

Quantum Information Science at DOE Office of Science

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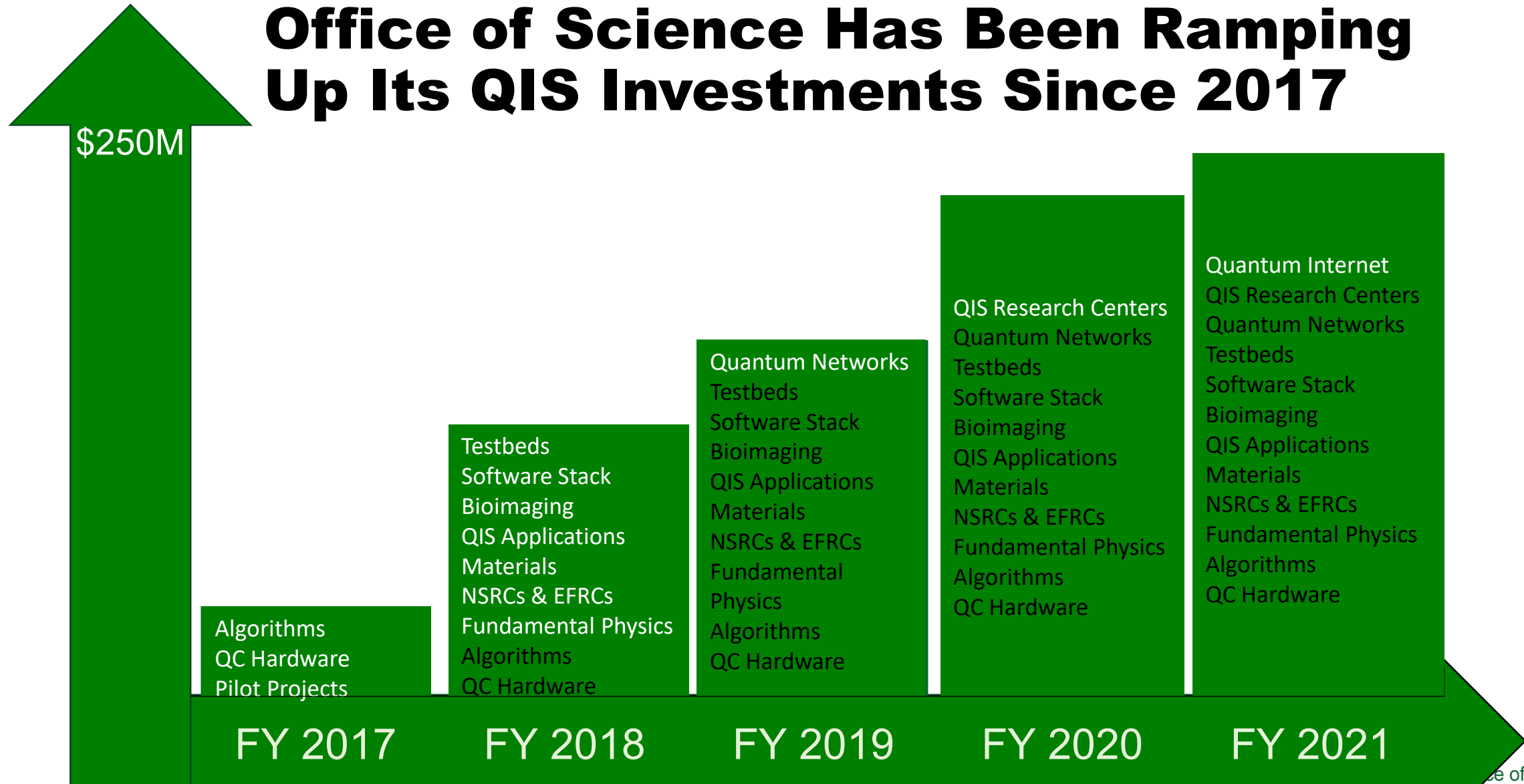
Advanced Scientific Computing Research



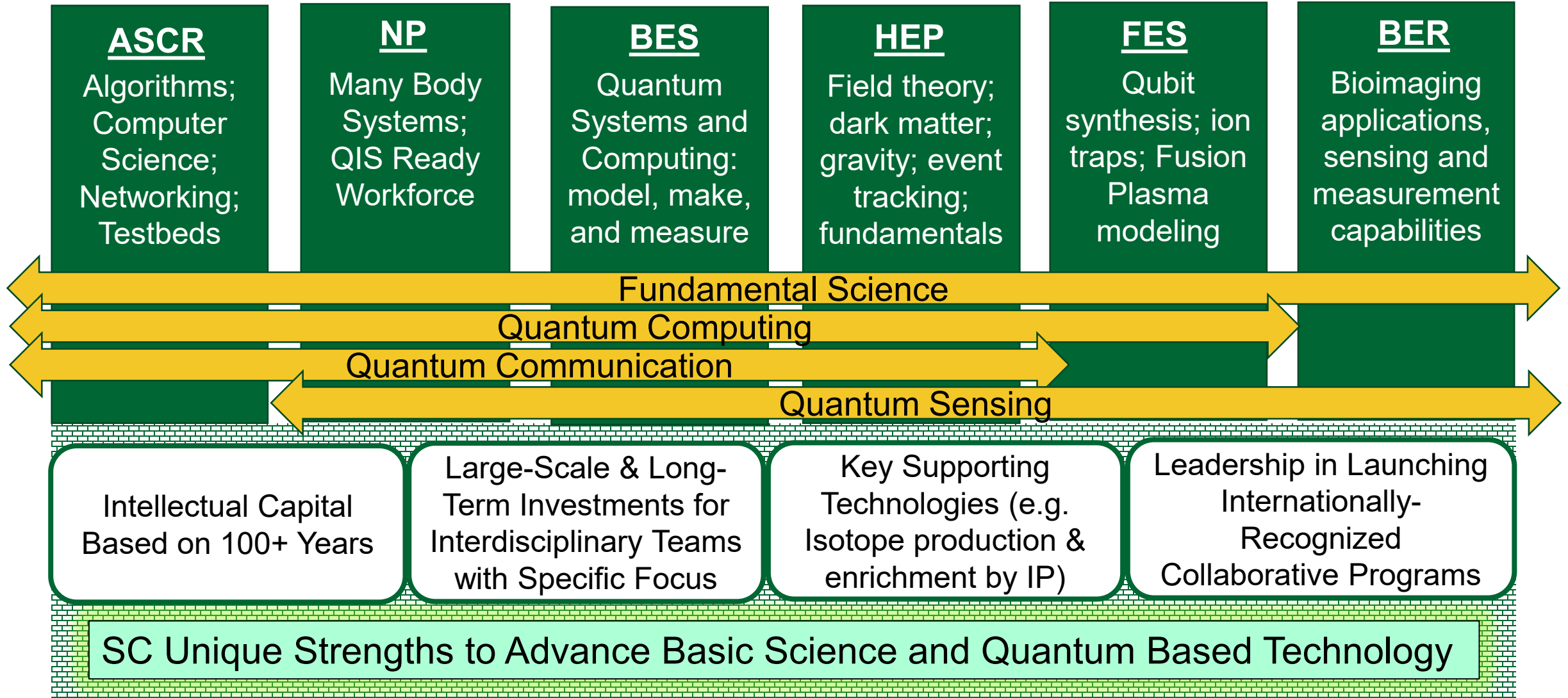
U.S. DEPARTMENT OF
ENERGY

Office of
Science

Office of Science Has Been Ramping Up Its QIS Investments Since 2017

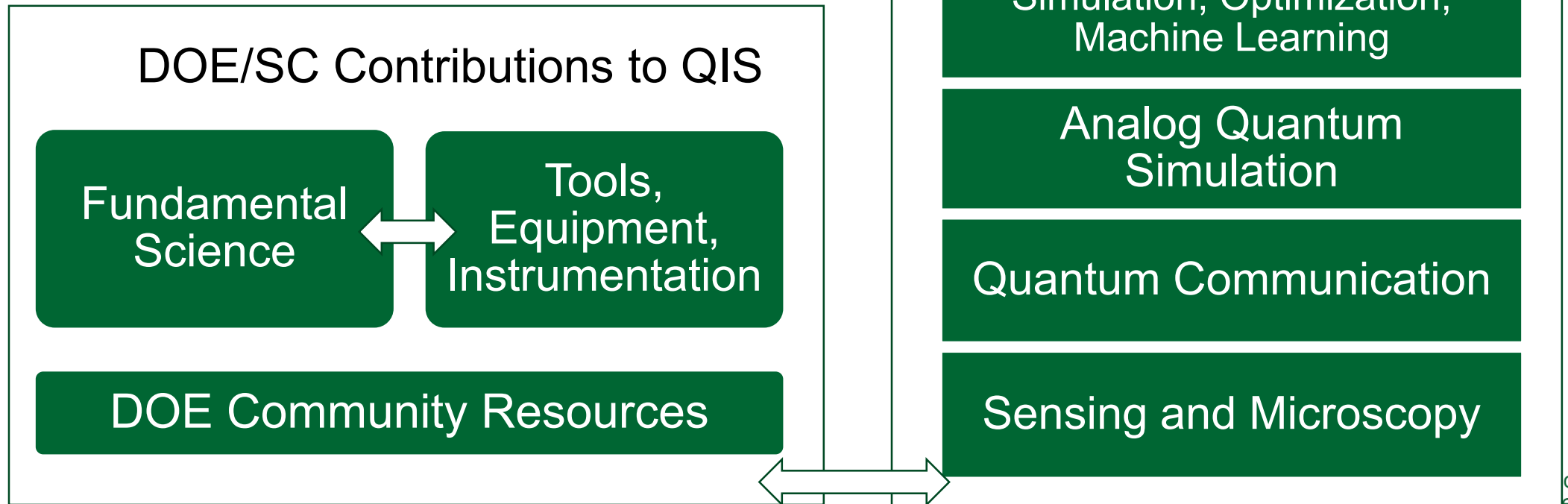


QIS Crosses the Technical Breadth of the Office of Science



SC's QIS Strategy

- ✓ Builds on community input
- ✓ Highlights DOE/SC's unique strengths
- ✓ Leverages groundwork already established
- ✓ Focuses on cross-cutting themes among programs
- ✓ Targets impactful contributions and mission-focused applications



National Quantum Initiative (NQI) Act

- **Public Law 115-368, signed by President Trump 12/21/2018**
- **Establishes a National Quantum Coordination Office and through the National Science and Technology Council a Subcommittee on Quantum Information Science as well as a National Quantum Initiative Advisory Committee**
- **Specific roles given to DOE, NSF and NIST**
- **DOE roles**
 - Provide support for National Quantum Coordination Office
 - Serve as co-chair on QIS Subcommittee
 - Leverage the collective body of knowledge from existing QIS research
 - Provide research and training for additional undergraduate and student students in QIS
 - Establish at least 2 but no more than 5 National Quantum Information Science Research Centers

National QIS Research Centers

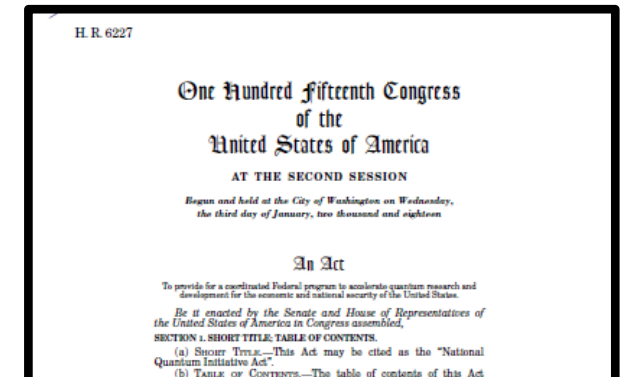
- First large-scale QIS effort that crosses the technical breadth of SC
- Scope built on extensive community-wide RFI inputs— from technical scope to partnership model to management construct
- Seamlessly integrates the S&T innovation chain to accelerate progress in QIS R&D
- Maximizes teaming flexibility and options (TIAs, cooperative agreements, field work authorizations, interagency agreements) to foster direct participation by academics, national/federal labs, and for-profits
- Leverages other federal agency investments such as NSF's Quantum Leap Challenge Institutes and the NIST Quantum Economic Development Consortium (QEDC)



January 10th, 2020: FOA Issued
February 10th, 2020: Pre-apps Due
March 10th, 2020: Pre-apps Response
April 17th, 2020: Proposals Due



2-5 Awards
\$10-25M/Year/Center
Up to \$625M in 5 Years



National Quantum Initiative Act

Quantum Internet

Groundwork

- SC's ESnet is among the world's fastest high-performance scientific network facilities
- 5 ASCR funded projects at ANL, BNL, FNAL, ORNL, SLAC and SNL to develop and to deploy a transparent optical quantum internet working ecosystem
- Quantum Internet Blueprint Workshop (February 5-6, 2020)

Why DOE?

- Secure communications for DOE National Labs using the laws of quantum physics
- Accelerate scientific discovery for all SC domains
- Create jobs and world-class workforce in quantum physics-based technology for National leadership and economic prosperity

Goal

Establish a secure, reliable quantum internet backbone initially connecting the National QIS Research Centers, then ultimately connecting DOE National Labs

Administration and DOE Priority

National Quantum Initiative Act

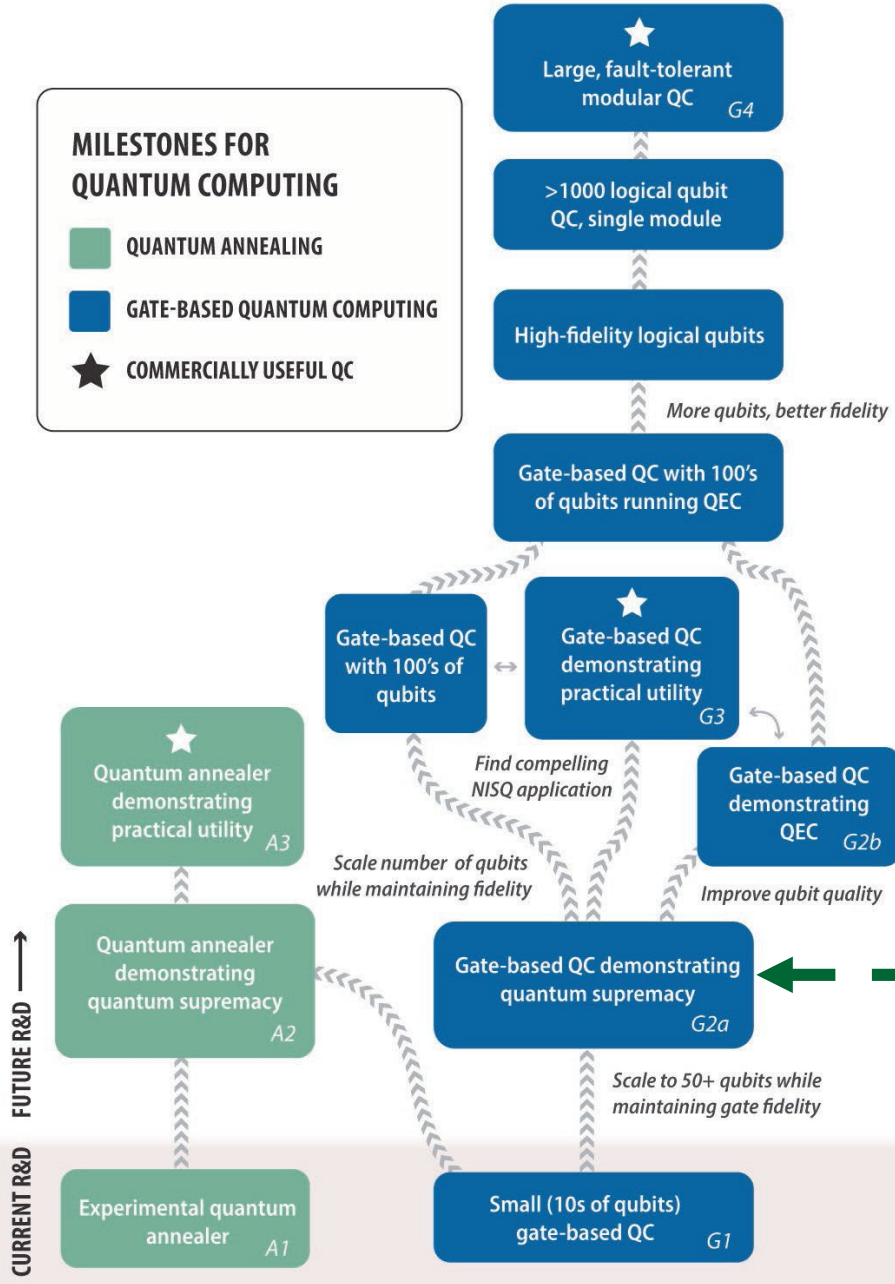
In July 2020, DOE unveiled the Quantum Internet Blueprint workshop report that lays out the strategy for the development of a national quantum internet National Labs, academia and private sector collaborations for basic science, engineering quantum-technology development

Annual DOE/SC QIS PI Meeting

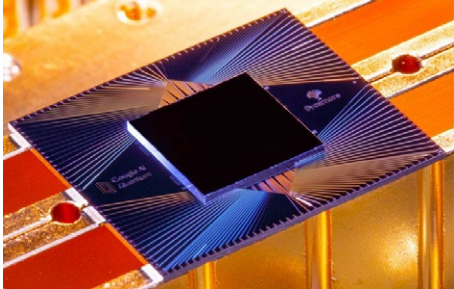
- SC's premier event that brings together PIs and observers from all SC programs, observers from other Federal Agencies, and international experts
- First DOE/SC QIS PI meeting held in January 31-February 1, 2019 with 267 attendees
- Next PI meeting will include National QIS Research Centers PIs

MILESTONES FOR QUANTUM COMPUTING

- QUANTUM ANNEALING
- GATE-BASED QUANTUM COMPUTING
- ★ COMMERCIALY USEFUL QC



QIS is still in early stages with broad as well as deep challenges in fundamental science, technology, engineering & workforce



Google's 54 qubit Sycamore chip, *Nature*, October 2019

Source: "Quantum Computing: Progress and Prospects", National Academies Press, 2019

SC's QIS Goals Encompass Multiple Time Scales

Investments with National Impact

E.g. National QIS Research Centers, Quantum Internet

Whole of SC & Whole of QIS

Keep all SC programs involved to advance basic research, technology development and workforce

Community Engagement

Continue with information exchanges

Collaboration

Industry: Innovation Economy

Other agencies: Coordination

International: Awareness

QIS in SC is a long-term effort

DOE Community Resources

World-Class National Laboratory resources

- Advanced fabrication capabilities, (e.g. Microsystems & Engineering Sciences Applications (MESA) facility at SNL)
- Specialized synthesis and characterization capabilities (e.g. Enriched Stable Isotope Prototype production plant)
- Internal research computing capabilities, experimental equipment, and prototypes (e.g. D-Wave, testbeds)
- Engineered physical spaces (e.g. EM-shielded rooms, low-vibration chambers, deep shafts)

Focused programs and intellectual property

- Internships and visiting programs for students and faculty
- National Laboratory technical assistance programs
- Access to intellectual property developed at National Laboratories via technology licensing agreements
- Early Career Research Program
- Small Business Innovation Research
- Computational Science Graduate Fellowship

User Facilities include:



Synchrotron and x-ray free electron laser light sources



Observational and communications networks



Nanoscale Science Research Centers



High Performance Computing and Network

National Quantum Strategy and the DOE Labs

DOE Labs are well aligned with the national quantum strategy which provides a framework and a vector to pursue our strategic objectives.



Quantum sensors for laboratory detection of dark matter (FNAL)



Quantum cryo-electron microscope with a spin polarized electron source to measure decoherence (LBNL)

Science

An expansive portfolio supported by SC, NNSA and LDRDs in 17 Labs

Workforce

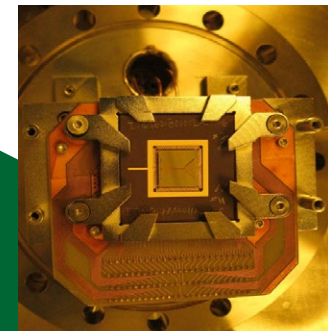
Leverage lab resources to support QIS careers

Industry

Labs are partnering with industry for QIS research and for access to technology



OLCF's quantum computing user program enable access to IBM, D-Wave, Rigetti and Atos platforms



Quantum scientific open user testbed at SNL develops early stage trapped ion platforms

Infrastructure

QIS specific technologies are added to existing facilities' capabilities

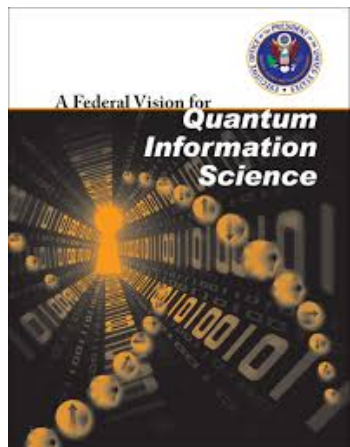
International

Partnerships with the international QIS community

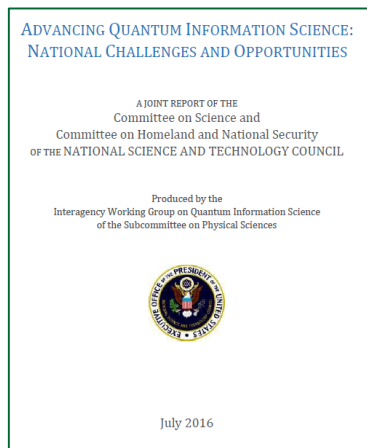
Economic & Security

Exploration of precompetitive technology mitigates risk for industry

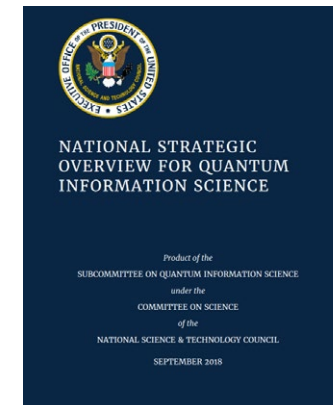
History of QIS at DOE



2014



2017



2020

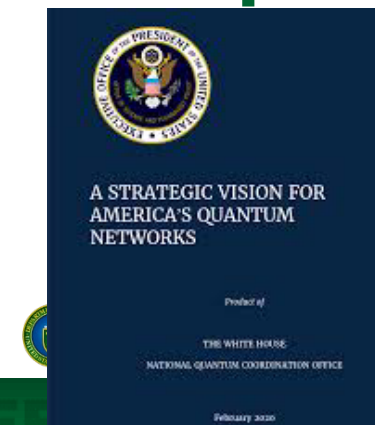
2009

- Interagency Working Group on QIS was created under NSTC's Committee on Science
- SC started engaging its communities through workshops

2016

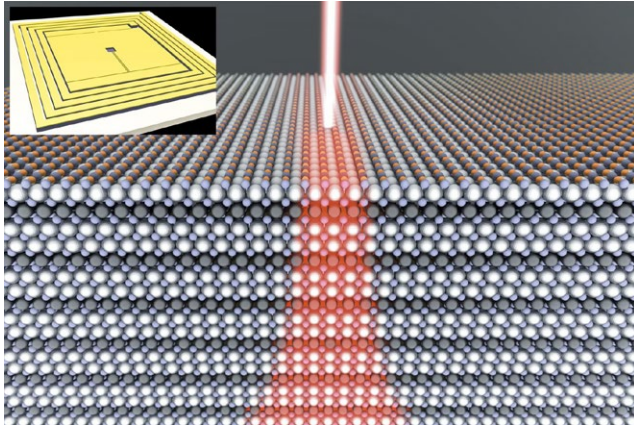
- SC initiated its main investments through two programs in ASCR

2018

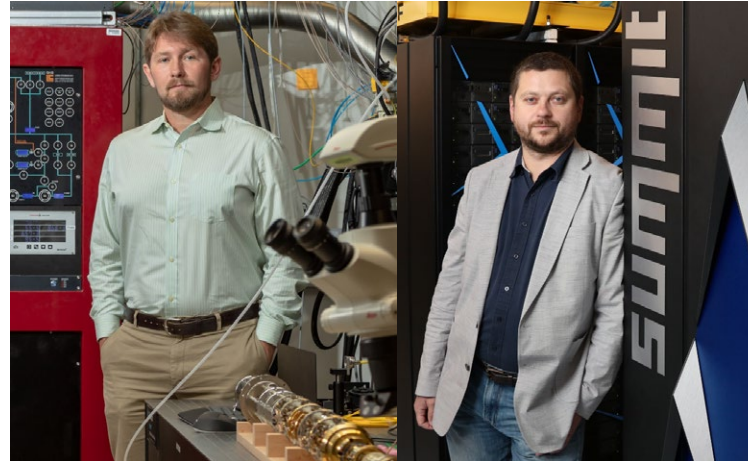


Groundwork That Advances QIS

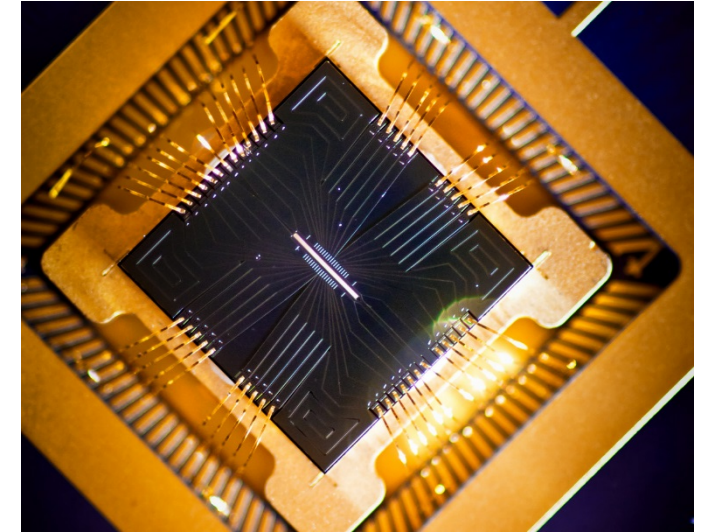
Decades of DOE investments established the groundwork critical to advance QIS



Research into Josephson junctions supported by BES led in 1985 to the discovery that SQUIDs exhibited multiple quantum levels or states—the first time such phenomena, common in atoms, had been observed in much larger, man-made devices. BES-supported research in this and related areas continued for several decades.



ASCR ECRP awardee Travis Humble (left) was part of a team that demonstrated quantum supremacy for the first time. A software library developed by ORNL's Dmitry Liakh (right) allowed the team to take full advantage of Summit to run a quantum benchmark code.



Fabrication of high-performance surface ion trap chips for quantum computation is a unique capability developed at SNL in 2009.

SC's QIS Strategy Builds On Extensive Community Engagement

