UT-BATTELLE

Role of National Laboratories in the U.S. R&D Enterprise

Presented to

Faculty, Students, and Distinguished Guests of University of Science and Technology Beijing

Jeffrey Wadsworth

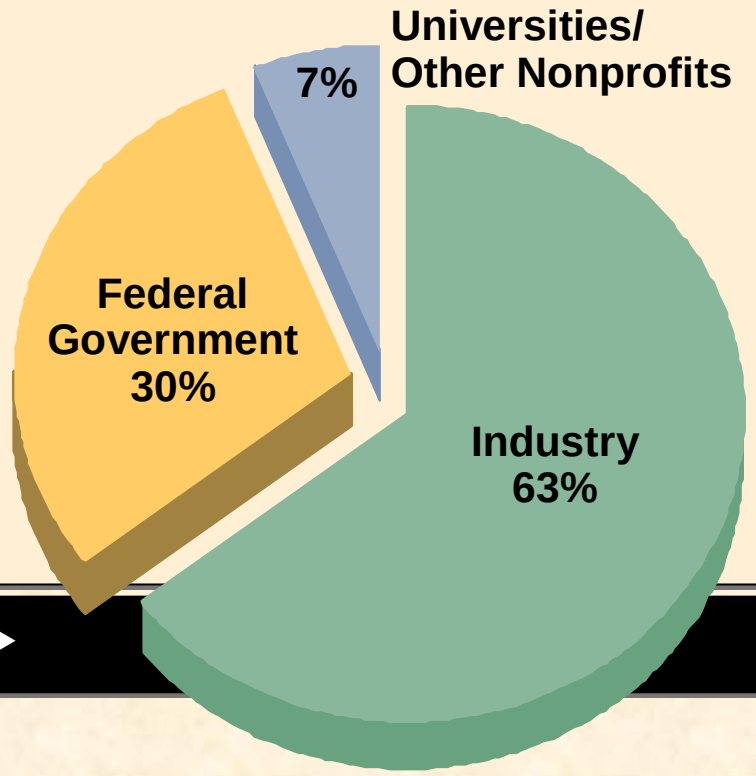
October 15, 2004
University of Science and Technology Beijing
Beijing, China

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

- 我很高兴能来到北京，并访问北京科技大学
- 非常荣幸的被聘为北科大荣誉教授

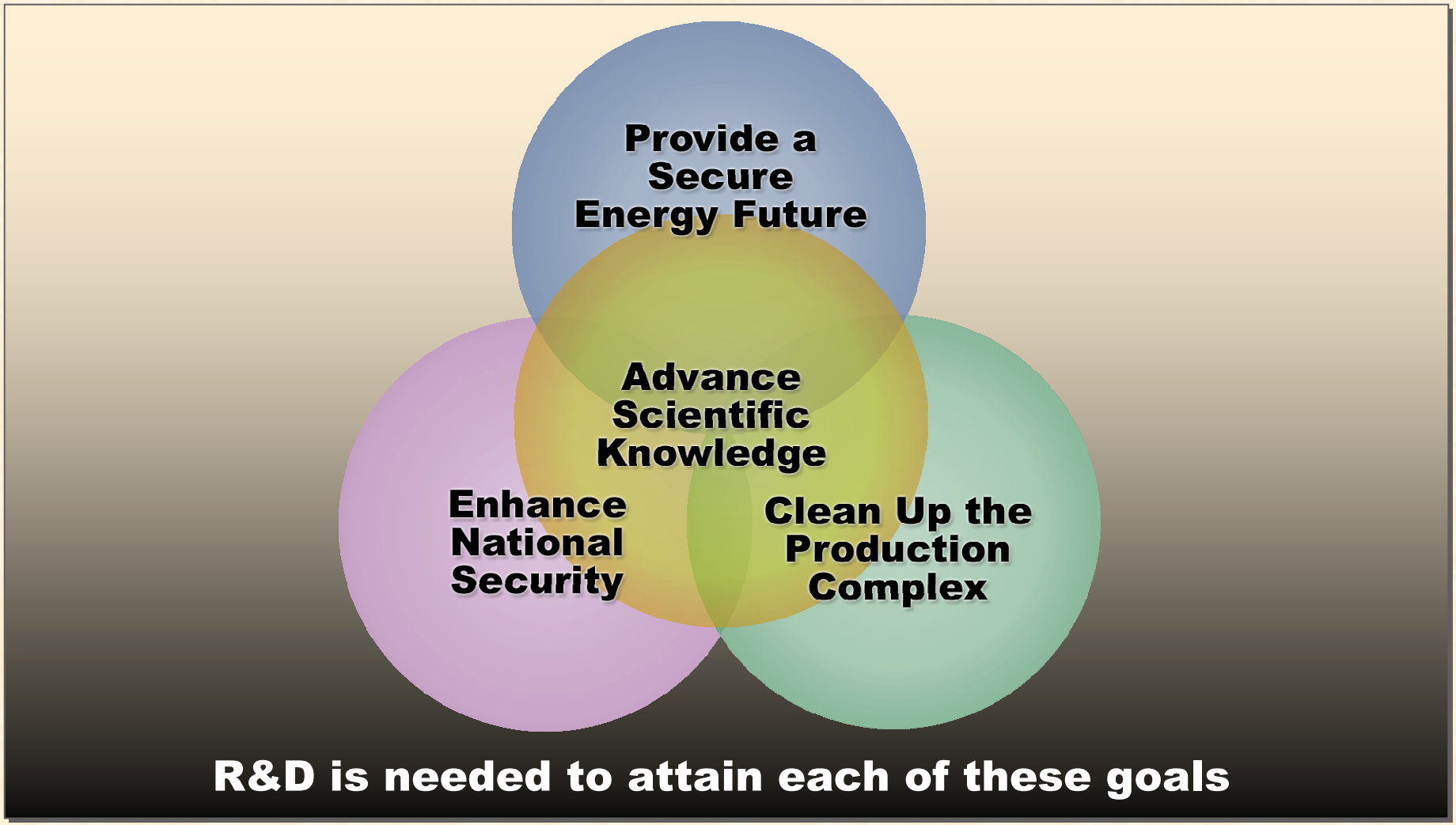
The United States invests about $300 billion a year in R&D

- The U.S. government provided $126 billion for R&D in 2004
- Government-funded R&D has grown by 40% since 2000
  - Defense
  - Homeland security
  - Medical research
  - Nanotechnology
- Government-funded research is performed by
  - Universities
  - Industry
  - Federal agencies
  - Federally funded R&D centers (including national laboratories)

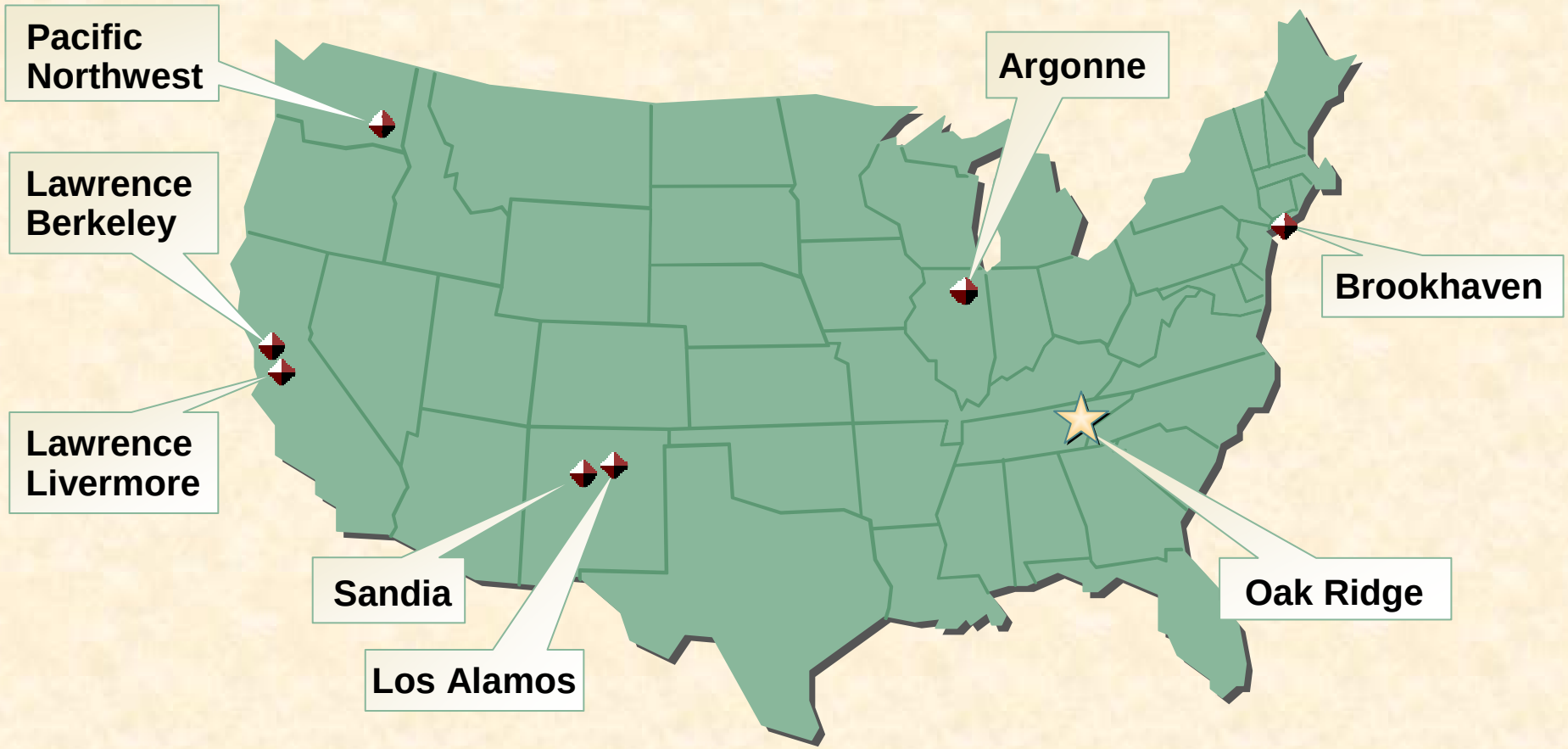


Sources of R&D funding ▶

The U.S. Department of Energy has four strategic goals

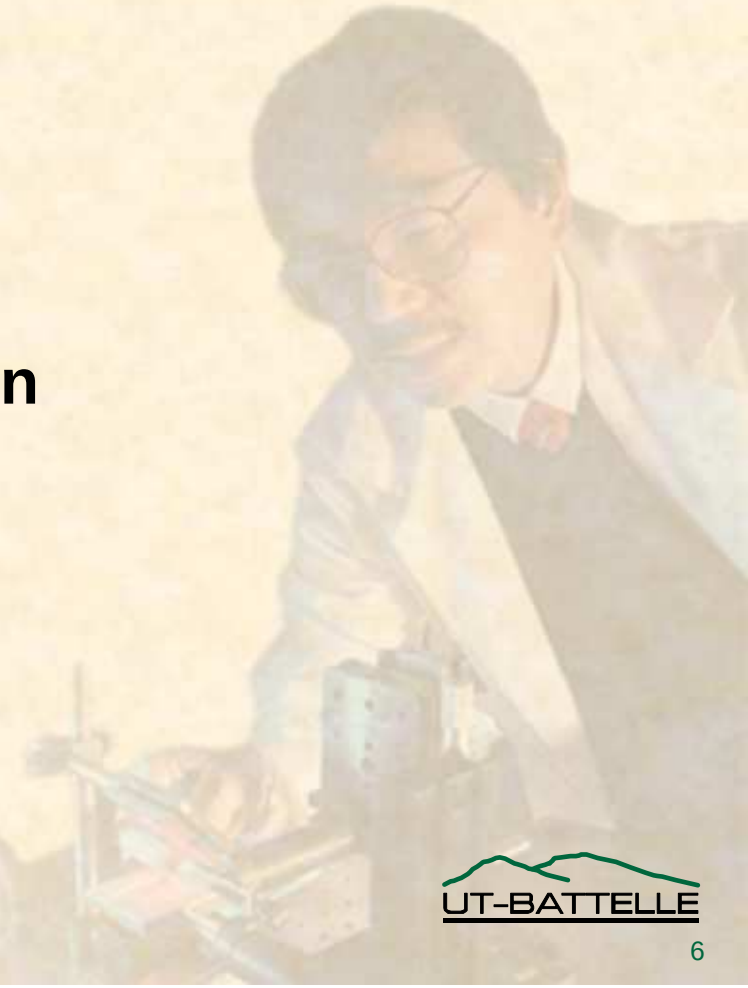


National laboratories perform R&D to meet DOE's mission needs

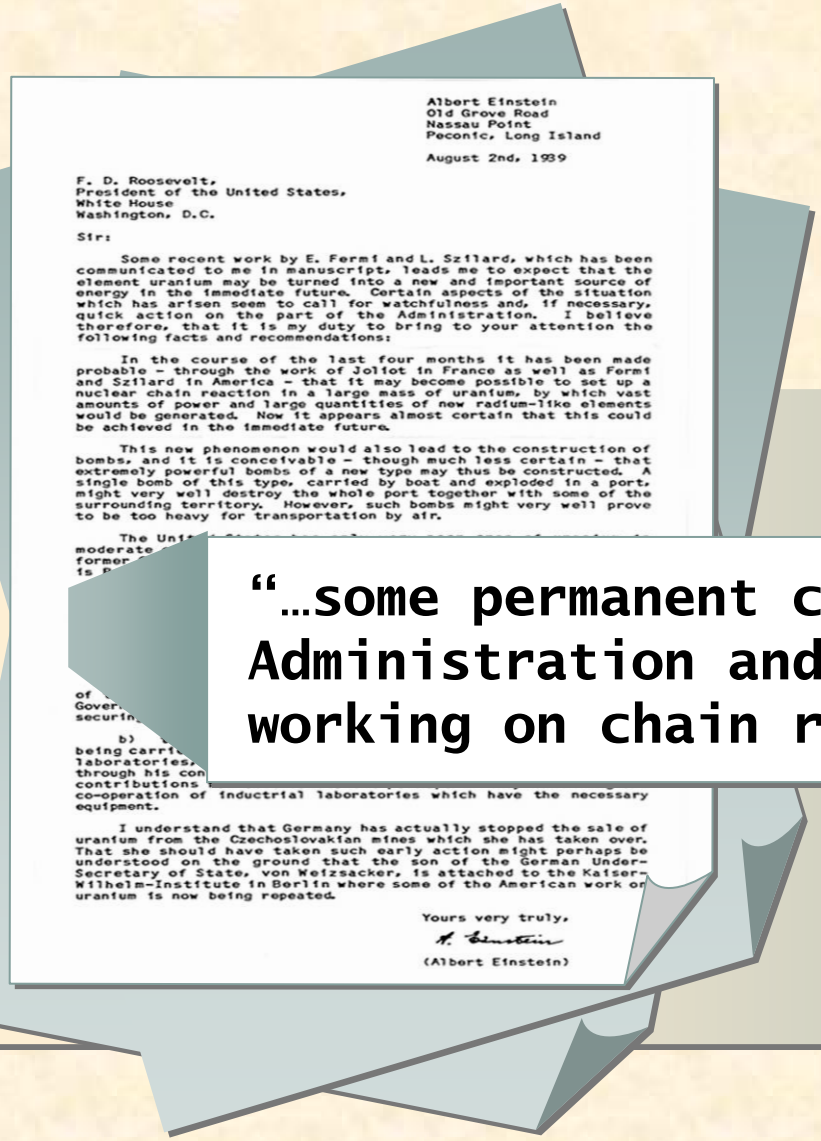


DOE national laboratories:
A flair for getting after very big and difficult matters

- **Multidisciplinary R&D to solve large-scale, long-term problems of national importance**
  - **National security**
  - **Energy**
  - **Environment**
- **Design, construction, and operation of unique research facilities and equipment**
- **Technology transfer**
- **Education**



The origin of the national laboratories: Einstein's 1939 letter to Roosevelt



Albert Einstein
Old Grove Road
Nassau Point
Peconic, Long Island

August 2nd, 1939

F. D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore, that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsacker, is attached to the Kaiser-Wilhelm-Institute in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,

(Albert Einstein)

"…some permanent contact . . . between the Administration and the group of physicists working on chain reactions"

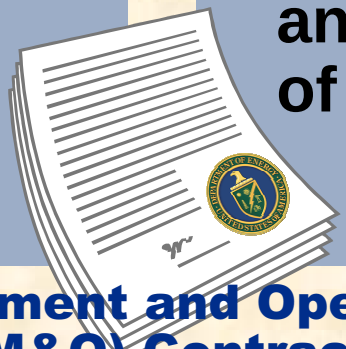
The GOCO concept

Government-owned

The national laboratories are the property of the U.S. Department of Energy

Contractor-operated

The Department of Energy contracts with the private sector for the management and operation of the laboratories



Management and Operations (M&O) Contract

Oak Ridge National Laboratory evolved from the Manhattan Project

ORNL in 1943
The Clinton Pile was the world's first continuously operated nuclear reactor

Today, ORNL is DOE's largest multipurpose science laboratory

- $1.06 billion budget
- 3,900 employees
- 3,000 research guests annually
- Nation's largest unclassified scientific computing facility

- Nation's largest science facility: the $1.4 billion Spallation Neutron Source
- Nation's largest concentration of open source materials research
- Nation's largest energy laboratory
- $300 million modernization in progress

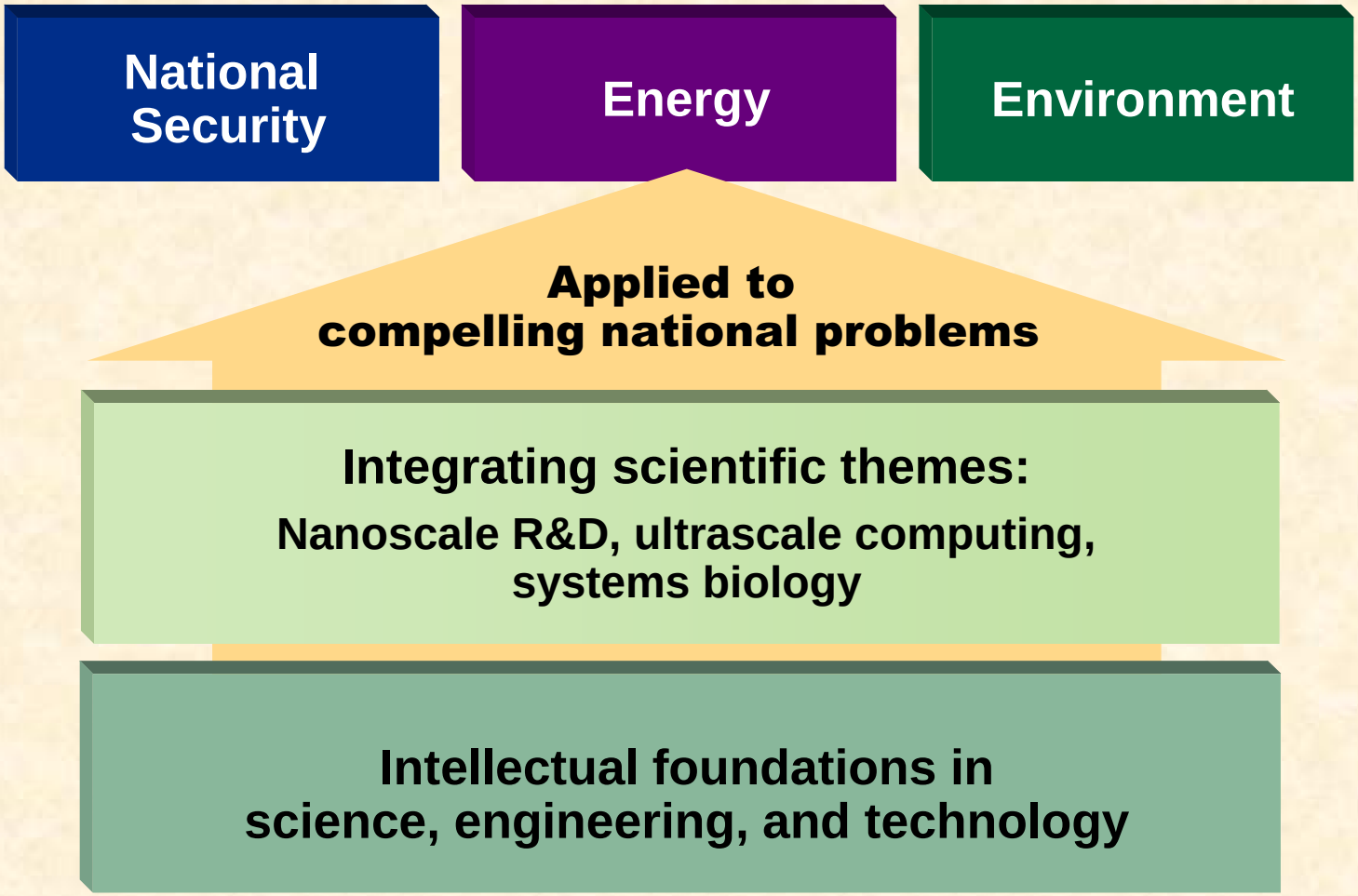
As a GOCO laboratory, ORNL is managed and operated by UT-Battelle

UT-BATTELLE
Limited Liability Company

University of Tennessee
Knoxville, Tennessee

Battelle
Columbus, Ohio

Oak Ridge National Laboratory's research framework



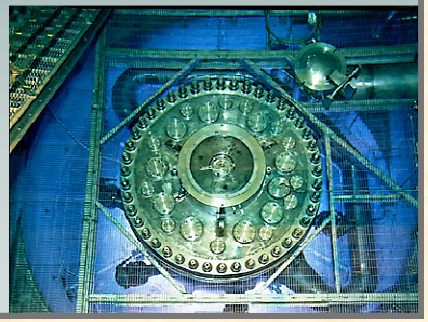
Our world-class capabilities for nanoscale R&D are coming on line

Spallation Neutron Source:

- Nation's largest science project
- On schedule, on budget, on scope — 85% complete

High Flux Isotope Reactor:

- Nation's leading research reactor
- World-class instruments installed

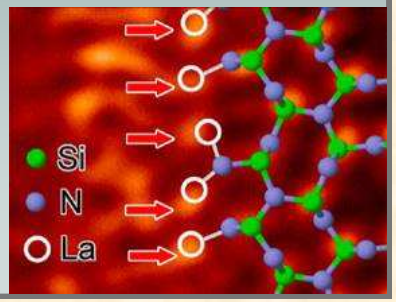


Center for Nanophase Materials Sciences

- First of five DOE-sponsored centers
- User program already under way

Ultrahigh-resolution microscopy

- New aberration-corrected electron microscope
- New Advanced Microscopy Laboratory
- New world record resolution: 0.6 Å



The Spallation Neutron Source
Total cost: $1.4 billion

- Operational in 2006
- World's most powerful pulsed spallation source
- With complementary resources at the High Flux Isotope Reactor, Oak Ridge will lead the world in neutron scattering

A vibrant environment for nanoscience research: Center for Nanophase Materials Sciences

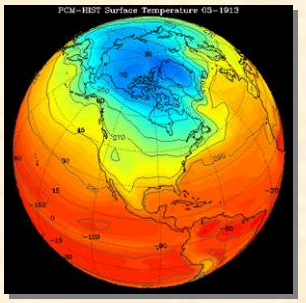
- Highly collaborative, multidisciplinary center for research and education
- State-of-the-art tools for synthesis and characterization
- Ready access to the Spallation Neutron Source and other ORNL facilities

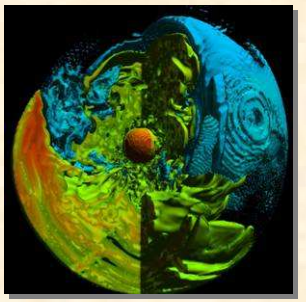
Technical focus areas

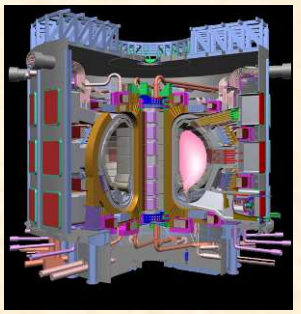
- Macromolecular materials
- Functional nanomaterials
- Catalysis
- Nanoscale magnetism and transport
- Theory, modeling, and simulation

We are at the forefront in computing and simulation

- Computing is essential to addressing major scientific challenges
- We lead DOE's effort to regain and retain U.S. leadership in this vitally important area
- Our goal is to bring the world's most powerful computer to Oak Ridge
  - To solve problems that cannot be solved experimentally
  - To solve problems that are too expensive to solve experimentally
  - To accelerate discovery as nano meets simulation





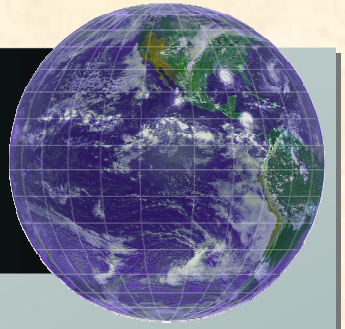


National Leadership Computing Facility

May 12, 2004

We are building momentum in systems biology

Challenge: Integrate biology and ecology based on the foundation of understanding molecular-level interactions



- Identify the composition and function of “molecular machines”
- Use biological processes to
  - Produce clean energy
  - Sequester carbon
  - Help clean up the environment
- Understand how living organisms react to their environments
- Determine the genetic basis for complex traits

We are applying our S&T resources to national and homeland security

- Detecting, preventing, and reversing the proliferation of weapons of mass destruction
- Deploying integrated systems for incident awareness, detection, and response
- Providing technology for detecting explosives at the part-per-trillion level
- Delivering enhanced protection and new capabilities to first responders and warfighters

We are meeting the energy challenges of the present and the future

Generation	Distribution	Consumption
Fossil Fission Renewables Fusion	Transmission technology Hydrogen Distributed energy resources	Buildings Industry Transportation
		

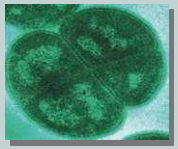
Supporting DOE's strategic goals for energy security and independence

We are developing resources to solve environmental problems

Climate change
- Ecosystem and carbon cycle experiments
- Computational climate science

Environmental remediation
- Microbial biology and ecology
- Bioremediation

Air quality
- Atmospheric chemistry
- Ecosystem science
- Environmental data systems
- Technology solutions



Ecosystem change detection and forecasting

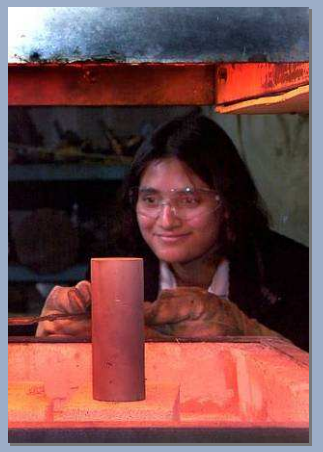
- Genomics-based approaches to understanding ecosystem responses
- Methods and sensors for identifying and measuring ecosystem changes
- Simulation and visualization to address interactions of nature and society

We operate user facilities that serve an international research community

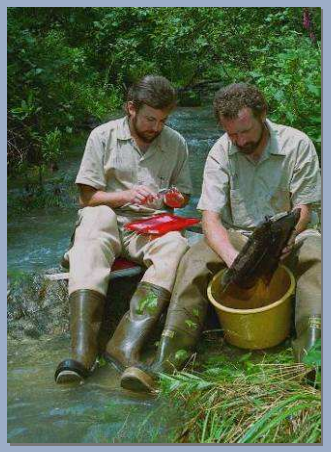
Buildings Technology Center

High Flux Isotope Reactor

High Temperature Materials Laboratory



Metals Processing Laboratory User Center



National Environmental Research Park

Providing access to unique and expensive tools and facilities for cutting-edge research

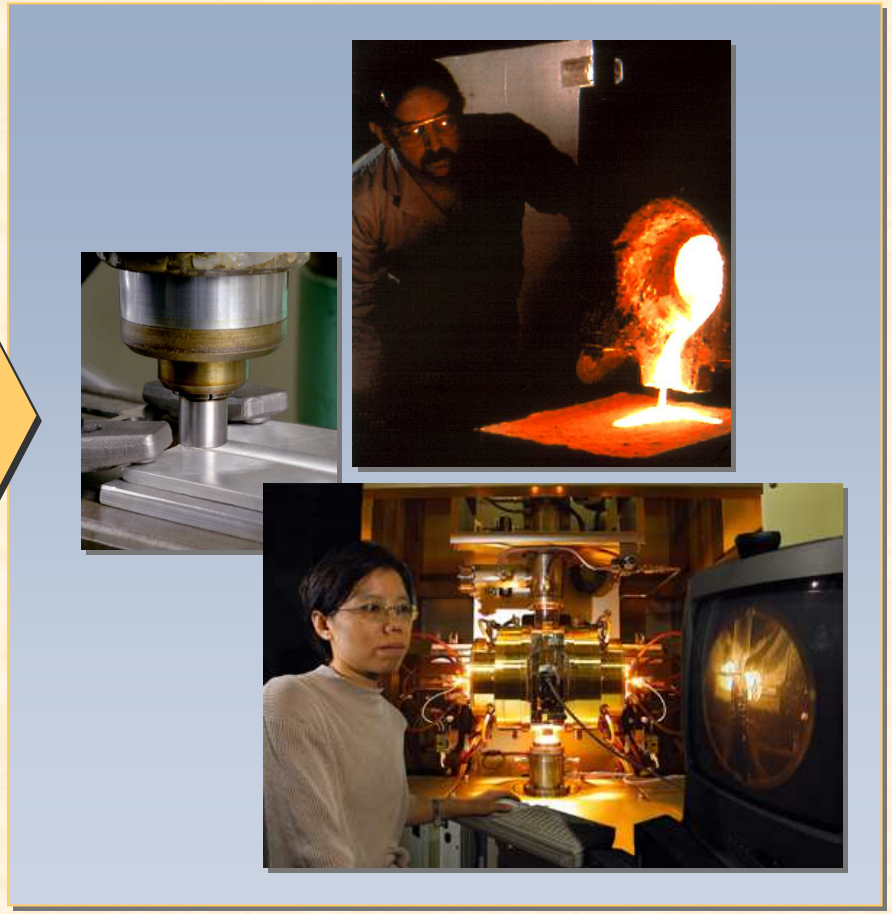
Sophisticated tools and facilities for materials synthesis, processing, and joining

Metals and alloys

- Melting
- Casting
- Welding
- Extrusion

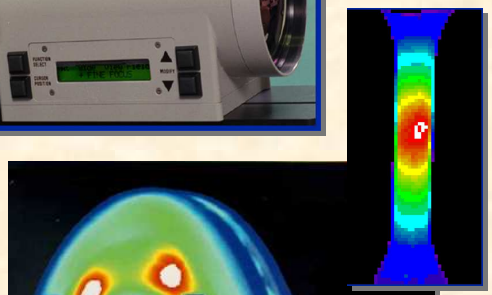
Ceramics

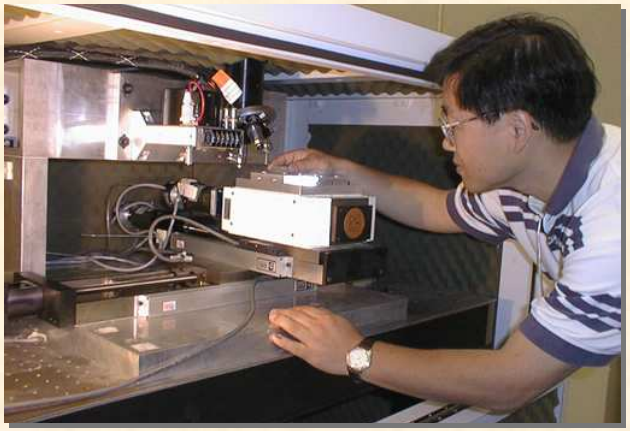
- Molecular beam epitaxy
- Microwaves
- Chemical vapor infiltration/deposition
- Gelcasting

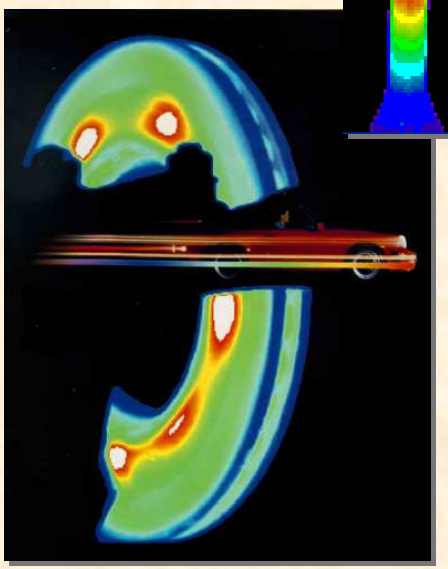


Sophisticated tools and facilities for determining physical and mechanical properties

- Infrared imaging
- Nanoindentation
- Ceramic machining
- Vacuum fatigue testing

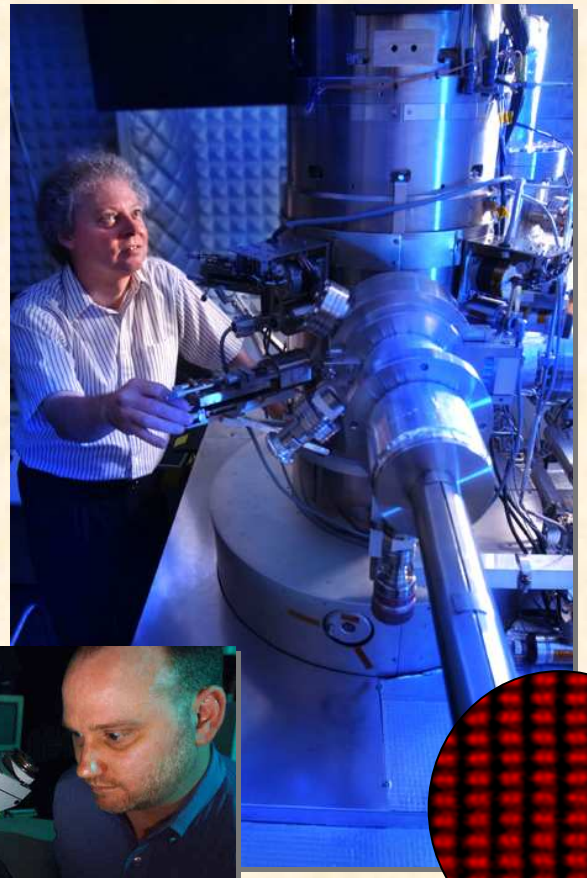


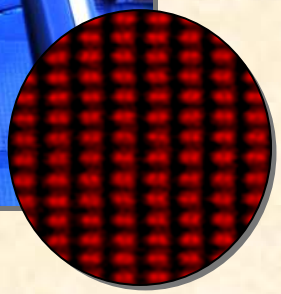




Sophisticated tools and facilities for determining structure

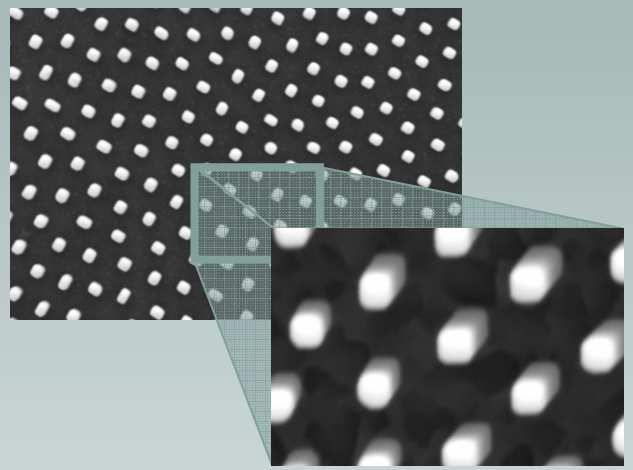
- Sub-angstrom-resolution microscopy
- Neutron scattering
- Synchrotron X-ray scattering
- Residual stress determination



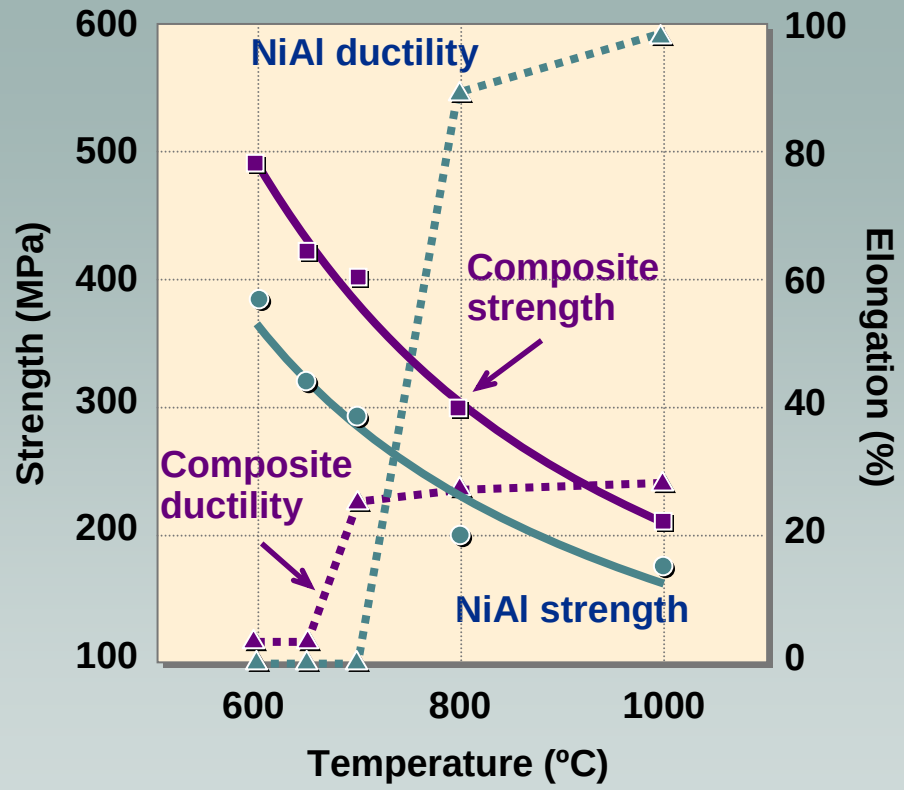


Microstructured and nanostructured materials: Mechanical behavior

Well-aligned, directionally solidified nanocomposites: Mo fibers in NiAl matrix



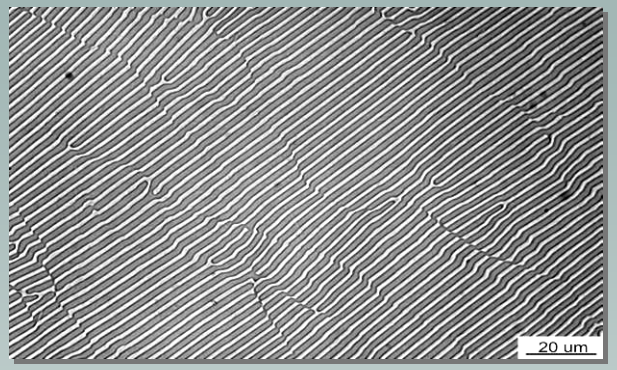
H. Bei, E. P. George, G. M. Pharr
ORNL and University of Tennessee



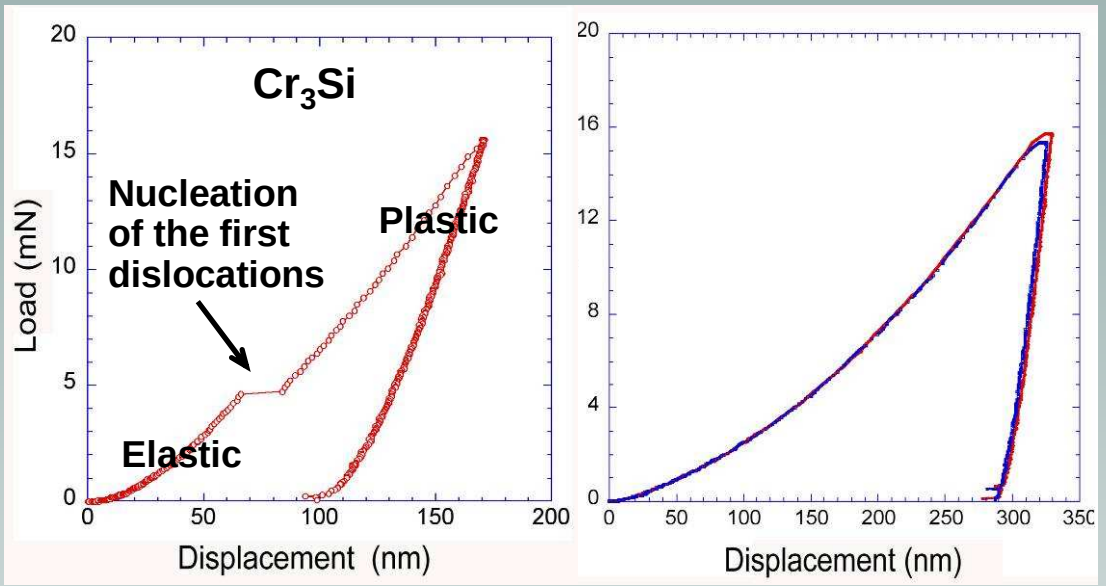
NiAl-Mo composite has higher strength and lower DBTT than NiAl matrix

Microstructured and nanostructured materials: Mechanical behavior

Well-aligned, directionally solidified nanocomposites: Cr-Cr_3Si



Cr-Cr_3Si lamellae

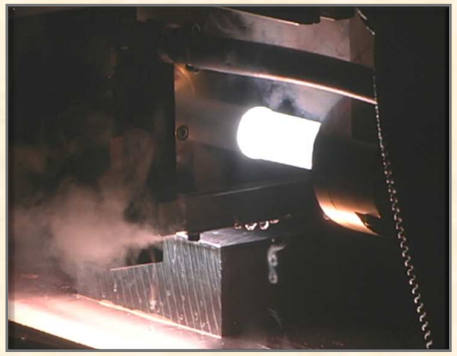


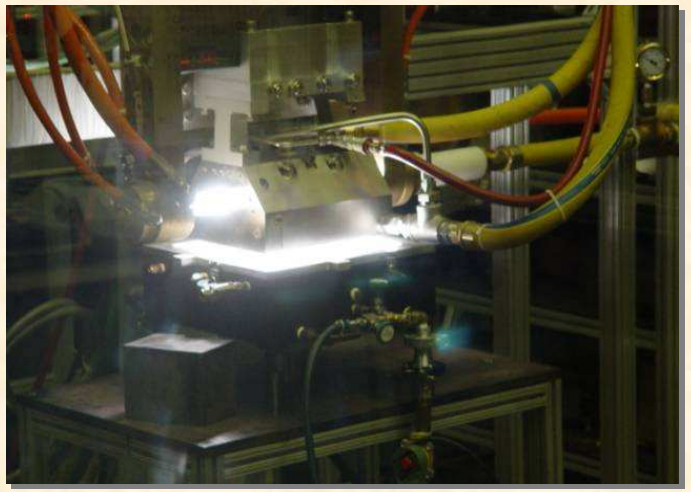
Nanoindentation of individual lamellae

	Cr_3Si	Cr
Hardness (GPa)	21.6	5.2
Modulus (GPa)	369	269

Pulse thermal processing of functional nanomaterials

- **Unique high-density infrared plasma arc lamp**
  - **World's most powerful radiant arc lamp**
- **Broad area processing**
- **Rapid heating to high temperatures**
  - **Allows controlled diffusion on nanometer scale**
- **Millisecond pulses**
- **Minimal thermal effects to substrate**
  - **Supports processing on polymers**





750,000-W uniform irradiance processing facility

Pulse thermal processing:
An enabling tool for broad-area nanoscale processing

- Sintering of nanoparticles for photovoltaic applications
- Phase change for magnetic storage media applications
  - FePt nanoparticles
  - NiMn
  - PtMn

TiO_2 nanoparticles (~35 nm) sintered on a polymer substrate for a photovoltaic application [0.7-s processing at ORNL]

Flexible solar modules

Philips flexible display

Potential for advancing many nanoparticle and thin-film technologies

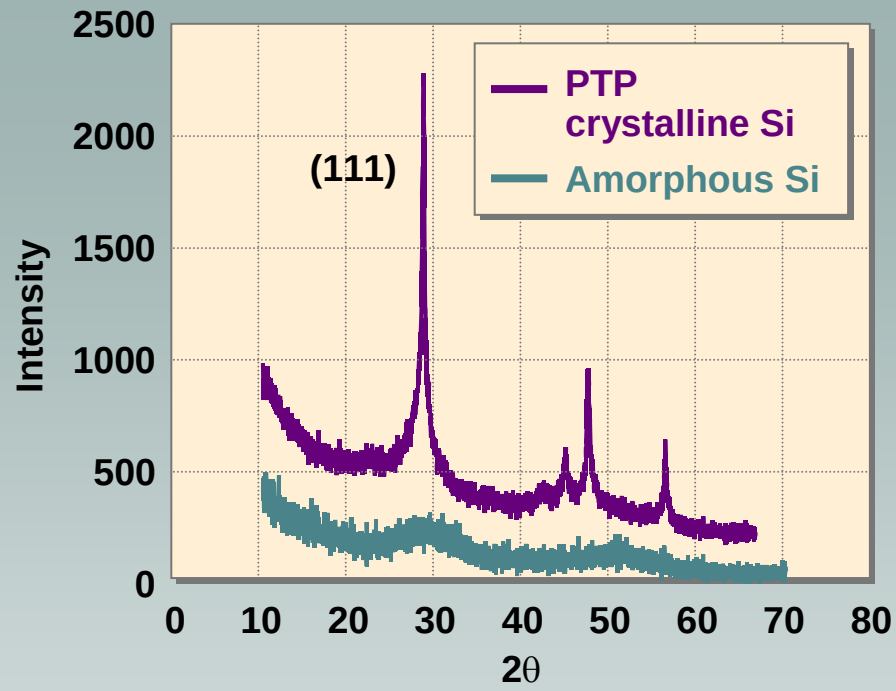
Pulse thermal processing:
An enabling tool for broad-area nanoscale processing

Crystallization of amorphous material

- α-Si for photovoltaic and thin-film transistor (TFT) applications
- Rapid heating rates produce fine grains with narrow grain size distributions

"We are standing at the beginning of the industrialization of flexible TFT backplanes"

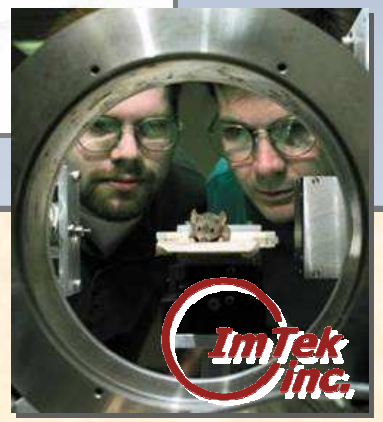
– Sigurd Wagner, Princeton University



Peak at 28.44° 2θ indicates formation of small Si crystallites (~100 nm) with majority (111) orientation [0.5-s processing at ORNL]

We partner with industry to put ORNL innovations to work

- Collaborative R&D agreements
- Creation and growth of businesses based on ORNL technologies
- Venture capital relationships
- Aggressive outreach



TECH 2020

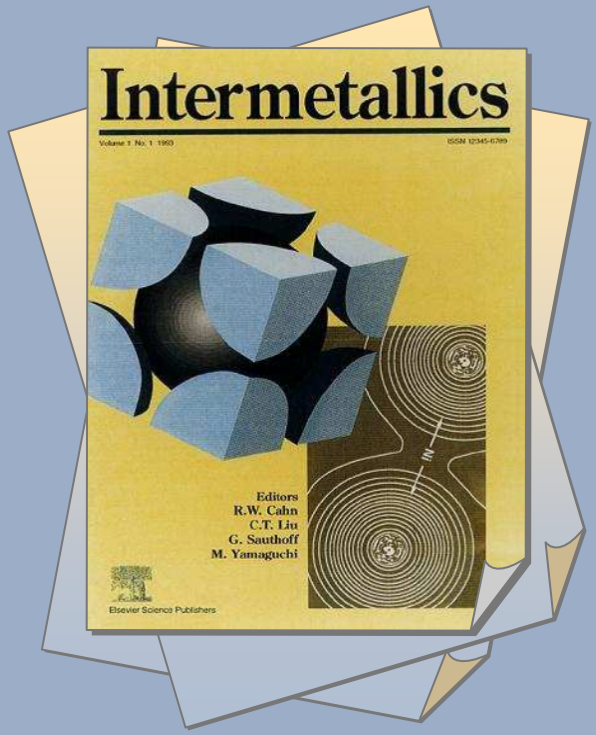
Since April 2000:

- 43 new companies
- $10 million investment
- $15 million in revenues
- 200 new jobs

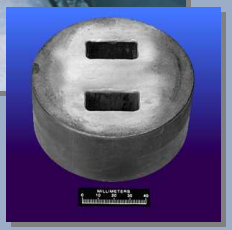
Putting ORNL innovations to work:
Ductile nickel aluminide intermetallics

1981: ORNL starts work to improve the ductility of Ni_3Al

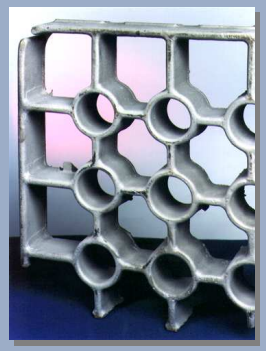
New subfield of alloy science



Wide range of industrial products



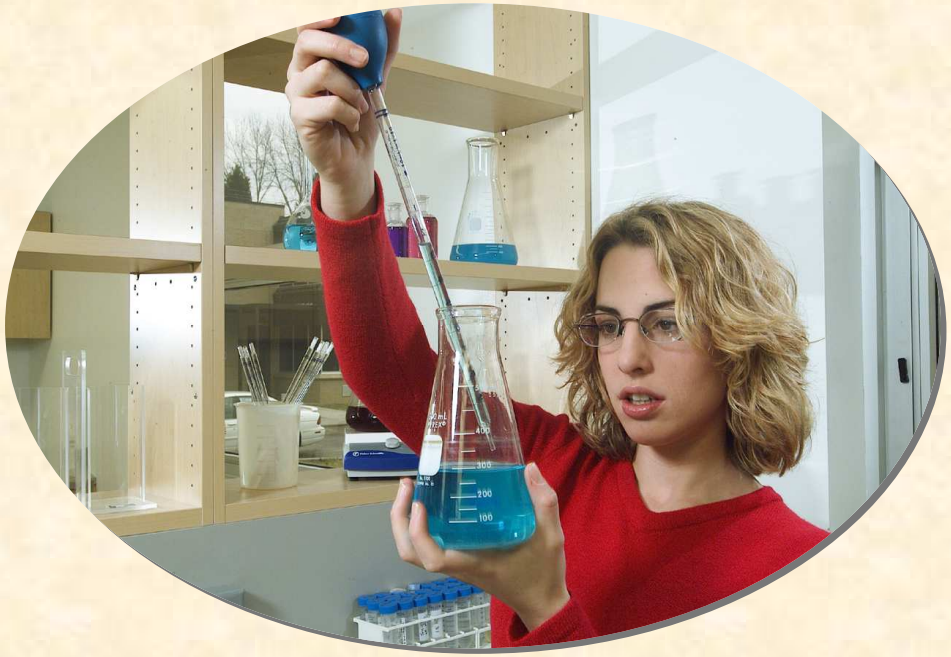
Magnet die
(Magnequench)



Furnace tray
(GM)

We use our resources to support science education

- University partnerships
- Student and faculty research programs
- Scholarships
- Support for science education in the community




• 谢谢北科大赠与的荣誉
• 希望能有机会在像树岭国家研究院接待诸位