NIST's Program in Quantum Information Science

Dr. Carl J. Williams, Deputy Director
Physical Measurement Laboratory

National Institute of Standards and Technology
U.S. Department of Commerce

Quantum Information Science Vision

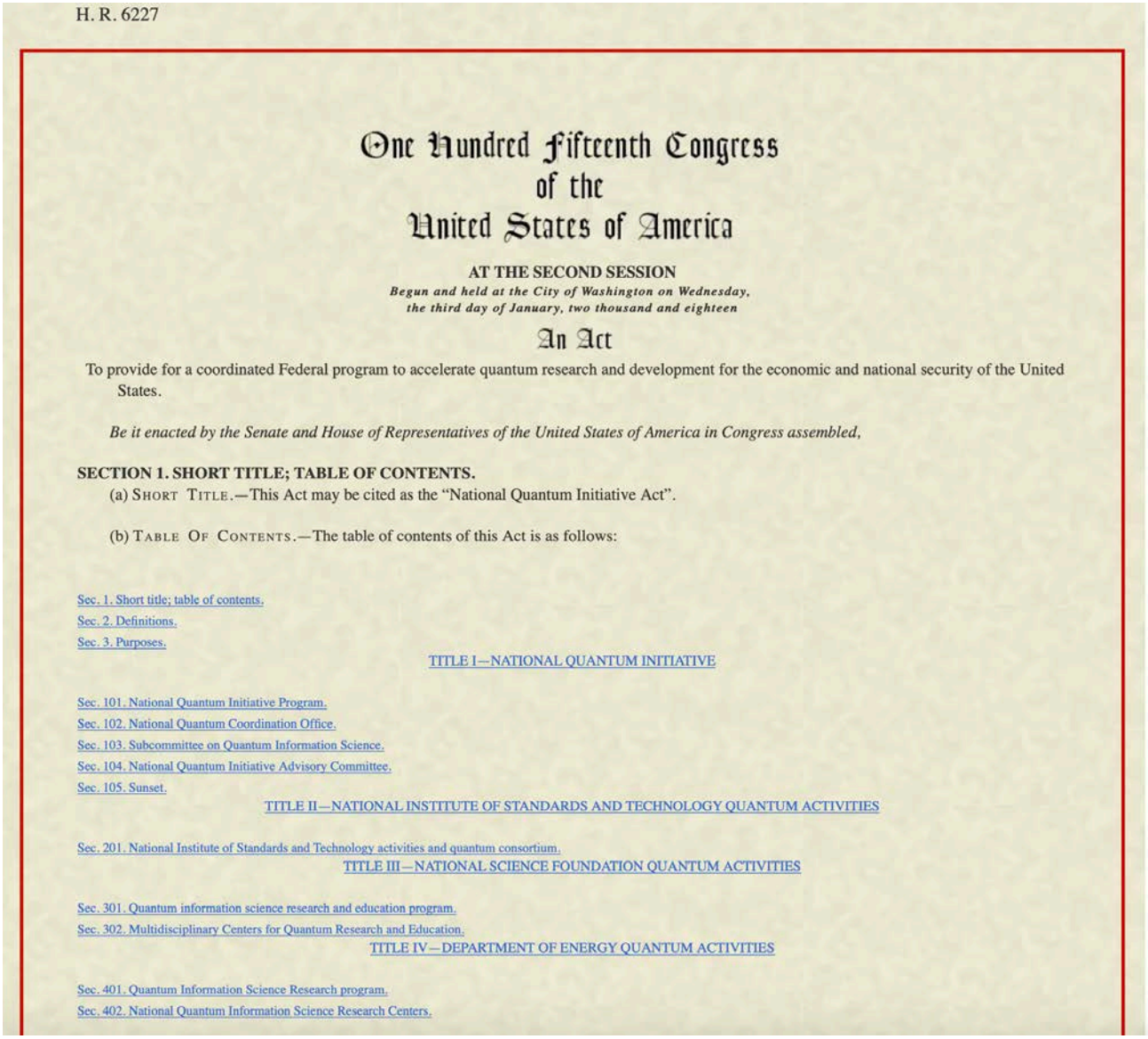
NIST will advance the metrology of quantum entanglement and superposition to provide a foundation for the encoding, transmission, and use of quantum information.

NIST QIS Program includes:

- *sensing and metrology:* precision navigation, timekeeping, magnetic fields
- *communication:* secure data transmission and storage, random number generation
- *simulation:* complex materials, molecular dynamics, QCD
- *computing:* cryptanalysis, quantum chemistry, optimization, quantum field theory and robust intellectual connections to numerous areas of basic research.

20-year QIS Program is a direct extension of our core research in precision time and electrical metrology and now represents a $40.5 M effort.

NQI Act and NIST (Sec. 201)



H. R. 6227

One Hundred Fifteenth Congress
of the
United States of America

AT THE SECOND SESSION
Begun and held at the City of Washington on Wednesday, the third day of January, two thousand and eighteen

An Act

To provide for a coordinated Federal program to accelerate quantum research and development for the economic and national security of the United States.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE; TABLE OF CONTENTS.

(a) SHORT TITLE.—This Act may be cited as the "National Quantum Initiative Act".

(b) TABLE OF CONTENTS.—The table of contents of this Act is as follows:

1. Continue and expand basic and applied R&D, including measurement and standards infrastructure necessary to advance commercial development of quantum applications

2. Use existing programs of NIST, in collaboration with other Federal departments and agencies, as appropriate, *to train scientists* in quantum information science and technology

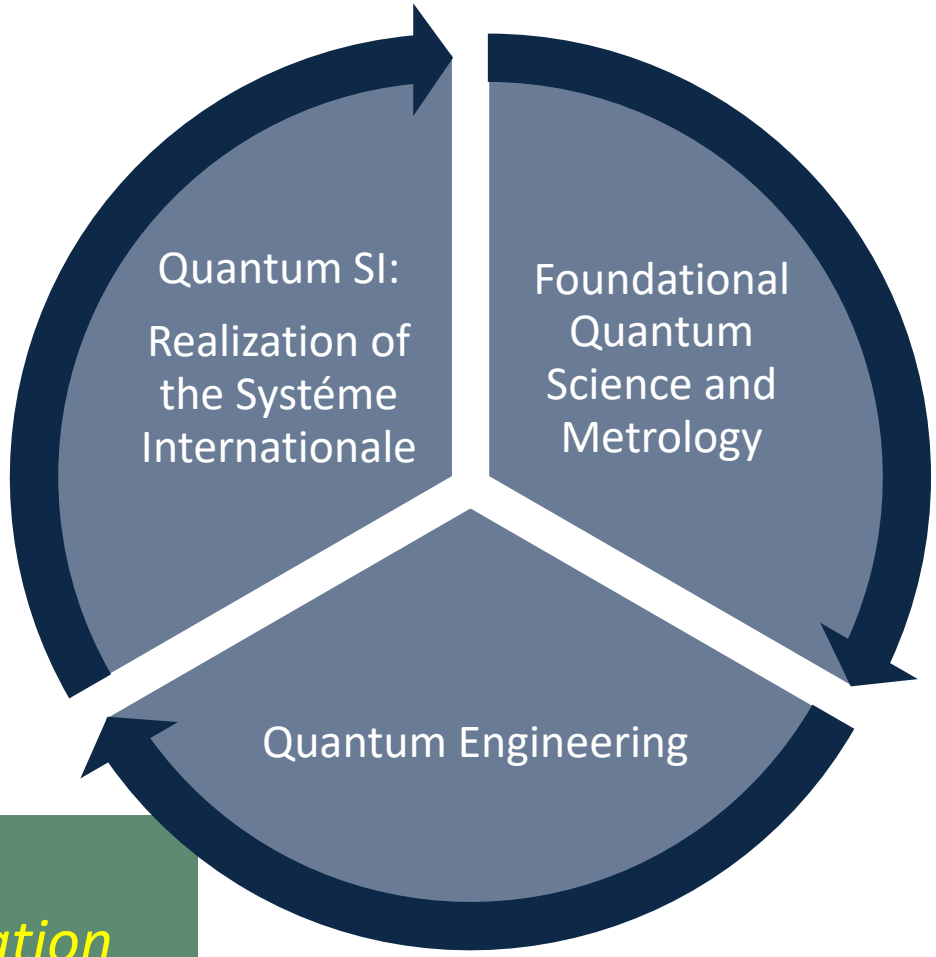
3. Establish or *expand* collaborative ventures or consortia with other public or private sector entities, … for the purpose of advancing the field of quantum information science and engineering

4. Enter into such contracts, including cooperative research and development arrangements, grants and cooperative agreements, or *other transactions*, in furtherance of the purposes of this Act

NIST QIS Strategic Vision

NIST will fulfill its mission in QIS through three coordinated efforts:

- Foundational research emphasizing QIS and Metrology
- Applied research to engineer and improve the robustness of prototypes: Quantum Engineering
- Realization and Dissemination of the units of measure: The Quantum SI



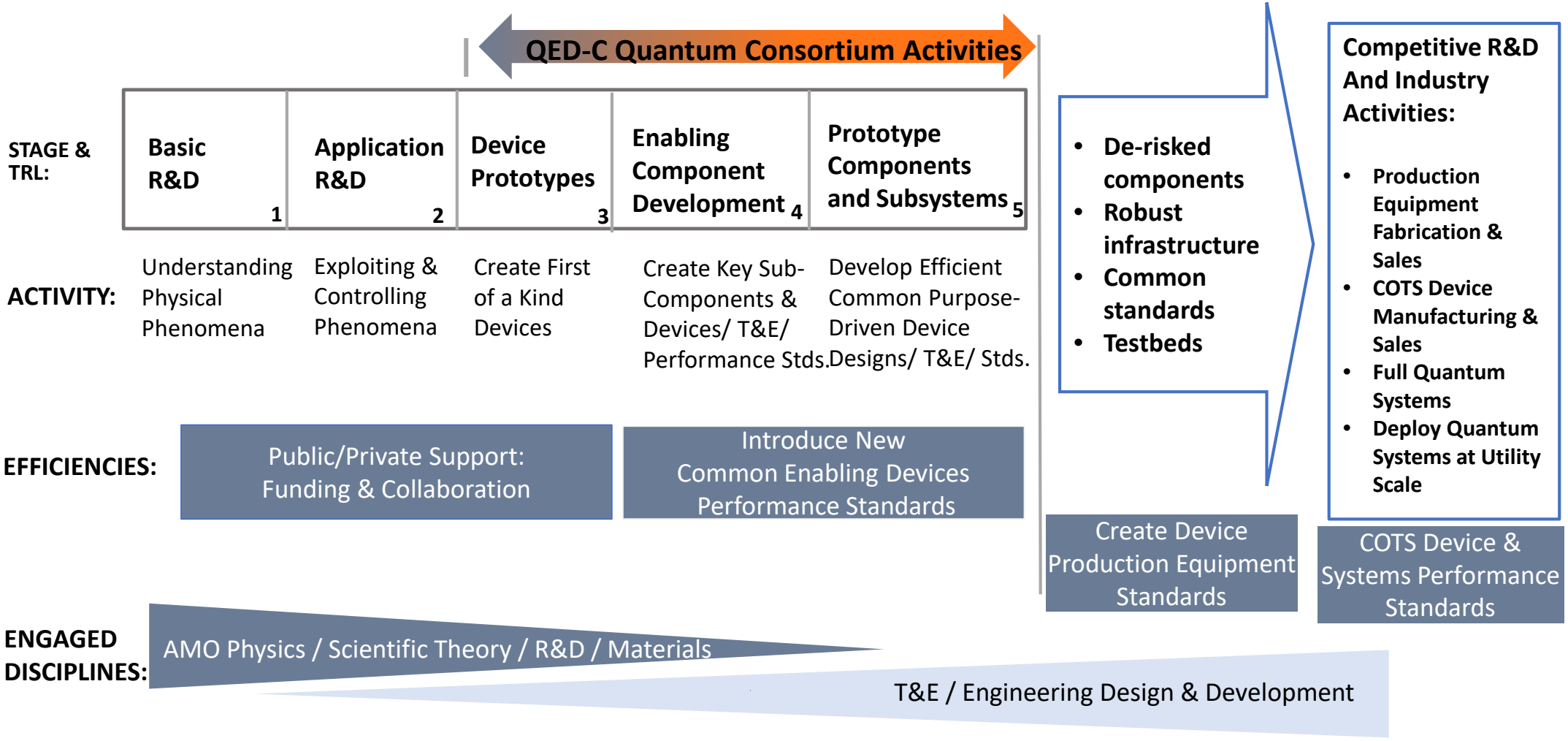
These three activities form an interrelated and self-reinforcing system in which, for example, next-generation atomic clocks are engineered to be smaller and more robust and thereby enable tomorrow's measurement services.

Joint Institutes Critical to Success

Three collaborative institutes at two locations provide opportunities to:

- Attract world class scientists
- Train students and postdocs
- Transfer technology

Quantum Economic Development Consortium: QED-C



QED-C established in partnership with SRI International

Joe Broz, Exec. Director
joe.broz@sri.com
and Celia Merzbacher, Deputy Director
celia.merzbacher@sri.com

For more information see www.quantumconsortium.org

QED-C Thriving

- Nine plenaries since 8/18; next 12/20
- Recent meetings have had over 200 company participants
- Workshops:
  - Cryogenics (10/19) in Boseman, MT
  - Materials and Losses in Superconducting Qubits (1/20) in Santa Barbara, CA
  - Q. Enabled Laser Technology (9/20)
  - Control Electronics and Component Tech. (9/20)
- Funded a framework report on quantum computing market value
- TAC on defense and national security led by AFRL to report to the GB
- International Engagement underway

Steering Comm. & TACs

- Steering Comm. elected: 3 large and 4 small/start-up companies, 2 government agencies
- 5 Technical Advisory Committees

NIST Support

5 Year *Other Transaction Authority* in place with maximum value $50 M

Legal Structure

Agreement signed by Steering Committee and over 110 additional companies, national labs, universities and professional societies

New NIST NQI Activities

1 QED-C

NIST has established the Quantum Economic Development Consortium (QED-C; www.quantumconsortium.org)

Over 110 Participation agreements have been signed

2 Quantum Repeater

NIST initiated an effort to build a prototype scalable quantum repeater based on ion-trap technology

3 Compact Atomic Clock

NIST initiated an effort to build a prototype compact optical atomic clock with sufficient holdover to provide a backup for GPS

4 Foundational Science

NIST expanded its efforts to understand manybody entangled quantum systems

Quantum Communications Activities

- NIST initiated an effort to prototype a quantum repeater that could be made small, compact, and robust based on ion-trap technology **(NQI)**
- Quantum Repeater is part of an internal effort at NIST to create a small (3-5) node heterogeneous quantum network
- NIST held a workshop in January around Clocks in Space
- NIST co-hosted with NASA a UC-Berkeley workshop on Space Based quantum communications
- NIST hosted a coordination meeting around quantum networks
- NIST is working to transition technology for the NASA-NIST-NRO space-based quantum communications demonstration: Marconi 2.0
- NIST co-chairs with NASA and OSTP the new QN-IWG

Atomic Clocks and Sensors

- NIST initiated an effort to prototype a potentially compact (~2 L) optical atomic clock with appropriate SWaP and stability to provide holdover for terrestrial based network as a backup for GPS **(NQI)**
- NIST continues to build out a hybrid microwave-optical time scale with the goal of an all optical time scale within a decade
- NIST is exploring quantum metrology within an optical clock network
- NIST has transitioned chip-scale atomic magnetometers and several companies are commercializing these
- NIST has built a portfolio of NIST-on-a-Chip (NoaC) devices based on quantum technology that are self-calibrating, fit-to-function, manufacturable, and reliable; working closely with DOD and industry

Quantum Network Grand Challenge

Leverage our world-leading quantum science portfolio to develop a simplified Quantum Network to identify and understand classical and quantum bottlenecks

- Grand Challenge goals:
  - Develop local testbed(s)
  - Determine interface specifications for plug-and-play components
  - Characterize components and networks, develop metrology framework
- Fundamental research provides foundation for robust standards to retain U.S. leadership in the QIS ecosystem

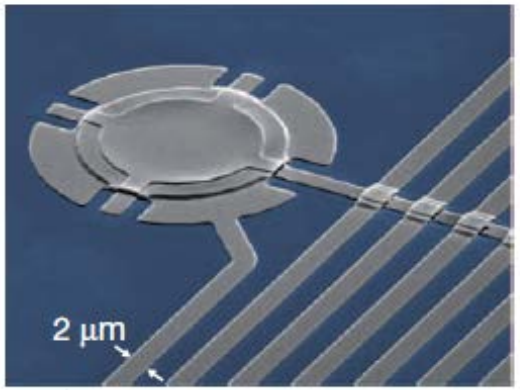
Credit: David Seiler

Superposition, Entanglement, and Raising Schrödinger's Cat

Nobel Lecture, December 8, 2012

by David J. Wineland

National Institute of Standards and Technology, Boulder, CO,



https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4674675

Quantum Standards Development

- Standards needs solid body of validated or broadly accepted foundational work
  - Premature standardization can entrench inferior approaches
  - Competing standards can hinder marketplace adoption
  - Aggressive participation by Chinese entities; strong push for Chinese priorities
- Most mature are in Quantum Key Distribution (ETSI) and Terminology (IEEE, ISO/IEC-JTC1)
- NIST is engaged in quantum standards activities in ITU-T (Telecom)
  - Under UN auspices, focused on telecom and network standards
  - Focus Group on Quantum Information Technology for Networks (FG-QIT4N)
  - Collaboration with QED-C to provide U.S. engagement, leadership
    - Ajit Jilla – Telecom Standardization Advisory Group (TSAG) which oversees the FG-QIT4N
    - Barbara Goldstein – Lead, Standardization Outlook and Technology Maturity subgroup
    - QED-C supports James Nagel (L3Harris) as FG Co-chair and Fred Baker (Lead, Implications of QIT on Networks WG)

SUMMARY: NIST On-Going Activities

Coordination

Continue QED-C leadership and facilitate a unified interagency strategy for Quantum Networks

Standards Development

Maintain a strong presence in relevant standards development bodies to protect US interests and promote the Quantum Economy

Research

Leverage existing expertise to develop a Quantum Sensors and a Quantum Network testbed

Technology Transfer

Explore possibility of a joint Quantum Engineering center to promote technology maturation and translation

QUESTIONS?

Other Select NIST Highlights

- NIST Post-Quantum Cryptography Standards has entered the final selection round – https://www.nist.gov/news-events/news/2020/07/nists-post-quantum-cryptography-program-enters-selection-round
- NIST demonstrated a new path for building single atom transistors that can form the basis for solid state quantum computing – https://www.nist.gov/news-events/news/2020/05/nist-scientists-create-new-recipe-single-atom-transistors; DOI: 10.1038/s42005-020-0343-1
- NIST developed methods to perform custom calibrations for the handful of companies that make Single Photon Devices; NIST is moving forward to create a calibration service – https://www.nist.gov/news-events/news/2019/12/counting-photons-now-routine-enough-need-standards; DOI: 10.1088/1681-7575/ab4533
- NIST demonstrated a next generation time scale that exploits NIST optical clocks and creates improved time transfer and that takes advantage of NIST's optical clocks – https://www.nist.gov/news-events/news/2019/10/jila-team-demonstrates-model-system-distribution-more-accurate-time-signals; DOI: 10.1103/PhysRevLett.123.173201