



**Boston, MA  
August 19, 2015**

***Introduction to Symposium:***  
**“Chemistry and the International System of  
Weights and Measures”**

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President, CIPM Consultative Committee on Metrology in Chemistry & Biology**

# Topics

- **Metrology and Its Need throughout the Ages**
  
- **Roles and Responsibilities of:**
  - **The International Committee on Weights and Measures**
  - **The International Bureau on Weights and Measures**
  - **National Metrology Institutes**
  
- **The Symposium's two Sessions and Demonstrations of the Realization of the Kilogram and the Mole**

**Mankind has long recognized the need  
for measurement science and standards**

# The Need for Metrology: Recognized Through the Ages

The ancient Egyptians were well known for their measurement capabilities

- 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 required on each full moon
  - Calibration / Traceability
  - Severe penalty for non-compliance



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

In addition to the well known Royal Cubit for length measurement, a host of other accurate measurement standards existed. For example in mass:



Predynastic  
Stone mass standard  
(5,000 to 7,000 years old)



The Deben,  
12g, 27g, 93.3 g  
(3,000 to 5,000 years old)

# 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*

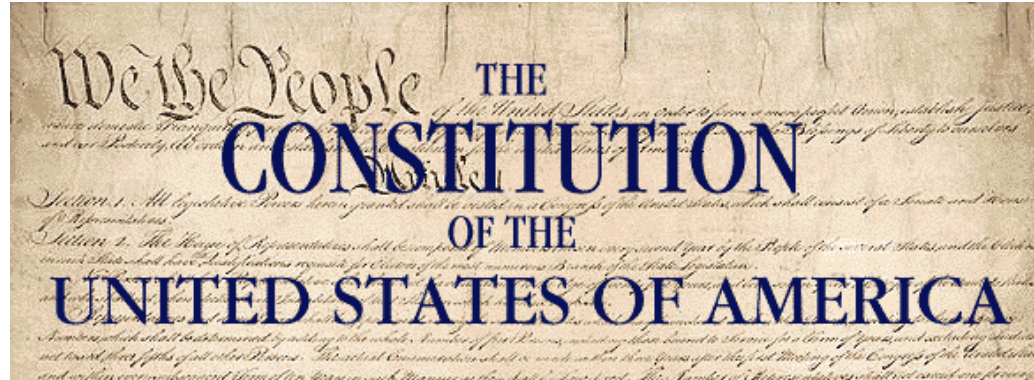


## Magna Carta of 1215

“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.”

# U.S. Federal Role in Metrology

## *The Constitution of the United States*



**Article 1, 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 ... (1788)**

**“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)**

# International Metrology Infrastructure: The Early Years

**20 May 1875**

**The Meter Convention**, an intergovernmental treaty signed by representatives of 17 nations, **established an organizational structure for member governments to act in common accord on all matters relating to units of measurement.**

It established:

- I. a scientific and permanent **International Bureau of Weights and Measures (BIPM)**
- II. operated under the direction of an **International Committee of Weights and Measures (CIPM)**
- III. controlled by the **General Conference for Weights and Measures (CGPM).**



# Advent of the NMIs

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**In subsequent years, National Metrology Institutes (NMIs) were established:**

**1887 PTR ⇒ PTB** “to supervise and direct calibration and to establish metrological standards”

**1900 NPL**

“for standardising and verifying instruments, for testing materials and for the determination of physical constants”

**1901 NBS ⇒ NIST** “for custody of the standards; the comparison of the standards...; the construction ... of standards; the testing and calibration of standard measuring apparatus; solution of problems which arise in connection with standards; the determination of physical constants and the properties of materials ...”



## Ideally, a National Metrology Institute (NMI)

- Is seen as its country's **ultimate reference point for measurements and standards** *to support industry, science and technology enterprise, national defense, national and international commerce, and quality of life for its citizens*
- Has some enabling legislation in support of this role that is recognized within its country
- Has its programs **well-aligned with its country's strategic priorities**

An NMI can provide and disseminate its National Standards through a centralized system, a distributed system, or a combination of both

## **NMI's around the world *are working together to link our global measurement system to the fundamental constants of nature***

<b>Unit</b>		<b>Reference value used to define the unit</b>		
		<u>in current SI</u>	<u>in the new SI</u>	
second,	s	$\Delta\nu(^{133}\text{Cs})_{\text{hfs}}$	$\Delta\nu(^{133}\text{Cs})_{\text{hfs}}$	Cs hyperfine splitting
metre,	m	$c$	$c$	speed of light in vacuum
<b>kilogram,</b>	<b>kg</b>	$m(\mathcal{K})$	$h$	Planck constant
ampere,	A	$\mu_0$	$e$	elementary charge
kelvin,	K	$T_{\text{TPW}}$	$k$	Boltzmann constant
<b>mole,</b>	<b>mol</b>	$M(^{12}\text{C})$	NA	Avogadro constant
candela,	cd	$K_{\text{cd}}$	Kcd	luminous efficacy of a 540 THz source

Rigorous realization of these units has provided undeniable impact on trade, commerce, and quality of life

In addition to supporting the realization of SI units, more and more countries are directing their NMIs to **focus increasing amounts of their research and measurement services activities on**

***Quality of Life and Economic & Social Sustainability***

Since NIST's inception as NBS, in addition to maintaining the more traditional National Physical Measurement Standards, **we have also focused a significant portion of our research and measurement services activities on addressing contemporary societal needs.**

**Supporting the Industrial Revolution**



**NIST has become:**

- a key player on the Administration's Innovation Team
- the nation's go-to agency for measurements, standards, and technology

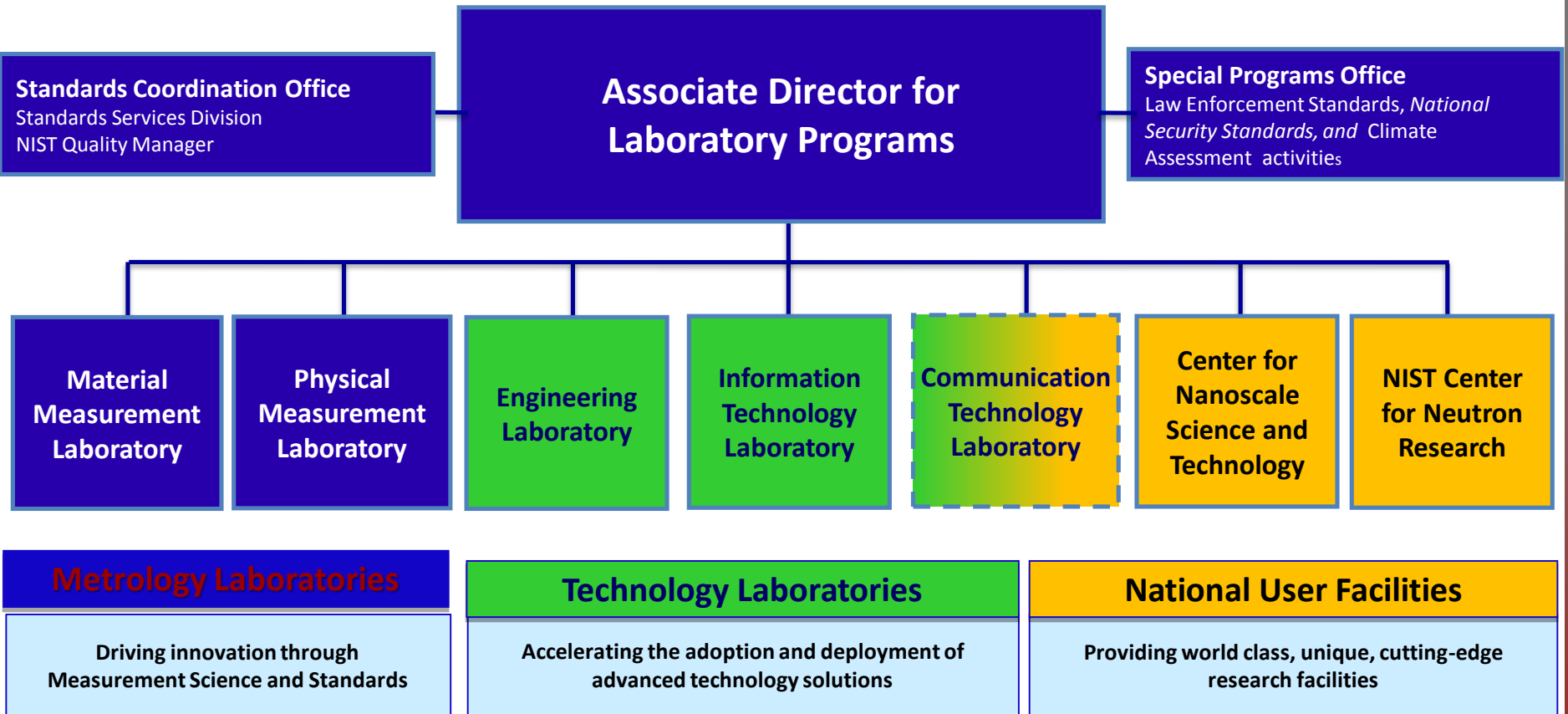
1901

2015

- **Advanced Communications**
- **Advanced Manufacturing**
- **Advanced Materials**
- **Cyber-Physical Systems**
- **Cybersecurity**
- **Disaster Resilience**
- **Forensic Science**
- **Greenhouse Gas Measurements**
- **Healthcare**
- **Quantum Science**

# NIST Laboratory Program

*providing measurement solutions for industry and the nation*

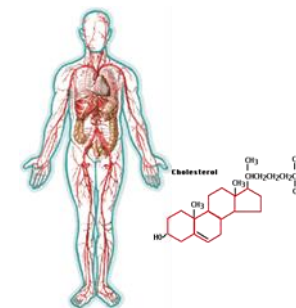
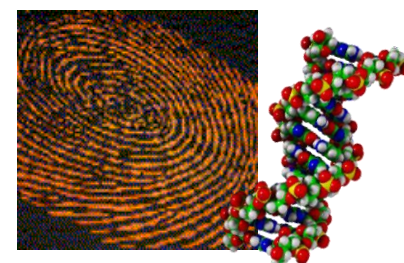
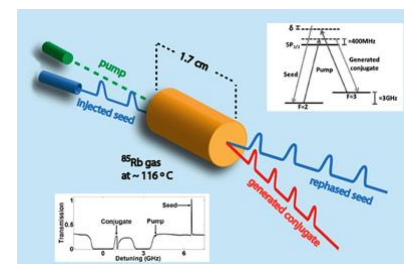


**A NIST, Meter Convention activities fall within two organizations**

# NIST Metrology Laboratories

Responsible for advancing the state-of-the-art for measurement science and the dissemination of this metrology into industry, other government agencies, and academia.

- **The Material Measurement Laboratory (MML)** serves as the national reference laboratory for **measurements in the chemical, biological, and material sciences** through activities ranging from fundamental and applied research, to the development and dissemination of certified reference materials, critically evaluated data, and other programs/tools to assure the quality of measurement results.
- **The Physical Measurement Laboratory (PML)** develops and disseminates the national standards of **length, mass, force and shock, acceleration, time and frequency, electricity, temperature, humidity, pressure and vacuum, liquid and gas flow, and acoustic, ultrasonic, and ionizing radiation** through activities ranging from fundamental measurement research to provision of measurement services, including calibration services, standards, and data.



# CIPM Mutual Recognition Arrangement

... was established in 1999 in response to a growing need for an open, transparent and comprehensive scheme to give users :

- **reliable quantitative information on the comparability of national metrology services** and
- to provide the technical basis for wider agreements negotiated for **international trade, commerce and regulatory affairs.**

## ***Requires:***

1. **Declaring and documenting calibration and measurement capabilities (CMCs)**
2. **Evidence of *successful* participation in formal, *relevant* international comparisons**
3. **Demonstration of system for assuring quality of each NMI's measurement services**

## Consultative Committees

### to the International Committee on Weights and Measures

- **CCAUV:** Acoustics, Ultrasound and Vibration
- **CCEM:** Electricity and Magnetism
- **CCL:** Length
- **CCM:** Mass and Related Quantities
- **CCPR:** Photometry and Radiometry
- **CCRI:** Ionizing Radiation
- **CCT:** Thermometry
- **CCTF:** Time and Frequency
- **CCQM:** Chemistry and Biology
- **CCU:** Units

#### They:

- *serve as advisers to the CIPM on scientific and technical matters, such as advances in science that directly influence metrology*
- *identify, plan and carry out key comparisons of national measurement standards among National Metrology Institutes*



# “Chemistry and the International System of Weights and Measures”

*Symposium at American Chemical Society (ACS) National Meeting*

Boston, MA, August 19, 2015

## **Session I:**

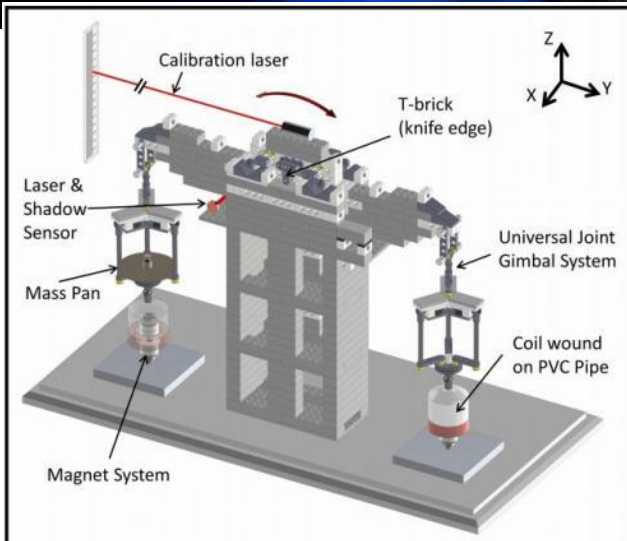
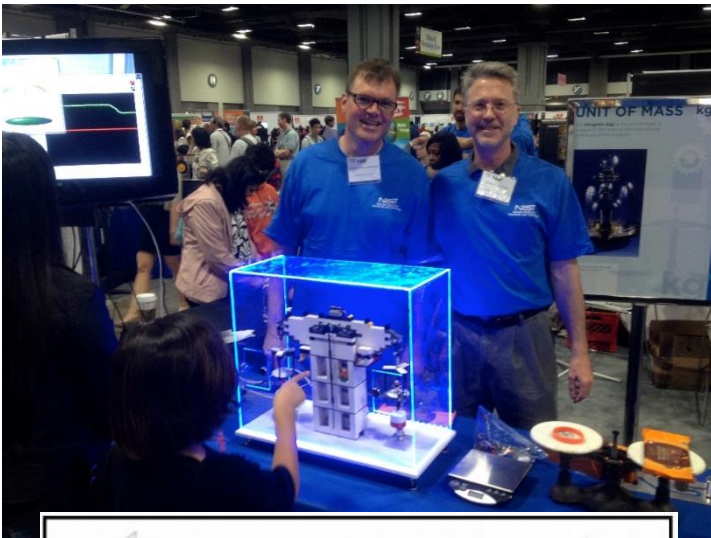
**The Consultative Committee on Metrology in Chemistry and Biology: Who We are, What We Do, and Why You Should Care**

## **Session II:**

**Redefinition of the International System of Units**



# NIST Lego Watt Balance and BIPM Aluminum Cube -- On display during symposium – *Demonstrating principles for the redefinition of the kilogram and the mole*



a 20 g cube of polycrystalline aluminium shows how the new definition of the kilogram will be realized from the physical properties of a near-perfect sphere made of single-crystal silicon. The aluminum cube, manufactured at the BIPM, can itself be used to determine  $h$  to better than 1 %. **The cube can even be weighed on the LEGO watt balance to show the two methods are comparable and complementary.**

**Thanks for Your Attention**



**Questions and Comments Welcome ?**