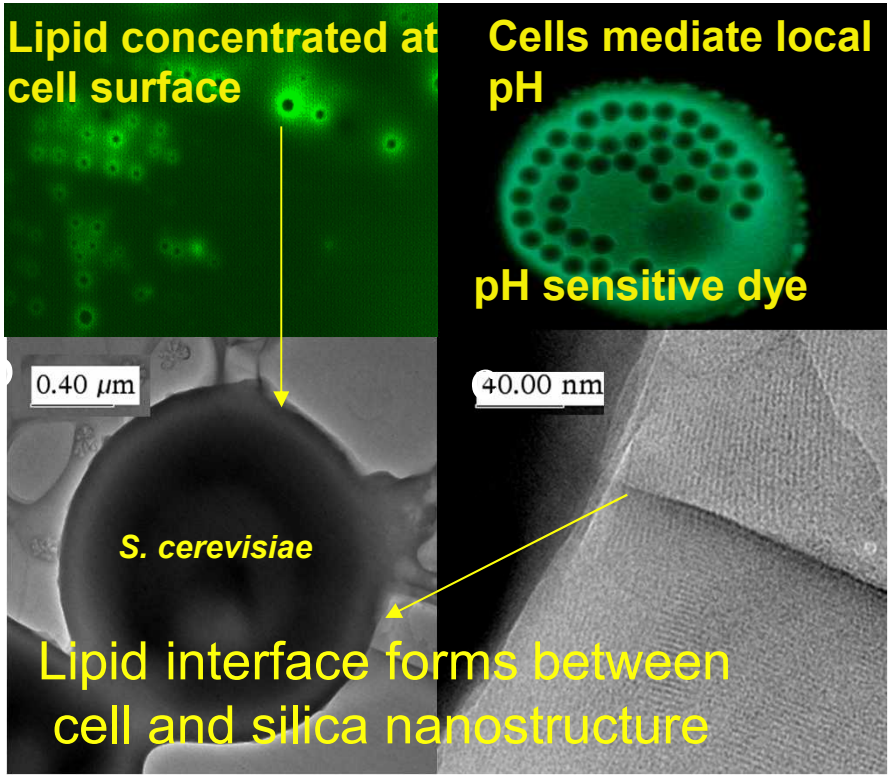
Sandia's nanostructures have been launched on NASA's shuttle Discovery

- Surfactant self-assembly directs the formation of nanostructures that function like an extracellular matrix and maintain cell viability
- Living cells added during self-assembly actively direct the formation of a unique bio/nano interface
- Cells remain alive for months exposed to desert conditions and even vacuum



H.K. Baca, C.J. Brinker, et al., *SCIENCE*, July 21, 2006

Overview – *who we are*

Recent Accomplishments:
Enabling the Programs

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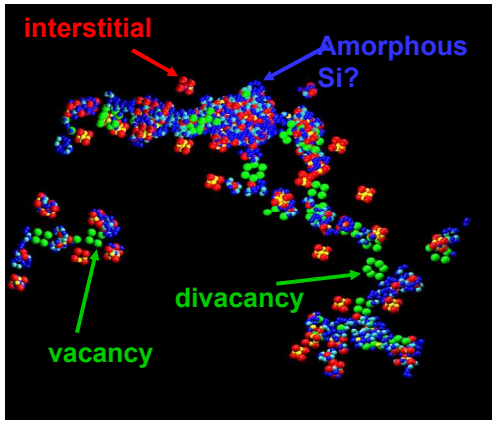
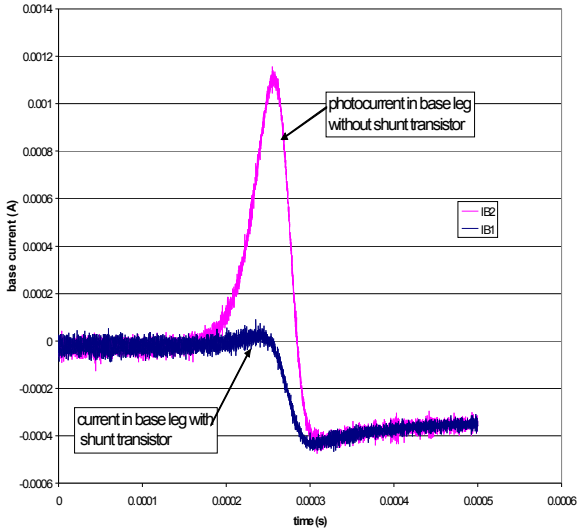
Goal is predicting circuit performance from fundamentals in a fast neutron environment

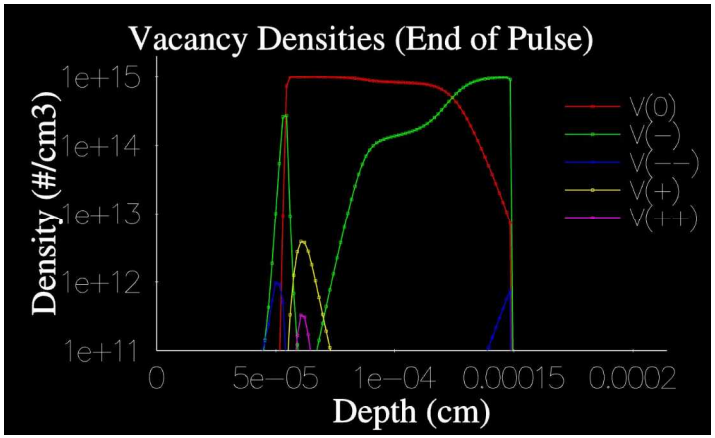
Molecular level understanding of defect formation (molecular dynamics simulation)



Actual circuit level measurements upon neutron exposure



Vacancy defect profile in a silicon bipolar junction transistor



Nuclear Weapons

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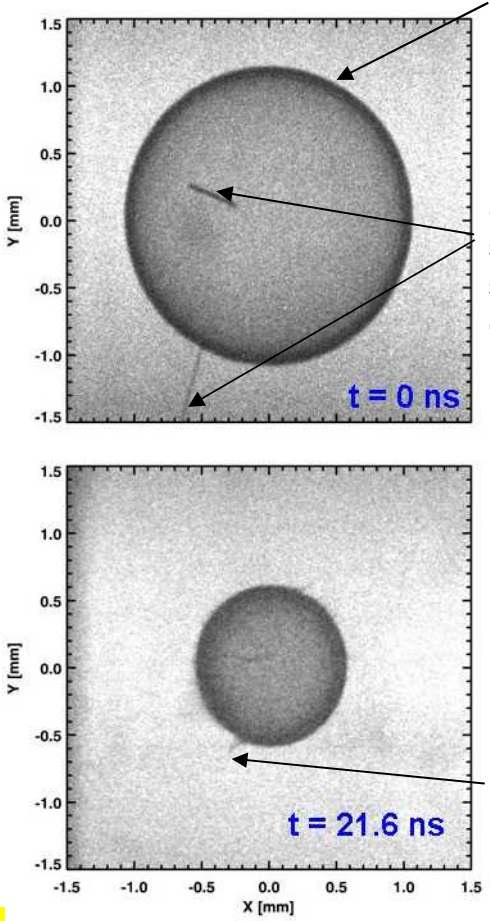
Diagnostic development on Z enables tests that inform design of NIF targets

optical image of capsule



CH tube is transparent in preshot radiograph

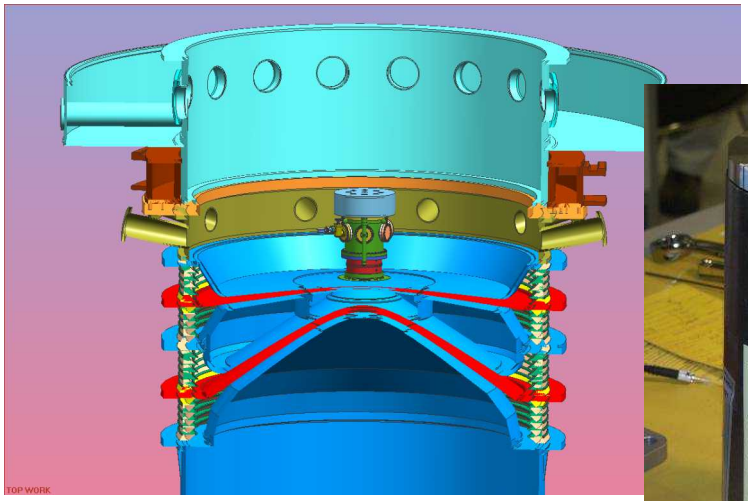
SiO_2 tubes shadowing small area of capsule

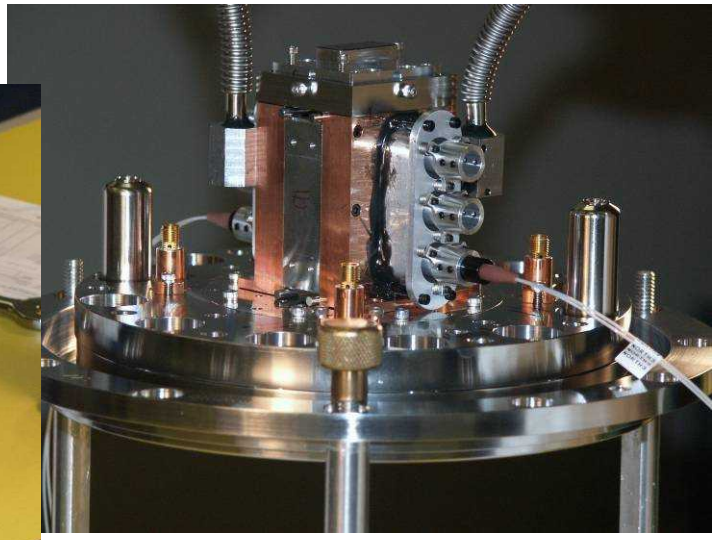
lagging material caused by tube shadowing

x-ray images with late beam

- Ability to obtain two time-separated backlit images on a single shot developed
- Information will be used to determine if ignition target fill tubes drive instabilities upon implosion
- Generating two laser beams within the Z-Beamlet single-beam structure was a significant effort
- Developed jointly with LLNL

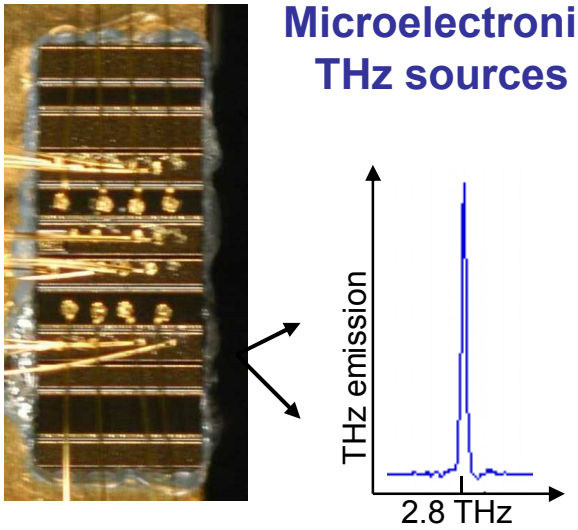
Sandia & LANL achieved the first isentropic compression experiments on Z for Pu

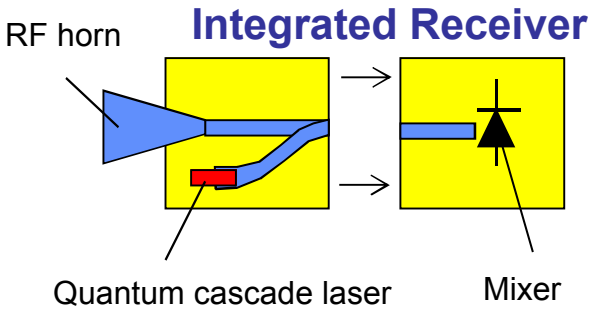




“ These experiments address one of the toughest questions on a top priority physics topic.” **Dawn Flicker, LANL**

Sandia is at the forefront of developing THz technology





- **The THz spectral region offers unique and undiscovered opportunities between the IR and microwave regions for national security applications**
  - imaging through opaque materials to scan for concealed weapons
  - high-specificity chemical detection of explosives and WMD proliferation signatures
- **Integration of the source and receiver into a THz micro-transceiver is unique in the world**
- **Sandia's microfabrication and quantum cascade laser capabilities are key**
- **Teamed with JPL, Virginia Diodes, UVa, MIT, UCSB, PNNL**

Defense Systems & Assessments

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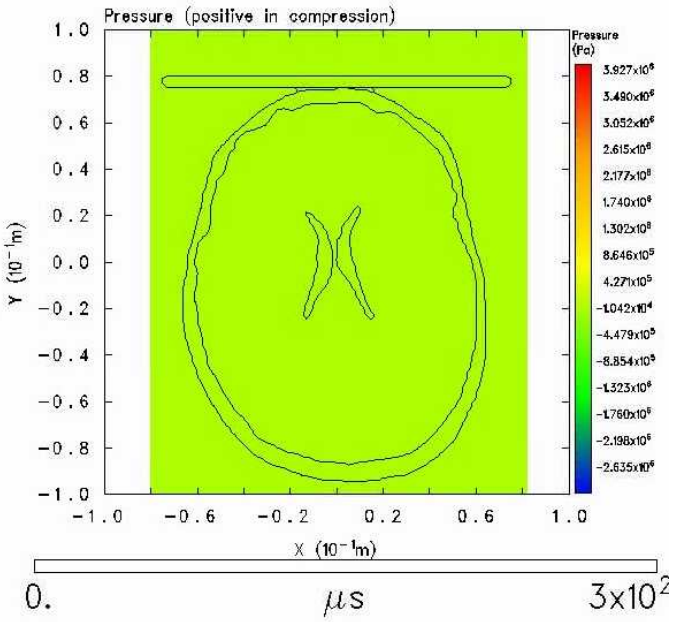
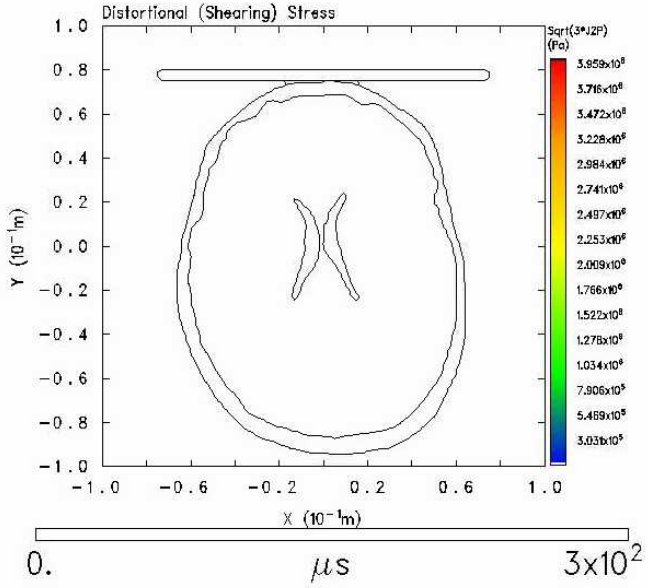
Simulation tools developed for nuclear weapons being used to study head trauma due to impact

Windshield



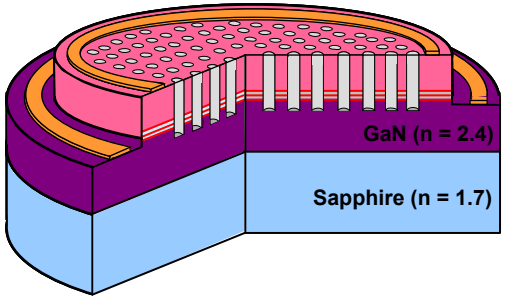
Pressure wave



Shear wave

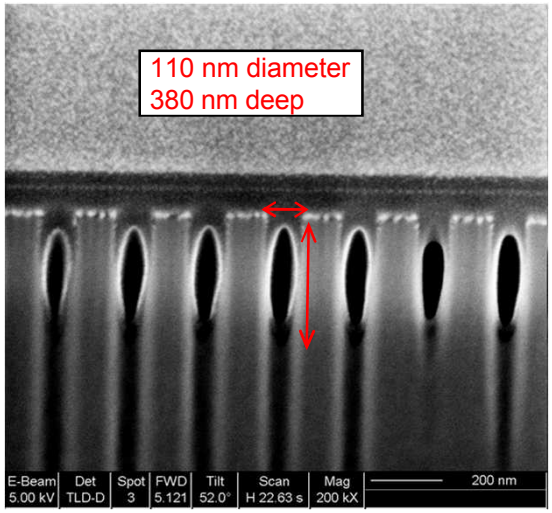
Extending previous collaboration with UNM to study brain damage effects on soldiers exposed to an IED blast wave.

Photonic crystal LEDs for solid state lighting

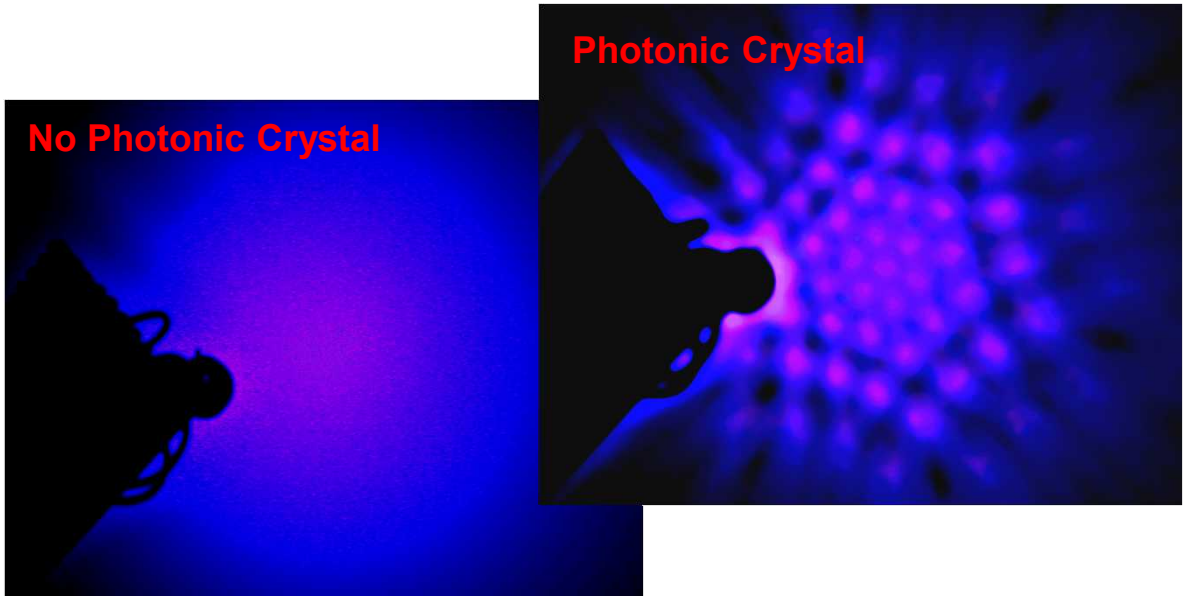


Schematic of an InGaN photonic crystal light emitting diode.

- **Collaboration with LumiLEDs Lighting**
  - **LED industry leader in the US**
- **50% increase in efficiency over non-photonic crystal LED!**
- **Funded by DOE's Office of Energy Efficiency and Renewable Energy (EERE)**

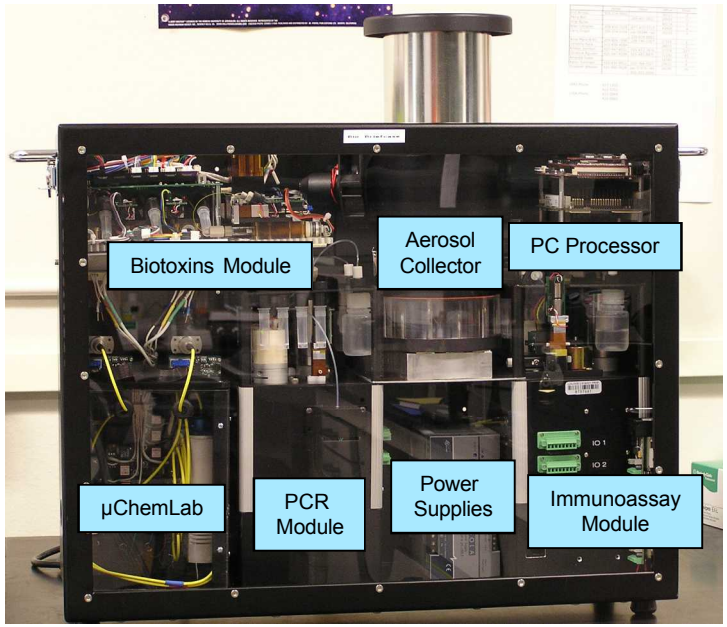


Focused ion-beam scanning electron microscope image of a photonic crystal etched in GaN.

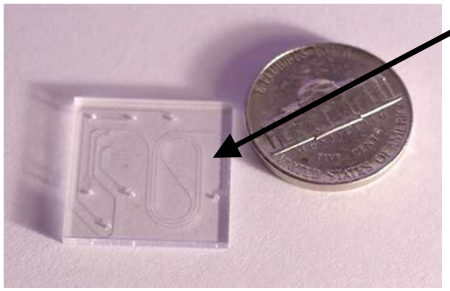


Energy, Resources & Nonproliferation

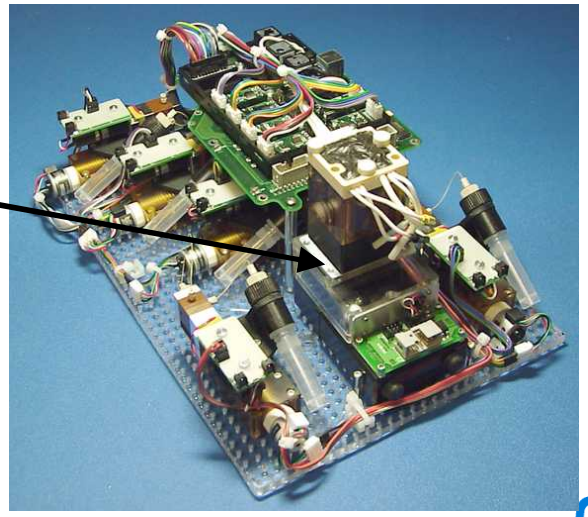
Biobriefcase: an autonomous bioagent detector



- Uses Sandia's micro-chemlab technology (capillary electrophoresis)
- Full system tests will be conducted at Edgewood Chemical & Biological Center in Fall 2006
- Being developed under HSARPA funding jointly with LLNL



Fluidics microchip from micro-chemlab module



Homeland Security & Defense

Sandia National Laboratories

CHALLENGES, STRATEGIES AND INITIATIVES

– *influencing and preparing for the future*

Key Challenges

- **Nurture the core**
  - Increase innovation and risk-taking
- **Stay at the cutting edge**
  - Increase Sandia's engagement in and recognition by national and international Science & Technology and Engineering communities including universities and industry.
- **Be relevant**
  - Improve application of R&D to Sandia programs
- **Anticipate the future**
  - Ensure that Sandia's science and engineering is anticipating and creating the future for the laboratory programs.

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Challenge – Nurture the core

Strategy

— Increase innovation and risk-taking —

Approach

- **Reshape the Laboratory Directed Research and Development program beginning in FY07**
- **Establish laboratory capabilities assessment**

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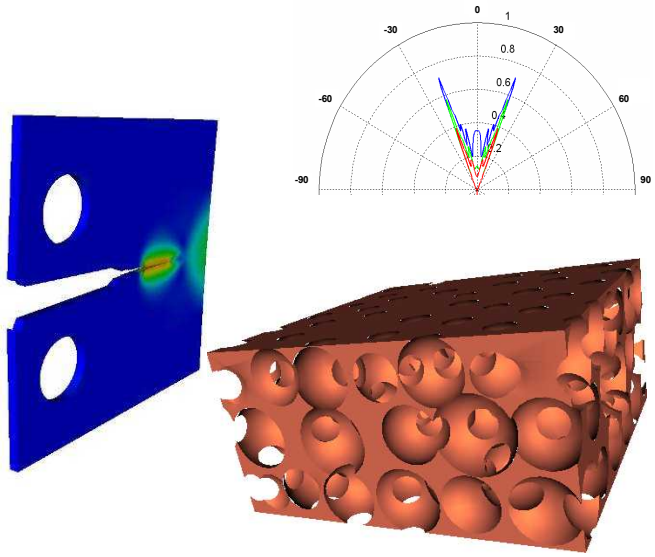
Laboratory Directed Research and Development (LDRD) enables creation of knowledge and future capability

- **Proposal driven R&D in three broad categories**
  - **Science and Technology**
  - **Mission Technologies**
  - **Grand Challenges**
- **$132 M in FY06**



LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

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FY07 LDRD program changes address innovation and efficiency

Issues

- Current portfolio tends to be risk averse and incremental
- Currently too many (subcritical) investment areas, complex processes, and fragmented principal investigator efforts

Approach

- Provide targets to investment areas for “discover – create – prove”
- Reduce the number of investment areas and increase their portfolio size to enable flexibility and healthy competition
- Establish a Senior Steering Committee (SSC) responsible for improved program quality, integration and consistency

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Encourage a portfolio balanced between fundamental and applied research

Create
novel solutions to problems or revolutionary advances by combining knowledge in new ways.

Discover
new understanding or new knowledge

Prove
our concepts in real-world environments

Investment Areas

- **Mission Technologies**
  - Defense Systems & Apps
  - Energy Resources & Nonproliferation
  - Homeland Security
  - Nuclear Weapons
- **ST&E Foundations**
  - Nanoscience to Microsystems
  - Enable Predictive Simulation
  - Science of Extreme Environments
  - New Directions

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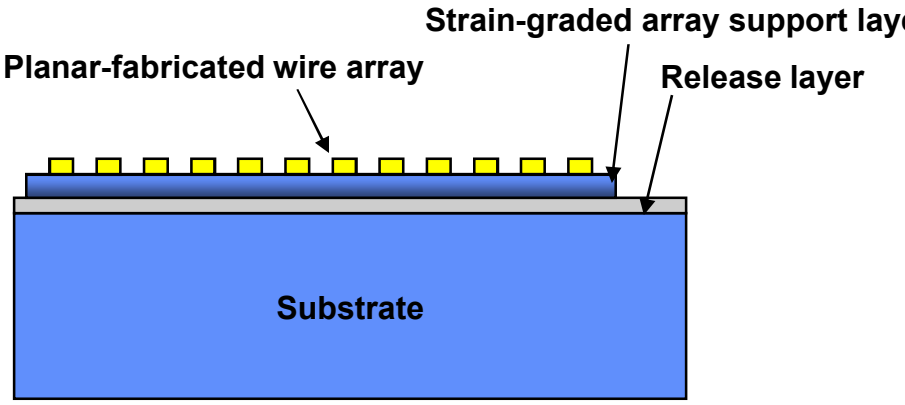
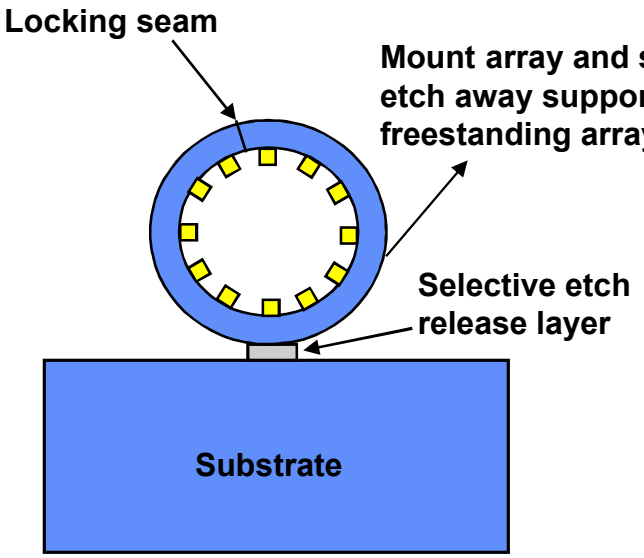
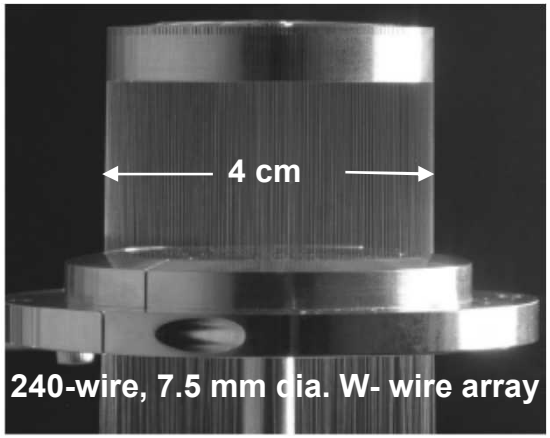
FY07 proposal: Microfabricated Z-Pinch wire arrays- A new 3-D microfabrication approach





- Manufacturable, reproducible process with inherently uniform electrical contacts to all wires
- Improved dimensional precision
- Scaling to arrays with more, finer wires for improved plasma uniformity and peak power
- Axial mass and/or composition tailoring for quasi-spherical implosions



Current Z-pinch wire array

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Challenge – Stay at the cutting edge

Strategy

— Increase Sandia's engagement in and recognition by national and international Science & Technology and Engineering communities, including universities and industry —

Approach

- Expand university partnerships (CINT, UT, …)
- Promote industry partnerships
- Increase visibility of Truman Fellowship
- Develop external communication tools to highlight Sandia STE

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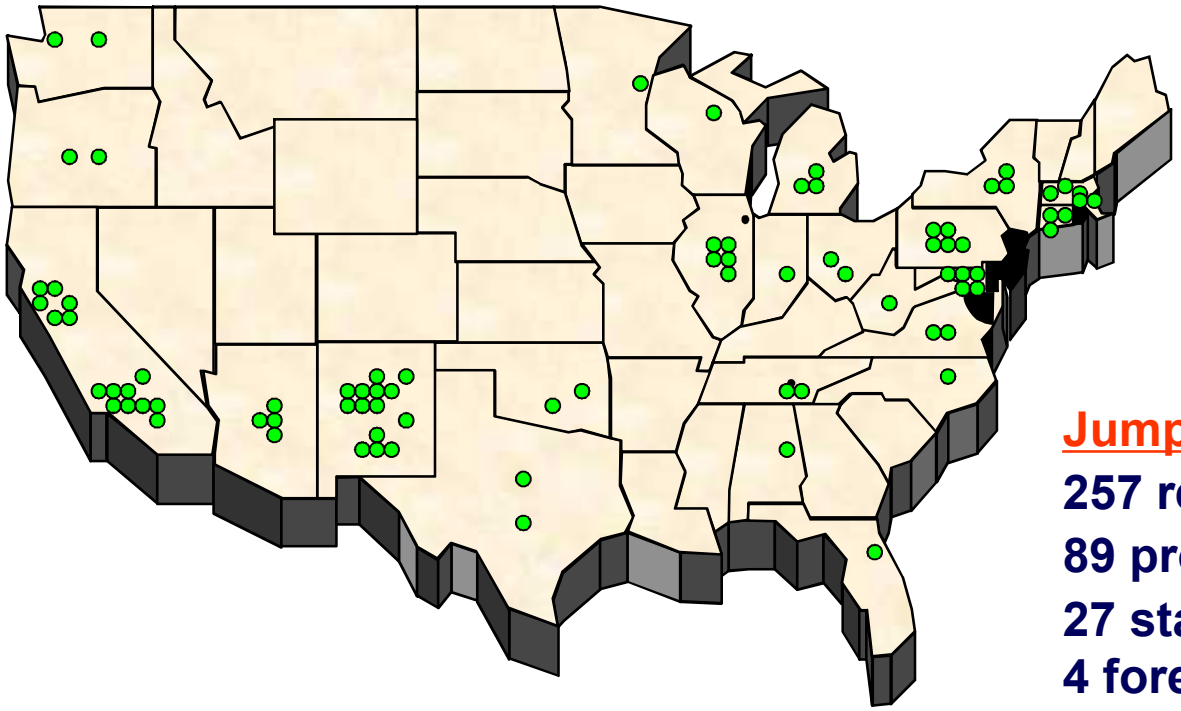
We are engaging a broad constituency through the Center for Integrated Nanotechnology



Jump-start User Projects

257 requests (2003-05)
89 projects approved
27 states
4 foreign countries
43 universities
5 private-sector
5 government labs

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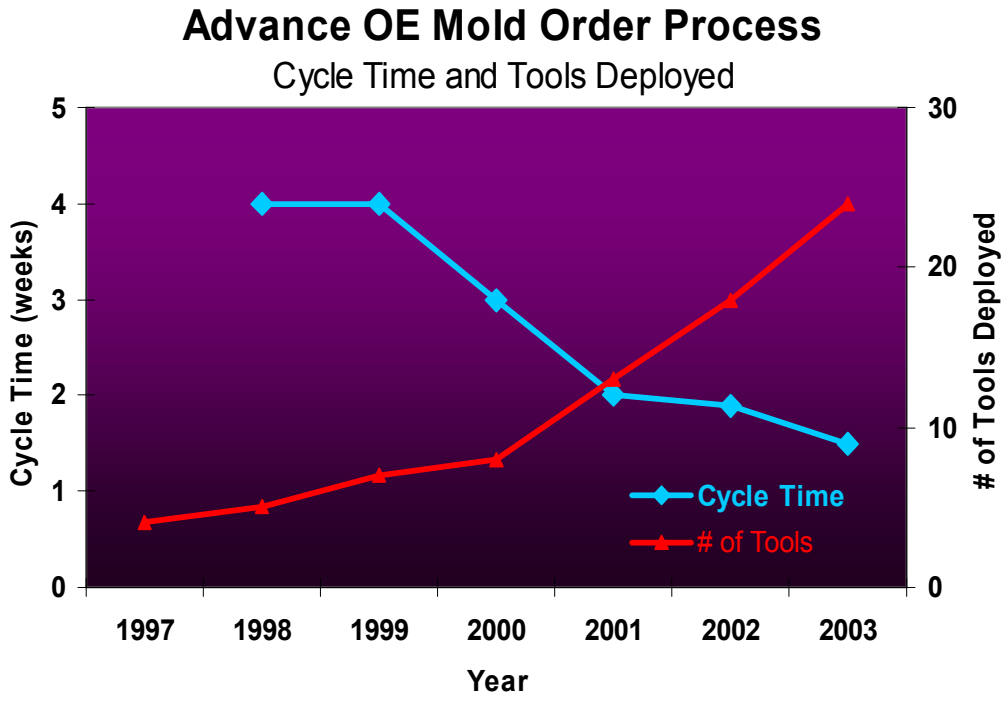
Goodyear's modeling-based innovation

2006 CIO 100 Award Winner: Goodyear designs and tests virtually.

"It has created a distinct competitive advantage for Goodyear…" – Joe Gingo (CTO)



With the deployment of more modeling, cycle time has improved.

Computer Science Research Institute Brings A New Collaboration Facility Online

… In the Sandia Science and Technology Park "where Research meets Innovation"

- Our "col-laboratory" with the world
- A meeting place for new ideas to keep our research fresh
- A resource for students and future staff
- Expands our focus on external partnerships for SNL computing R&D
- Aim is to create new customers we can jointly serve with our partners

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Challenge – Be relevant

Strategy

— Improve application of R&D to programs —

Approach

- Jointly develop key ST&E programmatic initiatives
  - GNEP (Global Nuclear Energy Partnership)
  - Waste storage
  - Bio-derived Fuels
- Provide STE Directors roles within programs

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Strategy – Anticipate the future

Strategy

— Ensure that Sandia's science and engineering is anticipating and creating the future for the laboratory —

Approach

- Use Grand Challenge LDRD to create new capabilities not currently funded by programs
- Use existing research foundation capability and LDRD to anticipate the future

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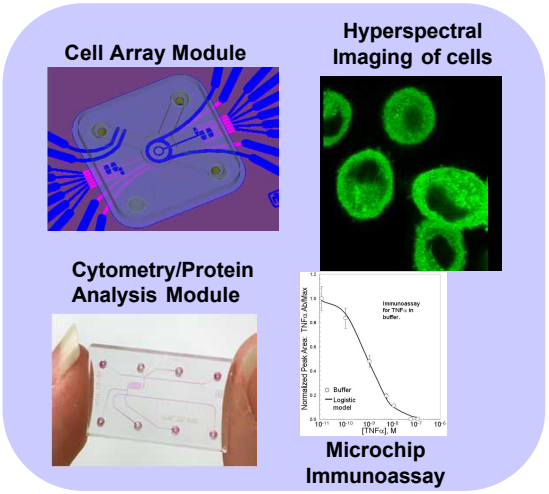
Grand Challenges: Anticipating the future



Microscale Immune Studies Laboratory

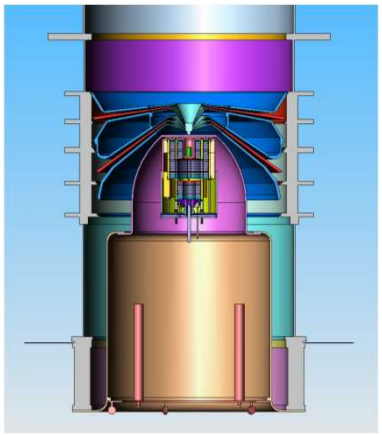
- Build a microengineered platform that integrates cell manipulation, imaging and proteomic analysis for studying molecular mechanisms of host-pathogen interaction at single cell resolution
- Joint with Univ of Texas Medical Branch and Univ of California at San Francisco

Building new capability at Sandia ….

Advanced Fusion: Neutrons for testing and energy

- Creating high energy density environments for national security and future energy applications
- Developing preliminary target designs high-yield concepts
- Interfacing with the non-proliferation community

… and avoiding technological surprise



Concept for neutron source testing machine

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Sandia responding to "Gathering Storm" and need for engineering innovation

www.sandia.gov/AEI

Intel	Harvard	RPI	DOE
Monsanto	U Florida	MIT	NNSA
Goodyear	U Michigan	Yale	LANL
Microsoft	U Wisconsin	UNM	NAE
ExxonMobil	U Illinois	UT Austin	
LMC	UC Davis	UC Santa Barbara	
IBM	Rose-Hulman		
HP	Harvey-Mudd	ORNL	

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Seven engineering themes from industry, university and government

1. Engineers need a broader education
2. Partnerships are critical to industry success
3. Foreign institutions are easier to partner with
4. Too much to teach in four years
5. Attract and retain graduates
6. Big problems and state-of-the-art facilities matter
7. Foreign government/university/industry institutes having increasing impact

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Sandia proposes to accelerate engineering innovation through Discovery Institutes

Recommendations….

- Establish Institute focused on Nano Engineering that utilizes CINT, MESA and high performance computing.
  - 200 graduate students
  - 50 industry fellows
  - 50 National Laboratory researchers
- Begin planning additional Discovery Science and Engineering Institutes across the DOE laboratories that utilize core facilities.

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In Closing

- **We must keep the creative and innovative spirit alive and well – both for current and future mission needs.**
- **We are using a strategy of driving improvements in LDRD to ensure R&D base remains vital, creative and innovative.**
- **We are increasing linkages to the national and international S&T activities to ensure we stay at the forefront of S&T.**
- **We have identified key challenges and a plan to address them.**

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