U.S. DEPARTMENT OF ENERGY | Office of Science

National Quantum Information Science Research Centers

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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

Request for Information (RFI)

To gather community input on the topic areas, organization, requirements, review criteria, and assessment processes to be described in this FOA, we issued a joint Federal Register notice constituting a combined Notice of Intent (NOI) and Request for Information (RFI) on May, 20th 2019. Comment period closed on July 5th, 2019.

Results:

- ✓ 38 distinct comments received (43 total, 5 duplicates or updates)
- ✓ Published here except for 1 confidential response https://www.regulations.gov/docket?D=DOE-HQ-2019-0025

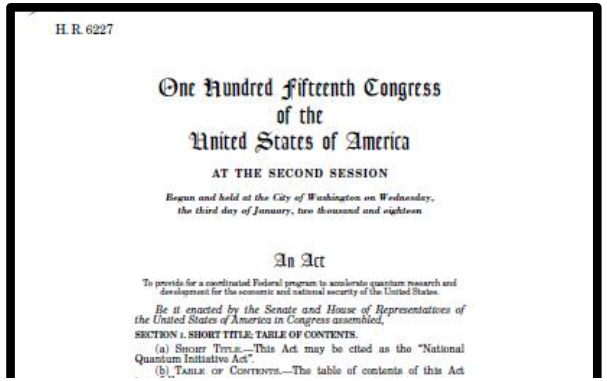
- Labs: Ames, ANL, BNL, FNAL, LBNL, ORNL, PNNL, SNL, SLAC
- Universities: Caltech, Cornell, CU-Boulder, CUNY, Georgia Tech, Harvard, MIT, Princeton, Purdue, SBU, SUNY Albany, UCalgary, UC-Berkeley, UCSB, UChicago, UHouston, UIUC, UMD, URochester, UWashington [in NQN], UWisconsin, Yale
- Companies: Casting Analysis Corp., Centeva, Entanglement Inc., Global Foundries, Google, IBM, Intel, Lockheed Martin, Microsoft, Perspecta Labs, SC Solutions

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 (QED-C)

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


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

National Quantum Initiative Act

Background on the FOA

- Aligning with the NQI Act
- Meeting DOE leadership's expectations
- Delineating the Centers from existing SC efforts
- Making sure that their scope is appropriate for the level of investment
- Incorporating the input received in response to the RFI
- Guiding the community but leaving flexibility

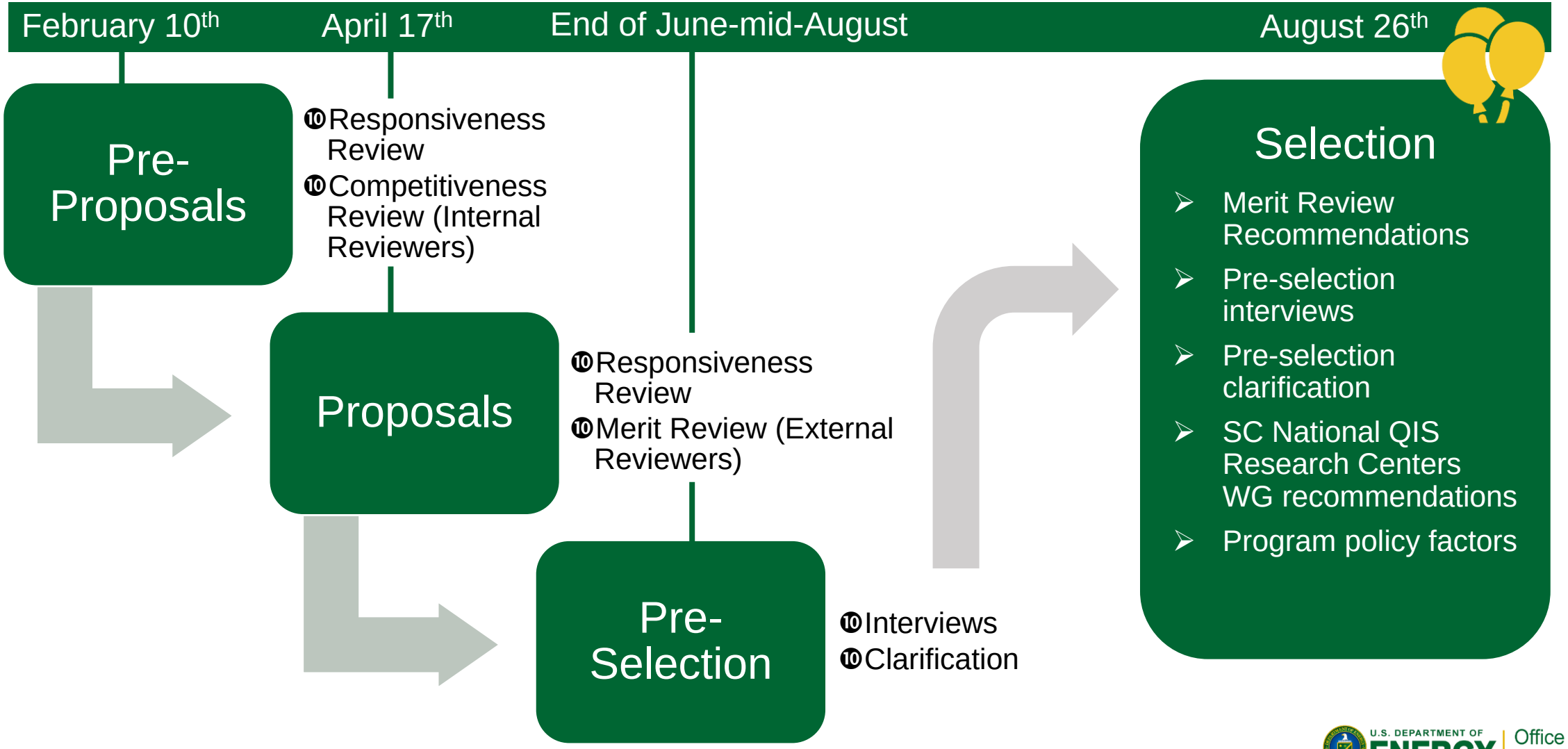
Describe required aspects up front:

- Significant National Impact
- Major Cross-Cutting Challenge
- S&T Innovation Chain
- QIS Ecosystem Stewardship
- Multi-disciplinary Leadership
- Collaborative Management Structure
- Well-Structured Plan and Metrics

Five essential components to capture the **multi-dimensional** nature of the Centers:

- QIS S&T Innovation Chain
- Technical Areas of Interest
- QIS Ecosystem Stewardship
- Management Structure
- Instrumentation and Facilities

Review Process



Five National QIS Research Centers

Q-NEXT • Next Generation Quantum Science and Engineering
(David Awschalom, ANL)

C²QA • Co-design Center for Quantum Advantage
(Steve Girvin, BNL)

SQMS • Superconducting Quantum Materials and Systems Center
(Anna Grassellino, FNAL)

- ✓ Significant National Impact
- ✓ Major Cross-Cutting Challenge
- ✓ Science and Technology Innovation Chain
- ✓ QIS Ecosystem Stewardship
- ✓ Multi-Disciplinary Leadership
- ✓ Collaborative Management Structure
- ✓ Well-Structured Plan and Metrics

QSA • Quantum System Accelerator
(Irfan Siddiqi, LBNL)

QSC • The Quantum Science Center
(David Dean, ORNL)

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

Q-NEXT innovations create a technology and training pipeline

https://www.q-next.org/

Promoting U.S. competitiveness with impactful science

5-year goals include repeater-enabled quantum interconnects, networked ultra-precise sensors, and a national resource for quantum materials.

Creating industrial engagement at all levels

10 U.S. member companies, leaders in their respective fields, provide pathways to the practical commercialization of quantum technology. *Q-NEXT will host the Intel Solid State Quantum Test Bed at Argonne*.

Training a quantum smart workforce

The Q-NEXT NEXT-GEN program builds on the successful NSF QISE-NET program to pair students with co-advisors at industry and National Laboratories. Q-NEXT will broaden access to quantum academic degrees and certifications.

Developing quantum standards

Incorporating processes, metrology, and tests into a National Quantum Devices Database.

Forging connectivity across the quantum ecosystem

Creating new synergies between investments in quantum research centers and leveraging world-class facilities including 3 light sources, Argonne's leadership computing facility, and its nanoscience center. *Quantum foundries at ANL and SLAC.*

3 National Labs

10 Universities

10 Industry Partners

C²QA: Co-design Center for Quantum Advantage

THE PROBLEM

Quantum computers have the potential to solve scientific and other kinds of problems that would be practically impossible for traditional supercomputers. Current Noisy Intermediate-scale quantum computers suffer from a high error rate due to noise, faults and loss of quantum coherence.

OUR GOAL

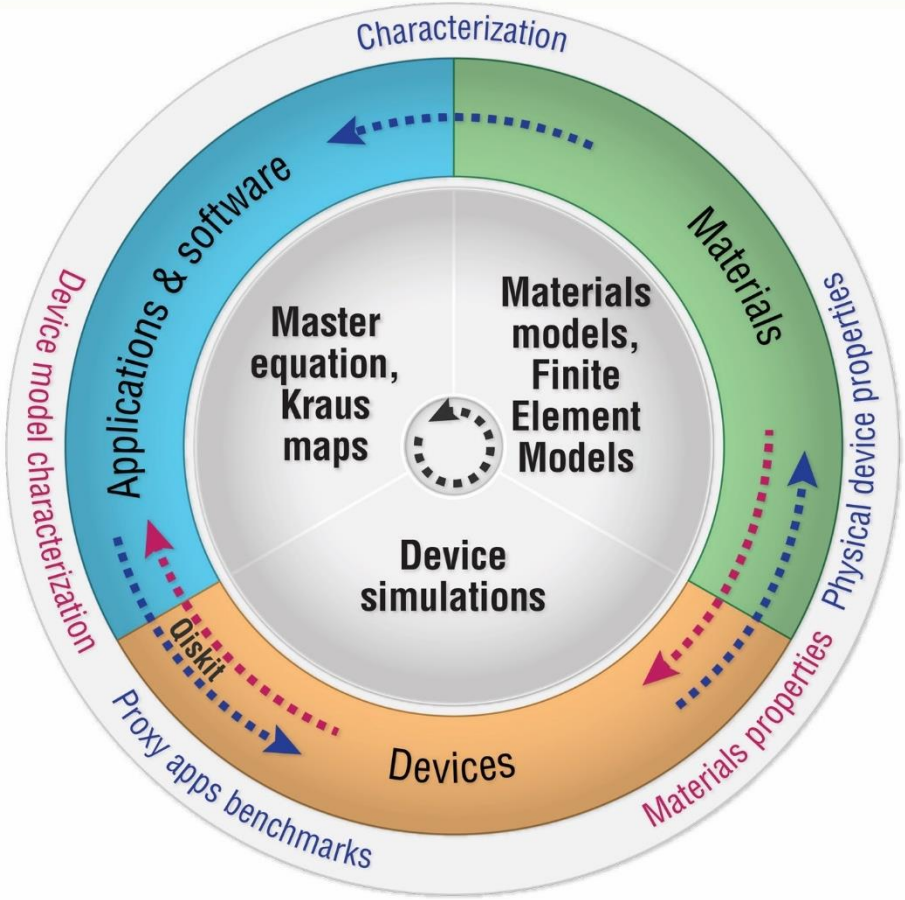
Through materials, devices, and software co-design efforts, our team will understand and control material properties to extend coherence time, design devices to generate more robust qubits, optimize algorithms to target specific scientific applications, and develop error-correction solutions.

OUR APPROACH

Our interdisciplinary team of world-leading scientists will integrate expertise across the Center's 24 partner institutions to develop co-design tools and benchmarks, develop and discover new materials and qubit devices and architectures.

WHAT IS CO-DESIGN

Traditional co-design is the joint design of hardware and software. We will develop and apply quantum co-design principles to target three research thrusts: Algorithms and Software, Devices and Materials.



BUILDING THE U.S. WORK FORCE OF THE FUTURE

Enhancing the quantum educational programs already underway at our team institutions, we will expand upon the quantum processing, quantum mechanics and quantum computing knowledge to develop programs for the general public, K-12 students, internships and training, career events, and online resources and videos.

MORE INFO

For more information:
www.bnl.gov/quantumcenter

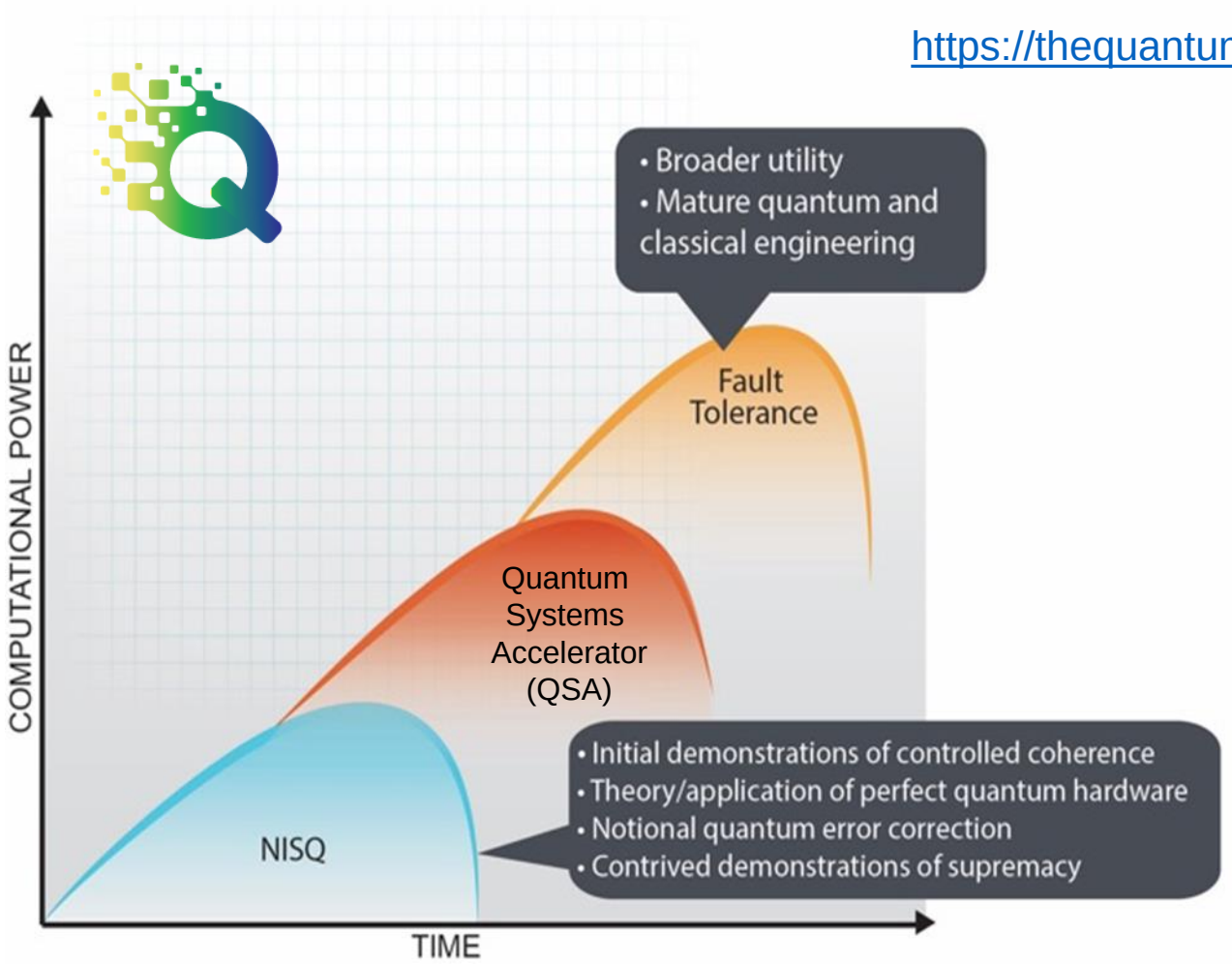
SQMS: Superconducting Quantum Materials and Systems Center

SQMS brings the power of DOE laboratories, together with industry, academia and other federal entities, to “achieve transformational advances in the **major cross-cutting challenge** of understanding and eliminating the decoherence mechanisms in superconducting 2D and 3D devices, with the final goal of enabling construction and deployment of superior quantum systems for computing and sensing.”

https://sqms.fnal.gov/

Quantum Systems Accelerator: Innovation Roadmap

https://thequantuminformationedge.org/quantum-systems-accelerator/



Harnessing Quantum

QSA will address how quantum complexity can be transformed into an engineering resource.

Programming Quantum

QSA will establish the precision tools to control naturally occurring atomic qubits and better engineered superconducting qubits for existing classical controls.

Engineering Quantum

QSA will establish metrics, benchmarks, and technology roadmaps to guide industry and bring quantum from the laboratory to the factory.

Engaging Quantum

QSA will establish a stable platform for cooperative research and a launchpad for young and mid-career scientists and engineers.

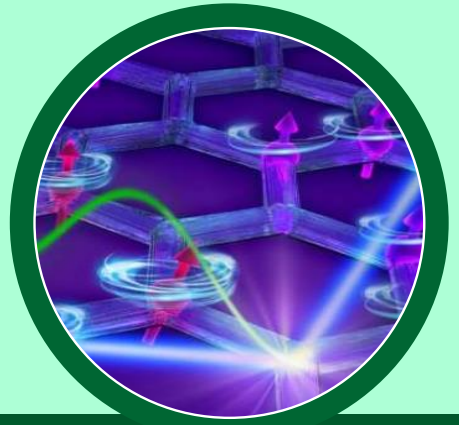
QUANTUM SCIENCE CENTER℠

Overcoming roadblocks in quantum state resilience and controllability to enable scalable quantum technologies

https://qscience.org/

Thrust 1

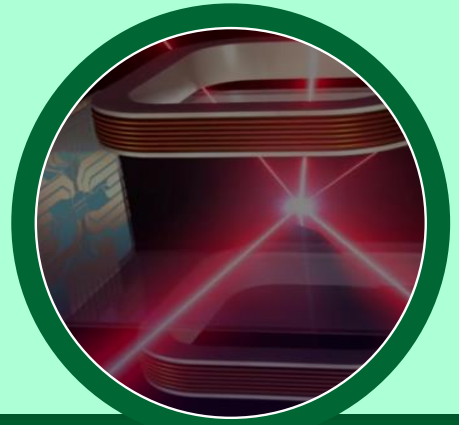
Address the fragility of quantum states through the **design of new topological materials** for QIS



Accelerated quantum information processing

Thrust 2

Develop **algorithms and software** for computation and sensing with current and future QIS hardware



Prediction of new physical and chemical behaviors

Thrust 3

Design new **quantum devices and sensors** to detect dark matter and topological quasiparticles

New quantum sensing capabilities to explore the previously unmeasurable

ENERGY | Science

National QIS Research Centers Portfolio

S&T Innovation Chain with Targets

Applications
Computing, communications and sensing for science and industry

Prototypes
Computing, sensing, network testbeds

Systems
SRF cavities, QPUs, detectors

Devices
Superconducting, ion trap, neutral atom, topological qubits, national quantum devices database, sensors, repeaters

Fundamental Science
Materials, theory, foundries, algorithms, software

Complementary Technical Areas of Interest

- **Quantum Communication**
- **Quantum Computing and Emulation**
- **Quantum Devices and Sensors**
- **Materials and Chemistry for QIS Systems and Applications**
- **Quantum Foundries**

Office of Science programs well-covered

U.S. DEPARTMENT OF ENERGY | Office of Science

National QIS Research Centers Portfolio

Diverse Management Structures

- Center Directors: 4 senior males, 1 mid-career female
- Deputy Directors: 4 males, 1 female; 4 senior, 1 early-career; 3 labs, 2 universities
- Recognition of project management best practices: ECP-like (ORNL) to Lean (FNAL)
- BEST experts in the world, clear commitment to significant national impact

Instrumentation & Facilities

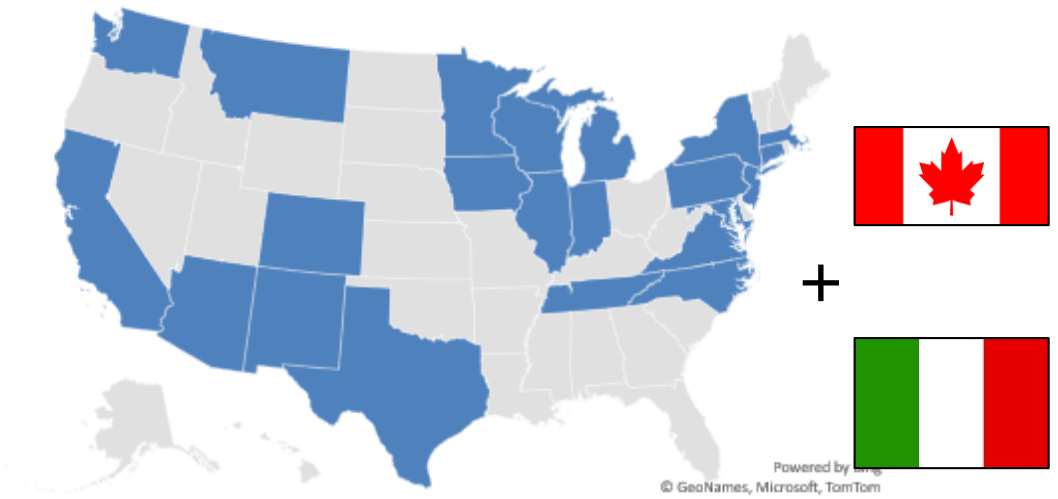
- Full leverage of DOE facilities across the lab complex
- Building new capabilities: e. g. ANL and SLAC quantum foundries
- Incorporating industry: e. g. ANL (Intel testbed)
- Using international facilities: e.g. FNAL (Gran Sasso, largest underground laboratory in the world)

QIS Ecosystem Stewardship

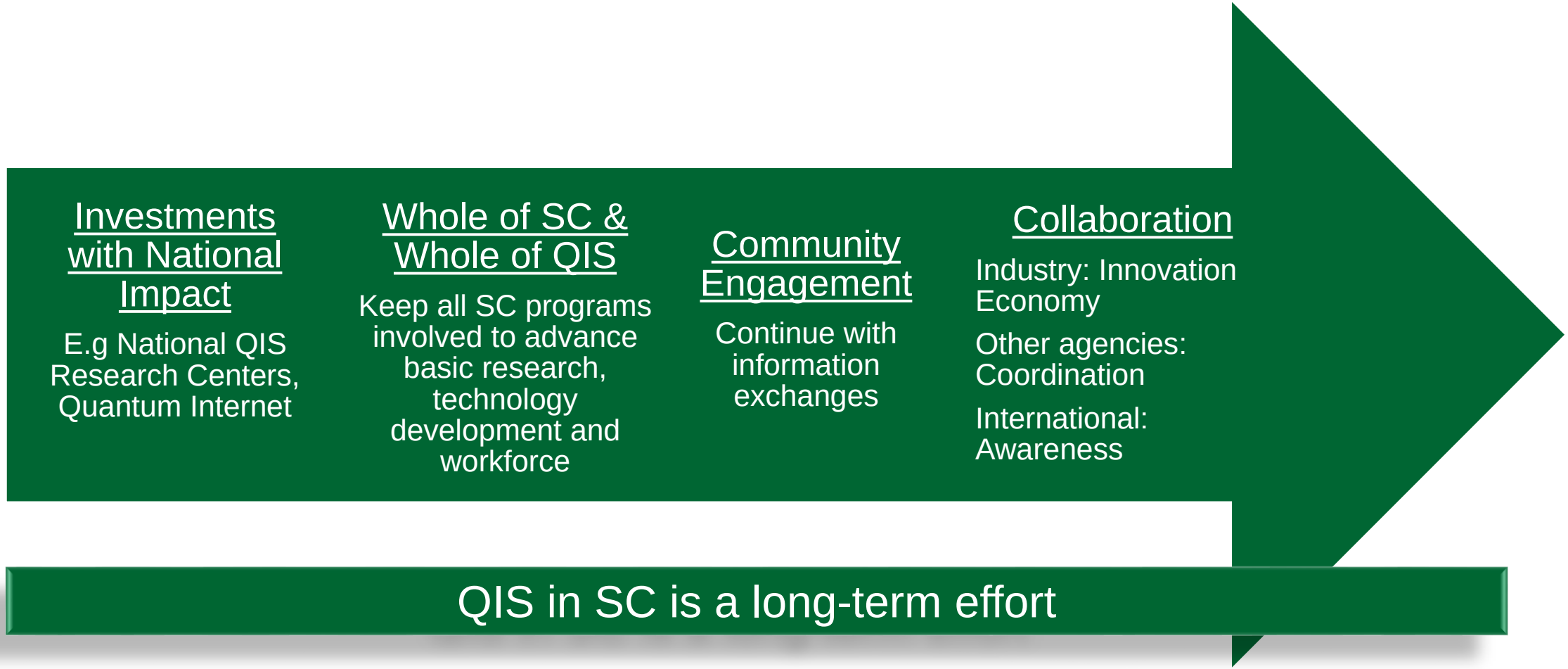
39 Academic institutions + 11 DOE Labs + 14 Companies +
3 Other agency entities + 2 Foreign institutions =

69 Institutions from 22 states + DC + Canada + Italy

Members of QED-C, connections to NSF Quantum Leap Challenge Institutes (e.g. Jun Ye in LBNL-led Center)
Unique approaches for workforce development and industry outreach (e.g. Simons Institute, pilot programs)
Leveraging other DOE investments (e.g. Testbeds, JCESR)



Our QIS Goals Encompass Multiple Time Scales



National QIS Research Centers are Key to Advancing our QIS Goals

Whole of SC & Whole of QIS

- DOE-team approach in the preparation of the FOA
- SC-wide and QIS-wide
- Need to better coordinate QIS within SC: A new structure that involves a QIS Committee and working groups & task forces

Community Engagement

- RFI as a prelude to the FOA
- New SC web-site: https://science.osti.gov/Initiatives/QIS
- Stewardship role

Coordination & Partnerships

- Facilitate participation by different types of institutions by flexible arrangements
- Focus on all levels of the S&T innovation chain

❖ **QIS S&T Innovation Chain**
- Technical Areas of Interest

❖ **QIS Ecosystem Stewardship**
- Management Structure
- Instrumentation and Facilities