Quantum Information Science at the Department of Energy

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Advanced Scientific Computing Research
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QIS Crosses the Technical Breadth of the Office of Science

ASCR
Algorithms; Computer Science; Networking; Testbeds

NP
Many Body Systems; QIS Ready Workforce

BES
Quantum Systems and Computing: model, make, and measure

HEP
Field theory; dark matter; gravity; event tracking; fundamentals

FES
Qubit synthesis; ion traps; Fusion Plasma modeling

BER
Bioimaging applications, sensing and measurement capabilities

Fundamental Science
Quantum Computing
Quantum Communication
Quantum Sensing

Intellectual Capital Based on 100+ Years
Large-Scale & Long-Term Investments for Interdisciplinary Teams with Specific Focus
Key Supporting Technologies (e.g. Isotope research, production & enrichment by IP)
Leadership in Launching Internationally- Recognized Collaborative Programs

SC Unique Strengths to Advance Basic Science and Quantum Based Technology
SC Has Been Ramping Up Its QIS Investments Since 2017

<table>
<thead>
<tr>
<th>Year</th>
<th>Algorithms</th>
<th>QC Hardware</th>
<th>Pilot Projects</th>
<th>Testbeds</th>
<th>Software Stack</th>
<th>Bioimaging</th>
<th>QIS Applications</th>
<th>Materials</th>
<th>NSRCs &amp; EFRCs</th>
<th>Fundamental Physics</th>
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A Long Path to National QIS Research Centers

December 2018
NQI ACT

May 2019
RFI

January 2020
FOA

February-Mid August 2020
Review Process

August 26th, 2020
Announcement
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)
- QSA • Quantum System Accelerator (Irfan Siddiqi, LBNL)
- QSC • The Quantum Science Center (David Dean, ORNL)

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

https://science.osti.gov/Initiatives/QIS
# National QIS Research Centers Portfolio

## S&T Innovation Chain with Targets

<table>
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<th>Applications</th>
<th>Computing, communications and sensing for science and industry</th>
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<tr>
<td>Prototypes</td>
<td>Computing, sensing, network testbeds</td>
</tr>
<tr>
<td>Systems</td>
<td>SRF cavities, QPUs, detectors</td>
</tr>
<tr>
<td>Devices</td>
<td>Superconducting, ion trap, neutral atom, topological qubits, national quantum devices database, sensors, repeaters</td>
</tr>
<tr>
<td>Fundamental Science</td>
<td>Materials, theory, foundries, algorithms, software</td>
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</table>

## 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
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 23 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)
Office of Science’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’s QIS Programs are well-aligned with the National Quantum Strategy**

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<th>Science</th>
<th>Workforce</th>
<th>Industry</th>
<th>National Security</th>
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<td>An expansive portfolio to support QIS solutions for DOE grand challenges</td>
<td>Leverage unique resources to support QIS careers</td>
<td>Labs are partnering with industry for QIS research and for access to technology</td>
<td>Invest in a secure quantum internet &amp; isotope R&amp;D</td>
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<th>Infrastructure</th>
<th>International</th>
<th>Economic Growth</th>
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<td>QIS specific technologies are added to existing facilities’ capabilities</td>
<td>Multiple collaboration models with the international community</td>
<td>Exploration of precompetitive technology mitigates risk for industry</td>
</tr>
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- **OLCF’s quantum computing user program enables access to IBM, D-Wave, Rigetti and Atos platforms**
- **Science**
  - Quantum cryo-electron microscope with a spin polarized electron source to measure decoherence (LBNL)
  - Quantum sensors for laboratory detection of dark matter (FNAL)
- **Infrastructure**
  - Quantum scientific open user testbed at SNL develops early stage trapped ion platforms