

# Geothermal Research at Sandia National Laboratories

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## Geothermal Research Overview

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Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

# 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

# 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
- ...





# **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***

# 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



# Drilling Dynamics Increase Drilling Costs

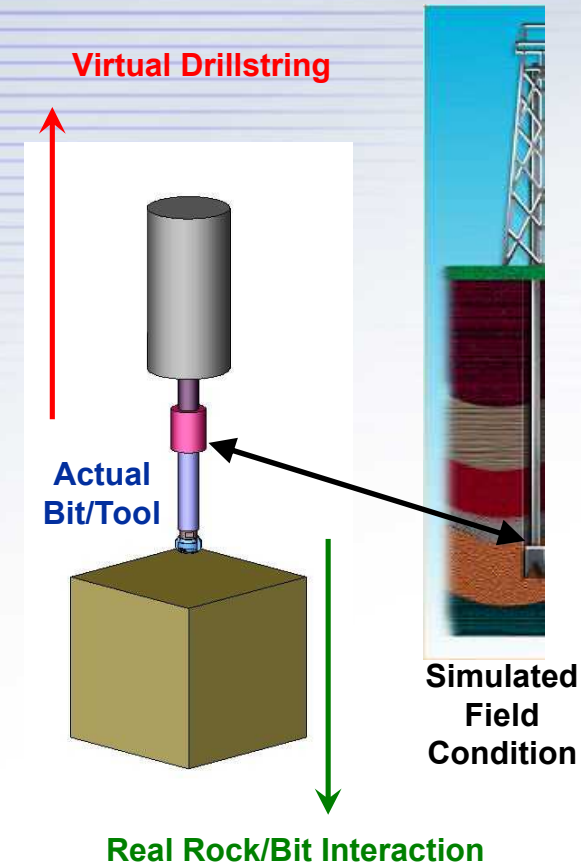


- **Drilling dynamic dysfunctions are one of the leading causes of Non-Productive Time**
- **The bit, BHA / drillstring and formation interact in a complex way resulting in a variety of vibration related problems**
  - **Low Rate of Penetration -- Inefficient Drilling**
  - **Bit & Tool Failure -- Excessive 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**



# 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





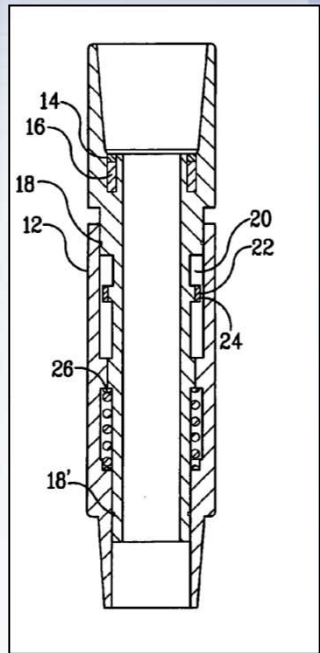
# Active Vibration Control

- **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**



# Diagnostics-While Drilling (DWD)

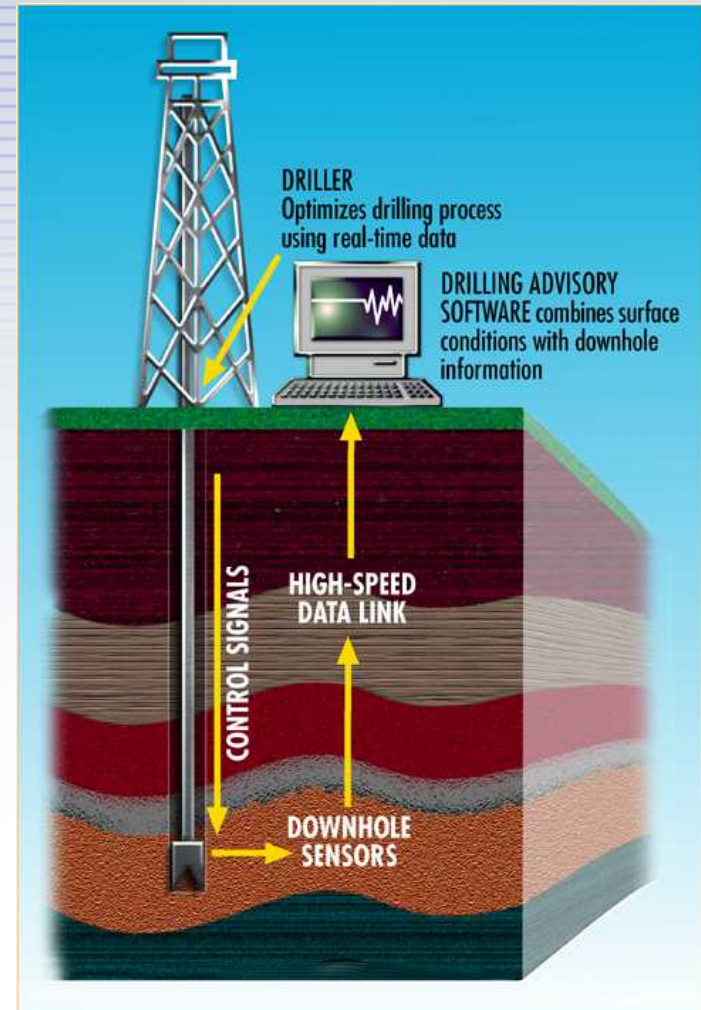
**Measurement sub** – acquires, conditions, and transmits downhole sensor data

**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.



# 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***



Sandia National Laboratories



# 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 H<sub>2</sub> 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



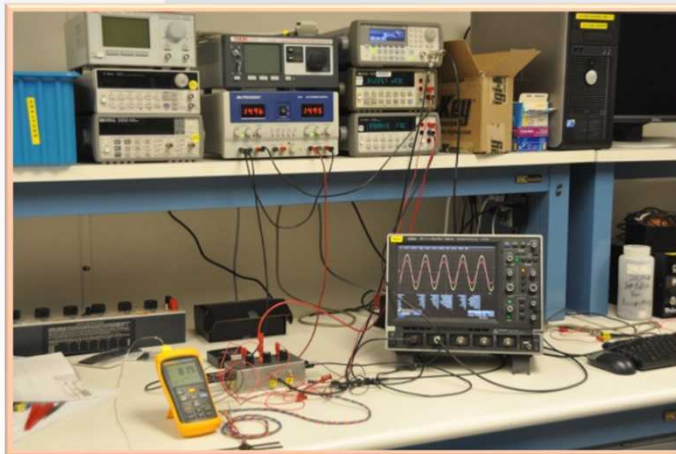
# HT Electronics Testing



***ARRA Tool Temperature Testing***



***Vessel for HT/H<sub>2</sub> Resistant Fiber Testing***



***Lab Testing of GE SiC Opamp***



***Clamping Arm Force Testing***

# 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 Flashed PTCS Tool

- Operating temperature  $>350\text{C}$



# 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  $\mu$ g – 165 mg measurement range





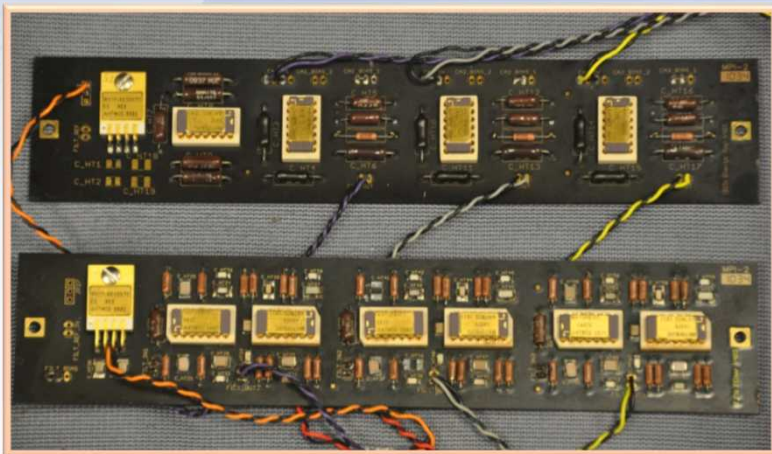
# HT Charge Amplifier MCM

- **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 in<sup>2</sup>/channel

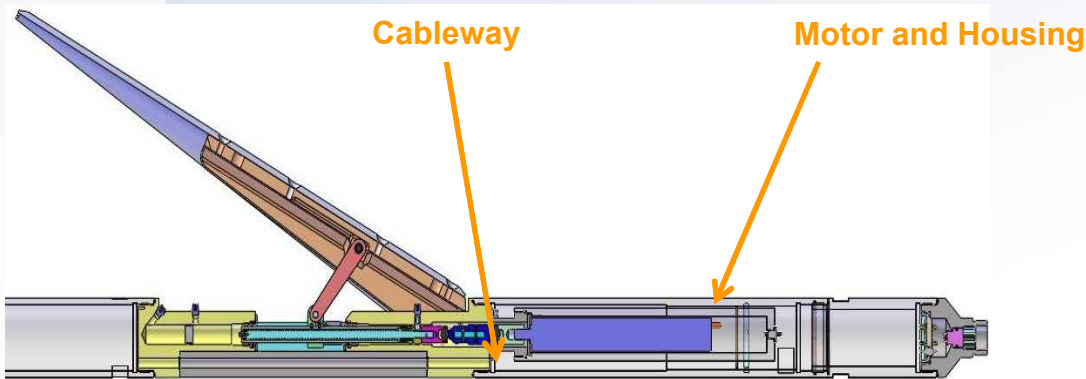
Charge amp MCM package



1 in<sup>2</sup>/channel

# 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



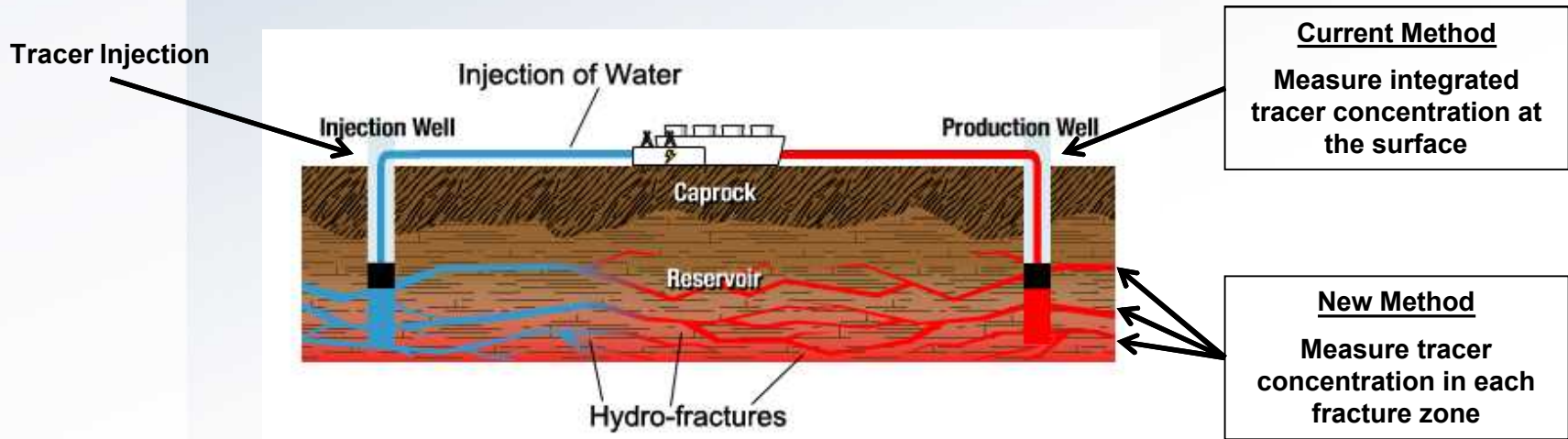
# HT High Speed Datalink

- **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



# Chemical Sensing Tool Overview

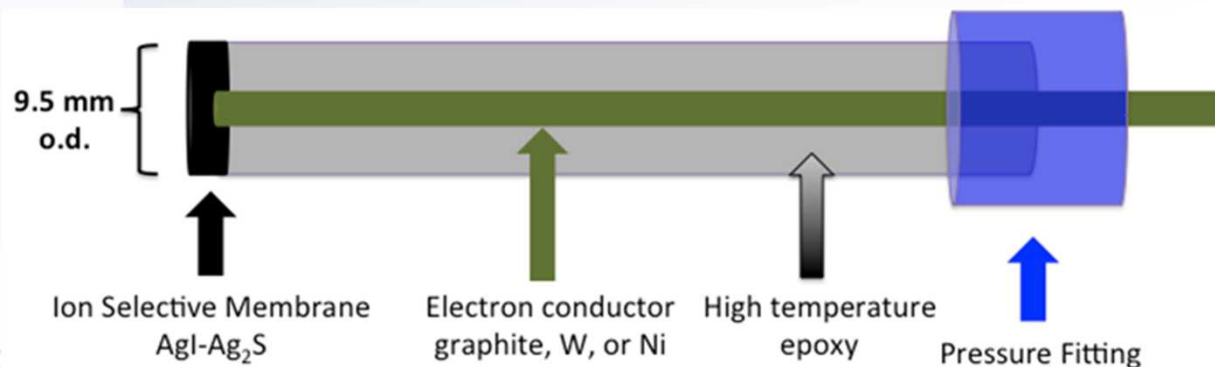
- **Purpose:** Design and build a prototype chemical sensing tool that can measure tracer concentration along the length of a wellbore
  - This tool will increase data resolution and provide new types of data for the characterization of fracture networks in enhanced geothermal systems
  - Joint effort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





# 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



# High Temperature Fiber Optic Data Transmission

- The goal of this project is to develop a high temperature ( $>250^{\circ}\text{C}$ ) high speed ( $>1$  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

