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Exceptional service in the national interest

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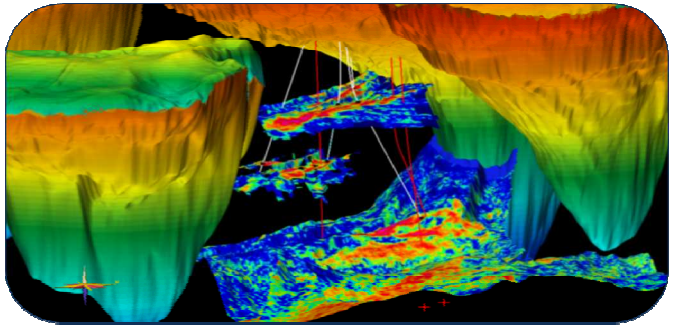

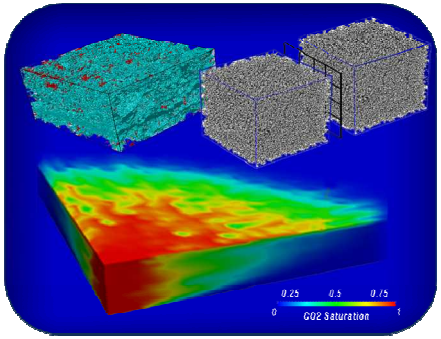

Geothermal Research
Sandia National Laboratories

Doug Blankenship, Manager

U.S. DEPARTMENT OF ENERGY

NNSA Nuclear Security Administration

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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 modeling and simulation
    - Vibration mitigation
    - Downhole telemetry
  - Key to the future of EGS

- Applying capability and technology to other industries and agencies
  - Frontier oil & gas, unconventionals, environmental, mine rescue
- Technology transfer to industry
  - PDC bits
  - High temperature electronics
  - Acoustic telemetry
  - Active vibration control

Geothermal Research Complements Mission of Geoscience Research Foundation

Sandia National Laboratories

1. Underground Access
   - Wellbore construction technologies allow preferred access to subsurface geology via design of wellbore interface
     - Rock Reduction Technology
     - Advanced Tool Development
     - Drilling Vibrations Research
     - Drilling Systems Field Trials
2. Subsurface Characterization
   - Via HT Electronics and diagnostics
   - Geo - mechanics modeling
3. Subsurface Engineering
   - Developmental fracking technologies

Rock Reduction

- Polycrystalline Diamond Compact (PDC) Bits
  - Fundamental work
    - FEM analyses, Bonding, Cutter tests, Bit design & analysis,

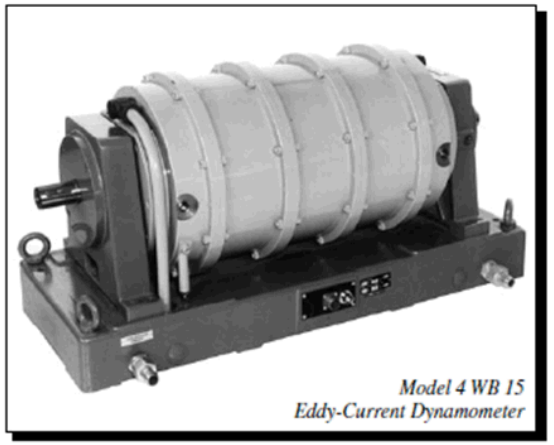
    Lab & field testing, CRADAs
  - Catalyzed a major industry (~ $1.5 billion)
  - Save industry $ billions annually
  - Over 60% of world footage today
  - Chocolate Mountains success is capstone

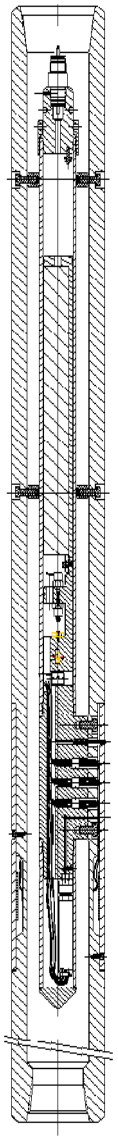
DOE Energy 100 Award for *Synthetic Diamond Drill Bits*

- Percussive Hammers
  - Efficient method to drill hard rock
  - Current limitations in HT Environment
  - Working with DOE and Industrial partners
  - R&D effort to apply increased power for fast drilling systems (e.g., Mine Rescue)
- Advanced Developments
  - Mudjet Augmented Bit - Cavitating jets for hydraulic augmentation
  - Downhole energy conversion for increased power delivery

Advanced Tool Development

- Diagnostic While Drilling (DWD) Sub
- Acoustic telemetry
- Vibration Management
  - Magneto-Rheological Fluid Damper
  - Active Compliance Elements
- Downhole Motors
  - Conventional solutions temperature limited
  - Sandia developing proprietary concepts
- Wellbore Diagnostics
  - Borehole Televiewer

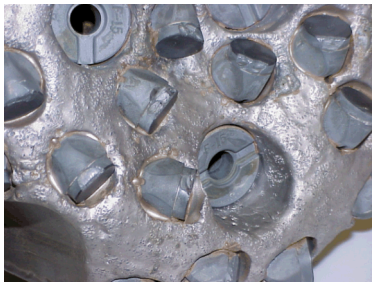




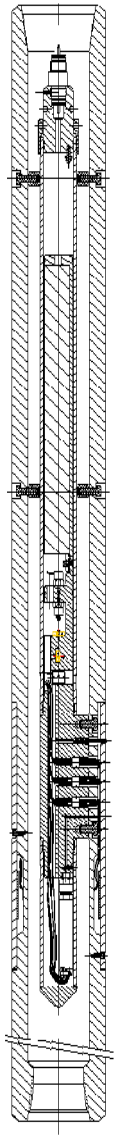
7” diam
DWD Tool

Drilling Vibrations Research

- Problem
  - Drilling dynamic dysfunctions are one of leading causes of Non-Productive Time
  - The bit, BHA / drill string 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
    - Tripping the drill string to replace the bit on an off-shore rig can exceed 1 million dollars



- Projects
  - Diagnostics While Drilling (down hole field measurements)
  - HRDF (laboratory drilling facility)
  - Drilling Dynamic Simulator (deep drill string simulator)
  - MR Fluid Damper Patent (down hole tool with controllable magneto-rheological fluid)



7” diam
DWD Tool

Drilling Systems Field Trials

- Survey advanced drilling technologies from other drilling sectors
- Provide industry assistance during well construction
- Develop and demonstrate developmental technologies (e.g., DWD)
- Migrate and demonstrate advanced technologies
  - Apply mature/proven rock penetration systems used in Oil &Gas/Minerals industry to improve geothermal drilling technology
  - Currently Partnered with
    - Navy Geothermal Program
    - Barbour Drilling
    - National Oilwell Varco/Reed Hycalog
    - Atlas Copco

High Temperature Electronics

- High temperature downhole instrumentation
  - Microseismic monitoring tool
  - Pressure/temperature/spinner/collar counter locator tool *(240˚C unshielded/400˚C shielded)*
  - Downhole fluid sampler and chemical sensor for in-situ tracer measurement – *FY13 new start*
- Enabling technologies R&D
  - Charge amplifier multichip module
  - High temperature motor controller
  - Optics for geothermal environments
  - Digital communication and signal processing for logging cables
- Integration with other Sandia programs
  - Sensor development
  - Wide bandgap semiconductor research
  - Power electronics
  - Microelectronics

Environmentally Friendly High-Rate Well Stimulation Methods

- Developing new high energy stimulation techniques to enhance EGS permeability through dynamic loading of the formation
  - Enable near wellbore fracturing along with shear destabilization in the far field
  - Novel reactive gas generating material and injection methods to fracture the formation are being developed suitable for use at EGS well temperatures