

# NIST Perspectives on Metrology Needs to Support Emerging Technologies

Claire Saundry, Ph.D.

Director

Office of International and Academic Affairs  
National Institute of Standards and Technology  
Gaithersburg, Maryland USA



SIMPOSIO Metrologia 2008

Querétaro, Mexico

22-24 October 2008

## Topics for Today

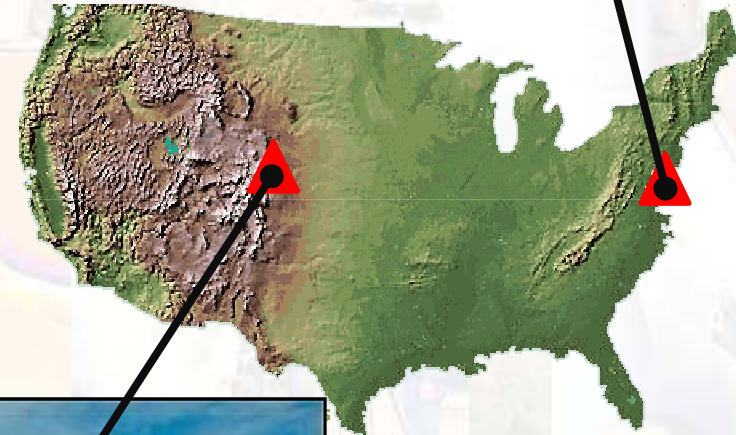
- **General Introduction to NIST**
- Role of Metrology in Emerging Technologies
- Measurement Challenges and NIST Activities to support emerging Nanotechnologies
- Measurement Challenges and NIST Activities in the Biosciences

# NIST at a Glance

**MISSION:** To promote U.S. **innovation** and industrial **competitiveness** by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life

**U.S. Department of Commerce**  
**2,800 employees**  
**1,800 guest researchers**  
**850 users of facilities**

**2 main campuses**  
**Gaithersburg, Maryland**  
**Boulder, Colorado**

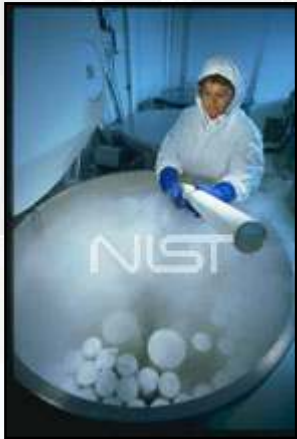


SIMPOSIO Metrologia 2008

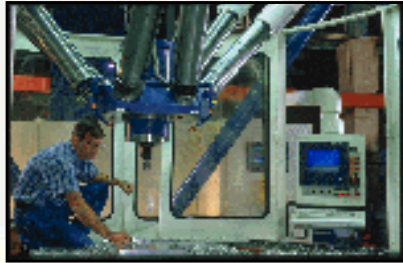
Querétaro, Mexico

22-24 October 2008

# NIST serves a broad customer base...



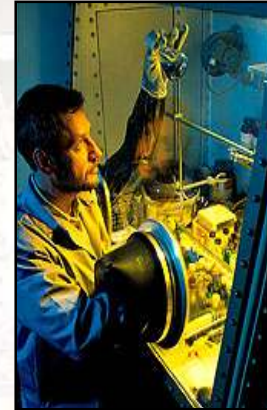
Environmental Technologies



Manufacturing



Pharmaceuticals



Nanotechnology



Transportation



Biotechnology



Food and nutrition



Law Enforcement



Computer software and equipment



Construction



Microelectronics

# NIST Programs

- NIST Laboratories
- Joint Institutes
- Extramural Programs
- Products and Services



SIMPOSIO Metrologia 2008

Querétaro, Mexico

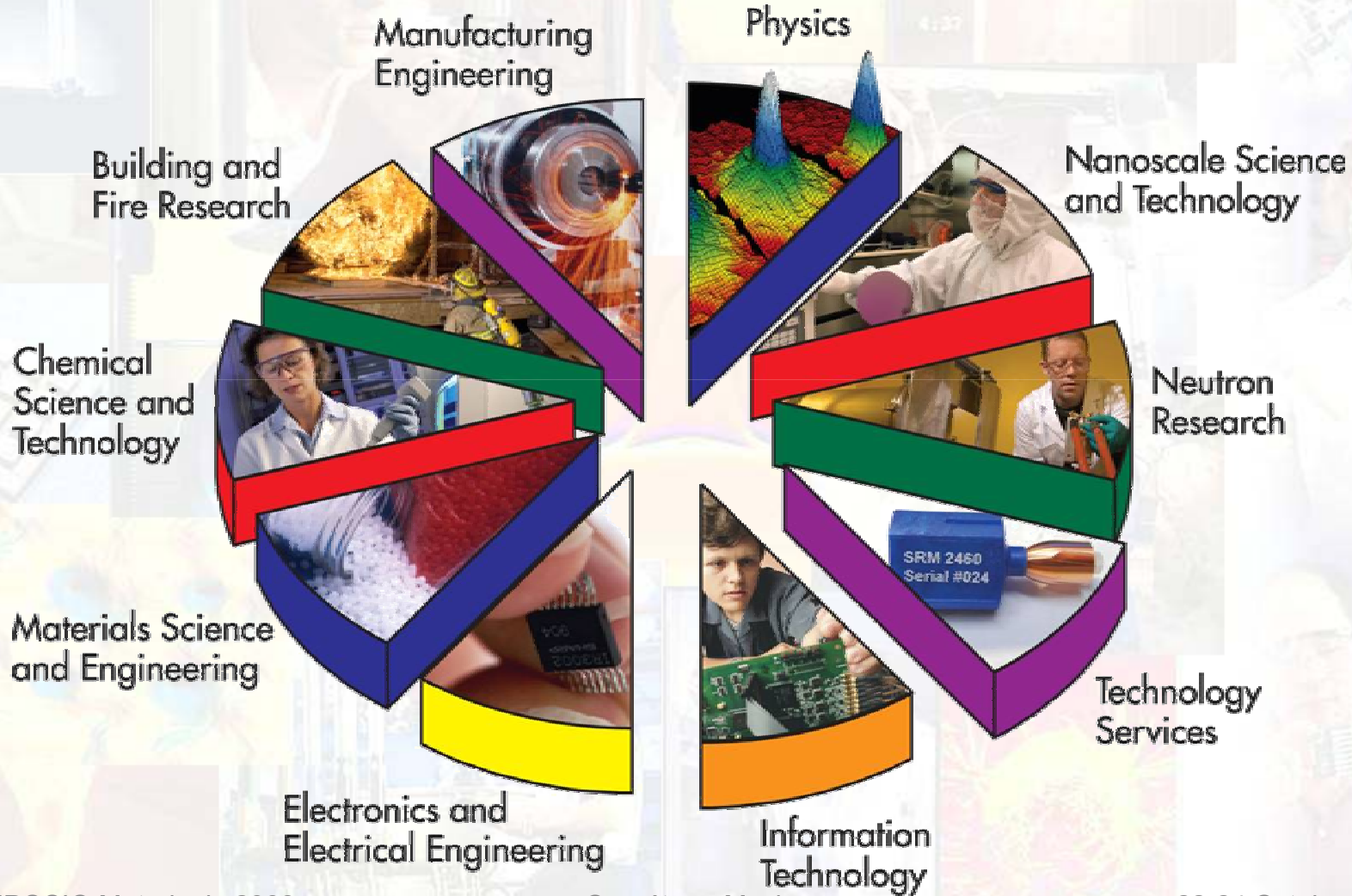


**MEP • MANUFACTURING  
EXTENSION PARTNERSHIP**



22-24 October 2008

# NIST at a Glance: Laboratories



SIMPOSIO Metrologia 2008

Querétaro, Mexico

22-24 October 2008

# NIST at a Glance: Joint Institutes



## JILA

- University of Colorado

## CARB

- University of Maryland  
Biotechnology Institute



## Joint Quantum Institute

- University of Maryland



## Hollings Marine Laboratory

- NOAA
- University of South  
Carolina
- College of Charleston
- Medical University of  
South Carolina



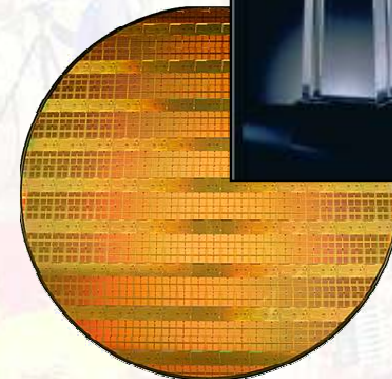
SIMPOSIO Metrologia 2008

Querétaro, Mexico

22-24 October 2008

# NIST at a Glance: Extramural Programs

- **Hollings Manufacturing Extension Partnership**  
Nationwide network of resources helping smaller manufacturers compete globally
- **Baldrige National Quality Program**  
Promoting and recognizing performance excellence via information and Presidential awards in manufacturing, service, small business, education, health care, and the nonprofit sector
- **Technology Innovation Program**  
Supports development of cutting edge technologies by the private sector and universities to address critical national needs and key societal challenges





# NIST at a Glance: Products and Services



Calibration Services



Laboratory Accreditation



Assistance for small manufacturers



Standard reference materials and data



Cybersecurity Best Practices



Quality Guidelines

SIMPOSIO Metrologia 2008

Querétaro, Mexico

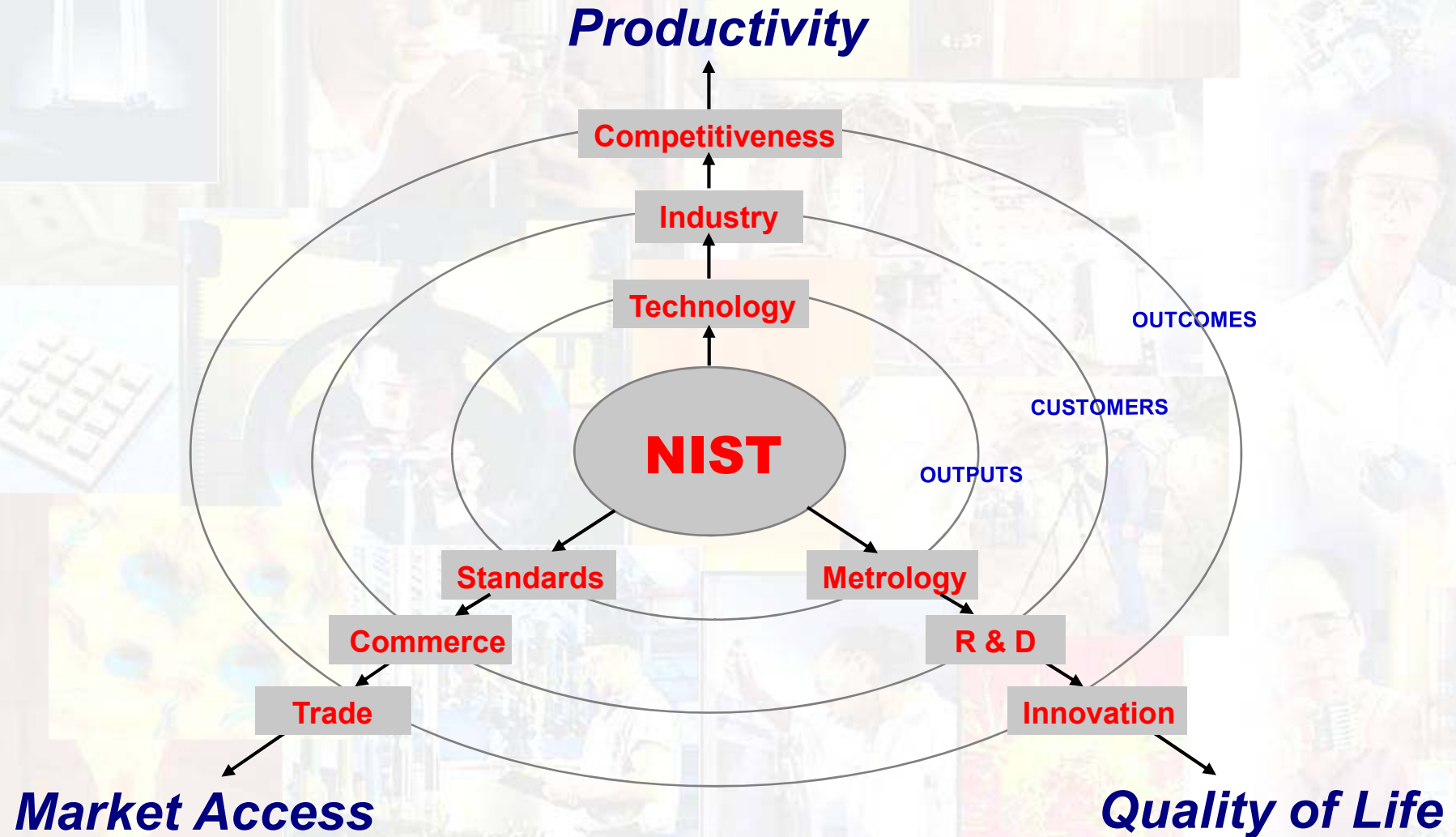
22-24 October 2008

# NIST Infrastructure Paves the Way to Innovation

- The equivalent of research “roads and bridges” the industrial and scientific communities need to develop and commercialize new technologies
- Groundbreaking research tools that enable work in emerging fields — nanotechnology, biosciences, quantum computing
- Research programs to develop better measurement methods to ensure quality in emerging fields
- Performance measures for accurate technology comparisons
- Standards to assure fairness in trade



# NIST Plays a Pivotal Role in the U.S. Economy



SIMPOSIO Metrologia 2008

Querétaro, Mexico

22-24 October 2008

## Topics for Today

- General Introduction to NIST
- **Role of Metrology in Emerging Technologies**
- Measurement Challenges and NIST Activities to support emerging Nanotechnologies
- Measurement Challenges and NIST Activities in the Biosciences

## Role of Metrology in Emerging Technologies

- A metrology infrastructure has underpinned all industrial revolutions
- Accurate measurement capabilities are critical to overcome technological challenges
- Emerging technologies will require improvement of existing measurement capabilities and the development of new measurement technologies

# Role of Metrology in Emerging Technologies

Revolution	Industry Mass Production	Process	Accuracy Need	Metrology	Accuracy Transfer Mechanism
<b>Machine 1800-1920</b>	firearms, sewing machines, automobiles	Machining, stamping, casting, forging	dimensioned, interchangeable machine parts	accurate length scale (~1 mil) via sets of gauge blocks	calipers
<b>Semiconductor 1950-2010</b>	semiconductor circuits	Planar multi-level lithographic processing	dimensioned and overlaid patterns	accurate length scale (~1 μm) via laser interferometers	optical or electron microscopes
<b>Nanoscale 2000-2050</b>	nanosystems (electronic, photonic, magnetic, biologic)	Planar lithographic processing  Self assembly of nano-objects	dimensioned and placed/overlaid patterns and nano-objects	accurate length scale (~1 nanometer) via optical encoders	electron or atomic force microscopes

## Measurement Challenges: Emerging Technologies

- Some existing measurement technologies are reaching the limits of their capabilities
  - Inadequate accuracy
  - Inadequate detection capabilities
  - Inadequate resolution
  - Inadequate sensing capabilities
- Important challenges to rapidly advancing technologies
  - Electronics
  - Materials
  - Biosciences - Health care
  - Nanotechnology

## Topics for Today

- General Introduction to NIST
- Role of Metrology in Emerging Technologies
- **Measurement Challenges and NIST Activities to support emerging Nanotechnologies**
- Measurement Challenges and NIST Activities in the Biosciences



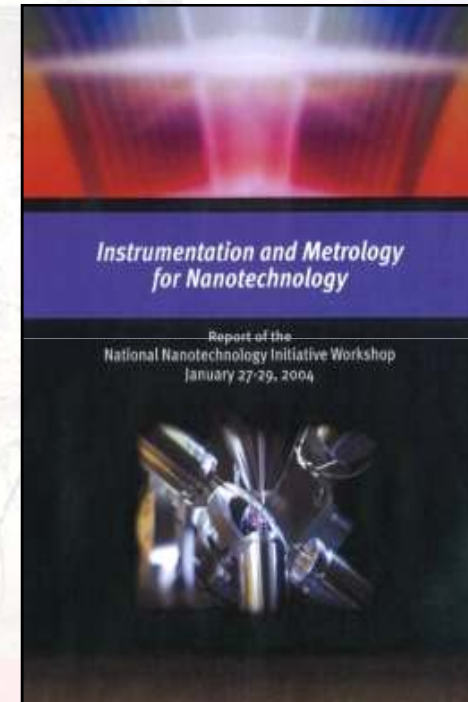
# Nanotechnology – Requirements and Challenges

## Measurement Requirements

- Accurate, high-resolution characterization of physical, chemical, and biological properties of materials at nanometer dimensions

## Challenges

- Current measurement techniques approaching fundamental limits
- Absence of tools to measure properties of nanomaterials and nanodevices as they relate to functional performance
- Measurements are not made quickly
- Limited ability to identify which key parameters must be measured to meet anticipated regulations



# Overcoming Challenges to Nanotechnology

## Benefits

- Vastly increase digital data storage capacities
- Development of smaller, faster, more power-efficient electronic devices
- Develop new families of high performance catalysts, sensors, and actuators
- Advance drug delivery systems
- Develop high-capacity fuel cells



## NIST Nanotechnology: Approach & Programs

- NIST applies a **multidisciplinary** approach to problem solving that involves partnering with industry, academia, and other government agencies
- **Center for Nanoscale Science and Technology (CNST)**
  - Provides **measurement methods**, standards and technology to support all phases of nanotechnology development from discovery to production
  - Develops and maintains a national shared use facility, **the Nanofab**, with state-of-the-art, nanoscale fabrication and measurement capabilities
  - Hub to **link the external nanotechnology community** to the vast measurement expertise that exists within the NIST Laboratories
- **NIST Laboratory Initiatives** – involves several laboratories

# NIST CNST: Research Program

Developing measurement capabilities through joint collaborations with existing NIST Laboratory programs

## Some Focus Areas

### Future Electronics

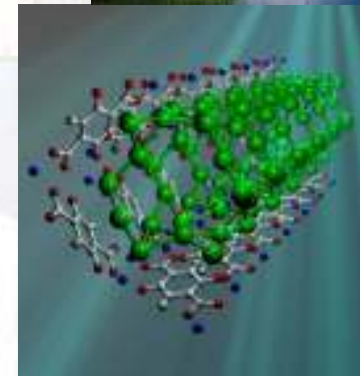
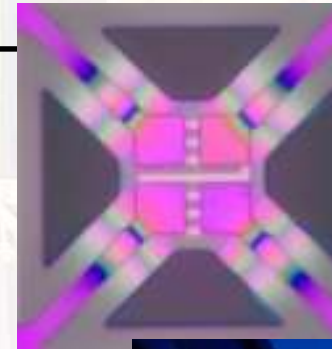
- Devices, architectures, interconnects

### Nanomanufacturing and Nanofabrication

- Top-down and bottom-up fabrication and assembly

### Energy

- Conversion, storage, and transport



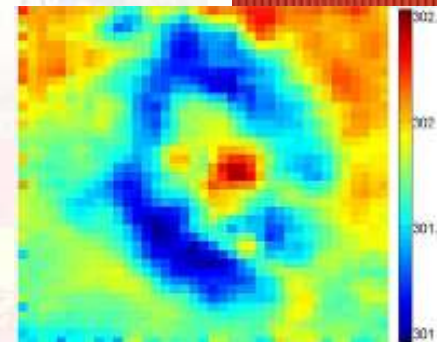
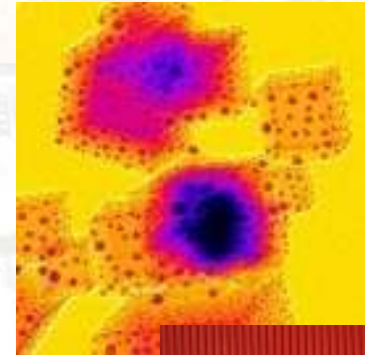
## Chemical Sciences and Technology - Nanotech Initiatives

### Nanometrology

- Physical and chemical properties of nanomaterials
- Nanoscale characterization of electronic devices and systems
- 3-D chemical analysis of composite materials

### Imaging

- 3-D Chemical Imaging at the Nanoscale
- SuperResolution, *in-situ Microscopies*



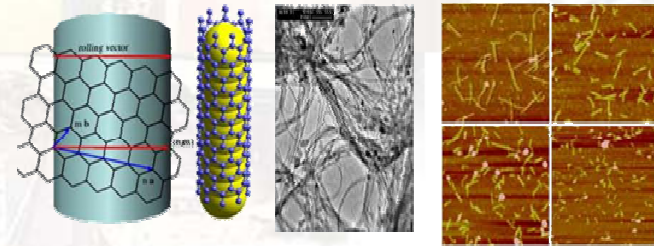
# Materials Science and Engineering – Nanotech Initiatives

## Polymers Division

### Carbon Nanotubes

Develop and maintain measurement standards...

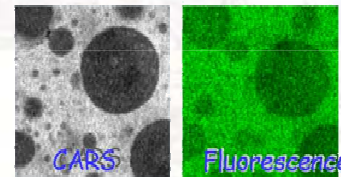
- Capability to produce carbon nanotube SRMs



### Tissue Engineering

Develop new knowledge of measurement....

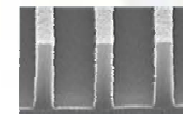
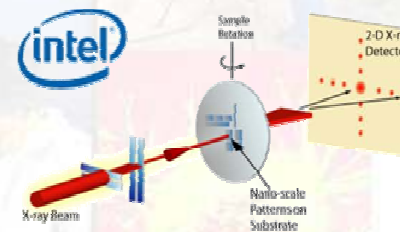
- New field coupling materials science and cell biology
- New imaging methods



### Nanoscale Dimensional Metrology

Use measurement science in new ways....

- Industry needs new (critical) dimensional metrology
- Develop new methods



## Topics for Today

- General Introduction to NIST
- Role of Metrology in Emerging Technologies
- Measurement Challenges and NIST Activities to support emerging Nanotechnologies
- **Measurement Challenges and NIST Activities in the Biosciences**

## Biosciences: Measurement Requirements and Challenges

### Measurement Requirements

- Accurate, high-resolution characterization of physical, chemical, and biological properties of materials

### Challenges

- Current measurement techniques approaching fundamental limits
- The combination of lack of accuracy and lack of fundamental knowledge, impedes the use of new biotechnologies
- Measurements are not made quickly
- Measurements and standards, such as performance standards and predictive tools, computer modeling techniques, biomarkers, that deal effectively with regulatory requirements



## Overcoming Measurement Challenges to Biosciences

### Sector Benefits

#### Agriculture

- Increasing yield, quality and safety in the world's food supply

#### Energy

- Obtaining sustainable energy from biological sources

#### Environment

- Understanding our planet through linking molecules to ecosystems

#### Manufacturing

- Obtaining higher quality products through better bioprocess measurements

#### Medicine

- Improving health through measurement of complex biological signatures

# NIST Mission & Unique Role in the Biosciences

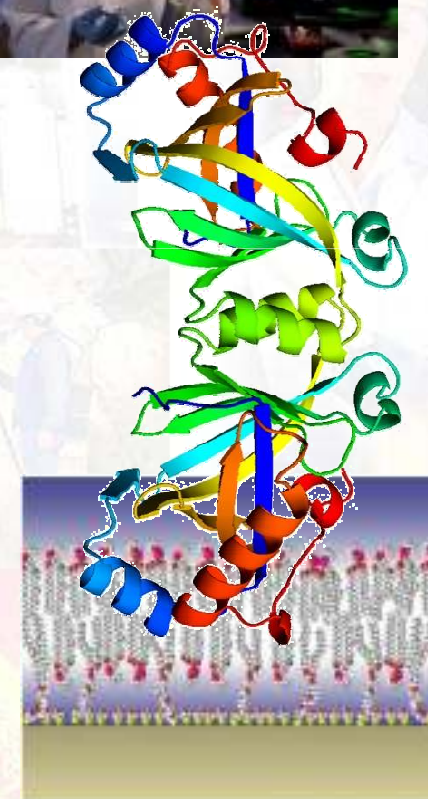
## Mission in Biosciences

To accelerate innovation in the biosciences and related technologies by overcoming measurement and standards-related challenges



## Unique Role

To leverage our vast **expertise in the quantitative physical and informational sciences** to provide the measurement infrastructure to **enable increased innovation and provide confidence in the results from measurements** of complex biological systems



## Chemical Science & Technology - Biosciences Initiatives

### International Conference

#### Objective

- Identify and prioritize measurement, standards and technology challenges

#### Focus areas

- Medicine improving health through measurement of complex biological signatures
- Energy obtaining sustainable energy from biological sources
- Manufacturing obtaining higher quality products through better bioprocess measurements

**International Conference - October 19-22, 2008**  
"Accelerating Innovation in 21st Century Biosciences: Identifying the Measurement, Standards, and Technological Challenges"

Co-Hosted by:

Location:  
National Institute of Standards and Technology (NIST)  
Gaithersburg, MD USA

Registration opened July 28

For conference information, updated list of plenary speakers, and registration:  
[www.csl.nist.gov/Biosciences.html](http://www.csl.nist.gov/Biosciences.html)

Sponsorship opportunities are still available!  
Email: [barriersworkshop@nist.gov](mailto:barriersworkshop@nist.gov)



- Agriculture increasing yield, quality, & safety in the world's food supply
- Environment understanding our planet through linking molecules to ecosystems

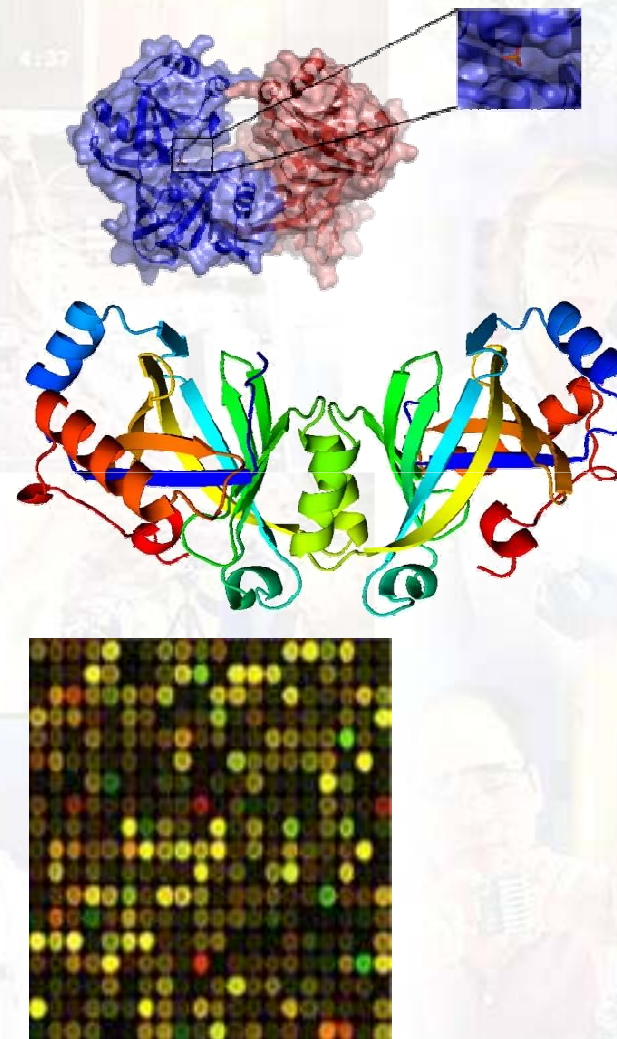
## Chemical Science & Technology - Biosciences Initiatives

### 3-D Chemical Imaging

- Optimized methods to obtain 3-D structures of proteins and DNA
- Approach/tools to assist in identifying functional assignment of proteins

### Metrology for Gene Expression

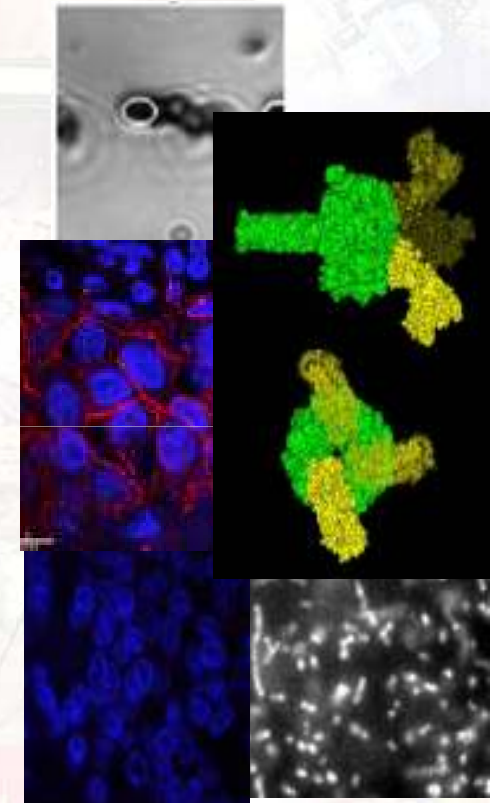
- Developing measurement science, data, standards, and models to support gene expression measurements
- Standard methods for measuring microarray performance
- Approach/tools for validation and performance of microarray scanners
- Characterizing statistical testing methods for microarray data analysis



# Chemical Science & Technology - Biosciences Initiatives

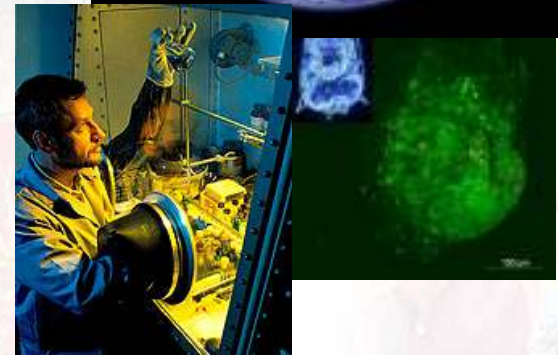
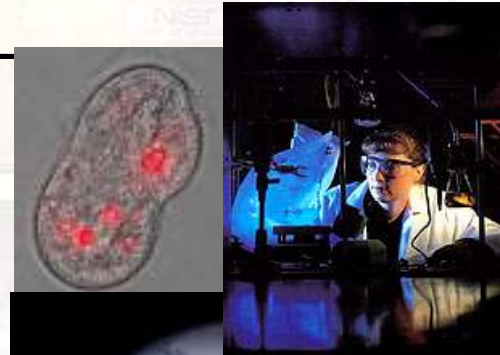
## Other Metrology Initiatives

- **Validation and Calibration of Biosensors**
  - Water quality monitoring
  - Pharmaceuticals and Biomedical
  - “Front Line” Biodefense – real-time monitoring
- **Biomarker Discovery and Use**
  - Develop cancer biomarker measurement science
  - Support health care measurements
- **Biochemical Metrology Technologies for Complex Biological Systems**
  - Develop and critically evaluate new multiplex biochemical measurement technologies and standards
  - Develop new quantitative cellular imaging tools and standards
  - Characterization and establishment of minimum performance requirements for current bio-measurement systems



# Closing thoughts...

- Emerging biosciences and nanotechnologies offer a formidable challenge to measurement technology
- Next "technology revolutions" will require an improved metrology infrastructure
- Improvement of current capabilities and development of new measurement technologies will benefit from a multi-disciplinary approach
- NIST is working with international counterparts to overcome these measurement challenges



# *Sistema Interamericano de Metrology (SIM)*

## *Activities*

- Regional metrology organization for the Americas
- Includes the National Metrology Institutes in the 34 member nations of the OAS
- Created to promote cooperation in metrology, SIM is committed to the implementation of a Global Measurement System
- Strong partnership between NIST and CENAM supports this effort



## Office of International and Academic Affairs

**NIST**  
National  
Institute of  
Standards  
and Technology

*...working with industry to develop and apply technology, measurements and standards*

<http://www.nist.gov>

Office of International and Academic Affairs

100 Bureau Drive, Mail Stop 1090

Gaithersburg, Maryland 20899-1090

Phone: 301-975-3069

Fax: 301-975-3530

E-mail: [oiaa@nist.gov](mailto:oiaa@nist.gov)

<http://www.nist.gov/oiaa/oiaa1.htm>

SIMPOSIO Metrologia 2008

Querétaro, Mexico

22-24 October 2008