

Quantum Sensing Applications for Nondestructive Evaluation in the Nuclear Industry



Luke Breon
Senior Technical Leader

Quest-IS
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Vision

To be a world leader in advancing science and technology solutions for a clean energy future

Mission

Advancing safe, reliable, affordable, and clean energy for society through global collaboration, science and technology innovation, and applied research.

Together...Shaping the Future of Energy®



EPRI Accelerates Technology Advancement

LABORATORIES AND UNIVERSITIES

*Basic research and
development*

SUPPLIERS AND VENDORS

*Technology
commercialization*



EPRI

*Collaborative technology
development, integration,
and application*

Thought leadership illuminates
emerging developments,
opportunities, and trends.

Technology Innovation Scouting
searches globally for emerging
technologies and concepts to
provide insights on industry
challenges and solutions.

Sector R&D conducts research
and demonstrations to address
challenges, deploy results, and
provide supporting services for
existing and emerging
technologies.

*EPRI stimulates innovation and plays a key role in validating technology
across multiple utilities, fostering widespread acceptance, and helping
accelerate technology to commercial development and industry adoption*

Quantum Sensors for Energy Supply

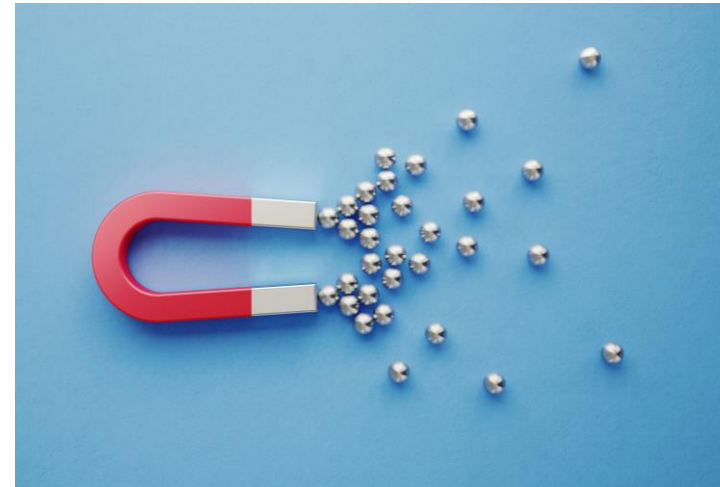
EPRI is *collaboratively exploring* quantum sensor technology and identifying potential use cases within Energy Supply

Quantum sensors both *exist now and have headroom* for Energy Supply applications

Broad *collaboration* and *coordination* across Energy Supply is needed



Quantum technology is
Different
...from the classical
world we know



Quantum is
Relevant
...to our industry

We're better...
Together

QUANTUM SENSING INITIATIVE

Objectives



Member Engagement

Engagement with members to form industry use-cases



Technology Forecasting

Maintain EPRI's leadership position to accurately track emerging and advanced technologies



Sensing Applicability

Assess the readiness and applicability of quantum sensing technology for the energy supply sector



Expertise

Build internal EPRI expertise to address the fit of quantum sensors for industry use-cases/needs



Integration Pathway

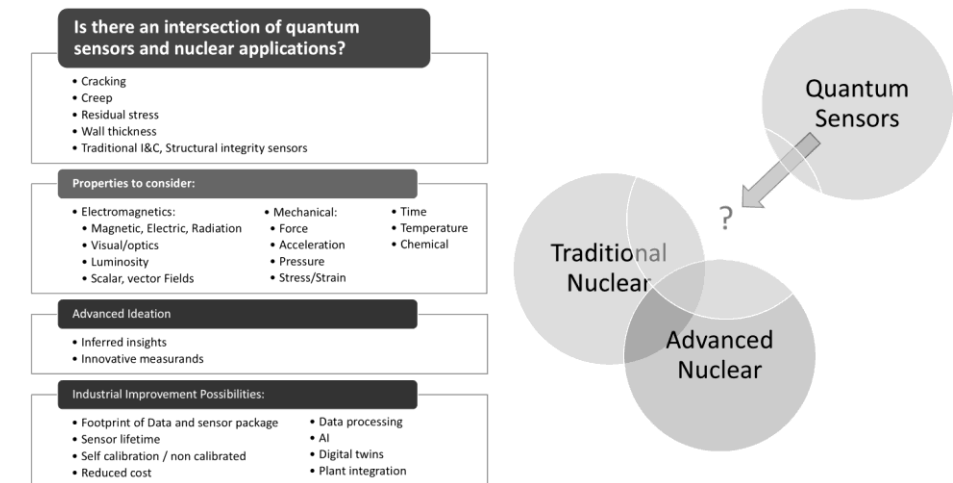
Evaluate the integration pathway for quantum sensors in energy supply

Solid-State Quantum Sensors Promise Practical Deployment in Energy Supply

- Super conducting quantum interference devices (SQUIDs) have provided exceptional magnetic field measurement, but require cryogenics
 - Not portable to field use and high-temperature environments
- Advent of Nitrogen-Vacancy (NV) defects in carbon diamond provide quantum sensor capabilities in thermally robust package
 - Deployable, resilient to heat, radiation
 - Multi-modal sensor capable of practical measurands
 - Magnetic field, temperature, voltage, pressure, etc
- Technology advancements merit review of technology applicability
 - Encoded photons
 - Clocks/frequency
 - Inertial capabilities (and more)

A year ago, the question was asked...

Where can Quantum Contribute?



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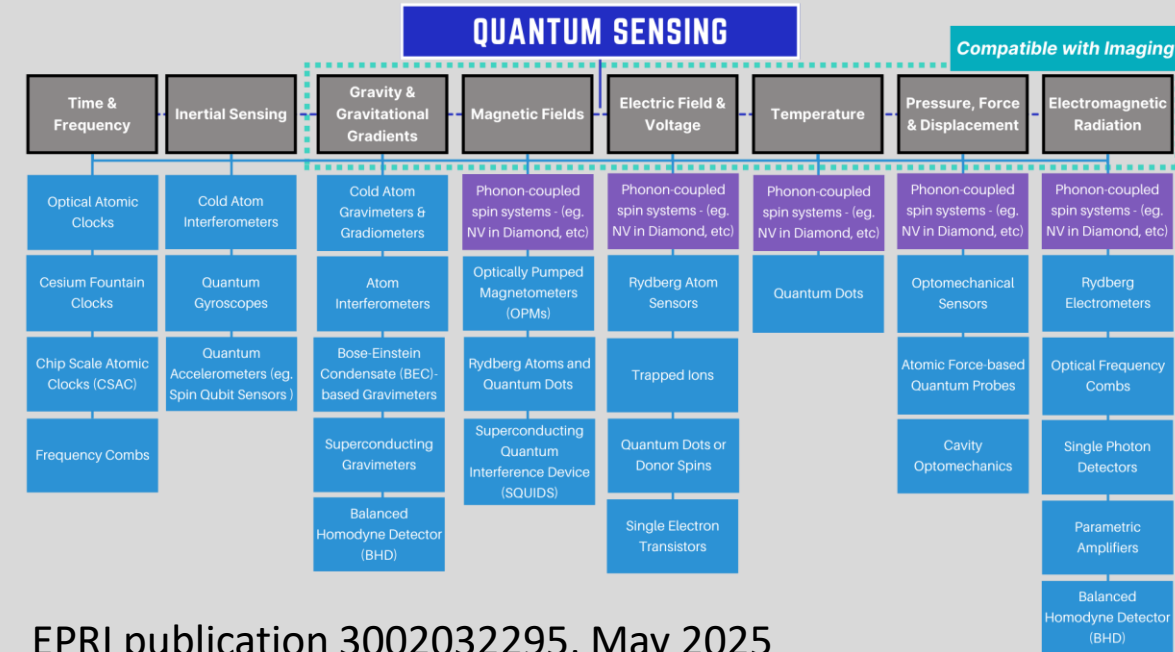
EPRI

Teratec TQCI Seminar, November 14, 2024

Exploration Indicates Many Potential Applications

- Practical quantum sensors have excellent performance for useful measurements and other properties
 - Timing/frequency—clocks
 - Magnetic fields—current
 - Drift-free and self-calibration
 - Multi-measurand
 - Electric fields—voltage
 - Electromagnetic
 - Optical interferometers
 - Inertia—gravity, acceleration, mass
- Some important potential applications as identified include:
 - Electrical component monitoring (generators, transformers, large motors)
 - Drift-free thermometry, and self-calibration for instrumentation and control (I&C)
 - Chip breakdown analysis for inverters
 - Welding arc cloud analysis
 - Nondestructive Evaluation
 - Battery health
 - Monitoring and early warning of biofouling and clogging hazards

Quantum Sensing Measurands and Sensor Types

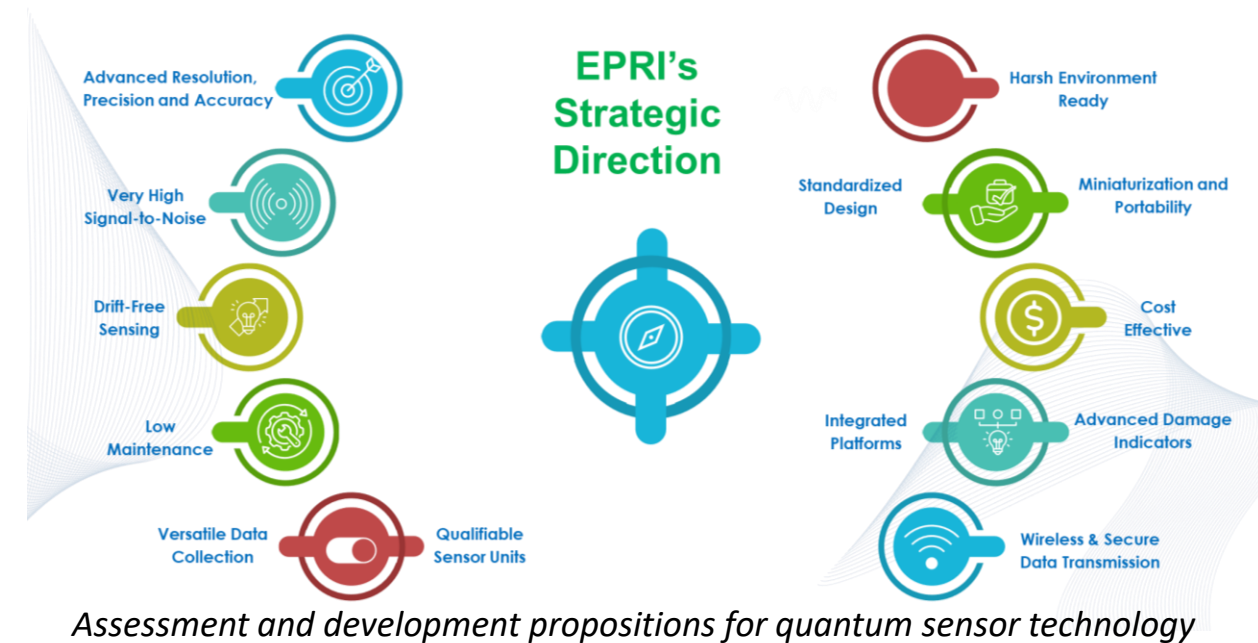


EPRI publication 3002032295, May 2025

This document is jointly authored by EPRI, EDF, CEA, the U.S. DOE, and NIST. The document presents a primer of quantum sensor technology in the context of energy supply applications and is a foundation for mutual education for sensor developers, end users in energy supply, and users in related industries.

Additional Next Steps

- Key focus areas for development, piloting, and research include:
 - Electrical component monitoring and sensing
 - Generators, transformers, large motors
 - Overcoming accessibility issues
 - Underwater, inaccessible
 - Sensor survivability enhancement
 - High temperature, radiation, caustic media
 - Chemical sensing
 - Damage detection (NDE)
 - Damage, damage precursors, monitoring
 - Materials development
 - Sensor test-bed
 - ***Continued collaboration & networking***

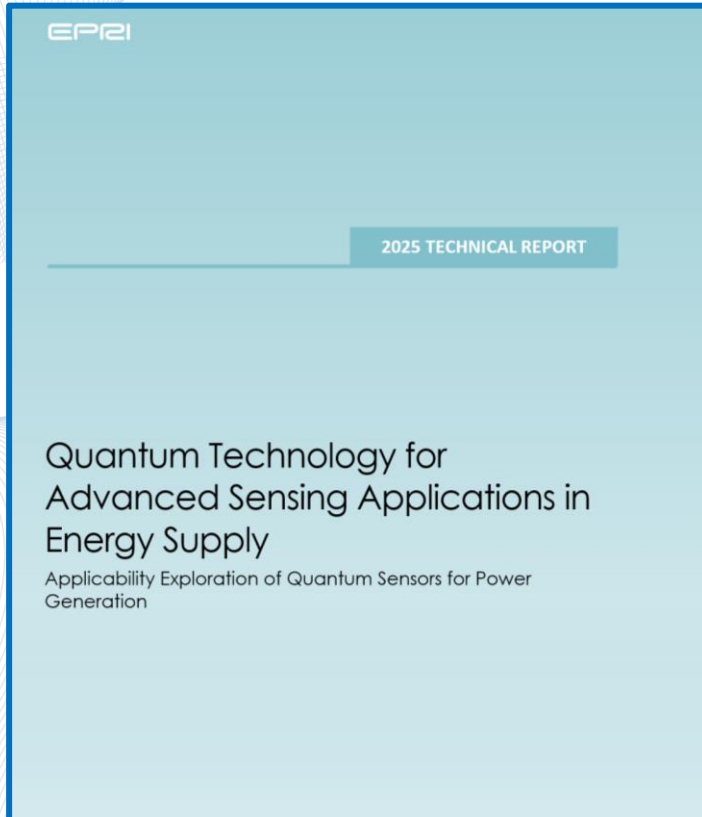


EPRI has sourced a laboratory prototype NV-diamond-based quantum sensor

- Thermometer / magnetometer
- Feasibility testing of sensor
- Feasibility testing of magnetics-based methodology
- Supporting follow-on R&D

Quantum Sensor Uses-Cases in Energy Supply

Planned Publication, Dec 2025



Contributors: EPRI cross-sector, Quantum Catalyzer

- Basic sensing modalities are widely used across various sectors, so a sensor designed for one application may have immediate relevance in adjacent domains.
- Identifying overlaps and synergies among similar use cases can foster collaboration and streamline sensor development.
- This work highlights and prioritizes potential use cases across the energy supply spectrum to guide roadmap development and R&D efforts.

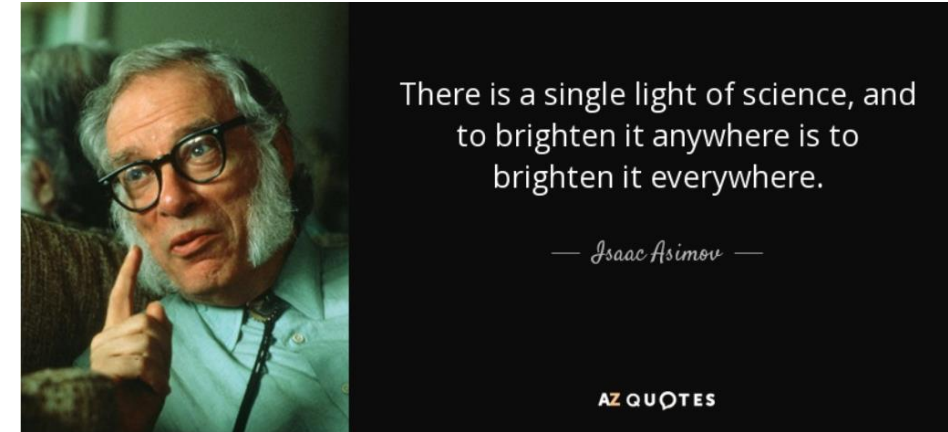


Strategic Direction

PM: Luke Breon

Conclusions

- Quantum technology offer substantial promise for improved sensors
 - An improvement to a sensor anywhere is an improvement to sensors, essentially, everywhere
- Identification of synergistic use cases and coordinated development efforts are important for responsible development
 - Onboarding now allows us to influence how quantum sensors develop
- Much work is needed for advanced sensors, including whatever contribution quantum can bring
- Contact Luke Breon lbreon@epri.com or Emma Wong ewong@epri.com to learn more and contribute to road-mapping
 - Or follow this link to join a quantum technology interest group:



<https://www.surveymonkey.com/r/B885589>



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