Integration of Wireless Sensor Networks and Battery-free RFID for Advanced Reactors

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Project Overview

OBECTIVES: Develop and demonstrate a cost-effective secure wireless sensor network for nuclear industry addressing ALL the challenges of nuclear systems and infrastructure for communications

DOE SBIR/STTR FY 2021 PHASE I RELEASE 2

"Wireless technology is increasingly deployed for the improvement and cost optimization of several common industrial applications, for example the use of Radio-Frequency Identification (RFID) in the distribution and retail sector. Proposals should consider how technical solutions with proven performance in other applications, outside of the nuclear industry, could be adapted to improve the performance and cost-effectiveness of nuclear systems"

GOALS:

- Using commercially available proven technologies to develop low-cost, low-power Wireless Sensing and Locating (WISLO) system to eliminate or significantly reduce the cables for through the containment wall sensor data transmission in Nuclear Power Plan
- Leverage the past DOE funded efforts (office of NE and Safeguards) to develop fully passive through-the-nuclear concrete-wall sensor data transmission capability.
- The goal is to keep the total cost for the system to <$5K (in mass production), yet improve security and reliability.
- This system can be used for the current fleet, future advanced reactors, and SMRs.

Technology Impact

- The novel design developed enhances both security and reliability by integrating two powerful commercially available technologies: (1) Wireless Sensor Networks (WSN) and (2) Passive (battery-free) Radio Frequency Identification (RFID) to address the unique wireless communication *challenges in nuclear facilities*.

- Low-power wireless sensor nodes from various sensor nodes securely communicate to a gateway where the sensor data is processed and transferred to a passive (battery-free) tag for secure transfer through the nuclear concrete wall to the outside.

- The GUI-monitor reports on the location and the sensor data using machine learning for rapid response to the anomalies when required.

- The transparent multiple media (air, concrete) hopping for wireless sensor communications is bound to have significant impact to reduce the need for cables, and in particular cables through nuclear concrete walls.

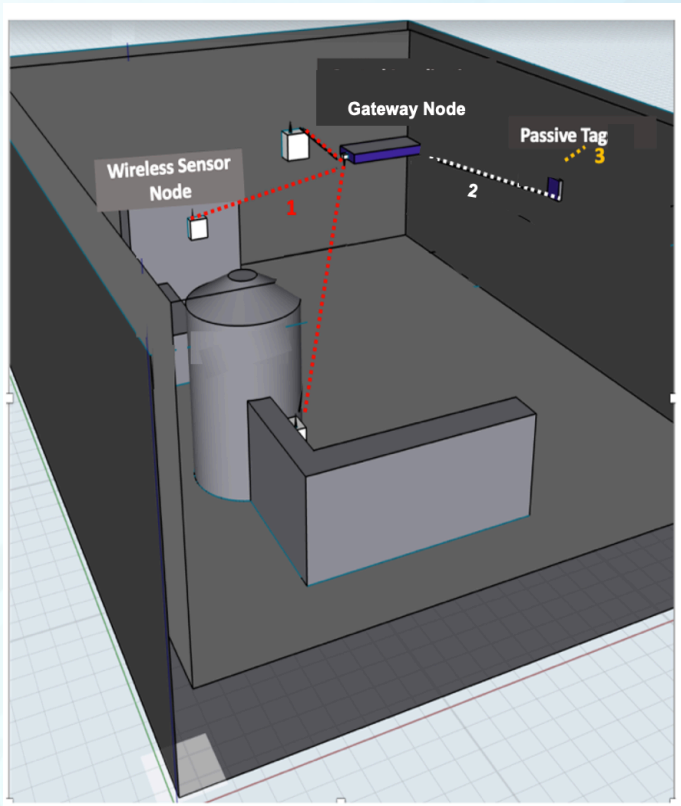
- The impact is in terms of cost, security, and reliability for nuclear industry sensor monitoring applications.

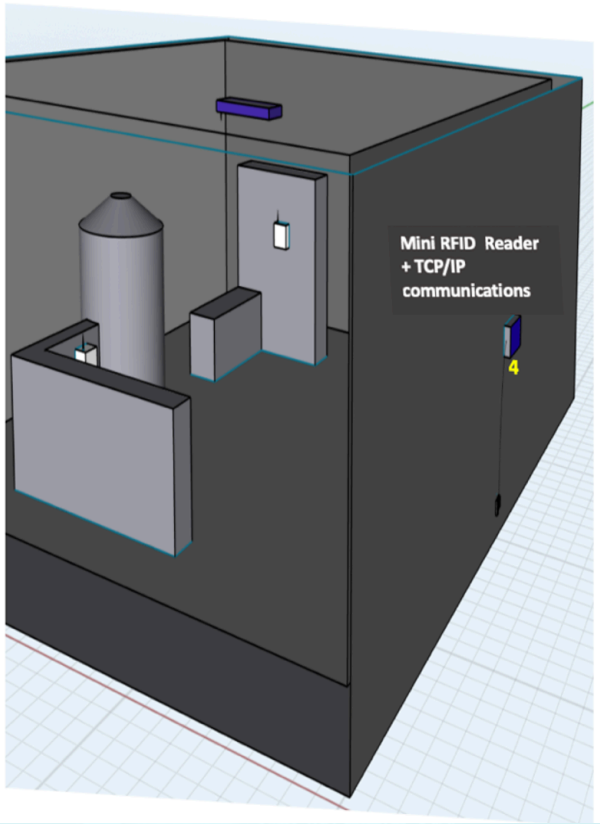
Evolution of DSI Wireless Sensor Communications for NE

- Active ultra-wideband (UWB) through-the-wall communications (Phase I&II SBIR ended in 2019). It has transitioned to other government programs (Army, Navy, DOE Safeguards)
  - DoD: Audio communications in military aircrafts
  - DOE: Video data transfer through 5 ft containment concrete (currently delivered to IAEA)
- Semi-passive through-the-wall UWB sensor communications - remote switching of batteries for long-lifetime.
- ⭐ Totally passive, low cost through-the-wall communications for sensor data and location.

Components of WISLO system for Dual Frequency Through-the-Wall Sensor Data Communications

- Low-cost (<$5K), regulatory approved, and commercially available components;
- Minimal dependency on batteries or wall power;
- Secure wireless sensor data transmission (AES encryption);
- Accurate sensor location information to localize points of anomaly;
- Sensor fusion data and machine learning for state-of-health (SOH) as well as environment sensing;
- Real-time high bandwidth sensor data collection including time-series data;
- Continuous or user programmable periodical sensor data collection;
- Ability to store large set of data with on-board processing equipped with machine learning models for predictive maintenance.





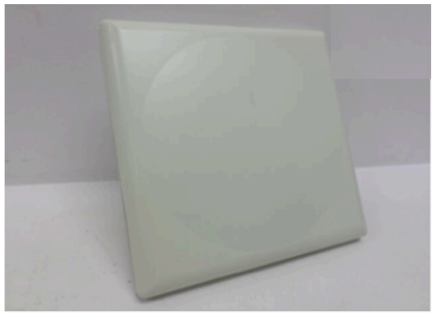
Wireless Sensing and Locating (WISLO) System integrates low-cost COTS technologies to significantly improve through-the-wall wireless sensor data transfer

Gateway Node

Sensor Node

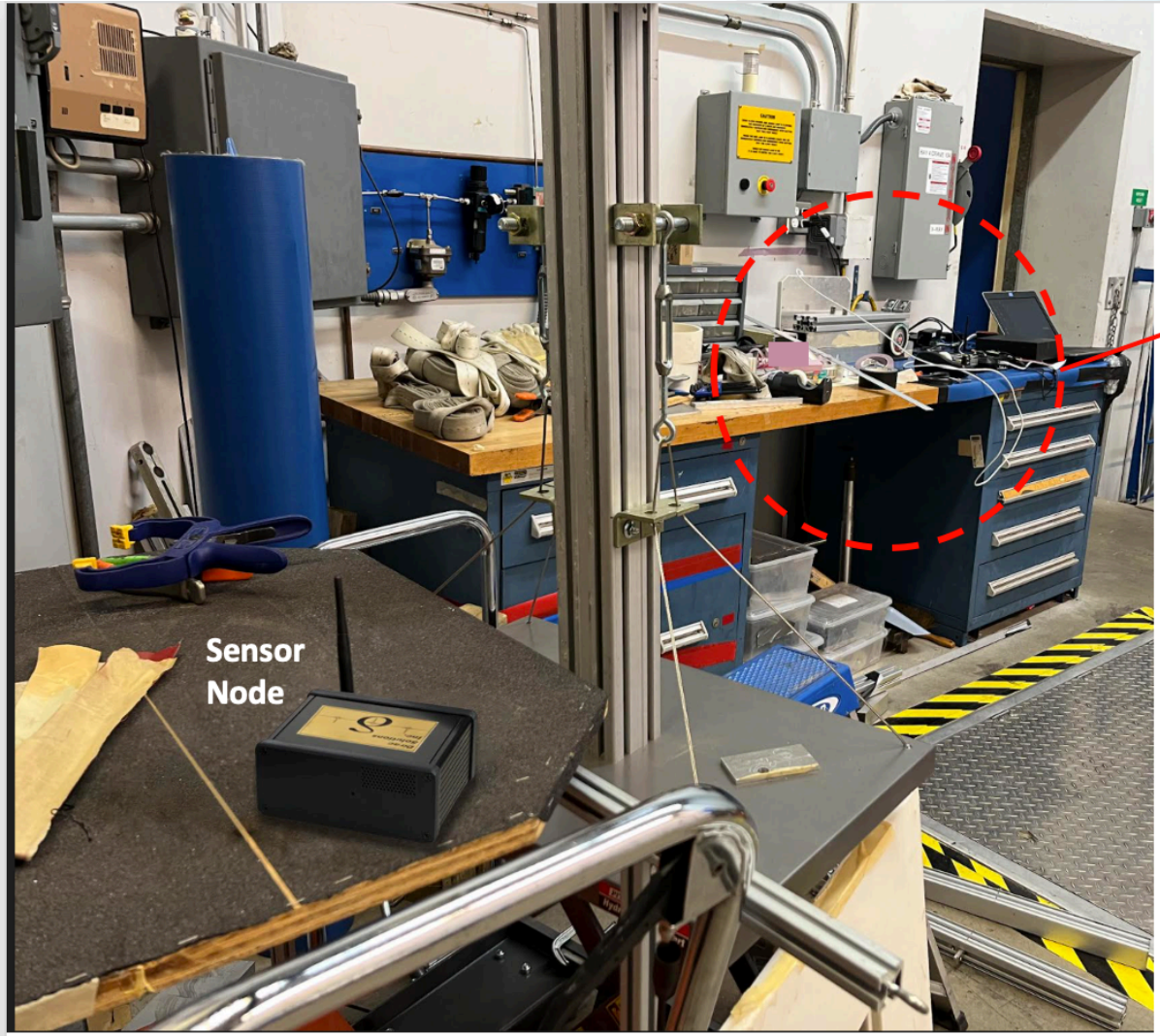
Passive Radiation
Hardened RFID Tags

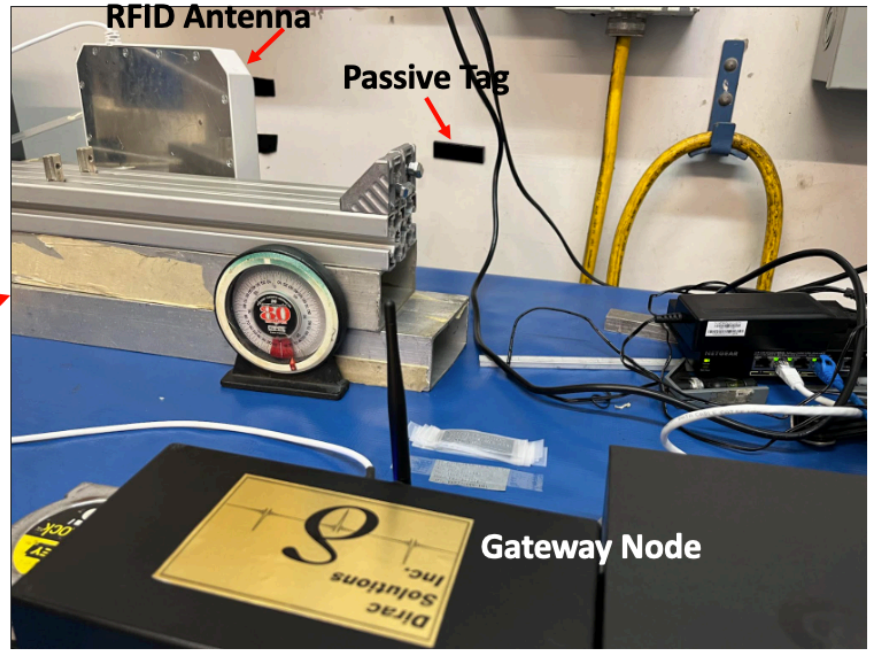
Mini RFID Reader with
TCP/IP Communications



Mini RFID Reader Antenna

Inside Sensor Room Setup at the McClellan Nuclear Center (UC Davis)





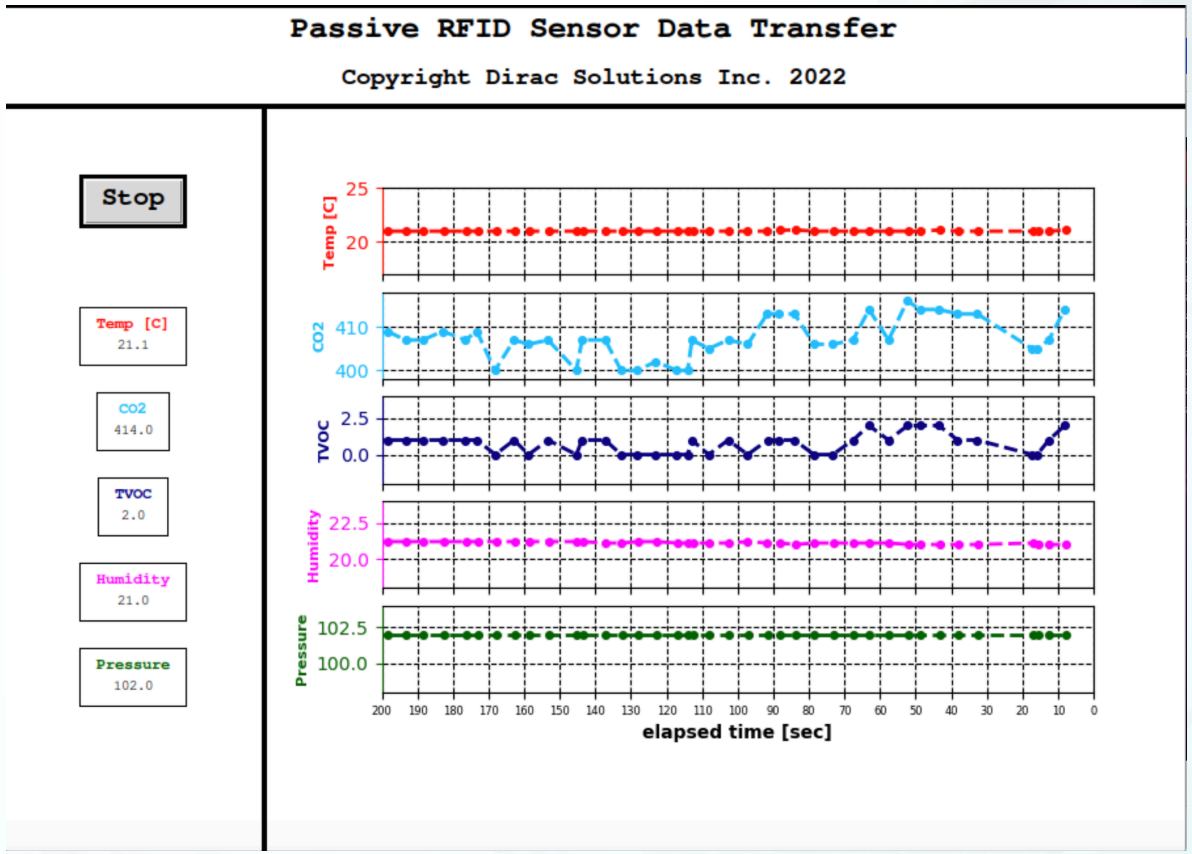
Inside containment room

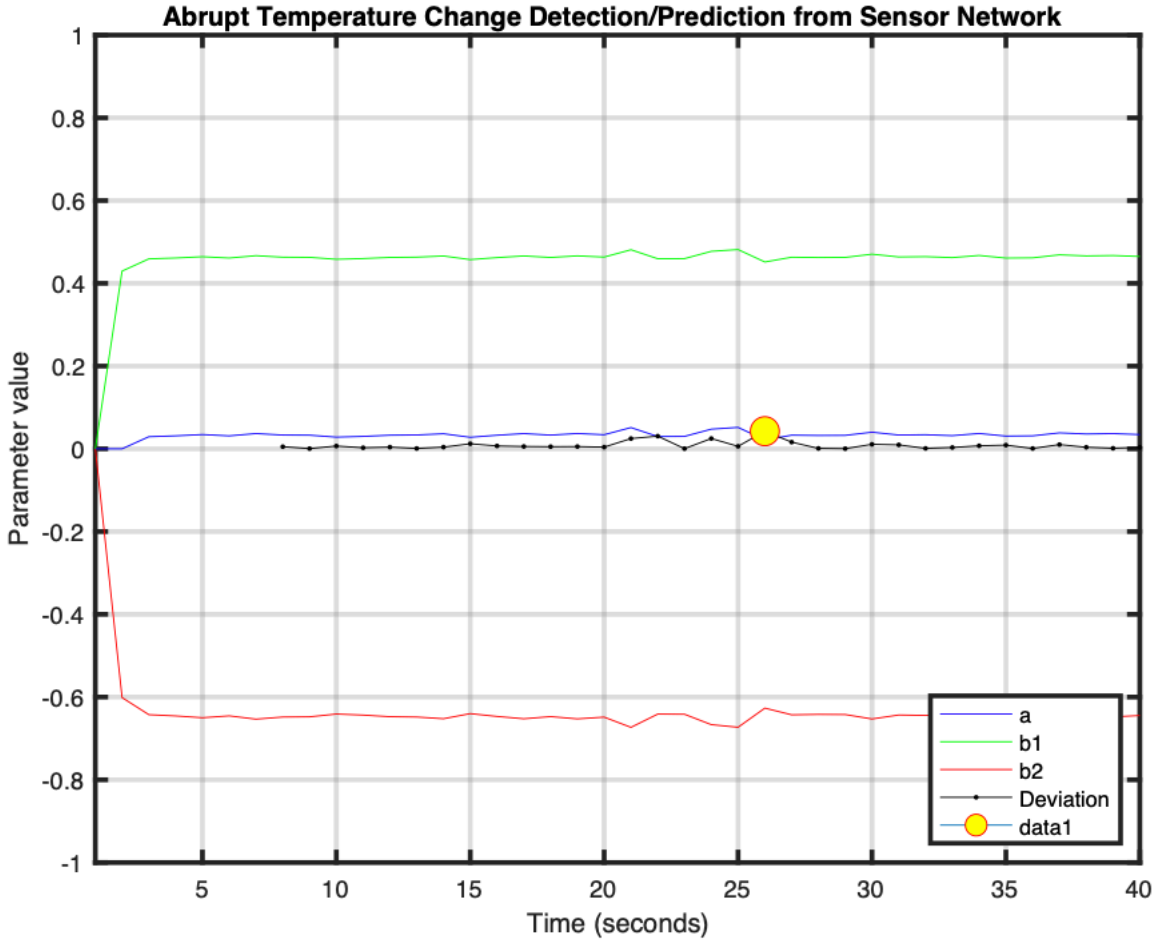
Outside Sensor Room Setup at the McClellan Nuclear Center (UC Davis)

RFID antenna and reader outside the containment wall with open door to show the wall thickness

Steel door closed, causing transmission through the wall only.

Successful Sensor Data Transmission Through 24” Nuclear Concrete





The continuous real-time multi-channel sensor data obtained from a seamless wireless communications backbone allows use of ML/AI tools for rapid anomaly detection and alarm conditions.

Summary and Concluding Remarks

- The Phase I SBIR effort showed reliable wireless sensor communications through the thick nuclear concrete wall with closed metallic doors.
- In Phase II we proposed to develop a low cost, battery-operated RFID reader for inside the containment room and remotely power the battery through the containment wall for 2+ years of battery life.
- A conference paper was submitted to the IAEA Safeguards Symposium and will be presented at the IAEA Safeguards symposium next week.
- The system was tested and demonstrated in real nuclear facilities
- As we achieved all objectives for secure reliable wireless sensor communications through wall with a low-cost system
- We are now seeking new opportunities for achieving minimal dependency to power sources and applying this technology to real operational facilities .

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Thank You