Federal Programs Supporting Innovation & Collaboration

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Agenda

Introduction to NIST
Funding Innovation within the Government: The American Competitiveness Initiative
Cost Sharing Innovation with Industry: The Advanced Technology Program
Maintaining the Infrastructure of Innovation: The International System of Units
Assessing the Infrastructure of Innovation: The US Measurement System
Inspiring the Next Generation: The Robocup
Summary
Introduction to the National Institute of Standards & Technology
NIST Mission

To promote U.S. innovation and industrial competitiveness by advancing

measurement science, standards,
and technology

in ways that enhance economic
security and improve the quality of life
for all Americans.
NIST Has Two Main Campuses...

Gaithersburg, MD

- 2,800 employees
- ~2,500 associates and facility users
- NIST Research Laboratories
- Hollings Manufacturing Extension Partnership
- Baldrige National Quality Award
- Advanced Technology Program

Boulder, CO
NIST has... four joint institutes

JILA
NIST + University of Colorado

Center for Advanced Research in Biotechnology (CARB)
NIST + University of Maryland

Joint Quantum Institute
NIST + University of Maryland + NSA

Hollings Marine Laboratory
NIST + NOAA + South Carolina
+ University of Charleston
+ Medical University of South Carolina
Hollings Manufacturing Extension Partnership

The MEP is a nationwide network that provides hands-on help to smaller manufacturers.

**Business assistance includes:**
- Quality management
- Human resource development
- Financial planning

**Technical assistance includes:**
- E-commerce
- Process improvement
- Plant layout
- Product development
- Energy audits

355,000 small U.S. manufacturers produce 55% of value added in manufactured goods, employ more than 12 million workers.
Advanced Technology Program

Co-funding of private sector R&D to accelerate the development of high-risk, broadly enabling technologies.

IT, electronics, materials, biotechnology, tissue engineering, DNA chips, etc.

www.atp.nist.gov
Baldrige National Quality Program

• Premier U.S. program for performance excellence and quality achievement.

• Awards in manufacturing, service, small business, education, health care, and non-profit organizations.

• More than 1 million copies of Criteria for Performance Excellence downloaded annually.

• Quality programs modeled on Baldrige: 55 state and local (up from fewer than 10 in 1990); 60 international.

Commerce Secretary Don Evans; James W. Owens, Chairman and CEO, Caterpillar, Inc.; James S. Beard, President; and President Bush
NIST Center for Neutron Research – A User Facility

National resource for neutron-based measurements
- “See” structure at the nanoscale
- Uniquely sensitive to hydrogen
- Probe magnetic structure
- Non-destructive probe

Preservation of pharmaceuticals

Chemistry of cement

Petrochemicals

Fuel cells

H₂ storage materials

Magnetic data storage
NIST has... ...world-class staff

Jan Hall
2005 Nobel Prize in Physics

Eric Cornell
2001 Nobel Prize in Physics

Bill Phillips
1997 Nobel Prize in Physics

John Cahn
1998 National Medal of Science

Anneke Sengers
2003 L’Oréal-UNESCO Women in Science Award

Debbie Jin
2003 MacArthur Fellowship
Nation’s Infrastructure

When things go well…

(Before 2003 blackout)

When things go wrong…

(During blackout)
NIST has a unique metrology mandate

Article I, Section 8: The Congress shall have the power to...

... fix the standard of weights and measures
Before There Were Standards…

1904
Out-of-town fire companies arriving at a Baltimore fire cannot couple their hoses to the hydrants. 1526 buildings razed.

1912
41,578 train derailments in previous decade due to inferior steel
NIST Performs Extreme Measurements

1940

1959

1968

2006
Consumers Count on Standards

**Consumer Trust** – ultimate references for $5 trillion in annual sales based on measurement

**Integrity of Financial Transactions** – time-stamping of stock trades, etc., totaling hundreds of billions of dollars daily

**Secure Automated Banking** – encryption technology embedded in nation’s 300,000+ ATMs
World Trade Center investigation

NIST led a public-private effort to determine technical cause of the WTC collapse and apply lessons learned to improve safety, survivability and emergency response.

- Results at [wtc.nist.gov](http://wtc.nist.gov).
- 30 recommendations for building codes
World Trade Center Investigation

Findings:

• Most of the jet fuel burned outside the building. The persistent fires were fed from the burning of building contents, and oxygen through broken windows.

• “Blown on” insulation was knocked free, leaving steel exposed

• Steel did not melt, but was weakened by the fire

• A fire persisting in a single location contributed to earlier collapse of WTC2

• There was no evidence of planted explosives
NIST Products and Services Include

- Measurement Research
  2,200 publications/year

- Standard Reference Data
  90 types available
  94 million datasets downloaded/year

- Standard Reference Materials
  >1,300 products available
  31,200 units sold/year

- Calibrations and Tests
  13,000 calibrations/year

- Laboratory Accreditation
  819 accreditations

- Technical Workshops
  >9,000 participants/year

- Standards Committees
  1324 members, 972 committees, 161 chairs
NIST: Closing the Gap Between Science & Technology…

“I guess there’ll always be a gap between science and technology.”
NIST is an International Resource

NIST recognizes that as a world-leading National Metrology Institute, it has a responsibility to help other nations
  – Provides measurement traceability throughout the Americas
  – Is providing voltage technology to other nations’ metrology institutes
  – Conducts and collaborates on measurement research with global benefits
    • The Electronic Kilogram
Electronic Kilogram

- NIST has been working for over a decade to construct an “electronic kilogram” to replace the last artifact standard – the kilogram
- Produced a landmark measurement of Planck’s constant – 36 ppb uncertainty
- NIST staff are now working at on other experiments in other countries to create a confirming result.
Funding Innovation within the Government: The American Competitiveness Initiative
ACI Philosophy

The role of government is not to create wealth. The role of our government is to create an environment in which the entrepreneur can flourish, in which minds can expand, in which technologies can reach new frontiers.
American Competitiveness Initiative

- Proposed in FY 2007 and continued in FY 2008 budget
- Doubles, over 10 years, investment in:
  - NIST core (laboratory and infrastructure)
  - National Science Foundation
  - DOE Office of Science
Goals of the ACI

• **300 grants** for schools to implement research-based math curricula and interventions
• **10,000 more scientists**, students, post-doctoral fellows, and technicians provided opportunities to contribute to the innovation enterprise
• **100,000 highly qualified math and science teachers** by 2015
• **700,000 advanced placement tests passed** by low-income students
• **800,000 workers getting the skills they need** for the jobs of the 21st century
American Competitiveness Initiative

NIST 2007 Investments

Rapidly developing technologies
- Nanotechnology from Discovery to Manufacture
- Quantum Information Science
- Enabling the Hydrogen Economy
- Innovations in Measurement Science
- Cyber Security

Critical national assets
- NIST Center for Neutron Research
- Synchrotron Measurement

Immediate measurement needs
- Innovation through Supply Chain Integration
- Structural Safety
- International Standards and Innovation
- Bioimaging
- Biometrics
Technical Highlights … Rapidly Developing Technologies

Atomic Switches:

- NIST Scientists have used a beam of electrons to move a single atom in a small molecule back and forth between two positions on a crystal surface.

- This research is a significant step toward learning how to build an “atomic switch” that turns electrical signals on and off in nanoscale devices.

NIST researchers used a scanning tunneling microscope (STM) to move a single cobalt atom (blue sphere) in a small molecule back and forth between two positions on a crystal surface (first two images). A computer-generated spatial map of the atom switching speed and probability shows that switching is most likely when the STM tip is positioned to the left of the cobalt atom (blue and white speckled area in the third image). Credit: J.A. Stroscio, J.N. Crain and R.J. Celotta, NIST.
New Advanced Imaging Facility Peers Inside Hydrogen Fuel Cells:

- With visualization powers 10 times better than those achieved previously, researchers using the newly commissioned Neutron Imaging Facility in the NCNR can “see” water production and removal in fuel cells under a range of simulated operating conditions, from arctic cold to desert heat.
Technical Highlights … *Immediate Measurement Needs*

Improved Methods for AC Voltage Measurement

- 10 years of research at NIST has unveiled the world’s first precision instrument for directly measuring alternating current (AC) voltages.

- The instrument is being tested for use in NIST’s low-voltage calibration service, where it is expected to increase significantly the measurement precision of industrial voltmeters, spectrum analyzers, amplifiers and filters.

*Charles Burroughs with the 1 volt programmable voltage standard system showing (left to right) the low thermal probe, the microwave and high-speed bias electronics, and the computer control.*
## American Competitiveness Initiative

### NIST 2008 Initiatives

<table>
<thead>
<tr>
<th>R&amp;D Priority</th>
<th>NIST Response (STRS)</th>
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<tbody>
<tr>
<td>World-class capability and capacity in nanofabrication and nanomanufacturing (ACI Goal, NNI Strategic Plan, OMB/OSTP FY08 Priority Memo)</td>
<td>Enabling <strong>Nanotechnology</strong> from Discovery to Manufacture ($6M)</td>
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<tr>
<td>Improve our understanding of climate variability and change (Global Climate Chg. Strategic Plan, OMB/OSTP FY08 Priority Memo)</td>
<td>Measurements and Standards for the <strong>Climate Change</strong> Science Program ($5M)</td>
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<tr>
<td>Overcoming technological barriers to the practical use of quantum information processing (ACI Goal)</td>
<td><strong>Quantum Science</strong> ($4M)</td>
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<td>Develop technologies and standards for improving structural performance during hazardous events (OMB/OSTP FY08 Priority Memo; ACI Goal; Subcommittee on Natural Disaster Reduction; NEHRP strategic plan)</td>
<td><strong>Disaster Resilient Structures</strong> and Communities ($4M)</td>
</tr>
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<td></td>
<td>National <strong>Earthquake Hazard Reduction</strong> ($3.25M)</td>
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Enabling Nanotechnology from Discovery to Manufacture (+$6M)

- Manufacturing with nanoscale components expected to be a dominant factor in the 21st century economy

- Exploiting nanoscale behaviors and properties requires new tools and methods
  - NIST is the NNI lead agency on “Nanoscale measurement science, instrument calibration, standard reference materials, and nanoscale physical and chemical properties standard reference data.”

- Initiative continues the creation of the Center for Nanoscale Science and Technology (CNST)
  - Partner with industry, universities, and other agencies to bridge the gap between science and production
  - Over 300 new researchers from industry and academia

- Expands research to support industry through nanoscale measurement science and standards
  - Develop new atomic-scale measurement capabilities
  - Support standards for environment, health, and safety
Quantum Science: Infrastructure for 21\textsuperscript{st} Century Innovation (+$4 million)

– The laws of physics are fundamentally different in the quantum world of atoms, electrons, and light particles. This enables revolutionary potential for:
  • Measurement capabilities otherwise impossible “classically”
  • “Unbreakable” codes (i.e. to protect financial transactions)
  • Powerful computers capable of solving problems impractical to solve today

– **NIST is a recognized world leader in the field**

– This initiative will
  • Accelerate the economic potential for exploiting the unique properties of the quantum world
  • Advance research on quantum information
  • Develop fundamentally new and unique measurement tools and methods
  • Further leverage the partnership with the Joint Quantum Institute (NIST, Univ. of MD, and NSA)
Measurements and Standards for the Climate Change Science Program (+$5M)

- Critical measurement uncertainties in solar output and effects of aerosols limit Nation’s ability to model global climate change

- Initiative addresses 2 critical gaps identified in Interagency Strategic Plan
  - Resolves discrepancies in satellite-based measurements of solar intensity
  - Provides quantitative understanding of effects of atmospheric aerosols on sunlight

- Results will help modelers to create an accurate picture of Earth’s climate through calibrations traceable to international standards
  - Standardized instrument calibration for satellites for accurate international intercomparisons and lower uncertainties
  - New measurement methods for aerosols
  - Database of aerosol properties

Total Solar Irradiance Database

- Target Accuracy 1 W m⁻²
- Target Precision 0.3 W m⁻²
Disaster-Resilient Structures and Communities (+$4M)

- Risk to lives, property, and major disruption of commerce increases as communities encroach on hurricane-prone coasts and fire-prone wildland-urban interface regions.
- Single major event (e.g., hurricane) can cost $80B-$200B.
- Need to assess community and regional scale risks.

This initiative will develop predictive tools that enable:
- Local officials to evaluate and mitigate risks via land-use planning and practices;
- Development of risk-based hazard maps at the community-scale; and
- Development of risk-consistent and cost-effective mitigation solutions incorporated into next-generation building codes and standards.

Predict fire behavior for communities based on fuel maps, local topography, cultural features, and micro wind patterns for real-time firefighting as well as improved building codes and community planning.
Earthquakes strike without warning – and a single major event can cost $100B - $200B

75 million Americans and $8.6 trillion worth of structures in the U.S. in moderate to high-risk areas

NIST tasked with conducting research to bridge the gap from construction theory to practice and to promote its adoption

This initiative will enhance the safety of:
- **New structures** by establishing and promoting performance-based standards for entire building designs and by accelerating the adoption of basic research into the model building codes, standards, and practices
- **Existing structures** through research on actual building performance in earthquakes; developing structural performance models and tools; and establishing cost-effective retrofit techniques for existing buildings
The ACI provides funds to critical government research facilities in the US, allowing them to contribute directly to innovation.
Cost Sharing Innovation with Industry: The Advanced Technology Program
**ATP Mission ...**

To *accelerate* the development of *innovative technologies* for *broad national benefit* through *partnerships* with the private sector.
The Difference ATP Makes

With the ATP, R&D is:

- Higher risk
- Creating leap-frog technologies
- Leading to multiple applications
- Expanding company and national competencies
- Broadly diffused
The Public-Private Funding Transition & the Valley of Death


- Initial Public Investors
- Federal Agencies, Universities, States
- Entrepreneur & Seed/Angel Investors
- Venture Capitalists
- IPO

Cash Flow

Valley of Death

Successful

Moderately Successful

Unsuccessful

SBIR & ATP

Time
Venture Capital Gap

• In 2006, venture capitalists invested $25.5B across 3,416 deals
• In 2006, start-up and seed funding represented $1.16B across 312 deals
• The top 3 industries receiving the most money were Software, Biotechnology, and Medical Devices accounting for about $12B of the year's total
• Silicon Valley dwarfs other regions in receiving VC investment (Silicon valley received $9B, the next closest was New England with $3B)
Today's Investments ...

Electronics and Photonics ($576 M)
- Microelectronics
- Optoelectronics
- Optics Technologies
- Power Technologies
- Wireless Electronics
- Organic Electronics

Biotechnology ($449 M)
- DNA Technologies
- Tissue Engineering
- Drug Discovery Methods
- Proteomics
- Medical Devices & Imaging
- Microfluidics

Information Technology ($504 M)
- Advanced Learning Systems
- Component-Based Software
- Digital Video
- Information Infrastructure for Healthcare
- Electronic Commerce
- Dependable Computing Systems
- Technologies for the Integration of Manufacturing Applications

Chemistry and Manufacturing ($252 M)
- Chemical Processing Sensors
- Metabolic Engineering/Catalysis
- Combinatorial Methods
- Separations/Membranes
- Materials Processing
- Advanced Materials
- Nanotechnology
- Material Interfaces

Manufacturing ($252 M)
768 ATP Awards
(Forty Four Competitions (1990 – September 2004))
Distribution of Company Size
Lead Companies

768 ATP Awards
(Forty Four Competitions (1990 – September 2004)

- Small: 66%
- Medium: 12%
- Large: 17%
- Other: 5%
- Small 66%
- Medium 12%
- Large 17%
- Other 5%
Two Major Criteria

• Scientific and Technological Merit (50%)
  – Technical innovation
  – High technical risk with evidence of feasibility
  – Detailed technical plan

• Potential for Broad-Based Economic Benefits (50%)
  – National economic benefits
  – Need for ATP funding
  – Pathway to economic benefits
ATP Bridges the Gap Between the Laboratory and Marketplace

Fuel cells
Digital Mammography
3D Facial Recognition
Artificial Thymus
Large area digital x-rays for cargo screening
Finding defects in molten steel
Energy / Fuel Cells

**Integrated Hybrid DMFC/EC Capacitor Powerpack**

MTI Microfuel Cells, Inc., Albany, N.Y.
Other Participant: E. I. du Pont de Nemours & Company, Wilmington, Del.

**Project**

To develop *miniaturized fuel cells* to replace rechargeable batteries in portable consumer electronics devices.

**Potential Impacts**

- Time between recharging a cell phone could be extended from days to a *month*
- Fuel cell would *generate electricity* – not just store it

October 2001 to September 2004
Total project budget: $9,343k
ATP Cost Share: $4,662k
ATP: Future Improvements

- Leveraging university R&D for better technology transfer
- Working closely with States currently developing clusters of technology expertise
- Greater emphasis on partnering
Maintaining the Infrastructure of Innovation: The International System of Units
The SI is

• An internationally agreed upon set of units
• Mandated by treaty
• Allows the comparison of independently generated scientific results
• Self-consistent
• Supports all science, innovation, industry
NIST traceable measurements enable innovation

- Basic Units
  - Time
  - Length
  - Mass
  - Temperature
  - Electric current
  - Light intensity
  - Amount of substance (mole)

- Derived Units
  - Frequency
  - Diameter
  - Volume
  - Acceleration
  - Density
  - Force
  - Pressure
  - Voltage
  - Radiation

- Standards & Calibrations
  - Global time service
  - Laser frequency
  - Gage blocks
  - Line standards
  - Radioactivity
  - Electrical quantities
  - Reference materials and data

- Applications
  - Telecommunications
  - Computer "chips"
  - Pharmaceuticals
  - Medical imagers
  - Gasoline pumps
  - Digital clocks
  - TV signals
  - CD-Roms
  - Aircraft...
NIST Provides Traceability to the SI through…

- **Realization** of the base units
  - Fundamental definition
  - Need an accurate realization and then a precise way to measure against it

- **Representation**
  - Implementation of the realization
  - Transfer standards to facilitate the use of the SI in practical applications

- **Dissemination**
  - Providing customers with the metrology they need
Accurate measurements enable scientific discovery & innovation

- Precision measurements taken at different laboratories couldn’t be compared without a shared, accurately measured set of units
  - With a shared system of units, research is leveraged and magnified
- For example, improvements in time & frequency have:
  - Made GPS possible
  - Enabled space exploration
  - Enabled a test of general relativity
Time and frequency

- **1904**: Pendulum clock (1 s / 3 yr)
- **1949**: First atomic clock (1 s / 300 yr)
- **1993**: NIST 7 (1 s / 6 Myr)
- **1999**: NIST F1 (1 s / 30 Myr)
- **20xx**: Optical clock (1 s / 30 Gyr)

chip-scale atomic clock
Supporting innovation ...

Global Positioning System

The Global Positioning System
Measurements of code-phase arrival times from at least four satellites are used to estimate four quantities: position in three dimensions (X, Y, Z) and GPS time (T).
The SI – an Indispensable Ingredient for Innovation

- Provides foundation for international collaboration
- Provides a platform upon which to innovate
- Measurement technology must support the leading edge – and thus spurs invention
Assessing the Infrastructure of Innovation: The US Measurement System
USMS

• NIST conducted an assessment of the state of the U.S. Measurement System

• Focus: measurement problems that pose barriers to technological innovation

  – Technological innovation is the introduction into the marketplace of products and processes incorporating new technology
USMS

• Gathered 723 Measurement Needs
  – Validated by industry
  – Some directly submitted by industry
  – Others extracted from 164 industry roadmaps
  – Categorized by Discipline, SI, Sector, Technology
• Held 15 Workshops
• Defined & conducted “inferential analysis”
USMS - Findings

• Breakthroughs in measurement technology are needed to fuel innovations in product technologies
• The 723 measurement needs identified represent measurement advances that are “past due”
• Lack of nanoscale measurements is hindering progress in multiple disciplines
Inspiring the Next Generation: The Robocup

or...

Since when have the Swiss won a soccer match?
RoboCup Nanogram Demonstration

NIST sponsored first nanoscale soccer competition at 1007 RoboCup, July 7-8, Atlanta, Georgia

Width of a grain of rice

Soccer Ball the width of a human hair

An array of 16 fields!
RoboCup Nanogram Demonstration

Goals:

- Foster innovation and advances in artificial intelligence and intelligent robotics
- Show the feasibility and accessibility of technologies for fabricating MicroElectroMechanical Systems (MEMS)

Os Jogadores
RoboCup Nanogram Challenges

2 Millimeter Dash
   Fastest time in sprint between goals

Slalom Drill
   Fastest time while avoiding “defenders”

Ball Handling Drill
   Most goals
RoboCup Nanogram Demonstration

Teams from:
- Carnegie Mellon University (Pittsburgh, Pa.)
- U.S. Naval Academy (Annapolis, Md.)
- Swiss Federal Institute of Technology (Zurich, Switzerland)

**WINNER!**
- Simon Fraser University (Burnaby, British Columbia, Canada).
Joga com Gente!

- RoboCup Nanogram Demonstration Project:
  - Craig McGray, craig.mcgray@nist.gov

- For more information on NIST and its programs:
  - Barbara Goldstein, bgoldstein@nist.gov
Summary

• Key US initiatives to foster innovation and collaboration include:
  – The American Competitiveness Initiative funds government agencies
  – The Advanced Technology Program cost-shares research with industry & academia

• NIST plays a key role in the US innovation infrastructure through maintaining the SI

• NIST tracks how well the US Measurement System is keeping pace with emerging technology needs

• NIST is an international resource, with special outreach to the Americas
“Our future depends on NIST for the discovery of new technologies that will lead to new products and create the jobs of the future that will stay in this country.”

Senator Barbara Mikulski
2006