

Geothermal Research at Sandia National Laboratories

SAND2014-17409PE



Geothermal Research Overview

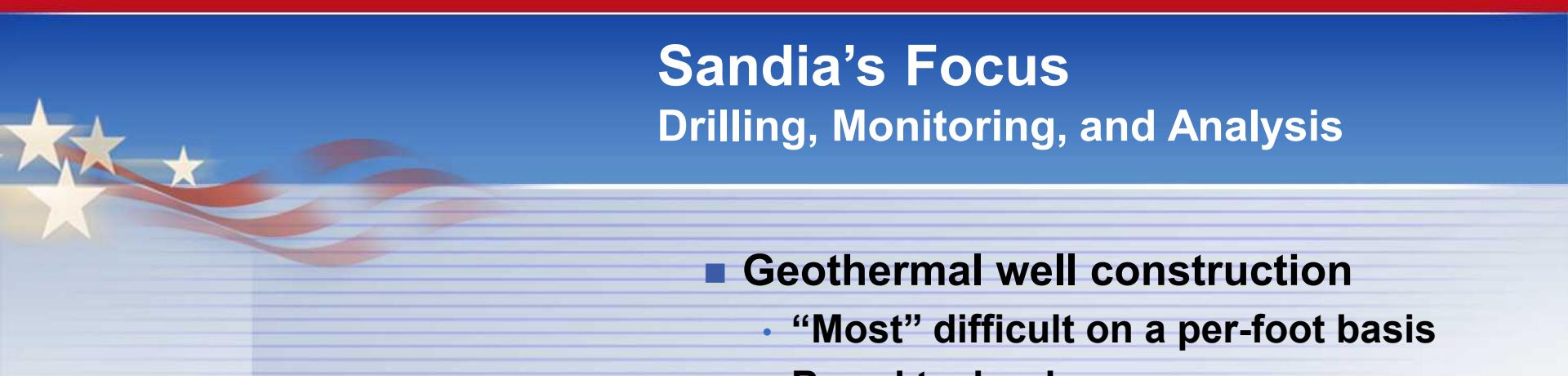
Grzegorz Cieslewski
and
Douglas Blankenship



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Sandia's Focus

Drilling, Monitoring, and Analysis



- **Geothermal well construction**
 - “Most” difficult on a per-foot basis
 - Broad technology areas
 - High-temperature electronics
 - Diagnostics
 - Rock reduction technologies
 - Wellbore integrity and lost circulation
 - Drilling dynamics mod/sim
 - Vibration mitigation
 - Downhole telemetry
 - **Key to future EGS**
- **Applying capability and technology to other industries and agencies**
 - Frontier O&G, unconventional, environmental, NIOSH



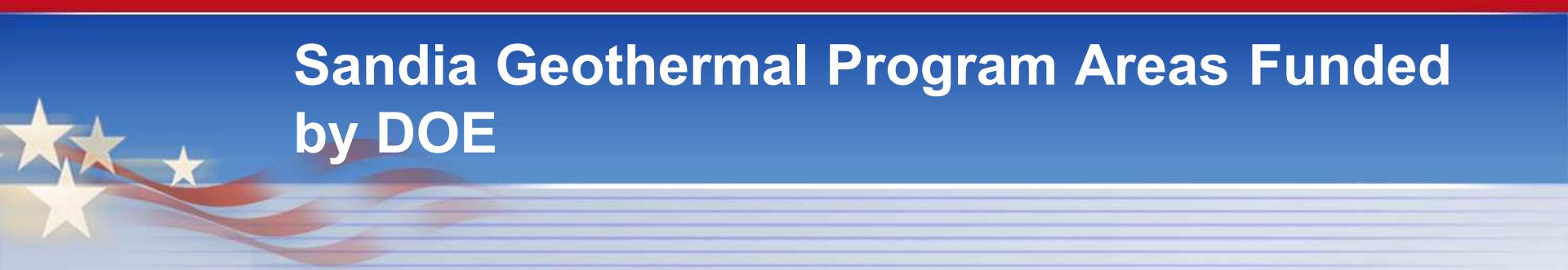
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Significant Geothermal Accomplishments – Technology and Products to Industry

- Polycrystalline diamond compact (PDC) bits
- High-temperature electronics
- Diagnostics-while-drilling
- LEAMS
- Active vibration control
- Slimhole drilling
- Acoustic telemetry
- Rolling float meters
- Insulated drill pipe
- Cavitating mud jets
- Drilling dynamics simulator
- Well cost models
- ...



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Sandia Geothermal Program Areas Funded by DOE

- Downhole seismic monitoring
- Fluid sampler (> 350 °C)
- High temperature component research (solders, ceramic boards, MCMs, optical fiber)
- Downhole chemical sensing
- Advanced bit demonstrations
- Downhole motor development
- Controlled propellant stimulation methods
- Emerging technologies
- Best practice sharing
- Rotational seismometer
- Expandable casing
- High temperature hammers
- Televiewer operations
- Self consuming downhole tools
- Seals
- MWD support
- Systems engineering and analysis (systems dynamics approach)
- Field demonstration support
- Technical monitoring for DOE HQ
- International program support



Polycrystalline Diamond Compact (PDC) Bits

- Fundamental work
 - FEM analyses
 - Bonding
 - Cutter tests
 - Bit design / analysis
 - Lab / field testing
 - CRADAs
- Catalyzed a major industry
- PDC bits now a ~ \$1.5 billion industry
- PDC bits save industry \$ billions annually
- Over 60% of world footage today



DOE Energy 100 Award for *Synthetic Diamond Drill Bits*



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DTTH Research

- Hammers are a very efficient method to drill hard rock
- Current limitations in HT Environment
- Working with DOE and Industrial partners in HT hammers and down-hole motors



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Drilling Dynamics Increase Drilling Costs



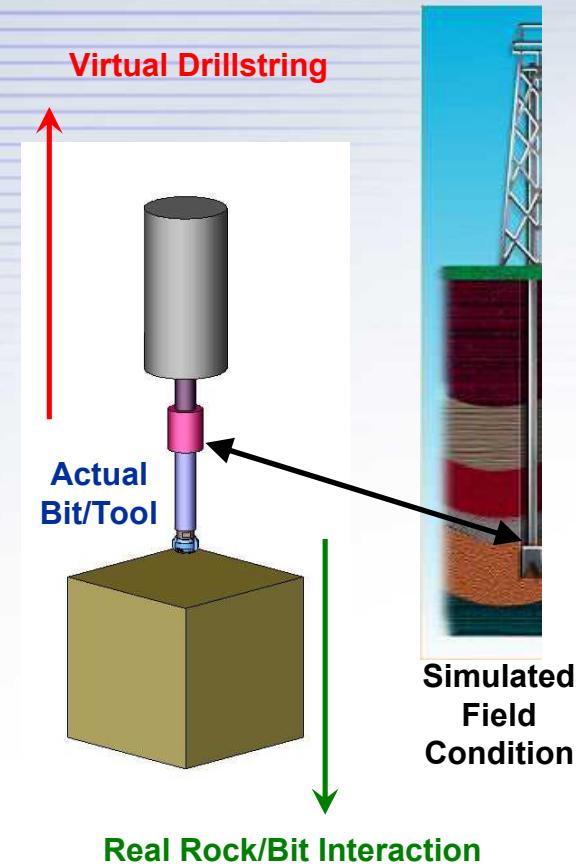
- Drilling dynamic dysfunctions are one of the leading causes of Non-Productive Time
- The bit, BHA / drillstring and formation interact in a complex way resulting in a variety of vibration related problems
 - Low Rate of Penetration -- Inefficient Drilling
 - Bit & Tool Failure -- Excessive Tripping
- Vibrations cause significant economic losses
 - For example: Tripping the drillstring to replace the bit on an off-shore rig can exceed 1 million dollars



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Simulation of Drilling Dynamics

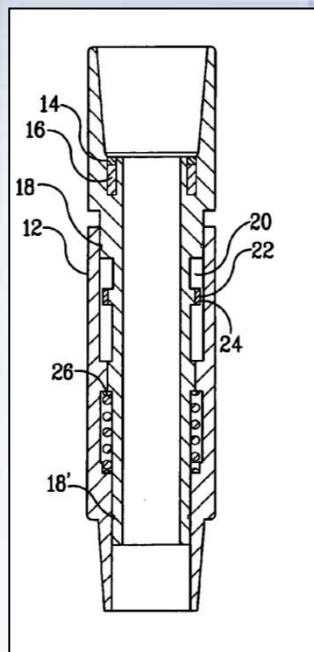
- Existing drilling research laboratories
 - Unrealistically rigid drill stems
 - Effective for evaluation of cutting structures, hydraulics, etc.
 - Don't address vibration
- Sandia is pursuing an innovative capability
 - Laboratory simulation of field conditions
 - Will improve bit and tool performance before committing to expensive field drilling
- Benefits
 - Improved capability for predicting bit vibration
 - Identify deficiencies in drill bit material properties and designs
 - Validate development of hardware and software for downhole tools that reduce vibration
 - Develop *Best Practices* for handling vibration



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Active Vibration Control

- Drill bits are susceptible to failure under shock & vibration
 - Dampers installed in down-hole tools can help
 - Optimal damper for each drilling condition
- Active vibration control tool developed using controllable fluids
 - Based on Magneto-Rheological (MR) Fluids
 - Carrier fluid with iron particle suspensions
 - Controllable damping force
 - Fast response (~ milliseconds) and low power (~ Watts)
 - Remotely powered and controlled
 - Controllability ensures applicability to broad range of drilling conditions
 - Drillstring changes with depth
 - Variable rock lithologies
 - Sidewall friction, etc.
- Intellectual property licensed to industry



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Diagnostics-While Drilling (DWD)

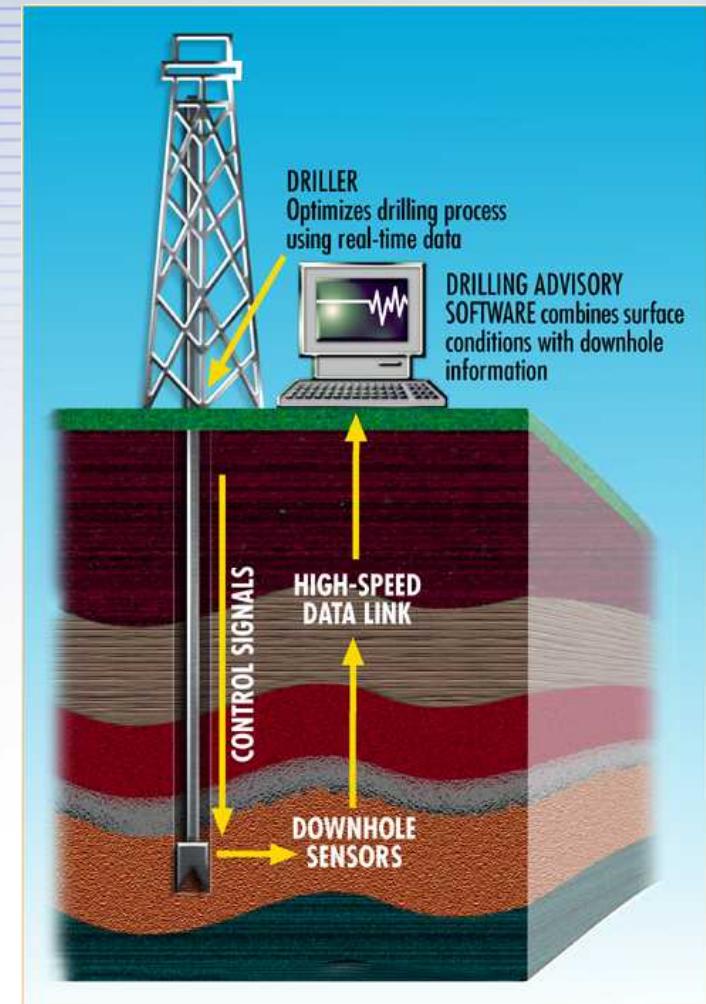
Measurement sub – acquires, conditions, and transmits downhole sensor data

Data Link - carries information and control signals between surface and downhole

Instrumented Drill Rig – provides for display and archive of surface drilling data

Driller's Display - displays selected set of real-time, high-resolution data from both downhole and surface. Display can be either raw or processed (FFTs, etc.) data.

Driller – experienced and willing driller can use more sophisticated display than traditional console.



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Acoustic Telemetry



- Communication between the bit and the surface via pressure waves in the drill pipe
 - Downhole telemetry a big need with today's tools
 - Mud pulse the standard (2 – 5 bits/sec)
 - Acoustic telemetry ~ 10x mud pulse
- Enabled by Sandia's theoretical, manufacturing and testing capabilities
 - Physics issues – propagating waves through drill pipe
 - Engineering and Applications Codes
 - Design and manufacturing of prototypes
 - Field testing
- Product licensed to several entities
 - Commercially available through Xact (STV and Extreme Eng JV)

R&D 100 Award for *Acoustic Telemetry*



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HT Electronics at Sandia

- High temperature electronics circuit, board, and system design, tools, seals, batteries and fiber up to 300°C
- Mechanical design expertise
 - Materials selection for high temperature
 - Pressure sealing techniques
- In-house production capabilities
 - High Temperature soldering processes
 - Lead forming capability for new HT electronic components
- Testing
 - Thermal testing up to 300°C
 - Pressure testing up to 5000 psi in H₂ environments
 - Instrumentation for long-term electrical and optical measurements
- Excellent relationship with HT electronics industry
 - We often receive first production or prototype HT components for independent evaluation



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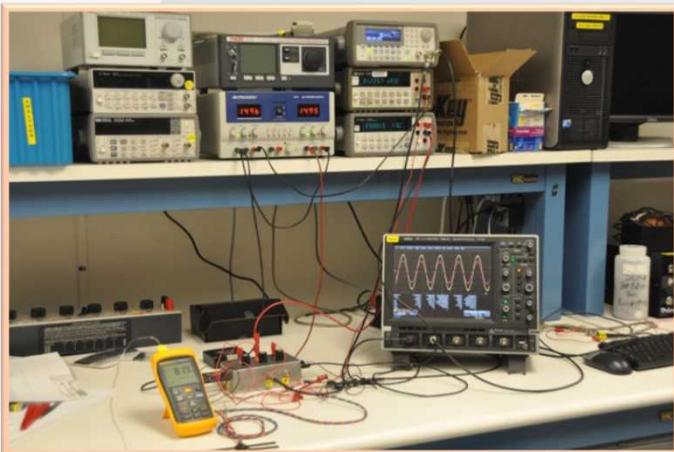
HT Electronics Testing



ARRA Tool Temperature Testing



Vessel for HT/H₂ Resistant Fiber Testing



Lab Testing of GE SiC Opamp



Clamping Arm Force Testing



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High Temperature PTCS Tool

■ Unshielded PTCS Tool

- Operating temperature up to 240C
- Pressure, temperature sensors
- Measurement of fluid flow via spinner
- Collar counter
- All SOI electronics

■ Devar Flasked PTCS Tool

- Operating temperature >350C



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High Temperature Seismic Tool

■ Capabilities

- Operation up to 210°C
 - SOI electronics except FPGA and Primary ADC
 - 24-bit ADC
- Three-axis accelerometer measurements
 - 30 Hz – 1000 Hz bandwidth
 - 20 V/g sensitivity
 - 295 μ g – 165 mg measurement range



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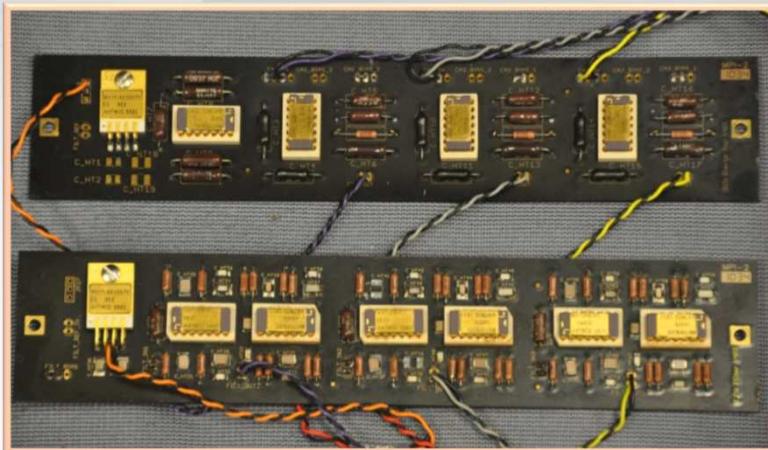
HT Charge Amplifier MCM

- **Project Goal:** Design, test and fabricate a charge amplifier multichip module (MCM) to increase the temperature capability and sensitivity of accelerometer based seismic monitors
- **Performance Specifications:**
 - 10 V/g output
 - Wide frequency range
- **Design Features**
 - Fully differential input stage to minimize noise
 - Current output mode for direct cable drive
 - Not implemented on MCM due to space/cost/licensing restrictions
 - Configurable as an instrumentation amplifier for use in interfacing to geophones, pressure sensors, and temperature sensors



HT Charge Amp Size Reduction

HT Seismic tool charge amp/filter boards



10.7 in²/channel

Charge amp MCM package



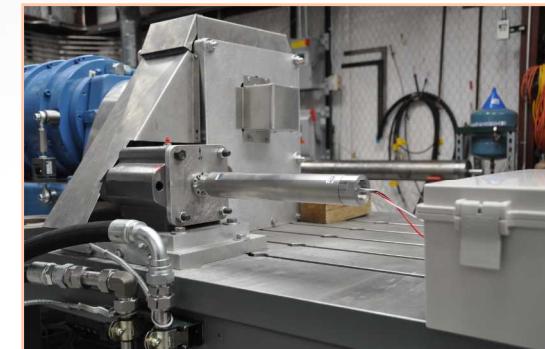
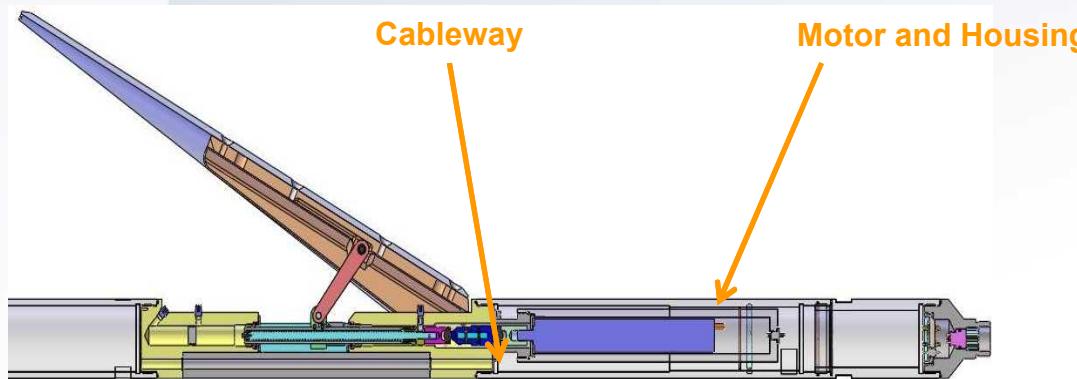
1 in²/channel



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Fiber Optic Seismic Tool

- Project Goal: Modify Sandia's current high temperature seismic tool to allow integration with commercial fiber optic seismic sensors
- Design Features
 - New high temperature motor to increase temperature range of the tool (225°C - 250°C)
 - New HT motor controller
 - Redesigned cableway to allow for fiber optic integration



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HT High Speed Datalink

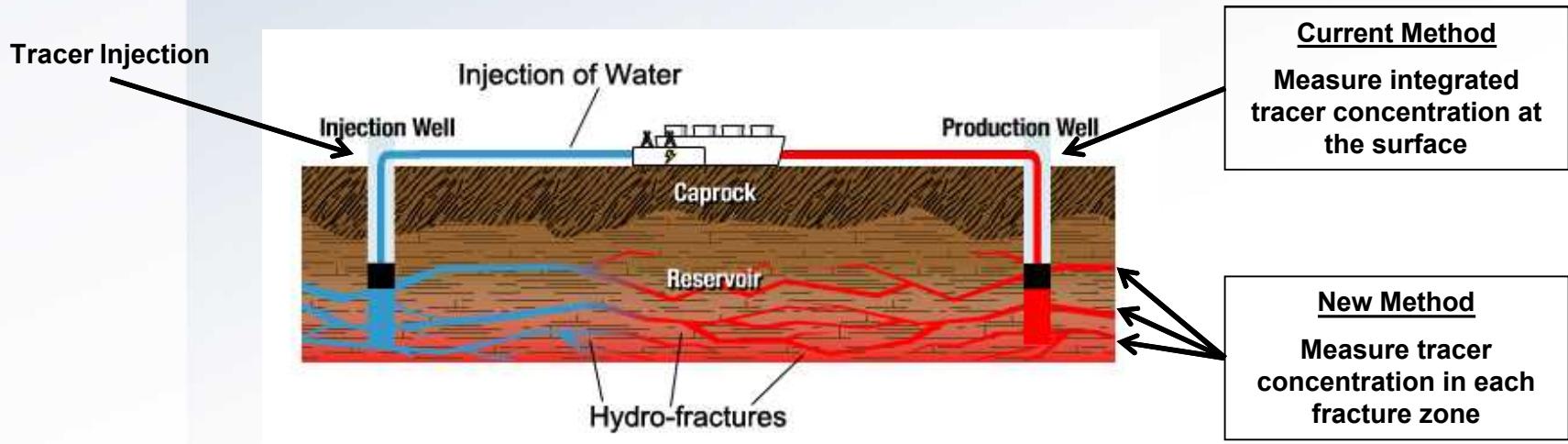
- Project Goal: Design, build and test the uphole and downhole components of a high temperature datalink
- Performance Specifications:
 - > 1 Mbps data rate at 5000ft of single conductor cable
- Design Features:
 - Leverages commercial telecom technologies
 - Adapts to well and cable conditions
 - Operates up to 210C
 - Higher temperatures possible at reduced speed
 - Mixture of HT SOI and HT TI components



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Chemical Sensing Tool Overview

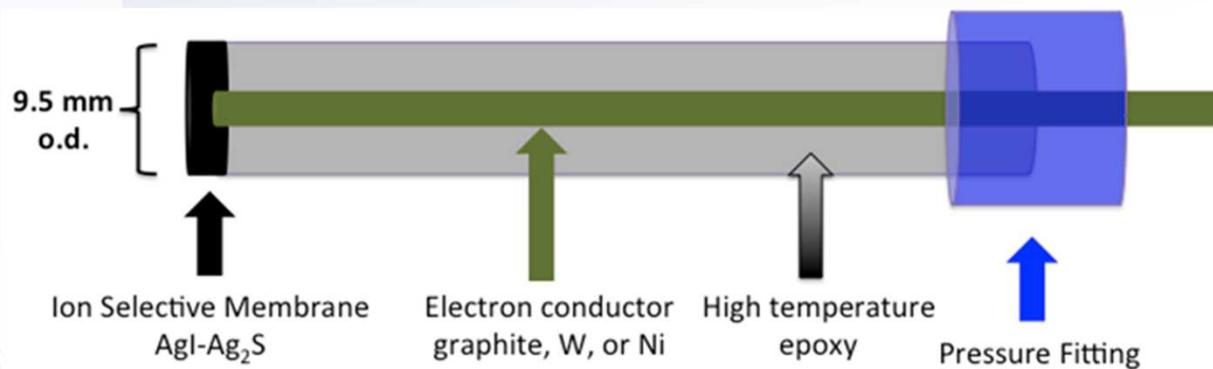
- Purpose: Design and built a prototype chemical sensing tool that can measure tracer concentration along the length of a wellbore
 - This tool will increase data resolution and provide new types of data for the characterization of fracture networks in enhanced geothermal systems
 - Joint effort between the Geothermal Research Department and Microsystems Enable Detection Department



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Proposed Capabilities

- The tool will operate up to 225°C
- Sensors
 - Temperature
 - Pressure
 - Fluid pH
 - Chemical concentration (goal: ppb level detection)
- Both manmade and natural tracers are under consideration
 - Natural: Li, Cs, or F ions (or other ionic compounds released during the fracture process)
- The prototype tool will only detect a single type of tracer
 - Sensors may be interchangeable



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High Temperature Fiber Optic Data Transmission

- The goal of this project is to develop a high temperature ($>250^{\circ}\text{C}$) high speed ($>1 \text{ Mbit/s}$) fiber optic data link
- High speed downhole data links are required for imaging tools and multi-level seismic tools
 - High temperature wireline is generally limited to 200 kbps or less depending on cable length and characteristics
- A high temperature data link coupled with high temperature sensor electronics can allow real-time tools to stay in the well for longer periods of time



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