Geothermal Research

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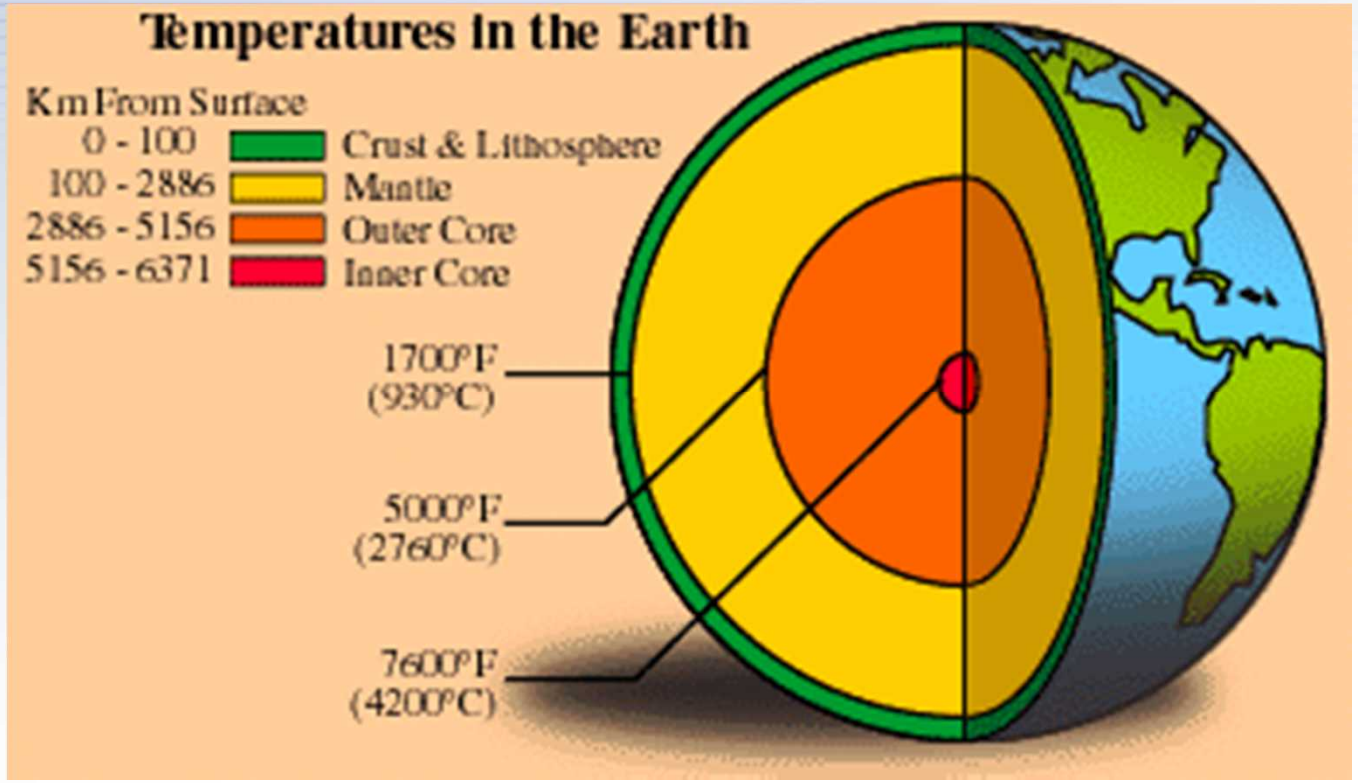
Geothermal Energy

Using the Earth's heat for electricity production, direct use applications, and as a heat exchange medium for geothermal heat pumps

The Earth's core is about the same temperature as the surface of the Sun



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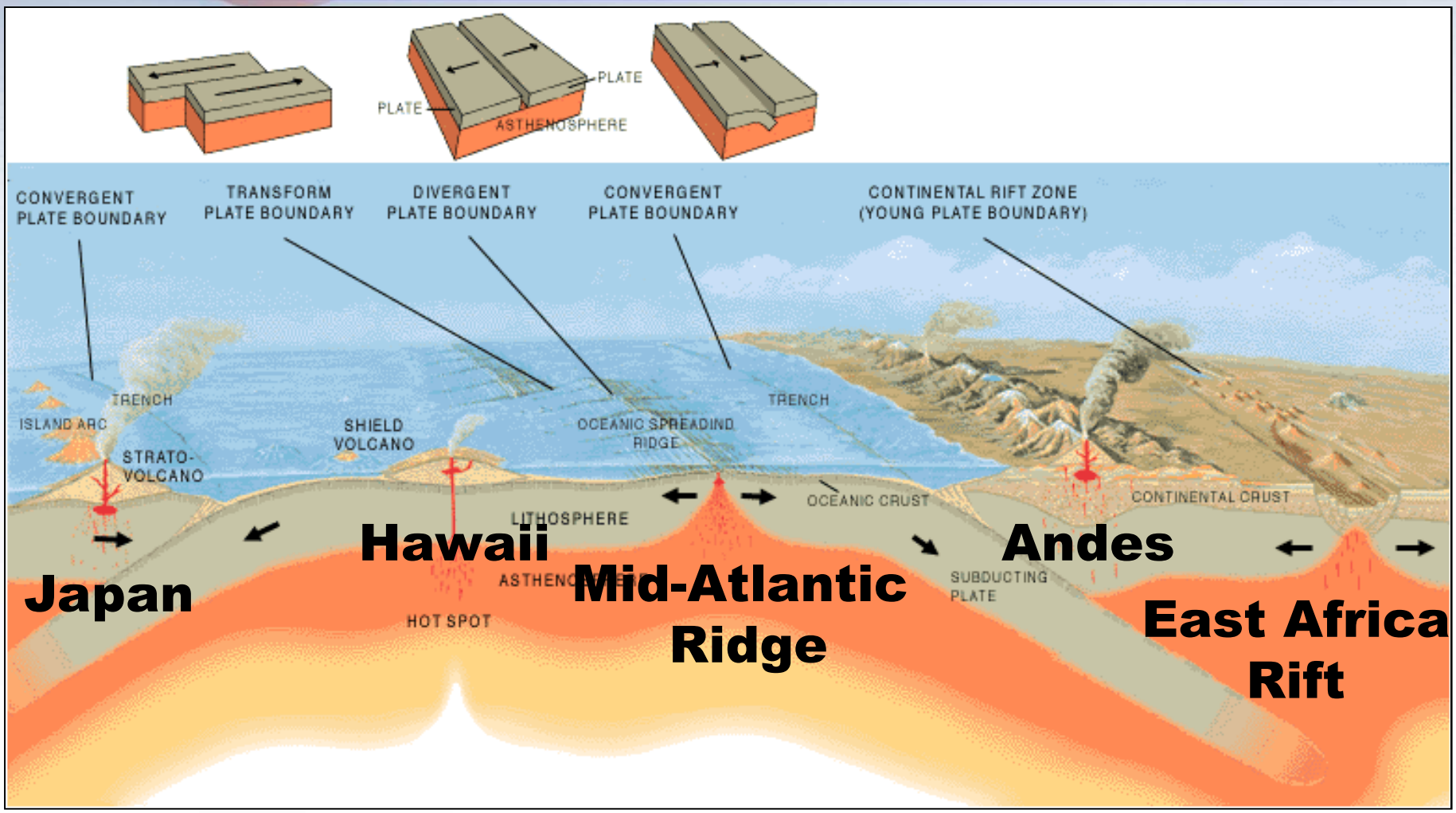
Heat Closest to the Surface at Plate Boundaries



Source: Fraser

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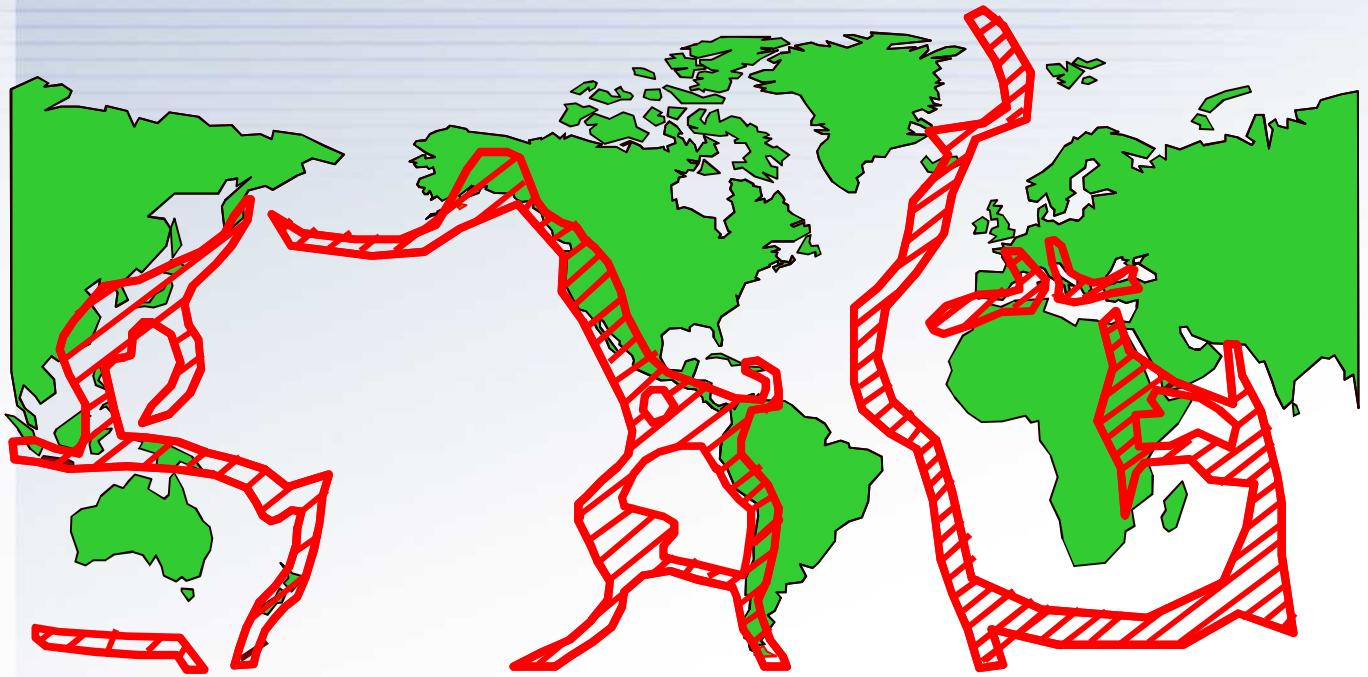
World Hydrothermal Resources

Worldwide Hydrothermal Electric Potential



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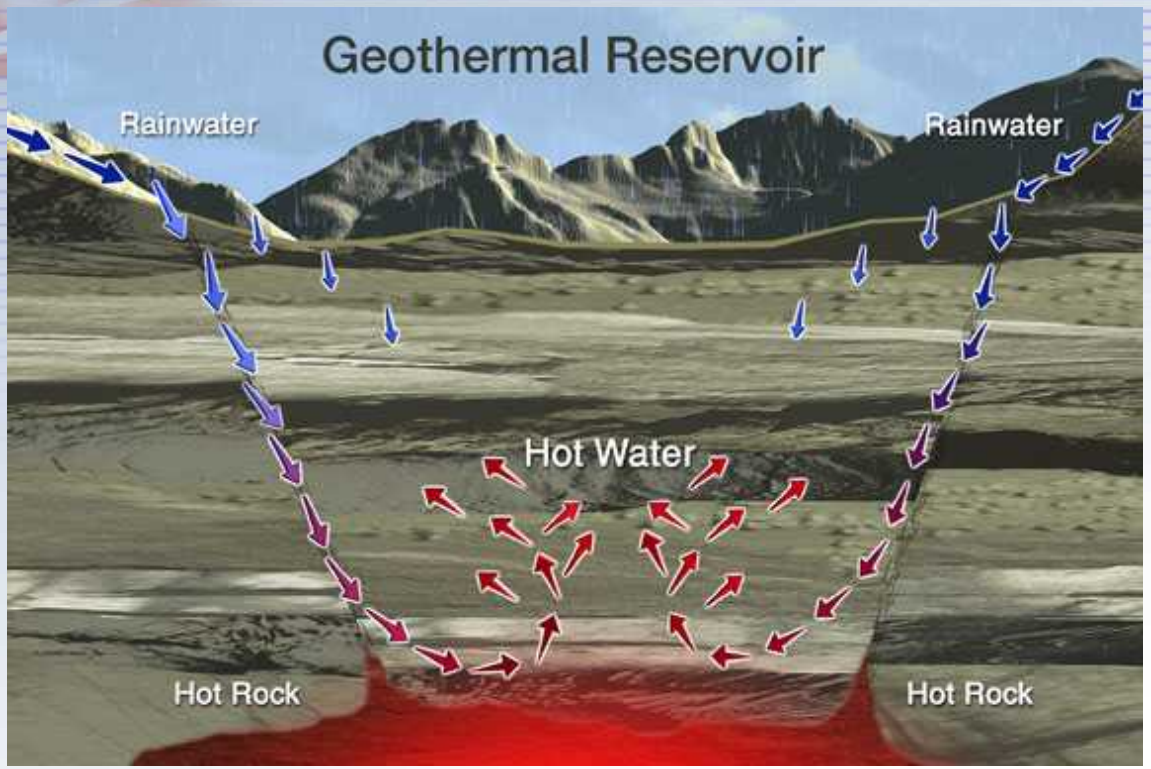
How Hydrothermal Geothermal Sites Are Created



Hydrothermal Geothermal resources are found where geological activity has brought hot rock near the surface. When hot water and steam is trapped under a layer of low permeability rock, it forms a geothermal reservoir.

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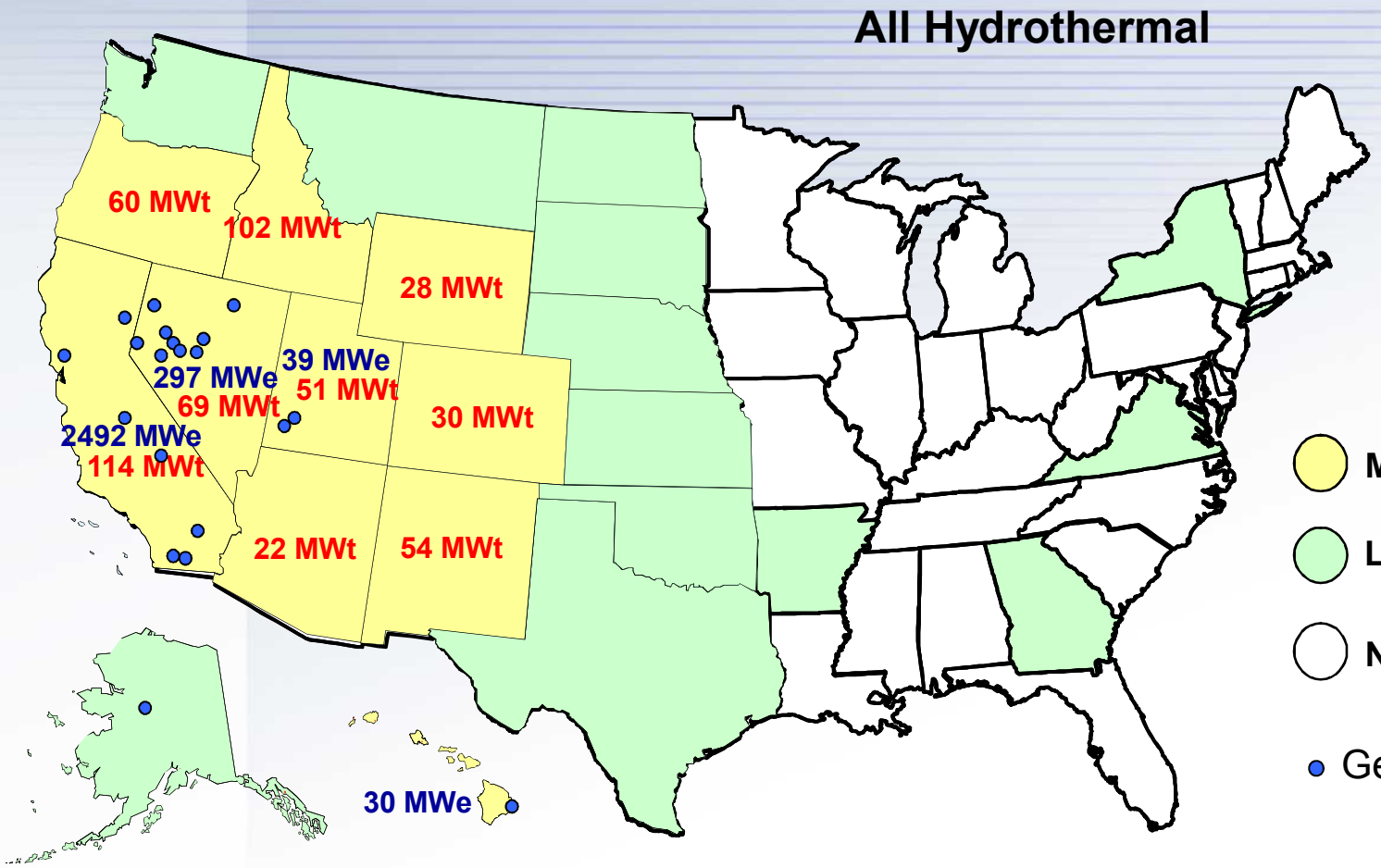
Installed Geothermal Capacity



Installed:
2851 MWe
600+ MWt

More Than 20 MWt

Less than 20 MWt

No installations

Geothermal Plant

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Geothermal Reservoir Requirements

- **Temperatures**
  - Greater than 350 °C to "warm"
    - Temperatures largely dictate use
      - Power generation to direct use
- **Permeability**
  - Measure of fluid transmission ability of the rock
    - Orders of magnitude variability
      - Tight to open
- **Fluid Availability**

Hydrothermal (current) → Enhanced Geothermal Systems (future)

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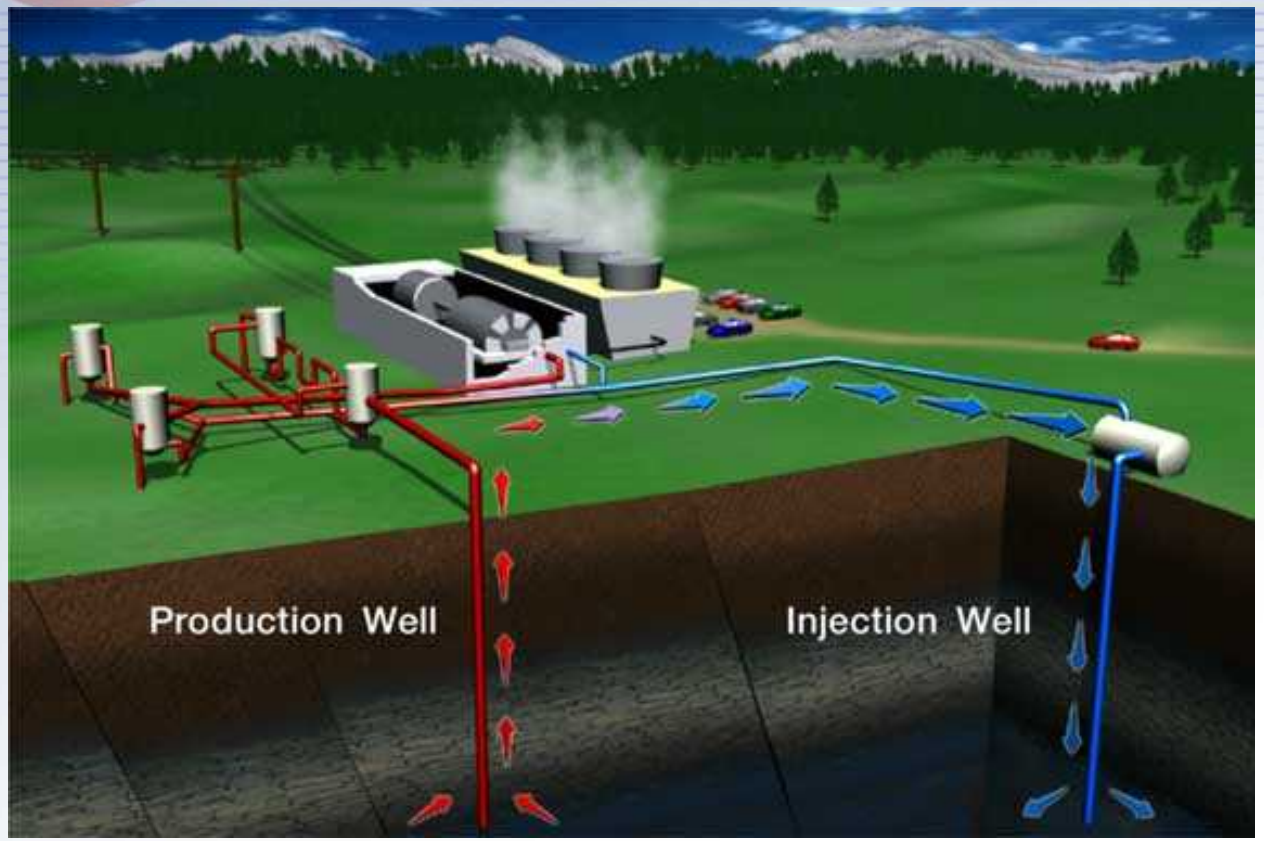
Geothermal Energy



Our focus in on electricity generation using hydrothermal and engineered geothermal systems (EGS)

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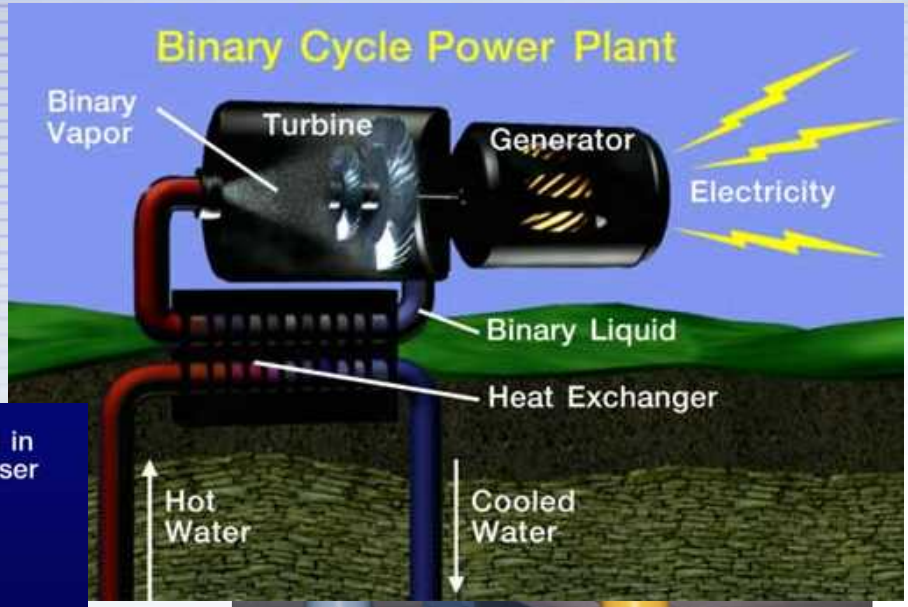
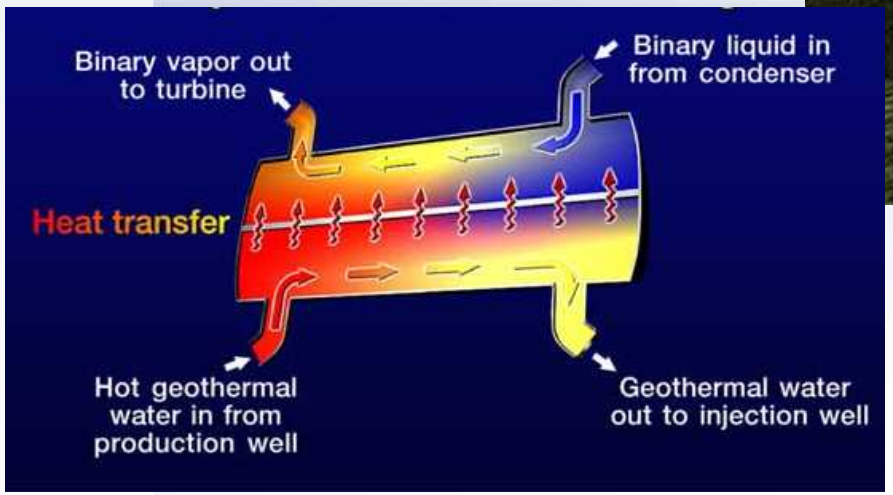
Binary Cycle Geothermal Plant

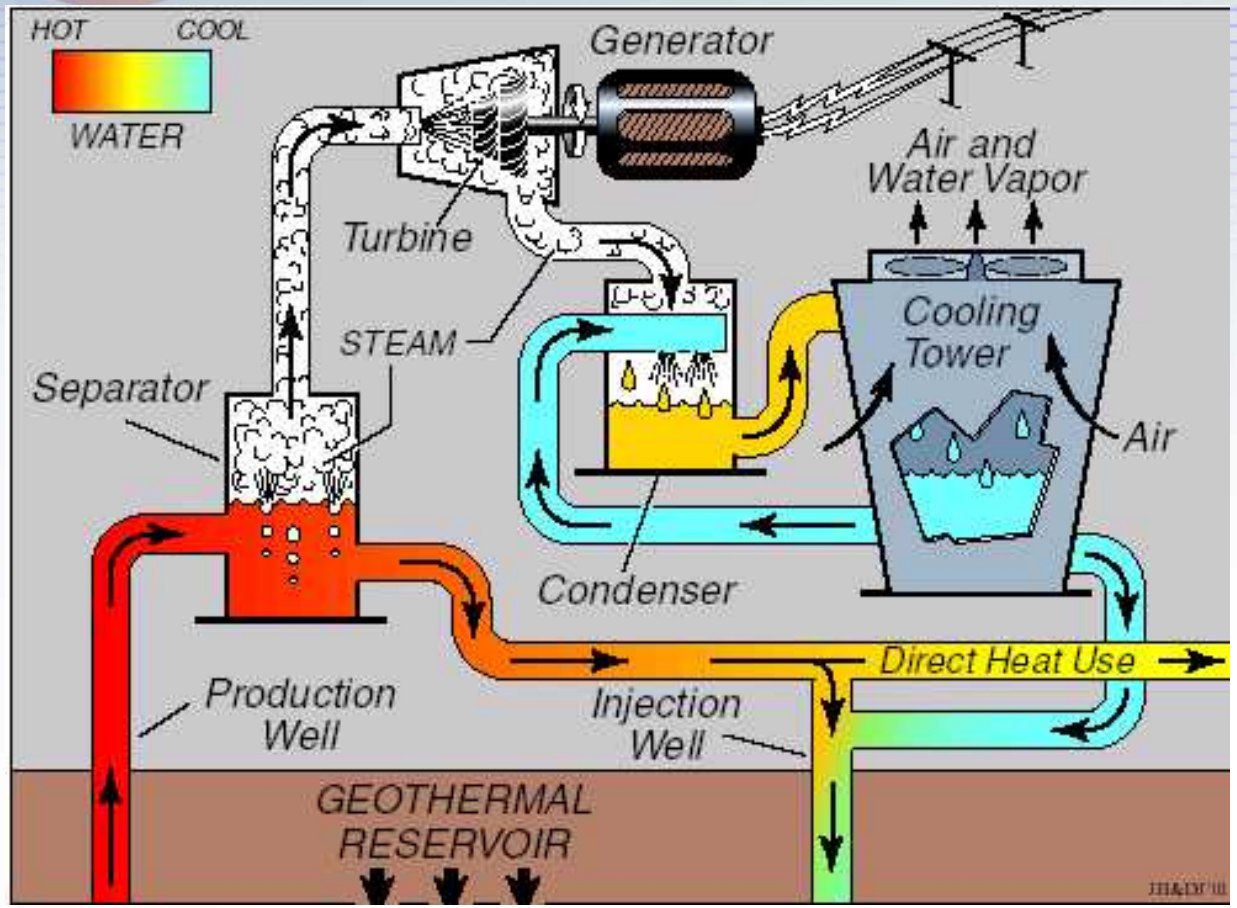
In a binary cycle plant, hot water is run through a heat exchanger to vaporize a working fluid that powers the turbine generator. The geothermal water is injected back into the reservoir.





This plate-type heat exchanger passes geothermal water over metal plates for heat transfer to the working fluid on the other side.

Flash Power Plant



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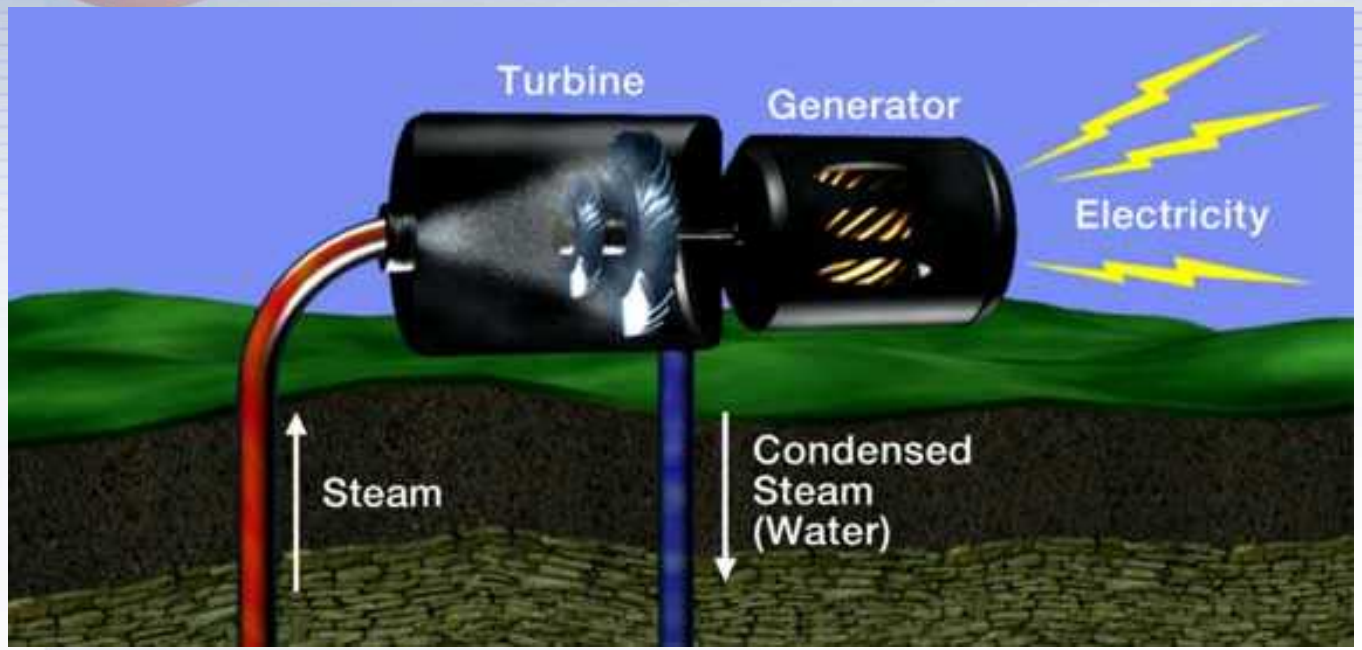
Dry Steam Power Plant



Courtesy of Geothermal Education Association

In dry steam power plants, the steam passes through a rock catcher (not shown) and then directly into the turbine. The steam spins the turbine blades, which spin the generator.

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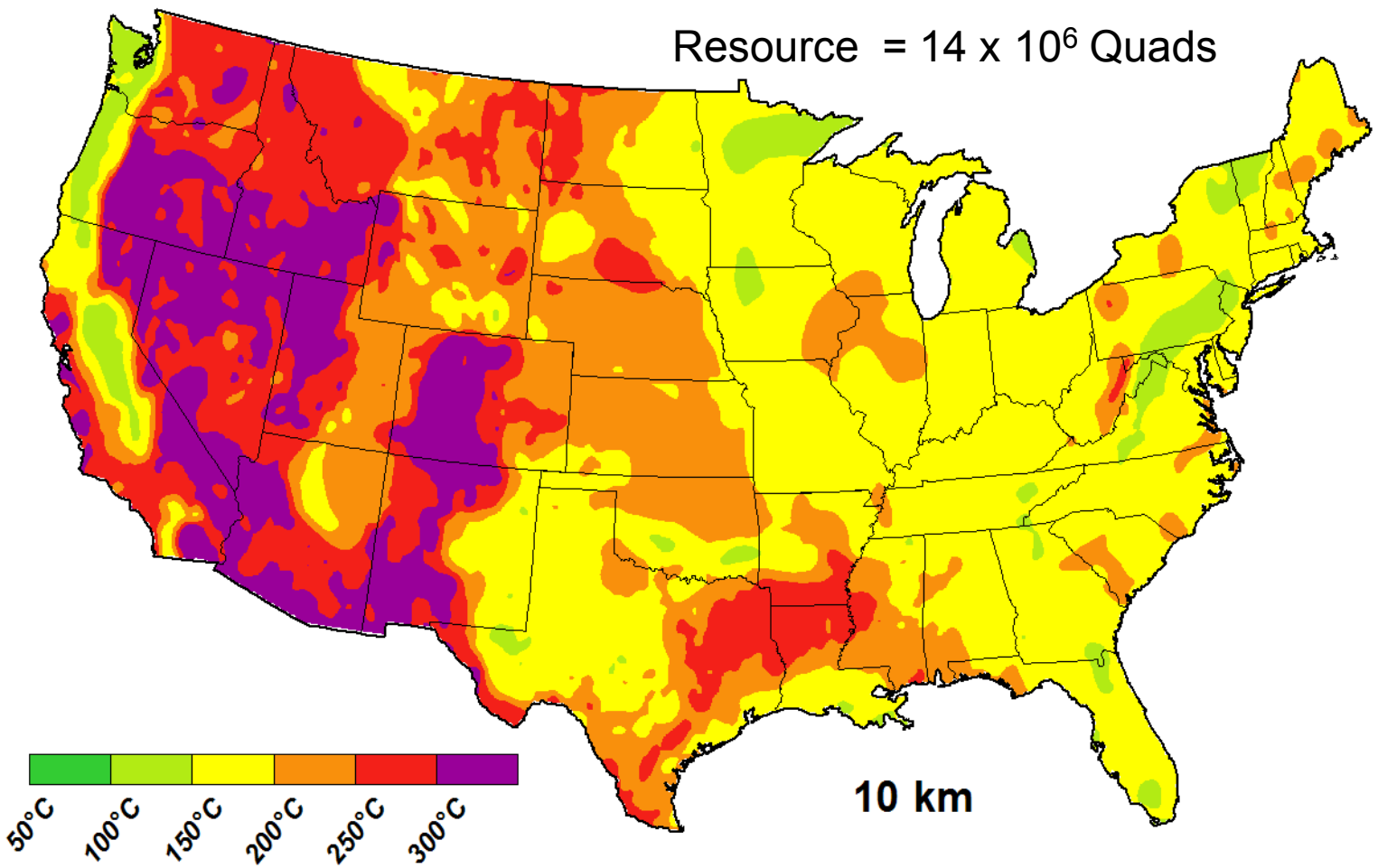
Geothermal Resource in the United States



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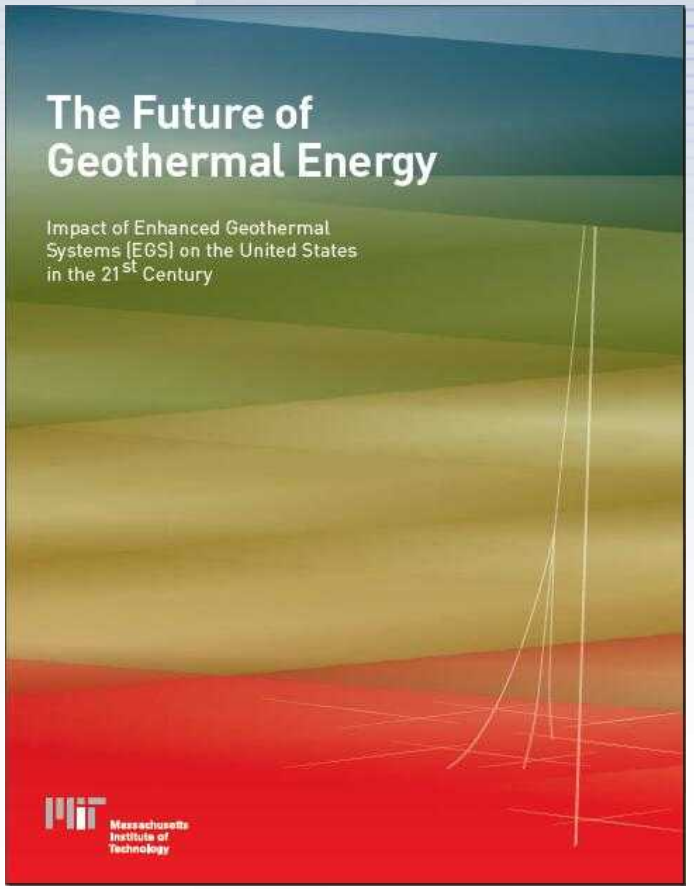
DOE Program Focused on EGS

Study of Enhanced Geothermal Systems (EGS) by MIT-Led Panel of Experts



Key Findings/Recommendations

- Extractable geothermal resource exceeds 2000 times the annual energy consumption of the United States
- EGS are versatile, modular, and scalable from 1 to 50 MWe unit sizes
- Technical issues are surmountable – no showstoppers
- Cumulative EGS capacity of 100,000 MWe can be achieved in the United States within 50 years
- Public/private investment of $800 million to $1 billion over 15 years would produce 100,000 MWe by 2050

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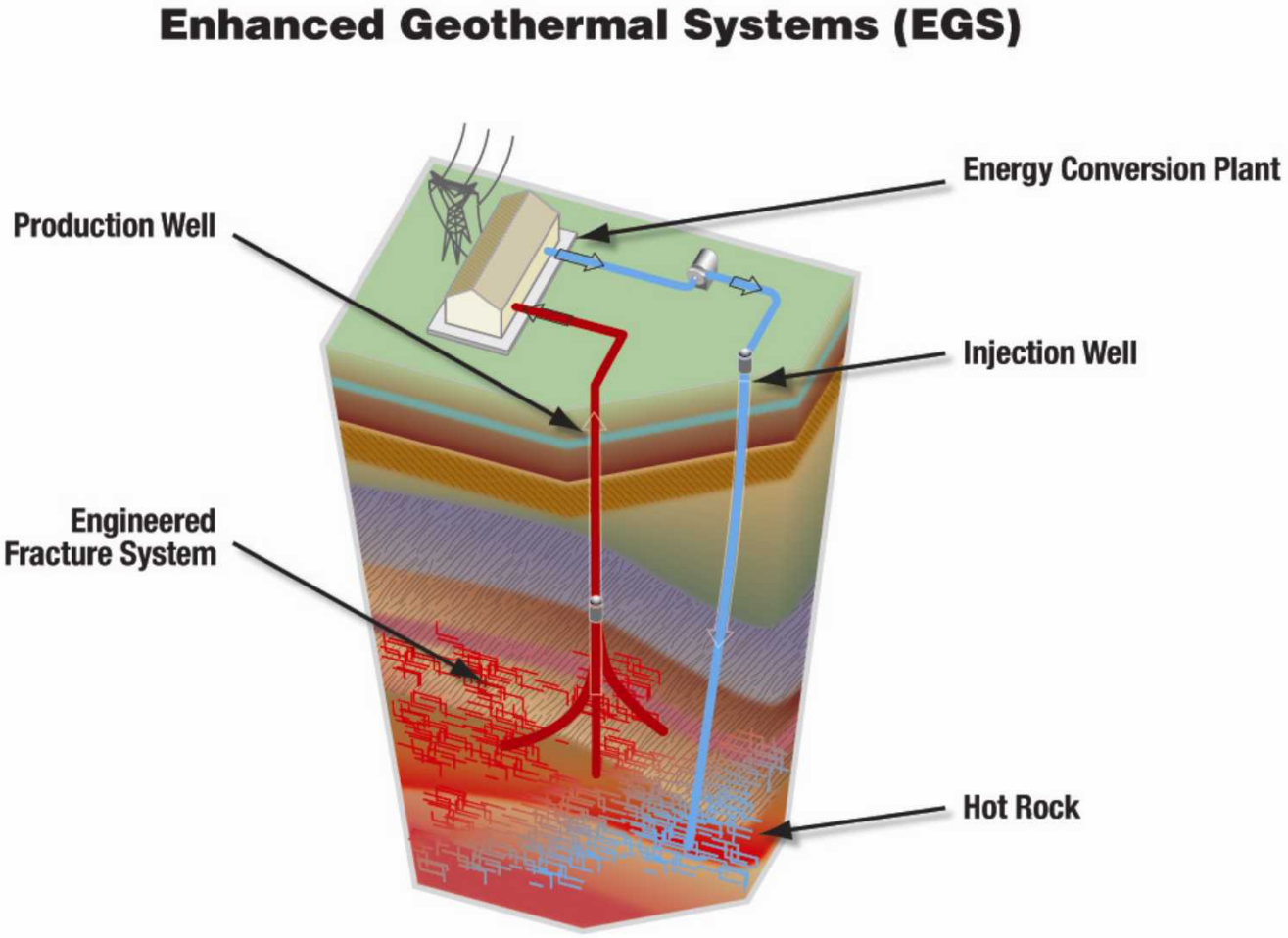
EGS System Components



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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, unconventionals, environmental, DOD, others**

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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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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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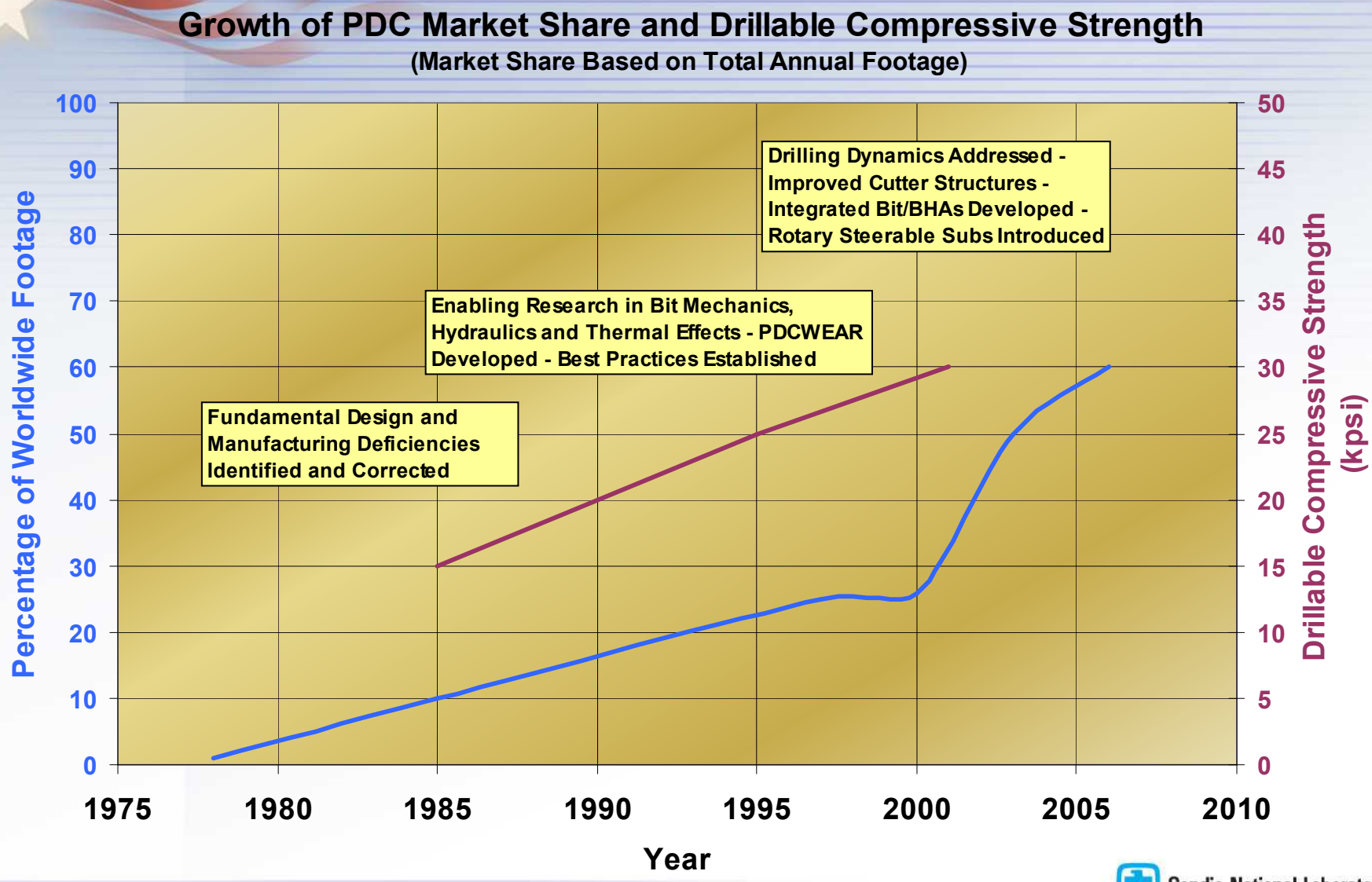
Growth of PDC Market Share



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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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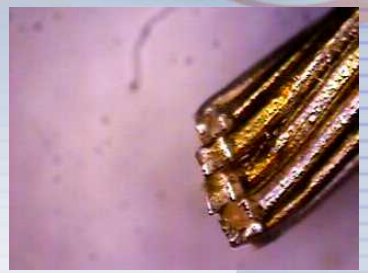
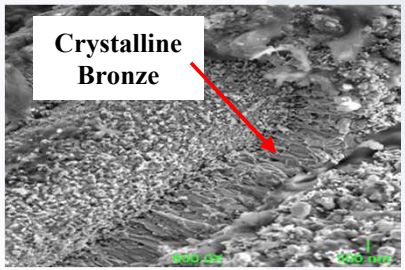
High-Temperature Electronics





- Includes components, tools, seals, batteries, fiber, …
- The enabling technology
  - High Temperature = High Reliability
- De facto “UL Labs” for high-temperature components
  - Work with almost all manufacturers
- Analyze failure and provide solutions
  - Exploit capabilities from weapons programs
- Develop tools and fabrication methods
  - Prototypes supplied to industry
- Broad application
  - Geothermal, aerospace, auto, O&G, PV, …
- Long-term testing
- Extensive interactions w/ industry motivate work activities

R&D 100 Award for *Solid State High-Temperature Batteries*

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Working with the High Temperature Industry

- Some of the companies we work with

Quartzdyne, UT
MRA Labs, MA
Presidio Components, AZ
Welaco, CA
Paine Electronics, TX
Multilayer Prototypes, CA
Halliburton, TX
Mitco, CA
Honeywell SSCS, MN
Kulite Semiconductor Products, MA
BP, TX
Cissoid, Belgium
Weed Instrument Company, TX
JH Capacitors, NV
Pacific Processes, CA
RdF Corp, NH
Kemlon Products, TX
Semisouth Laboratories, MS
Custom Electronics, MA
Baker Inteq, TX
Rockwell Scientific/ GTI, CA
Endevco Corp., CA
Biotronics
Schlumberger, TX
Regal Plastic Supply Co.
Solid State Devices, CA
Honeywell Richmond, WA
General Atomics, CA
Diamond Research, TX
Advanced Products, CO
Electrochemical Systems, TN

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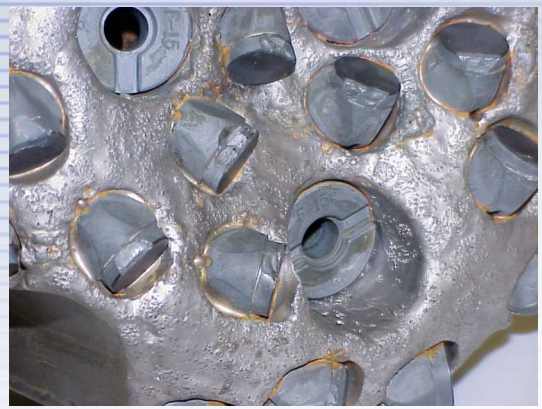
Drilling Dynamics Increase Drilling Costs



- 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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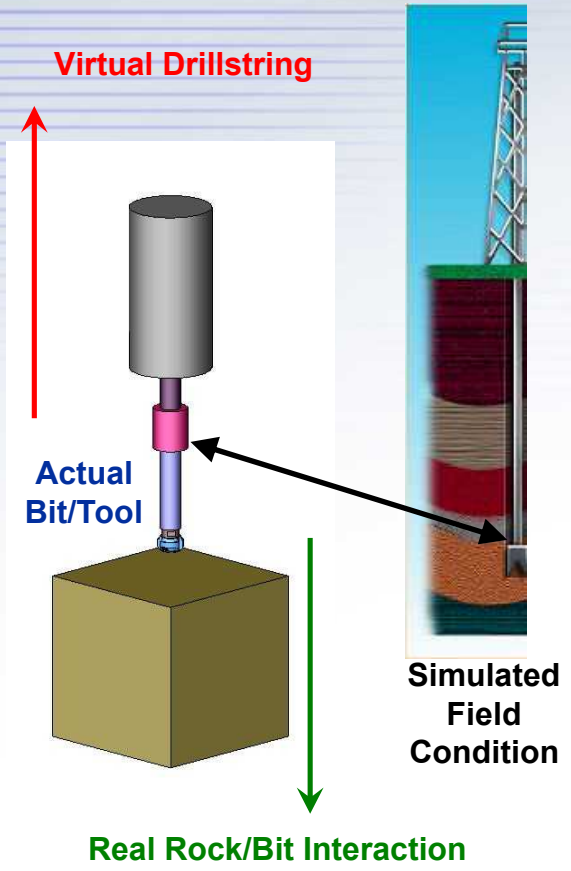
Simulation of Drilling Dynamics

- **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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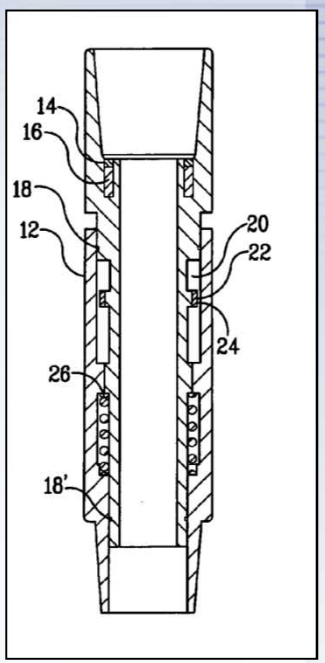
Active Vibration Control



- **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)

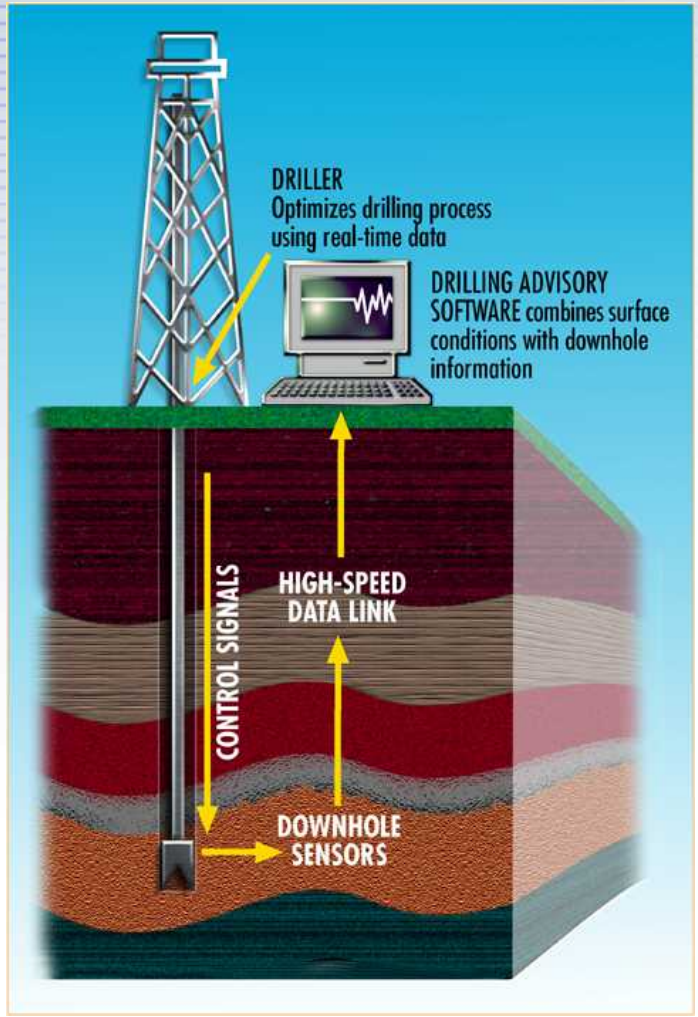
Measurement sub – acquires, conditions, and transmits downhole sensor data

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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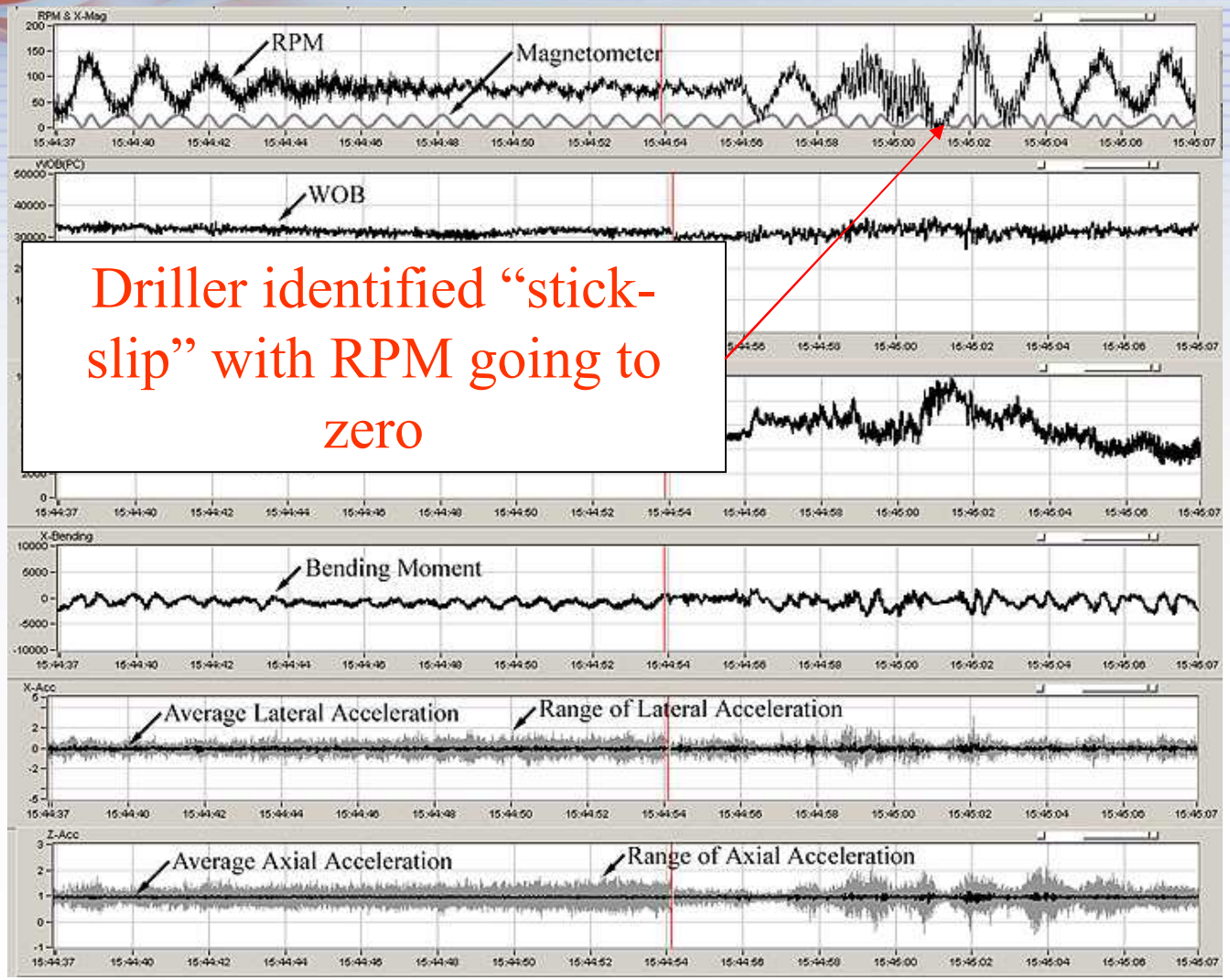
Drillers Can Use DWD



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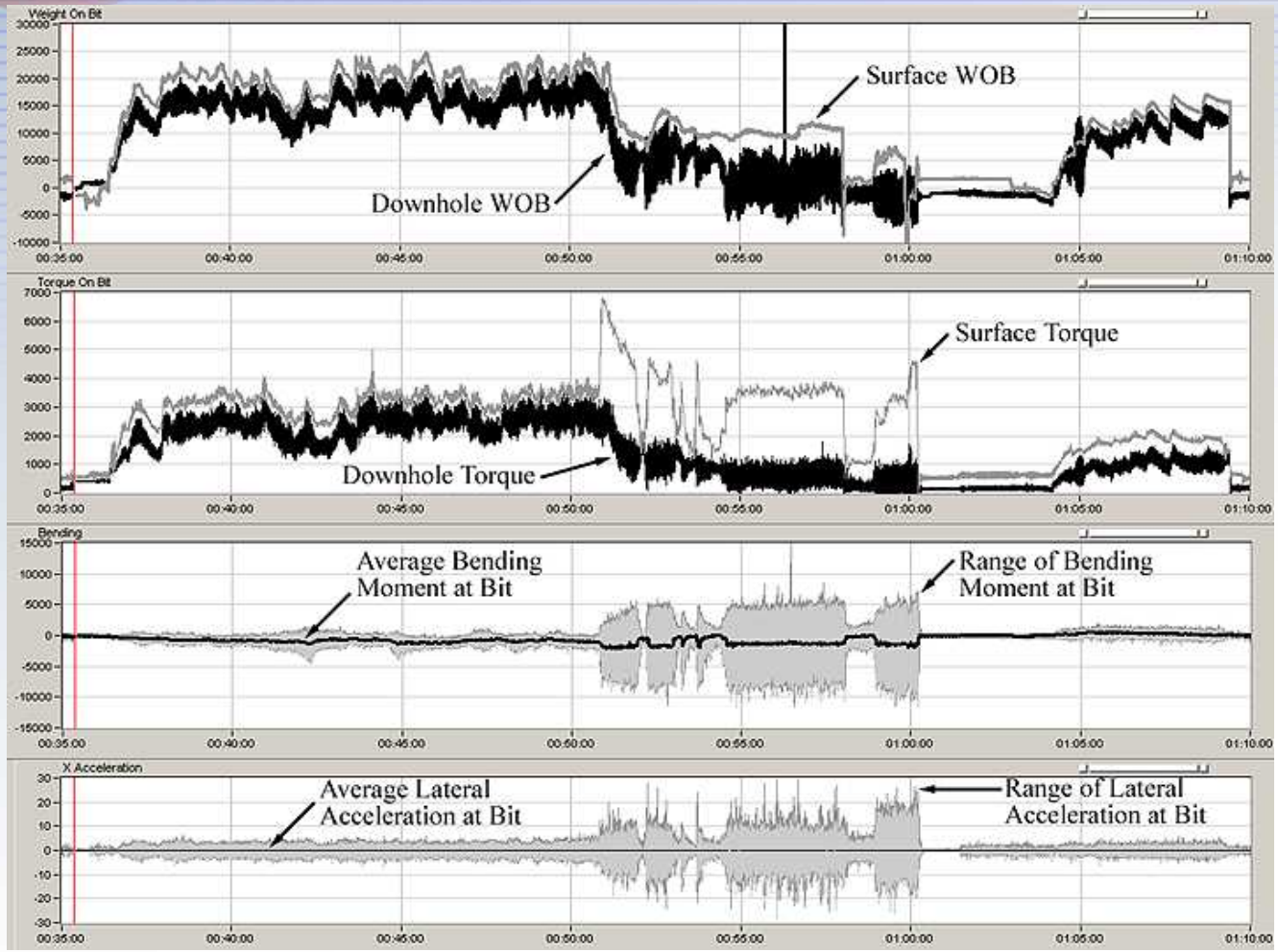
DWD Systems Can Help the Driller



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Thank You

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