# DOE Basic Energy Sciences Program Overview for Office of Science Advisory Committee

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DOE Office of Science

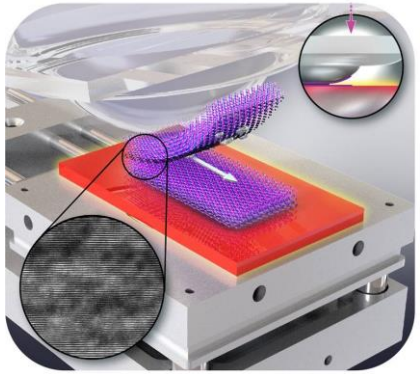
U.S. DEPARTMENT OF ENERGY | Office of Science

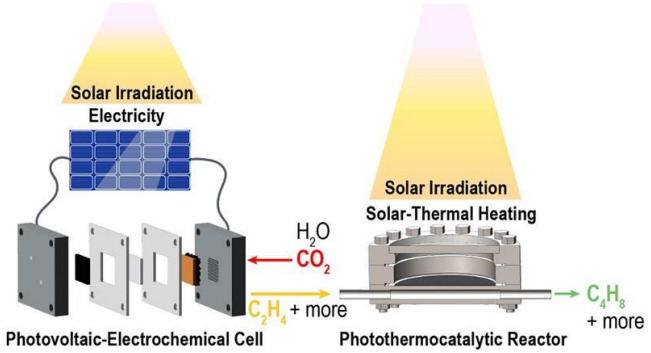
https://science.osti.gov/bes

# Why Fundamental Research for the Energy Mission?

Advancing technologies for the generation, conversion, transmission and storage of energy requires the discovery, design, and control of materials and chemical systems across large scales of time and space.

The “grand challenge” and “use-inspired” science required to address National priorities in energy, security, and the environment necessarily requires sustaining an **integrated ecosystem** of scientists, engineers, and enabling capabilities.





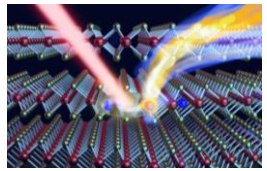


# Mutually Reinforcing Efforts in an Integrated Ecosystem

Enabling scientific discoveries for energy requires **sustained investment** in individuals and teams and the **development, construction, and operation of tools** that can probe deeper into increasingly complex systems.

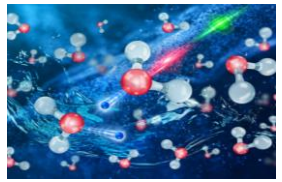
The results of BES **sustained investment** influence the national conversation on priorities that ultimately inform strategic programmatic directions.

**U.S. universities and DOE National Laboratories**



**Foundational Research**
Single PIs and small teams

**Team Science**
Multi-disciplinary, Multi-institutional teams



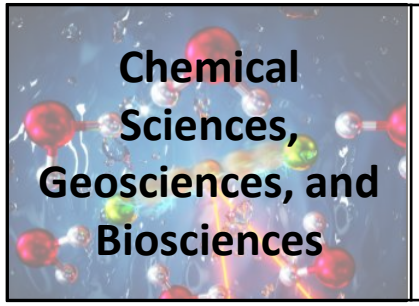
*Scientific Discovery*

*Administration Guidance*

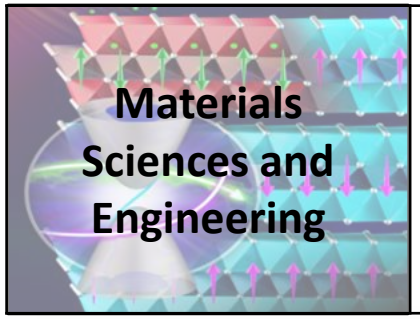
**National Priorities**
Energy Technology, Microelectronics, Quantum Information Sciences, Artificial Intelligence/Machine Learning, Critical Materials, Biopreparedness

**Scientific User Facilities**
**DOE National Laboratories**
Large-scale X-ray light and neutron sources and Nanoscale Science Research Centers

# Fundamental Science for Next-Generation Technology

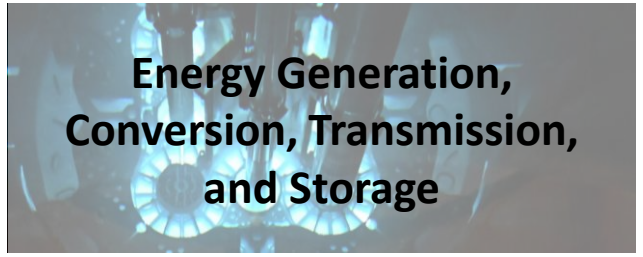


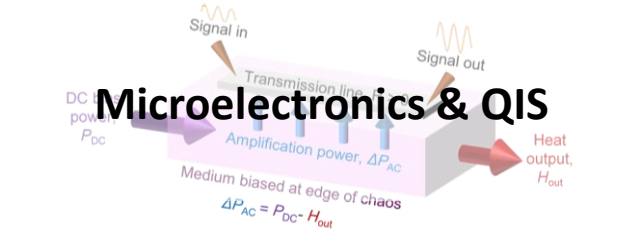

Fundamental Interactions
Photochemistry and Biochemistry
Chemical Transformations

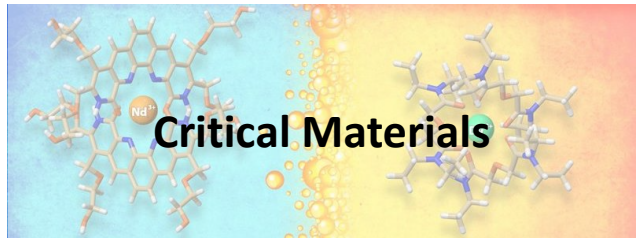



Materials Discovery, Design, and Synthesis
Condensed Matter and Materials Physics
Scattering and Instrumentation Sciences

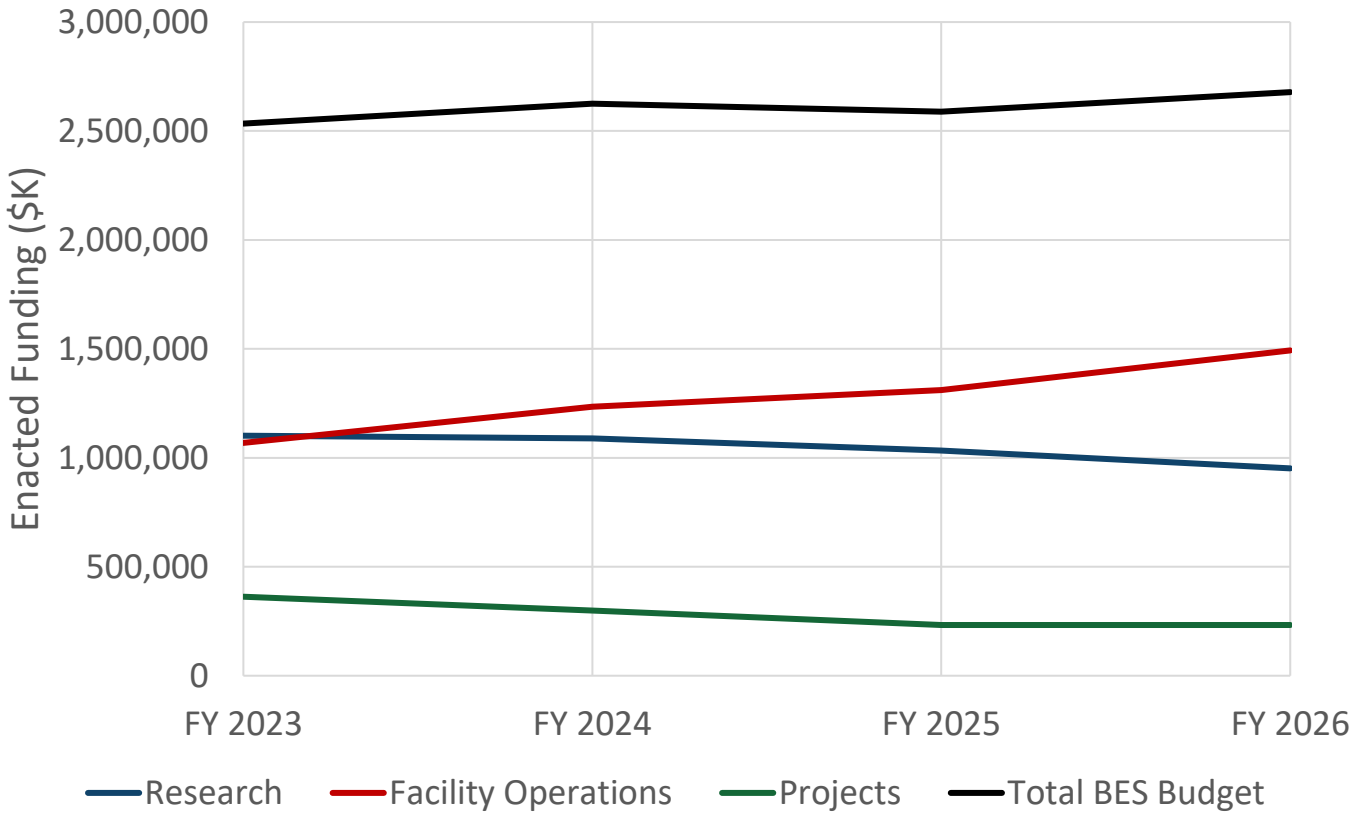

Facility Operations
Major Construction Projects
Accelerator and Detector R&D

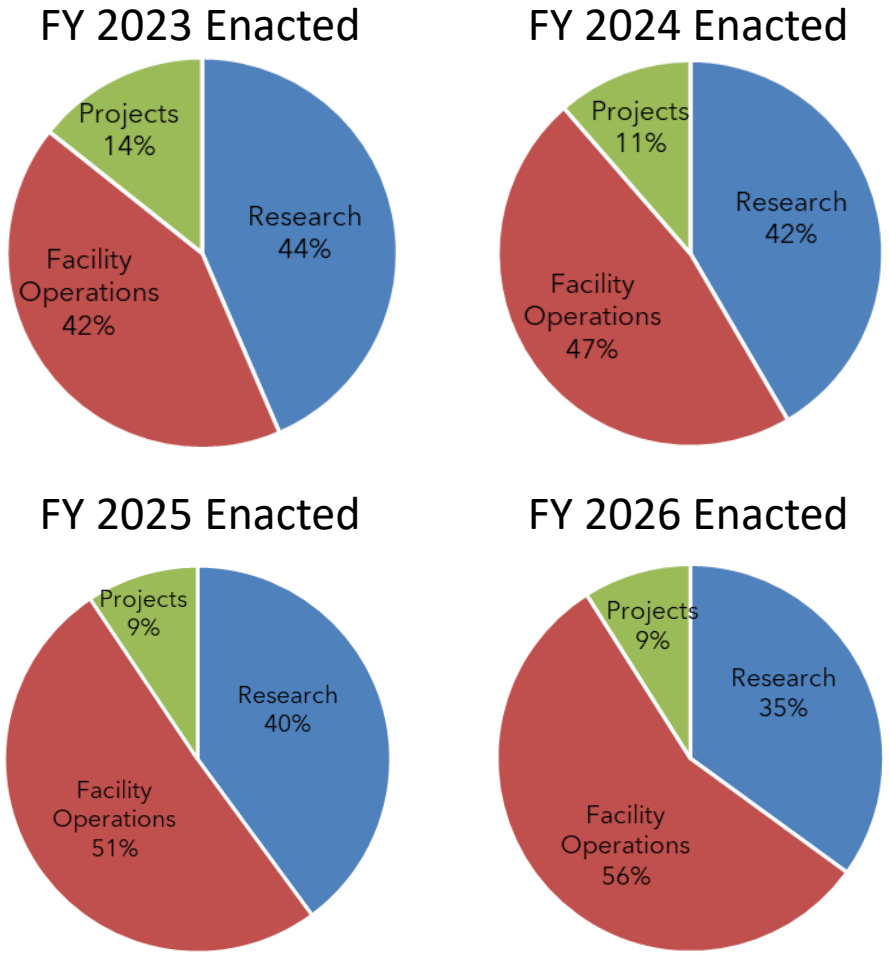



# BES Funding: Research, Facility Operations, Projects



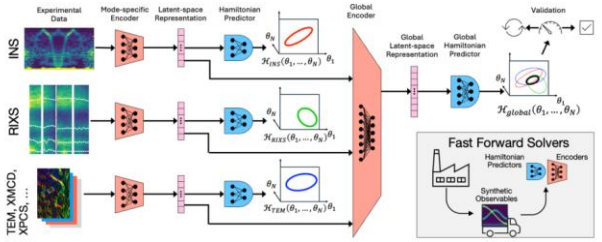




*FY 2026 Enacted includes $150M in IIJA funds in Facility Operations

# BES User Facilities: More Than 15,000 Users Annually from Across the U.S. and the World

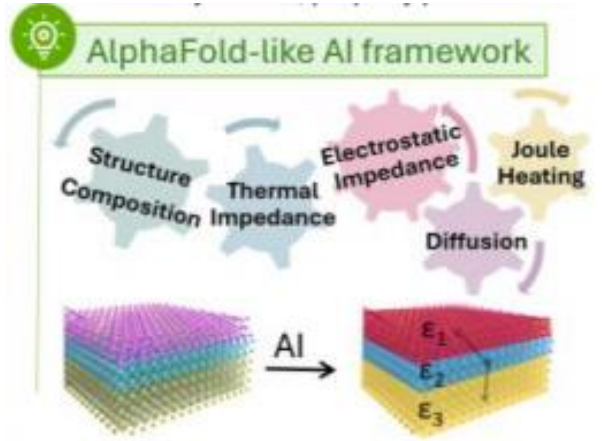

5 X-ray Light Sources
5 Nanoscale Science Research Centers
2 Neutron Sources

# AI Facility Pathfinder Call: Using BES User Facility Data to Refine AI models for Scientific Discovery



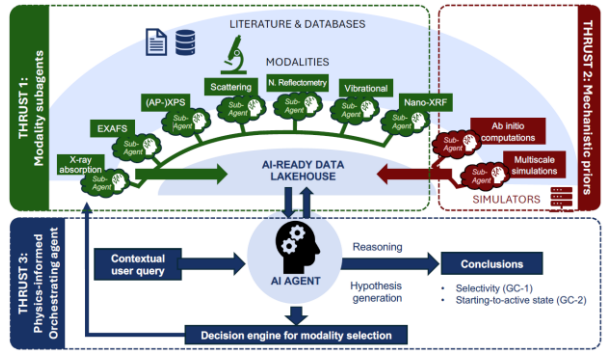

**Motivation:** Issued in response to Administration and Congressional priorities to develop transformational AI models that can leverage the scientific data of the Department of Energy

**Goal:** Advance the development and application of AI/ML models across BES scientific user facilities that will leverage the wealth of current and future experimental and simulation data to accelerate scientific discoveries




**Details:** BES user facility-led, multi-facility, multi-lab collaborative efforts, including domain subject matter experts from DOE labs, U.S. universities, and/or private companies (as unfunded partners; may contribute in-kind).

**Three projects** each address a science and technology problem—catalysis, microelectronics, or quantum materials—where AI/ML models can enable breakthroughs through the thoughtful use of data sets from multiple sources

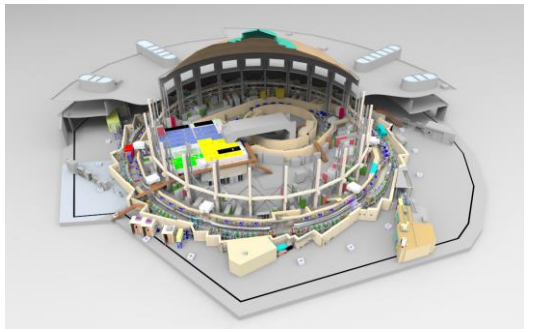


# BES Construction Projects
# Beyond Critical Decision (CD)-2

## Advanced Photon Source Upgrade

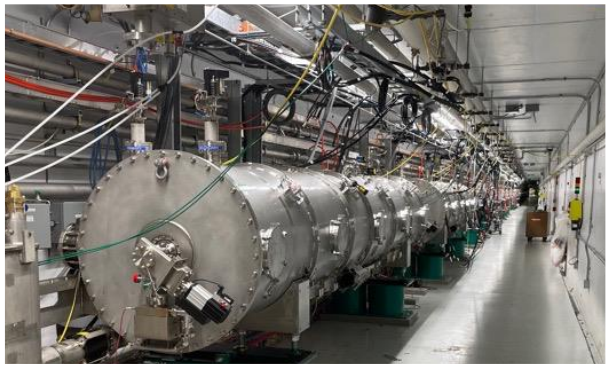

Delivering the world's most powerful hard X-ray synchrotron light source, with nearly 500x increased brightness and coherent flux

## Advanced Light Source Upgrade



Delivering revolutionary new X-ray capabilities and building on more than two decades of global leadership in soft X-ray science.

## Proton Power Upgrade



Enabling increased neutron flux to the Spallation Neutron Source (SNS) beamlines and positioning the facility for the Second Target Station

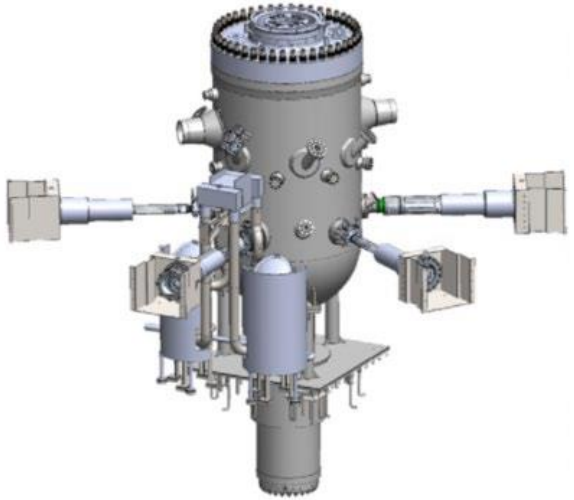
## Linac Coherent Light Source-II – High Energy

Delivering an ultrafast, ultrabright X-ray nanoscope capable of transformative insights in materials, chemical and biological systems, and devices

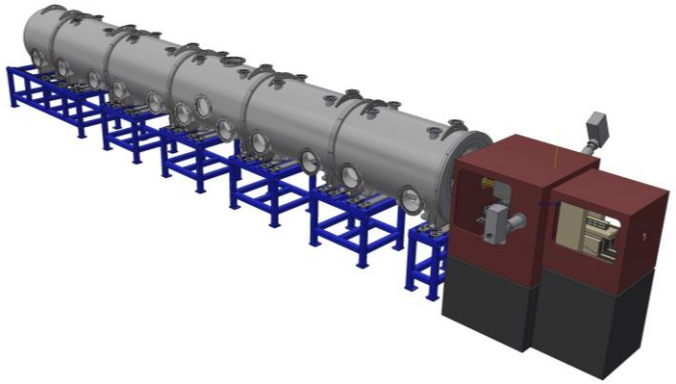
# BES Construction Projects

## Pre-CD-2

**Second Target Station**
A next-generation, short-pulse, cold neutron source with a suite of unique neutron scattering instruments capable of accelerating progress in quantum materials, structural materials, protein characterization, and other challenges

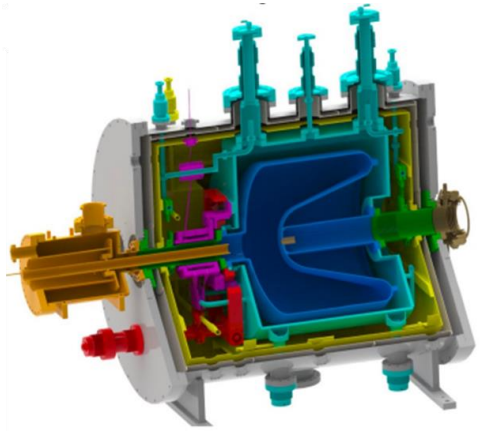


**High Flux Isotope Reactor (HFIR) Pressure Vessel Replacement**
Sustaining and enhancing HFIR critical missions in neutron scattering, isotope production, neutron activation, and materials irradiation

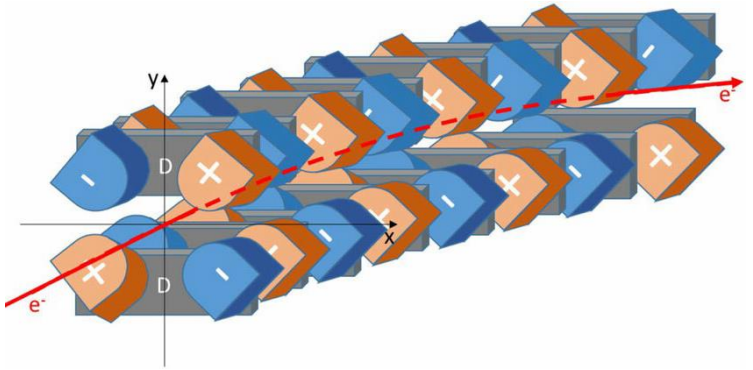


**National Synchrotron Light Source (NSLS)–II Experimental Tools-III**
New Beamlines to enhance NSLS-II capabilities for a wide range of applications, including energy generation, storage, and utilization, microelectronics, QIS, and biology

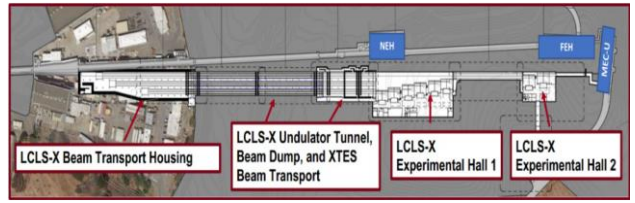
# Pre-decisional Upgrades and Future Facilities



**Linac Coherent Light Source (LCLS) – Low Emittance Injector**
Would push LCLS to higher X-ray power and enable innovations for coherent imaging of the structure and dynamics of real-world materials and chemical and biological systems in natural environments




**National Synchrotron Light Source-II Upgrade**
Would provide the highest brightness X-rays across a very broad energy range, from soft to hard X-rays, as well as unmatched, world-leading performance in the tender X-ray regime.




**LCLS-X**
The next leap in X-ray Free Electron Lasers, fully leveraging investments in the LCLS superconducting linac to dramatically increasing the opportunity for transformative science.

**Next Generation Characterization Facility:** A large-scale, AI-enabled characterization facility leveraging future technologies and designed to tackle the Nation's premier science challenges beyond 2035.

# Science Enabling Critical Technology Development

Basic Energy Sciences supports a large and topically diverse portfolio of research, as well as the development and operation of enabling tools, that is producing discoveries vital to advancing development in the fields of **microelectronics** and **quantum information sciences**.

## Quantum Information Sciences

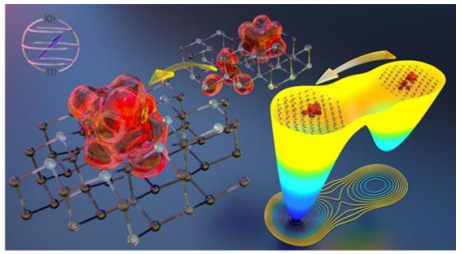
Q-NEXT NEXT GENERATION QUANTUM SCIENCE AND ENGINEERING

C²QA Co-design Center for Quantum Advantage

QUANTUM SCIENCE CENTER

*Primary oversight of two QIS Research Centers, Q-NEXT and C²QA, with significant funding support for QSC.*

*Investment in infrastructure for QIS across the BES user facilities*

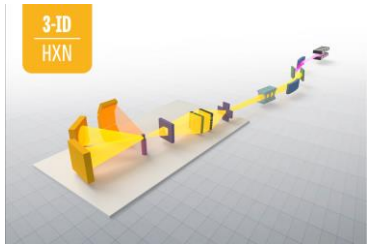


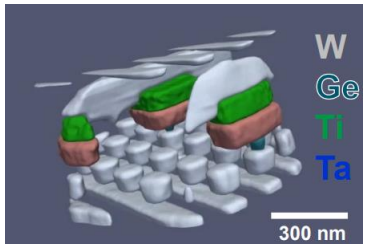
*Support for QIS research in both the core and centers.*

## Microelectronics

| Microelectronics Energy Efficiency Research Center for Advanced Technologies (MEERCAT) | Co-design and Heterogenous Integration in Microelectronics for Extreme Environments (CHIME) Center | Extreme Lithography and Materials Innovation Center (ELMIC) |
|---|---|---|

*Cross-SC support for sixteen lab-led awards self-organized into three Microelectronics Science Research Centers*




*Sustained support for research in the core, centers ( e.g. EFRCs) and facilities.*

# Benefits of an Integrated Ecosystem: Record lifetime of information in 2D tantalum transmon qubits

C²QA Co-design Center for Quantum Advantage

**Discovery to Impact**: Originating within the C²QA, a National QIS Research Center, the use of tantalum as a superconducting qubit material has since been adopted by leading industry players (Google, Amazon, IBM, Rigetti)

> *"From the invention of the transmon qubit with reduced charge-sensitivity to breakthroughs in tantalum-based qubit fabrication, academic teams have consistently provided their expertise to understand decoherence mechanisms and develop mitigation strategies. Their vital contributions have led to an impressive five-orders-of-magnitude improvement in superconducting qubit coherence times, from a few nanoseconds to more than a millisecond." – Google CEO*

C²QA scientists have led efforts to understand and improve lifetimes in these qubits, culminating in recent work that demonstrates record lifetimes up to 1.7 ms, which is **25 times the average qubit lifetime in Google's Willow processor**.

A tantalum transmon device developed by C²QA with coherence exceeding 1ms

# Concluding Thoughts/Summary

## Summary

- Realizing progress for energy – its generation, conversion, transmission, and storage – requires the discovery, design, characterization, and control of both materials and chemical systems across broad length and time scales
- BES is uniquely suited to addressing the “grand challenges” in energy science and other priority areas because of its sustained support for an integrated ecosystem of people and enabling capabilities distributed across the U.S.
- Sustained funding for BES basic research portfolios (single investigators, small and large teams, centers) has been transformative for entire fields of study and provides valuable input into government-wide dialogues
- The breadth of the BES portfolio contributes extensively to the advancement of technology in other National priority areas beyond energy (e.g., microelectronics, QIS, AI, critical materials)
- BES supports innovative development, design, and construction of enabling research capabilities for the Nation, from lab-scale instrumentation to large-scale user facilities. BES stewardship and operation of the latter provides unparalleled resources and capabilities to researchers from academia, national labs, and industry.

## Challenges and Opportunities

- Long term sustained funding for foundational research is fundamental for maintaining U.S. leadership in basic energy sciences and continuing to feed the innovation pipeline.
- Leadership in large-scale facilities is challenged by a competitive international landscape and budget pressures, requiring careful strategic planning and potentially international partnerships with like-minded allies.


# Questions/Discussion