Metrology in the 21st Century: NIST Role

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Measurement Science Conference
Symposium and Workshop
Anaheim, California
January 16, 2004

Outline

- Historical Perspective
- NIST 2010 – Strategic Plan
- New Drivers for Metrology
- Metrology Infrastructure for Fed. Agencies
- NIST Measurement Services
- Summary

Metrology in Ancient Times

- Standard unit of length - the length of Pharaoh's forearm plus the width of his palm
  - The Cubit
- The "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

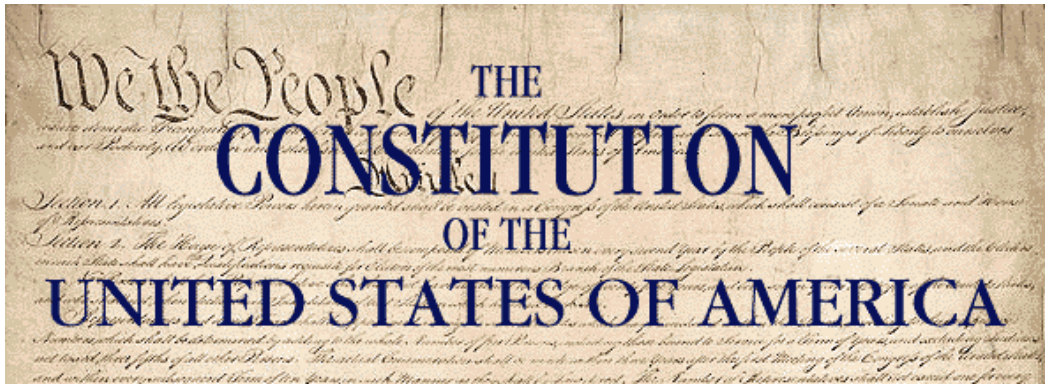
Long term stability? "Standard" Pharaoh?

"to prevent such abuses, to facilitate exchanges, and thereby to encourage all sorts of industry and commerce, it has been found necessary, in all countries that have made considerable advances toward improvement, to affix a publick stamp upon certain quantities of such particular metals, as were in those countries commonly made use of to purchase goods. Hence the origin of coined money, and of those publick offices called mints; institutions exactly of the same nature with those of the aulnagers and stampmasters of woollen and linen cloth. All of them are equally meant to ascertain, by means of a publick stamp, the ***quantity and uniform goodness*** *of those different commodities when brought to market."*

Adam Smith
"The Wealth of Nations"
1776

U.S. Federal Role in Metrology

The Constitution of the United States



"Foreign traders had begun to voice concern that goods might not be assigned a proper quantitative value at American custom-houses and that, as a result, assessed duties might be unfair and uneven from port to port."

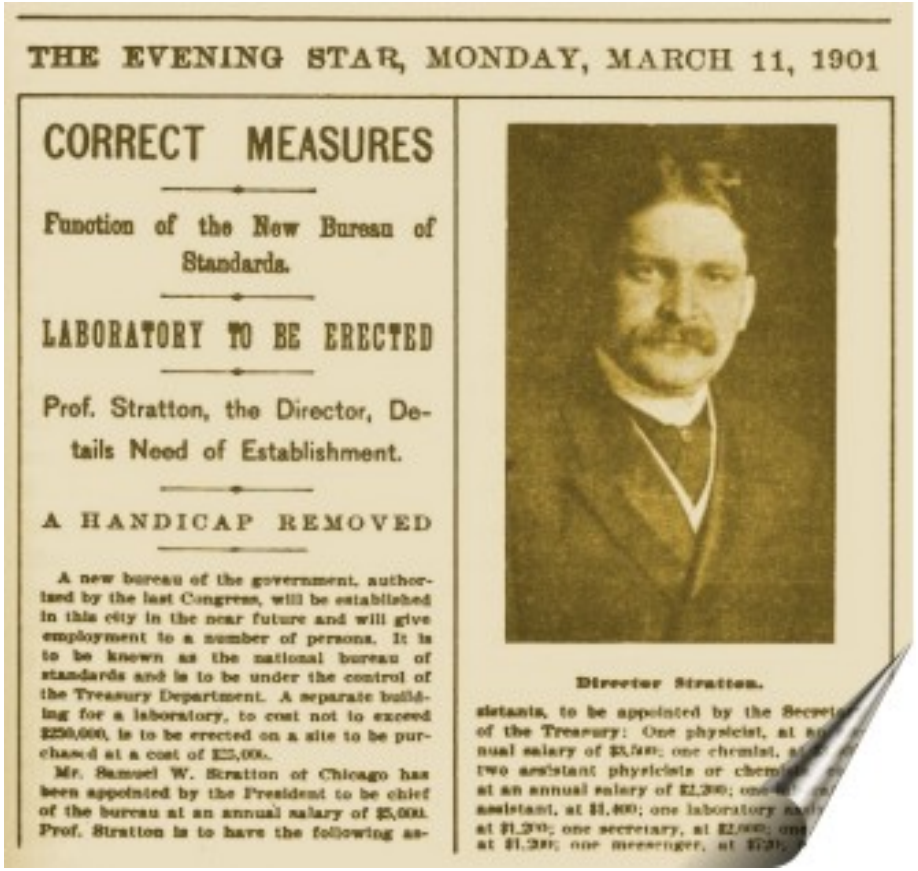
John Quincy Adams (1817)

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 … (1787)*

"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 Secret... of the Treasury: One physicist, at a... nual salary of $3,5...; one chemist, at... two assistant physicists or chem... at an annual salary of $2,2...; one... assistant, at $1,400; one laboratory ... at $1,2...; one secretary, at $2,...; one... at $1,2...; one messenger, at $...

Director Stratton.

NBS NIST NIST NIST

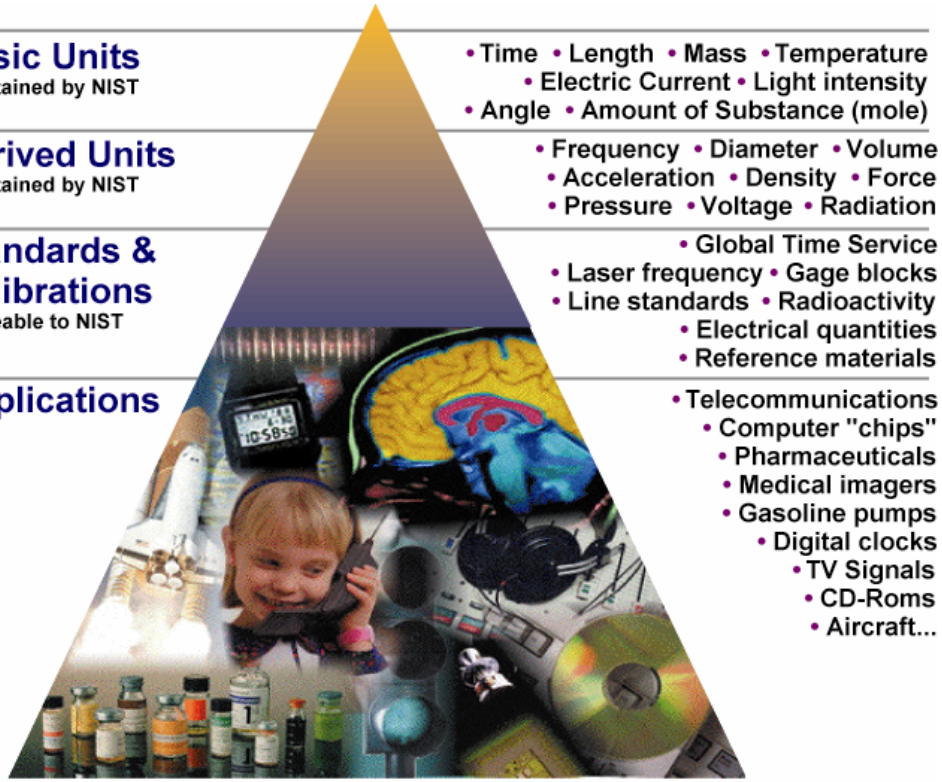
NIST CENTENNIAL 1901-2001

Impact of NIST Measurement and Standards Programs

ADVANCING TECHNOLOGY...

- Is vital for commerce and international trade
- Accounts for ~50% of U.S. economic growth
- Drives demand for new measurements and standards

TRACEABILITY



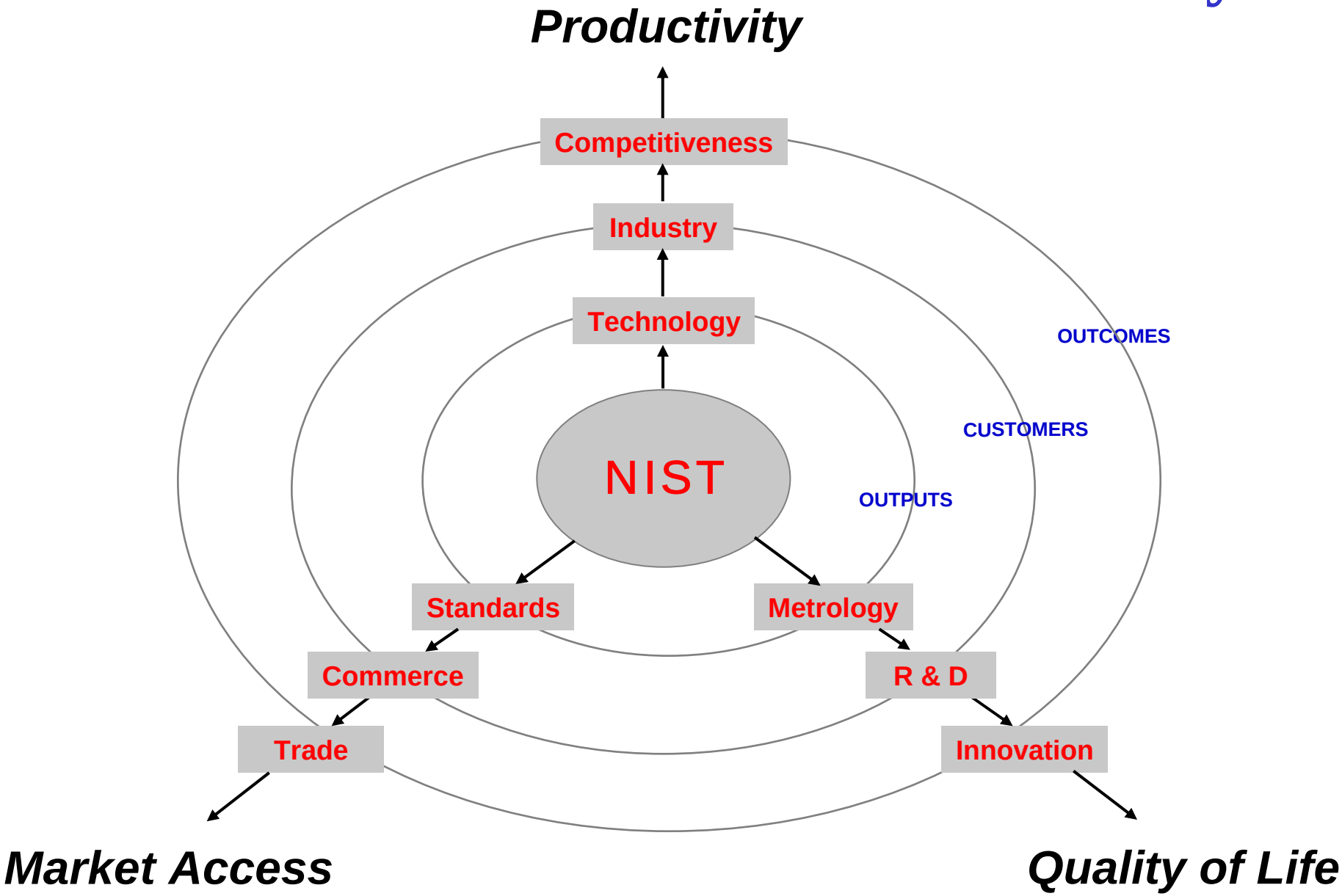
LEVERAGE

Approx. $500 M/yr NIST investment (0.7% of federal R&D)

Undergirds ~$10 B/yr of private sector investment in measurements and standards

Impacts U.S. economy - More than half of $7.6 T/yr U.S. GDP in sales supported by measurement

NIST's Pivotal Role in U.S. Economy



NIST 2010 – A Strategic Plan

Mission

NIST's mission is to develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.

Vision

Preeminent Performance - Future economic competitiveness, national security, and public well-being will be shaped by revolutionary developments in the biosciences, nanoscience, and information and knowledge management —a transformation enabled by NIST's unique measurements, standards, enabling technologies and services.

NIST 2010 Goals & Strategies

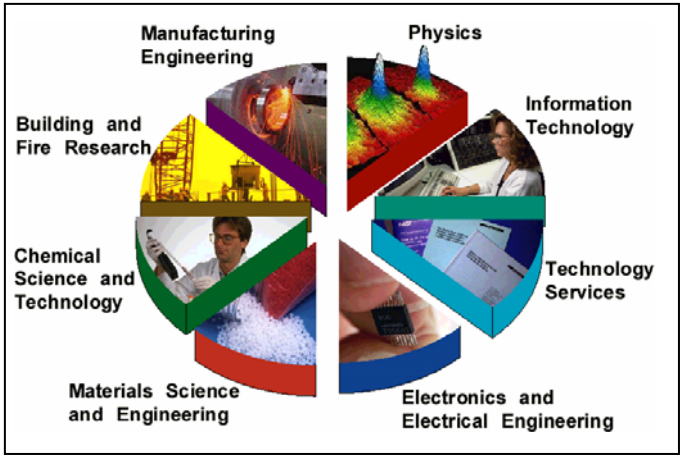
Intramural Research and Services

Goals

1. Research and develop the measurements and standards needed to support emerging science and technology-intensive industries

2. Develop and efficiently disseminate the measurements and standards needed to support the nation's strategic interests in homeland security

3. Assure the availability and efficient transfer of measurement and standards capabilities essential to established industries



NIST 2010 Goals & Strategies

Extramural Programs

Goals

1. Accelerate private investment in and development of high-risk, broad-impact technologies

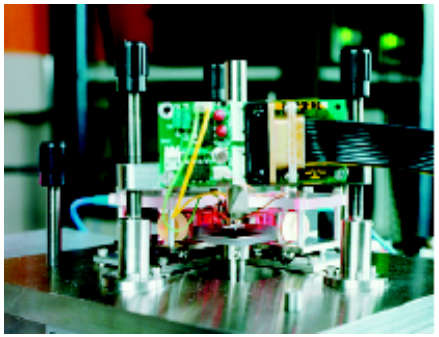
2. Raise the productivity and competitiveness of small manufacturers

3. Catalyze and reward quality and performance improvement practices in U. S. businesses and other organizations

NIST 2010 Strategic Focus Areas

Health care quality assurance: NIST will provide the measurements and standards tools needed by industry, academe, and other government agencies to advance life sciences research….

Nanoscale measurements and data: NIST will seek to achieve a technological advantage in nanometrology and a sophisticated understanding of other nanotechnologies to ensure that industry, government, and university research efforts benefit from nanoscale measurement …..

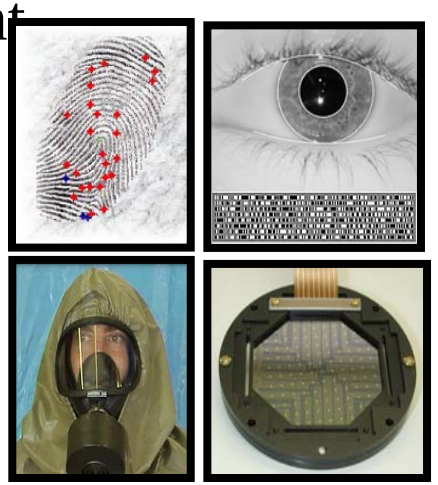


NIST 2010 Strategic Focus Areas

Information / Knowledge Management: NIST will develop new measurement, test, and standards tools that enable more effective intelligent systems and control processes, improve interoperability…

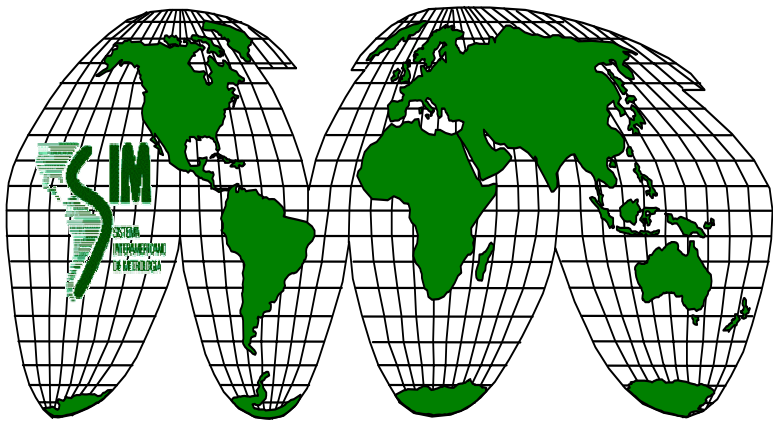
Homeland Security: NIST research and measurement services will develop and disseminate measurement and standards tools and capabilities that address the nation's homeland security needs:

- ***Cybersecurity and Critical Infrastructure Protection***
- ***Chemical, biological, radiological, nuclear and explosives detection and security***



New Driving Forces for Metrology

- Globalization of Commerce
- Telecommunications
- Health Care
- Global Environment
- Global Policy Issues
- Homeland Security



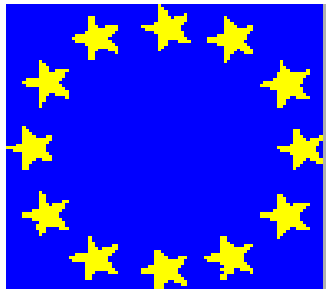
Mutual Recognition Agreement between the US and the EU

Purpose:

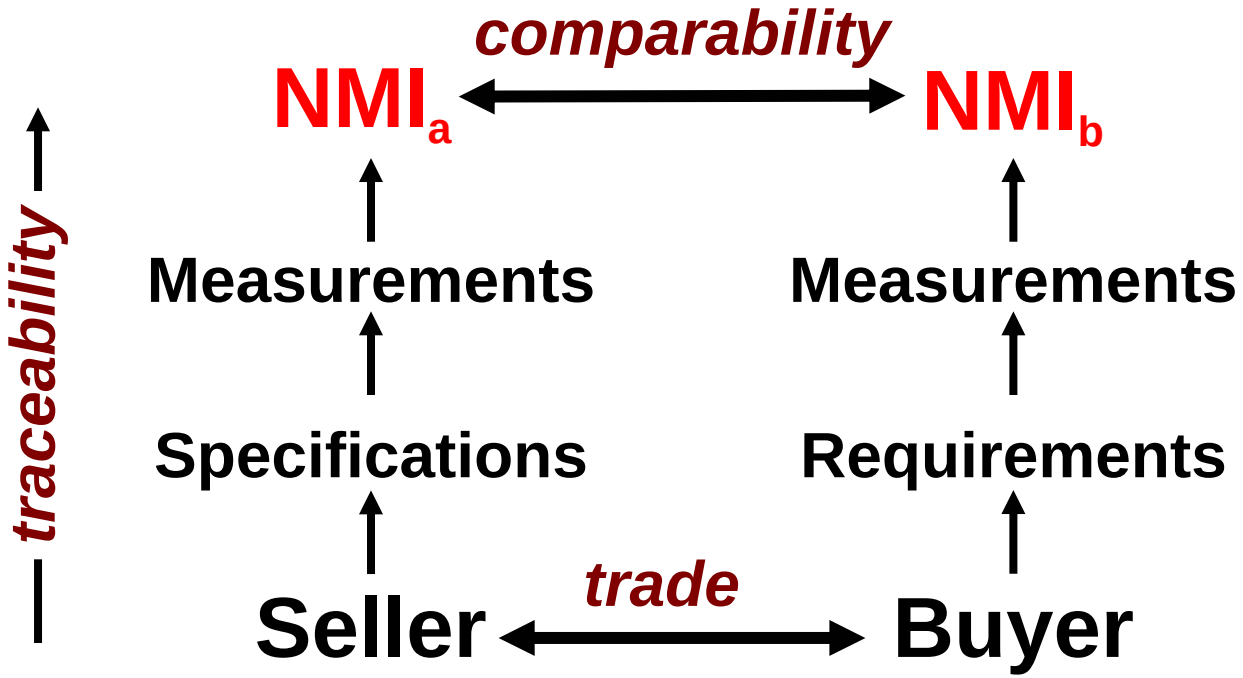
"… to facilitate bilateral trade between the United States and the European Community, … and mutual recognition of conformity assessment activities as an important means of enhancing market access …"

Regulatory Areas included in agreement:

1. Avionics
2. Environmental Protection
3. Pharmaceuticals and Medical Devices
4. Electromagnetic Compatibility and Interference
5. Occupational Health and Safety



International Trade Requires Traceability and Comparability



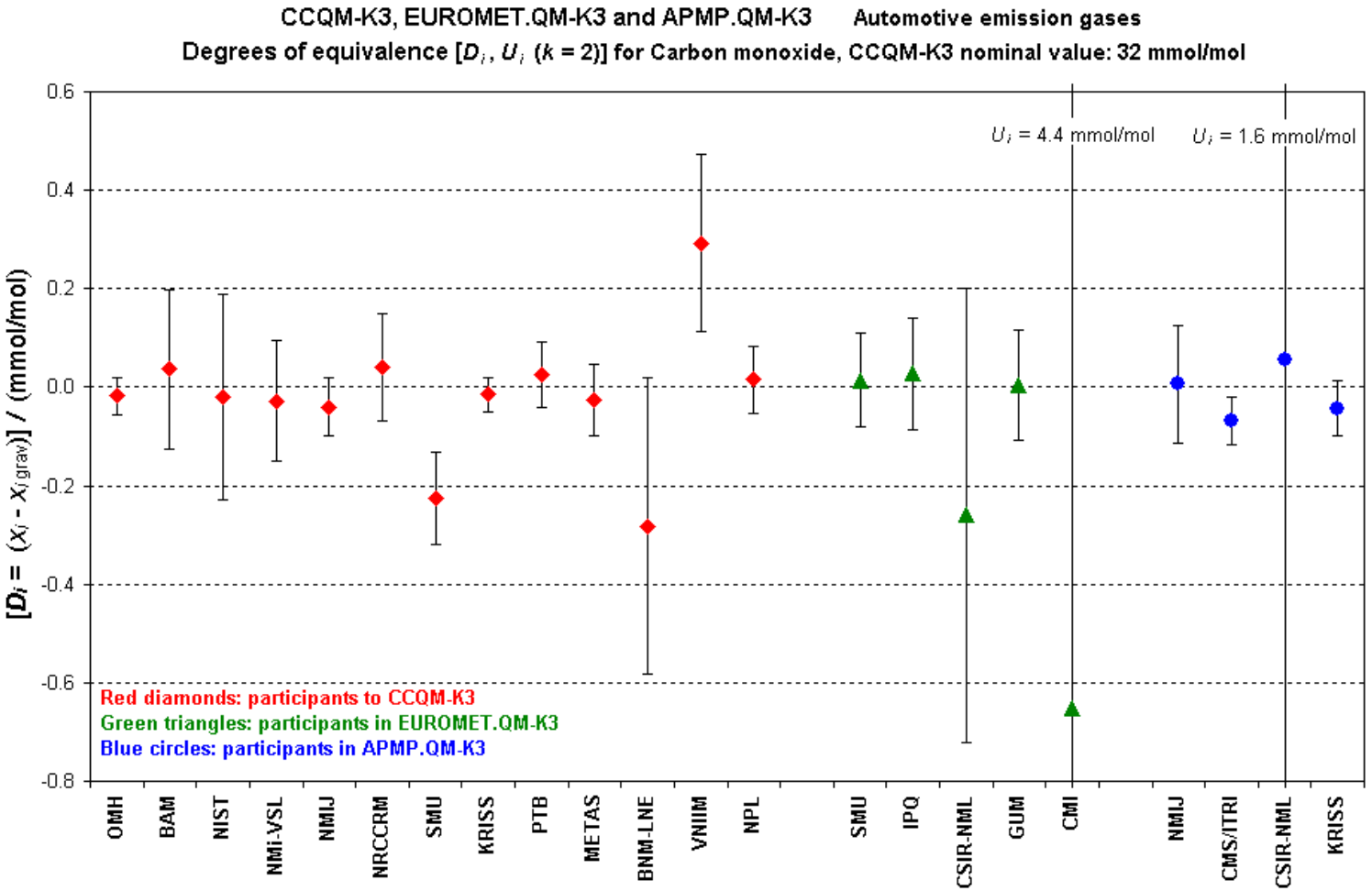
CIPM MRA (1999)

CIPM Mutual Recognition Arrangement

Objectives:

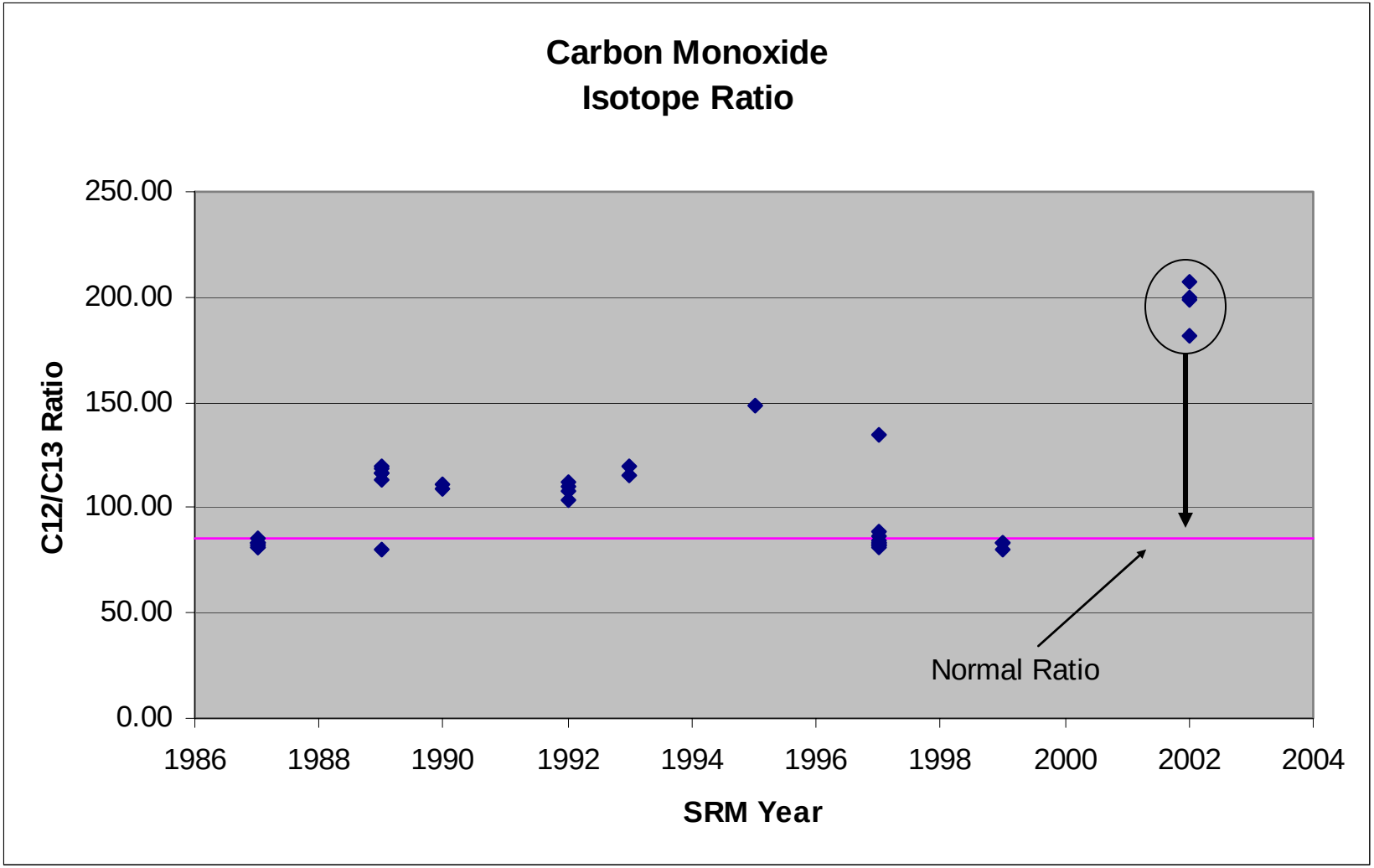
- **Establish the degree of equivalence of national measurement standards maintained by NMIs**
- **Provide for the mutual recognition of calibration and measurement certificates issued by NMIs**
- **Provide a secure technical foundation for wider agreements related to international trade, commerce and regulatory affairs**

CIPM MRA Appendix B - *Graph of Equivalence*



CO in Nitrogen – 1998-1999

Carbon Monoxide SRMs

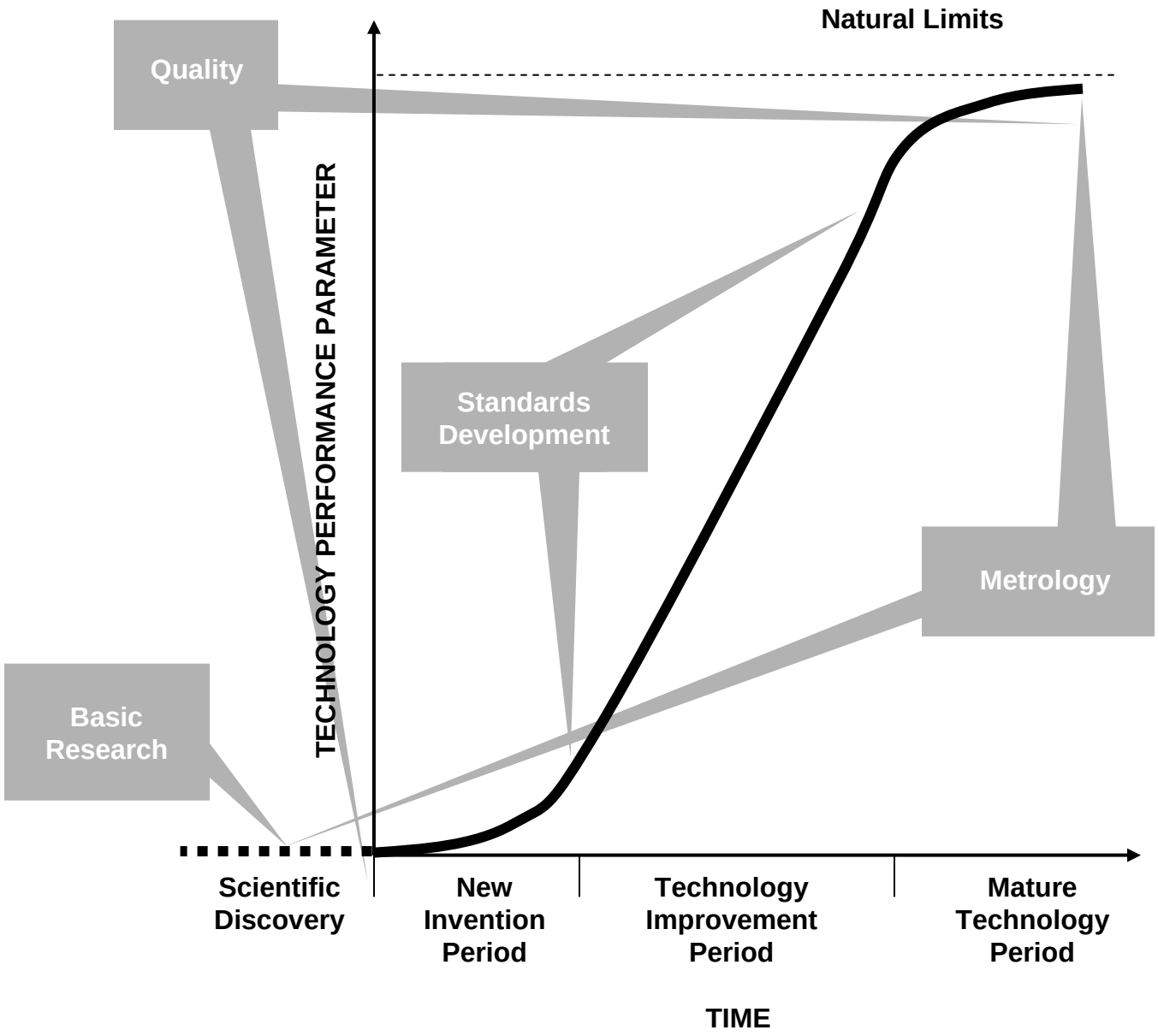


Results from NIST analysis

Critical Findings

- NDIR is sensitive to $^{13}C/^{12}C$ ratio
  - Only those with gas-filled cells (most are)
  - ^{13}C depleted in some regions of the world
  - ^{13}C removed for delivery into ^{13}C labeled chemical market
  - Bias can be as high as 1.5% relative
- NDIR users must insist that their supplier use naturally abundant Carbon Monoxide
  - A “correction factor” is not possible for this bias

Technology Development Cycle



SI Units – The Basis for Scientific Advancement

- The Meter Convention created BIPM in 1875
- The 11th CGPM established the SI system in 1960

SI Base Units		
Base Quantity	Name	Symbol
Length	Meter	M
Mass	Kilogram	Kg
Time	Second	S
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	Mol
Luminous intensity	Candela	cd

Evolution of Standards

CIPM Consultative Committees

Electricity and Magnetism (CCEM) (1927)

Photometry and Radiometry (CCPR) (1933)

Thermometry (CCT) (1937)

Length (CCL) (1952)

Time and Frequency (CCTF) (1956)

Ionizing Radiation (CCRI) (1958)

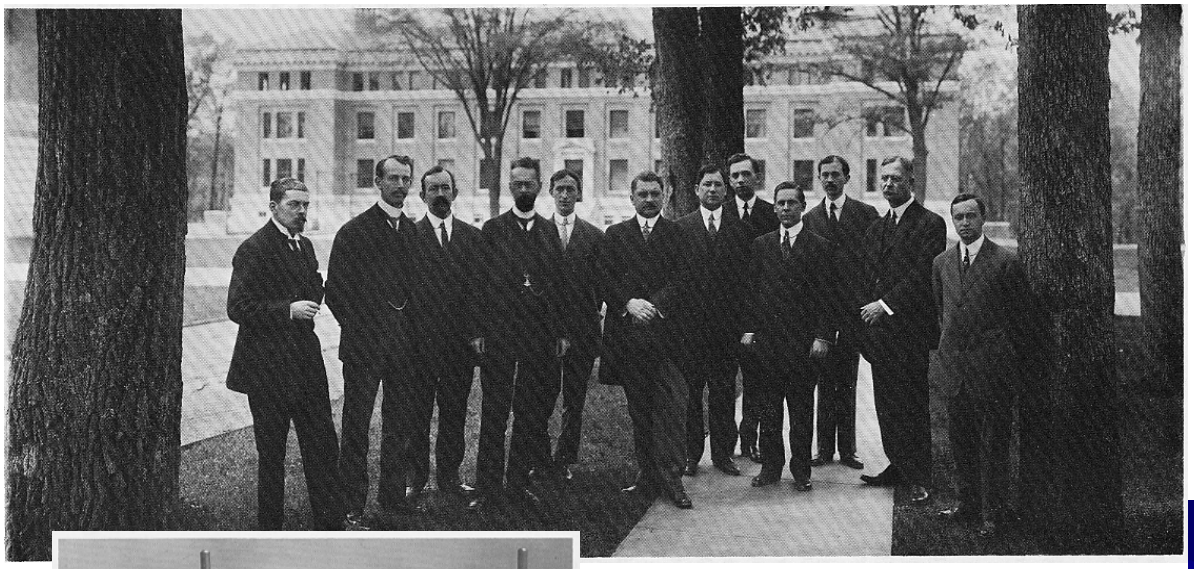
Units (CCU) (1954)

Mass (CCM) (1980)

Amount of Substance (CCQM) (1993)

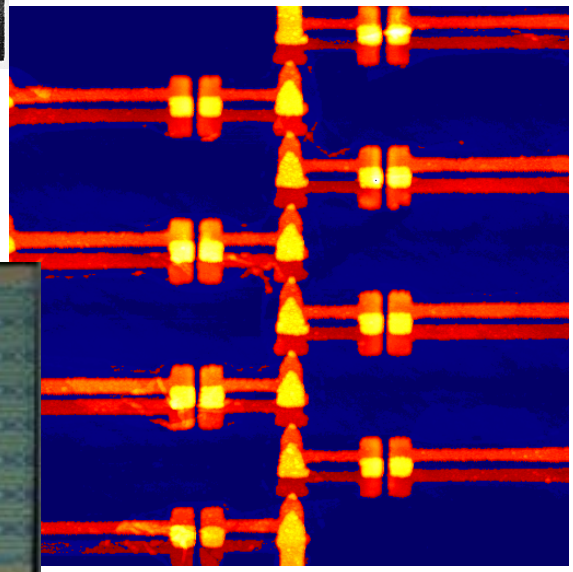
Acoustics, Ultrasound, and Vibration (CCAUV) (1998)

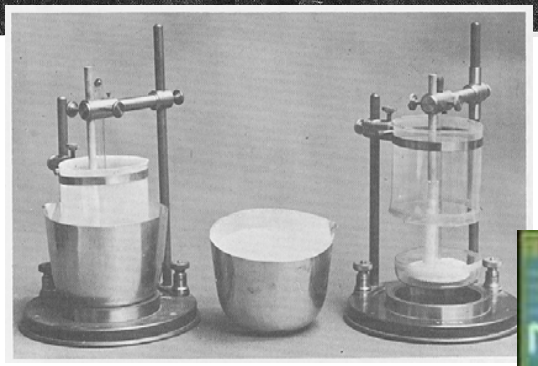
Evolution of Standards - *The Volt*



International Technical Committee of 1910

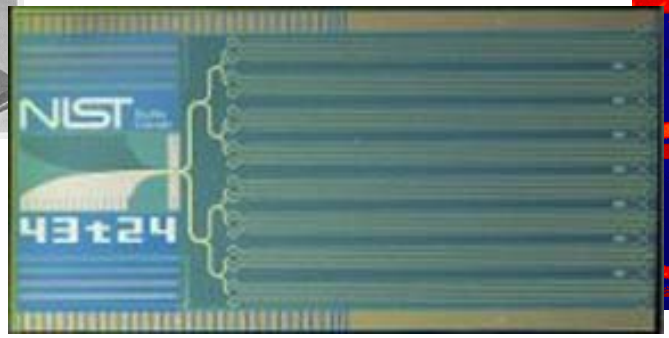
Single electron counter



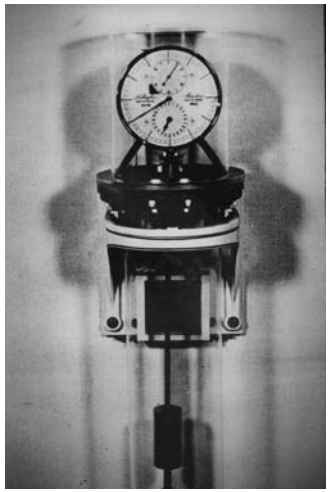


Silver Voltmeter Standard

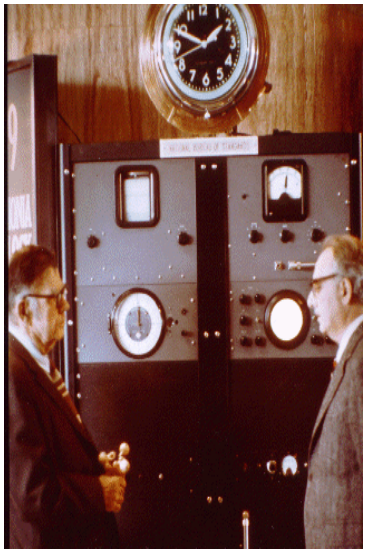
10 V Josephson Voltage Standard



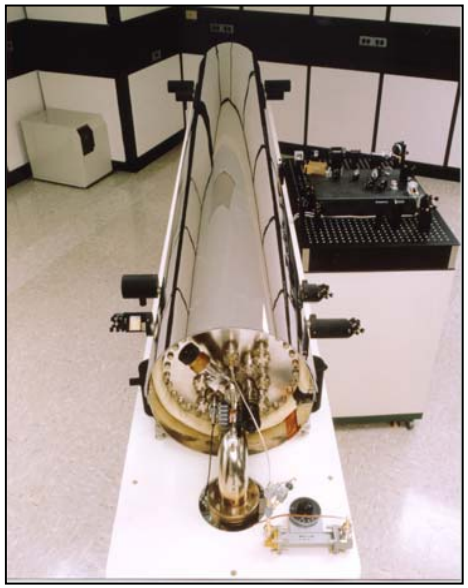
Evolution of Standards - *The Second*



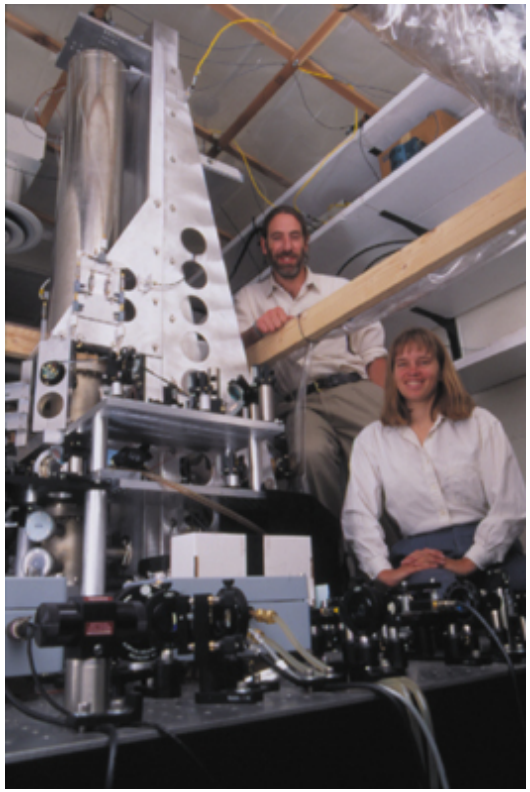
NBS Pendulum clock 1s in 3 years (1904)



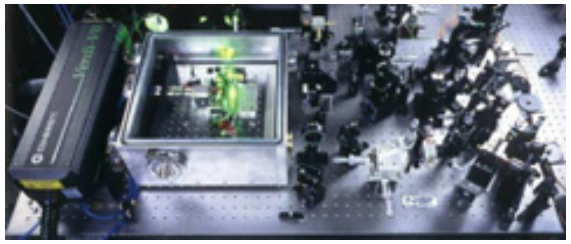
Ammonia resonator 1s in 300 years (1949)



NIST 7 1s in 6 million years (1993)



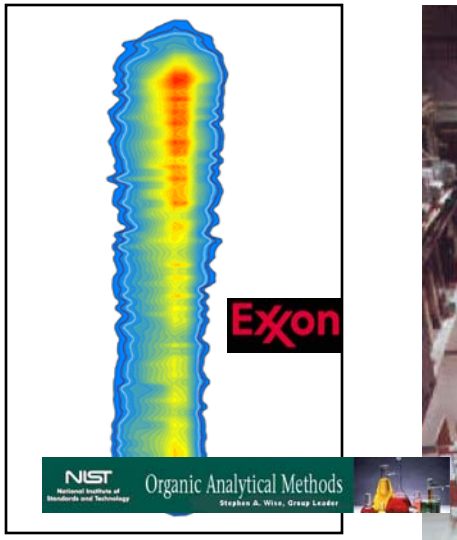
NIST F1 1s in 30 million years (1999)

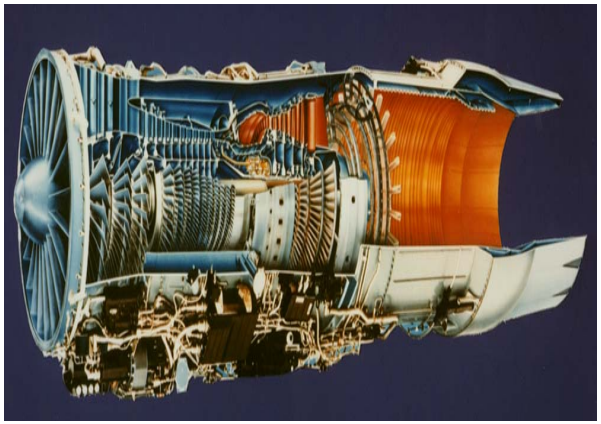


Optical clock: 1s in 30 billion years (?)

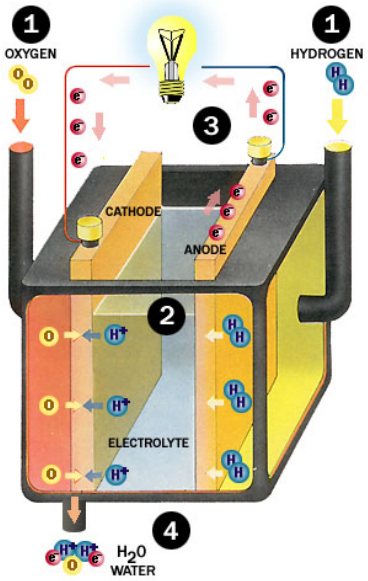
H_2! Where art thou?

Wet Chemistry





Jet Engine

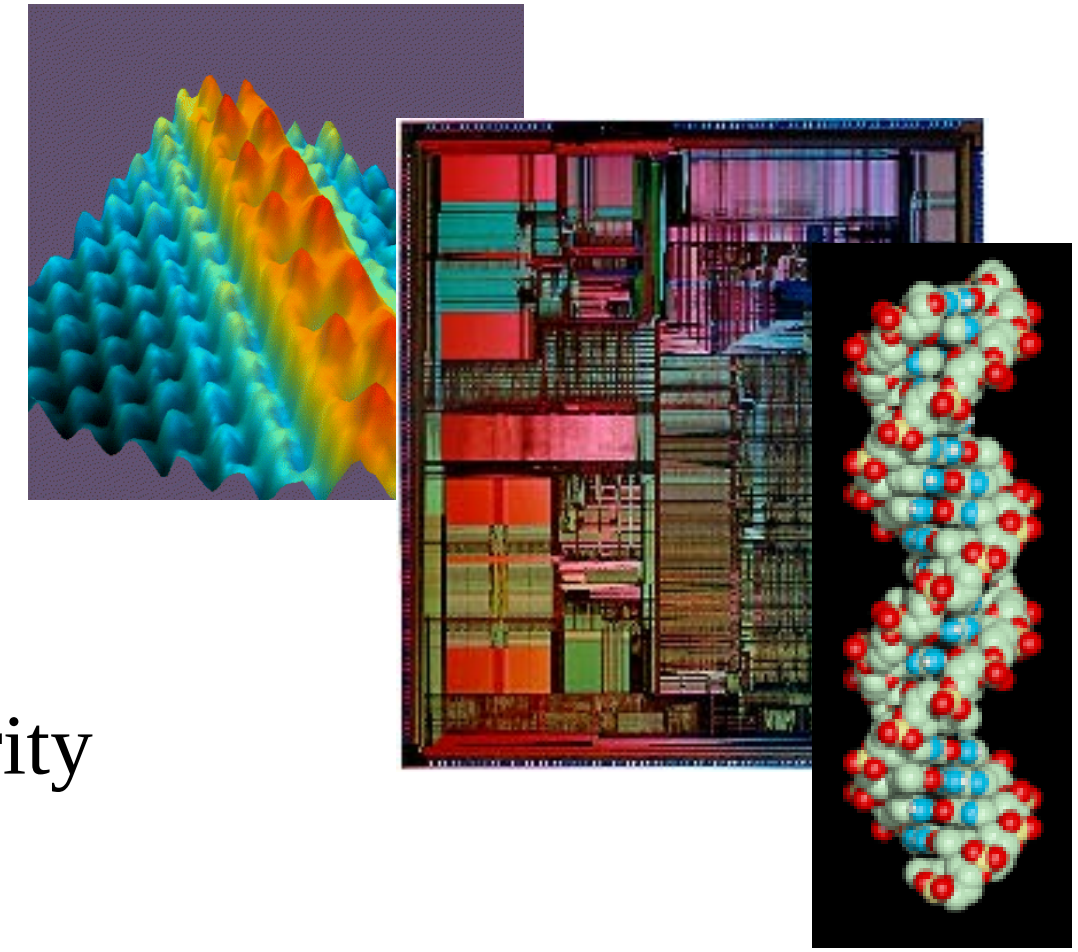


Fuel Cell

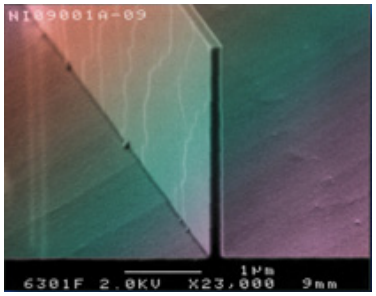
Neutron Chemistry?

NIST 2010 : Advanced Technologies Driving Metrology Needs

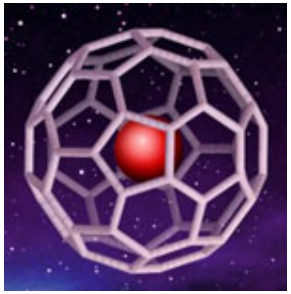
- Nanotechnology
- Biotechnology
- Informatics
- Homeland Security



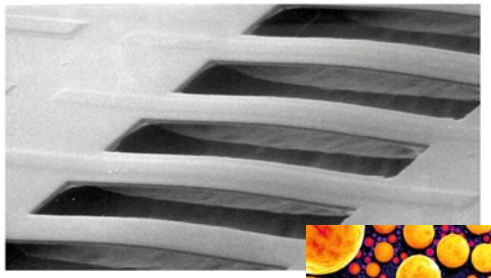
Nanotechnology



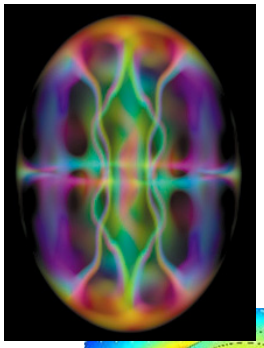
Basic nanoscale metrology

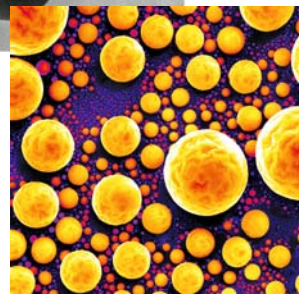


Nanomaterials characterization

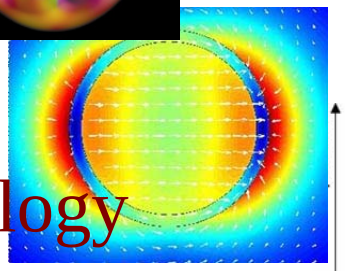


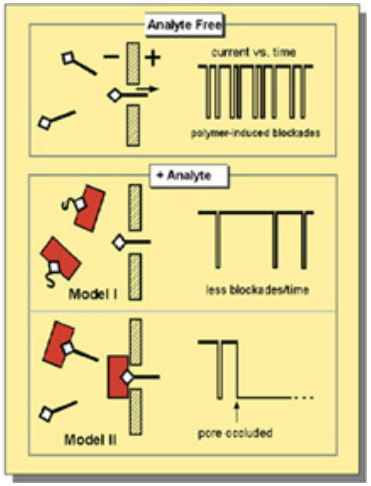
Nanoelectronics



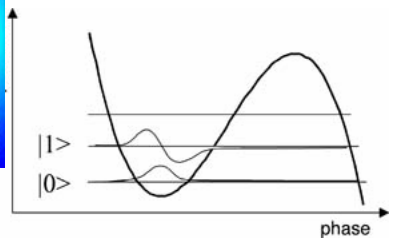


Nanomagnetics



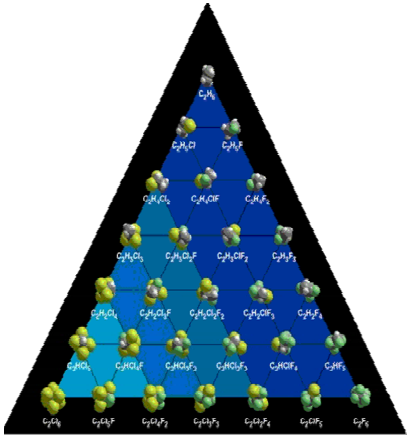


Nano-biotechnology



Quantum devices and measurements

Informatics



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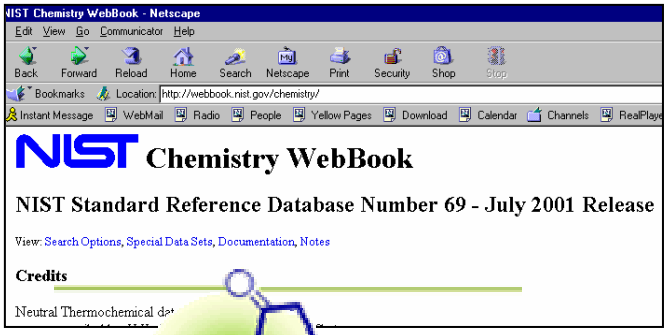
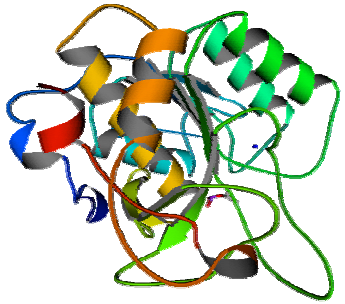
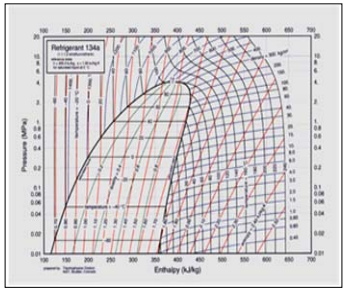
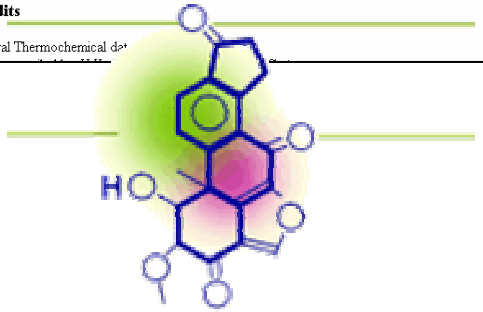








TRC

Thermodynamics Research Center

NIST DATA

FTIR Database

NIST Roles in Homeland Security

Provide the measurements, standards, and data infrastructure necessary for support of government and industry homeland security efforts

Federal Bureau of Investigation
www.fbi.gov

U.S. Department of Homeland Security

National Institute of Justice
The Research, Development, and Evaluation Agency of the U.S. Department of Justice

NIST Programs in Support of DoD

A partnership for Advanced Measurement Standards:

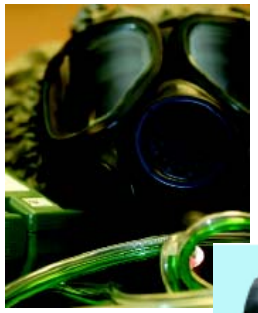
The Calibration Coordination Group (CCG) of the Department of Defense and The National Institute of Standards and Technology (NIST)

CCG Participating Military Organizations

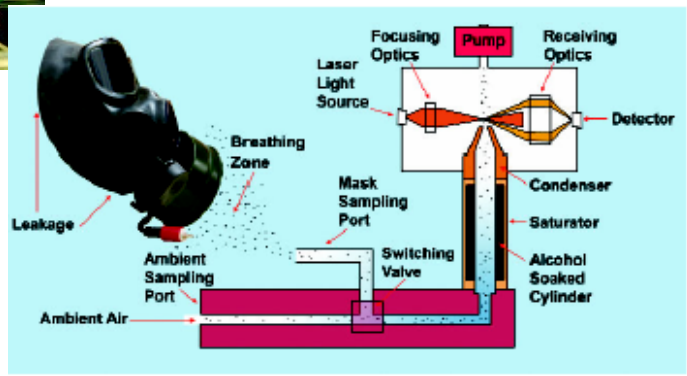
GPS Calibration

SS Voltage Standards

IC Josephson Junctions

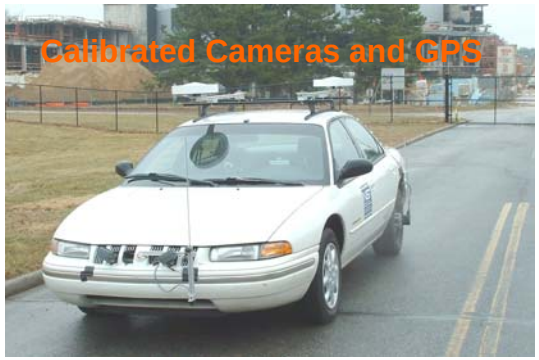


RCS Measurement



Gas Mask Tester

NIST Programs in Support of DoD



Intelligent Control of Mobility Systems Program

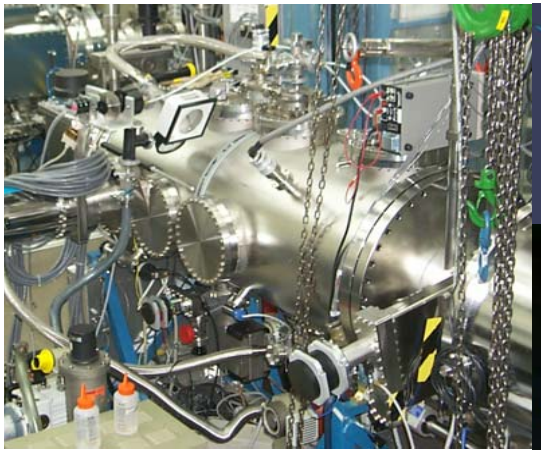
Military: **Demo III Project (Army)**

Transportation: **DOT Project**

Autonomous Vehicle Program

NIST - AFTAC
40 Years of Collaboration

- **QUALITY ASSURANCE & STANDARDS**
- **MEASUREMENT RESEARCH**



LEAP on SM-3 Rocket Navy

EKV Army

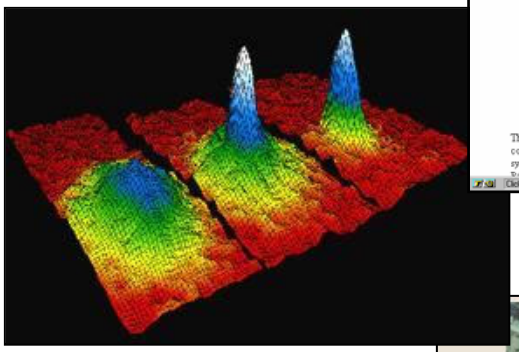
NIST Low Background Infrared (LBIR) Facility

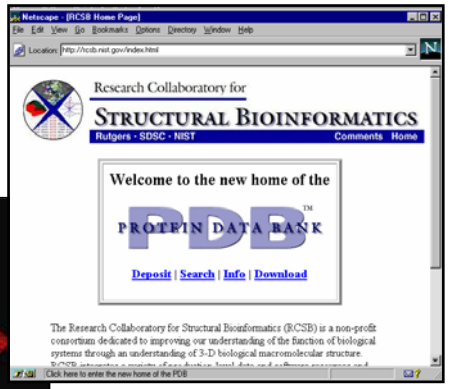
NIST Measurement Services

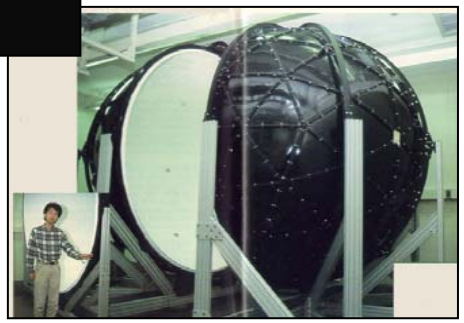
Vision for the 21st Century

NIST will provide a robust and accessible suite of measurement services based upon SI units and other national measurement standards that will enable the U.S. to continue its lead in technology development and to sustain the strength of the economy and the security of the nation

- **Measurement Research**
  >2,000 publications/year
- **Standard Reference Data**
  62 types available
  5,300 units sold/ year
- **Standard Reference Materials**
  1,300 types available
  38,000 units sold/year
- **National & International Standards**
  24 international, 99 national
- **Calibrations and Tests**
  >3,500 items/year







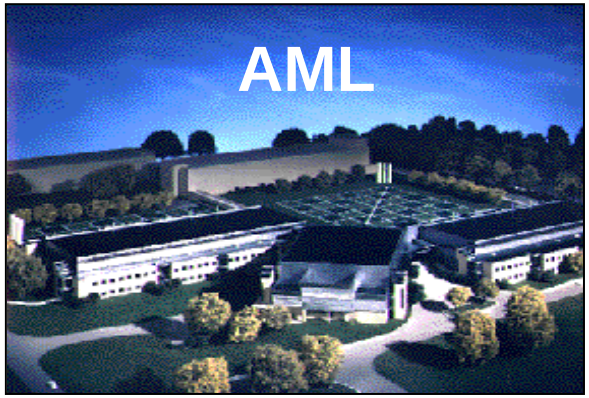
NIST Measurement Services

Guiding principles

NIST measurement services are to be:

- Those most needed by the U.S. for leadership in technology development of importance to economy and national security
- Of excellent quality based on unassailable metrology
- Cost effective to the American taxpayer
- The source of metrology knowledge, guidance, and support for U.S. citizens and industry via educational programs and advisory support
- Managed for worldwide acceptance
- Traceable to results of measurements or values of standards that NIST itself provides, either directly or through an official NIST program or collaboration

Unique NIST Research Facilities



- Completed on-time in 2004
- World-leading laboratory facilities: air quality, temperature, vibration, humidity
- Will meet stringent industry measurement requirements: nanotech, semiconductors, biotech, advanced manufacturing, information technology….

- Cold rooms (4 °C) for biotechnology research
- Clean rooms and non-metallic modules
- High velocity ventilation systems; perchloric acid hoods
- Control of temperature to ± 0.5 °C
- Improved humidity control (40% ± 5% RH)
- Vibration dampened areas for sensitive equipment

Summary

NIST's vision is to be the best in the world in measurements and standards -- enabling technologies and services

- Equity in trade issues initial drivers for metrology programs
- International trade has been the major driving force for metrology in recent years
- The new driving forces for metrological advances in the 21st Century come from new technologies, as they have since the industrial revolution
- National security continues to be high priority for NIST metrology programs

Increasing Need for International Measurement Standards

Global Trade

Mutual Recognition of Measurements & Standards

Deregulation of Utilities

Natural Gas, Electricity

New Environmental Regulations

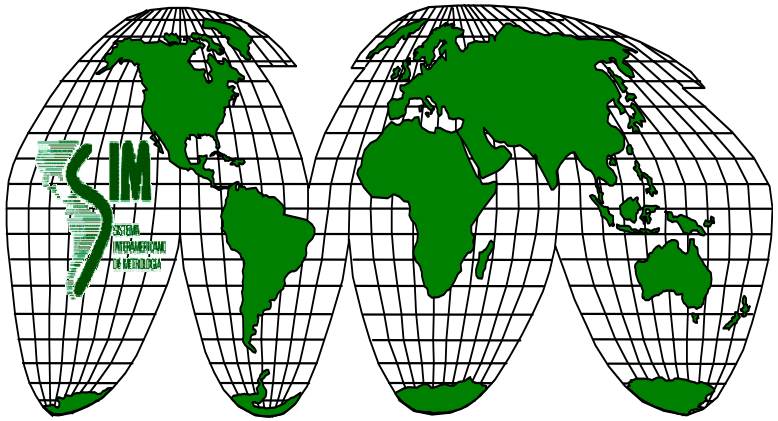
Clean Air Act Amendment

Increased technical barriers to trade

EU IVD Directives, GMO Issues

Global Policy Issues

Global Climate Change



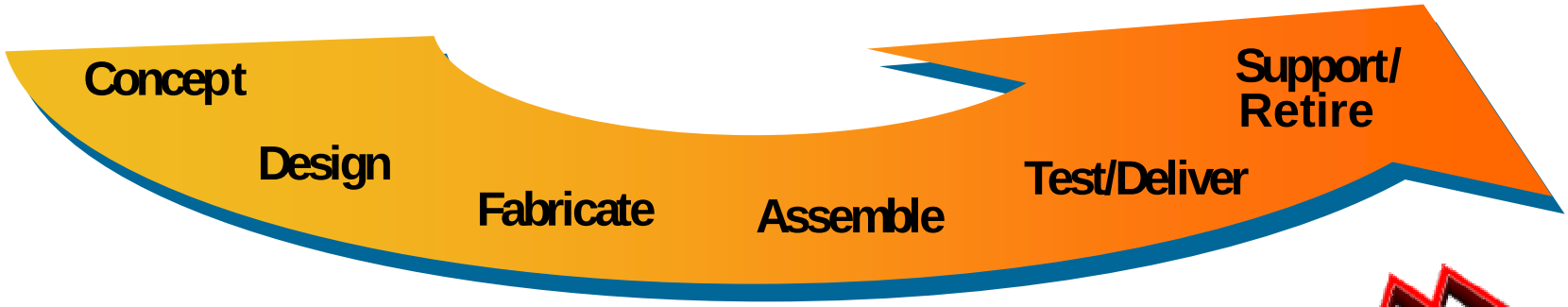
Competitiveness

- a measure of a country's advantage or disadvantage in selling its products in international markets. *Organization of Economic Cooperation and Development (OECD)*

- the ability of an entity to operate efficiently and productively in relation to other similar entities …the overall economic performance of a nation, particularly its level of productivity, its ability to export its goods and services, and its maintenance of a high standard of living for its citizens. *Joan Spero and Jeffrey Hart, The Politics of International Economic Relations, http://www.indiana.edu/~ipe/glossry.html*

- how successful one party is in offering favorable terms and securing the business. More favorable terms may involve a lower price, higher quality, a faster delivery time, and other aspects of the product. *Operations Management Course, William J. Stevenson*

Informatics



Product Life Cycle

PDES, Inc.®

- Intelligent Interconnected Systems
- Interoperability for Collaboration and Sharing
- Virtual Measurements and Dynamic Data Infrastructure