

National Institute of Standards and Technology

Cornerstone of the U.S. Innovation Infrastructure

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Bucknell University
March 29, 2005

National Institute of
Standards and Technology

NIST

Outline

A little history

NIST assets and mission

Innovation – engine for the economy

Measurement science for the future

NIST outputs and economic impact

Partnerships



Standards in ancient times

- Standard unit of length
 - Length of Pharaoh's forearm plus width of his palm
 - The cubit
- “Royal Cubit Master”
 - Primary standard in granite
- Realization of the cubit
 - A stick of wood
 - Working standard, comparability
- Re-calibration of cubit stick on each full moon
 - Calibration, traceability
 - Severe penalty for non-compliance

- Uniformity of length measurement in Egypt was achieved to a relative accuracy of 0.05 % over a distance of 230 meters

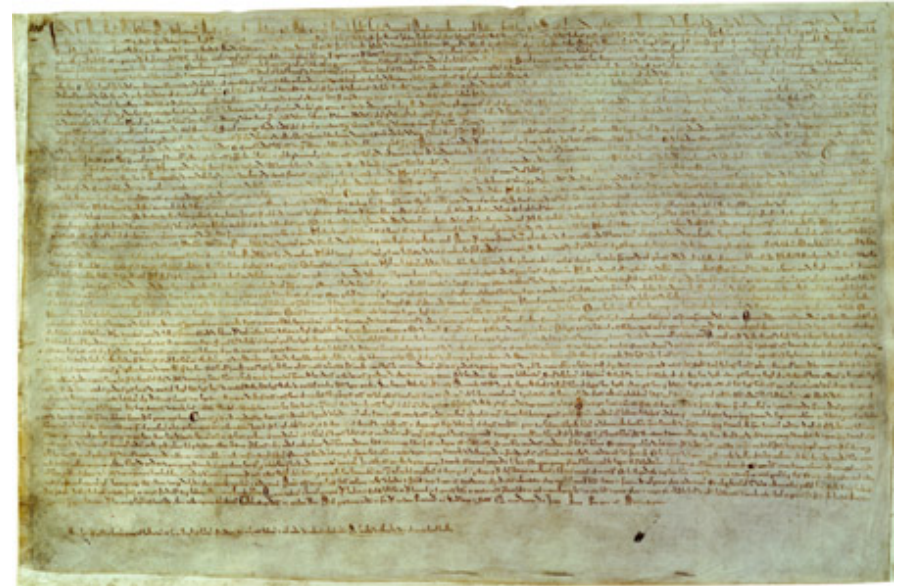


Long term stability? “Standard” Pharaoh?

Standards in medieval times

“Throughout the realm there shall be the same yard of the same size and it should be of iron”

Assize of Measures, 1196



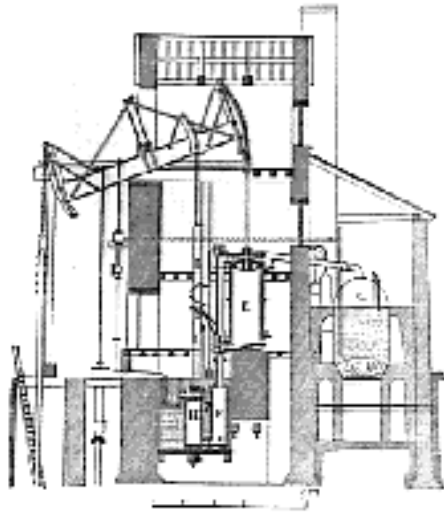
Magna Carta of 1215

“There shall be standard measures of wine, ale, and corn (the London quarter), throughout the kingdom. There shall also be a standard width of dyed cloth, russett, and haberject, namely two ells within the selvedges. Weights are to be standardised similarly.”

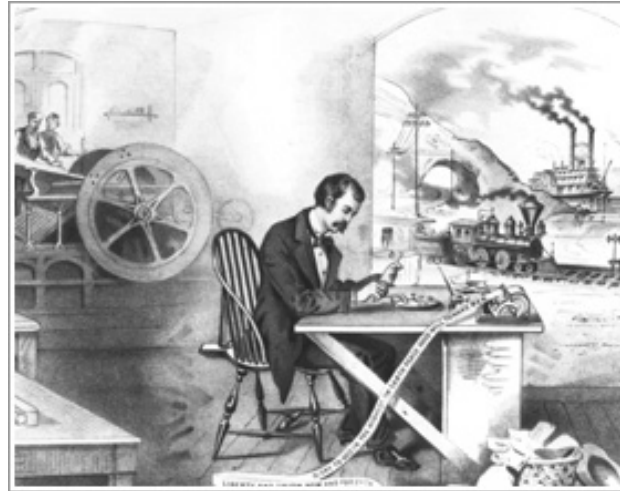
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The Industrial Revolution



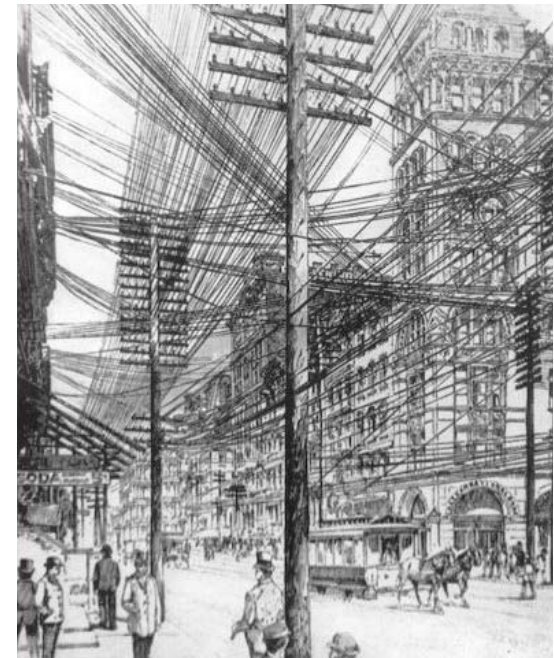
1769: the first Watt engine



Currier & Ives print depicting four major inventions of the Industrial Revolution

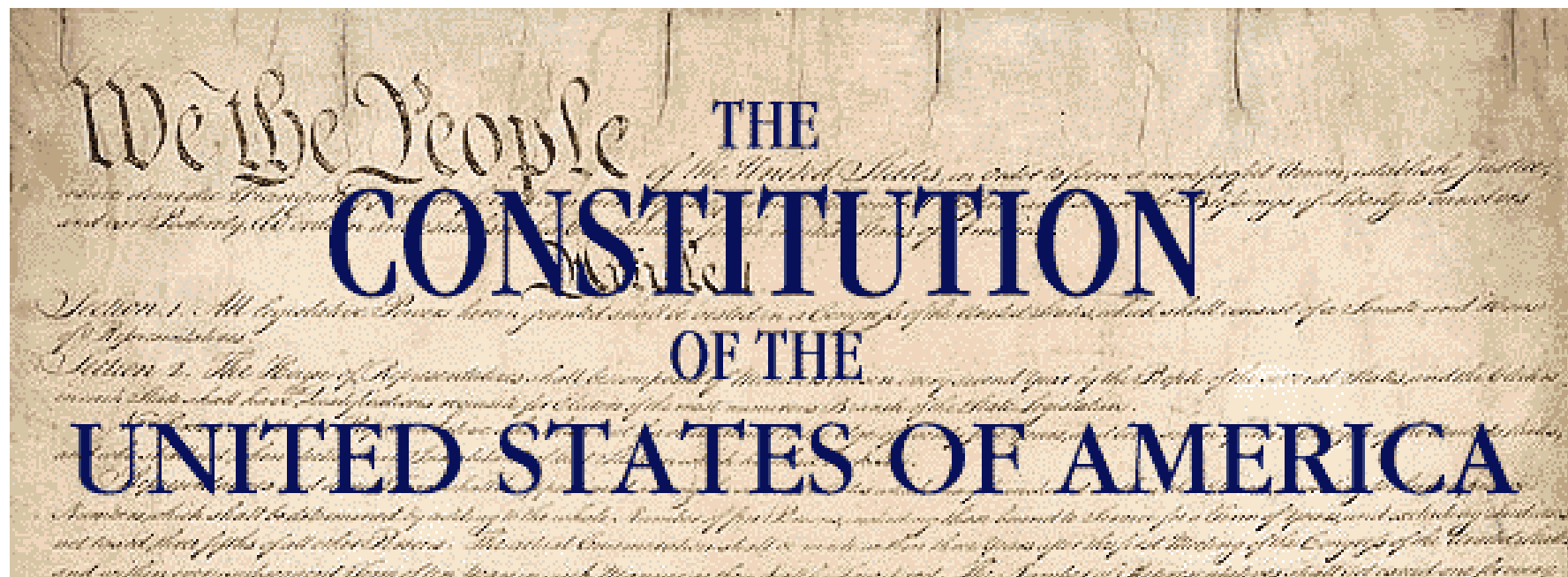


1900: Weston voltmeter made in the USA, used internationally, but calibrated in Germany due to lack of USA standards



1890: the Age of Electricity in New York City

Constitutional authority in 1788



Article I, Section 8: The Congress shall have the power to ...*coin money, regulate the value thereof, and of foreign coin, and fix the standard of weights and measures*

NBS (NIST) established in 1901

“It is therefore the unanimous opinion of your committee that no more essential aid could be given to **manufacturing, commerce**, the makers of scientific apparatus, the **scientific work** of the Government, of schools, colleges, and universities than by the establishment of the institution proposed in this bill.”

*House Committee on Coinage,
Weights and Measures,
May 3, 1900,
on the establishment of the
National Bureau of Standards
(now NIST)*

THE EVENING STAR, MONDAY, MARCH 11, 1901


CORRECT MEASURES

Function of the New Bureau of Standards.

LABORATORY TO BE ERECTED

Prof. Stratton, the Director, Details Need of Establishment.

A HANDICAP REMOVED



A new bureau of the government, authorized by the last Congress, will be established in this city in the near future and will give employment to a number of persons. It is to be known as the national bureau of standards and is to be under the control of the Treasury Department. A separate building for a laboratory, to cost not to exceed \$250,000, is to be erected on a site to be purchased at a cost of \$25,000.

Mr. Samuel W. Stratton of Chicago has been appointed by the President to be chief of the bureau at an annual salary of \$5,000. Prof. Stratton is to have the following assistants, to be appointed by the Secretary of the Treasury: One physicist, at an annual salary of \$3,500; one chemist, at an annual salary of \$3,000; two assistant physicists or chemists, at an annual salary of \$2,500; one laboratory assistant, at \$1,800; one laboratory assistant, at \$1,500; one secretary, at \$2,000; one messenger, at \$1,200.

Director Stratton.

Early drivers for standards and measurements



1904

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

1905

Standard samples program begins with standardized irons.



1912

41,578 train derailments in the previous decade lead to NBS measurement and test program

NIST assets and mission

3,000 employees

Gaithersburg, Maryland

Boulder, Colorado

Charleston, South Carolina

1,600 associates

1,700 users of facilities

\$858 million FY 2005 budget

NIST Laboratories

Advanced Technology Program

Manufacturing Extension Partnership

Baldrige National Quality Program

NIST mission

“To develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.”

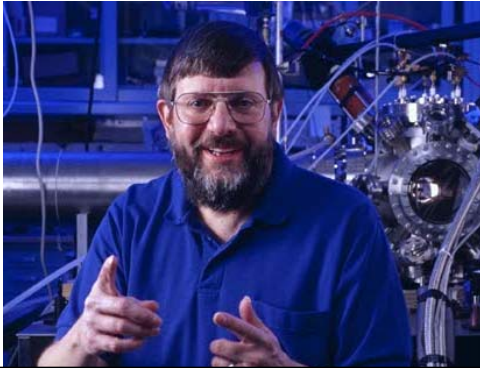


**National Institute of
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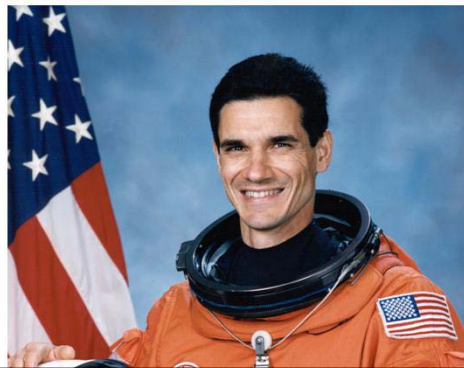
NIST

NIST has...

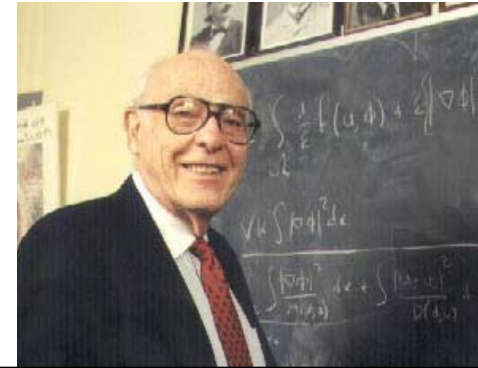
...world-class staff



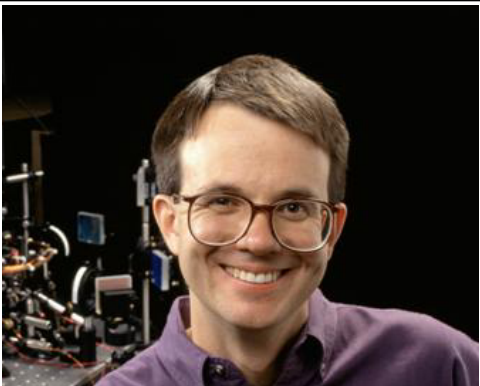
Bill Phillips
*1997 Nobel Prize
in Physics*



Greg Linteris
2 Space Shuttle missions



John Cahn
*1998 National Medal of
Science*



Eric Cornell
*2001 Nobel Prize
in Physics*



Anneke Sengers
*2003 L'Oréal-UNESCO
Women in Science Award*



Debbie Jin
*2003 MacArthur
Fellowship*

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NIST has...

...unique research facilities



**Advanced Measurement
Laboratory (2004)**

**Advanced Chemical Sciences
Laboratory (1999)**



**NIST Center for
Neutron Research**

**National Institute of
Standards and Technology**



NIST

Technological Innovation and Growth

Economic studies over several decades have shown that:

1. Technology accounts for *one-half of output (GDP) growth* in all industrialized nations (except Canada).
2. Technology accounts for *three-quarters of productivity growth*.
3. The increase in U.S. productivity growth that began in the mid-1990s is *entirely due to technology investments*.
4. The productivity advantage of the U.S. economy over other OECD countries accounts for *three-quarters of the per capita income gap*.
5. The rate of return to basic science is about *three times* that for applied R&D, which, in turn, has *twice* the return on physical capital.

Innovation... ..driving force for the economy

“... we live in a competitive world ... We shouldn't take our preeminence as the world's greatest economy for granted. We've constantly got to make sure the economic environment here is strong. We've got to make sure that we're innovative.”

President G.W. Bush (April 5, 2004)

“America’s challenge is to unleash its innovation capacity to drive productivity, standard of living and leadership in global markets.

... Innovate or Abdicate”

Council on Competitiveness (December 2004)

National Innovation Agenda

Talent

- National Innovation Education Strategy
- Next Generation of American Innovators
- Workers to Succeed in the Global Economy

Investment

- Frontier and Multidisciplinary Research
- Entrepreneurial Economy
- Risk-taking and Long term Investment

Infrastructure

- National Consensus for Innovation Growth Strategies
- 21st Century Intellectual Property Regime
- America's Manufacturing Capacity
- 21st Century Innovation Infrastructures

Measurement science:

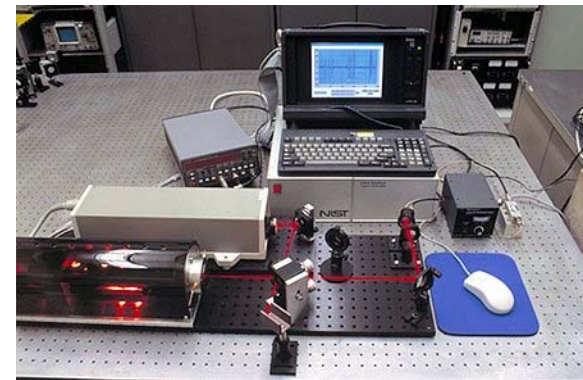
length standards



platinum-iridium
meter bar (1889)



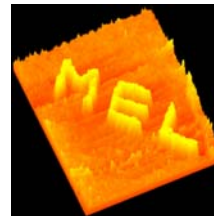
krypton 86
lamp (1960)



iodine stabilized
He-Ne laser
(1980)

*1 m \equiv length traveled
by light during
1/299,792,458 s*

definition of c (1983)



atomic-scale
standards

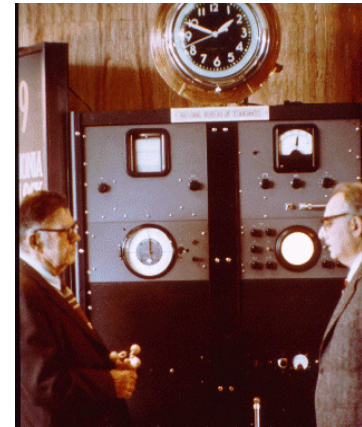
Measurement science:

time standards

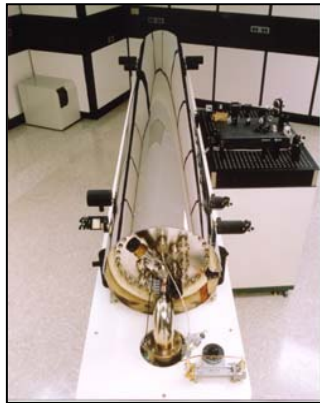
pendulum clock
1 s in 3 years
(1×10^{-8})
(1904)



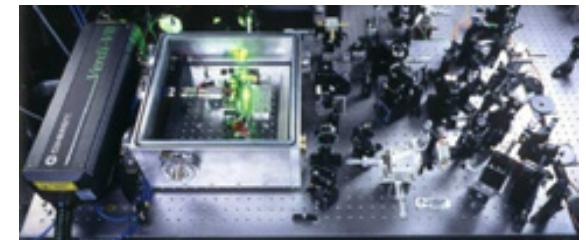
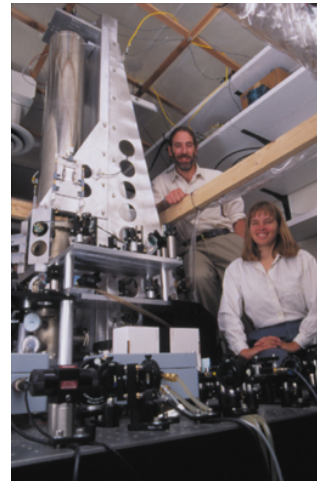
first atomic clock
ammonia
1s in 300 years
(1×10^{-10})
(1949)



NIST 7
1 s in 7 M yr
(5×10^{-15})
(1993)



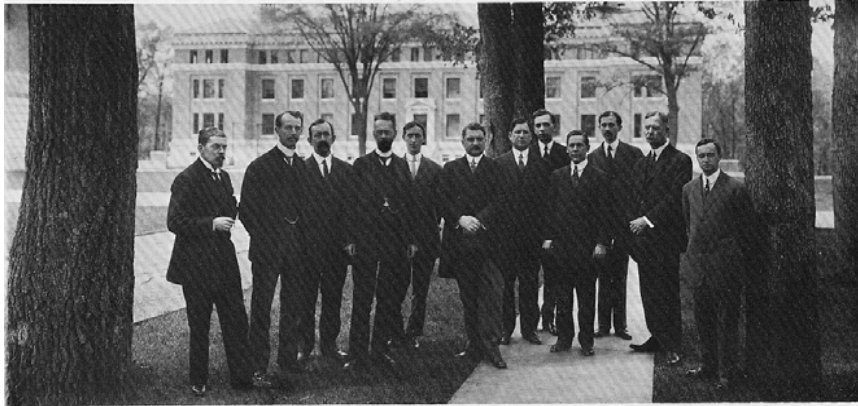
NIST F1
cesium
fountain
1 s in 30 M yr
(1×10^{-15})
(1999)



optical clock
1s in 30 G yr
(1×10^{-18})
(20xx)

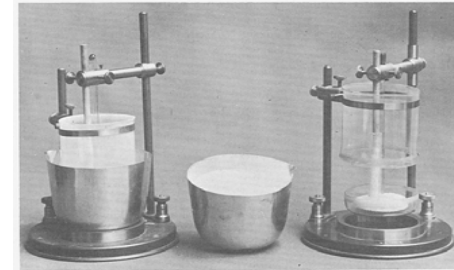
Measurement science:

electrical standards

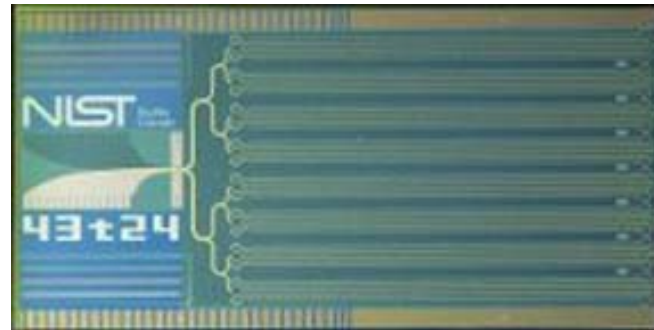


**International Technical Committee
(1910)**

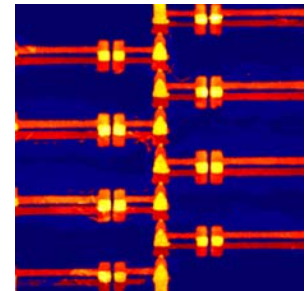
**silver voltameter
current standard
(1910)**



**Josephson voltage
standards
1 V (1985)
10 V (1990)**

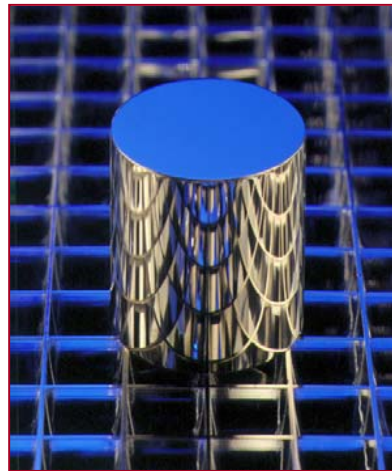


**single
electron
counter
(20xx)**

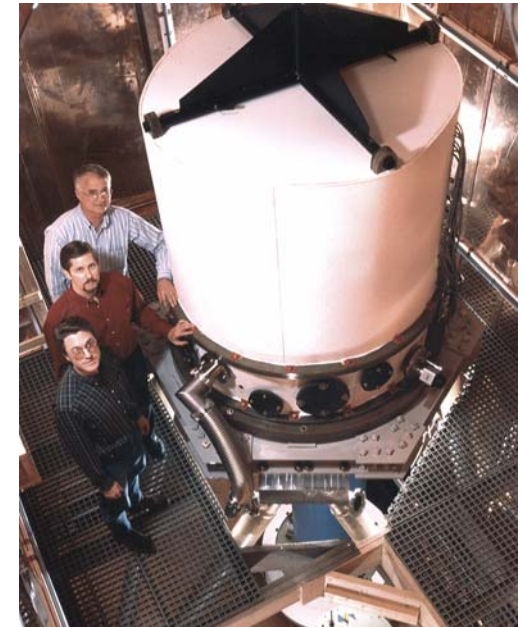
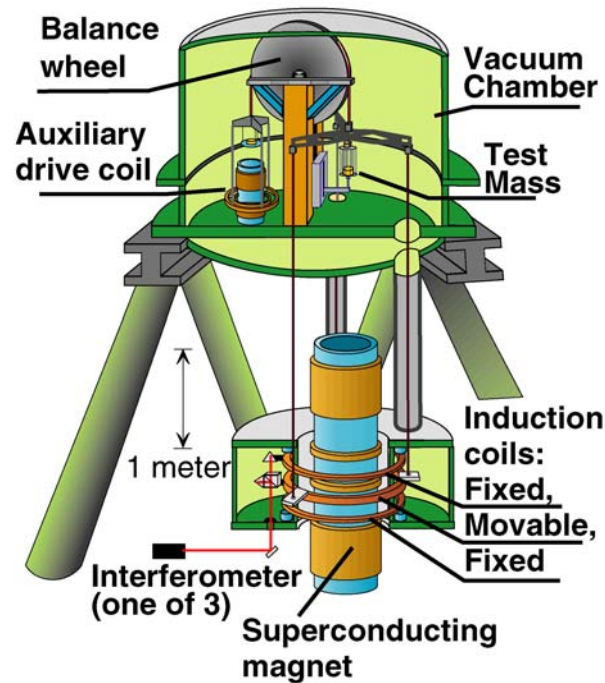


Measurement science:

mass standards



physical artifact
(1889)



electronic kilogram
(20xx)

$$F = -\partial \Phi / \partial z I$$

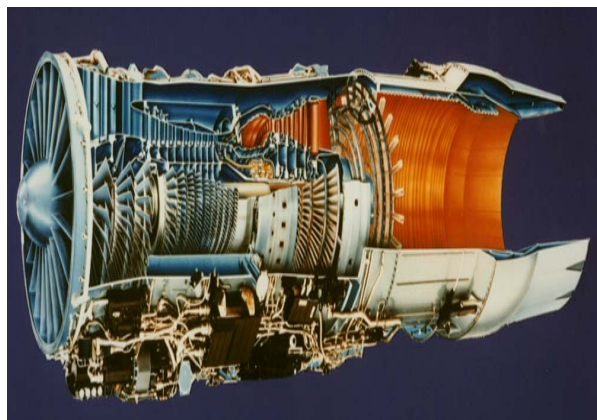
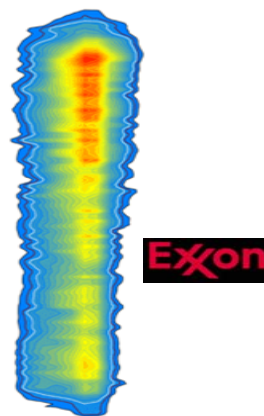
Measurement science:

the mole

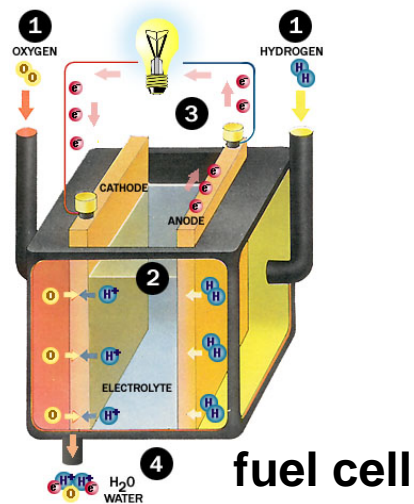
H₂! Where art thou?



wet chemistry



jet engine



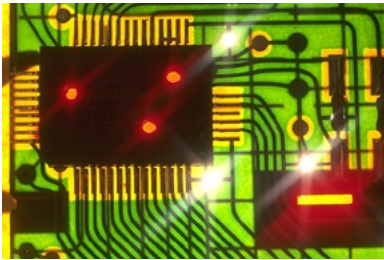
fuel cell



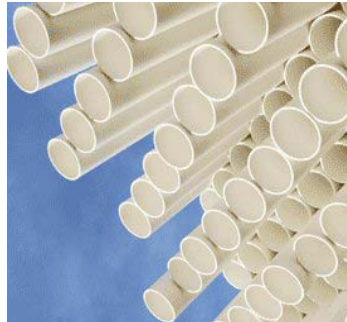
neutron chemistry?

NIST strengthens the innovation infrastructure to...

...advance manufacturing and services



**semiconductor
electronics**



**“lean manufacturing” of
plastics**



**automobile
manufacturing
interoperability**



pharmaceuticals



chemicals



**fuel cell
technology**



healthcare

Advances in...

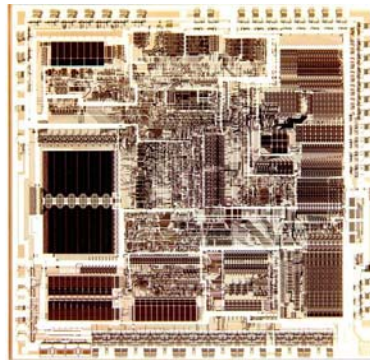
...electronics



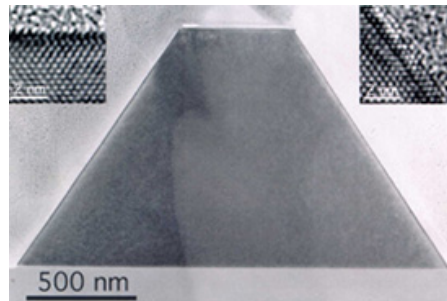
milli electronics
vacuum tubes &
discrete transistors
1900 - 1960
*copper, glass, barium,
germanium*



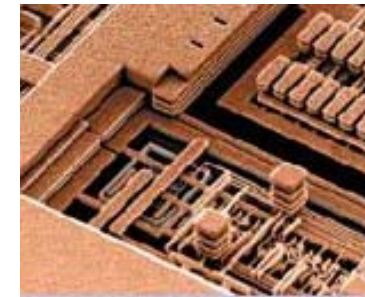
first neon signs



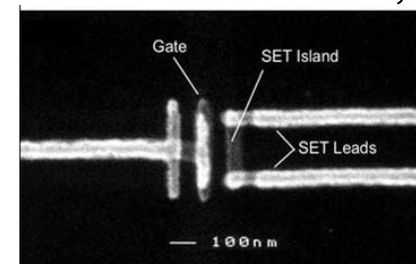
micro electronics
integrated circuits
1960 - 1990
silicon, aluminum



*single-crystal silicon
critical dimension artifact*



nano electronics
integrated circuits
1990 - 20xx
*silicon, copper,
exotic dielectrics, ...*



*single electron
tunneling device*

Advances in...

...manufacturing



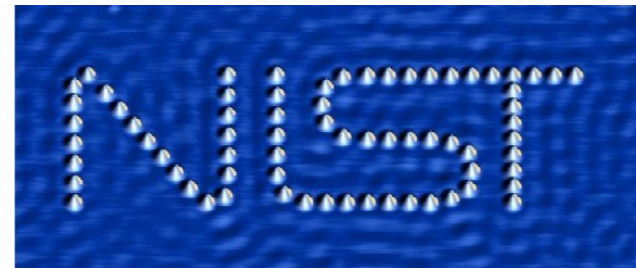
1920
experimental cotton mill



1983-1995
Automated
Manufacturing
Research Facility



2004 simulation technology for
manufacturing operations



20xx
automated and optimized
assembly of single atom
constructions

Interoperabilityof critical importance

Cost of inadequacies in supply chain infrastructures:

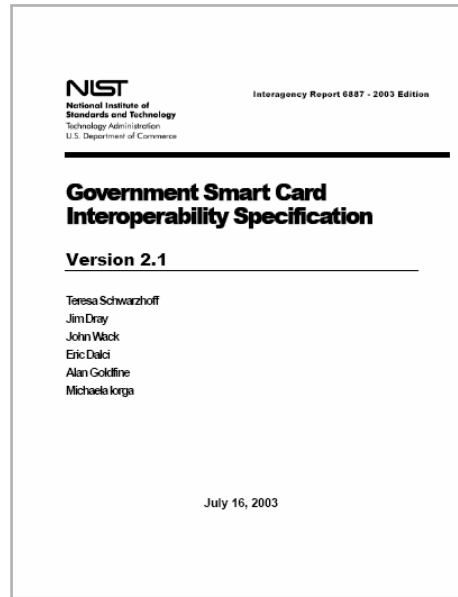
automotive	\$ 5 billion
electronics	\$ 3.9 billion
commercial buildings & industrial facilities	\$15.8 billion

99-1 Planning Report
Interoperability Cost Analysis of the U.S. Automotive Supply Chain
 Prepared by:
 Research Triangle Institute
 for
 National Institute of Standards & Technology
 Program Office
 Strategic Planning and Economic Analysis Group
 March 1999

NIST
 U.S. Department of Commerce



Smart Card Interoperability Specification (GSC-IS)



Interoperability testbed for dimensional metrology systems

NIST strengthens the innovation infrastructure to...

...improve public safety and security



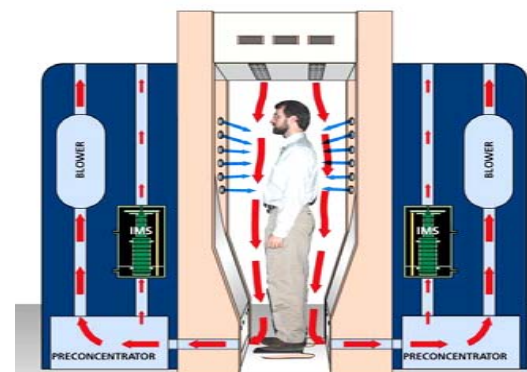
metal detectors



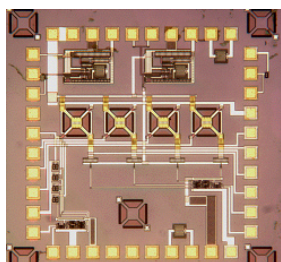
wireless interoperability among first responders



smoke detectors



Trace explosives detection portal



novel sensors to detect gases



altimeter calibration

standards for body armor



World Trade Center investigation



NIST is leading an investigation to determine the technical cause of the WTC collapse and apply lessons learned to improve safety, survivability and emergency response.

NIST received more than 200 pieces of WTC steel for analysis

National Construction Safety Team Act

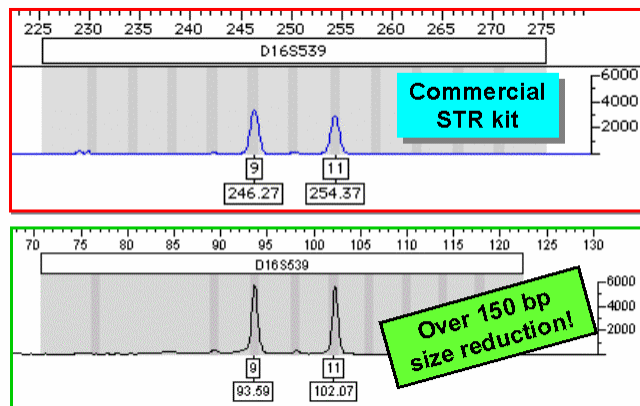
Investigation plans and results at
wtc.nist.gov



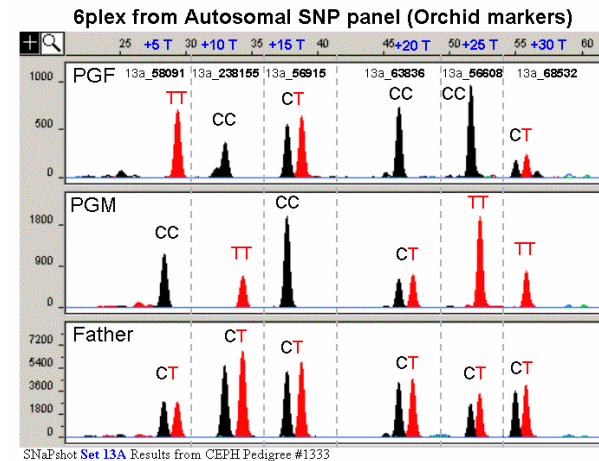
DNA identification of World Trade Center victims



- Bone and tissue samples collected from the WTC site were highly degraded by severe conditions during the collapse and the subsequent month-long fires.
- Only about 50% of the specimens yielded results with standard short tandem repeat (STR) DNA testing methods.
- NIST staff worked closely with NYC-OCME and KADAP.



NIST developed mini STRs to aid testing of degraded DNA samples. (Commercialized by Bode Tech.)



NIST validated new genetic markers used in commercial SNP kits. (Orchid Cellmark)

Personal Identity Verification (PIV) standards



NIST-developed system for studying the performance of facial recognition software programs

Homeland Security Presidential Directive HSPD-12

“Policy for a common identification standard for Federal employees and contractors”

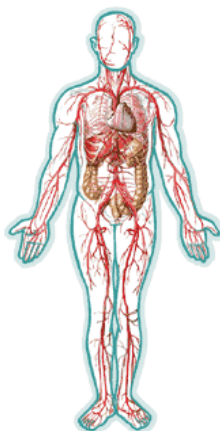
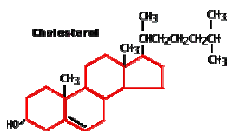


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NIST strengthens the innovation infrastructure to...

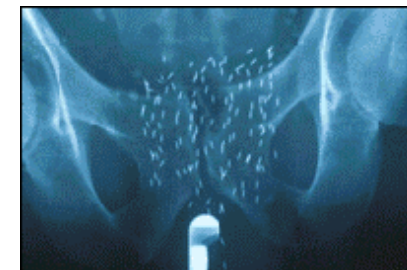
... improve quality of life



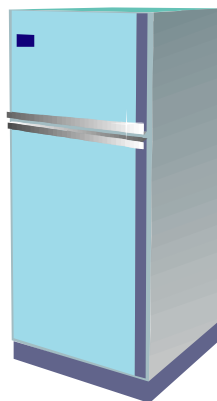
**cholesterol standard
reference material**



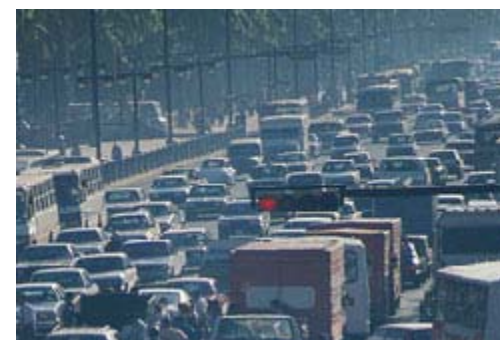
drinking water quality



**prostate and breast-
cancer treatment**



**database and
measurements
for alternative refrigerants**



**standards for sulfur
in fossil fuels**

NIST strengthens the innovation infrastructure to...

...facilitate trade



secure automated banking



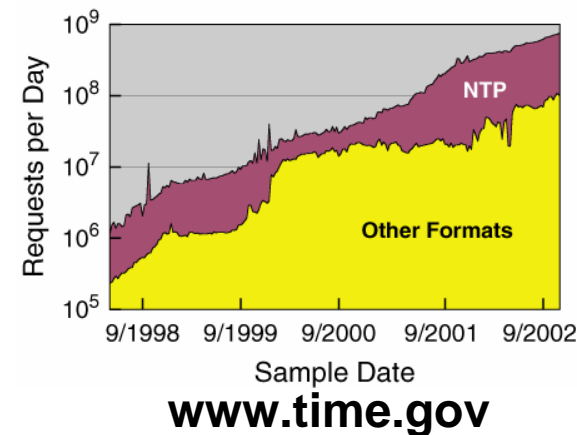
electric power metering



state field standards: testing an LP gas meter

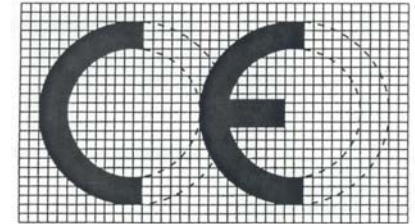


volume and flow standards

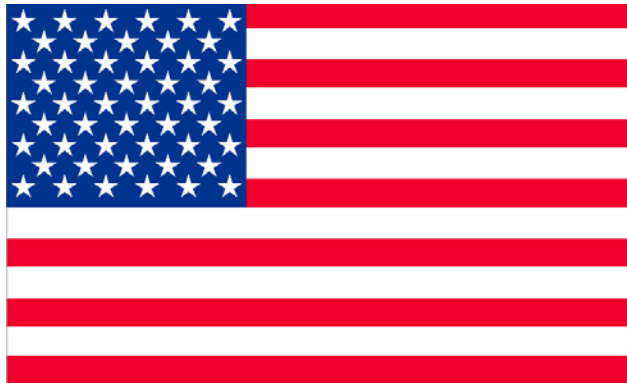


Removing barriers to trade

EC Directive on In-Vitro Diagnostic Devices



- Eliminates trade barriers *within Europe* by using only one product approval, indicated by the CE mark.
- IVD products sold in Europe must meet EC requirements.
- Traceability to “standards of the highest order” required.
- Worldwide in vitro diagnostic device market is ~\$20B.
- U.S. companies supply more than 70% of European market.



NIST Laboratories' products and services

Research

2,100 publications / year

Standard Reference Data

90 types available

5,000 units sold / year

Standard Reference Materials

>1,200 products available

30,000 units sold / year

Calibrations and tests

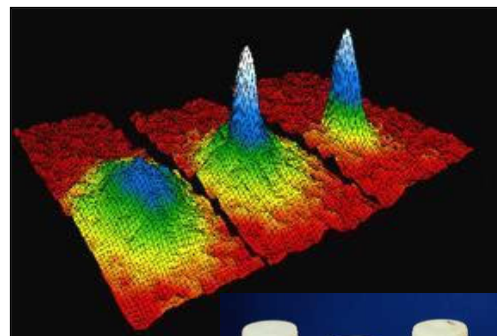
3,200 items calibrated / year

Laboratory accreditation

826 accreditations

Standards committees

390 NIST staff, 450 committees

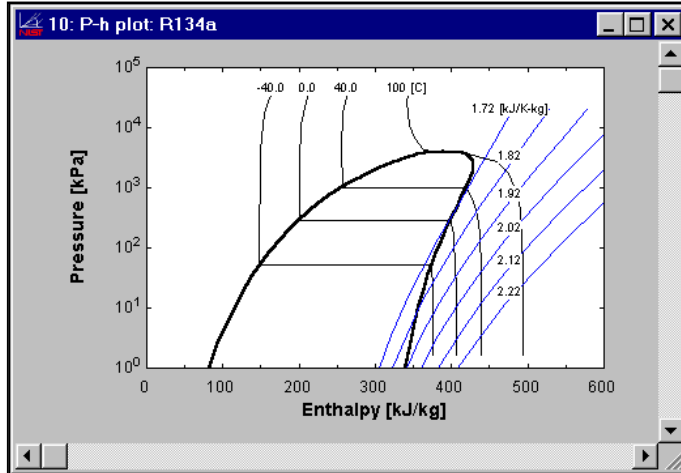


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Economic assessment of NIST programs

**1997 Radiopharmaceutical standards
97:1 benefit-to-cost ratio**



**1998 Alternative refrigerants
4:1 benefit-to-cost ratio**



**2000 Sulfur in fossil fuels
113:1 benefit-to-cost ratio**

Economic impact of NIST programs

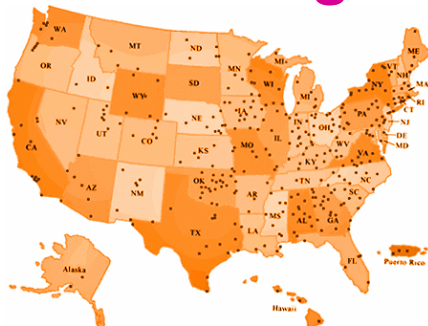
Advanced Technology Program

Since inception, returns from just 6 % of portfolio:



- \$17 billion in economic benefits
- 8 times total ATP investment

Manufacturing Extension Partnership



In 2003:

- \$4.1 billion new & retained sales
- 50,315 jobs created & retained

Baldrige National Quality Program

Since 1988:

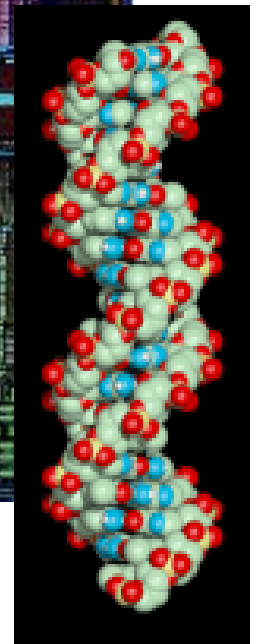
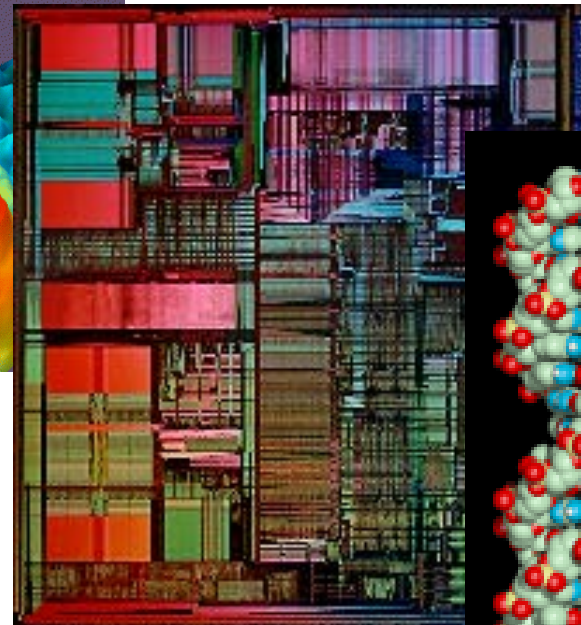
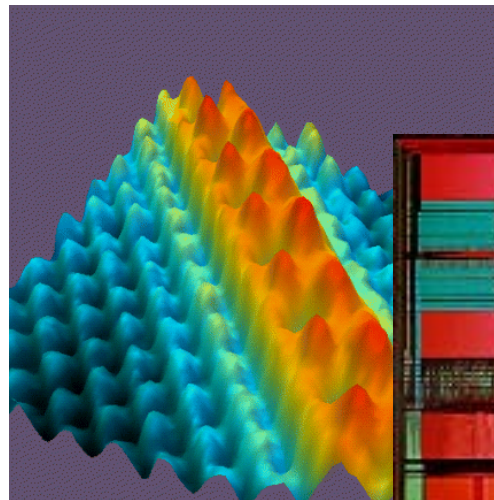
- \$25 billion in economic benefits
- 207:1 benefit-to-cost ratio



NIST 2010 : A strategic plan

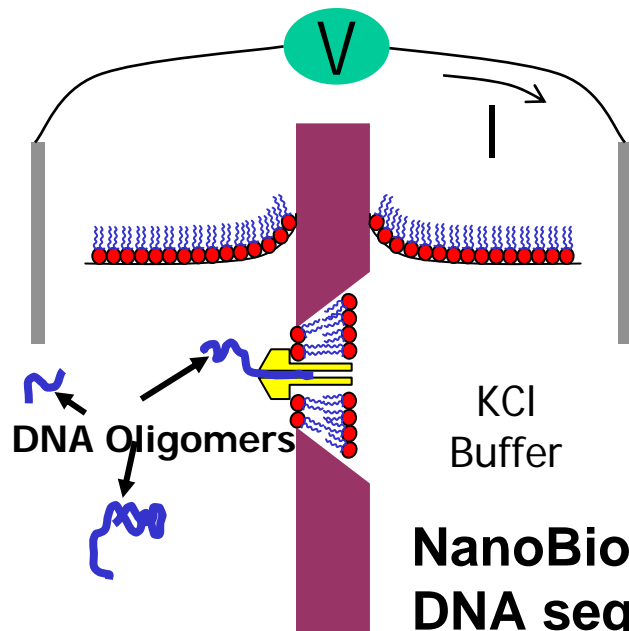
Advanced technologies driving metrology needs

- **Nanotechnology**
- **Biotechnology**
- **Informatics**
- **Homeland Security**

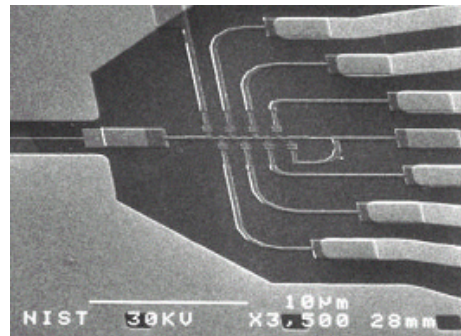


NIST enables innovation in...

...nanotechnology

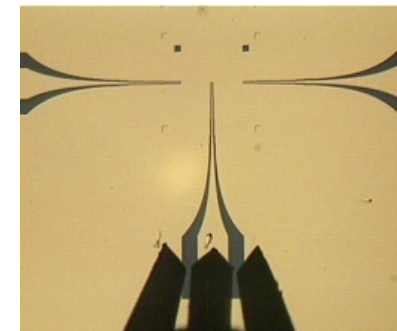
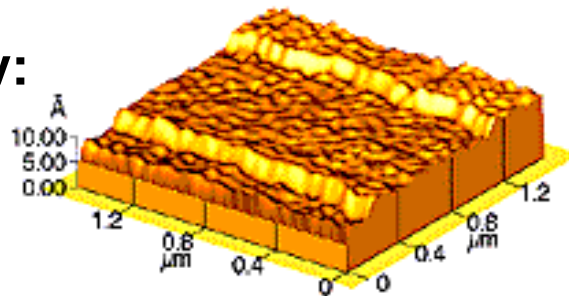


NanoBiotechnology:
DNA sequencing
through nanopores



NanoElectronics:
manipulation of
paired electrons

NanoMetrology:
atomic scale
dimensional
standard



NanoMagnetics:
precessional switching in
spin valve devices

NIST enables innovation in...

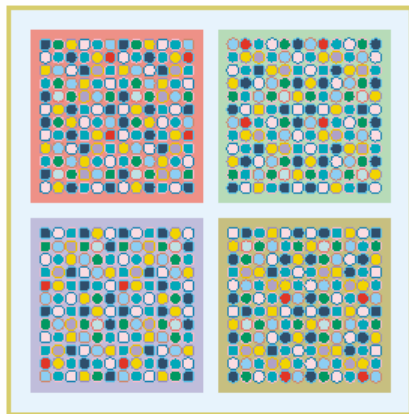
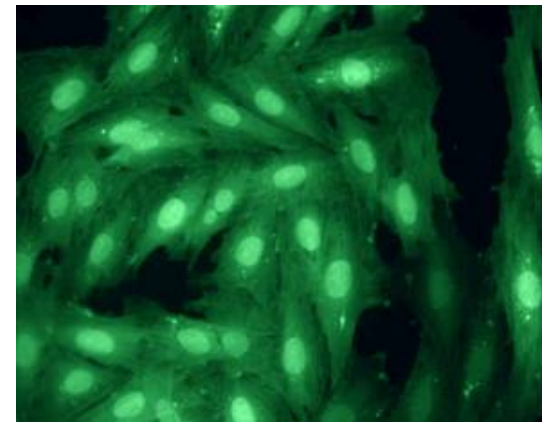
...bioscience and health care



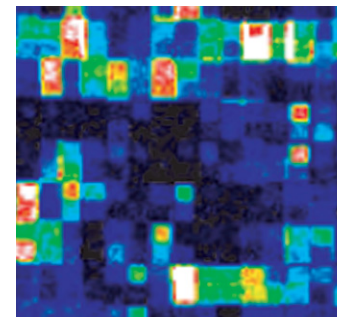
NIST SRM 2921 (human cardiac troponin) helps diagnose heart attacks.

PDB
PROTEIN DATA BANK

Tissue engineering:
Quantitative microscopy
verifies response of
indicator cells.



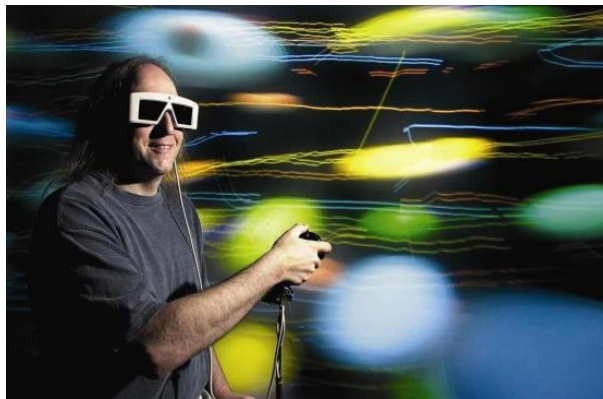
Standards for microarrays
promise to bring order to
gene expression profiling.



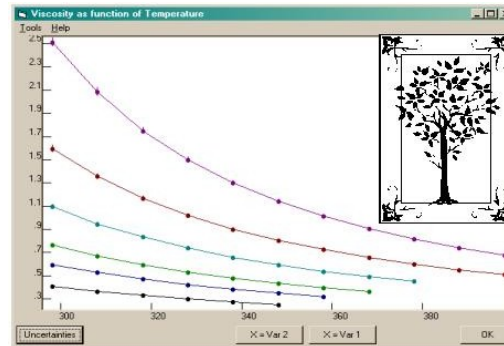
Affymetrix's
GeneChip
microarray.

NIST enables innovation in...

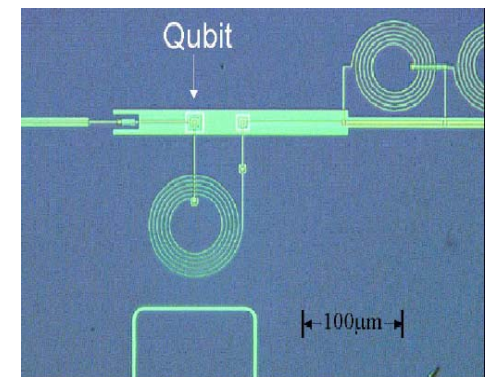
...informatics



immersive visualization



Guided Data Capture Software



Quantum computing

AES

A Crypto Algorithm for the Twenty-first Century . . .

"Working closely with industry"



128 bit key: *NIST@100NIST@100*



95285ac3f244a6ef4a466b03d7af1275
b8f8e0db1f14c9d33e72d598f12a14fc



NIST Chemistry WebBook

National Institute of Standards and Technology

NIST

NIST enables innovation in...

...homeland security

Measurements and standards infrastructure that ensures the accuracy, reliability, and security of systems critical to public safety and homeland security

Develop, compare, and test new technologies.
Enable safe and effective response to incidents.

World Trade Center Investigation

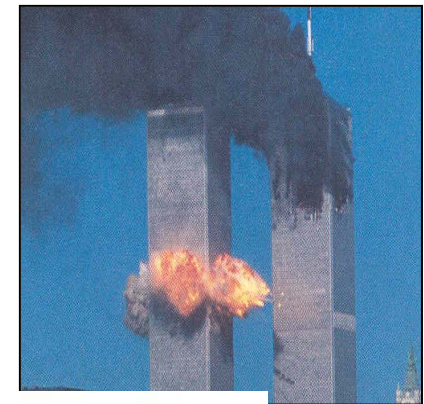
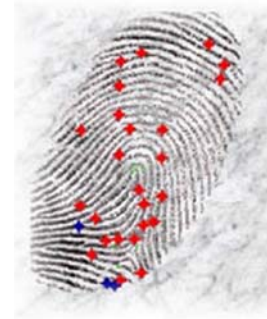


mail irradiation

gas mask performance standards



biometrics



DNA standards

NIST has...

...strong partnerships

Partnerships with industry, academia, and other government agencies have been an **integral part of NIST culture** since 1901.



Hollings
Marine
Laboratory



INTERNATIONAL TECHNOLOGY
ROADMAP FOR SEMICONDUCTORS



National Institute of
Standards and Technology

NIST

NIST has...

...strong partnerships



How students and faculty can work with NIST

Students

summer jobs

internships

SURF (Summer Undergraduate Research Fellowships)

DoC summer internship programs

DHS student program (graduate & undergraduate)

Postdoctoral research associates

NIST / NRC

NIST / NIH

NIST / DHS (future)

Faculty

collaborations

grants in precision measurement, fire research, ...

IPA sabbaticals

Opportunities at NIST

NIST

www.nist.gov

Student jobs

www.nist.gov/public_affairs/employment.htm

SURF

www.surf.nist.gov/surf2.htm

DHS student program

www.orau.gov/dhsed/

Postdocs

NIST / NRC

www.nist.gov/oiaa/postdoc.htm

NIST / NIH

nationalacademies.org/ (search “nist nih”)

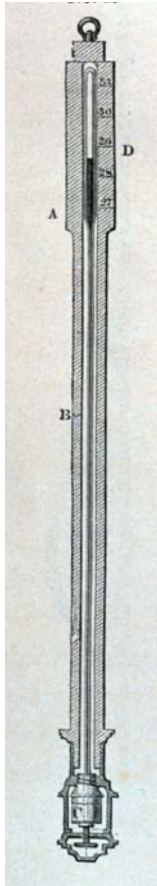
NIST grants

www.nist.gov/public_affairs/faqs/qgrants.htm

www.nist.gov/public_affairs/grants.htm

csrc.nist.gov/grants/

Measurement science: temperature & pressure



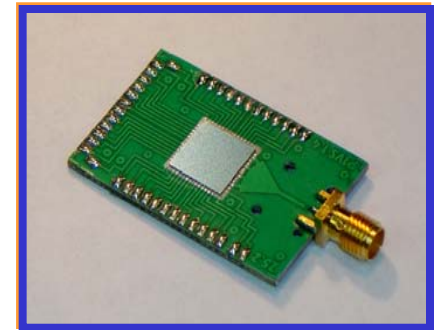
barometer



liquid-in-glass
thermometer

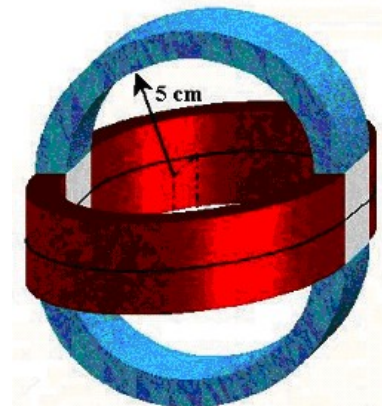
Johnson noise thermometry
Determines temperature by comparing voltage noise from a resistance thermometer with voltage noise from a calculable source.

$$V = (4kTR\Delta f)^{1/2}$$



Josephson-junction
array package

Atomic standard of pressure
Determines pressure by comparing dielectric constant measured for helium with density calculated from first principles.



quasi-spherical
microwave cavity

Food safety and nutrition

Nutrition Facts	
Serving Size ½ cup (114g)	
Servings Per Container 4	
Amount Per Serving	
Calories 90	Calories from Fat 30
% Daily Value*	
Total Fat 3g	5%
Saturated Fat 0g	0%
Cholesterol 0mg	0%
Sodium 300mg	13%
Total Carbohydrate 13g	4%
Dietary Fiber 3g	12%
Sugars 3g	
Protein 3g	
Vitamin A 80%	Vitamin C 60%
Calcium 4%	Iron 4%

- NIST developed *food SRMs* that support compliance with nutritional labeling laws.
- Present efforts are directed toward standards for dietary supplements and biotech foods

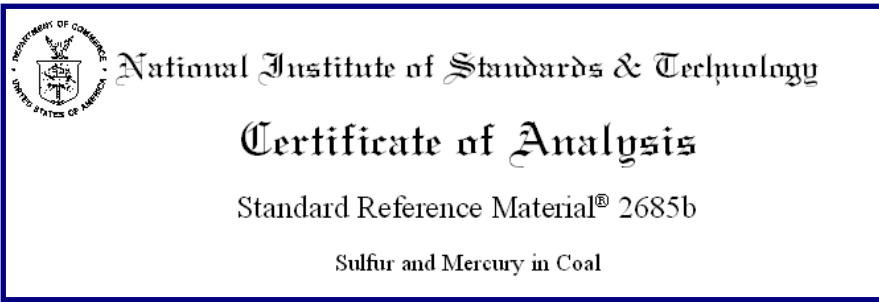
In collaboration with FDA and NIH, NIST is developing *botanical dietary supplement SRMs* with certified concentrations of active ingredients and contaminants.



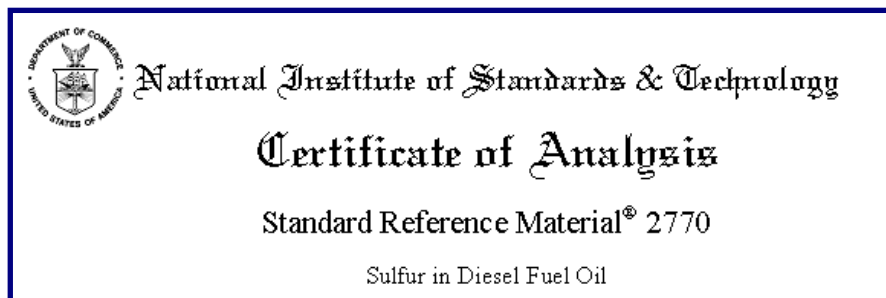
NIST developing methods that provide accurate and traceable measurement of total plant DNA.

DNA quantitation plays an important role in commerce, e.g. for the detection of biotech crop material commingled with conventional crops.

Emissions standards



SRM 2685b Sulfur and Mercury in Coal



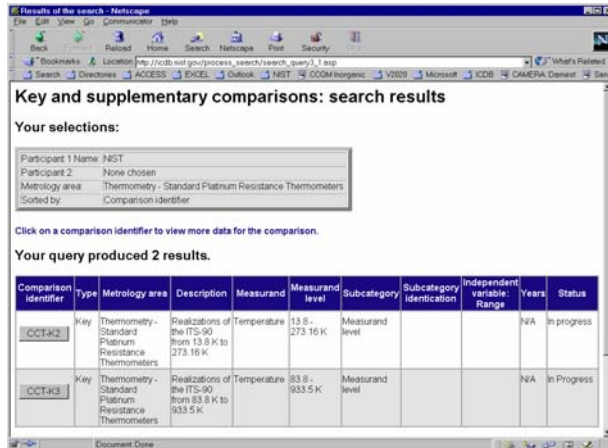
SRM 2770 Sulfur in Diesel Fuel Oil



**Indoor air quality:
“Transient Analysis of VOC
Concentrations for
Estimating Emission Rates”**

Mutual Recognition Agreements

Key Comparisons and the International Comparisons Database



Results of the search - Netscape

Key and supplementary comparisons: search results

Your selections:

Participant 1 Name: NIST
Participant 2: None chosen
Metrology area: Thermometry - Standard Platinum Resistance Thermometers
Sorted by: Comparison identifier

Click on a comparison identifier to view more data for the comparison.

Your query produced 2 results.

Comparison identifier	Type	Metrology area	Description	Measurand	Measurand level	Subcategory	Subcategory identification	Independent variable: Range	Years	Status
ICCTK2	Key	Thermometry - Standard Platinum Resistance Thermometers	Realizations of the ITS-90 from 13.8 K to 273.16 K.	Temperature	13.8 - 273.16 K	Measurand level			N/A	In progress
ICCTK3	Key	Thermometry - Standard Platinum Resistance Thermometers	Realizations of the ITS-90 from 83.8 K to 933.5 K.	Temperature	83.8 - 933.5 K	Measurand level			N/A	In Progress

- Critical for implementation of CIPM Mutual Recognition Agreements
- Prototype database developed by NIST
- Provides CIPM key comparison information
- *icdb.nist.gov*



Transfer standard package for
Key Comparisons of absolute pressure (K4)
and differential pressure (K5)

CSIRO (Australia)
IMGC (Italy)
KRISS (South Korea)

NIST (USA)
NPL (United Kingdom)
PTB (Germany)

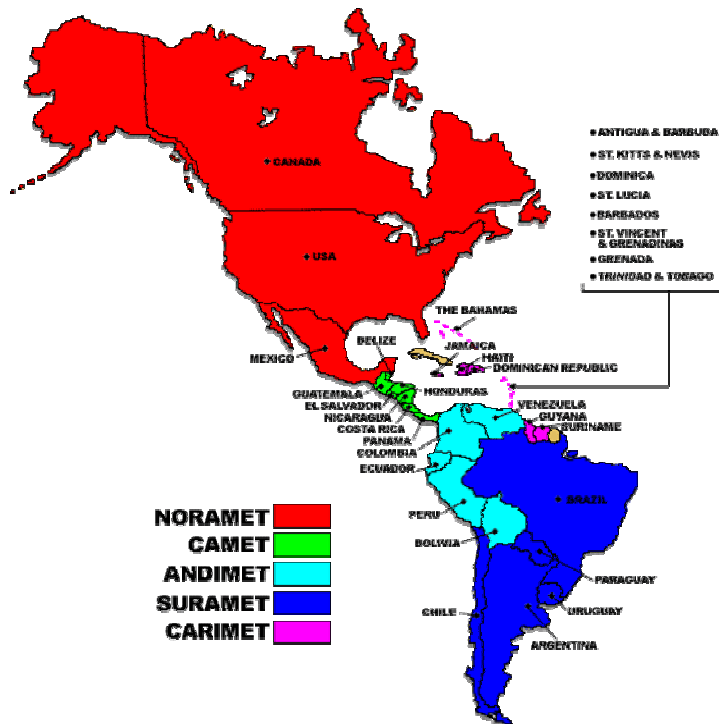
National Institute of
Standards and Technology

NIST

Toward global standardization

The Convention of the Metre

- Conférence Générale des Poids et Mesures (CGPM)
- Comité International des Poids et Mesures (CIPM)
- Bureau International des Poids et Mesures (BIPM)



NORAMET
CAMET
ANDIMET
SURAMET
CARIMET



International Organization of Legal Metrology



National Institute of Standards and Technology

NIST