NQI, QED-C and the Nano-Quantum Superposition

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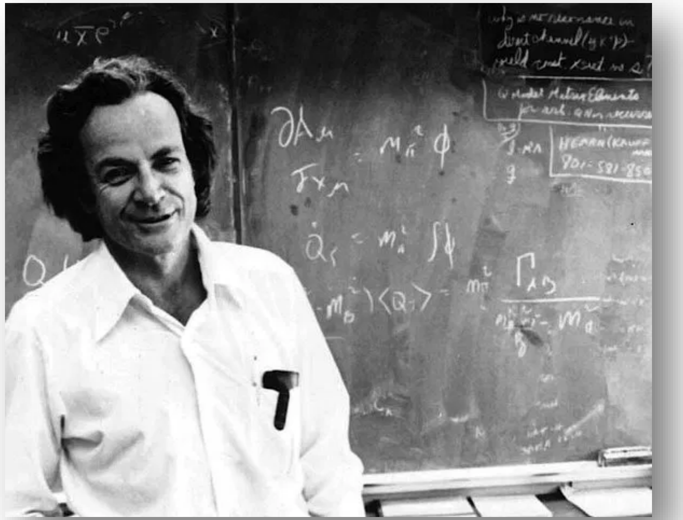
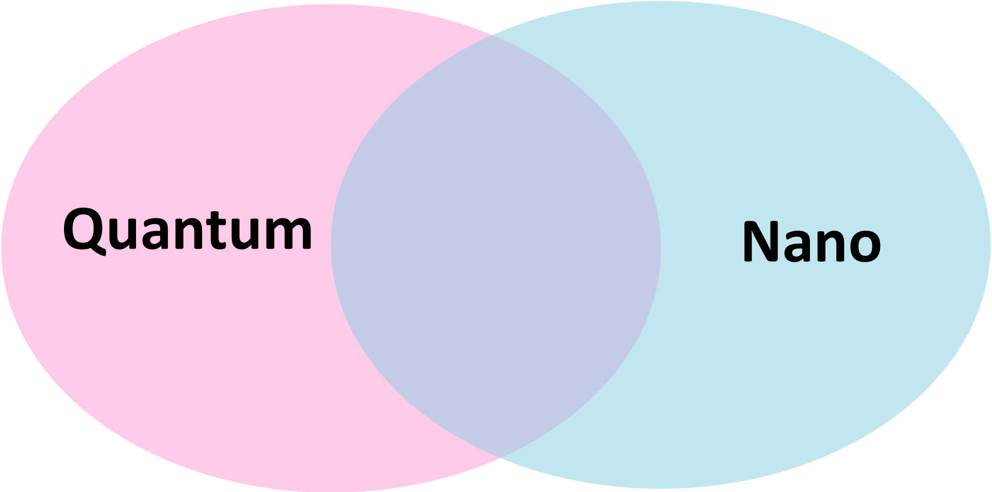
What is quantum technology?

- Harnessing "non-classical" phenomena that occur at small length scales
  - Quantized states
  - Tunneling
  - Particle-wave duality
  - Probability/uncertainty
  - Superposition
  - Entanglement





Promising quantum “2.0” applications

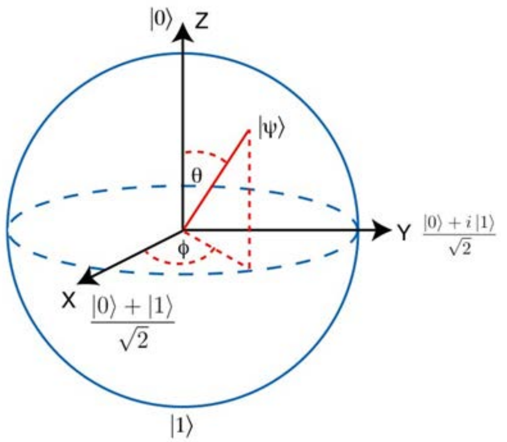
- Exquisitely sensitive sensors/measurement technologies
- Provably secure communication networks
- Computers that can solve currently intractable problems

✓ ***All part of “quantum information science” (QIS)***

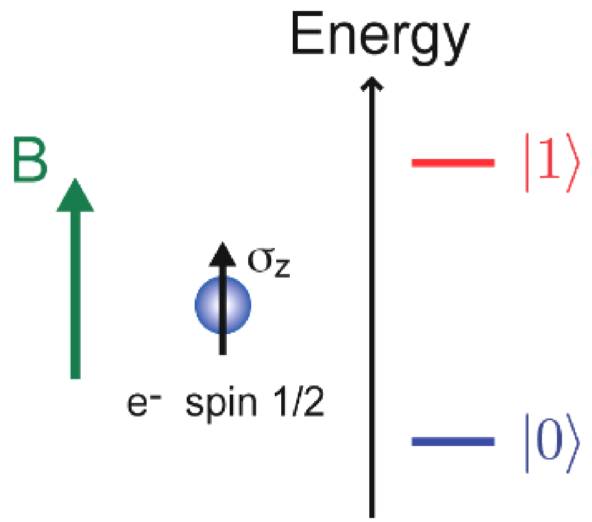
Distinguishing characteristics of quantum 2.0 systems:

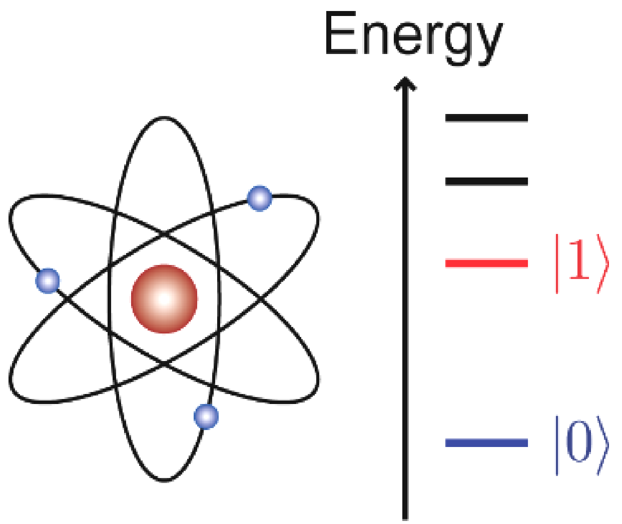
- Superposition
- Entanglement

Classical “bit”

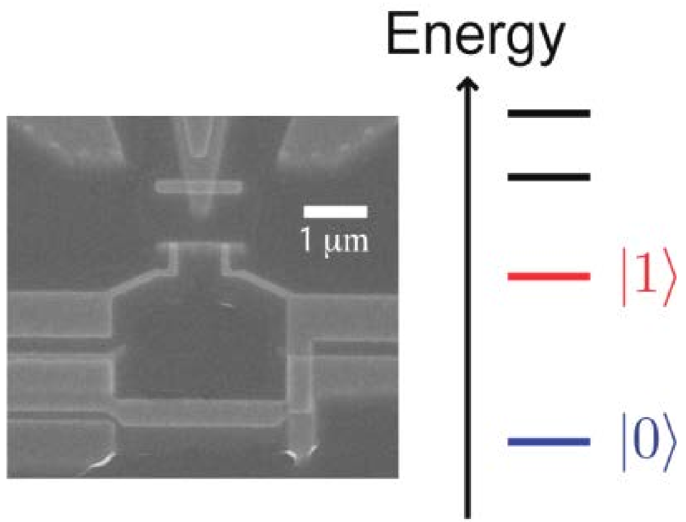


Quantum “bit”





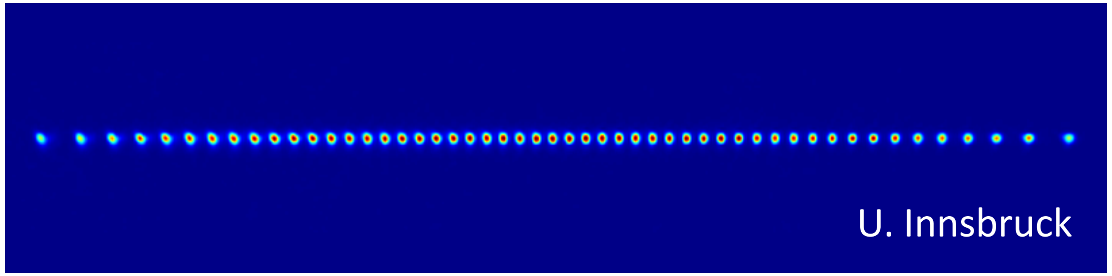
Atomic states



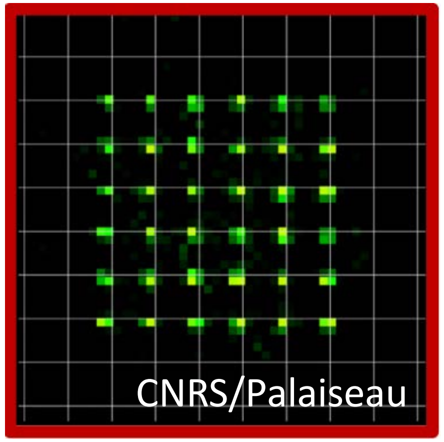
Superconducting circuit

Credit: Daniel Slichter, NIST

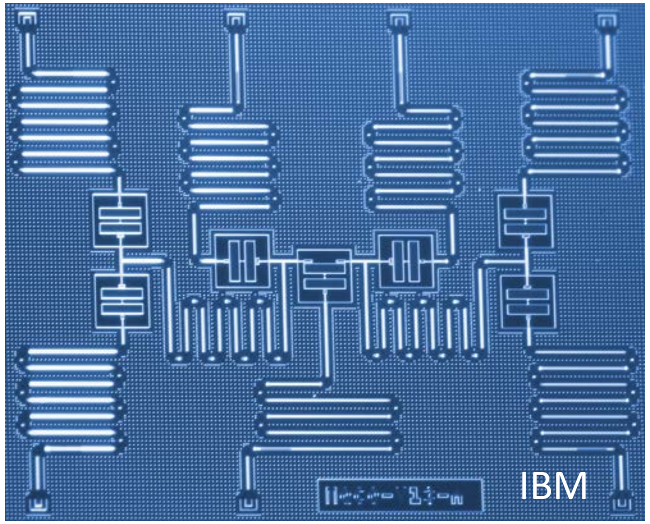
Candidates for practical qubits



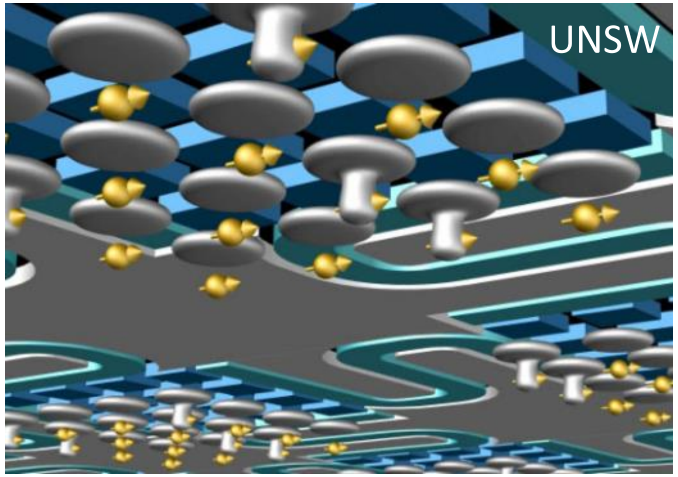
trapped ions



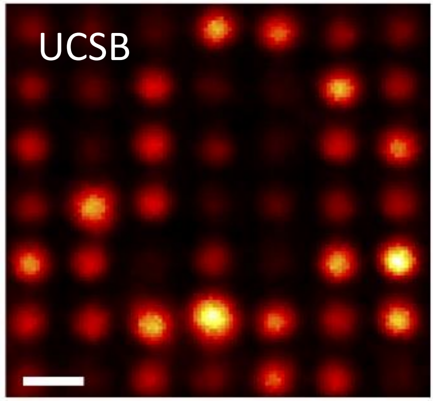
neutral atoms



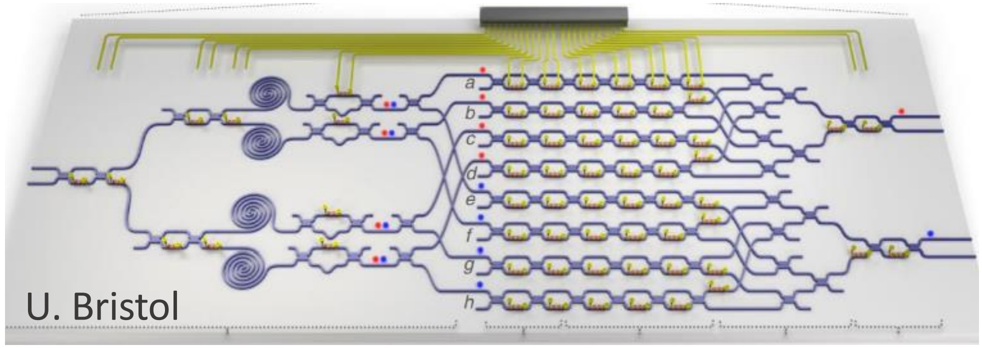
superconducting qubits



Si qubits



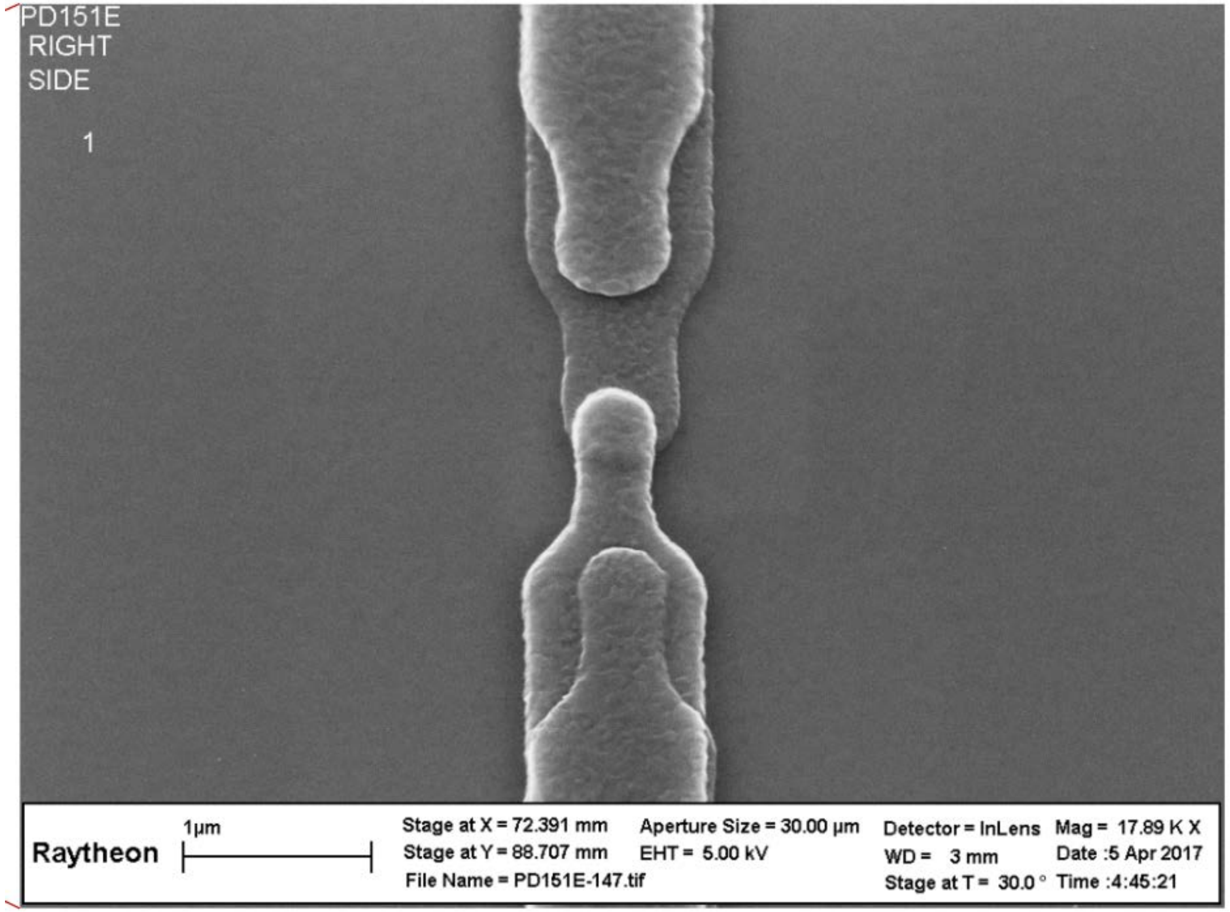
NV centers

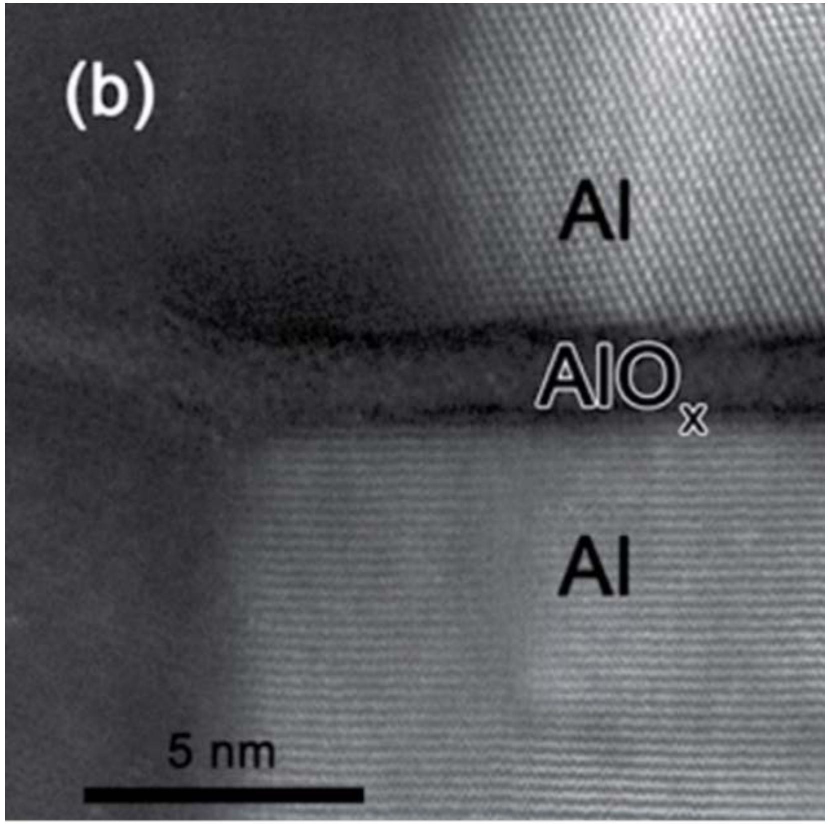


photonics

Credit: Daniel Slichter, NIST

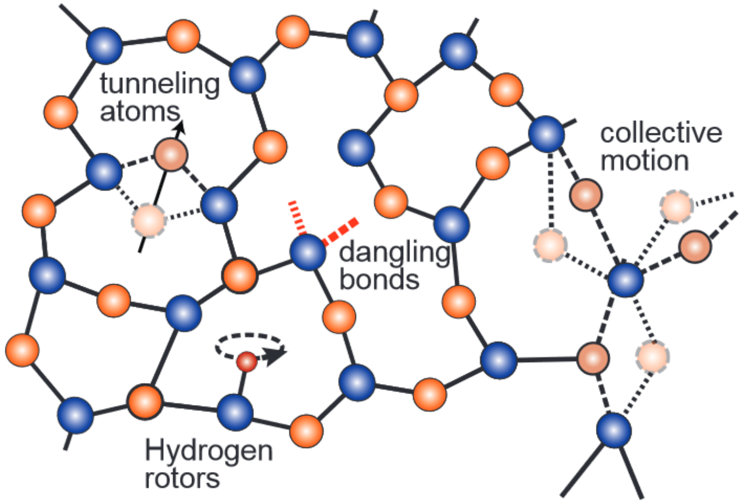
At the heart of a superconducting qubit is a Josephson Junction (SC-insulator-SC sandwich)

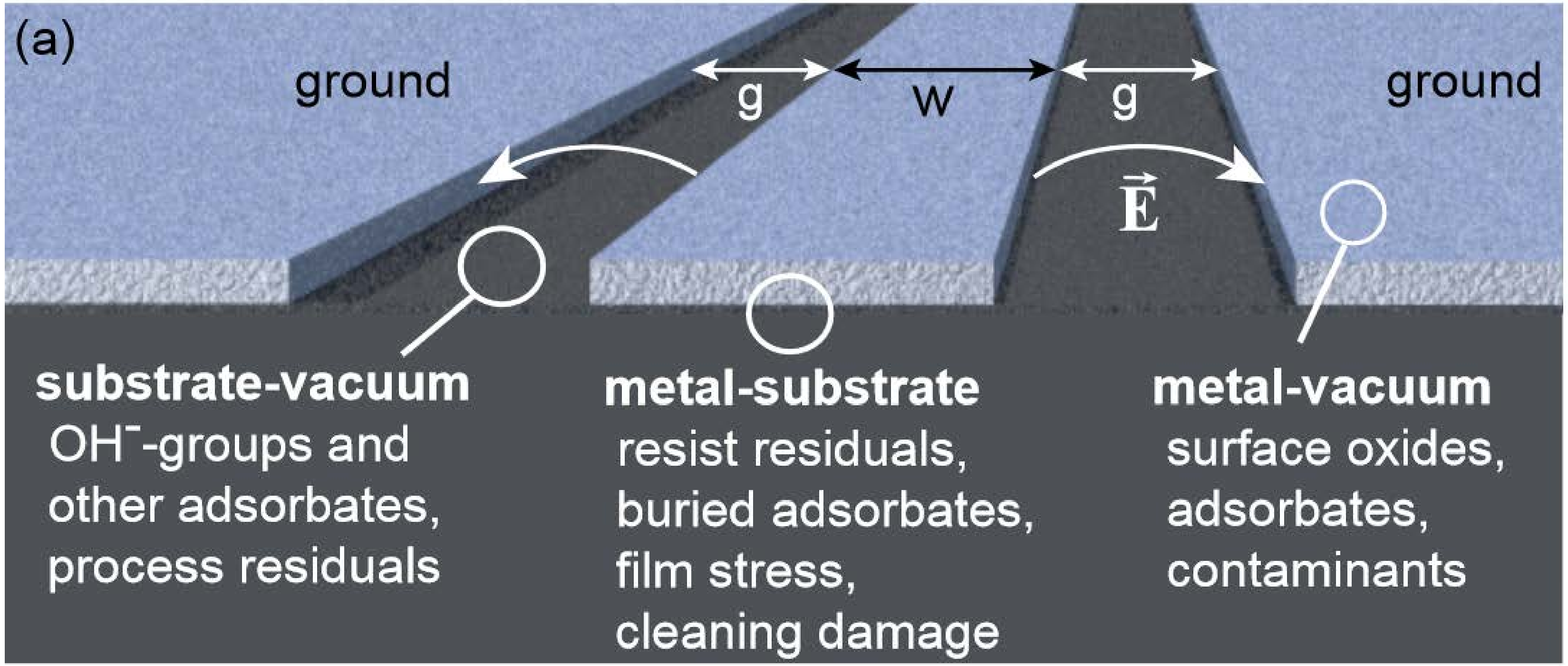




Zheng et al. J. Phys D 48 395308 (2015)

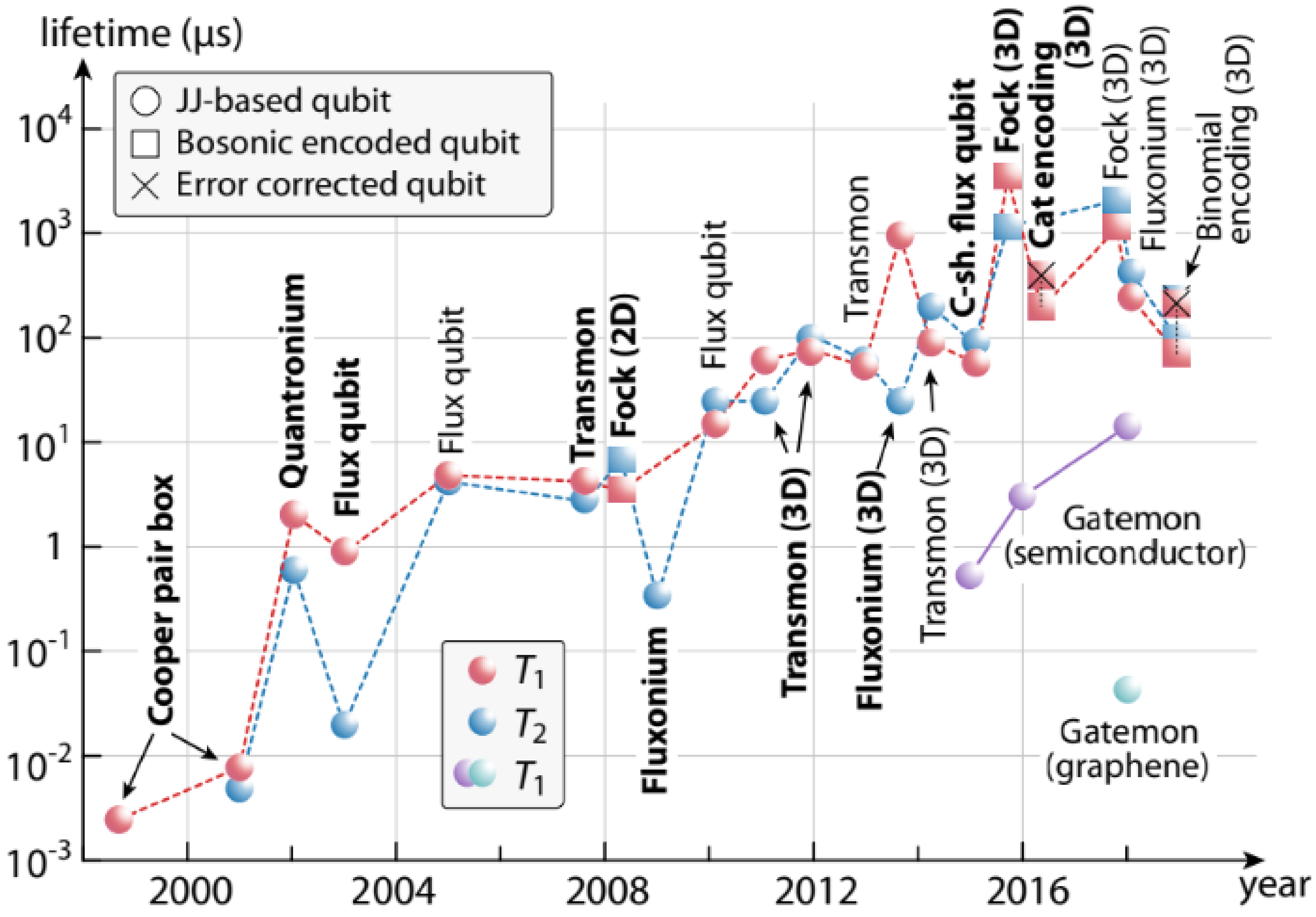
Materials-related sources of loss & decoherence





C Muller et al. (2019) 1705.01108v3

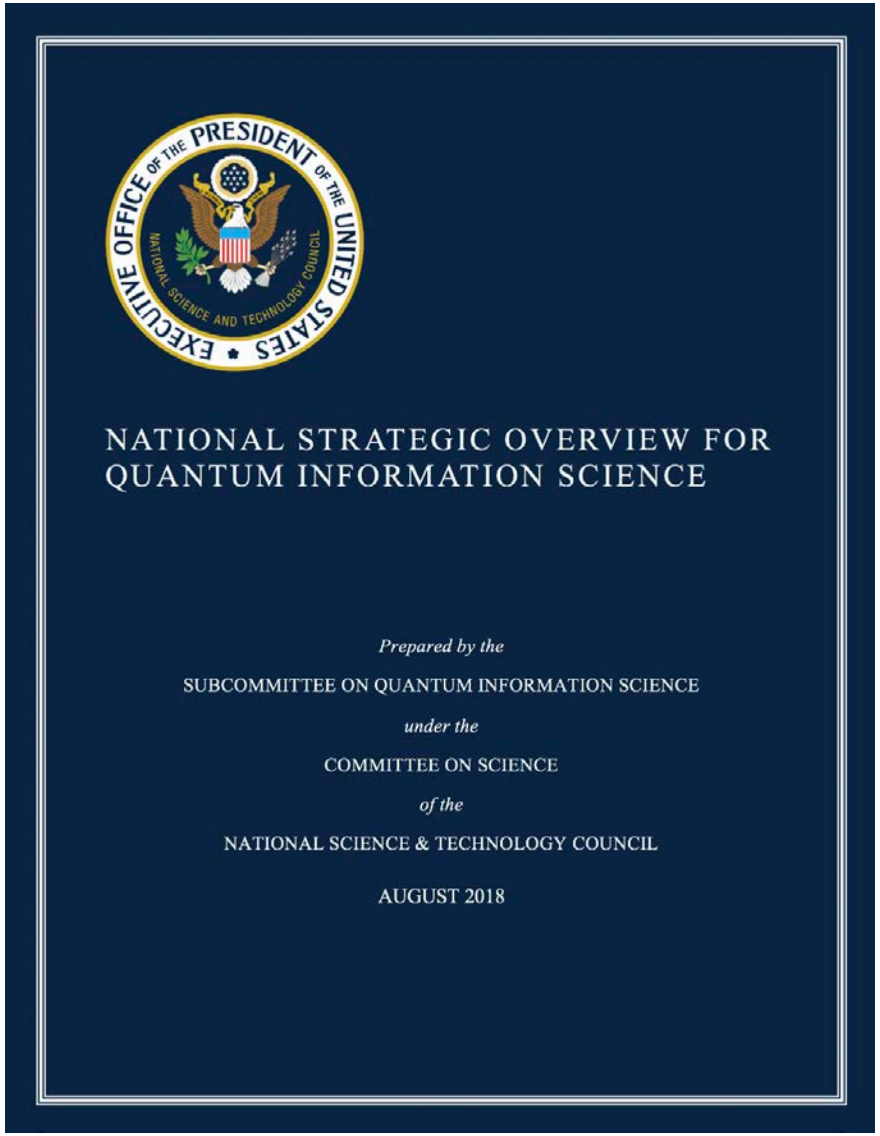
Superconducting qubit lifetime (aka coherence) is improving



Due to advances in materials, design, fabrication and environmental control

Kjaergaard et al. (2019) 1905.13641v2

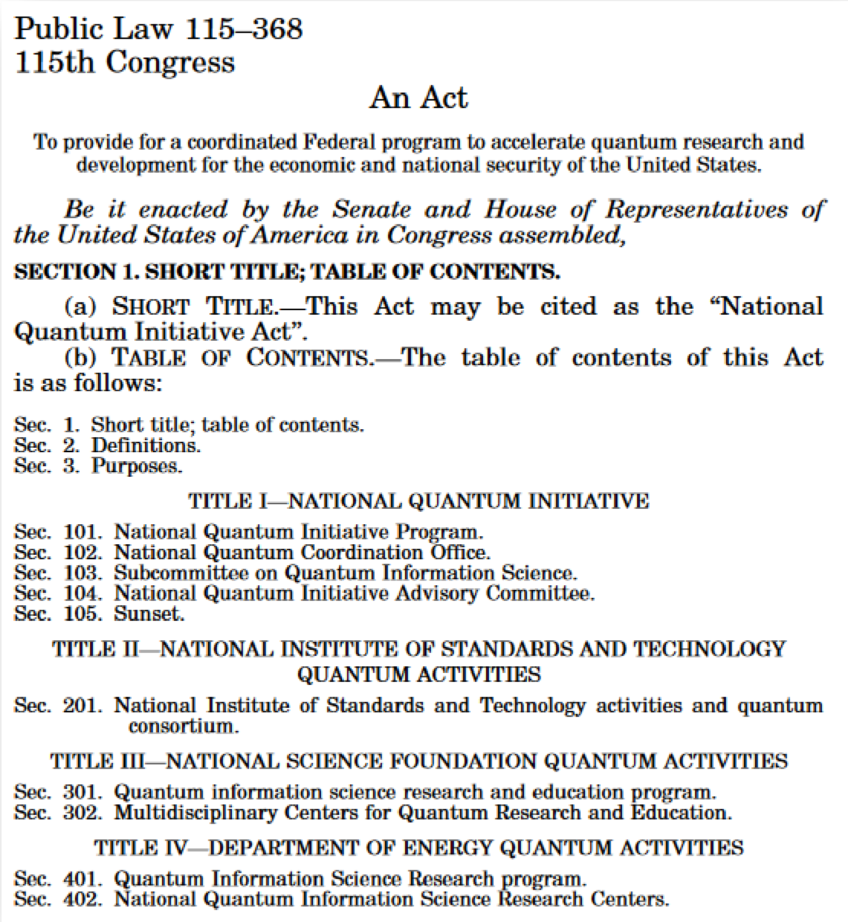
National QIS Strategy: Key Policy Principles



- ✓ Choosing a science-first approach
- ✓ Creating a quantum-smart workforce
- ✓ Deepening engagement with industry
- ✓ Providing critical infrastructure
- ✓ Maintaining national security and economic growth
- ✓ Advancing international cooperation

https://www.whitehouse.gov/wp-content/uploads/2018/09/National-Strategic-Overview-for-Quantum-Information-Science.pdf

National Quantum Initiative Act (PL 115-368)


Public Law 115–368
115th Congress

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".

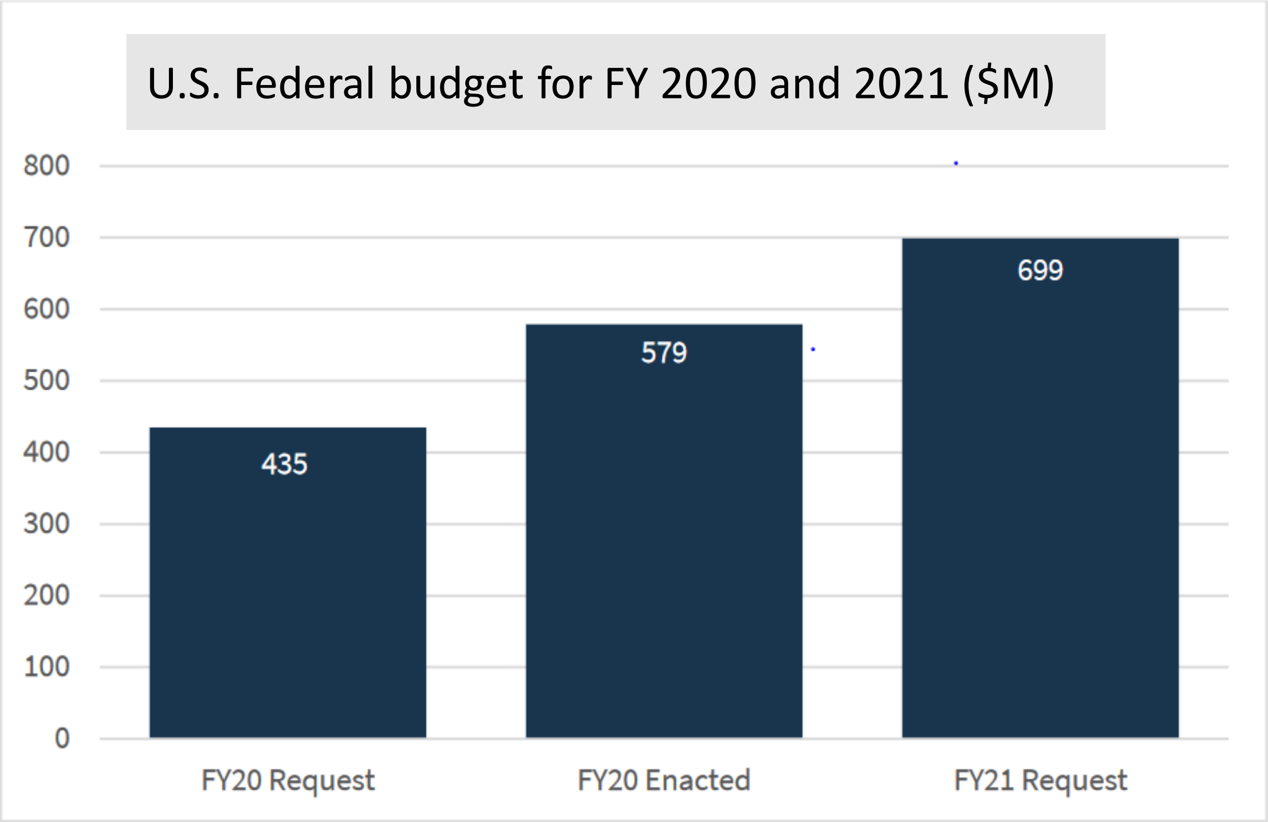
(b) TABLE OF CONTENTS.—The table of contents of this Act is as follows:

The purpose of this Act is to ensure the continued leadership of the United States in quantum information science and its technology applications

1. **Support research, development, demonstration, and application of quantum information science and technology--**
   a) develop a **workforce** pipeline
   b) promote multidisciplinary curriculum and research opportunities
   c) address basic research gaps
   d) promote the further development of facilities and centers
   e) stimulate research on and promote **more rapid development of quantum-based technologies**
2. Improve the interagency planning and coordination
3. Maximize the effectiveness of the Federal Government's quantum information science and technology research, development, and demonstration programs
4. **Promote collaboration** among the Federal Government, Federal laboratories, industry, and universities
5. Promote the development of international standards for quantum information science and technology security

Authorizes $1.275 billion over 5 years.

Federal Spending Proposal for 2021 up 60%

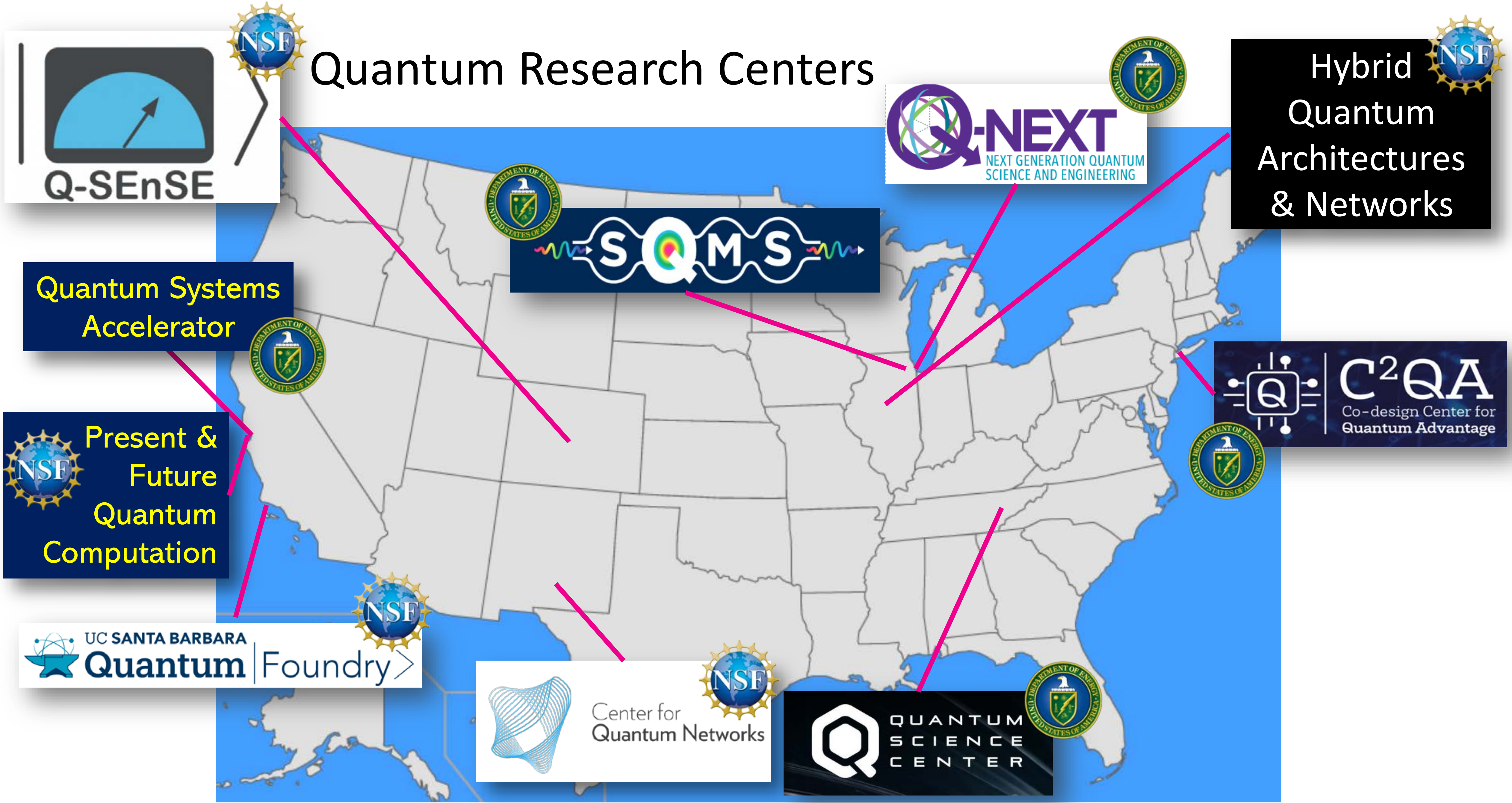


Source: OMB and National Quantum Coordination Office

- NSF spending to nearly double to $226 million, up $120 million over FY2020
- DOE proposed budget up $58M to $237M, including $25M for quantum internet research.

https://www.whitehouse.gov/wp-content/uploads/2017/12/Artificial-Intelligence-Quantum-Information-Science-R-D-Summary-August-2020.pdf

Quantum Research Centers

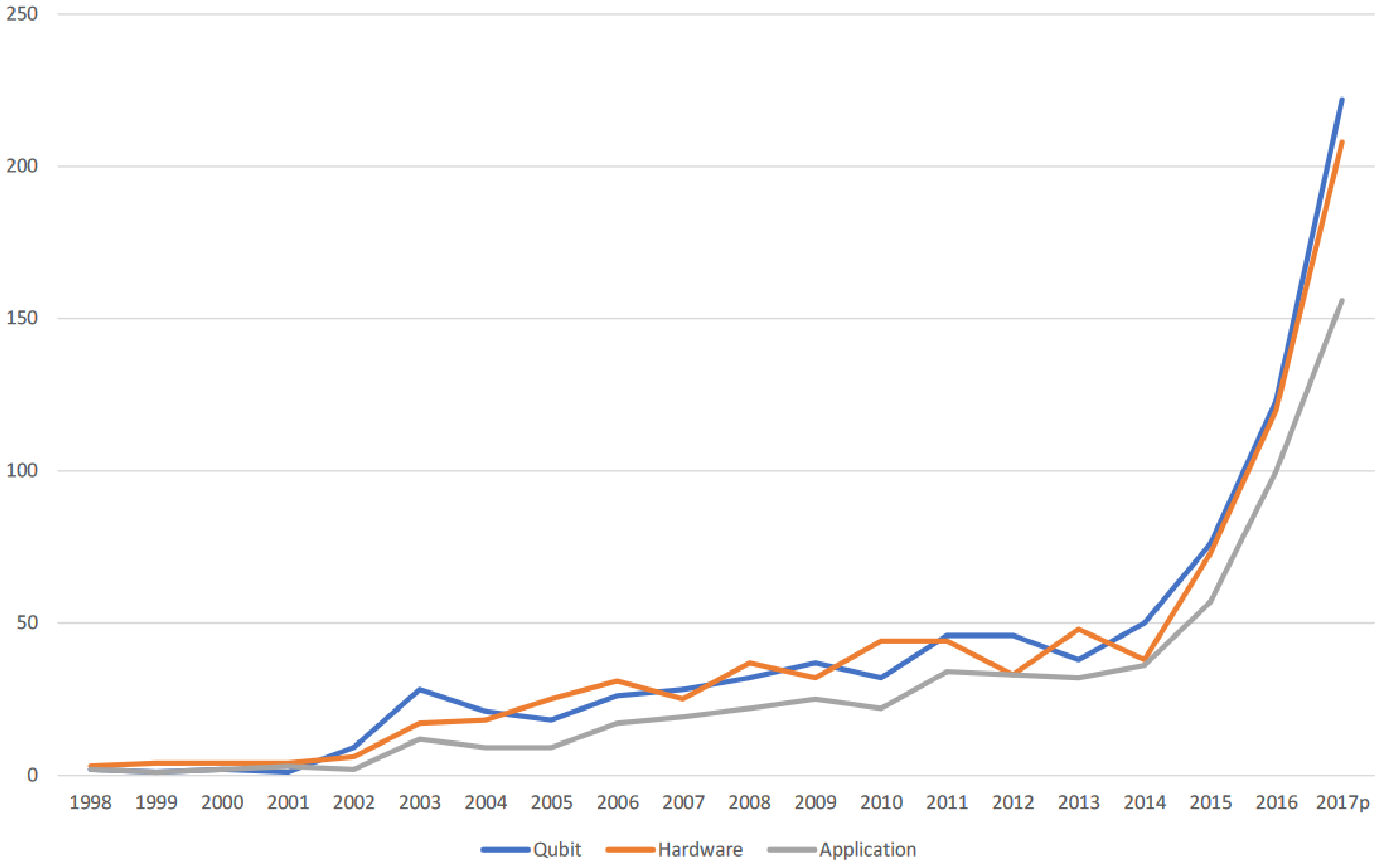


https://science.osti.gov/Initiatives/QIS/QIS-Centers

• Quantum Computing Patent Families by Category and Publication Year

- The jump in the number of patent families in 2003 was driven primarily by documents related to qubit technologies, followed by hardware type and applications.

- Publications related to qubit technology and hardware have seen the greatest amount of growth over the period of rapid expansion that began in 2015 followed by applications.



Note: Based on 1,952 Quantum Computing patent documents from a worldwide search in Thomson Innovation; limited to one document per family, based on DWPI with US as primary country; Documents can appear in more than one category; Currently 293 documents for 2017.

Source: Patinformatics http://patinformatics.com/wp-content/uploads/2017/10/Quantum-Computing_Full_Report_Final_opt.pdf=

NQI Act calls for consortium

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115th Congress

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Calls for NIST to create a "consortium of stakeholders" to identify needs to support development of a robust QIST industry in the United States.

Consortium Goals

- ✓ Assess the current research on those needs
- ✓ Identify gaps in the research necessary to meet those needs
- ✓ Provide recommendations on how NQI can address those gaps

NIST selected SRI to manage the Quantum Economic Development Consortium (QED-C) in 2018

All segments of R&D continuum are required

QED-C Focus (spanning stages 3–5)

	Basic R&D	Application R&D	Device Prototypes	Enabling Component Development	Prototype Components and Subsystems
STAGE & TRL:	1	2	3	4	5
ACTIVITY:	Understanding Fundamental Phenomena	Exploiting & Controlling Phenomena	Create First of a Kind Devices	Create Key Sub-Components & Devices/T&E/ Performance Stds.	Develop Efficient Common Purpose-Driven Devices/ Designs/T&E/ Stds.

Federally funded research (spanning stages 1–3)

MATURE INDUSTRY

- De-risked components
- Robust infrastructure
- Common standards
- Testbeds

Competitive R&D And Industry Activities:

- Production Equipment Fabrication & Sales
- COTS Device Manufacturing & Sales
- Full Quantum Systems
- Deploy Quantum Systems at Utility Scale

EFFICIENCIES:

- Public/Private Support: Funding & Collaboration
- Introduce New Common Enabling Devices Performance Standards
- Create Device Production Equipment Standards
- COTS Device & Systems Performance Standards

ENGAGED EXPERTISE:

- Physics / Comp Sci / Materials / Engineering
- Test &Eval / Valid. &Verif. / Manufacture

QED-C Mission and Goals

Mission: Enable and grow a robust U.S. quantum industry

Goals:

- Identify and develop strategies to address gaps in the following
  - Enabling technologies (cryogenics, electronics, lasers, etc.)
  - Standards, benchmarks and performance metrics
  - Workforce
- Identify economically important applications and use cases
- Facilitate industry coordination and interaction with government
- Provide government with a collective industry voice, e.g., to guide R&D investments, inform regulatory policy, and develop a quantum-ready workforce

QED-C LOI Signatories (as of 8/28/2020)

Corporate

- Accenture
- Advanced Research Systems
- Aliro Technologies
- AlphaRail
- Amazon
- ANSYS
- AOSense
- Aperio Global
- Architecture of Things
- ARM Research
- AT&T
- Atom Computing
- BAE Systems
- Benchmark Electronics
- Bleximo
- BlockQAI
- Boeing
- Booz Allen Hamilton
- Boston Consulting Group
- BP North America
- Bra-Ket Science
- Bright Apps
- CEC Security
- Citi
- Coherent
- ColdQuanta
- Corning
- Cosmic Microwave Technologies
- Crowdmole
- Cryomech
- D-Wave Government Systems
- Dallas Quantum Devices
- Desner Group
- Digital Optics Technologies
- dxChain
- Entanglement Institute
- Equal1.Labs
- EZ Form Cable
- FieldLine
- FLIR Systems
- Galois
- GE Global Research
- General Dynamics Mission Systems
- Google
- Great Lakes Crystal Technologies
- Holzworth Instrumentation
- Honeywell
- HPD
- HRL Laboratories
- Hyperion Research
- IBM
- Infinity Labs
- inFocus Networks
- Inside Quantum Technology
- Intel
- IonQ
- Janis Research
- JTEC-Consulting
- Keysight
- KMLabs
- L3Harris
- Lake Shore Cryotronics
- Lockheed Martin
- Marki Microwave
- McKinsey & Company
- Microchip/Microsemi
- Microsoft
- Millimeter Wave Systems
- MinneQuantum
- Montana Instruments
- Northrop Grumman
- Northwest Engineering Solutions
- NuCrypt
- Ode L3C
- OEwaves
- Palo Alto Research Center (PARC)
- Photodigm
- Photon Spot
- Physical Science Inc.
- PQ Secure Technologies
- Psi Quantum
- Q-CTRL
- Q-Sensorix
- QC Ware
- QPRI
- Qrypt
- Quacoon
- Quantum 1 Group
- Quantum Bit Labs
- Quantum Circuits
- Quantum Computing
- Quantum Computing Report
- Quantum Design
- Quantum Industry Coalition
- Quantum Microwave
- Quantum Opus
- Quantum Semiconductor
- Quantum Thought
- Quantum Xchange
- Qubitekk
- QuEra Computing
- Qulab
- Qunnect
- Raytheon-BBN Technologies
- Rigetti
- Riverside Research
- Rydberg Technologies
- Savantly Health
- Scout Ventures
- Semicyber
- Sharpe Engineering
- Sivananthan Laboratories
- Sky Quantum
- SkyWater Technology
- Southwest Sciences
- Speqtral Quantum Technologies
- Splunk
- SRI International
- Stable Laser Systems
- Strangeworks
- StratConGlobal
- StrategicQC
- Sumitomo (SHI) Cryogenics of America
- Super.tech
- Synopsys
- Takeda USA
- Terranet Ventures
- Thorlabs
- TOPTICA Photonics
- TSI Semiconductors
- Twinleaf
- United Technologies Research Center
- US Advanced Computing Infrastructure
- Vapor Cell Technologies
- Vescent Photonics
- Virtual Broadcasting Information Center
- Wells Fargo
- Xofia
- Young Basile Hanlon & MacFarlane
- Zapata Computing
- Zettaflops
- ZRG Partners
- Zyvex Labs

Academic

- Bridgewater State University
- Caltech/INQNET
- Clarkson University
- Colorado School of Mines
- Fordham University
- George Mason University
- Georgia Institute of Technology
- Harrisburg University of Science and Technology
- Indiana University
- Lehigh University
- New York University
- Northeastern University
- Pittsburgh Quantum Institute
- Purdue University
- Rochester Institute of Technology
- Southern Methodist University
- Stanford University
- SUNY Polytechnic Institute
- Texas A&M
- University of Arizona
- University of Buffalo
- University of California – Los Angeles
- University of California – Santa Barbara
- University of Chicago/Chicago Quantum Exchange
- University of Colorado
- University of Illinois
- University of Maryland
- University of Notre Dame
- University of Oklahoma
- University of Rochester
- University of Wisconsin
- Virginia Tech

Other

- American Physical Society
- Ames Laboratory
- Federal Reserve Bank of Philadelphia
- Fermi National Accelerator Laboratory
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- MITRE Corporation
- Optical Society of America
- Sandia National Laboratories
- SEMI
- SLAC
- SPIE
- Universities Space Research Association

189 Participants:

- 143 Corporations
- 32 Universities
- 14 Others

QED-C

Managed by SRI International

https://quantumconsortium.org/signatories/

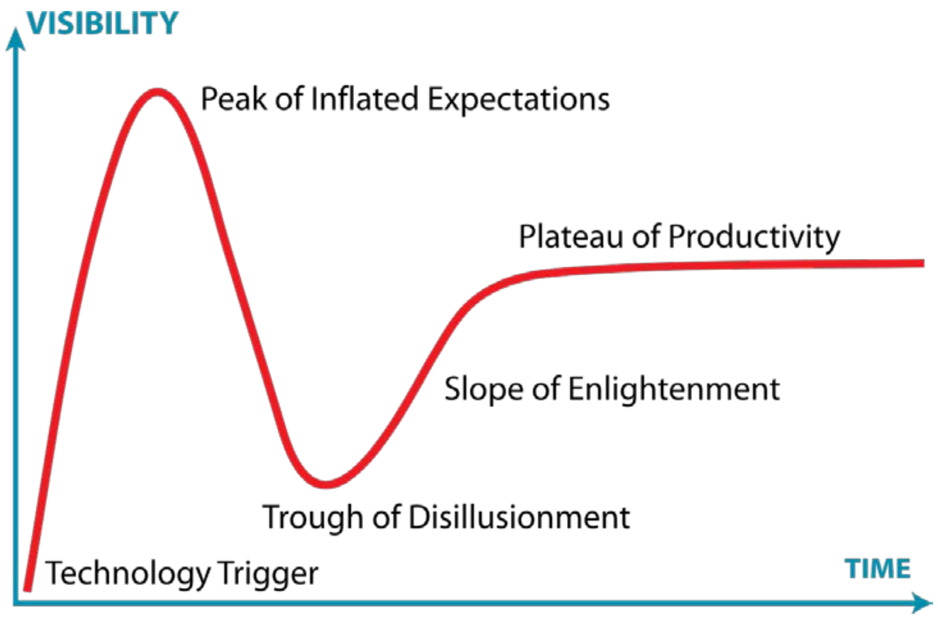
Benefits of being a QED-C member

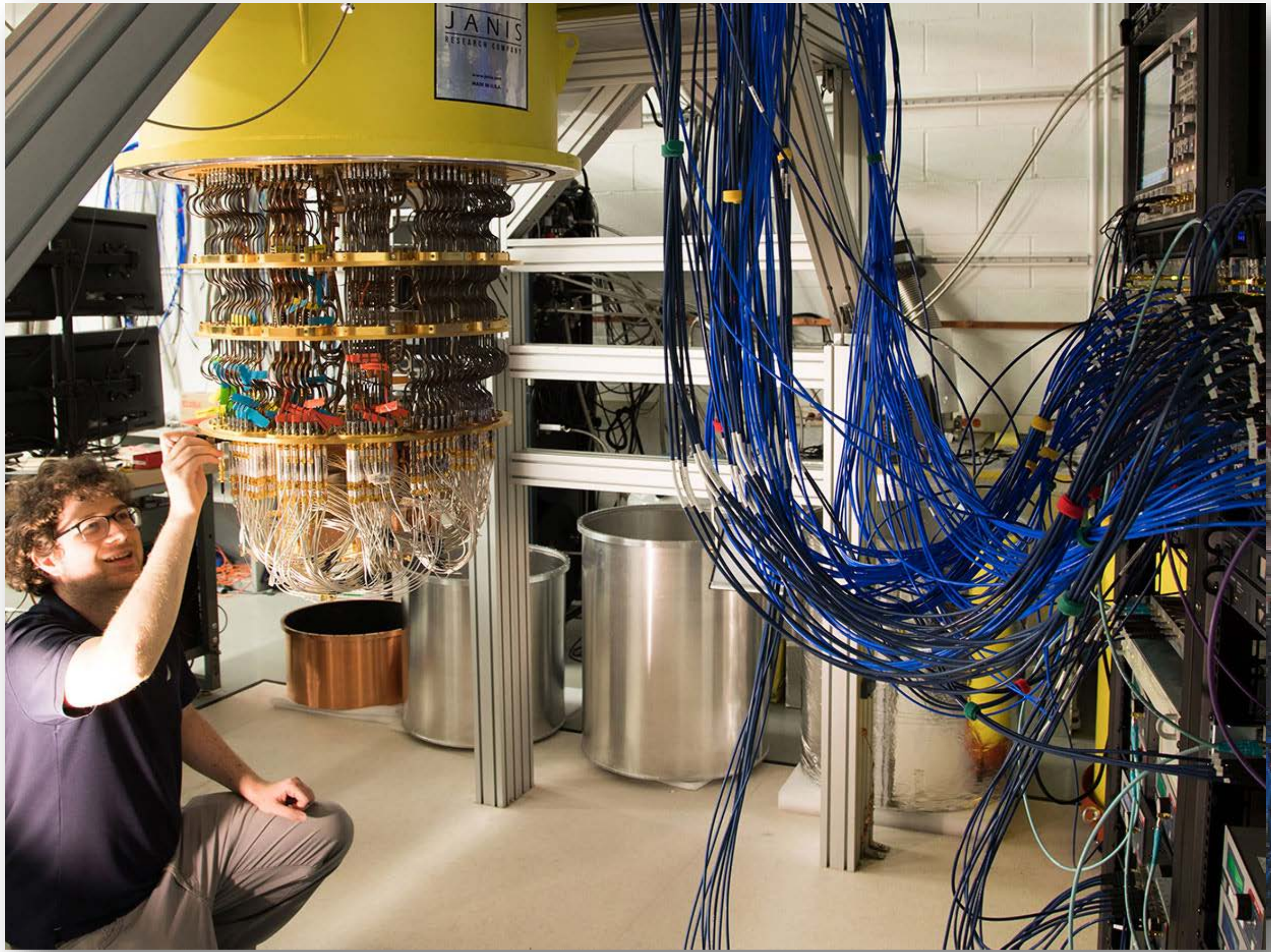
- ✓ Connect with stakeholders from across the innovation ecosystem
- ✓ Get insight from fellow members
- ✓ Access R&D funding to close enabling technology gaps*
- ✓ Access to QED-C reports, analyses, roadmaps, etc.*
- ✓ Shape standards and performance metrics
- ✓ Tap into a pool of qualified talent

The superposition of nano and quantum

Quantum information science and technology (QIST) devices and systems require:

- ✓ Understanding and control of matter at the nanoscale.
- ✓ Scalable methods of nanofabrication
- ✓ Convergence of multiple disciplines, departments, sectors, etc.
- ✓ Novel approaches to educating the future quantum workforce
- ✓ Public outreach to explain the technology
- ✓ Management of expectations/hype





https://spectrum.ieee.org/tech-talk/semiconductors/design/google-team-builds-circuit-to-solve-one-of-quantum-computings-biggest-problems

https://www.ibm.com/blogs/research/2020/09/ibm-quantum-roadmap/

For information:

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https://quantumconsortium.org