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Downhole Smart Collar Technology for Wireless Real-Time Fluid Monitoring

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Presenters

Andrew Wright

S&E R&D Electronic Engineer
Geothermal Department

- **MS, Electrical & Computer Engineering**
  - Focus: Electromagnetics and Photonics
  - Designed and packaged 94 GHz narrow band SiGe amplifiers at the IC Level
- **Phase Sensitive Innovations**
  - Designed and packaged ultra high frequency IC
  - Developed mmW receivers
- **Sandia National Laboratories, Geothermal Department**
  - Designing and Evaluating High Temperature Electronics
  - Development of Subsurface tools

Project Purpose

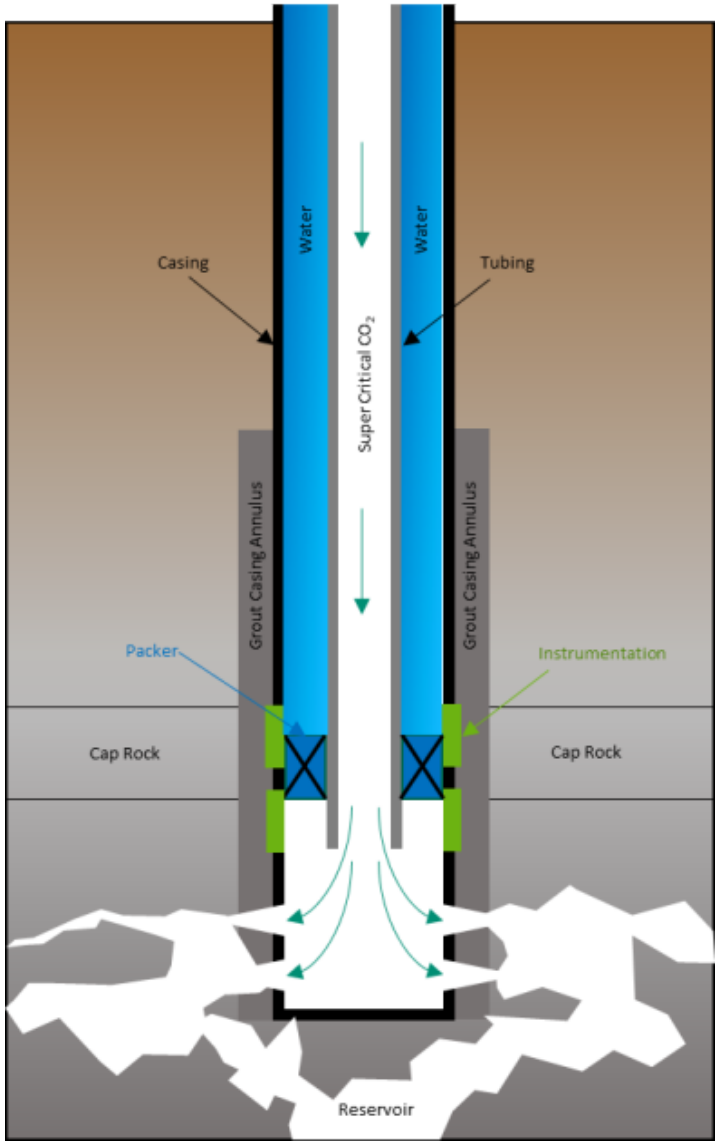
Purpose and Method Review

Sandia Developing Carbon Sequestration Technology

- Subsurface diagnostic technology
  - Wireless embedded monitoring devices
  - Long term subsurface monitoring
- Geothermal department is developing technology for carbon sequestration
  - Subsurface experience
  - Development of logging tools

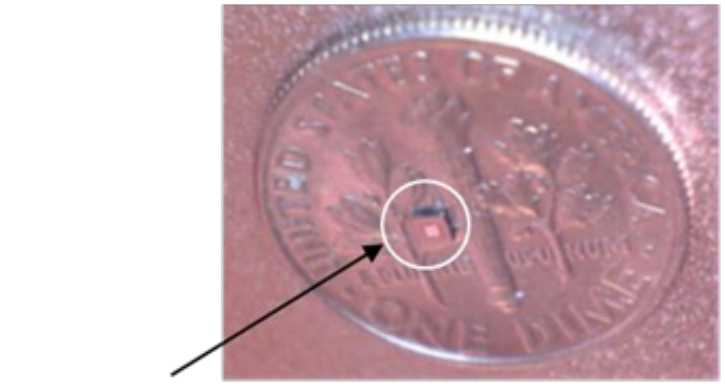
Carbon Sequestration

- Injection of CO_2 in the subsurface
  - Super critical CO_2 injected via tubing
  - Injection process extend for 20+ years
- Requires CO_2 leakage monitoring
  - Monitoring instrumentation at the cap rock
  - Monitoring during and after injection

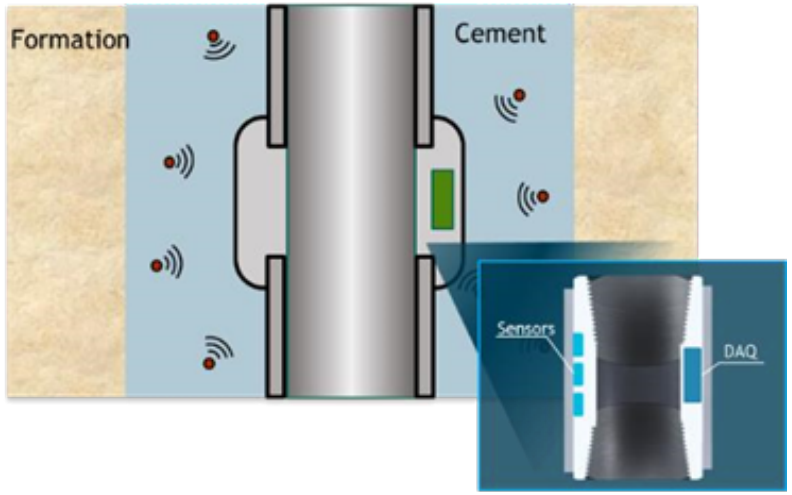


Project Overview

- Near-wellbore reservoir monitoring using RFID sensor
  - Measures fluids in casing annulus
- Smart Collar
  - Wireless communication/power to RFID sensor
  - Wired pipe used for power and communications

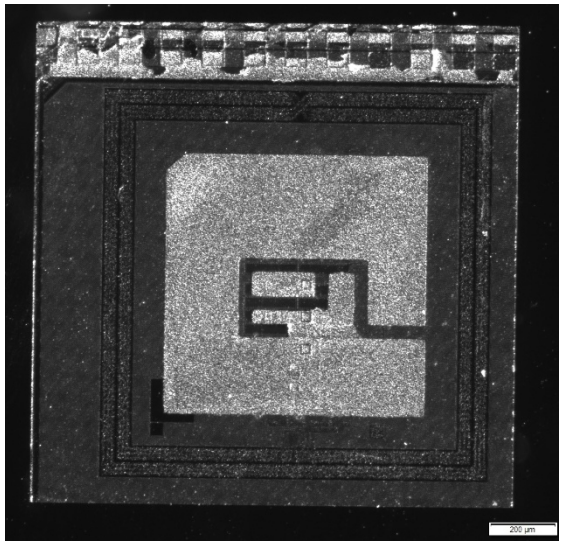


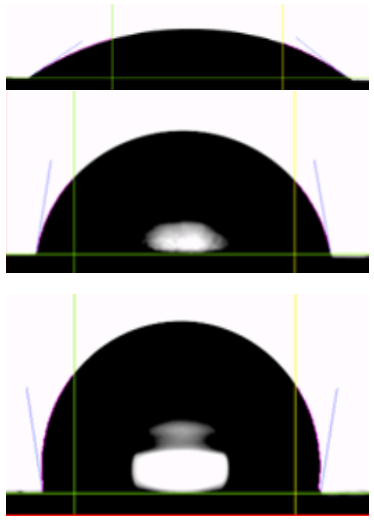
1mm System
on a chip (SoC)



RFID Sensor and Encapsulation

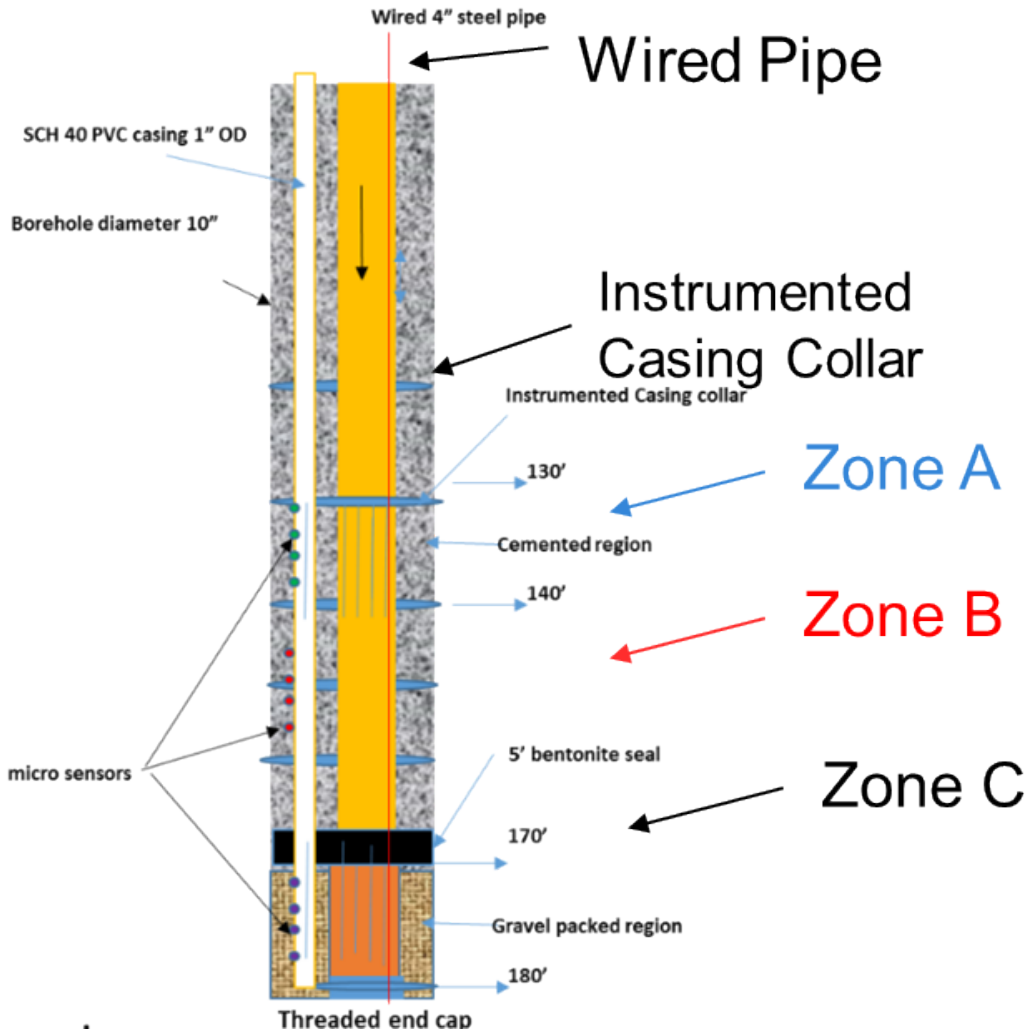
- RFID Sensor development at Caltech
  - Designing to measures pH, CO_2, CH_4, temperature
  - Operation band of 902-928 MHz
- Encapsulation development at RTI
  - Protects from casing annulus cement process
  - Porous to desired fluid
- Developed for medical research





Field Experiment

- Field demonstration at UT's test site
- Permanent emplacement of Smart Collar
- 160 feet of wired pipe
  - Smart Collar positioned at the bottom
- Detection fluid flow through system

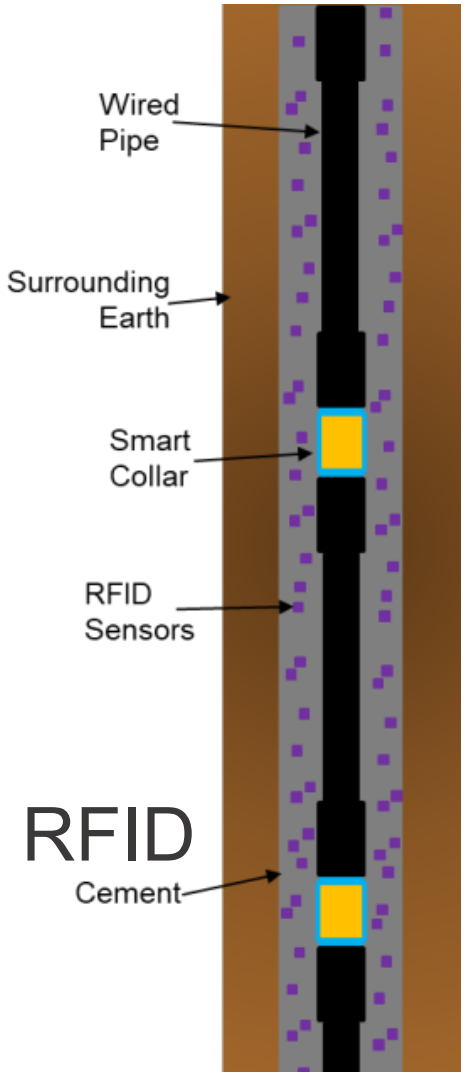


SNL Smart Collar System

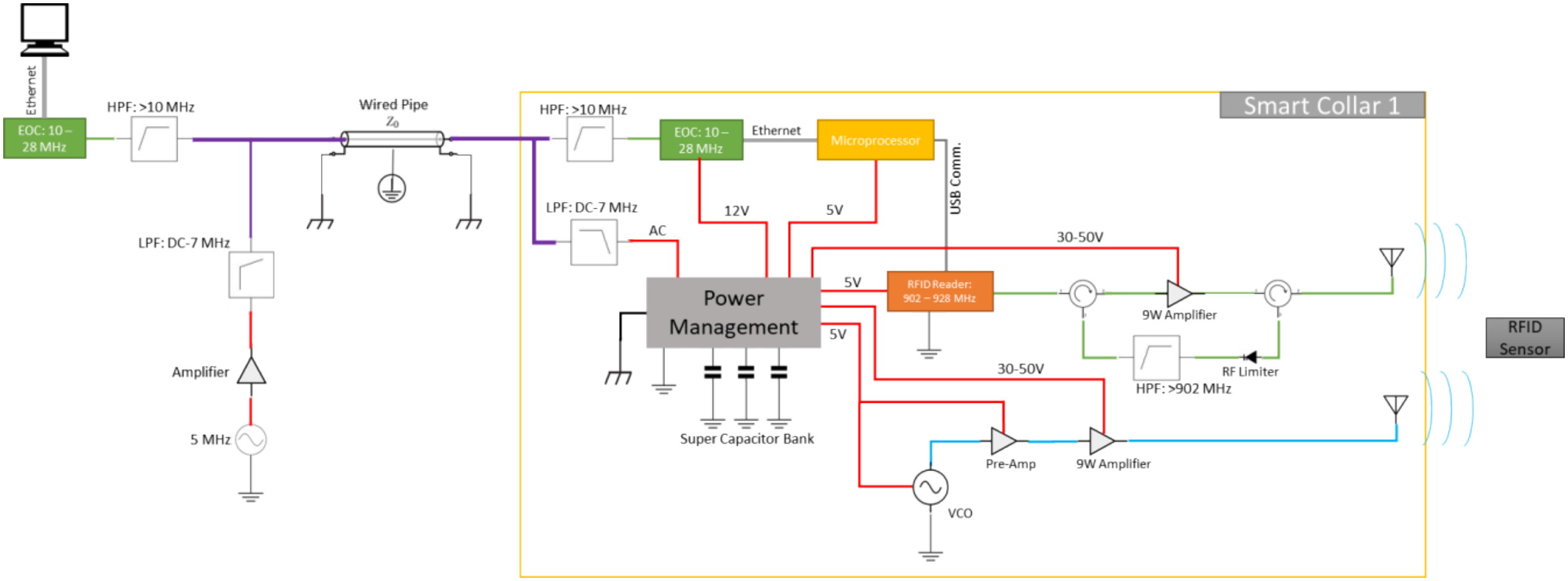
System Design and Current Status

Smart Collar Technologies Goals

- Smart Collar
  - Connects to IntelliServ's wired pipe
    - High speed communications
    - Power transfer
  - Couples between two wired pipes
  - Position at various locations
    - Expand RFID communication range
  - Wireless powers and communicates with RFID sensor

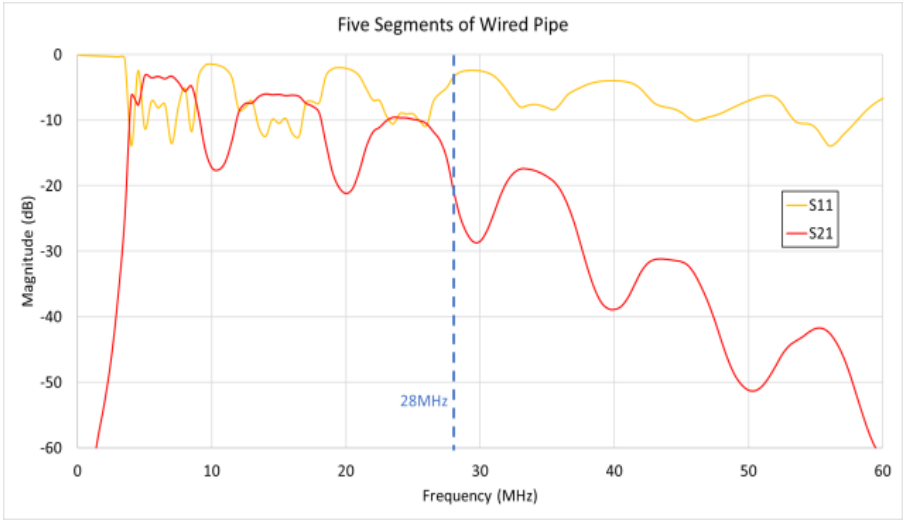


Smart Collar – Comms, Power Block Diagram

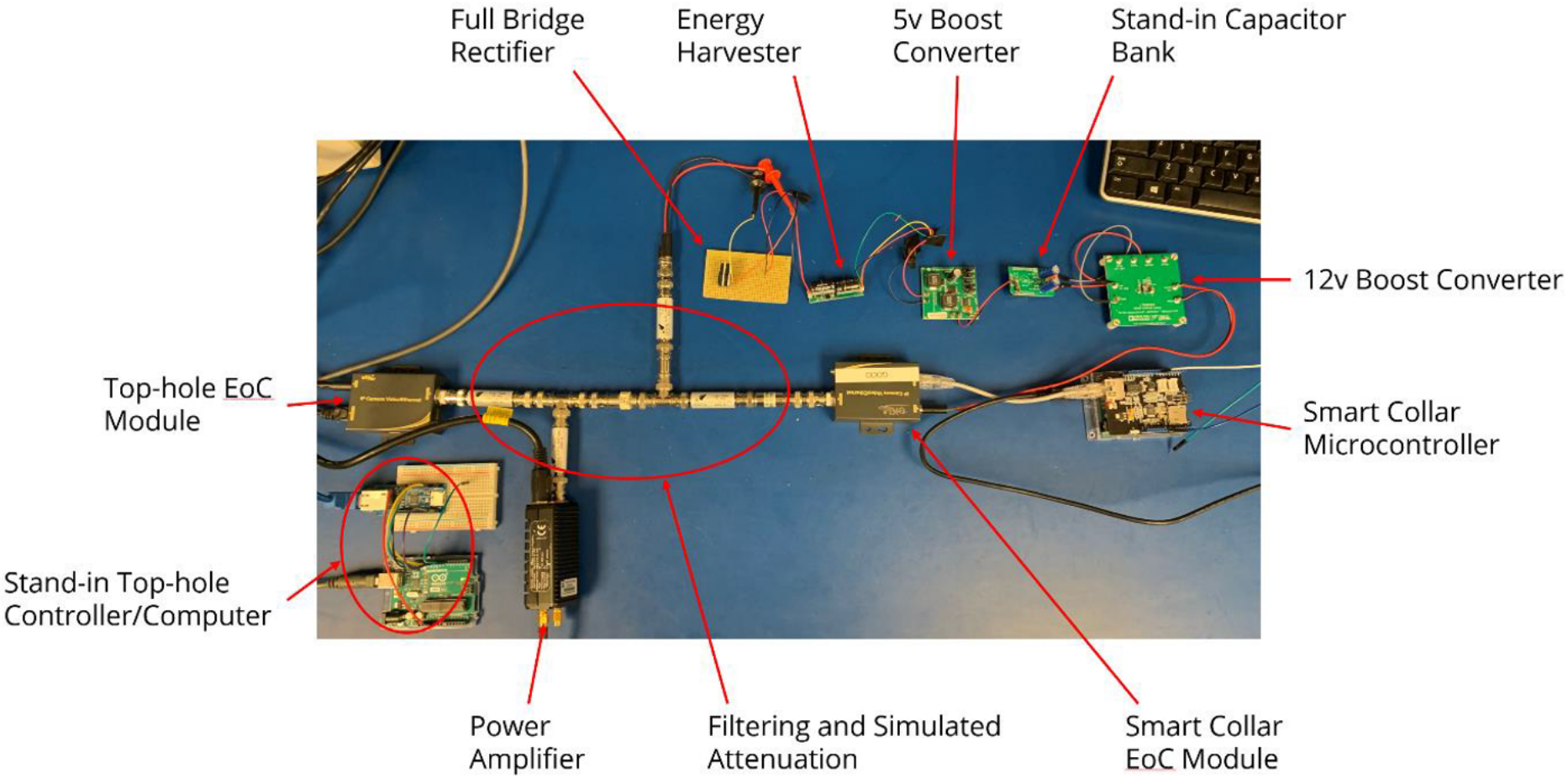


Wired Pipe Characterization

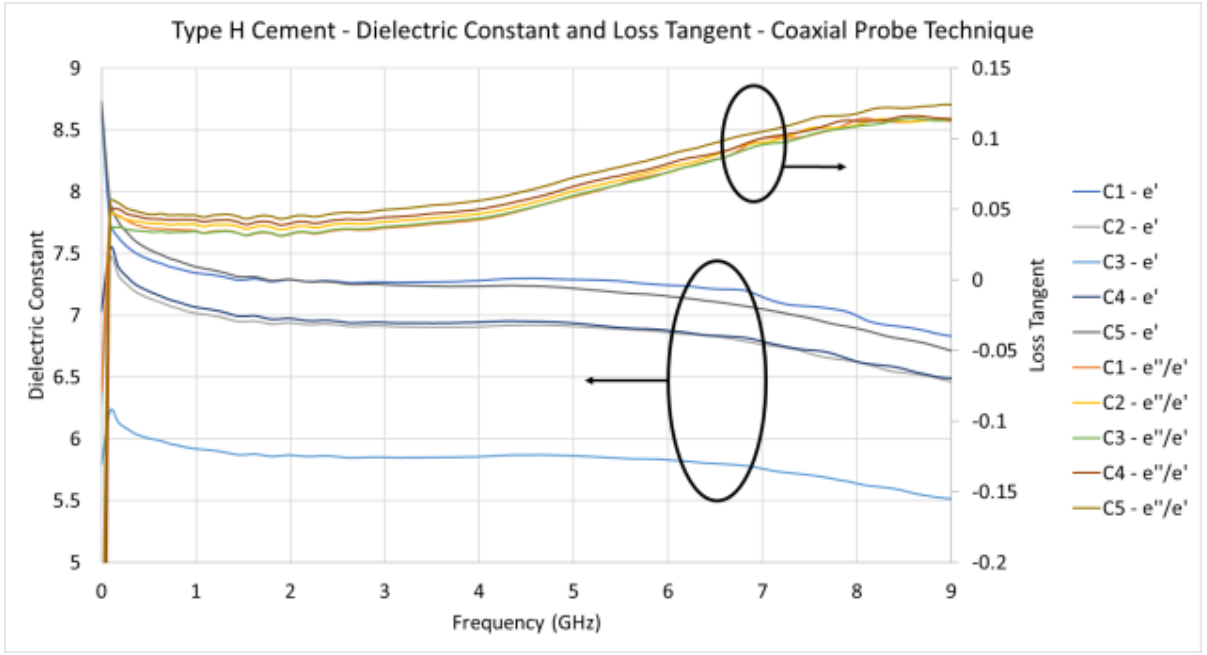
- S-parameters of 160 ft wired pipe
  - Attenuation and reflection
- 4-21 dB attenuation across the EoC bandwidth
- AC power band at 4 MHz
- 85 Mbits/sec with EOC and wired pipe



Smart Collar Communication and Power – Lab Testing



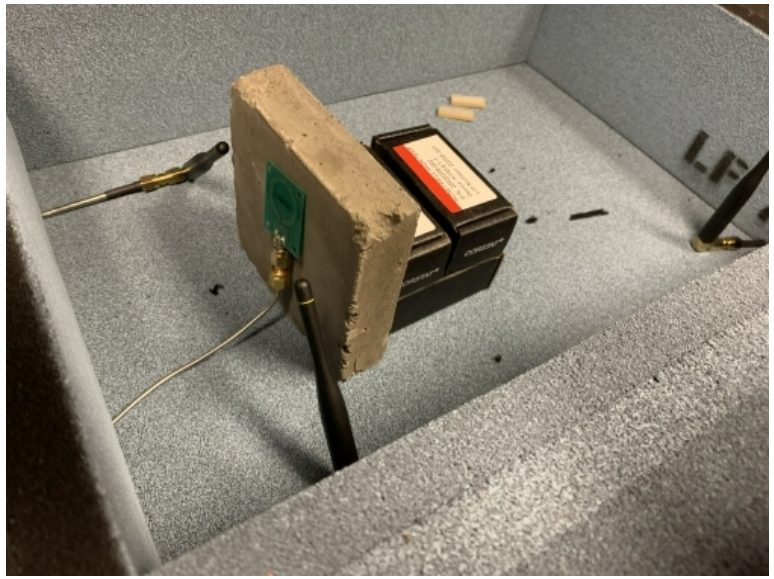
Characterize Dry Cement Samples



- Coaxial open-ended probe characterization technique
- Dry Sample: Loss tangent @ 1 GHz: 0.04 – 0.05, Dielectric Constant @ 1 GHz: 7 – 7.4
- Cement soaked in brine: 0.1%, 2%, and 10% for a couple weeks
  - Loss tangent @ 1GHz: 0.08(0.1%), 0.16(2%), 0.23(10%)
  - Dielectric Constant @ 1GHz: 9.5(0.1%), 10(2%), 14(10%)

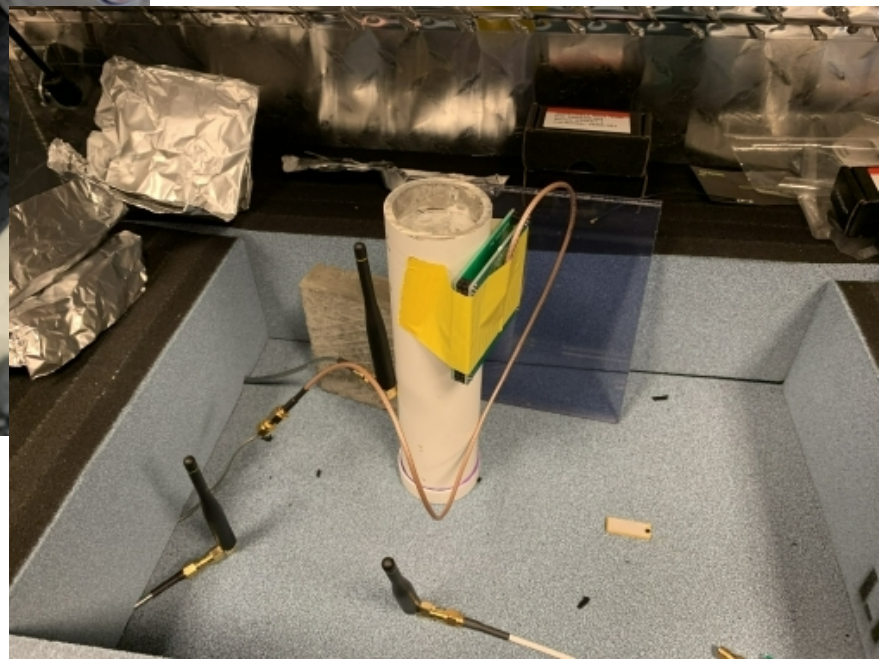
RF Cement Testing

- Wireless communications through 1 inch cement
- Off-the-shelf Abracon RFID tags
  - Larger antennas compared to Caltech RFID sensors
- 1 watt RF power
  - Spark Fun RFID Reader
  - M6E Nano



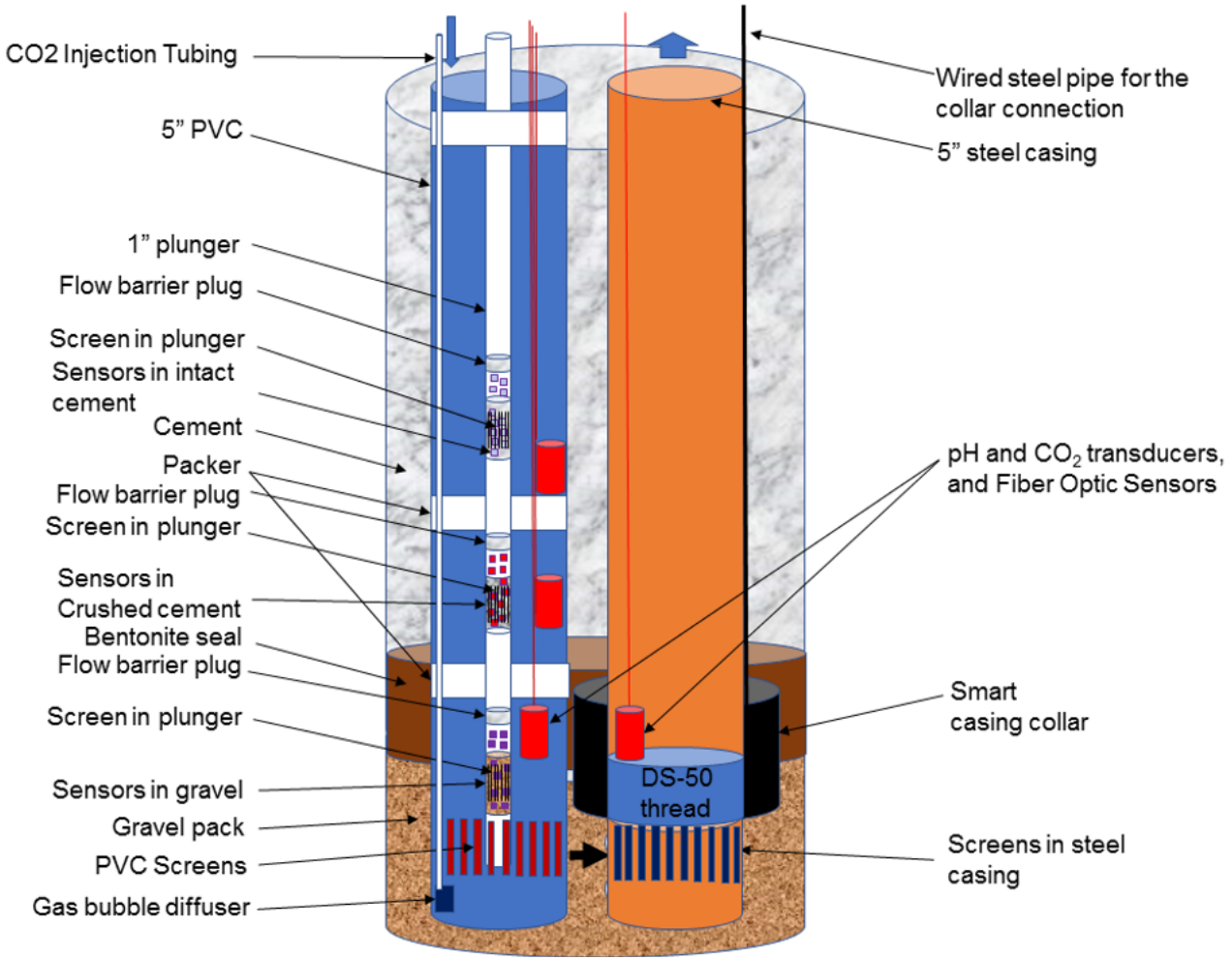
Embedded RFID Tag Communications

- Embedded Abracon RFID tags within 1.5 inch PVC, surround with cement
- Communications confirmed with tags
  - 1 watt RF comms.
    - CAENRFID circular polarized antenna
  - 2 watt RF power
    - Omnidirectional antenna



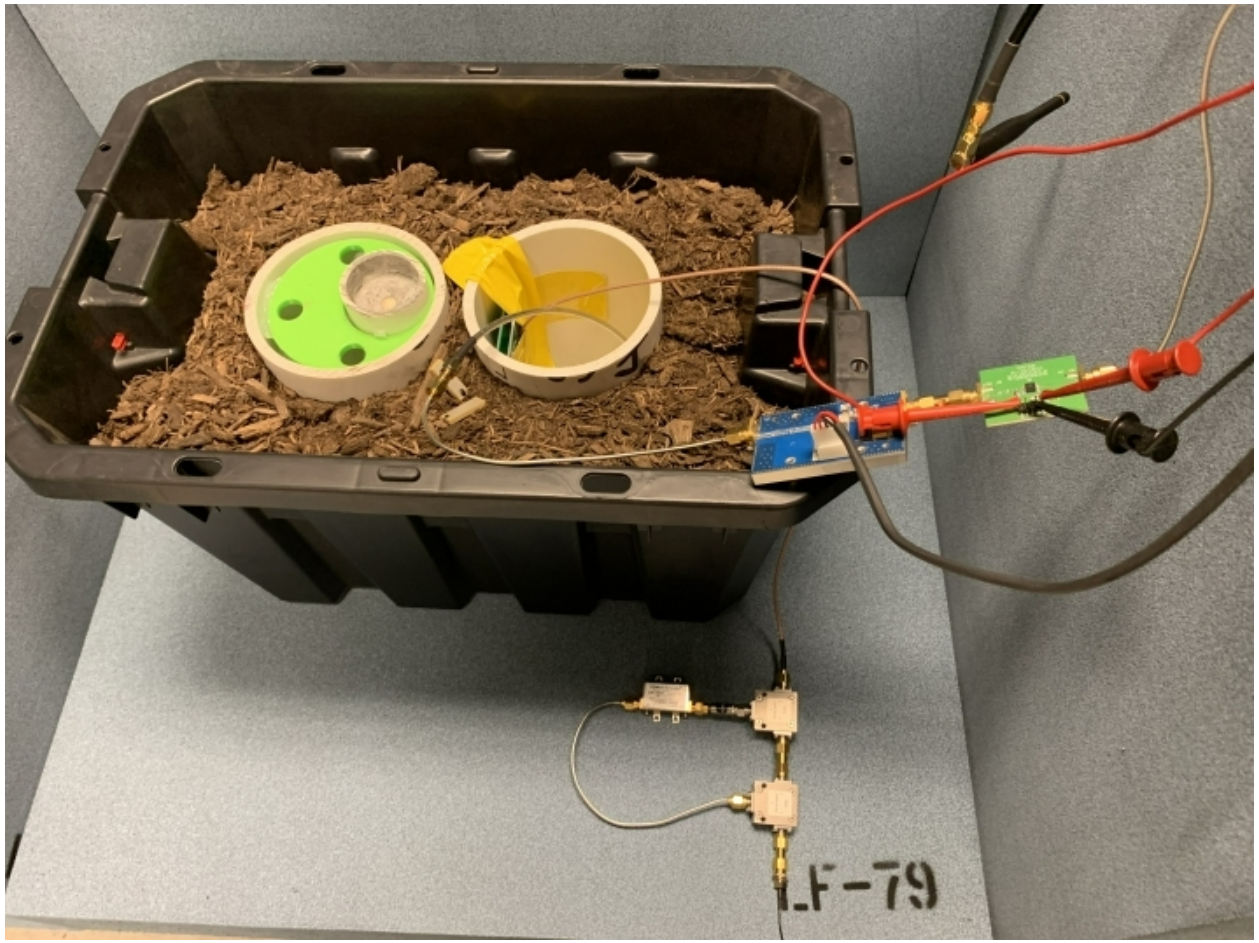
Devine Test Site – Well Design

Packers should have Three holes:
- 1 for central outflow pipe,
- 1 for gas bubbling, and
- 1 for the data and fiber optic cables, together



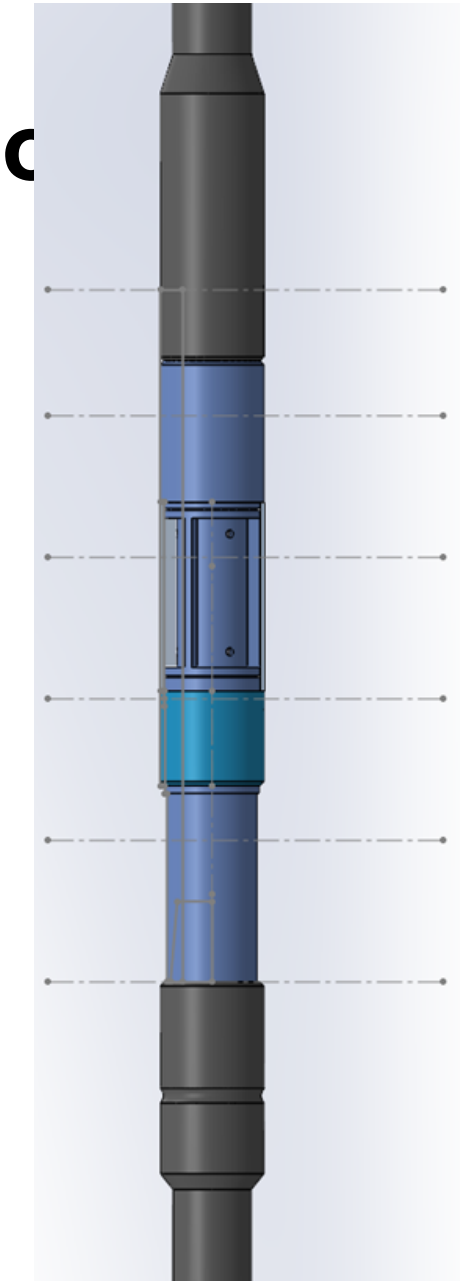
Devine Test Site - Lab RF Testing Setup

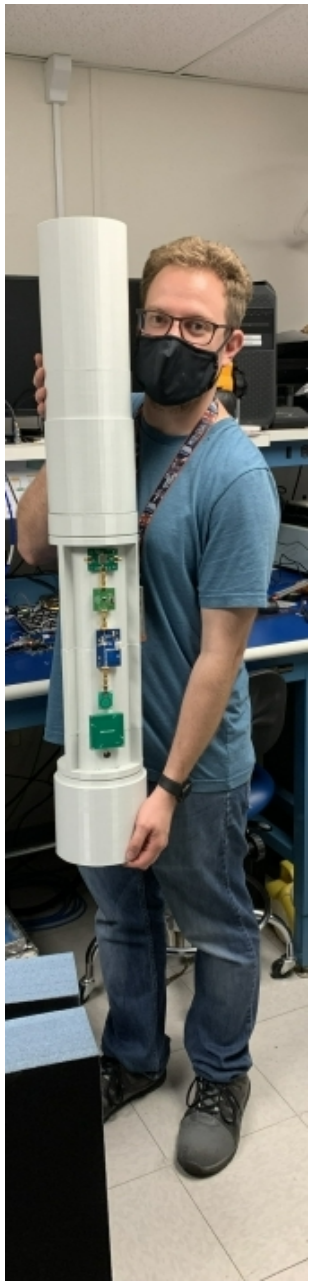
- Preparing setup to mimic Devine Test Site
- 4 inch pipe for Smart Collar and parallel pipe
- 9 watt RF Power
- 1 watt RF communications
- 20 dB anechoic chamber



Housing and RF Transmissio

- Inductive coupler for wired pipe communication
- Delrin shell
  - Seals against externals pressures
  - Allows RF propagation
- Compartment for electronics





Conclusion

- Technology would enable long-term observation of CO_2
  - >20 year monitoring
- Results of year 2 effort
  - Smart collar communication and power
  - Communications through cement with RFID tags
  - Initial housing design
- Completing prototype by March 2023
- Start evaluating technology underground in September 2023

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Funding Statement

This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

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Acknowledgment

Wired drill pipe used under this effort was purchased from IntelliServ. SNL would like to thank IntelliServ for allowing to utilize the wired pipe technology to enable this new approach for Carbon Sequestration subsurface monitoring.

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Thank You!

Questions or Comments