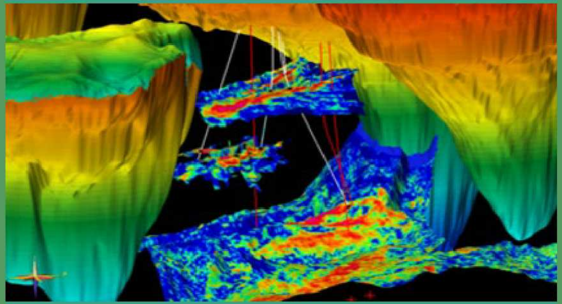
SAND2019-7791PE

# RESEAD

## REAL-TIME SUBSURFACE EVENT ASSESSMENT AND DETECTION



*PRESENTED BY*


PI: Ed Matteo

*PM: Giorgia Bettin*

*Sandia National Labs*

*Department of Geothermal Research*

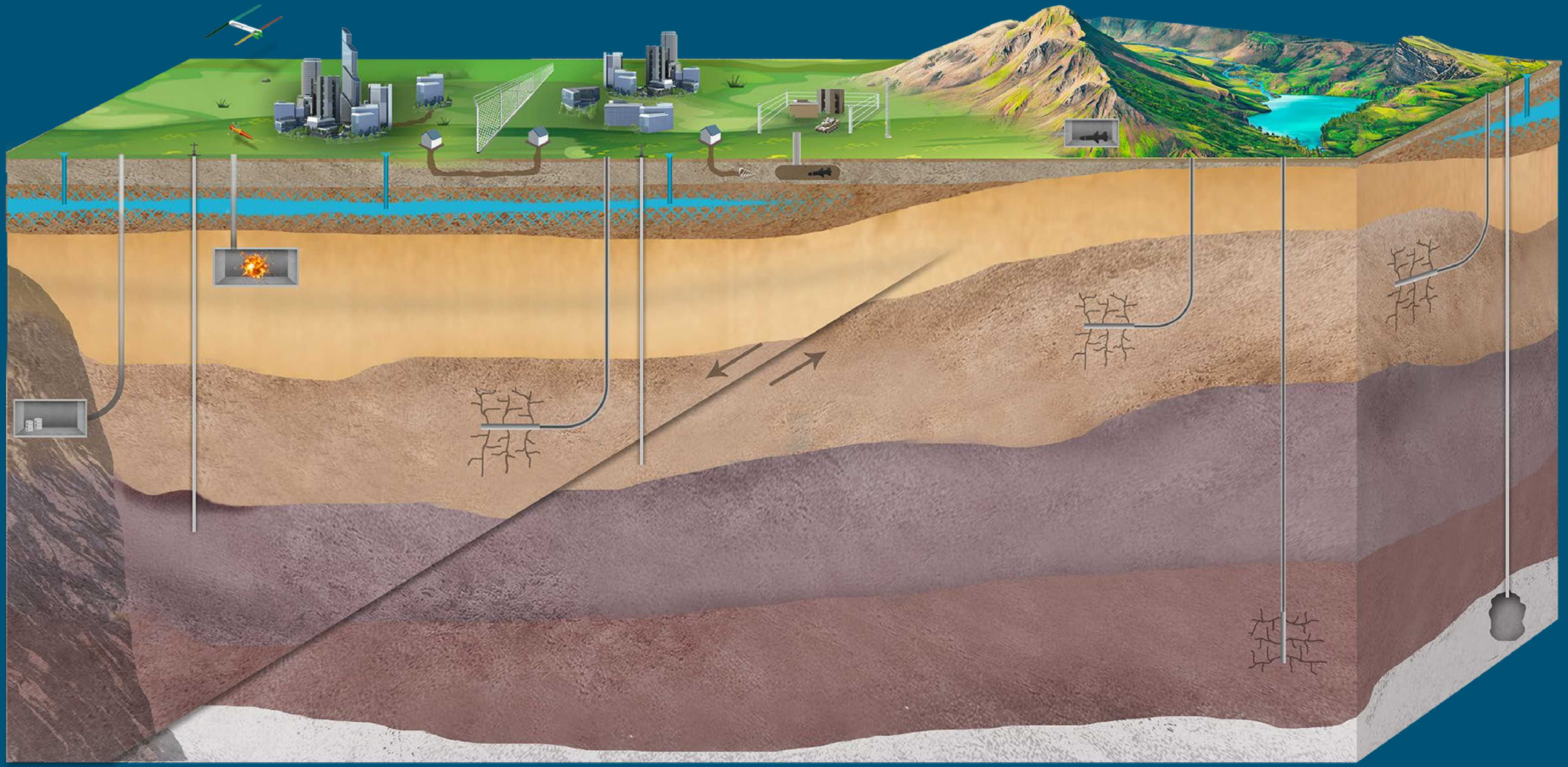


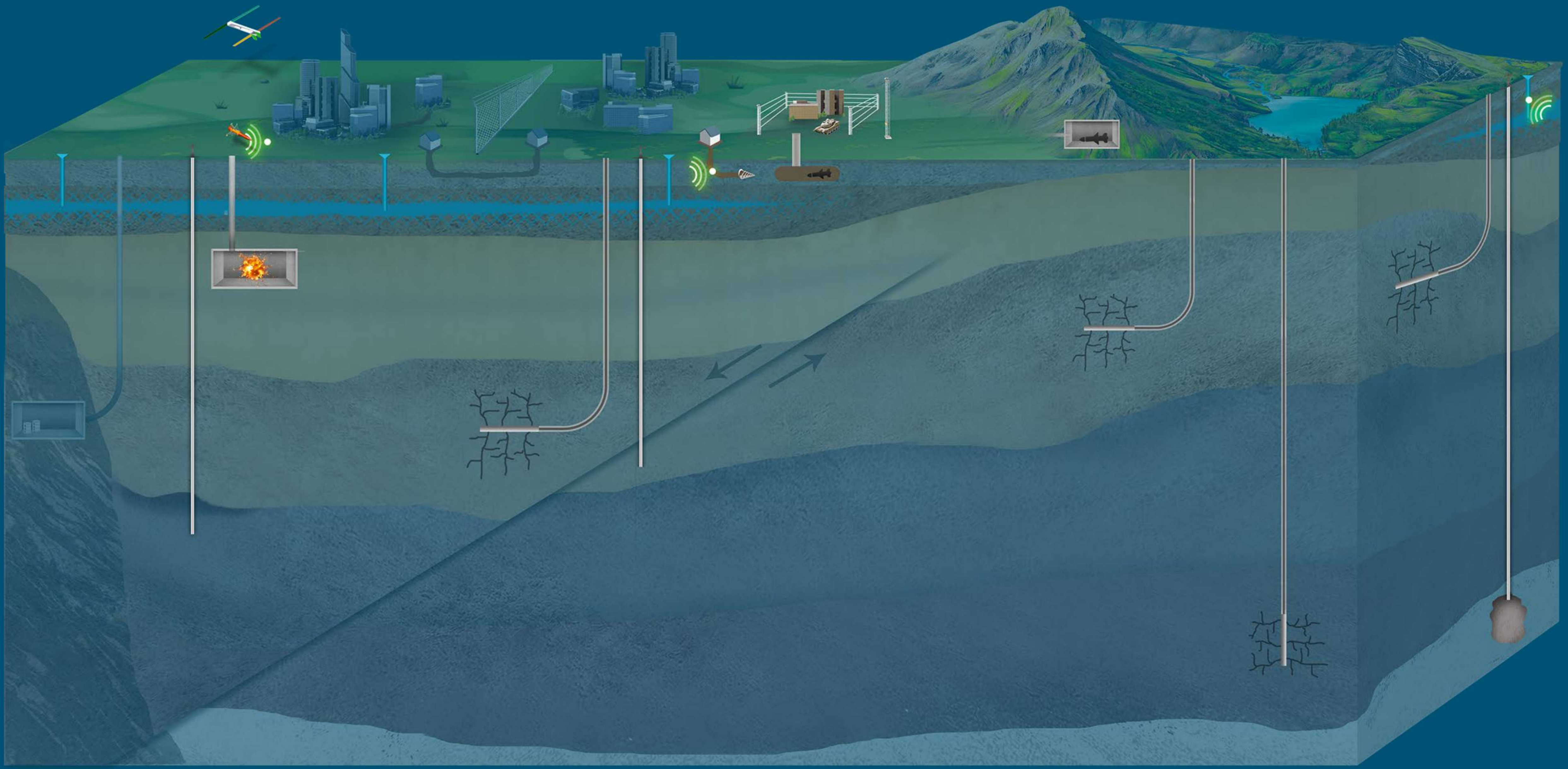
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND2019-XXXX

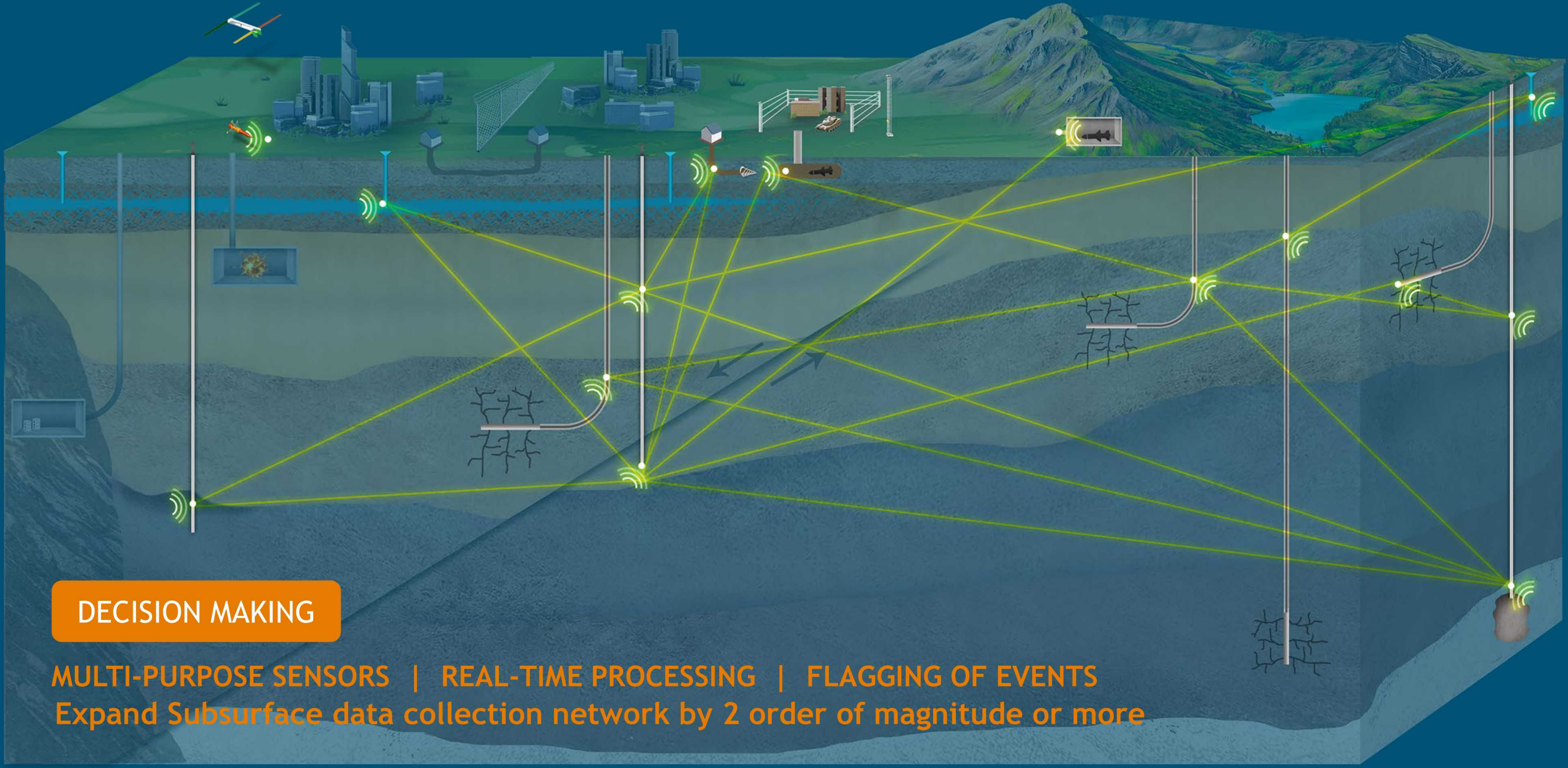
Sandia National Laboratories


Expand existing subsurface real-time data collection network by 2 or more orders of magnitude

# SENSING THE SUBSURFACE IS CRITICAL







DECISION MAKING

MULTI-PURPOSE SENSORS | REAL-TIME PROCESSING | FLAGGING OF EVENTS

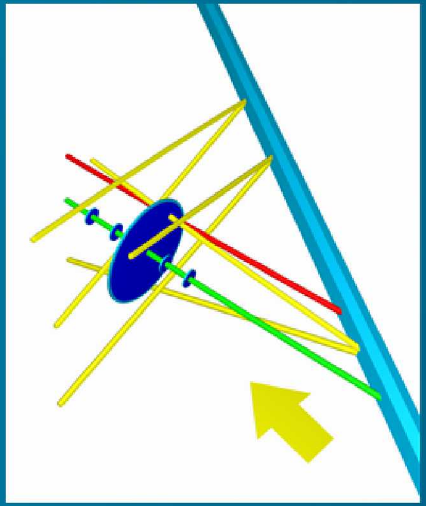
Expand Subsurface data collection network by 2 order of magnitude or more

# GEOSCIENCE LDRD GOALS

## DEVELOP DATA ANALYTICS FRAMEWORK

- ✓ Realtime Event Monitoring
- ✓ Hybrid Machine Learning and Physics Based model

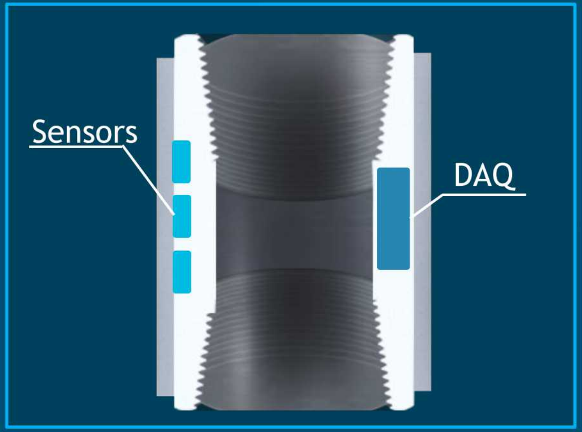
### FRACTURES DETECTION & CHARACTERIZATION



## DEVELOP A POWER & COMMUNICATION PLATFORM

Versatile HTHP data acquisition platform

### SMART COLLAR

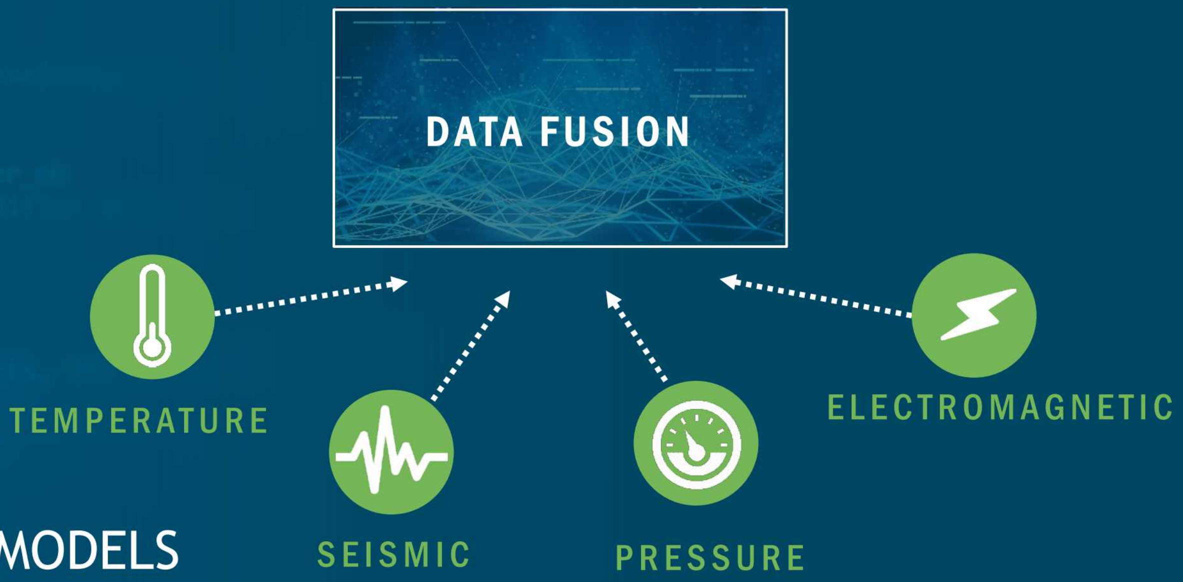


# DATA SCIENCE THRUST

## R&D CHALLENGES ML DATA ANALYTICS

### INTEGRATION OF MULTIPLE DATA STREAMS

- Sensors may not be temporally synchronized
- Variable data quality
- Variable relevance of sensor types
- Multiple observations of single phenomena can disagree




### MERGING MACHINE LEARNING AND PHYSICS BASED MODELS

- Nascent area of research
- Capture information in different ways
- Translating between the two remains challenging

# DEVELOPMENT OF DATA ANALYTICS FRAMEWORK

## EXEMPLAR PROBLEM

- ✓ Detection & characterization of subsurface fractures

## SYNTHETIC DATA

- ✓ Event signals and noise

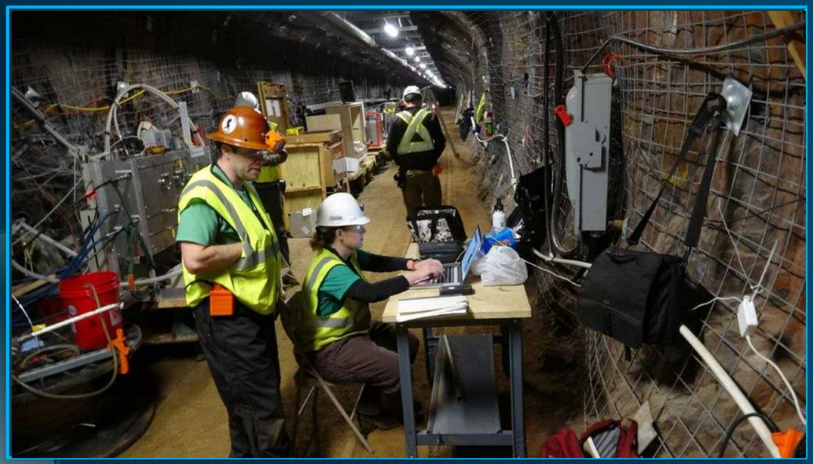
**Use data driven methods (Machine Learning) + model based methods (full inversion) to develop appropriate framework**

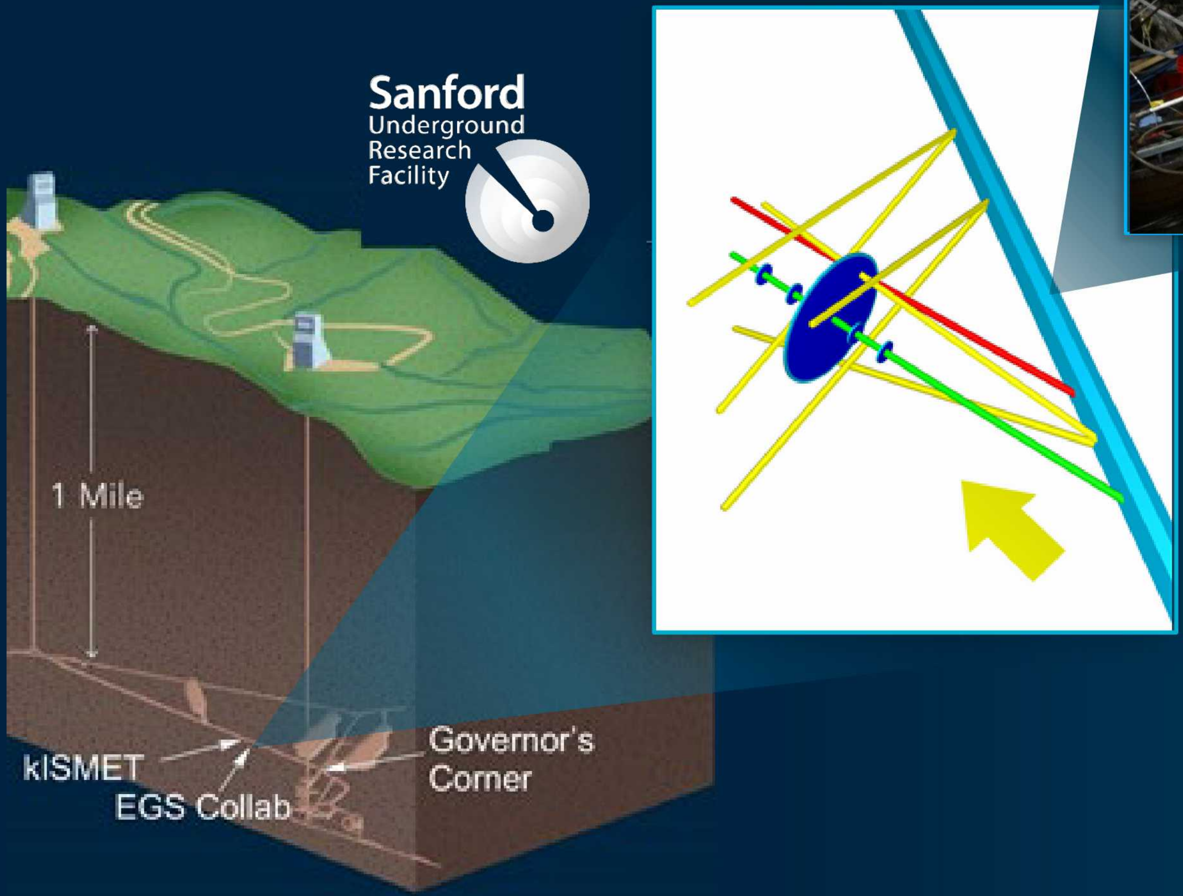
# EXEMPLAR PROBLEM: DETECTION & CHARACTERIZATION OF SUBSURFACE FRACTURES

Scaled-Reservoir size field (10s of meters)

Injection, production and monitoring wells

Multistage stimulations





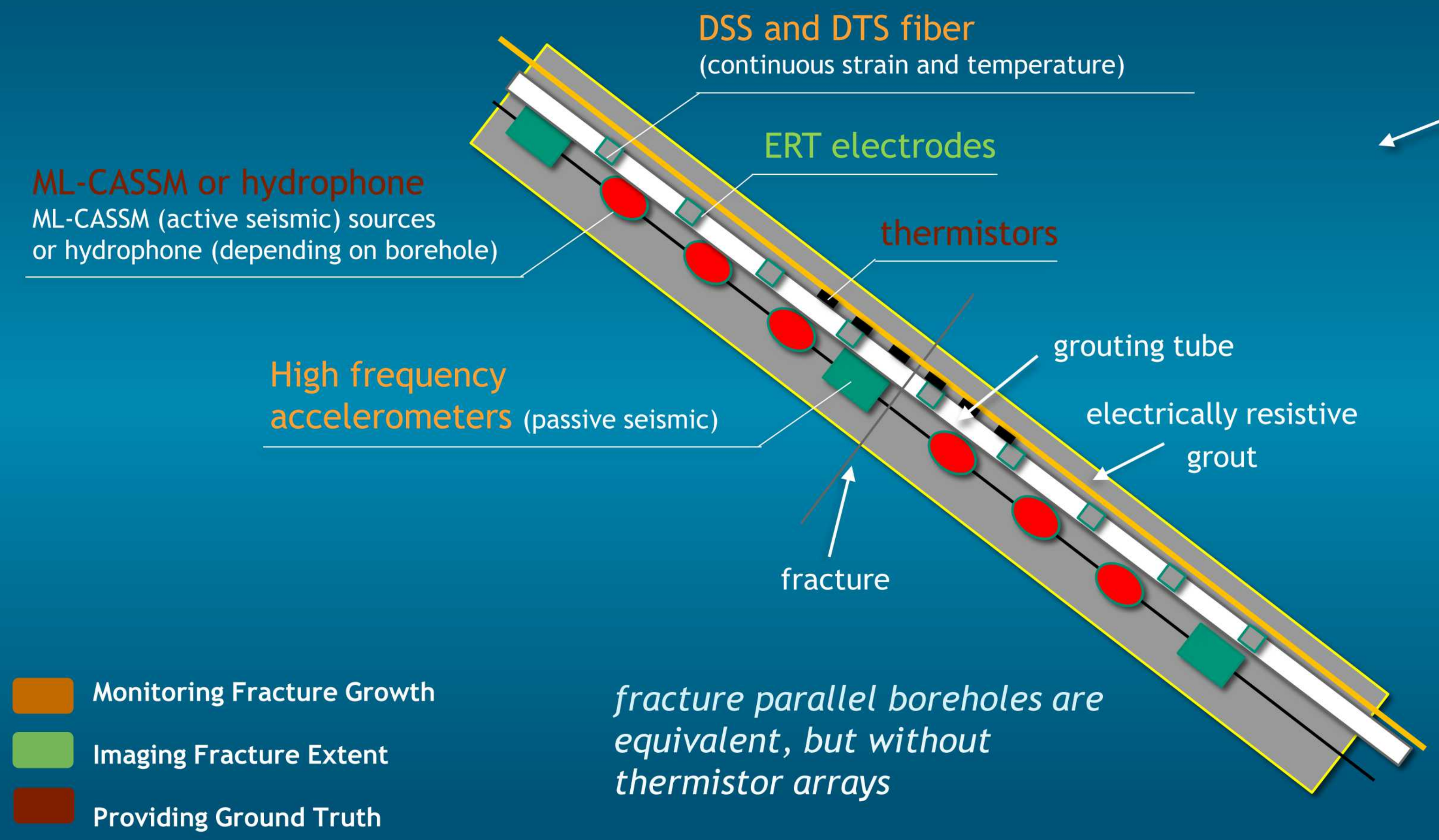

COLLAB
A PATH TO FORGE
U.S. DEPARTMENT OF ENERGY

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

*Geothermal Technologies Office*

# TEST BED & MONITORING SYSTEM DESIGN

## INSTRUMENTATION CONFIGURATION




*fracture parallel boreholes are equivalent, but without thermistor arrays*

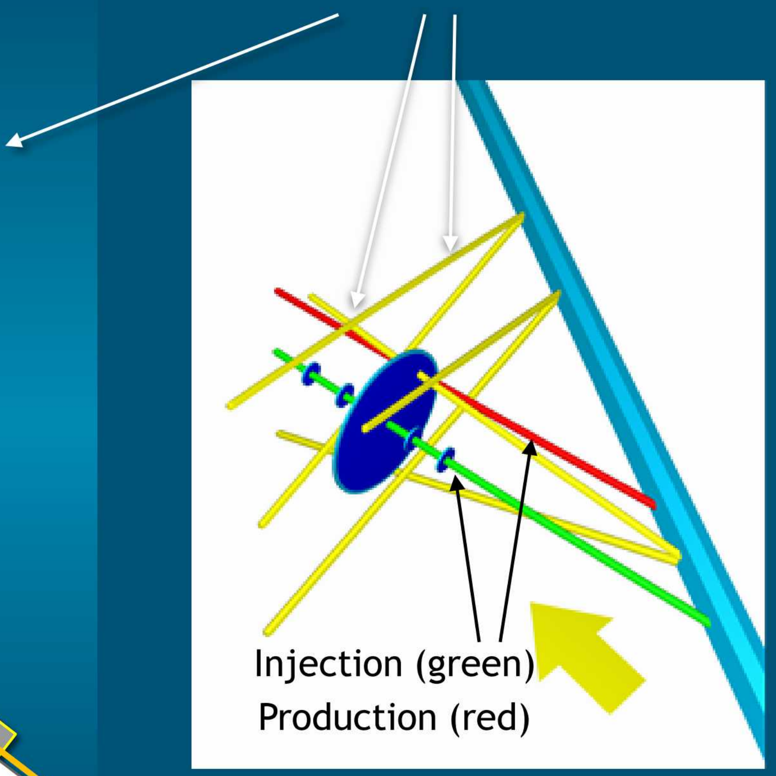


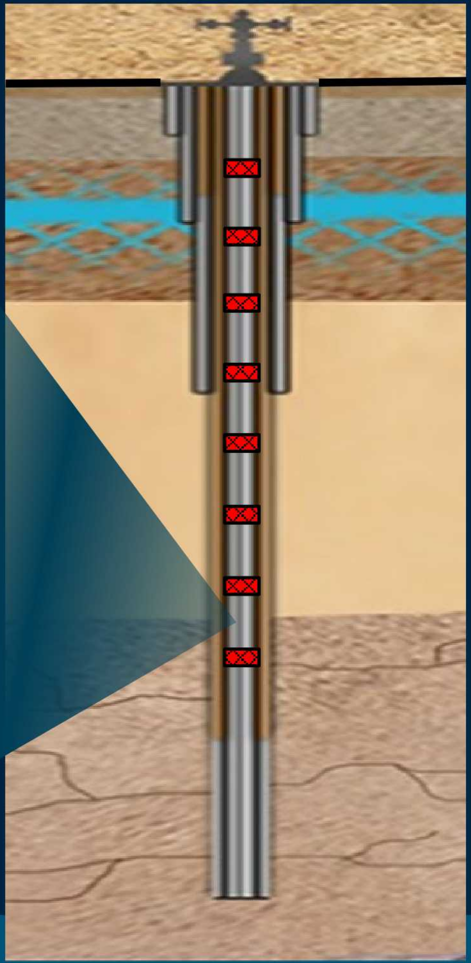

Figure by: J. Ajo-Franklin (LBNL) & T. Johnson (PNNL)

# SENSORS TECHNOLOGY THRUST

## R&D CHALLENGES

- ✓ Sensors size
- ✓ Power requirements
- ✓ Wireless communication distances and rate limitations
- ✓ Sensors and data acquisition reliability at HT & HP

### SMART LOW SWAP TECHNOLOGY



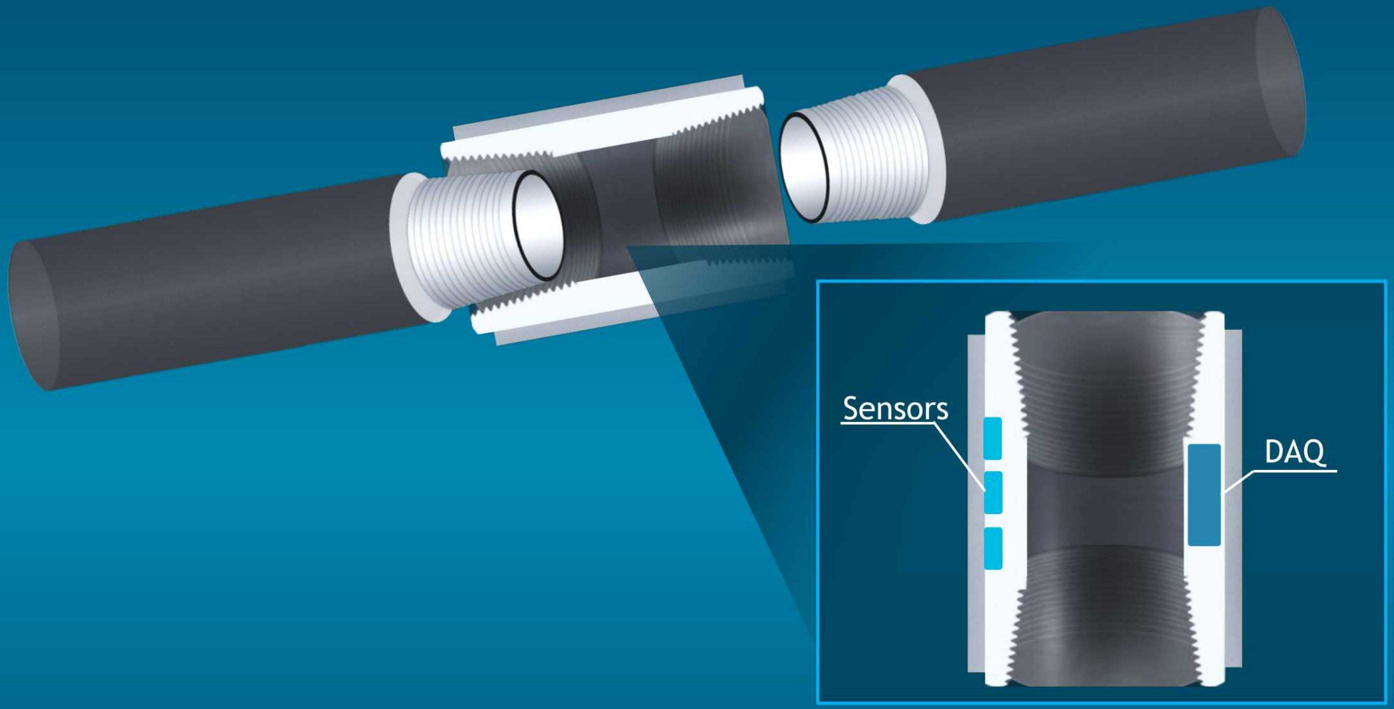
- ✓ Easily adoptable with current practices and technologies
- ✓ Robust, HT, Modular design
- ✓ Distributed sensor network external to casing

**Sensors of interest**

- Seismic
- ERT
- Temperature
- Pressure
- Flow
- EM
- Etc…

# SENSING TECHNOLOGIES THRUST

INITIAL ACQUISITION PLATFORM WILL BE DEVELOPED USING WIRED PIPE(PROVEN TECHNOLOGY).

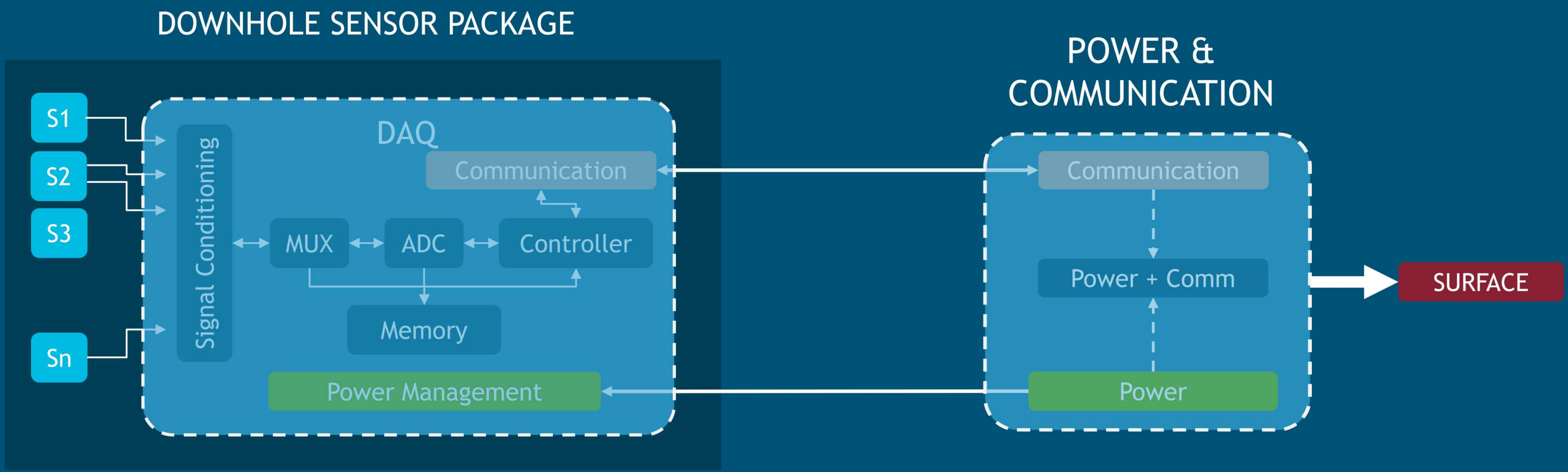



**SMART COLLAR**

- Allows for lowest risk initial platform development and minimized downselect of sensor type
- Versatile HTHP sensing platform

# SENSING PLATFORM REQUIREMENTS

- ✓ Power
- ✓ Communication
- ✓ Timing
- ✓ Controller
- ✓ Multiplex



# COMMUNICATION AND POWERING ANALYSIS

Wired: Power, communications and sync all handled by wire

PROS: maximum simplicity, versatility, high data rate
CONS: wired pipe is expensive

Wireless:

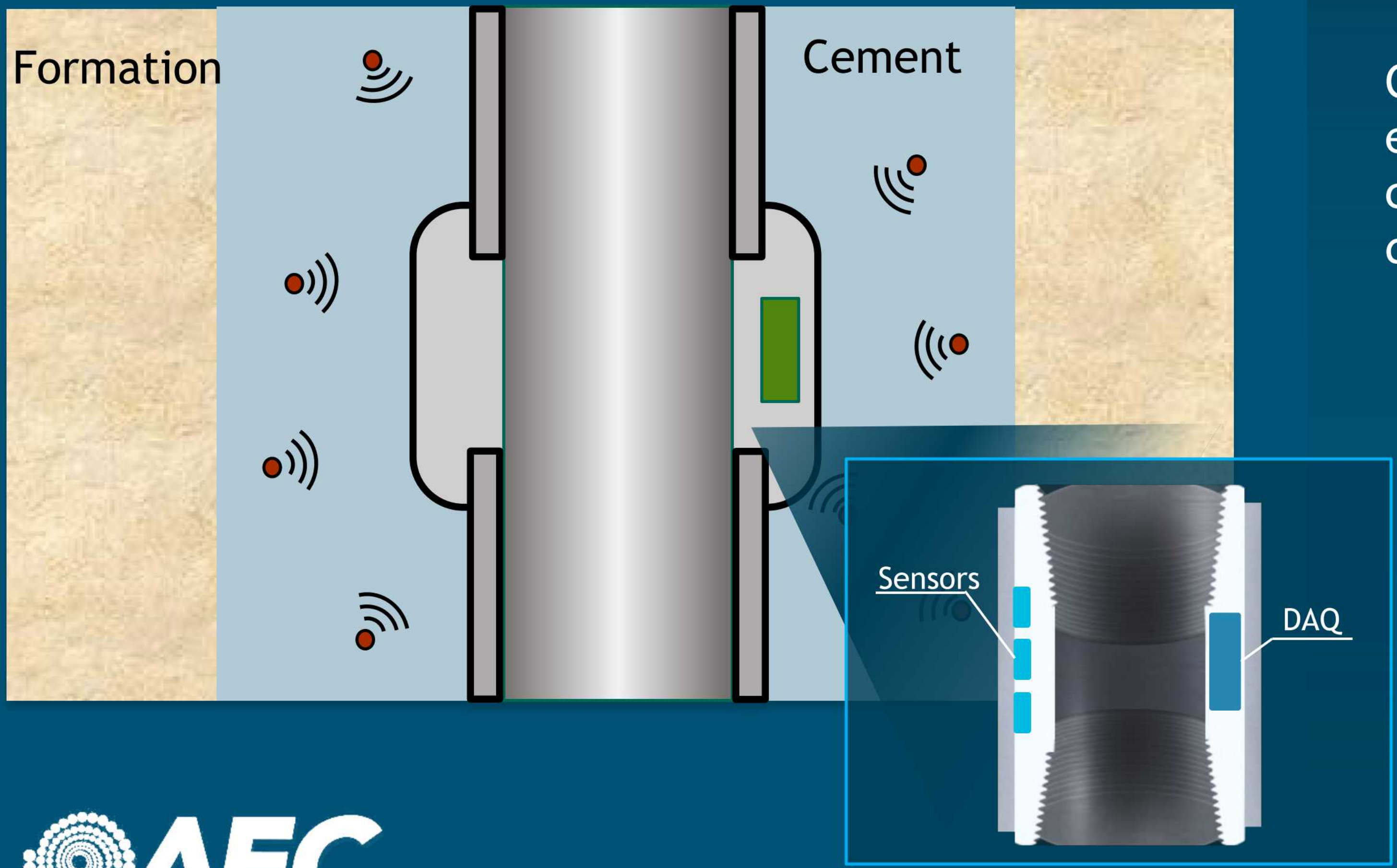
- Acoustic, EM, Power and/or Comm
- Possible local power harvester (Dynamo, piezo, thermoelectric)
- Possible tool-chase/data retrieval scheme

PROS: Simple interface to existing O&G system, no need for wired pipes so cost is not depth dependent.
CONS: Low data rate, power limitations, time sync challenges

| | Type | Max rate | Range | Power |
|---|---|---|---|---|
| Mechanical | Acoustic (pressure wave) | 100 bps | 1000s of ft (steel) | ? |
| | Pulse telemetry | 10 bps | 1000s of ft | Harvesting |
| Electro Magnetic | Fiber Optics | $10^9$ bps | 1000s of ft | 1 W |
| | Radio frequency (Ex. Wifi) | $10^6$ bps | ft | ? |
| | Low Freq. EM | 10 bps | 1000s of ft | <1 W |
| | Induction | 10 bps | 10s of ft | 1-100 W (dependent on geometry) |
| Electrical | Electric wire | $10^5$ bps | 1000s of ft | $10^3$ W |

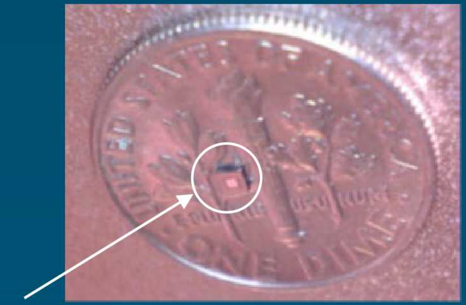
# EMBEDDED SENSORS COMMUNICATION

Versatile HT system to enable interface with many types of sensors including wireless interface to locally embedded micro and nanoscale sensors




SMART COLLAR

Collaboration:
enable short range two-way wireless communications from smart collars to distributed sensors outside of casing



1mm System on a chip (SoC)

1mm Proprietary System on a single Chip Temp, Resistivity, pH

# OTHER POSSIBLE COLLABORATIONS AND PARTNERS

TEXAS
The University of Texas at Austin

THE UNIVERSITY OF NEW MEXICO

OAK RIDGE
National Laboratory

Battelle

Los Alamos
NATIONAL LABORATORY
EST. 1943

BROOKHAVEN
NATIONAL LABORATORY

BUREAU OF
ECONOMIC
GEOLOGY

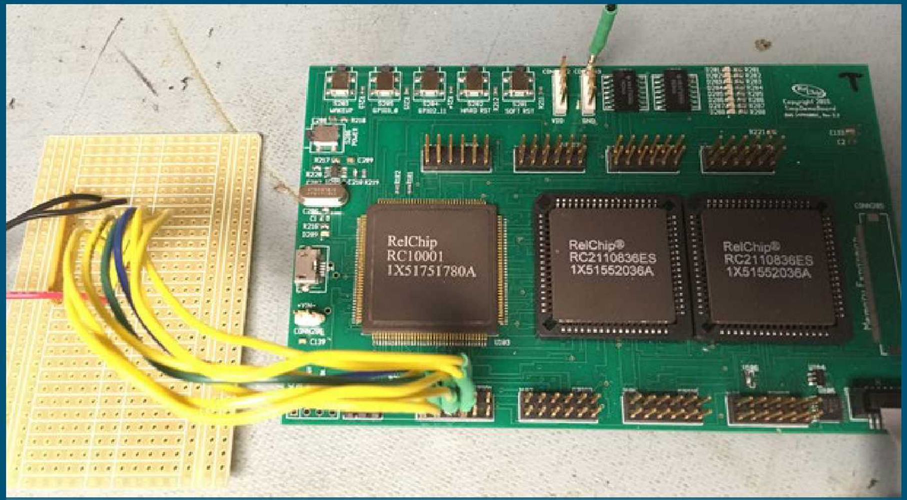
TransCanada

# Back up

# HT MICROCONTROLLER

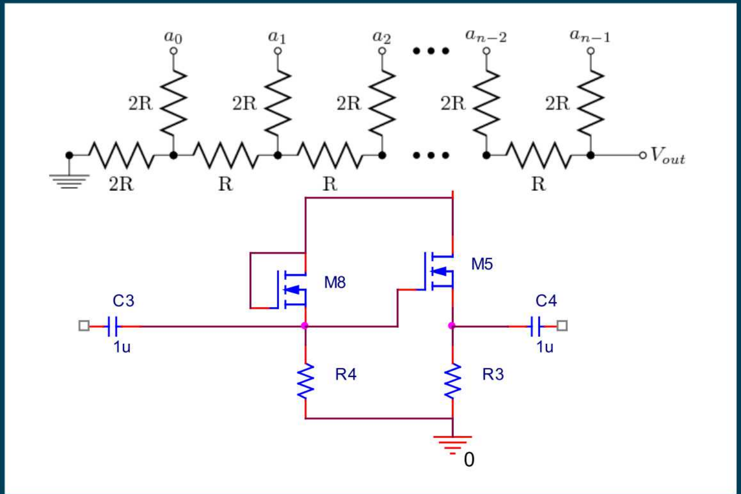
Microcontroler (Relclip RCI 1001) 4MHz CORTEX MO
32-bit processor operates up to 300 C.

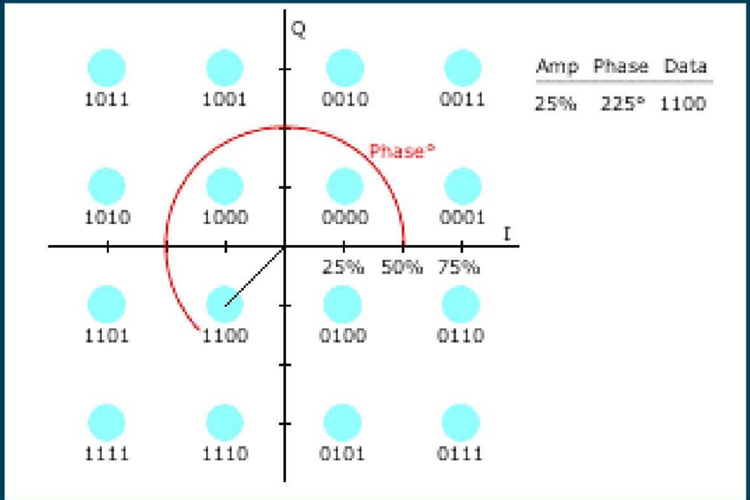
| Device | Manufacturer | CPU | Maximum Rated Operation Temperature | Maximum Clock Frequency | Internal Memory | Estimated Maximum Serial Baud | ADC | Nominal Power |
|---|---|---|---|---|---|---|---|---|
| SM320F2812-HT (DSP)[13] | Texas Instruments | 32-bit TMS320C28x | 220°C | 150 MHz | 128Kx16 Flash | 20Mbps | 12-bit 16-Ch | I/O Supply: 3.3V Memory Supply: Core Supply: 1.9V |
| SM470R1B1M-HT (MCU)[14] | Texas Instruments | 32-bit ARM7TDMI | 220°C | 60 MHz | 1MB Flash, 64KB SRAM | 10Mbps | 10-bit 12-Ch | I/O Supply: 3.3V Core Supply: 1.8V |
| HT83C51 (MCU)[15] | Honeywell | 8-bit 8XC51FC | 225°C (300°C derated) | 16 MHz | 8KB ROM | 1.3 Mbps | N/A | Single Supply: 5V |
| RC10001 (MCU)[16] | RelChip | 32-bit Cortex M0 | 300°C | 4 MHz | 4KB SRAM | 1Mbps | N/A | Single Supply: 5V |

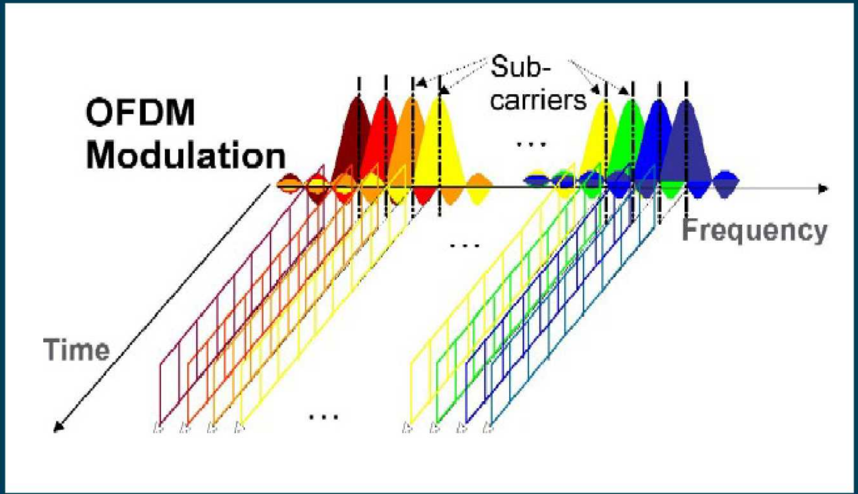


# TELEMETRY HIGH-TEMPERATURE HIGH-SPEED DATA LINK

Quadrature Amplitude Modulation (QAM) over Orthogonal Frequency Division Multiplexing (OFDM).




- Industry max ~200kbps. 2Mbps demonstrated in the lab with this system over 5,000 ft wireline.
- Developing HT systems
- Divides the available bandwidth into multiple narrow band channels
- Each channel uses QAM to encode the data
- The data is encoded by changing the amplitude and phase of a sinusoid
- Compensates for channel distortions

Ref: Cashion et.al