



Sandia
National
Laboratories



New Mexico is a Quantum State:

Development of Sandia's QIS program

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QIS Impacts Many Key Areas of National and Economic Security

Prevent strategic technological surprise associated with quantum sensing, computation, and communications

Flight path optimization.

Positional sensing for a variety of ND applications, including fuzing.

Sensing with entangled particles can substantially reduce dark counts in sensors.

Electric field sensing, including non-destructive sensing of shielded devices such as improvised nuclear devices (INDs).

Treaty verification based on improved seismic resolution and sensing large masses or mass gradients.

Simulation of systems at extreme temperatures and pressure.

Navigation using atom interferometry, including in GPS denied environments and in space.

Provably secure communication for critical infrastructure and military applications.

Quantum gravimetry can detect bunkers and other hardened sites.

Explosion monitoring and characterization based on luminance.

Submarine detection using magnetometry.

Energy grid distribution optimization.

Quantum computing offers exact methods to simulate materials without the exponentially scaling costs associated with these methods.

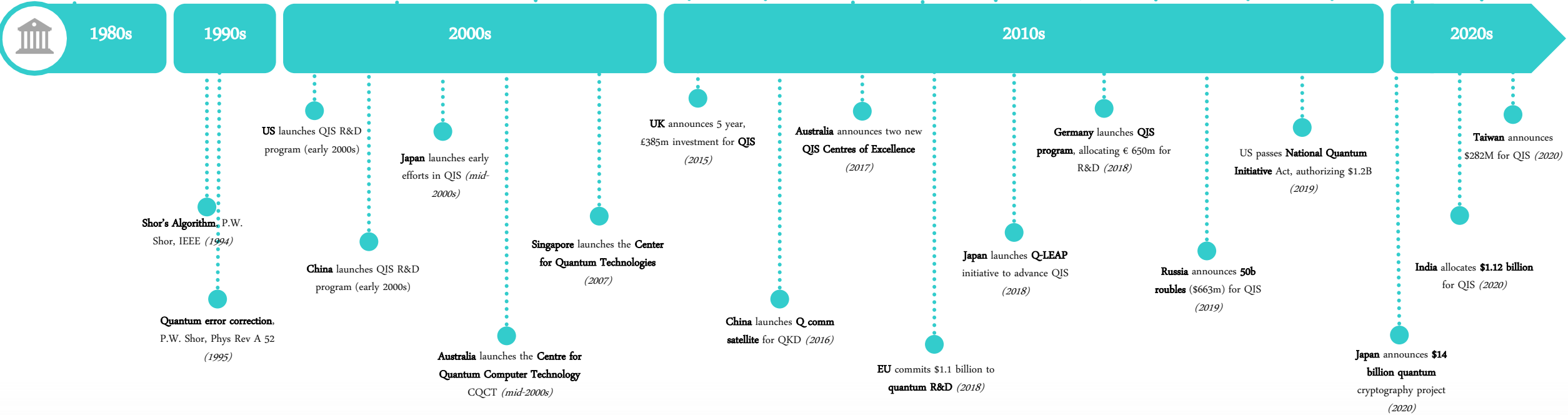
Aerial sensing of chemical species with reduced background.



INDUSTRY AND GOVERNMENT QIS TIMELINE

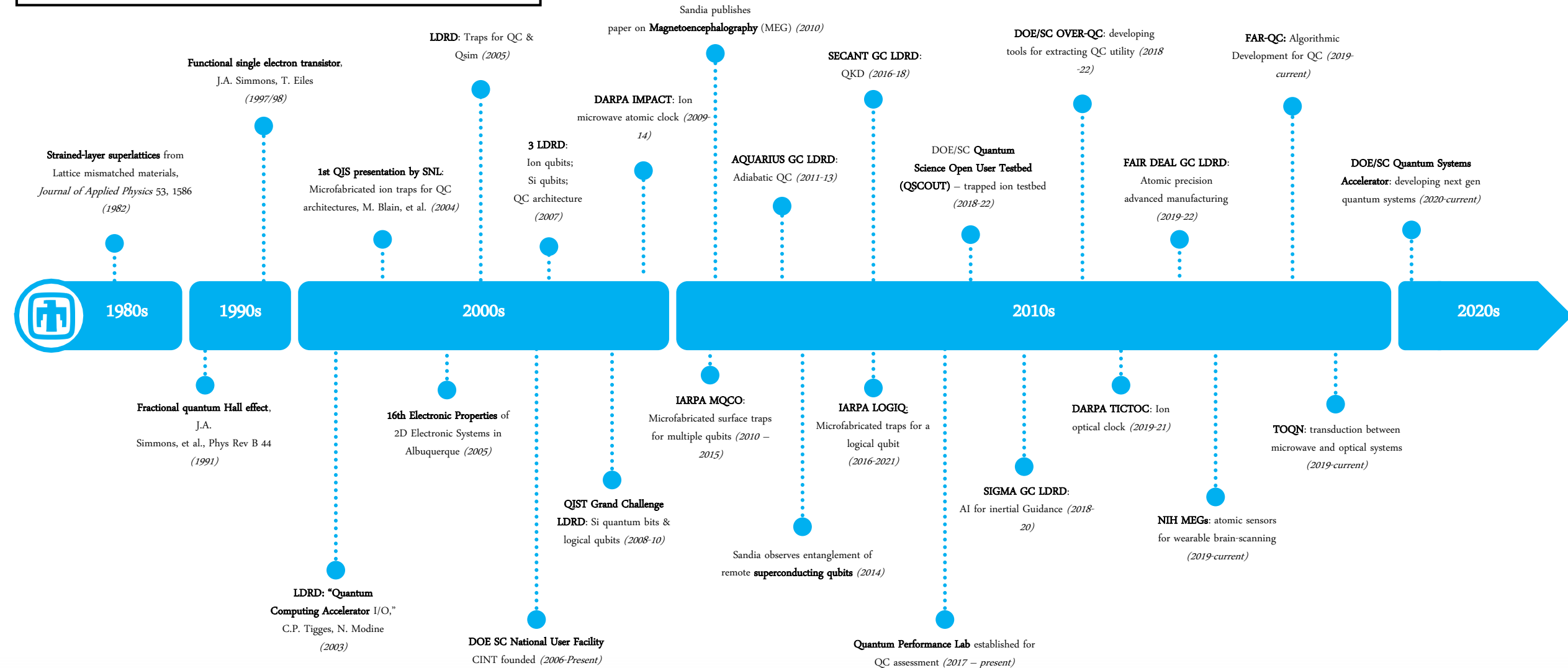
Estimated Timeframes of Industry and Government QIS activities and programs

Simulating physics with computers.
R.P. Feynman, Int J Theo Phys 21
(1982)

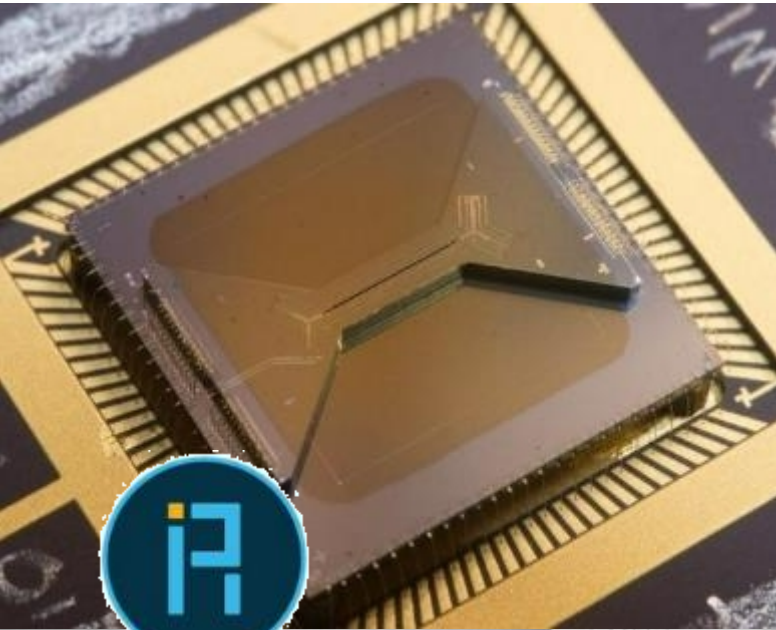


SANDIA QIS R&D TIMELINE

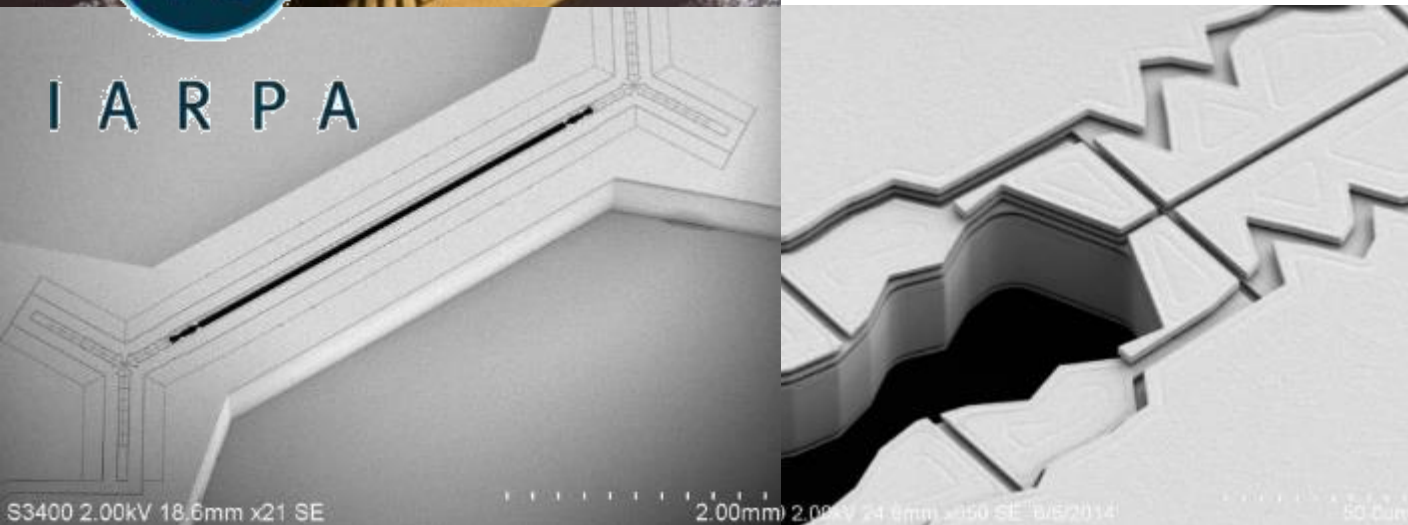
Estimated Timeframes Sandia QIS activities and programs



IARPA Ion Trap Foundry



- Sandia is the world leader in design and realization of microfabricated (MEMS) ion traps, used by the leading ion trapping groups worldwide
 - Development of surface trap by Tigges and Blain
 - Two key IARPA projects: MQCO & LOGIQ
- “Plug and Trap” - standardized package compatible with many chambers
- “known good trap” - eases deployment



Office of the Director of National Intelligence

I A R P A
BE THE FUTURE



Sequential GCs Built Sandia QIS Foundations



FY08 – FY10
Si-based qubits

- Silicon quantum dot qubits
- Architecture & logical qubit design



FY11-FY13
Alt. Architecture

- Adiabatic architecture assessment
- Atomic precision lithography development
- Neutral atom computation



FY14-FY16
Comms/QKD

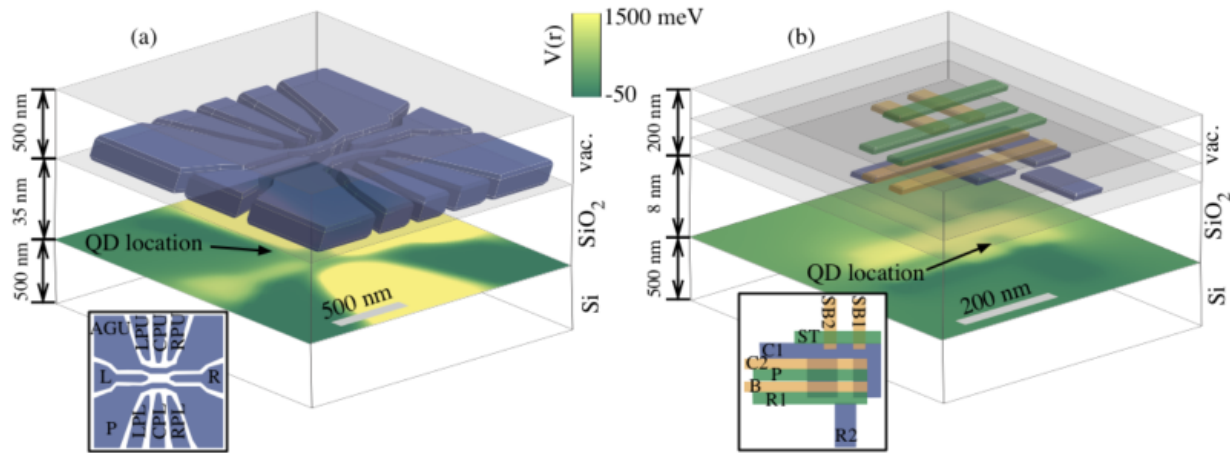
- Quantum key distribution development
- Photonic communications/networking development



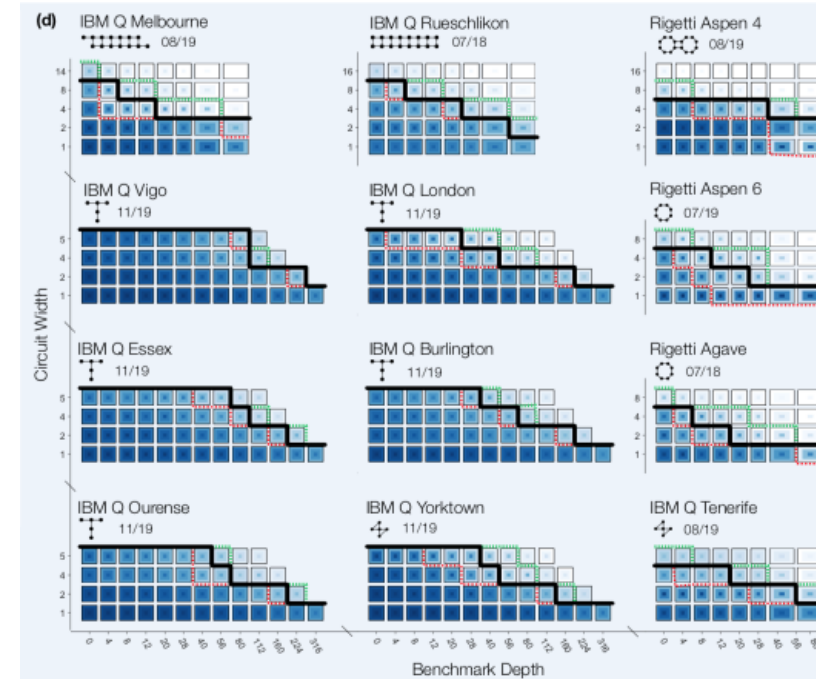
FY18-FY20
Atom Interferometer

- Develop deployable quantum devices
- Quantum sensing based location determination

Modeling and Characterizing Quantum Processors



Sandia has developed an extensive **quantum device modeling effort** for different platforms and at different levels of operations that guides the development of quantum devices and the interpretation of quantum experiments.



The **Quantum Performance Laboratory** provides tools and technologies to characterize qubits, benchmark quantum processors, and analyze the sources and types of errors that occur in quantum devices.

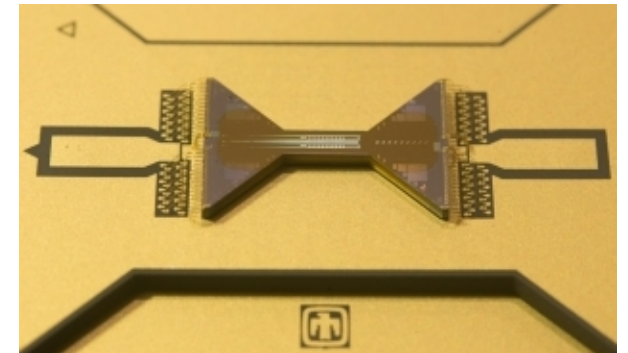


Quantum Scientific Computing Open User Testbed

PI: Susan Clark

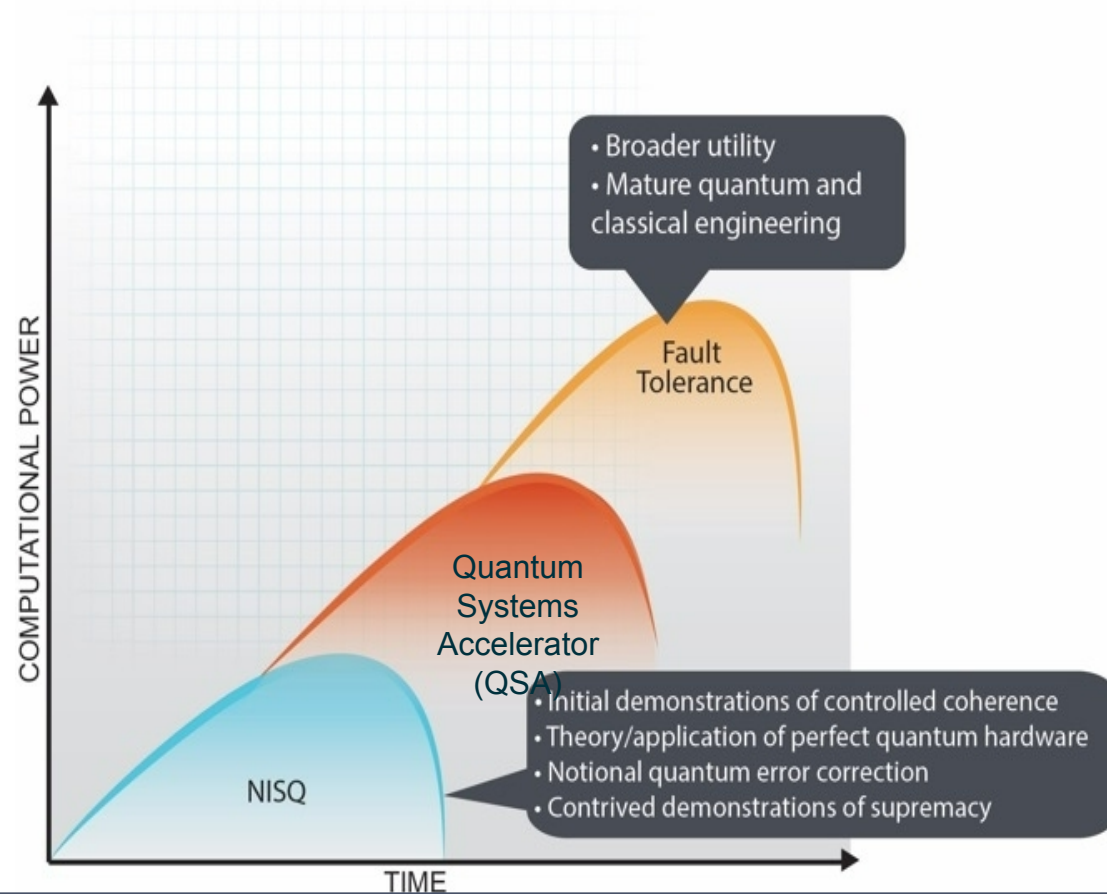


- DOE/ASCR quantum testbed to understand promise of quantum computing platforms for DOE science problems
- Low-level access provided by QSCOUT is not available in existing commercial systems and enables researchers to study the behavior of quantum hardware
- Access to high-fidelity quantum operations
 - Qubit coherence time ≈ 14 s
 - Parallel single qubit gates on all qubits, target fidelity 99.5%
 - Serial two-qubit gates between any pair of qubits, target fidelity 98%
- Jaqal Quantum Assembly Language offers low-level access, control of gate scheduling and execution, and extensible native gates.
- QSCOUT serving users:
 - 5 projects for first round (2021), 5 projects for second (2022)



Peregrine Trap

Quantum Systems Accelerator



Catalyzing national leadership in quantum information science to co-design the algorithms, quantum devices, and engineering solutions needed to deliver certified quantum advantage in Department of Energy scientific applications.



Caltech



HARVARD UNIVERSITY



USC

THE UNIVERSITY OF TEXAS
— AT AUSTIN —



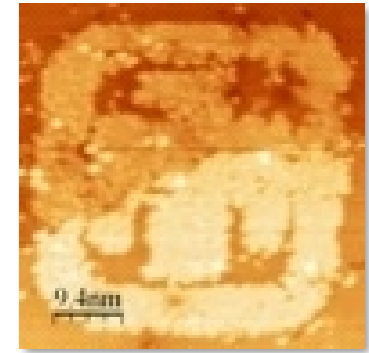
UNIVERSITÉ DE SHERBROOKE

Tufts
UNIVERSITY

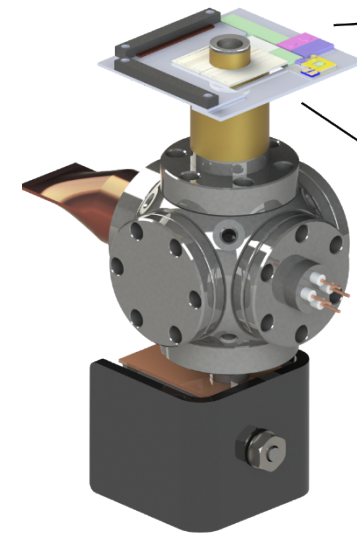
Sandia's Future Vision is Integrated Quantum Science



- The critical bottleneck to achieving quantum goals is *integration*.
 - The only way to simultaneously increase qubit capacity and fidelity is to modularize and integrate repeatable units.
 - Challenge: what *capabilities* can be integrated for hybrid quantum devices?
 - Challenge: how to we create, distribute, and maintain quantum resources?
 - Challenge: what opportunities are available with integrated computing and sensing?
- 5 Year Vision: Quantum device integration for national impact.
 - Build on the high fidelity and full connectivity available with trapped ions
 - Integrate chip-based photonic elements and electronics with existing physics devices.
 - Develop algorithms and protocols to deal with connectivity limitations
 - Extend to other Sandia quantum systems



Advanced fabrication



Advanced Integration