

Measurement Services and the Role of an NMI

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NIST Chief Metrologist

Outline

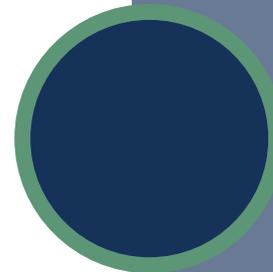
- History
- NIST as an NMI
- Advancing measurement science
- The expanding role of NIST
- Some concerns

History

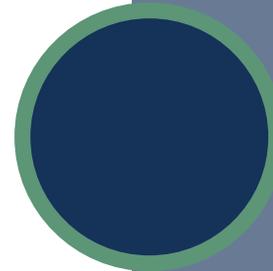
Requirements of a Measurement System



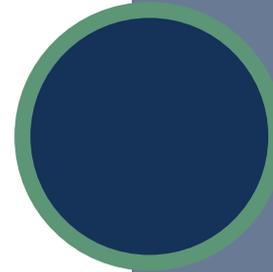
The "Royal Egyptian Cubit" was decreed to be equal to the length of the forearm from the bent elbow to the tip of the extended middle finger plus the width of the palm of the hand of the Pharaoh or King ruling at that time.



Consistency



Accessibility



Universality

The Metric System was born in France.

Philosophies of the French Revolution

Liberté, égalité, fraternité

Control of the national measurement system was one issue at the time

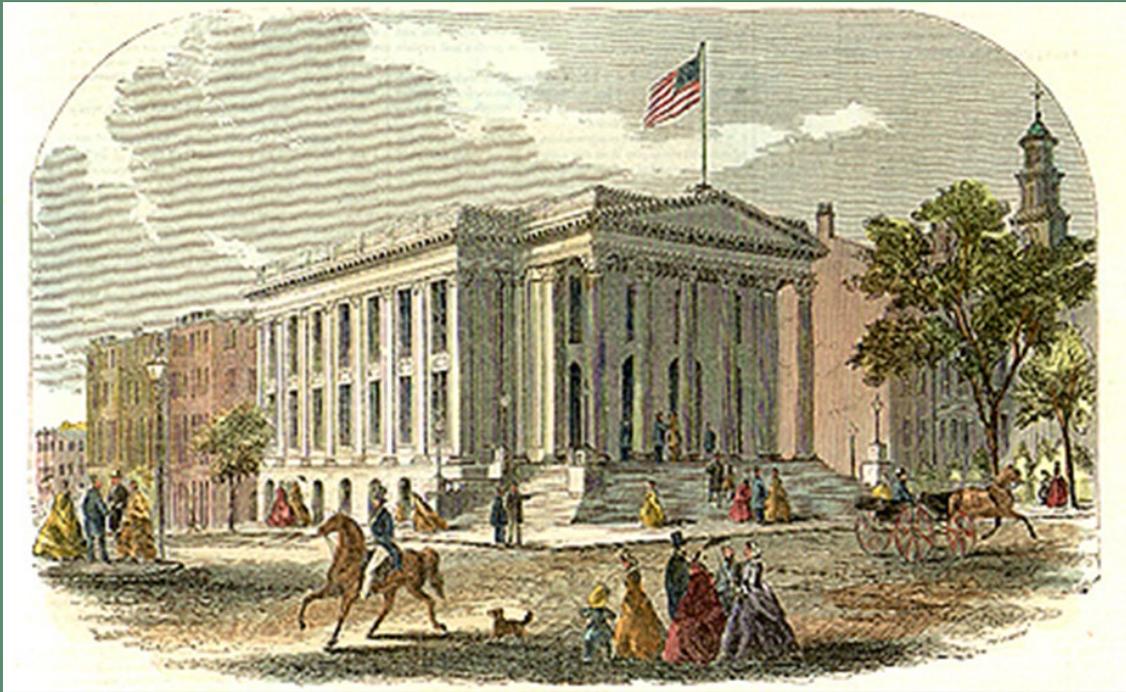
“À tous les temps, à tous les peuples”

Measurement system based on natural law

- Meter: 1/10,000,000 of Earth’s half-meridian (North Pole to Equator)
- Kilogram: weight of 1/1000 cubic meter of pure water



**Storming of the Bastille
July 14, 1789**



Credit: Robert Mills: Library of Congress, Washington, D.C. (reproduction no. LC-DIG-pga-08159)

**A U.S. Custom House
hand-colored wood engraving
ca 1850–1860**

- Prior to the Income Tax (1861), the Federal Government was funded by duties levied at ports.
- Weights and measures were the province of the Treasury Department.
- Concerned about the accuracy of the weights and measures used in custom houses, the Senate asked the Secretary of the Treasury to investigate.

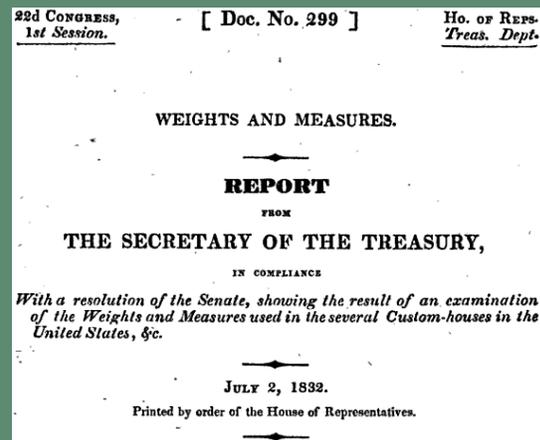
“A serious evil . . .”



Credit: NOAA digital library

Ferdinand Rudolph Hassler

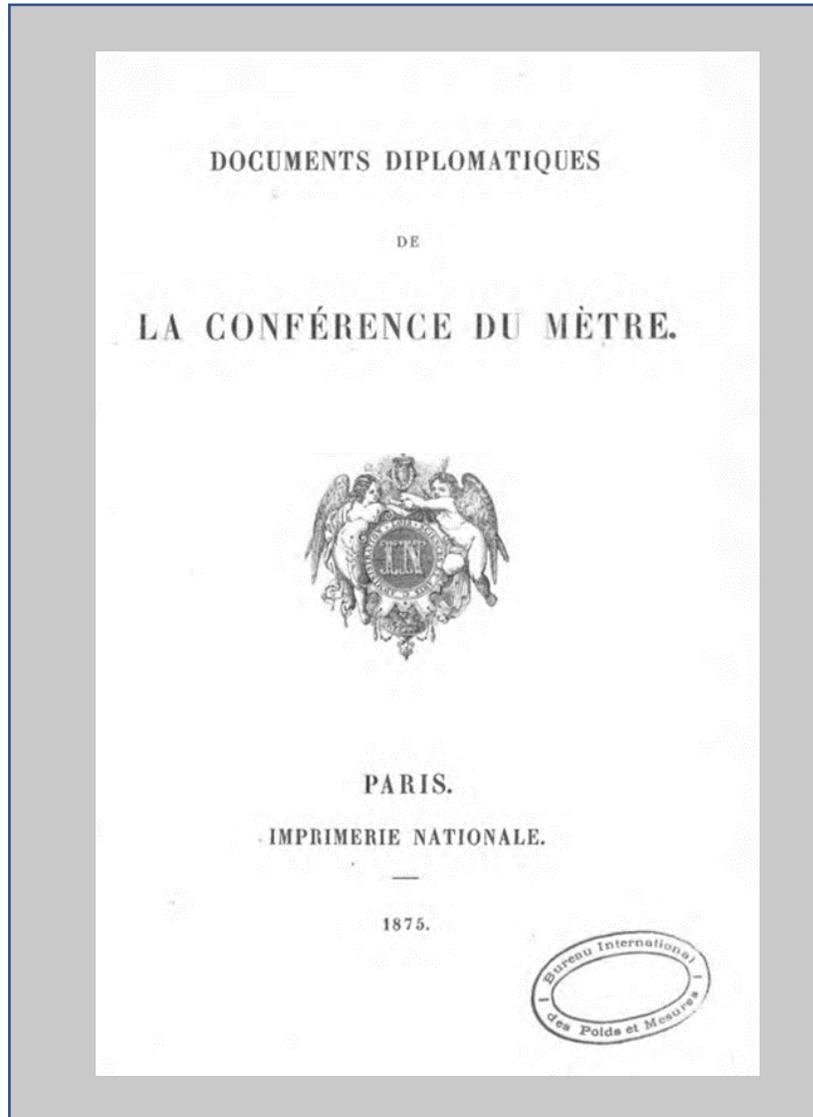
The report precipitated the formation of the Office of Weights and Measures in 1836.



This examination has been made with great care and ability; and the report presents fully both the results, and the means employed in obtaining them. It will be seen that **great discrepancies exist** between the weights and measures used in the different custom-houses—some being too small, and others too large; but, that the mean corresponds nearly with the standards as fixed by the English laws, previously to, and at the epoch of the declaration of American independence.

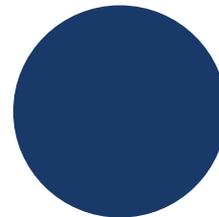
The existence of these discrepancies is not surprising considering the manner in which the weights and measures have been obtained in the custom houses. **It is, nevertheless, a serious evil,** inasmuch as it produces inequalities in the duties levied at the different ports; and thus contravenes the spirit of the constitution, which declares that all duties, imposts, and excises, shall be uniform throughout the United States. It is believed, however, that this department has full authority to correct the evil, by causing uniform and accurate weights and measures, and authentic standards, to be supplied to all the custom-houses. With this view, proceedings were instituted by my predecessor, with the President's approbation, and are now in progress, for effecting that object, by fabricating at the United States' Arsenal in this city, under the immediate personal superintendence of Mr. Hassler, the necessary standards, as well as weights and measures, which

Treaty of the Meter (1875)

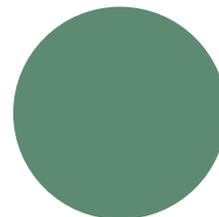


Signed in Paris on 20 May 1875 by representatives of 17 nations

Argentina, Austria-Hungary, Belgium, Brazil, Denmark, France, Germany, Italy, Peru, Portugal, Russia, Spain, Sweden and Norway, Switzerland, Ottoman Empire, United States of America, and Venezuela



Arranged for the creation and distribution of new prototype standards of the meter and the kilogram



Established a new governance structure to ensure the continued relevance and required evolution of the system

The U.S. Prototype Standards



Credit: NIST

Standard Meter prototypes
Shown: National Prototype Meter
No. 27, received by the U.S. in 1890



Credit: NIST

Eddie Mulhern holding K20

BIPM Headquarters



Credit: NIST



Credit: BIPM

- Approximately 60 staff
- 10.7 acre site
- Technical programs in chemistry, ionizing radiation, physical metrology, and time

Birth of National Metrology Institutes

- 1887 – PTB established in Germany
- 1900 – NPL established in the United Kingdom
- 1901 – *March 3* – NBS is established in the U.S.
- 1901 – *July 9* – LNE established in France
- 1903 – NMIJ established in Japan
- 1916 – NRC established in Canada
- All other developed countries followed

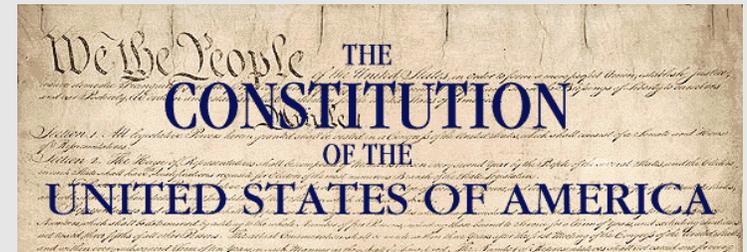
Founding of NBS (1901)

Founded with the mandate:

- *to provide standard weights and measures, and to serve as the national physical laboratory for the United States*

Changed to NIST in 1987:

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



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***

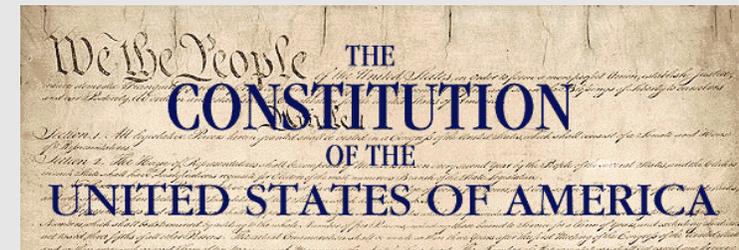
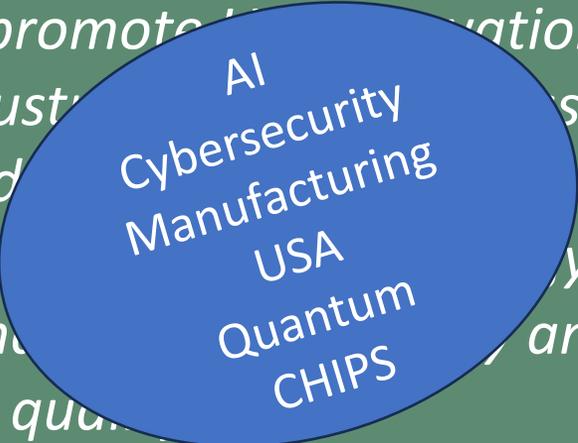
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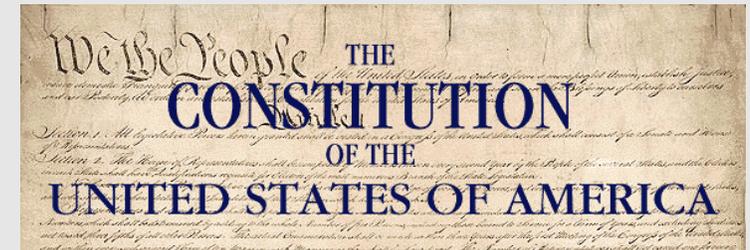
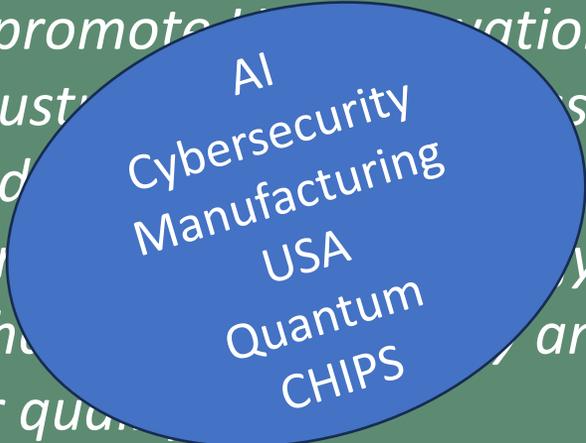
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Being the national measurement institute of the United States is the only unique role of NIST

NIST as an NMI

What is a National Measurement Institute?

A unique organization authorized by a country's government to:

- maintain the country's primary measurement standards and provide traceability for all national measurement needs;
- represent the country to support the international system of units for trade and science;
- engage with industry, government and academia to determine and address their measurement needs;
- advance measurement science to support the economic competitiveness of the country; and
- utilize measurement expertise to support the development of technically sound documentary standards

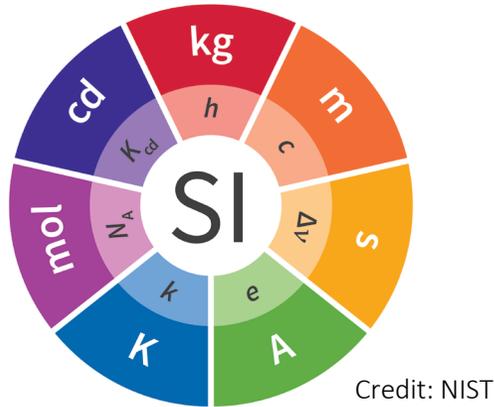
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- maintain the country's primary measurement standards and provide traceability for all national measurement needs;
- represent the country to support the international system of units for trade and science;
- engage with industry, government and academia to determine and address measurement needs;
- apply measurement science to support the economic competitiveness of the country; and
- utilize measurement expertise to support the development of technically sound documentary standards

How does NIST fulfill these roles?

Measurement Services by the Numbers



“Random” selection of direct service users

- Google – SRD, SRMs
- Lawrence Livermore – SRD, calibrations, SRMs
- University of Chicago – SRD, SRMs
- MITRE – SRD
- University of MD – SRD, calibrations, SRMs
- Case Western – SRD
- Microsoft – SRD, SRMs
- University of Arizona – SRD, calibrations, SRMs
- Boeing – SRD, calibrations, SRMs
- Keysight – SRD, calibrations, SRMs

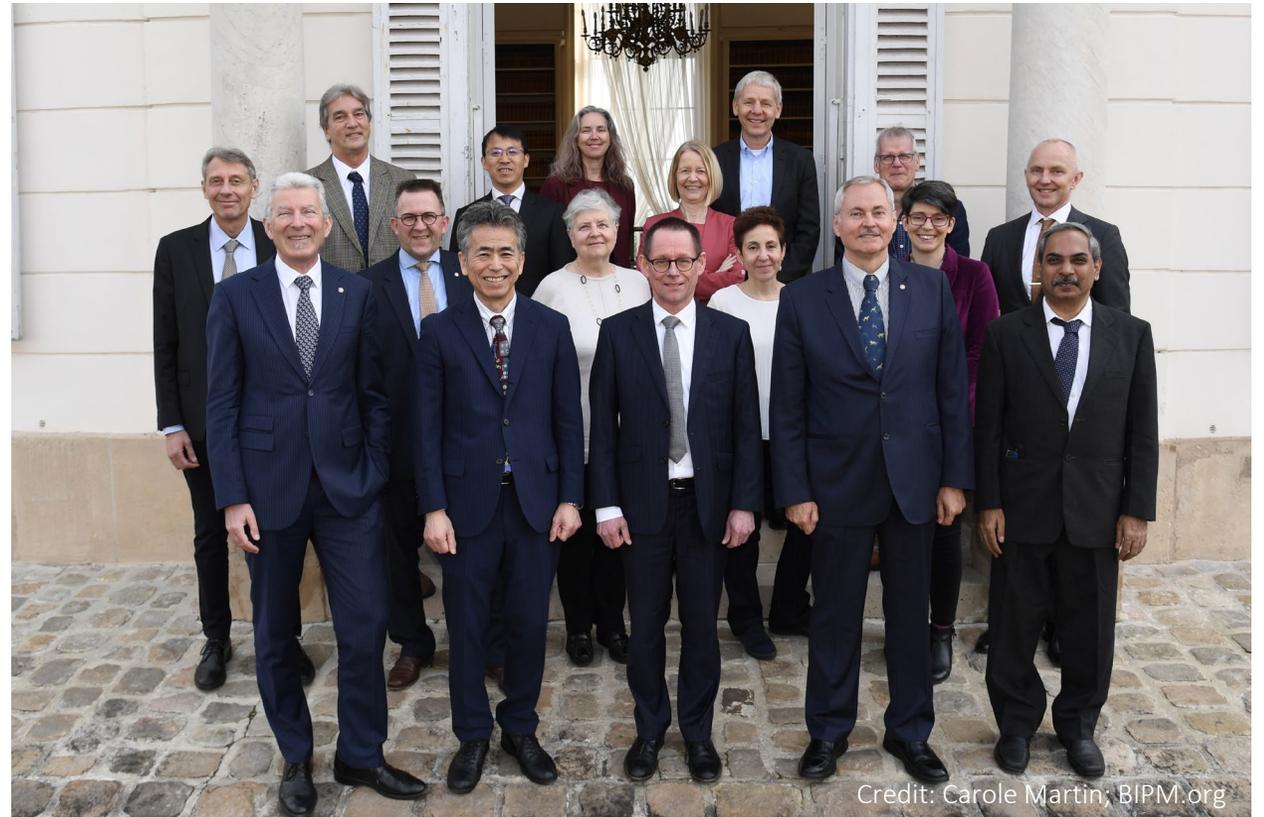
Service	Volume	Customers (FY23)
Calibrations	14k per year	360
SRMs	30k units/year	2900
SRD (online)	>25M views/year	>3.5M
Internet time	100B hits per day	>500M

International Engagement by the Numbers



NIST staff engaged in nearly every international metrology effort

- 90 CIPM Consultative Committees, working groups, and task groups
- 10 SIM working groups
- Vice-president of CIPM
- Past-president of SIM
- SIM Quality Systems Task Force President



CIPM at BIPM, March 2024

External Interactions by the Numbers



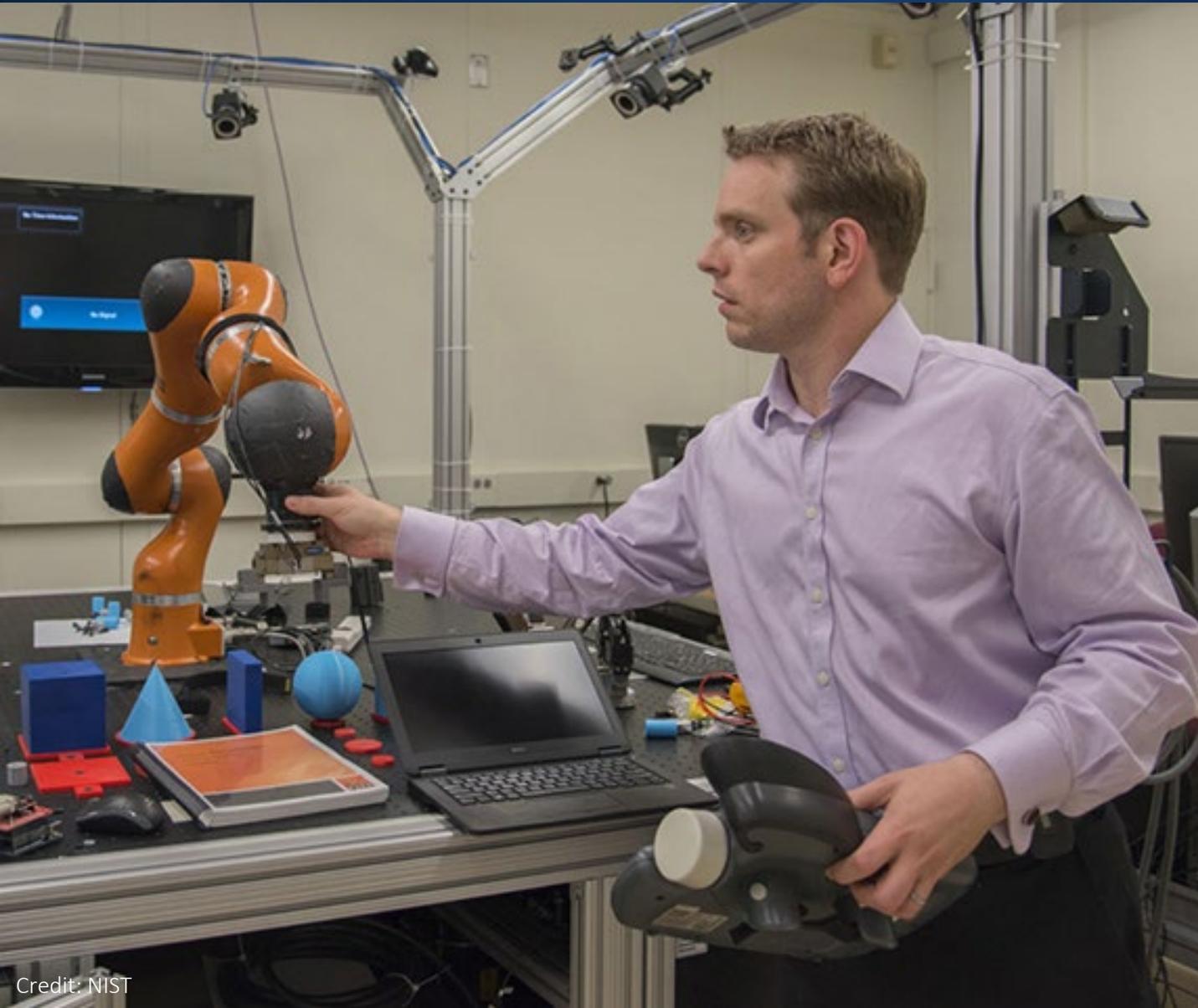
FY23 Engagements	
Cooperative Research and Development Agreements	137
Material Transfer Agreements	116
Patent Applications	120
Invention Disclosures	55

NIST leads many industry-centered consortia, including:

- 5G mmWave Channel Model Alliance
- Big Data Working Group
- Cyber-Physical Systems Public Working Group
- Flow Cytometry Standards Consortium
- Genome Editing Consortium
- Genome in a Bottle
- nSoft
- International Technical Working Group on IoT-Enabled Smart City Framework
- Public Safety Broadband Demonstration Network
- Quantum Economic Development Consortium (QED-C)
- Rapid Microbial Testing Methods Consortium

We'll talk about this in more detail later

Documentary Standards by the Numbers



Extensive engagement

440+ NIST technical staff in
1,669+ standard committees with
210+ NIST technical staff serving in
leadership positions in
105+ standards development
organizations

NIST's technical expertise results in improved standards and U.S. competitiveness.

>9,300 participants in training events

Advancing Measurement Science

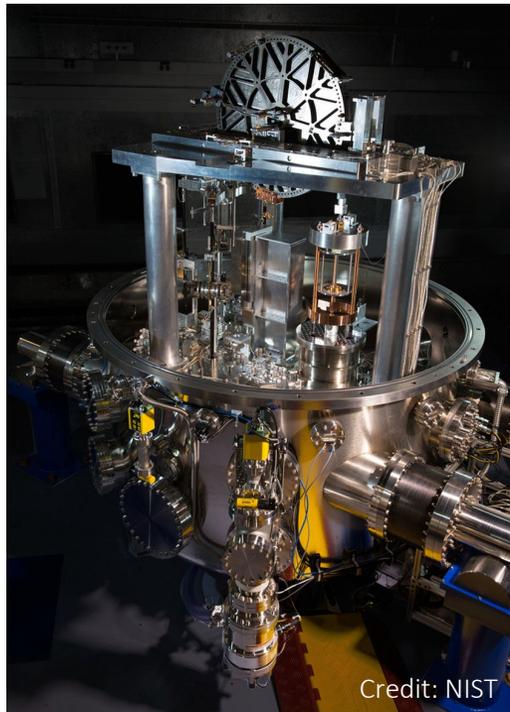
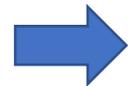
Measurement Science: *The investigation of all aspects of measurements and the development of tools and technologies enabling the implementation and application of a universal and trustworthy system of measurements.*

Redefinition of the SI

Kibble Balance requires the most advanced electrical, dimensional, temperature, frequency, and gravity measurements in the world

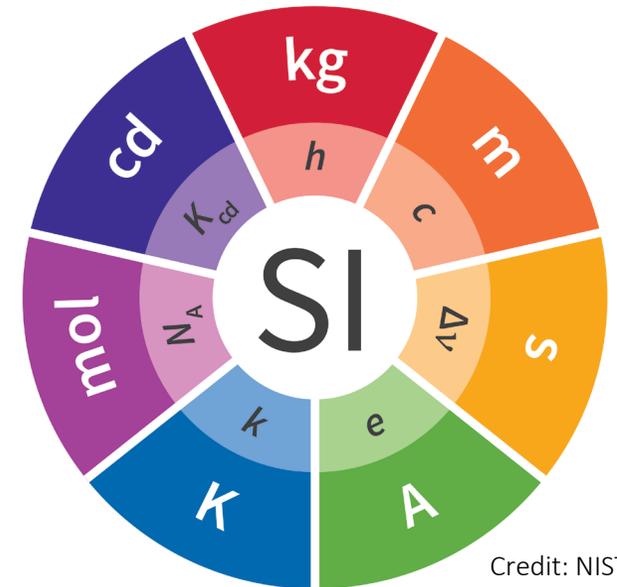
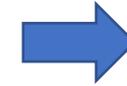


Credit: © Bureau International des Poids et Mesures (BIPM)



Credit: NIST

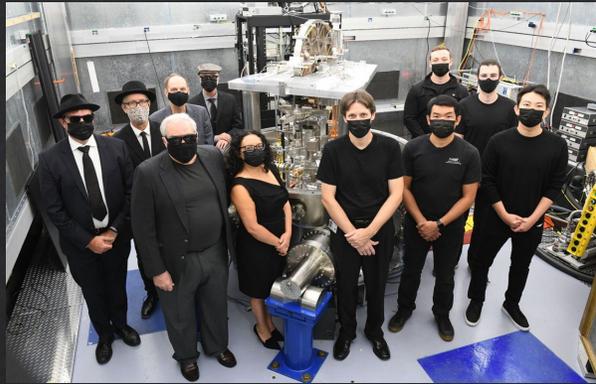
NIST Kibble Balance



Credit: NIST

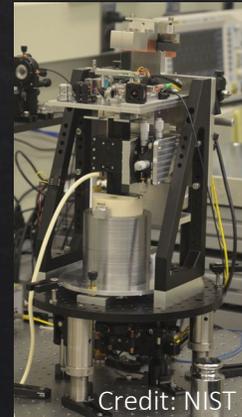
SI Based on Fundamental Constants

The History of the Electronic NST Torque Realizer



2014-2019 NIST-4 Kibble Balance

2017-2019 First Tabletop Kibble Balance

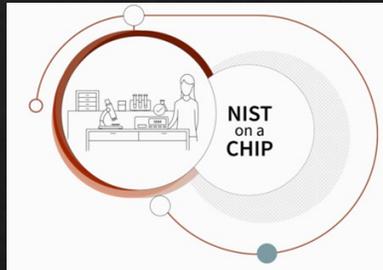


Credit: NIST
Metrologia
PAPER • OPEN ACCESS
The performance of the KIBB-g1 tabletop Kibble balance at NIST
To cite this article: Leon Chao et al 2020 Metrologia 57 035014

2020 Pitch TTKB at AF



2019 Inducted into NOAC



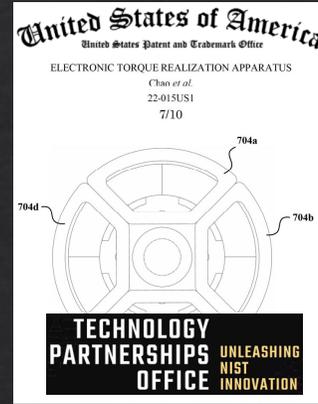
Credit: Tin Bačić, N. Hanacek/NIST

Wait, you use mass to realize torque? Why not directly leverage the new SI?!



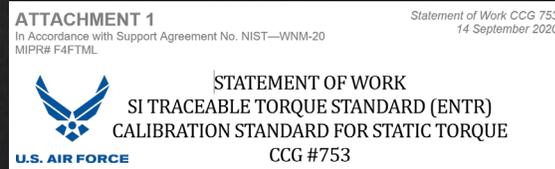
The Ah-ha Moment

Credit: NIST



2022 ENTR Patent

2021-2023 First Tabletop Kibble Torque Standard



Development of this technology required expertise in:

- Mass
- Torque calibrations
- Electrical
- Fabrication
- Tech transfer



2023 IEEE Publication



2024 CRADA Partnership, Snap-On

Performing Absolute Radionuclide Assays NIST

The challenge

- Need 70+ pure materials
- Each a multi-method process
- Slow (years)



Funded by IMS project
of ~\$6M over 5 years

TRUE Bq

Diverse NIST Team Required
across six NIST Divisions

Radioactivity

Mass and Force

Quantum Sensors

Mathematical Analysis and Modeling

Inorganic Chemistry

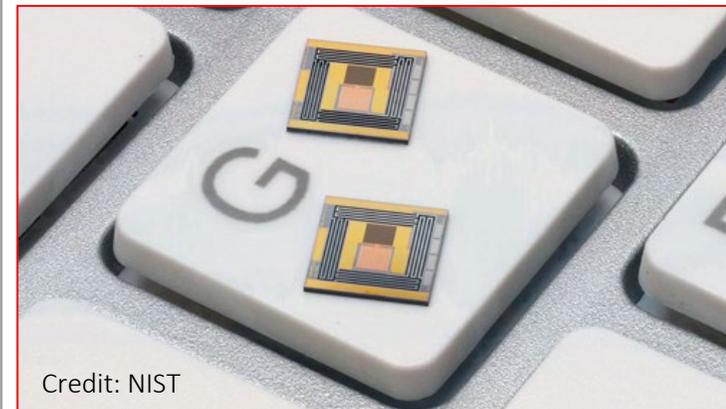
Surface and Trace Chemical Analysis

Los Alamos

Houghton University

The solution

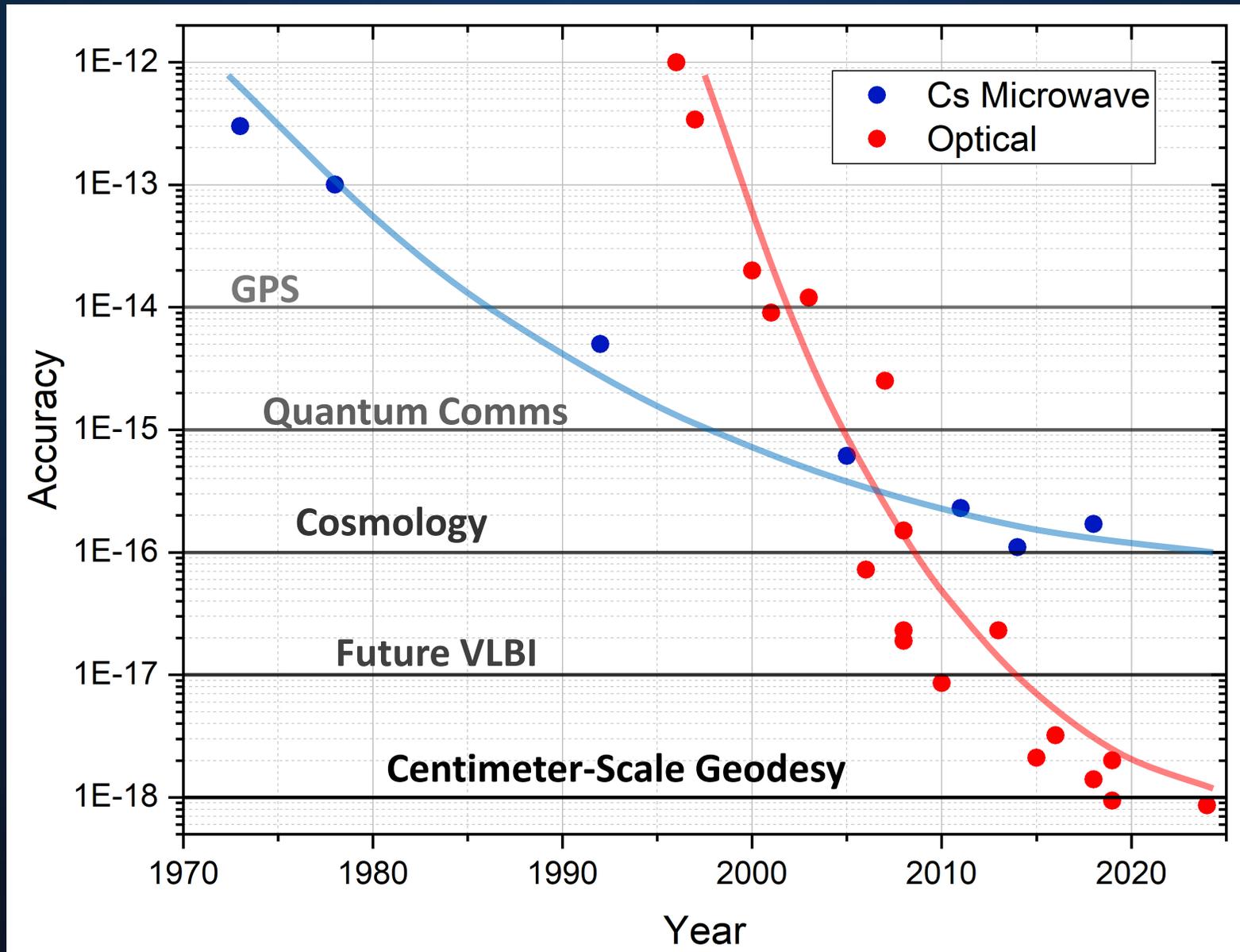
- Use NOAC technology
- Measure mixed samples
- Single, fast method



Interest from...



Impact of improving frequency standards

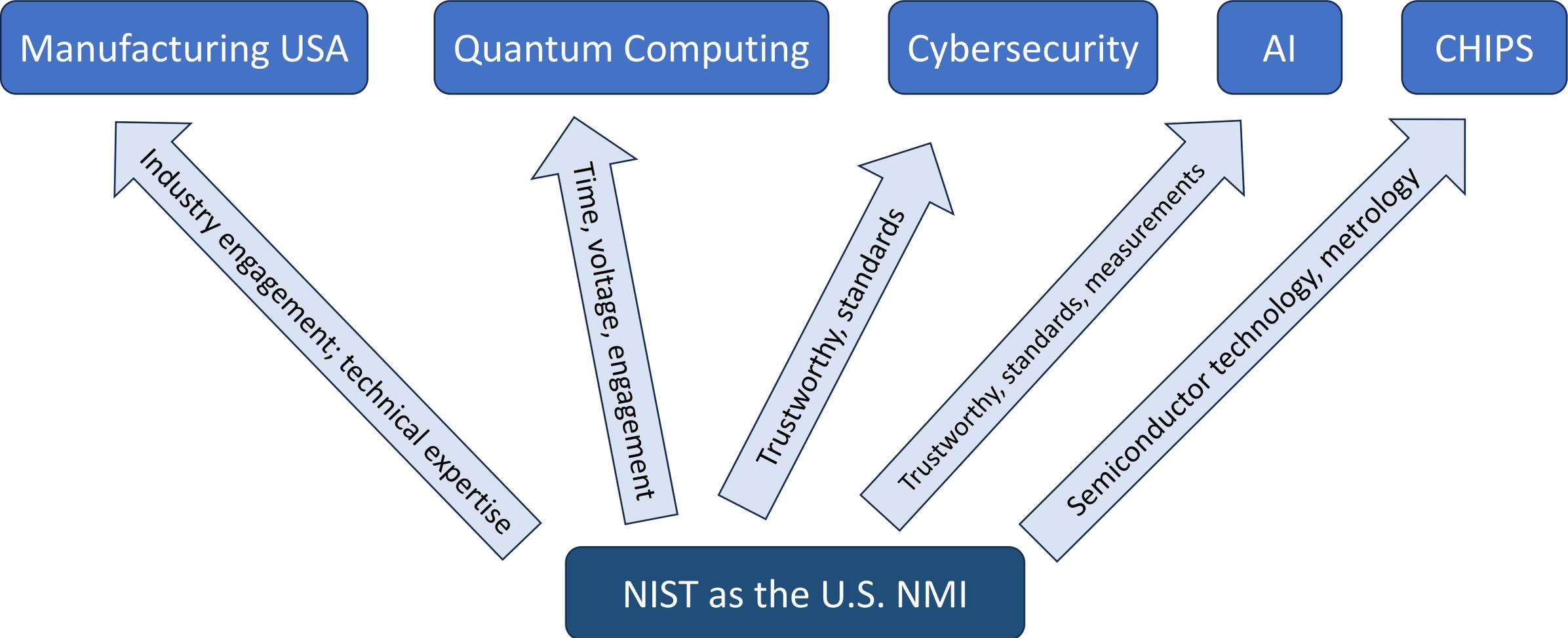


Limit to the SI "Hz" as defined in terms of Cesium-133



The Expanding NIST Role

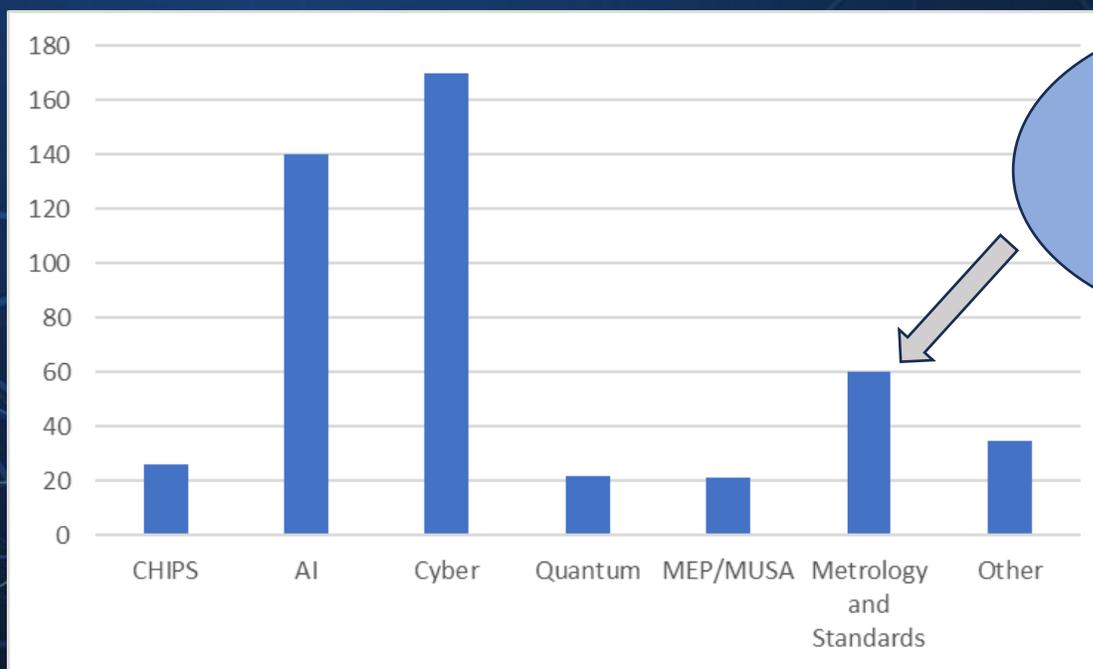
The NMI is the Root of Expansion



NIST in the news

Articles in popular press mentioning NIST: First weeks of Feb. - May

Nearly 500 articles



>50% related to leap second or daylight savings time



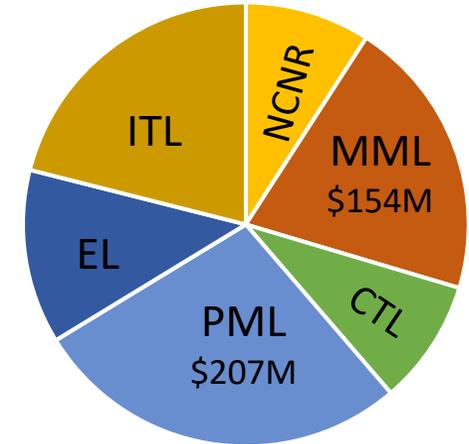
NATIONAL INSTITUTE OF
STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

Some Concerns

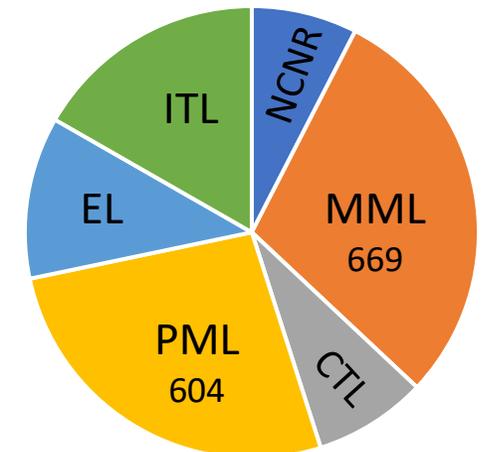
Rough Comparison of NMIs

NMI	Approximate Annual Budget (USD)	Approximate Staffing
NIST - USA	\$1.2 B	3,300
PTB - Germany	\$280 M	2,100
NPL – United Kingdom	\$200 M	1,300
NMIJ - Japan	\$60 M	443
NRC - Canada	\$27 M	200
NIM- China	>\$200 M	>1,000

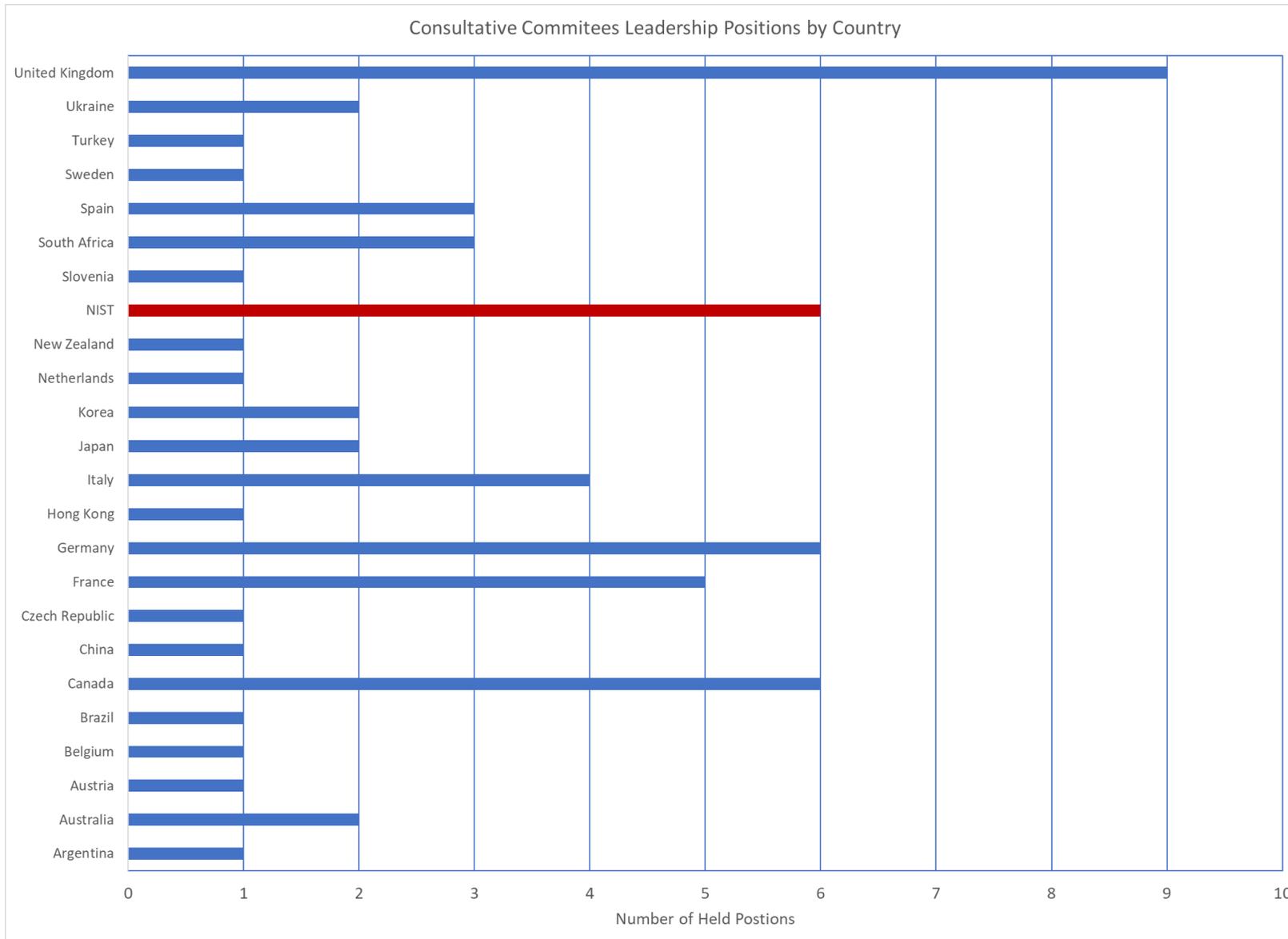
\$750 M in NIST Labs



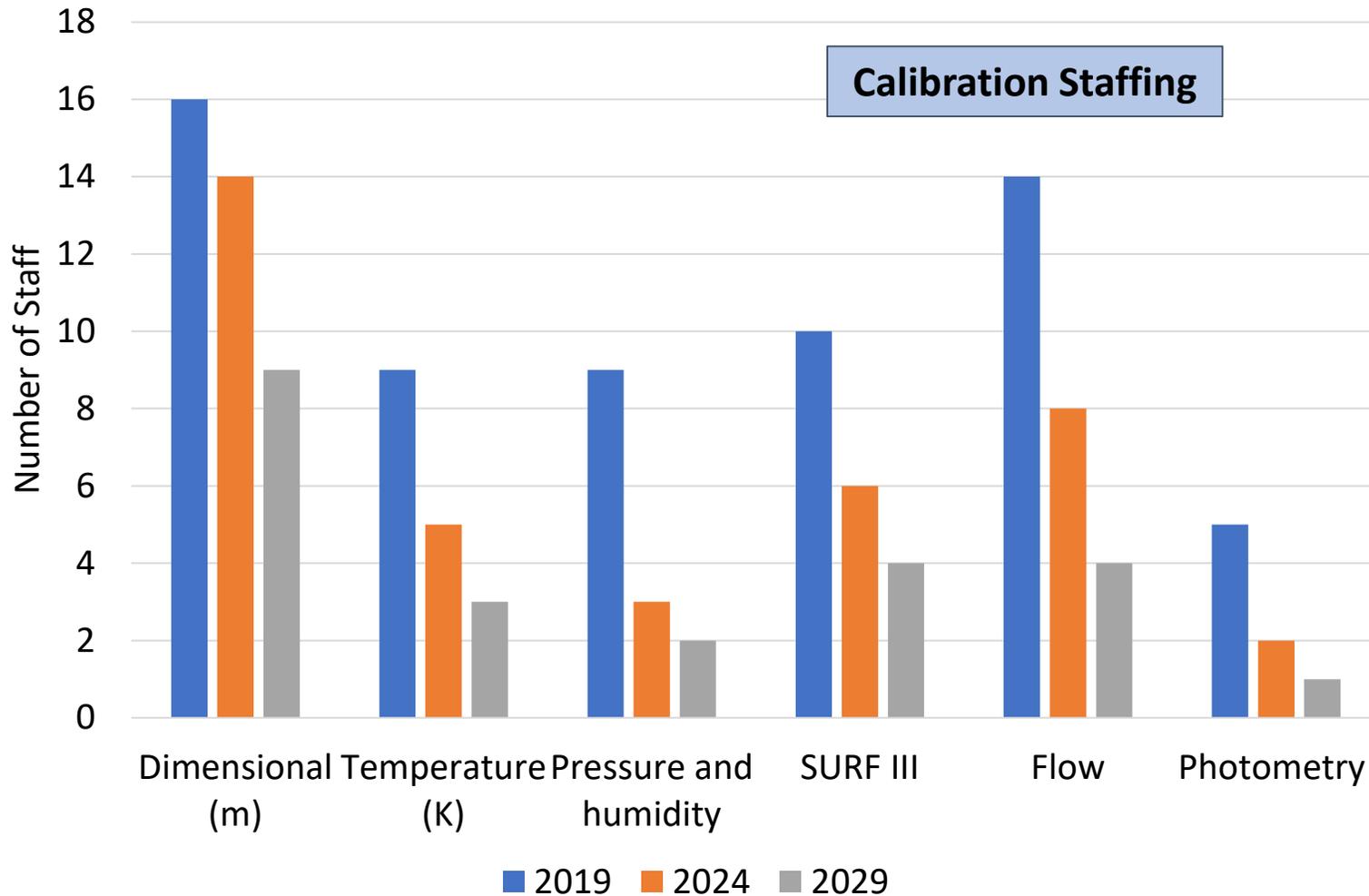
NIST Lab staffing (~2,300)



NIST Leadership in Consultative Committees

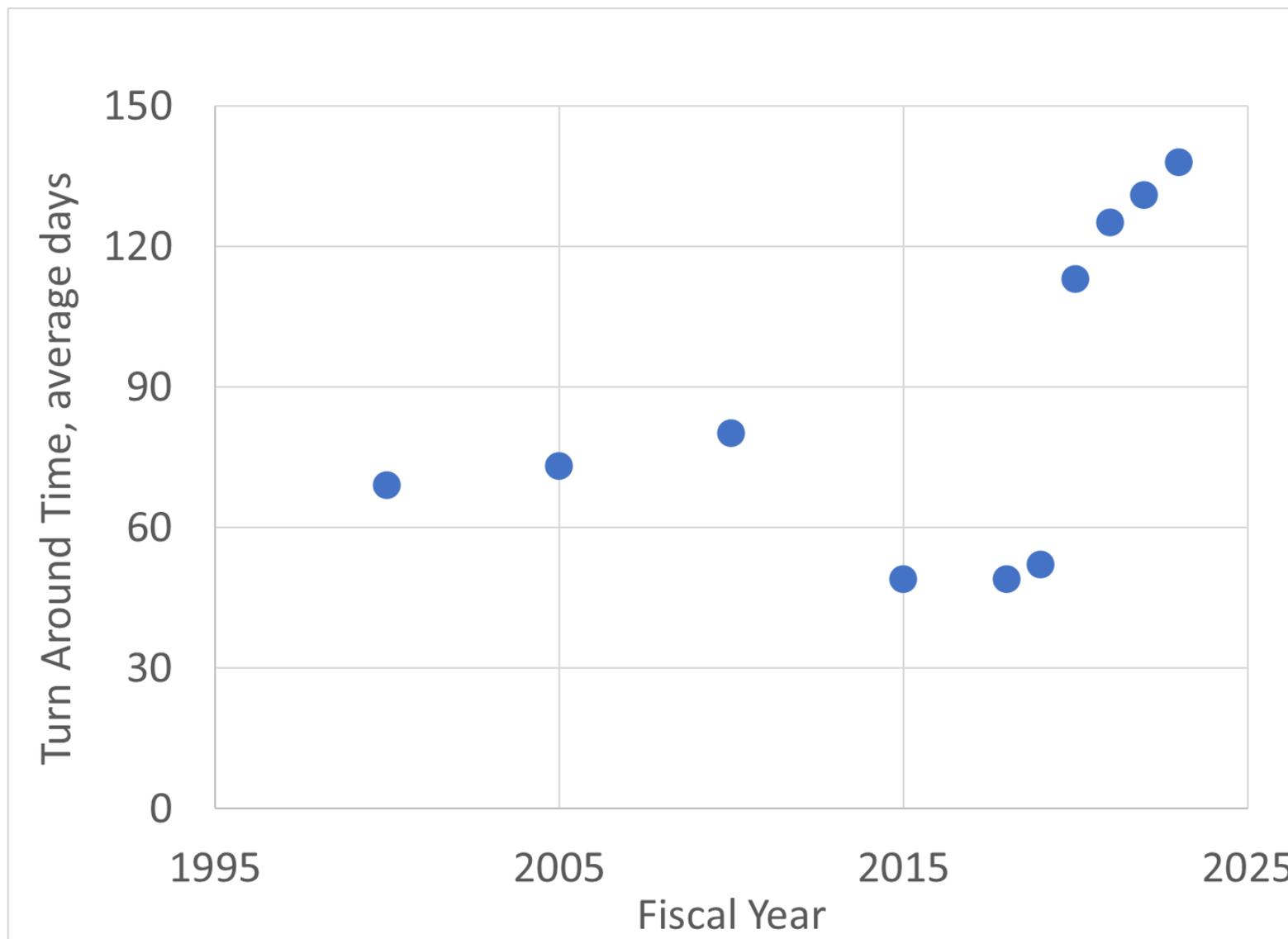


Sensor Science Division Staffing Trends

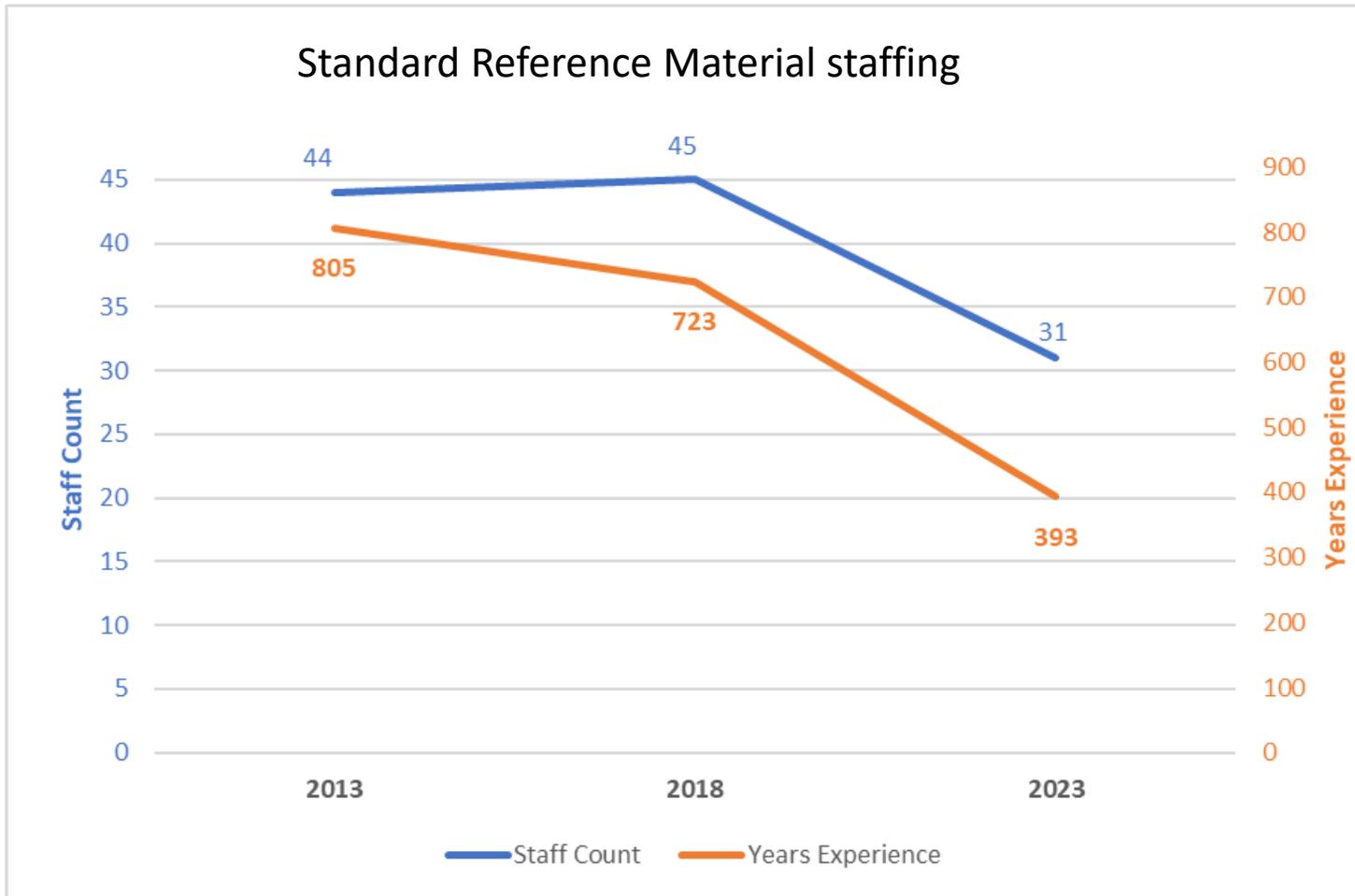


- 60% of calibration staff are eligible for retirement.
- Most measurement services have little bandwidth for innovation or to respond to new measurement needs.
- Measurement services staff have insufficient time for leadership opportunities in international organizations

Turn Around Time across All Calibrations



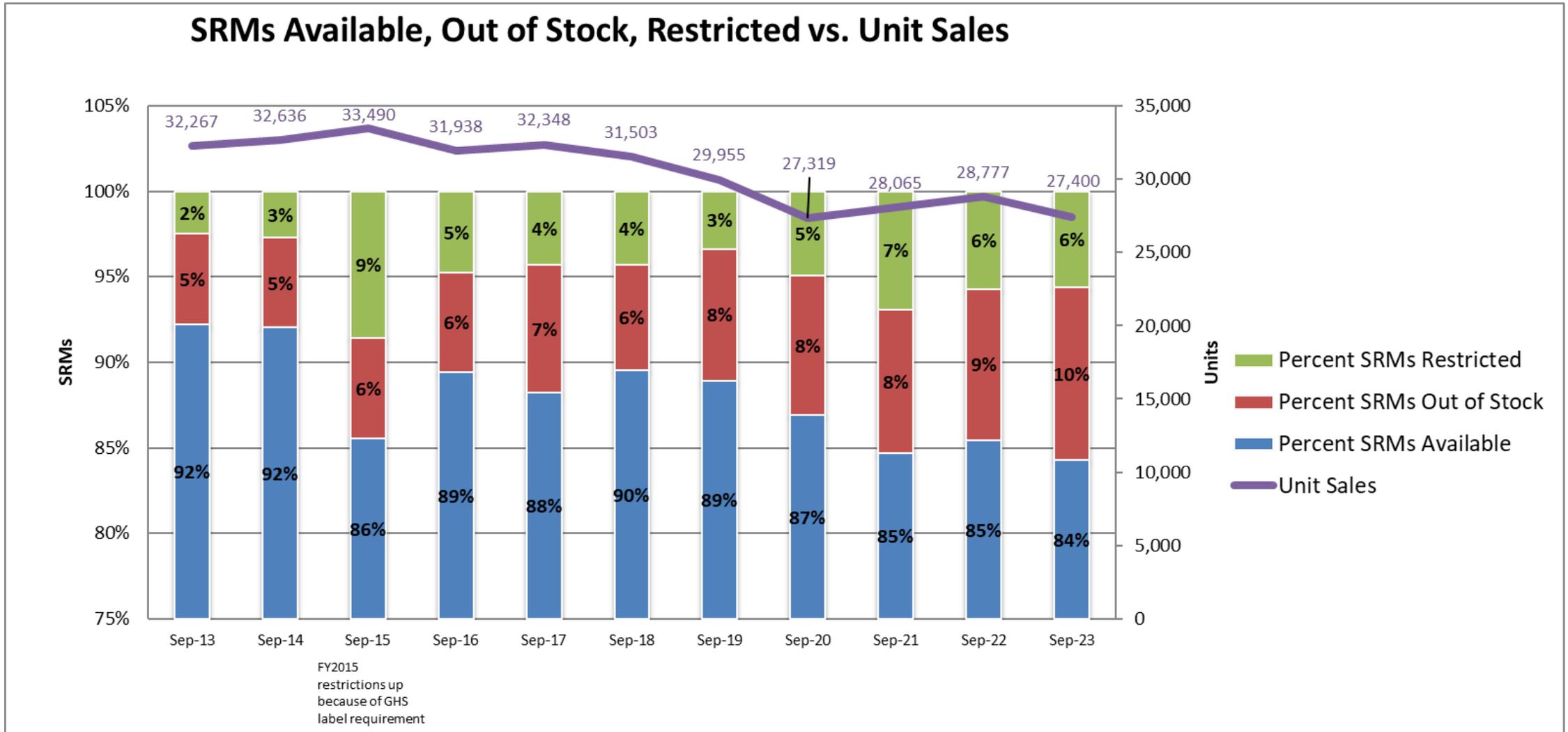
Chemical Science Division Staffing Trends



In last 10 years the number of personnel doing SRM work in the Chemical Science Division:

- dropped by >30%, but
- The years of experience dropped by over >50%

Available SRMs are Decreasing



Some Final Thoughts

Three key points:

- Being the U.S. national measurement institute is NIST's only unique role.
- The expansion of NIST responsibilities is an extension of capabilities, expertise, and reputation as the NMI of the U.S.
- The importance of NIST's NMI role is underappreciated and often unrecognized.

NIST programs have expanded greatly to cover critical areas of technology because of NIST's excellence at being the national measurement institute of the United States. The success of these programs requires a strong core measurement program at NIST.

- How can we highlight broadly the importance of national measurement institutes?
- How do we expand awareness of NIST's NMI role?
- Is it understood that our core measurement programs must be successful for all our programs to be successful?
- As the VCAT considers various issues this year, how does NIST's NMI role play into your thinking?

Thank you

james.olthoff@nist.gov

<https://www.nist.gov/video/romance-precision-measurement>