

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



- 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

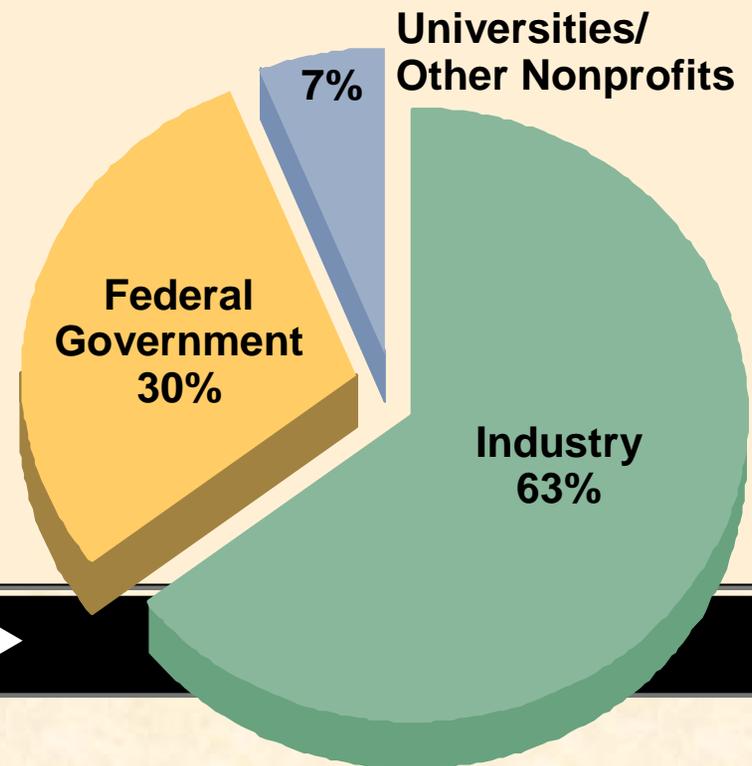
OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

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UT-BATTELLE

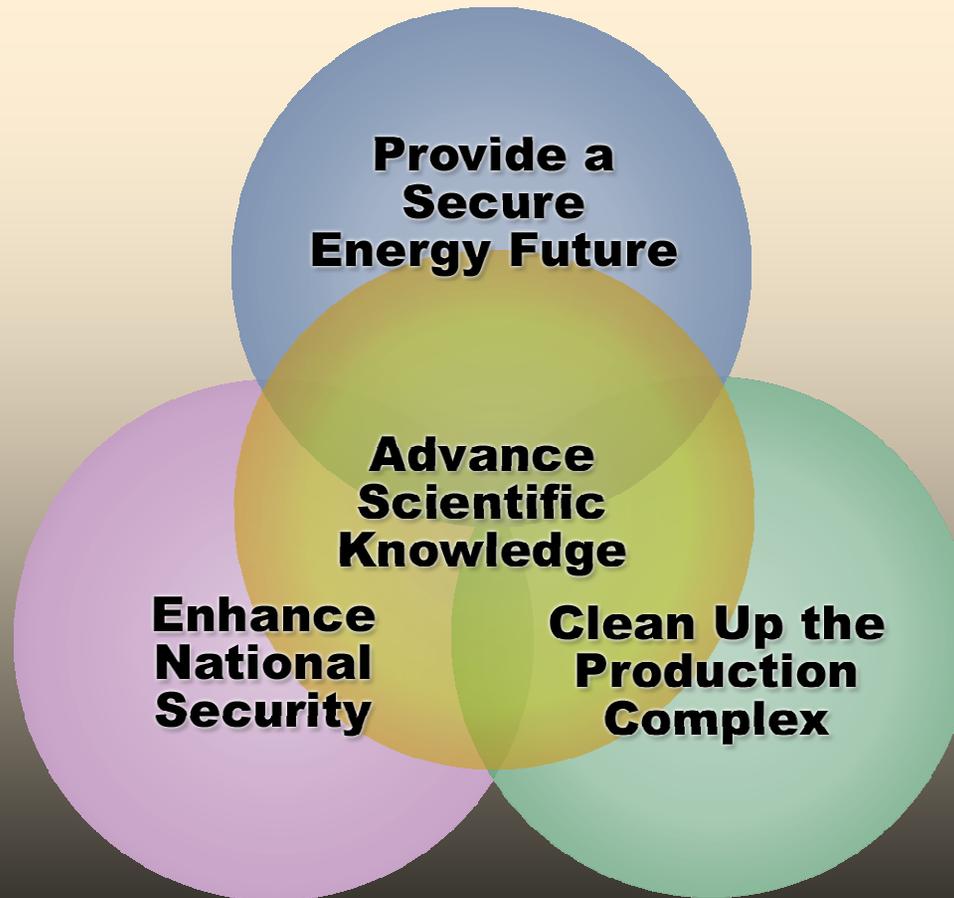
The United States invests about \$300 billion a year in R&D

- 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)



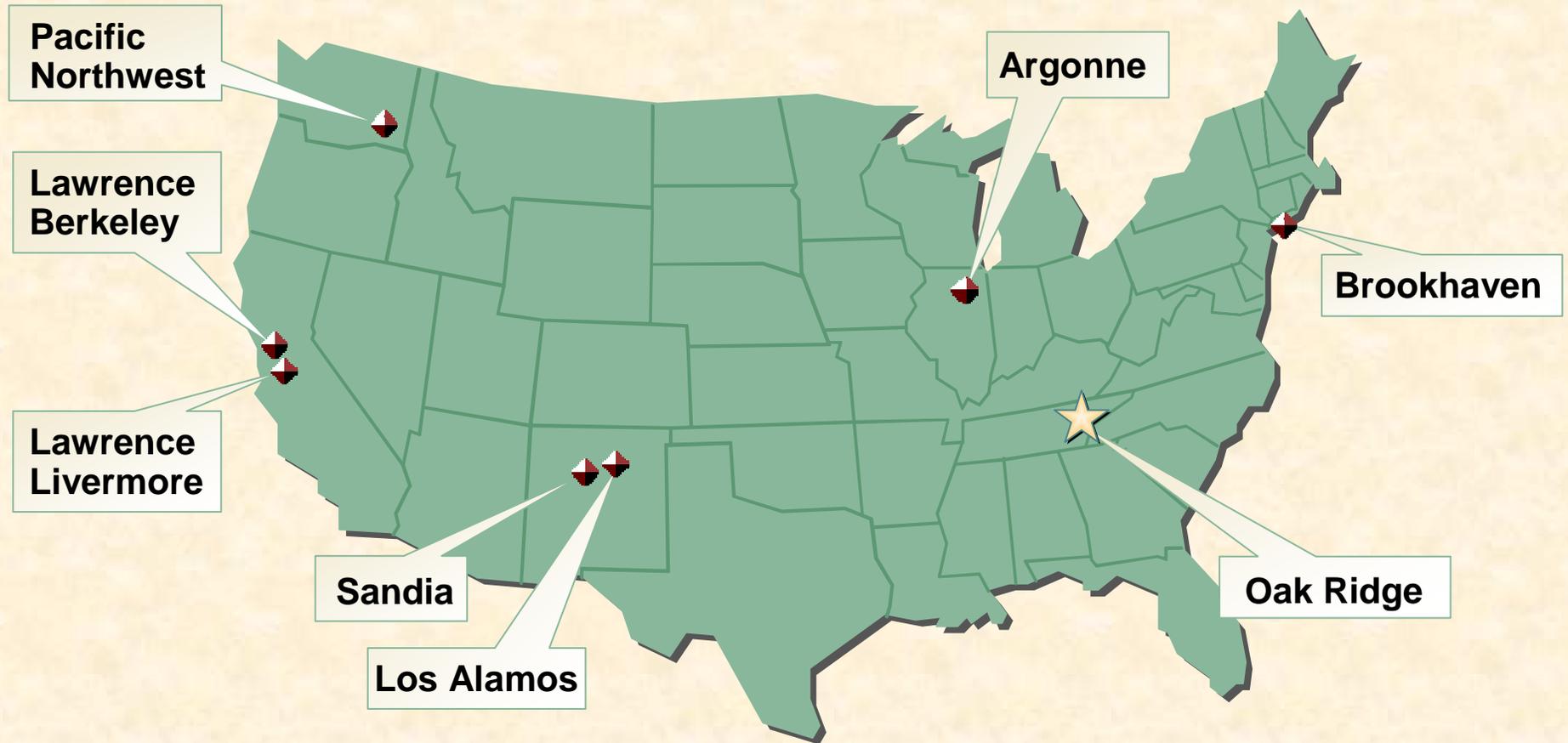
Sources of R&D funding ►

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



R&D is needed to attain each of these goals

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



OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY



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**

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The logo for UT-Battelle, featuring a stylized green mountain range above the text "UT-BATTELLE" in a bold, black, sans-serif font.

UT-BATTELLE

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.

The United States is now in a position to manufacture moderate quantities of uranium, and it is possible that the former is being used for the purpose of producing plutonium.

“...some permanent contact . . . between the Administration and the group of physicists working on chain reactions”

of the Government, and the securing of the necessary equipment.

b) It is suggested that the Government should be carried out in the laboratories, through his contributions, 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,
A. Einstein
(Albert Einstein)

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**

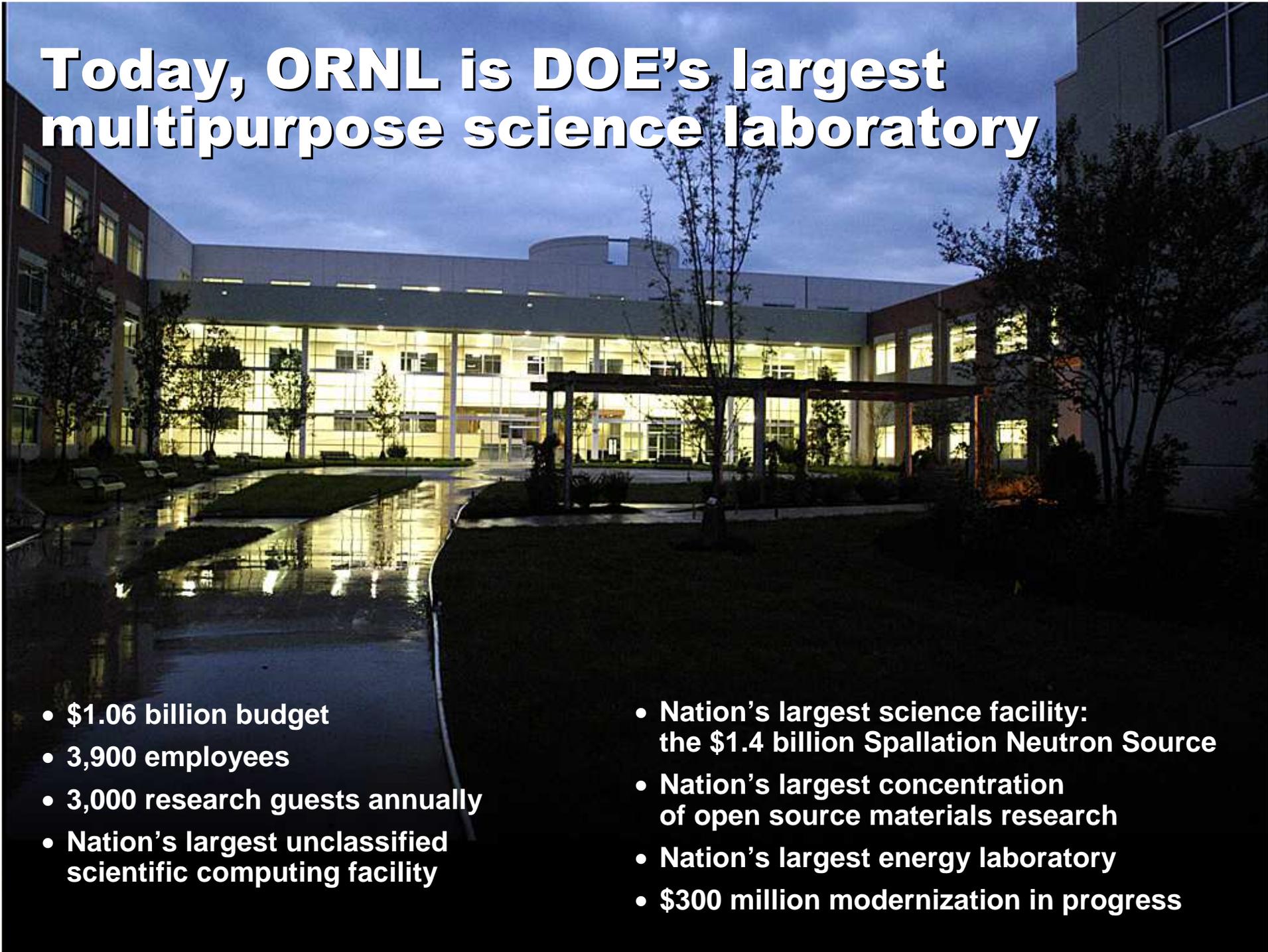
Oak Ridge National Laboratory evolved from the Manhattan Project



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

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

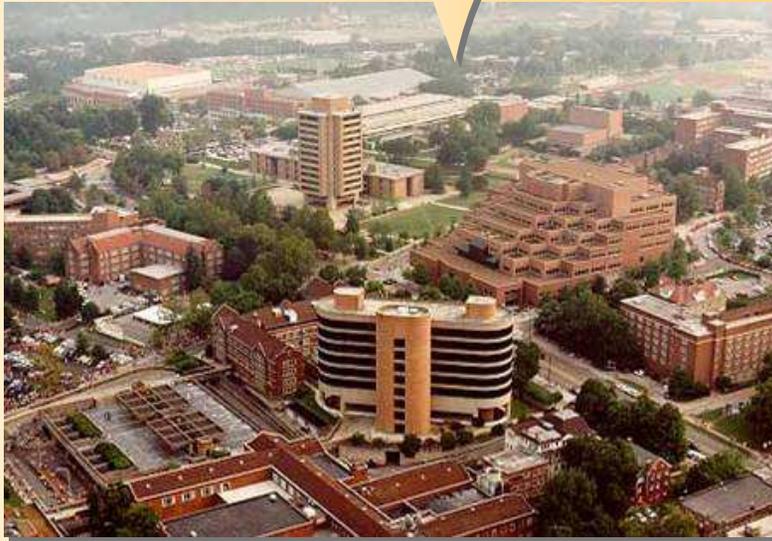
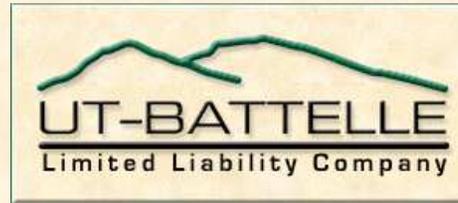

UT-BATTELLE



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



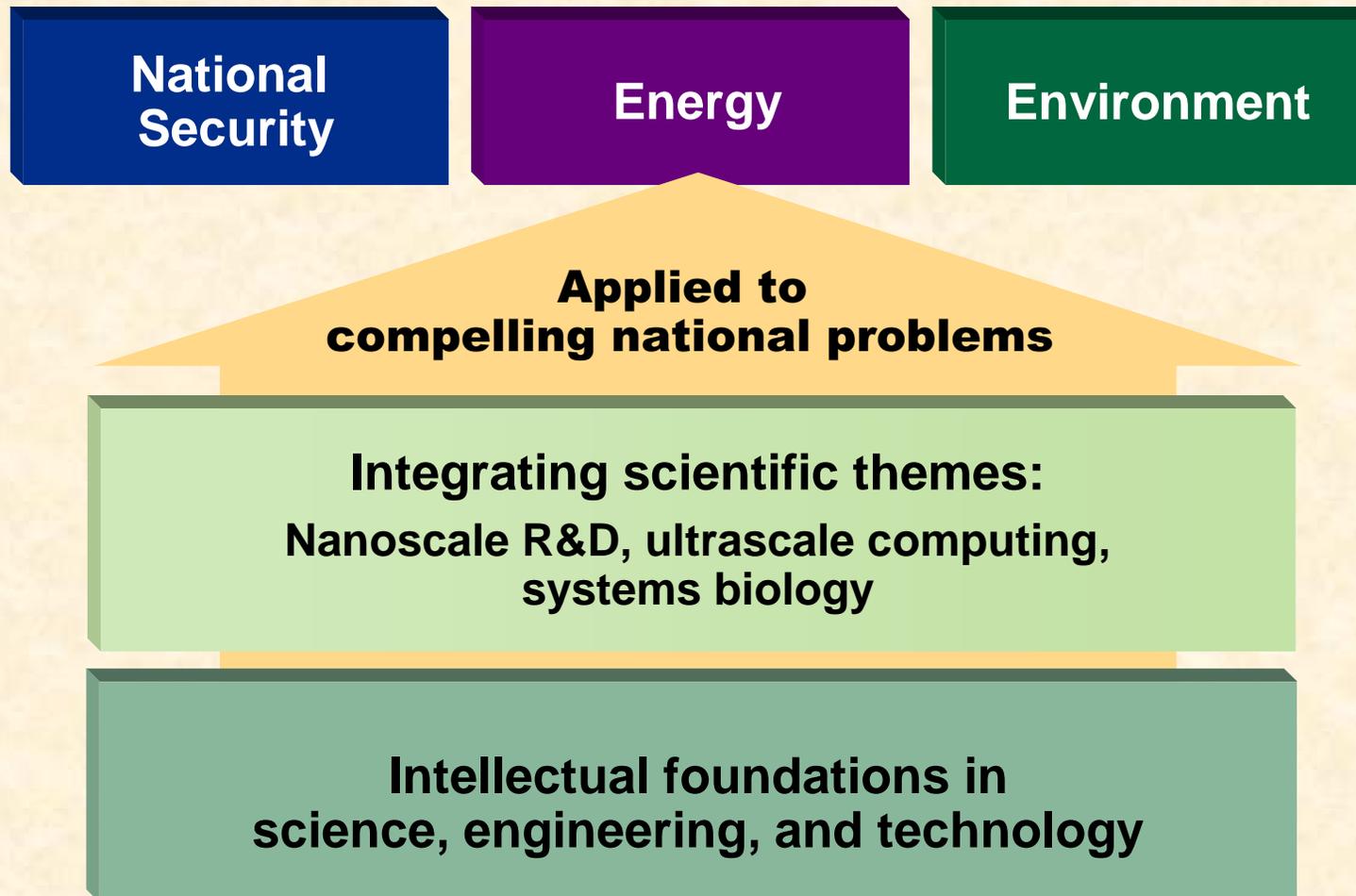
University of Tennessee
Knoxville, Tennessee



Battelle
Columbus, Ohio

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Oak Ridge National Laboratory's research framework



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

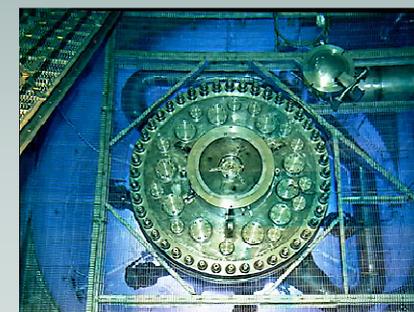
Spallation Neutron Source:

- 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



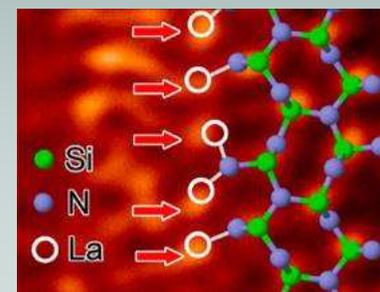
Center for Nanophase Materials Sciences

- 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

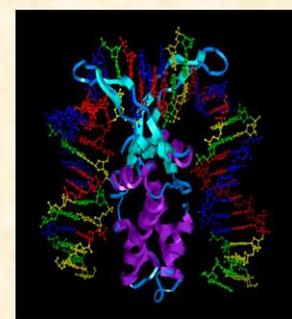
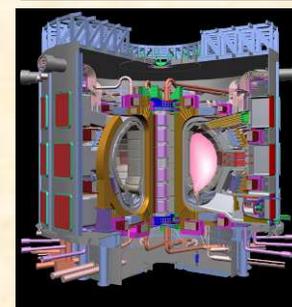
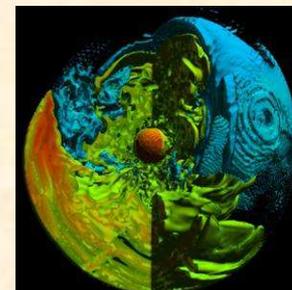
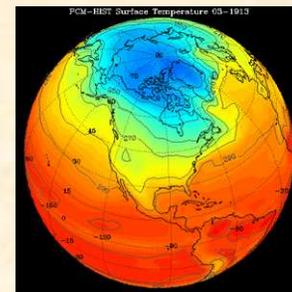


OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY



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



THIS WEEKEND IN RESERVE

16W.COM

Oak Ridge gets super win

"Feeds spark high-end computing resurgence"

By Tom Ichniowski
OAK RIDGE, Tenn. — Oak Ridge National Laboratory's new leadership computing facility is a major milestone in the nation's effort to become a global leader in high-performance computing. The facility, which is the largest and most powerful supercomputer in the world, is expected to be completed in 2005. It will be capable of performing 1.1 quadrillion operations per second, or 1.1 petaflops. This is a significant increase from the current world record of 369 teraflops, set by the Earth Simulator in Japan. The facility will be used for a wide range of scientific and engineering applications, including climate modeling, materials science, and nuclear energy research. It will also be used for national security and defense research. The facility is a testament to the leadership of the U.S. Department of Energy and the Oak Ridge National Laboratory in the field of high-performance computing.

CNN

U.S. Moves to Build Top Supercomputer

By Tom Ichniowski
WASHINGTON, May 12, 2004 — The U.S. Department of Energy has announced plans to build the world's fastest supercomputer, a project that will cost \$250 million. The computer, which is expected to be completed in 2005, will be capable of performing 1.1 quadrillion operations per second, or 1.1 petaflops. This is a significant increase from the current world record of 369 teraflops, set by the Earth Simulator in Japan. The facility will be used for a wide range of scientific and engineering applications, including climate modeling, materials science, and nuclear energy research. It will also be used for national security and defense research. The facility is a testament to the leadership of the U.S. Department of Energy and the Oak Ridge National Laboratory in the field of high-performance computing.

ITmedia NEWS

U.S. Energy Dept. Awards \$250M Grant for Supercomputer Build

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ComputerWeekly

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COMPUTERWORLD

Energy Department Grant Spurs Work on Supercomputer

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BusinessWeek

Where No Computer Has Gone Before

By Tom Ichniowski
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News Tech News

U.S. to Build Civilian Supercomputer

By Tom Ichniowski
WASHINGTON, May 12, 2004 — The U.S. Department of Energy has announced plans to build the world's fastest supercomputer, a project that will cost \$250 million. The computer, which is expected to be completed in 2005, will be capable of performing 1.1 quadrillion operations per second, or 1.1 petaflops. This is a significant increase from the current world record of 369 teraflops, set by the Earth Simulator in Japan. The facility will be used for a wide range of scientific and engineering applications, including climate modeling, materials science, and nuclear energy research. It will also be used for national security and defense research. The facility is a testament to the leadership of the U.S. Department of Energy and the Oak Ridge National Laboratory in the field of high-performance computing.

The Atlanta Journal-Constitution

Computer to be more than a bit faster

By Tom Ichniowski
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Uncle Sam Wants World's Fastest Computer

Hunt To Surpass Japanese Supercomputer

By Tom Ichniowski
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TechWeb

Tennessee is a Rising Star in Supercomputing

By Tom Ichniowski
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WASHINGTON TECHNOLOGY

DOE Orders World's Fastest Supercomputer

By Tom Ichniowski
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San Francisco Chronicle

U.S. Government Moves to Build World's Fastest Civilian Computer

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矽谷科技

全球最快速民用科研電腦

由橡樹嶺國家實驗室 (Oak Ridge National Laboratory) 興建全球最快速的民用科研電腦，備受矽谷科技界矚目。該電腦將由美國能源部資助，預計於 2005 年完工。這台電腦將具有 1.1 萬億次浮點數運算能力，將是目前的全球紀錄保持者——日本地球模擬器 (Earth Simulator) 的三倍。這台電腦將用於廣泛的科學和工程應用，包括氣候建模、材料科學和核能研究。它也將用於國家安全和國防研究。這台電腦是美國能源部和橡樹嶺國家實驗室在高性能計算領域領導地位的體現。

GLOBEANDMAIL.COM

U.S. Aims to Regain Computer Speed Lead

By Tom Ichniowski
WASHINGTON, May 12, 2004 — The U.S. Department of Energy has announced plans to build the world's fastest supercomputer, a project that will cost \$250 million. The computer, which is expected to be completed in 2005, will be capable of performing 1.1 quadrillion operations per second, or 1.1 petaflops. This is a significant increase from the current world record of 369 teraflops, set by the Earth Simulator in Japan. The facility will be used for a wide range of scientific and engineering applications, including climate modeling, materials science, and nuclear energy research. It will also be used for national security and defense research. The facility is a testament to the leadership of the U.S. Department of Energy and the Oak Ridge National Laboratory in the field of high-performance computing.

DOE Leadership-Class Computing Capability for Science will be Developed at Oak Ridge National Laboratory

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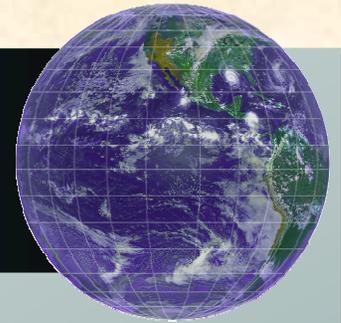
CENTER FOR COMPUTATIONAL SCIENCES
OAK RIDGE NATIONAL LABORATORY

Office of Science
U.S. DEPARTMENT OF ENERGY

We are building momentum in systems biology

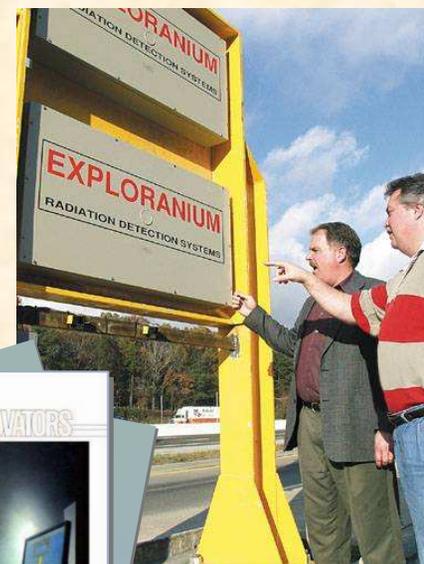
Challenge: Integrate biology and ecology based on the foundation of understanding molecular-level interactions

- 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
<p data-bbox="304 495 619 771">Fossil Fission Renewables Fusion</p> 	<p data-bbox="840 495 1291 812">Transmission technology Hydrogen Distributed energy resources</p> 	<p data-bbox="1459 495 1848 698">Buildings Industry Transportation</p> 
<p data-bbox="514 1161 1512 1258">Supporting DOE's strategic goals for energy security and independence</p>		

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**

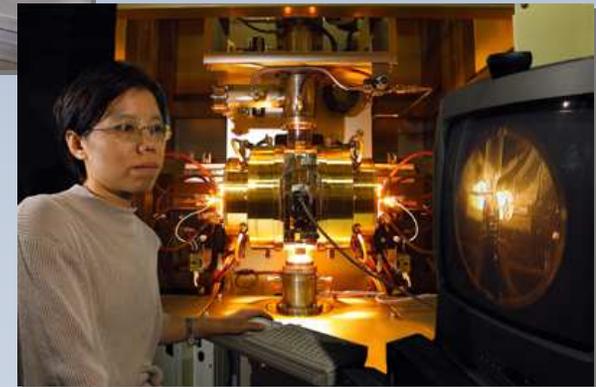
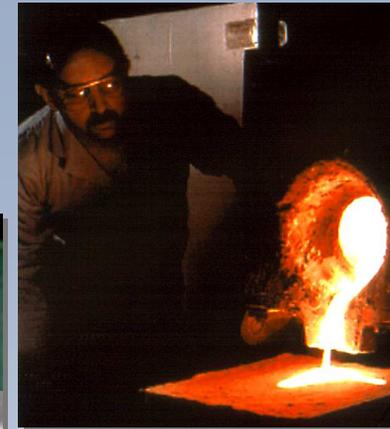
Sophisticated tools and facilities for materials synthesis, processing, and joining

Metals and alloys

- Melting
- Casting
- Welding
- Extrusion

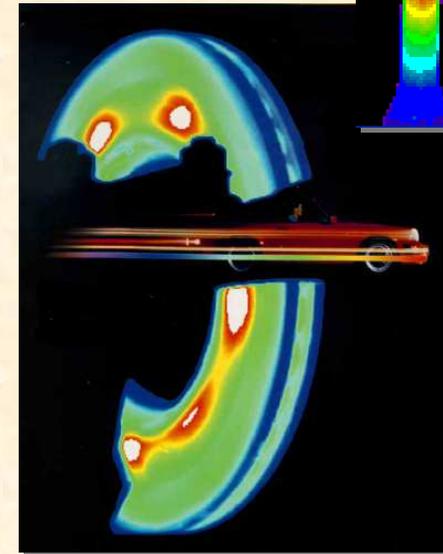
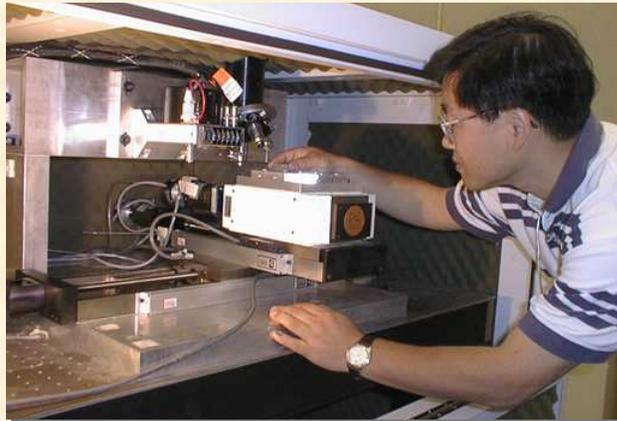
Ceramics

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



Sophisticated tools and facilities for determining physical and mechanical properties

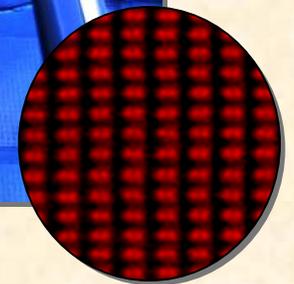
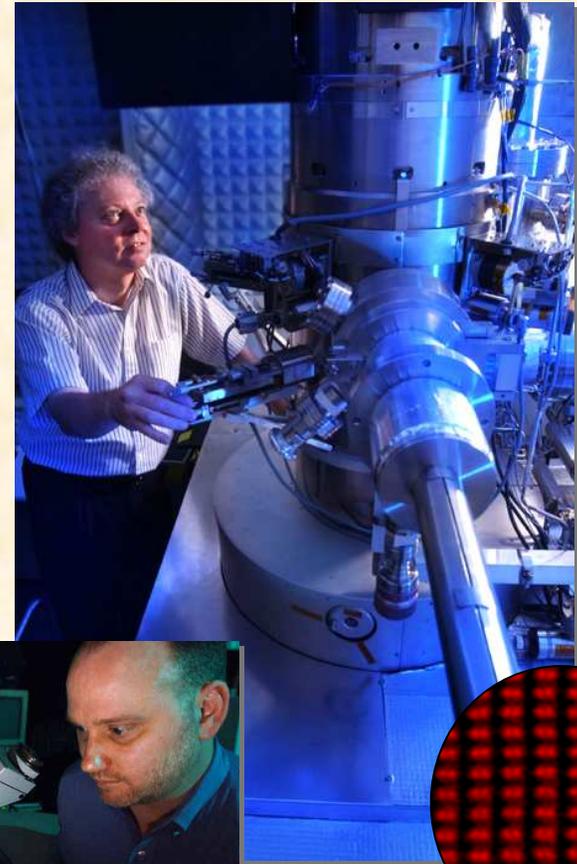
- Infrared imaging
- Nanoindentation
- Ceramic machining
- Vacuum fatigue testing



OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Sophisticated tools and facilities for determining structure

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



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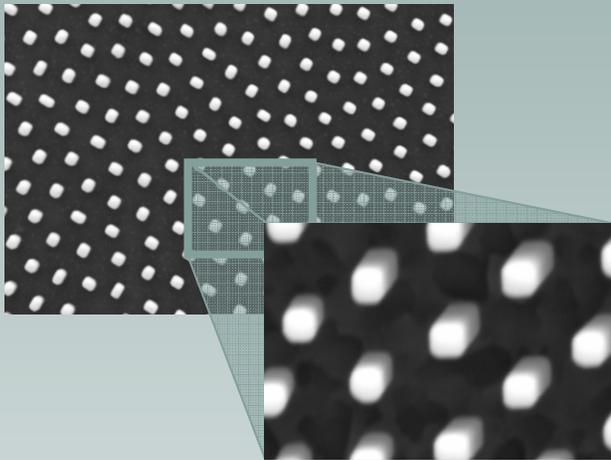
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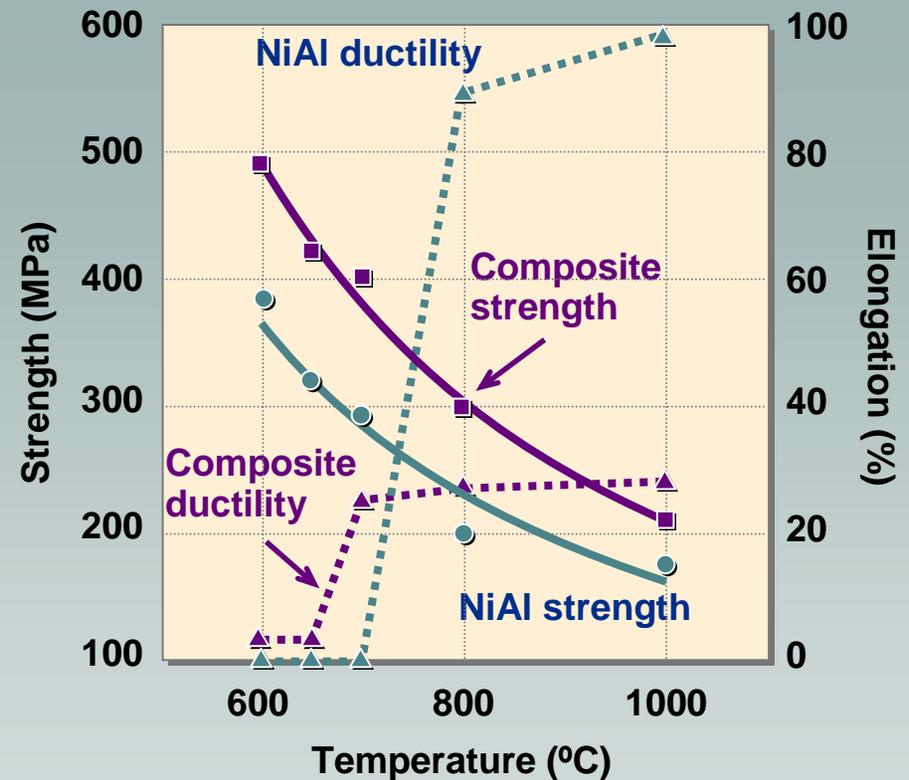
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Microstructured and nanostructured materials: Mechanical behavior

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



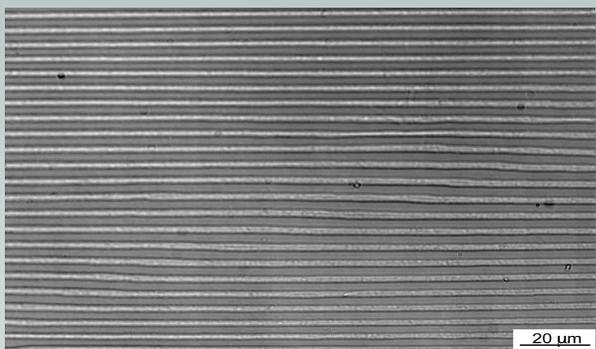
H. Bei, E. P. George, G. M. Pharr
ORNL and University of Tennessee



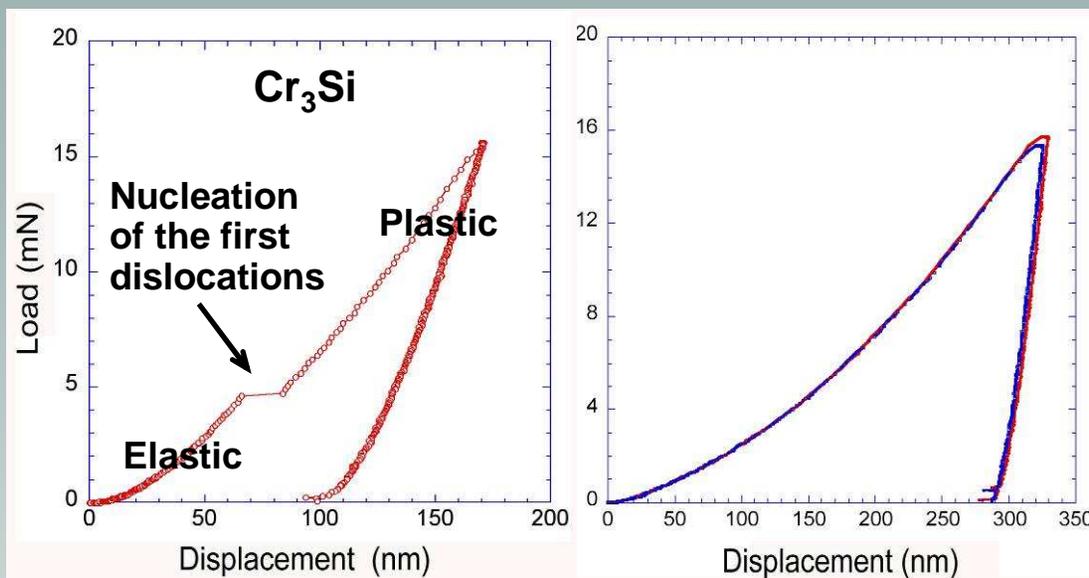
**NiAl-Mo composite has higher strength
and lower DBTT than NiAl matrix**

Microstructured and nanostructured materials: Mechanical behavior

Well-aligned, directionally solidified nanocomposites: Cr-Cr₃Si



Cr-Cr₃Si lamellae

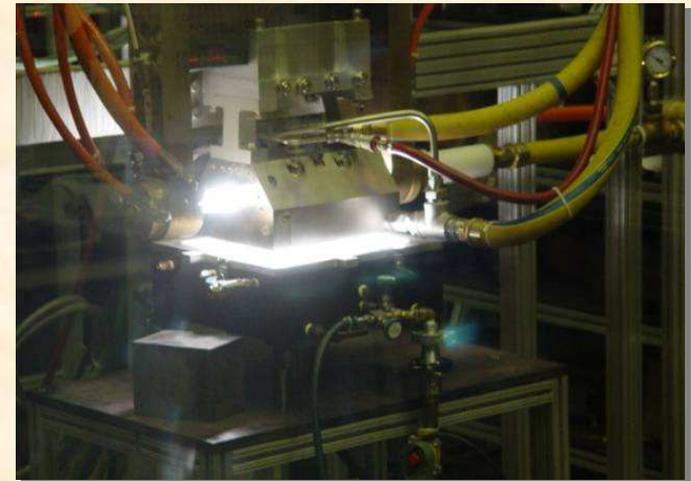


Nanoindentation of individual lamellae

	Cr ₃ Si	Cr
Hardness (GPa)	21.6	5.2
Modulus (GPa)	369	269

Pulse thermal processing of functional nanomaterials

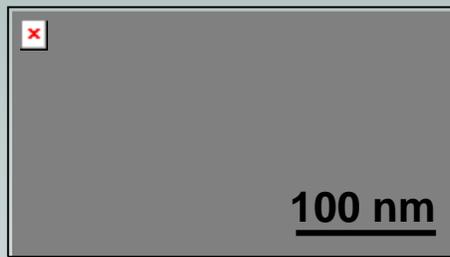
- Unique high-density infrared plasma arc lamp
 - World's most powerful radiant arc lamp
- Broad area processing
- Rapid heating to high temperatures
 - Allows controlled diffusion on nanometer scale
- Millisecond pulses
- Minimal thermal effects to substrate
 - Supports processing on polymers



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

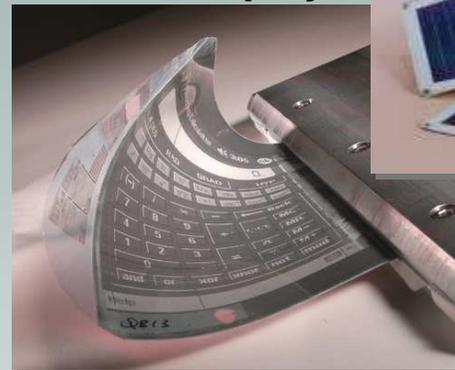


TiO₂ nanoparticles (~35 nm) sintered on a polymer substrate for a photovoltaic application [0.7-s processing at ORNL]

Flexible solar modules



Philips flexible display



Potential for advancing many nanoparticle and thin-film technologies

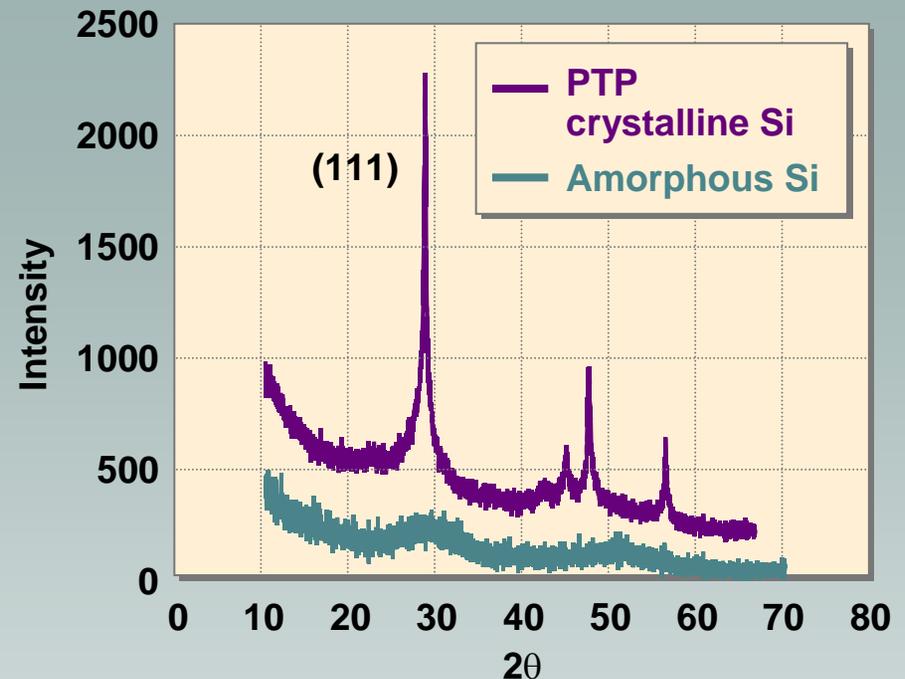
Pulse thermal processing: An enabling tool for broad-area nanoscale processing

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”

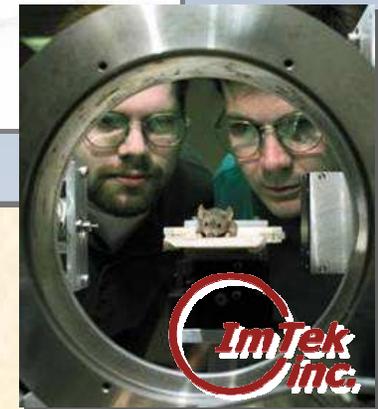
– Sigurd Wagner,
Princeton University



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



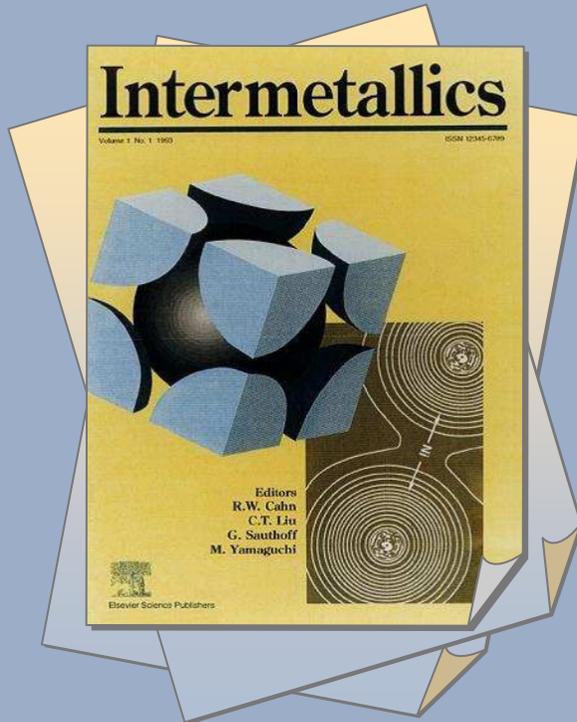
Since April 2000:

- 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**



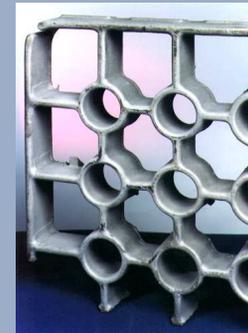
**Wide range
of industrial products**



Furnace rolls
(Bethlehem Steel)



Magnet die
(Magnequench)



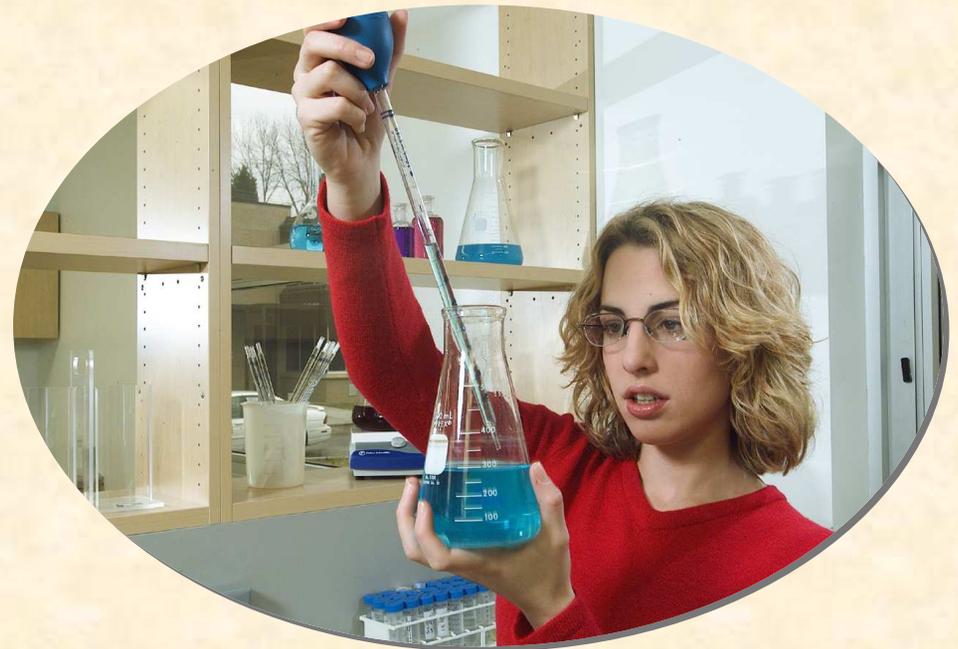
Furnace tray
(GM)

**OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY**

UT-BATTELLE

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
- 希望能有机会在橡树岭国家研究院接待诸位