Geothermal Drilling Research at Sandia National Laboratories

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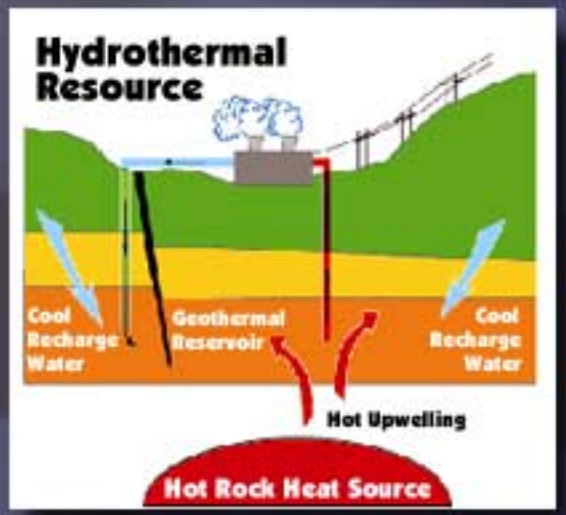
2001

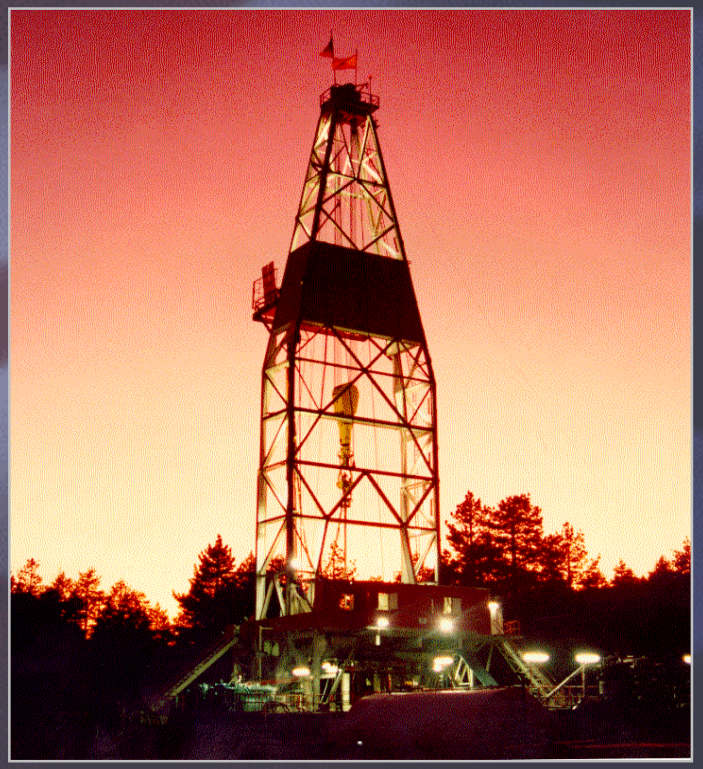
The Geysers, CA



Drilling Research Program Focuses on Reducing Well Construction Costs

… increasing the nation's proven geothermal reserves and assisting U.S. industry to expand the use of geothermal heat & power

- **Conventional Drilling:**
  - Develop technology for reducing the cost of geothermal wells by 25% or more
- **Advanced Drilling:**
  - Reduce drilling costs by another 25% through revolutionary developments in technology
  - Focus is on a Diagnostics-While-Drilling system for process monitoring and control



35% - 50% of a Geothermal Project Cost Is in Drilling and Completion

Challenges of Geothermal Drilling

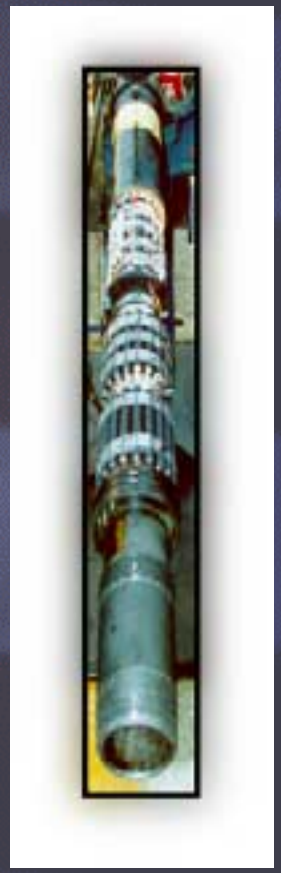
- **Hard Rock**
  - 35,000 psi compressive strength
  - Abrasive
  - ROP < 20 ft/hr, Bit life < 400 ft.
- **Lost circulation**
  - 15% of well cost
  - Large cracks (inches), difficult to plug
- **High Temperatures**
  - T > 600°F
- **Small Market**
  - # wells drilled per year < 0.1% of # Oil/Gas wells
  - Few $ for R&D

Geothermal Well at Imperial Valley, California

Reduction of Well Construction Costs Requires a Multi-Faceted Program

Lost Circulation Control

Hard-Rock Drill Bit Technology



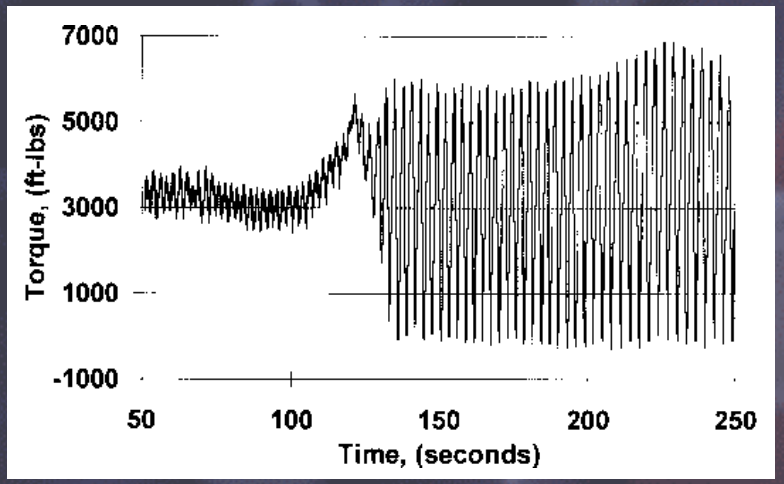
High Temperature Instrumentation

High Data Rate Telemetry

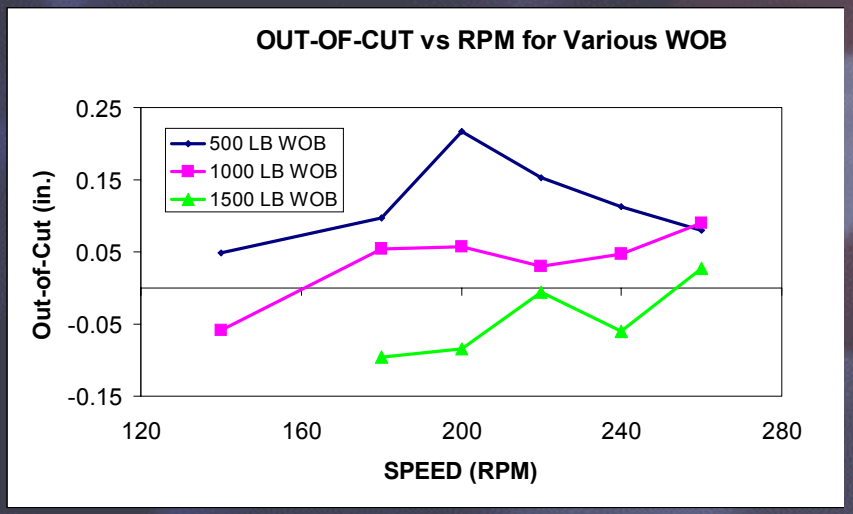
Hard-Rock Drill Bit Technology

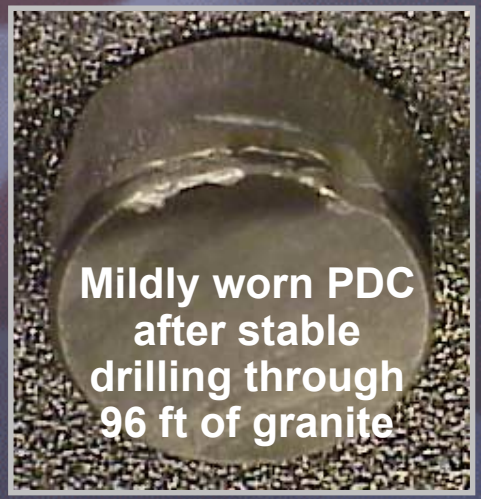
- **Objective:** Develop technology to double ROP and bit life in high-temperature, hard-rock drilling
- **Approach:** Work with drill bit companies and researchers to improve drag bit performance in harder rocks through modeling, materials research and testing

Vibrational Instability Limits PDC Bit Performance in Hard Rock



Test facility provides axial compliance





Sandia is Advancing HT Electronics for Downhole Applications

- Developing a simple unshielded data logger for 300ºC
  - Components are presently becoming available for a 250°C data logger
- Developing new HT batteries for 150ºC to 300ºC operation
- Sharing information with American industries, HiTED (High-Temperature Electronics Downhole)
- Supporting SBIR initiatives for new 300ºC components
  - Capacitors, large valued >10uF
  - MEM inclination sensors
  - High accuracy clock references
  - High accuracy pressure
  - Pressure/Temperature tool
- Developing HT, long-life fiber optics for sensing and downhole communications applications

We Are Testing Electronics At 300°C

83C51 Microprocessor

"Glue Logic" (54AC373, 54AC00)

32 Kbyte SRAM

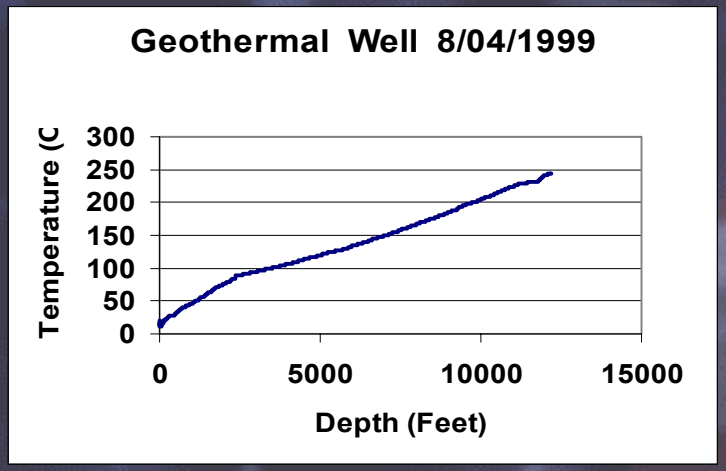
Temperature Sensor Circuit (HT 1104 Op. Amp.)

Initial testing

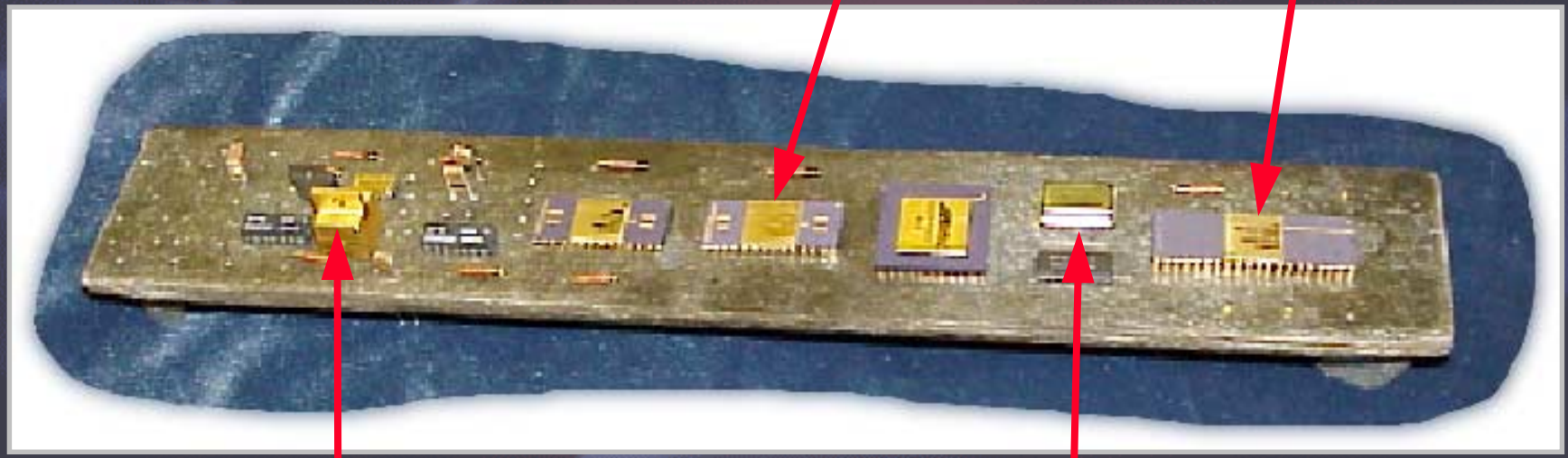
The above circuit demonstrated at HiTEN 98

Joe Henfling tested this first circuit to 300°C without failure.

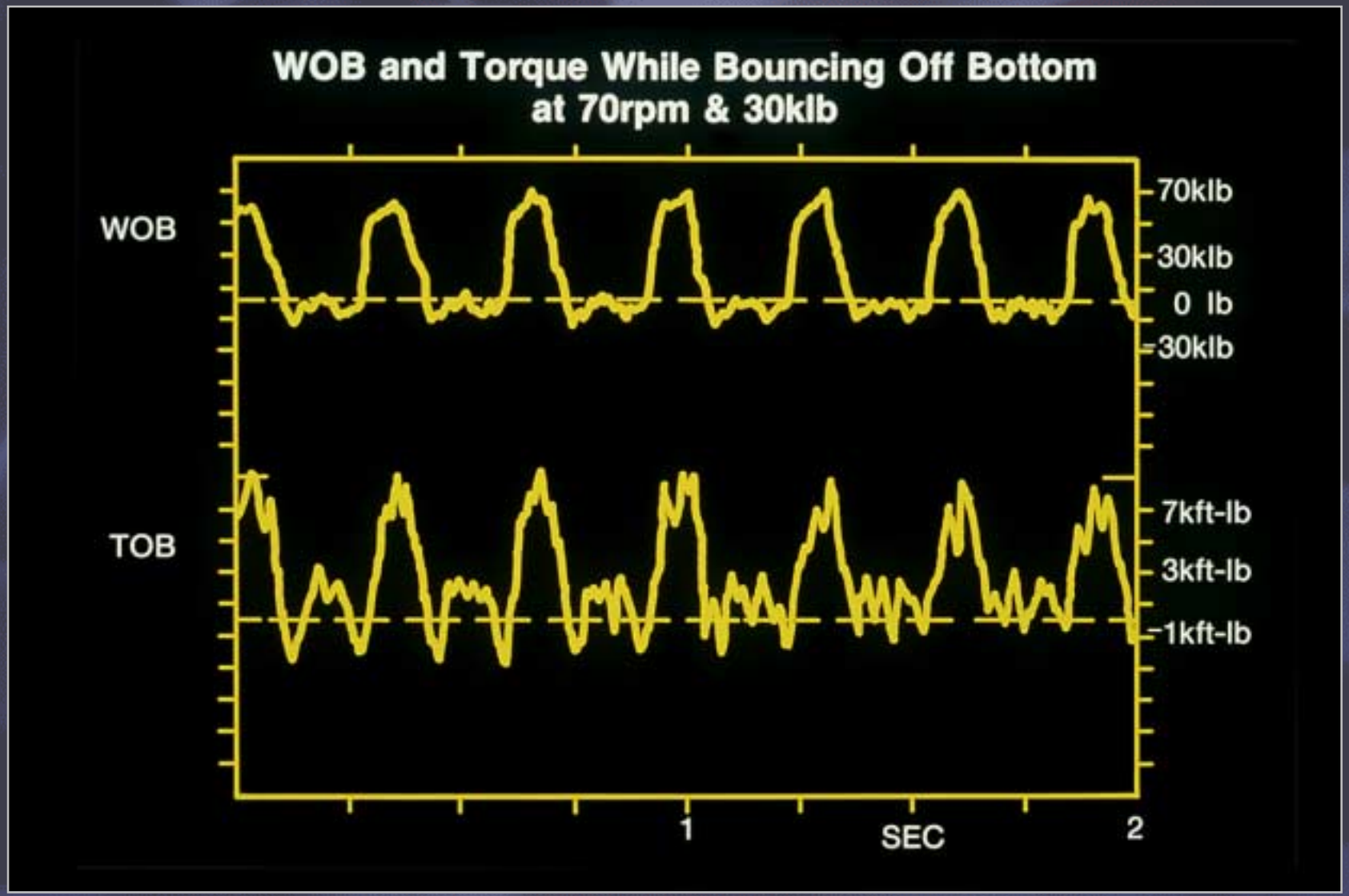
Prototype Data Logger Goes in Barefoot



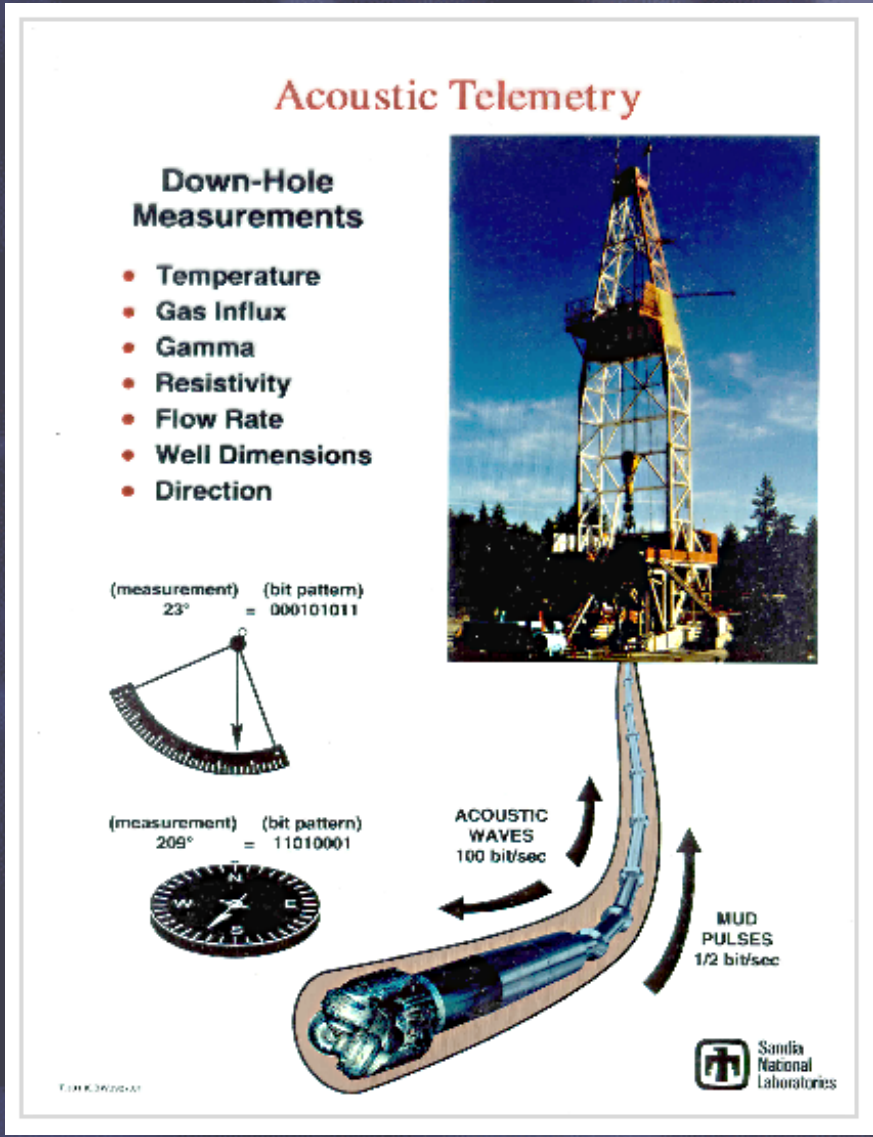
P/T tool ran 48 hrs at 240°C during log without heat-shielding



High Data Rates Are Needed To Improve Drilling Efficiency



Acoustic Telemetry Can Increase Data Rates

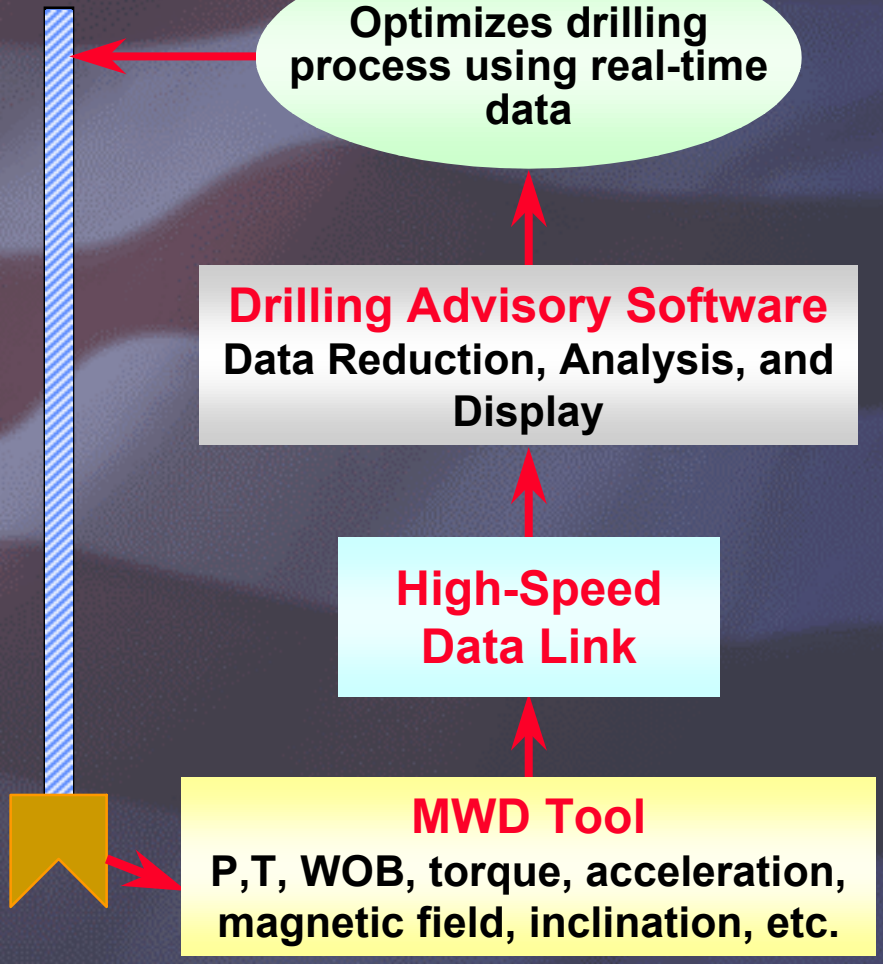


- Sound waves travel through steel pipe and can be used to transmit data
- These acoustic systems use frequency bands devoid of drilling noise
- Drill pipe threads and tool joints do not block these signals
- Two-way communication does not depend upon the condition or presence of drilling mud

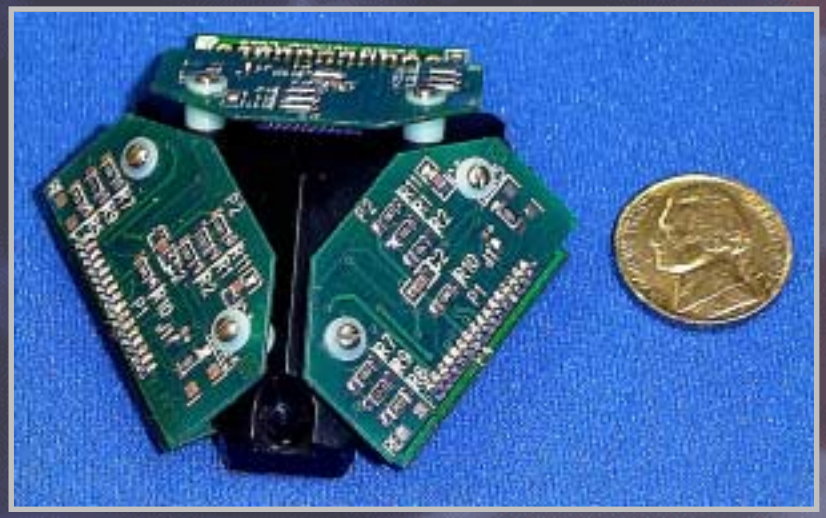
Diagnostics-While-Drilling System

… Provides the driller with instantaneous status of downhole tools and conditions so that drilling performance can be maximized

- **DWD System Consists of:**
  - Driller
  - Drilling Advisory Software
  - High-Speed Data Link
  - Measurement While Drilling Tool



Advanced Technology

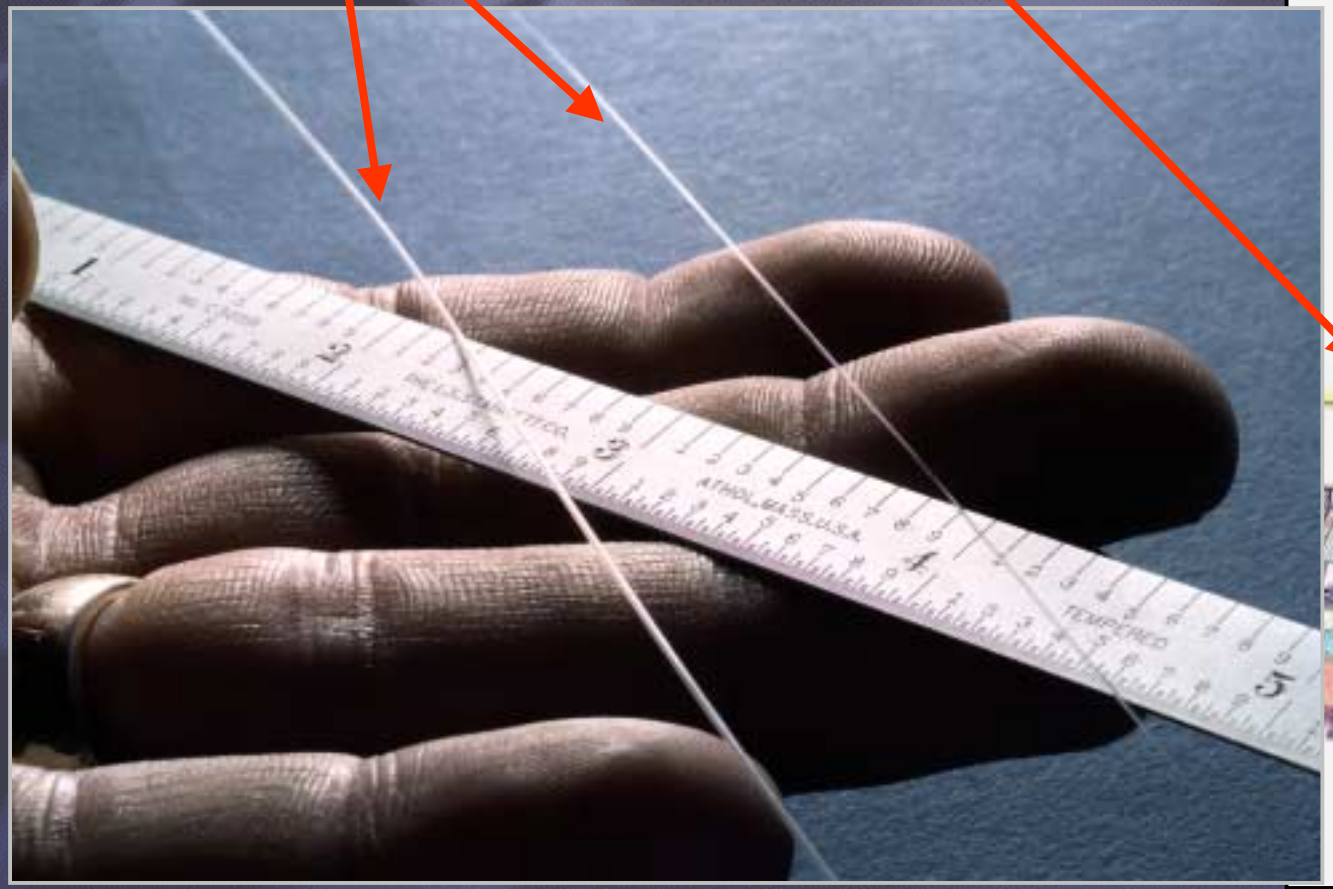


Three, 1-Axis IMEMs Accelerometers

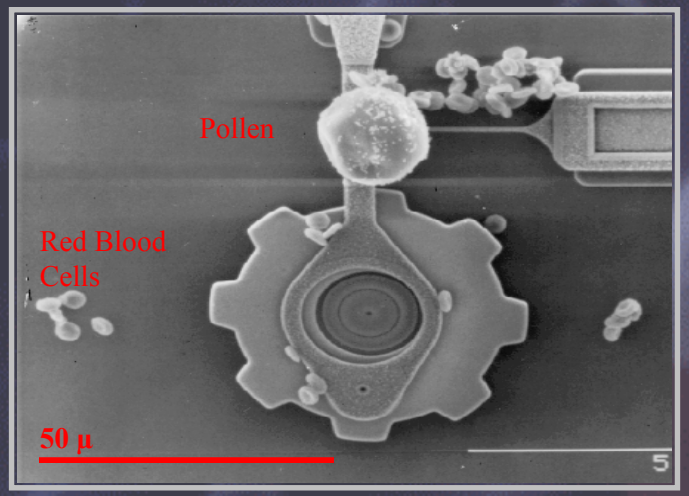
Deployment of Fiber Optics

Challenge:

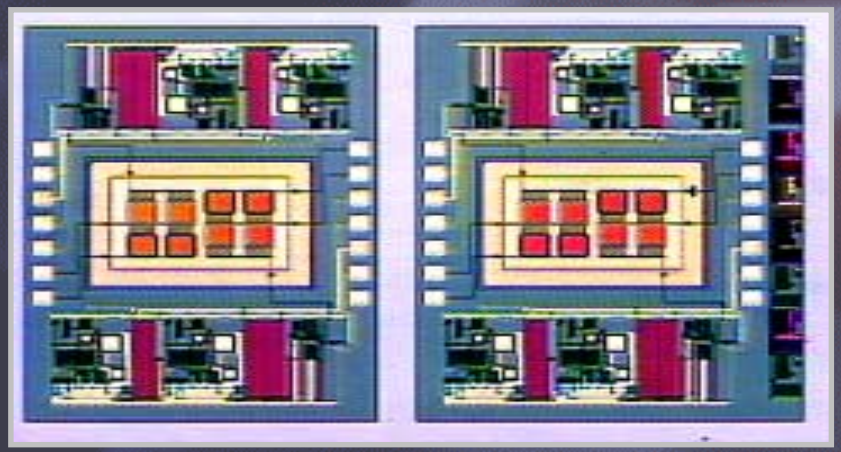
Can this survive this?

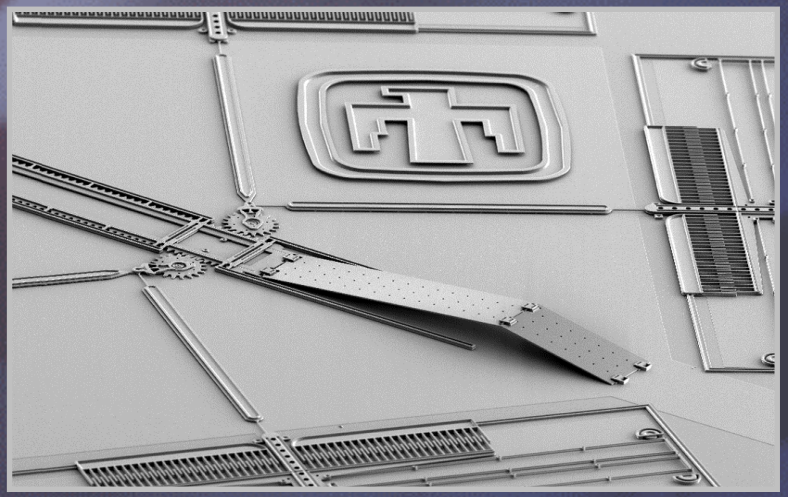


Intelligent Micromachines: Keys to "The Next Silicon Revolution"



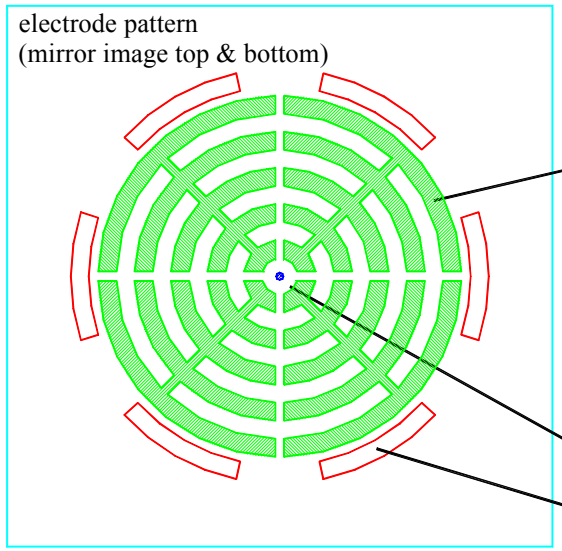
- Miniature mechanical systems with micron feature sizes
- Batch fabricated with no assembly required
- Exploits microelectronics infrastructure
- Common technology base for sensors, Actuators, and Electronics



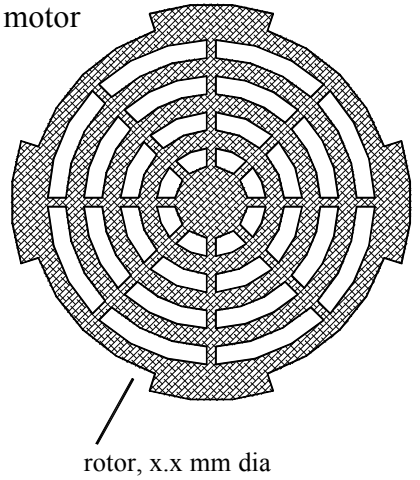


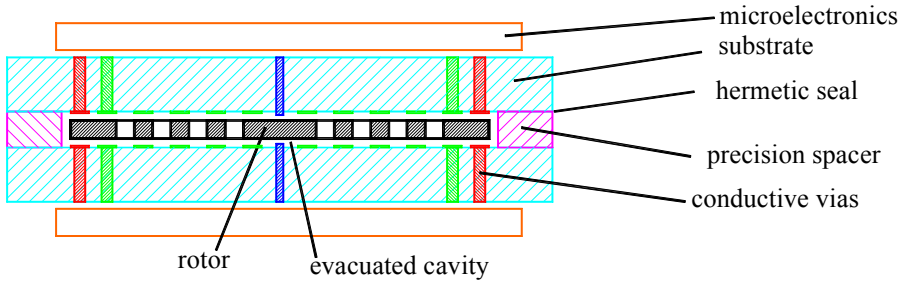
Spinning Mass Micro-Gyro

Hybrid MEMs, 2-Axis Gyro w/ Flip-chip Electronics



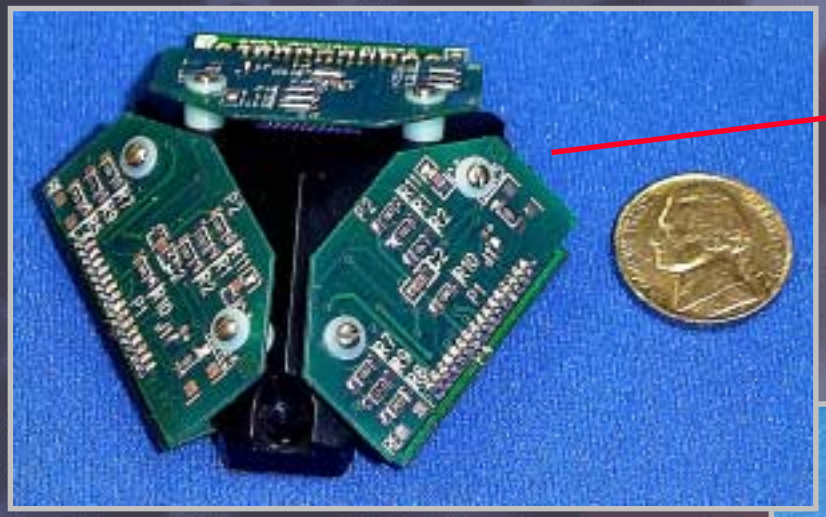
- closed loop suspension & rebalance
  (capacitive sensing/electrostatic actuation)
- synchronous electrostatic spin motor





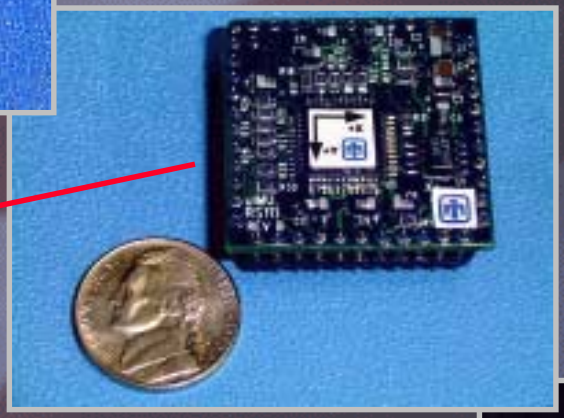
2-Axis Micro-Gyro Goals
< 10 deg. / hr. bias stability
> 1,000,000 RPM spin rate

IMEMs Accelerometer Deliveries



1.6 cu. in., 50 gram

Three, 1-Axis IMEMs Accels in Triad , 9/99
- Delivered to IDF telemetry flight
- 2 micron poly (Sandia design)
- 100 mg performance class
- ± 10 g full scale



0.7 cu. in., 15 gram

One, 2-Axis IMEMs Accel in PGA, 12/99
- Delivered to EFI telemetry flight FTU-17
- 6 micron poly (U.C. Berkeley design)
- 2 mg performance class
- ± 10 g full scale

0.1 cu. in., 1 gram

One, 3-Axis IMEMs Accel in LCC, TBD
- Future delivery ?
- 6 micron poly (Sandia design)
- 500 μg performance class
- ± 10 g full scale