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Randy Normann and John Witham of Sandia National Labs

Dr. Michael Ropp Professor of Electrical Engineering, South Dakota State University

Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000

NNSA National Nuclear Security Administration

Sandia National Laboratories

Resume

- Georgetown, Tx HS Graduate
- USAF – Farmers Ins – Chevron Dealer
- 1984: BS EE from OIT
- 1984: Sandia Telemetry Designer
  - W88, W80, B53, B61 (w-wireless, b-memory)
- 1992: MS EE from UNM
- 1994: Sandia Geothermal Drilling Dept.
  - Flasked tools compete with industry so changed directions to unshielded tools
  - PI for HT Electronics & Fiber Optics
    - Technical Chair HiTEC 10 years?
    - SAE –EA7 HTEP co-founder
  - Only 1/3 for our funding comes from DOE-Geothermal!

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HT Electronics & DOE

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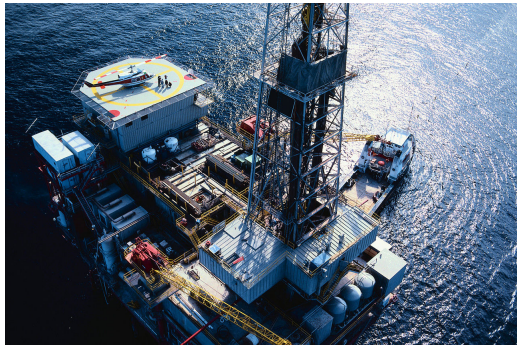
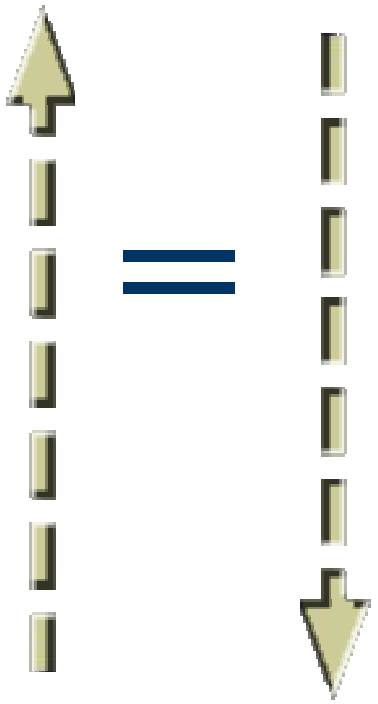
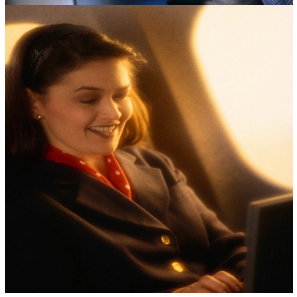
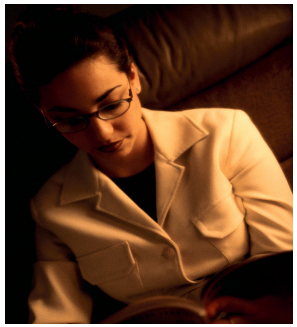
Introduction

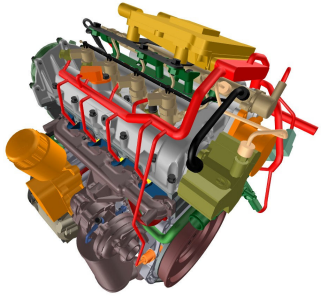
To demonstrate that new reliable HT electronics benefits both sides of the energy equation.

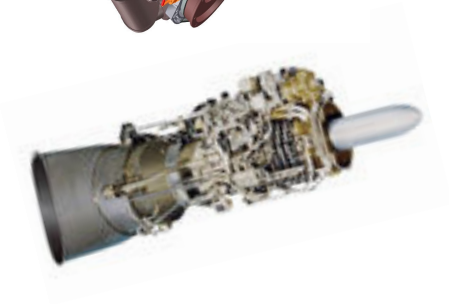


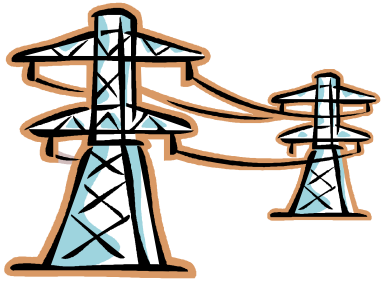












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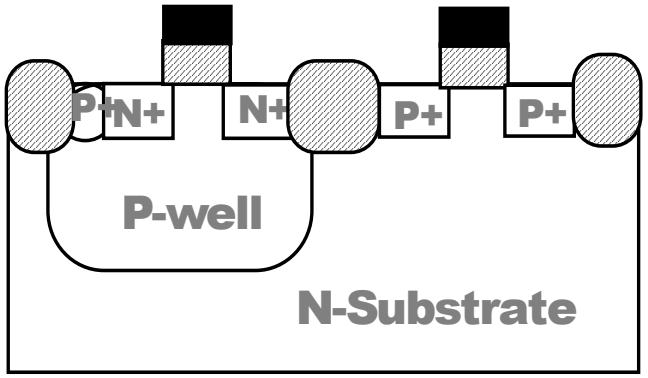
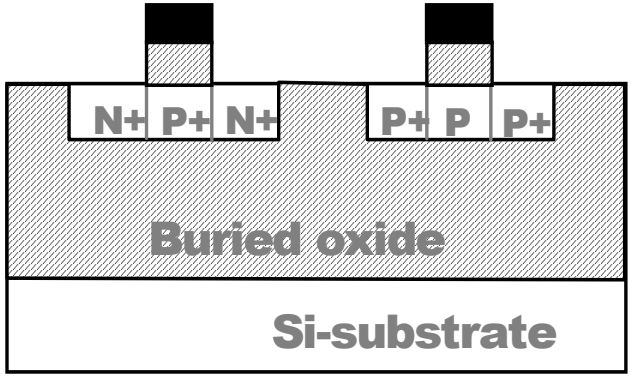
SOI Technology for Robust Electronics

- Silicon-On-Insulator (SOI) isolates transistors on an insulating material providing:
  - Isolation reduces leakage currents by ~100 times!
  - Latchup immunity
  - 25% Faster Switching
  - Better isolation for analog and digital on the same die
- SOI can operate at much higher temperatures



A: Cross-section of bulk CMOS inverter



B: Cross-section of a SOI CMOS inverter

In short, SOI is just a better way to build silicon electronic devices

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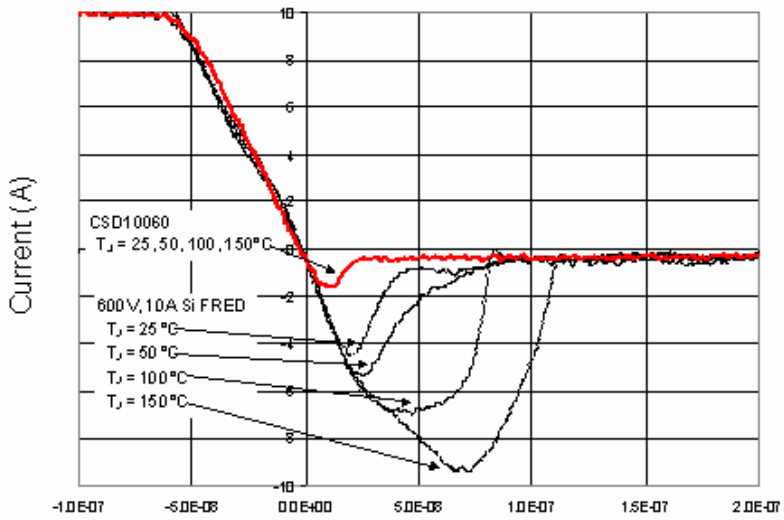
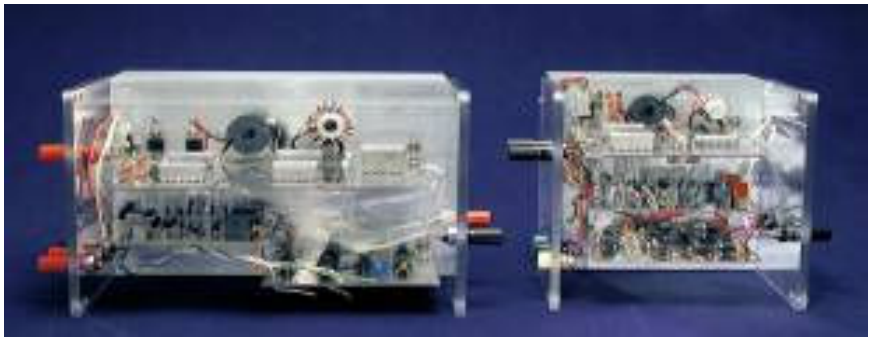
SiC Power Devices

- SiC has higher voltage breakdown than Si
- SiC has a better thermal conductivity than Si
- SiC power devices can be produced 5 to 10 times smaller than Si
- The smaller SiC power transistor can be operated much faster allowing for smaller passives devices



Courtesy Anant Agarwal, Cree HiTEC 2006



Silicon **SiC**

Courtesy Emil Hanna, Teledyne 2006

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Results of this Technology

- Future electrical power systems will be:
  - Smaller
  - Lighter
  - More efficient (2-5%)
  - Require less heat dissipation
- A large number of industrial benefits
  - More Electric Aircraft (MEA)
  - Hybrid vehicles
  - More efficient power inverters/converters
  - Enabled new drilling tools for the Geothermal industry
  - New power grid controls

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Working with the HT Industry

- Below is a short list of the companies we are currently working with

Electrochemical Systems

Quartzdyne Inc.

Paine Electro

Kulite Semiconduct

Weed

Kemlon

$$Millions in R & D directed at the larger markets

Inc.

s, Inc

Honeywell SSCS

Cissoid

Semisouth Laboratories

Endevco Corp

Rockwell Scientific/ GTI

Regal Plastic Supply Co.

Biotronics

Honeywell Richmond

Solid State Devices Inc.

General Atomics

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Other Industry Drivers

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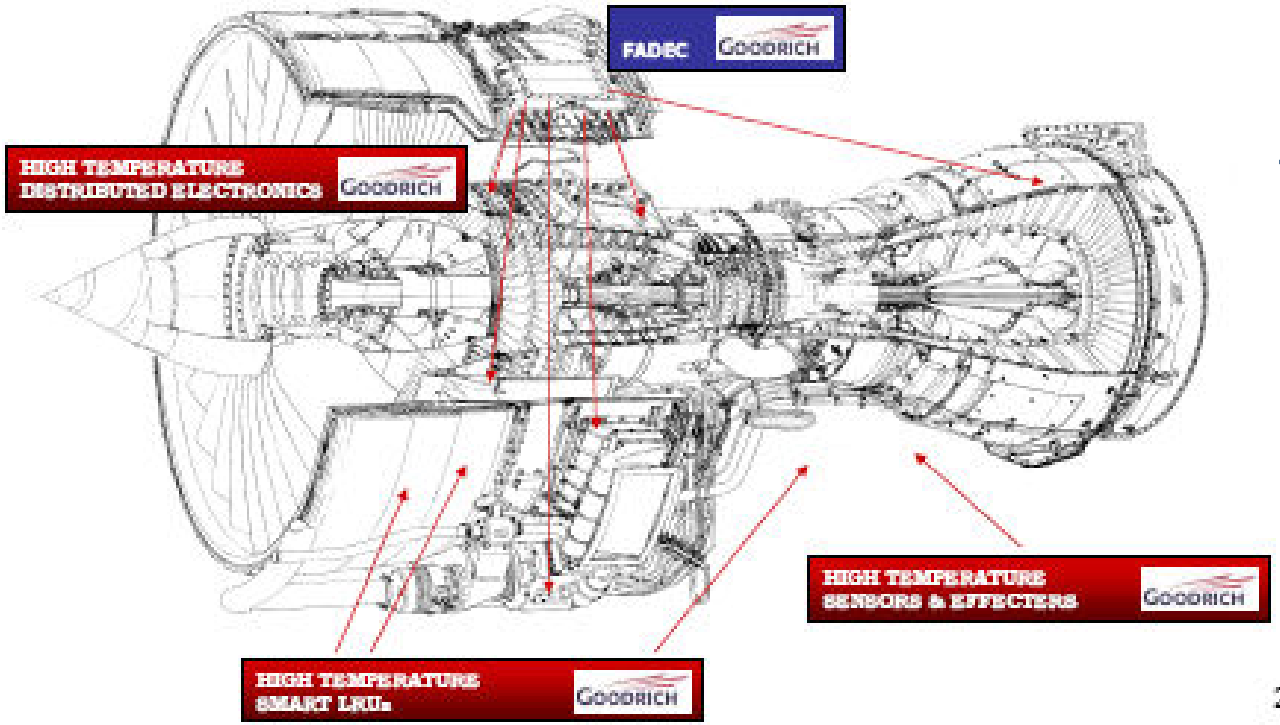
Distributed Engine Controls Save LBS



Engine controls are currently in the cockpit. Distributed engine controls can save >600 lbs/engine in copper cables.

Engine Requirements:
40,000 hrs at 220C and 80,000 hrs at 200C

Thanks to Peter Shrimpling, Goodrich, UK

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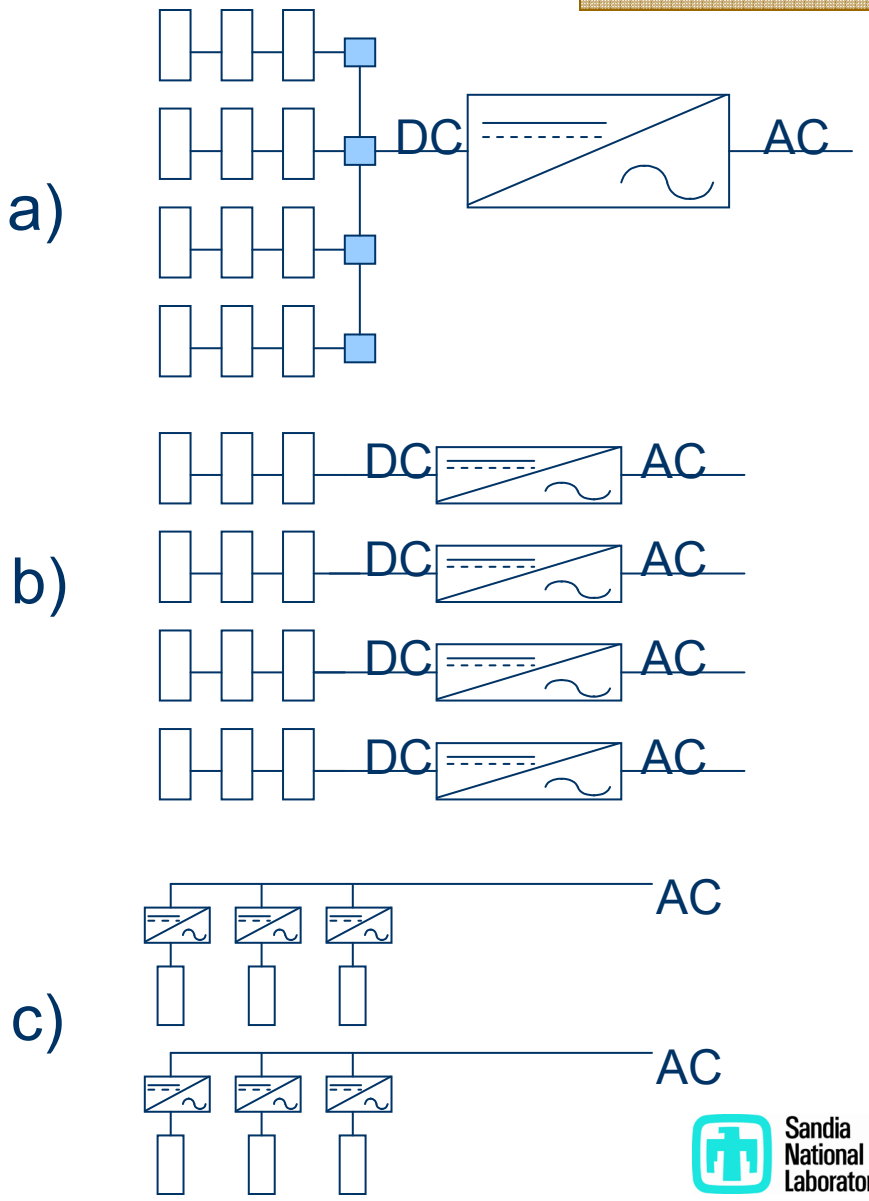
PV Inverters are Evolving

In the past, we used centralized inverters in which all the power went through one unit (a).

Some manufacturers now offer a "string inverter" in which each module string has its own inverter (b).

We wish to move to "AC modules" in which each module has an on-board inverter (c). This increases modularity, improves reliability through redundancy (!), increases system output through individual max power tracking, and *dramatically* simplifies system design and installation.



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Environment for AC module inverters

- Module temperatures up to 85°C; inverter operating temperatures up to 130°C
- Humidity from 0%→100%
- Salt spray and high-speed snow, dust and sand all possible

SOI and SiC could be key enabling technologies

Dr. Mike Ropp, Sandia's Solar Group

- SiC has better tolerance of voltage transients (such as lightning-induced ones on the AC or DC sides)
- PV inverters can use SiC JFETs (MOS not required); possible early market penetration point for SiC
- Previously-mentioned reduction in volume enabled by SiC would be highly advantageous
- SOI "brains" would permit higher levels of distributed intelligence and communications capability, with error-free functioning at elevated temperatures
- SOI, alternative metallization (W instead of Al), and larger trace sizes (against current trends!) would enable longer lifetimes at high T

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Now a Word from My Sponsor
DOE - Geothermal

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Potential is great

- According to a study presented by the German Parliament the total technical potential for electricity production form EGS sources amounts to about 1,200 EJ (300,000 TWh)
- Corresponds to 600 times the annual consumption in Germany
- Australia might the first to create major man made geothermal reservoir

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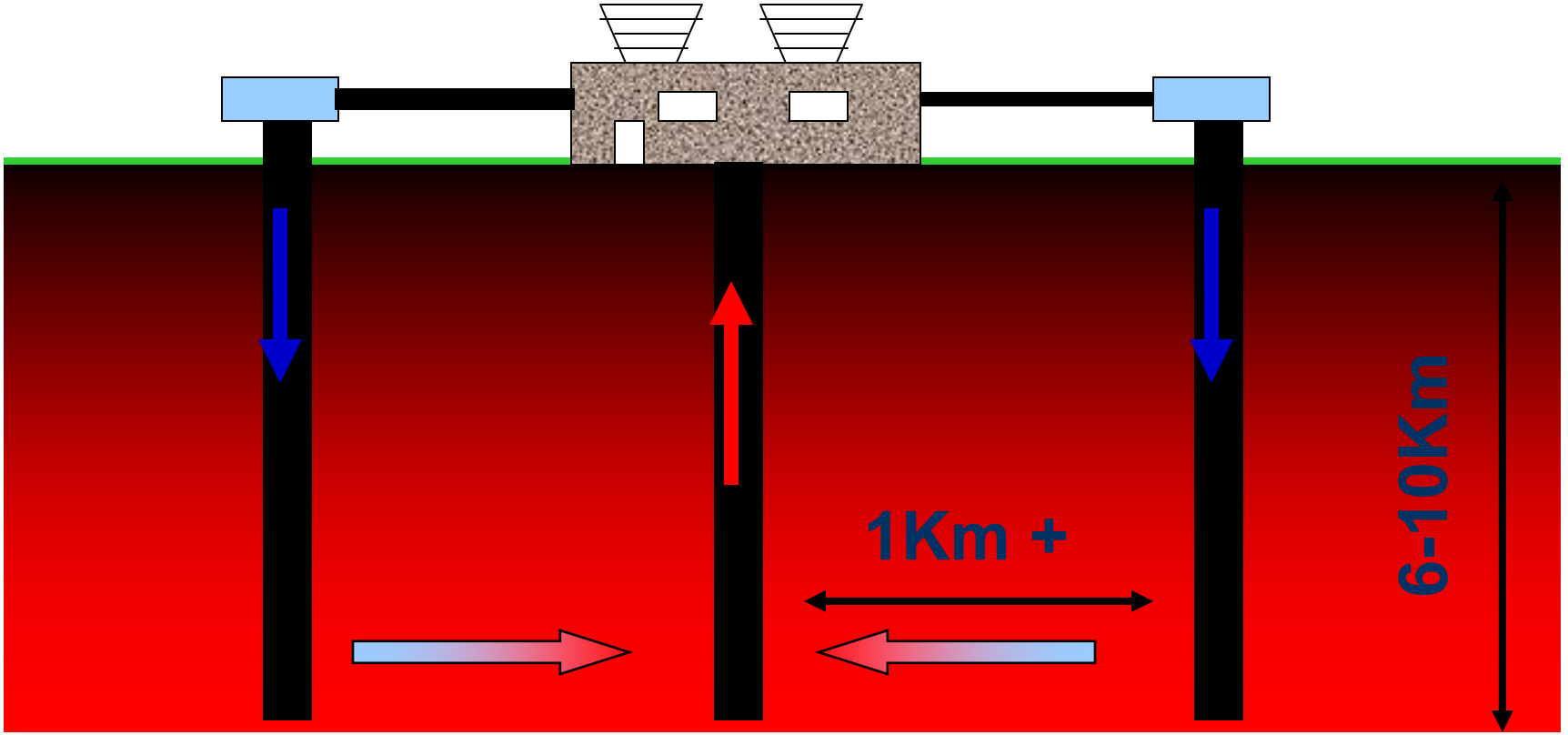
Enhanced Geothermal System



- The Earth is hot. At depths of 6 to 10Km temperatures exceed 200C
- Geothermal tools require electronics to operate from 250 – 325C
- The heat is mined by water flow from injectors to the producer via manmade hydraulic enhanced fractures in the rock.

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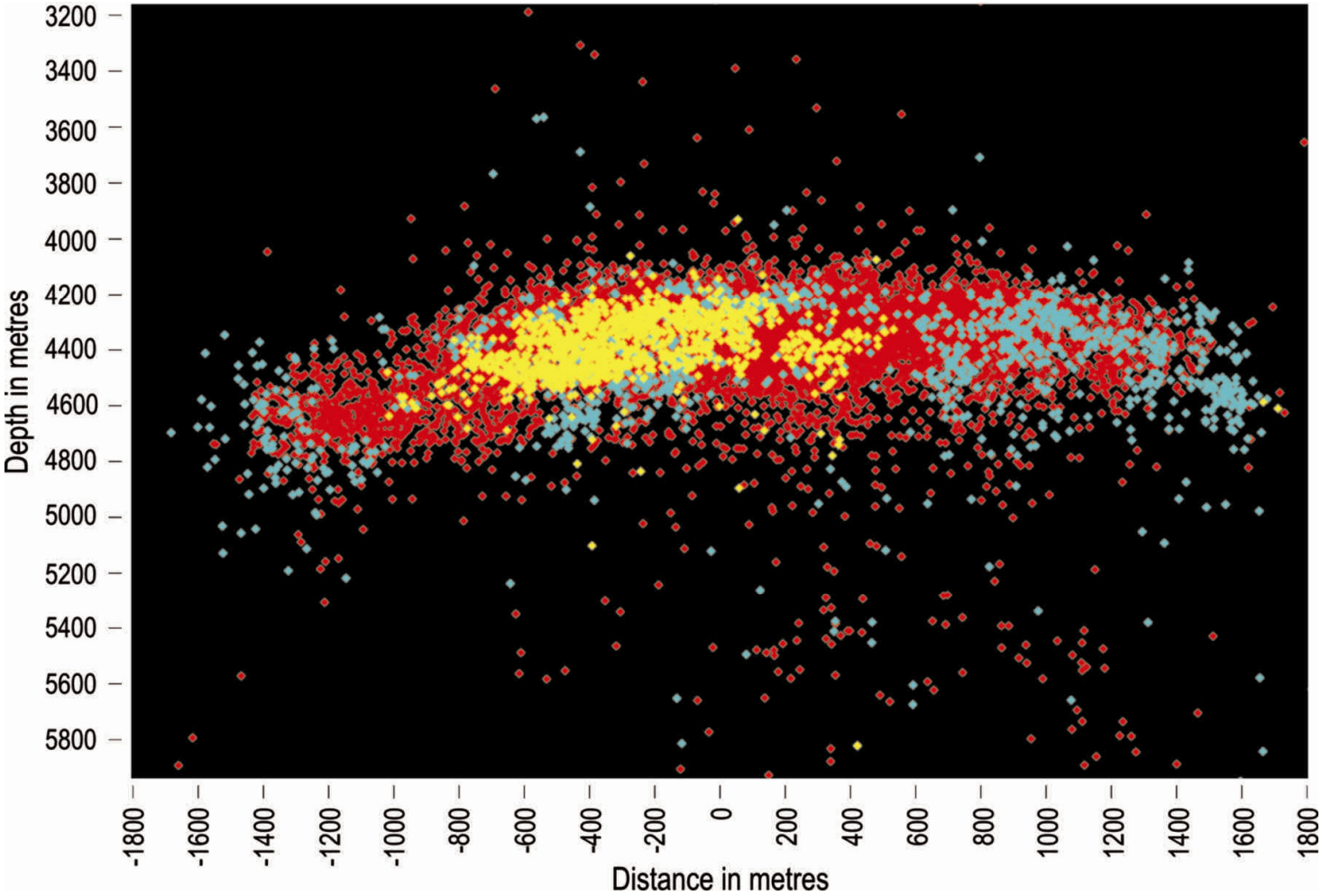
Fracturing Rock Away From the Well

Seismic Sensors Track Rock Fractures as Hydraulic Pressure is Applied



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Creating a Larger Market

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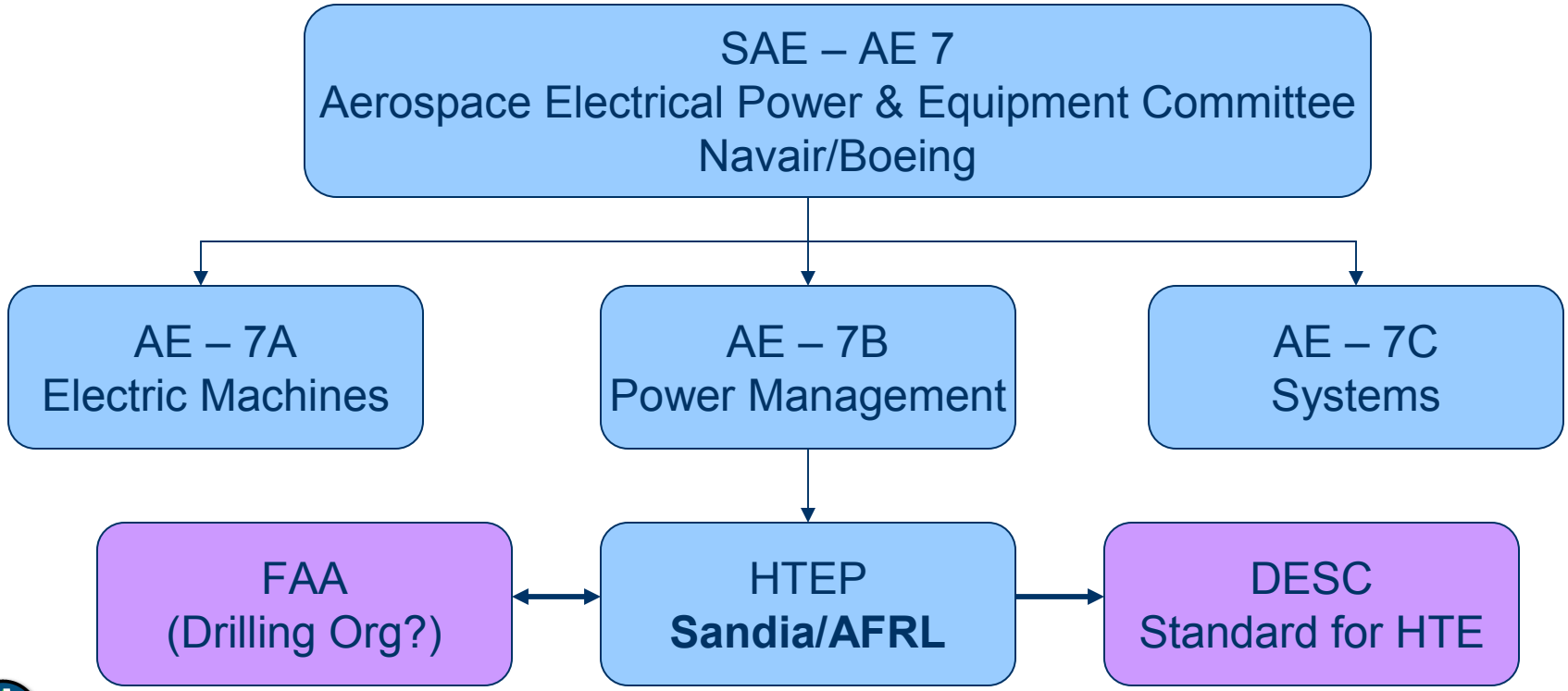
Creating a Standard to Cross Industry Boundaries

- Society of Automotive Engineers – Aerospace Electronics Chapter 7
- HTEP – High-Temperature Electronics Panel



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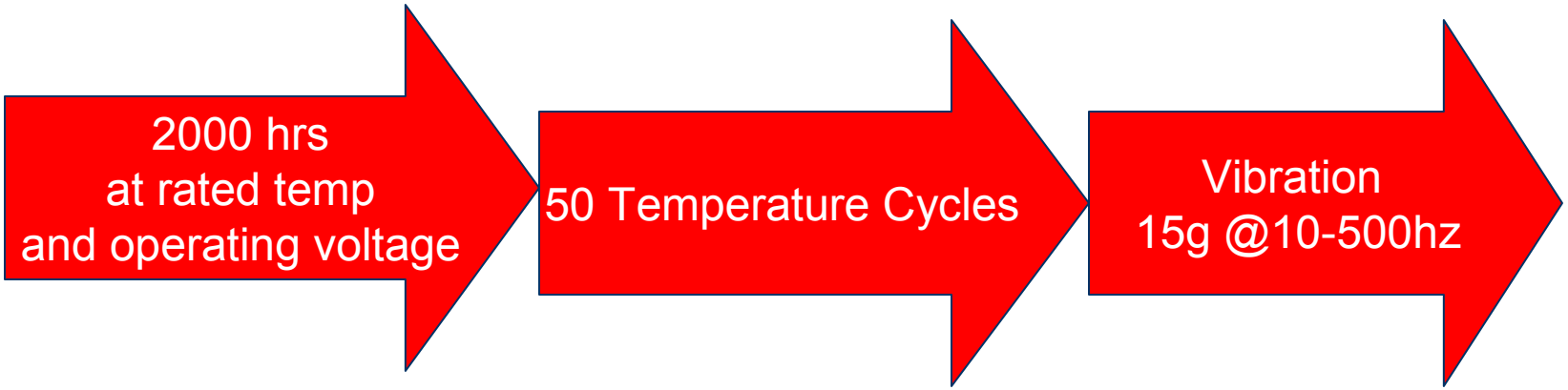
Minimum Testing for HT Components and Sensors

(Proposed Guidelines Being Developed by High-Temperature Electronics Panel (HTEP) of Society of Aerospace Engineers (SAE) – AE7 Committee)

Test device is calibrated to manufacturers operating specification

Test device is tested against manufacturers operating specification



A failed device is any device falling outside of the manufacturers specification. A complete set of test data, test devices and procedures must be reported in open publication.

(The SAE will have the draft HT Testing Guide Lines for review and comment at their web site
Under AIR5711)

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Our Past Work Building Tools

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Qualifying Components

- Sandia has a complete DAQ 250C (482F) tool able to stay in the well indefinitely up to 300C (580F) for moderate periods.
  - We can quickly modify our tool to use almost any electronic component or sensor
  - We have access to geothermal and steam-flood wells for testing
  - Currently testing a 300C tool in Bakersfield, Ca
- DWD tool
  - Lab tested at 225C
  - Field tested
  - Measures 3 axis accels, 3 axis mags, WOB, pressure, TOB and bending

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Long-Term Demonstration Test

Sandia's SOI tool has 800+days in the well @ 193C.

We fully calibrated and qualified our tool at 200C for 1 month prior to going into the well.

Future tools will be expected to operate for 15-20 years and in some cases operate wireless

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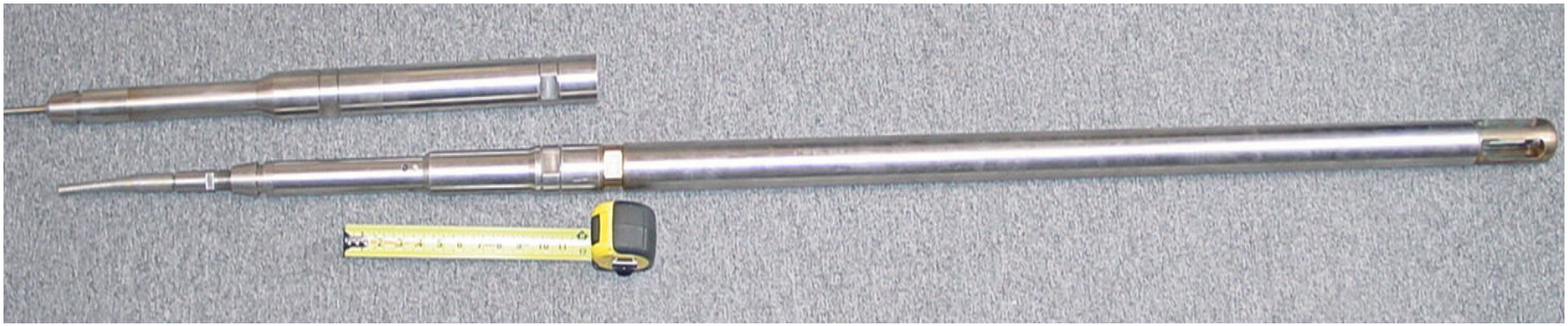
The 2003 & 2005 Coso HT SOI Tool



The SOI demonstration tool is shown with two cable heads. This is a very common type of logging tool housing was used in 2002. In 2005-6, we are testing several metal-metal seals and tool coatings.

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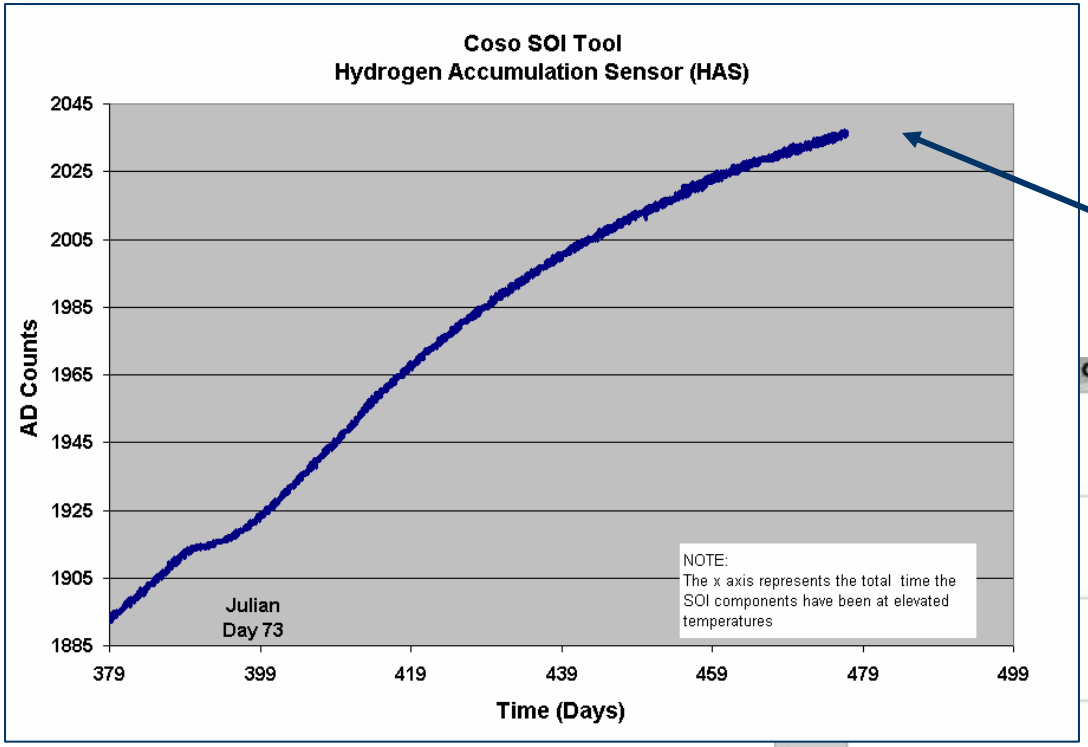
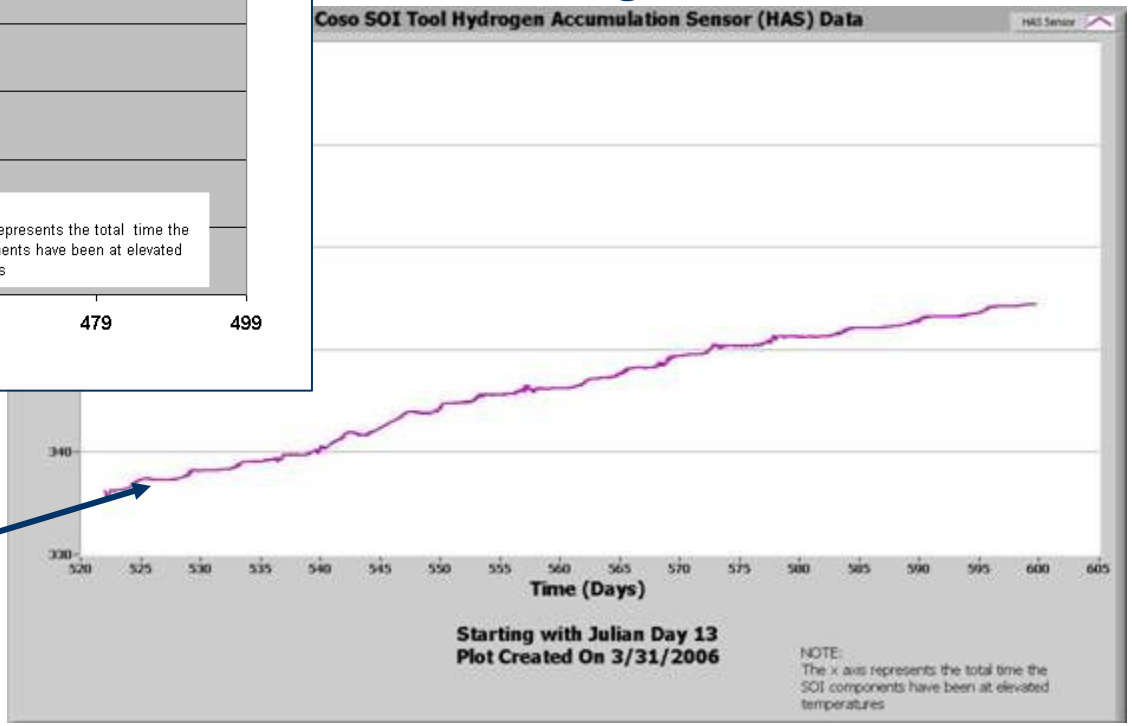
Hydrogen not an Issue for SOI



First time in the tool, found settings to be too sensitive.
Starting to saturate.



We reduced sensitivity the second time around. In any case, SOI seams unaffected by the presents of H!

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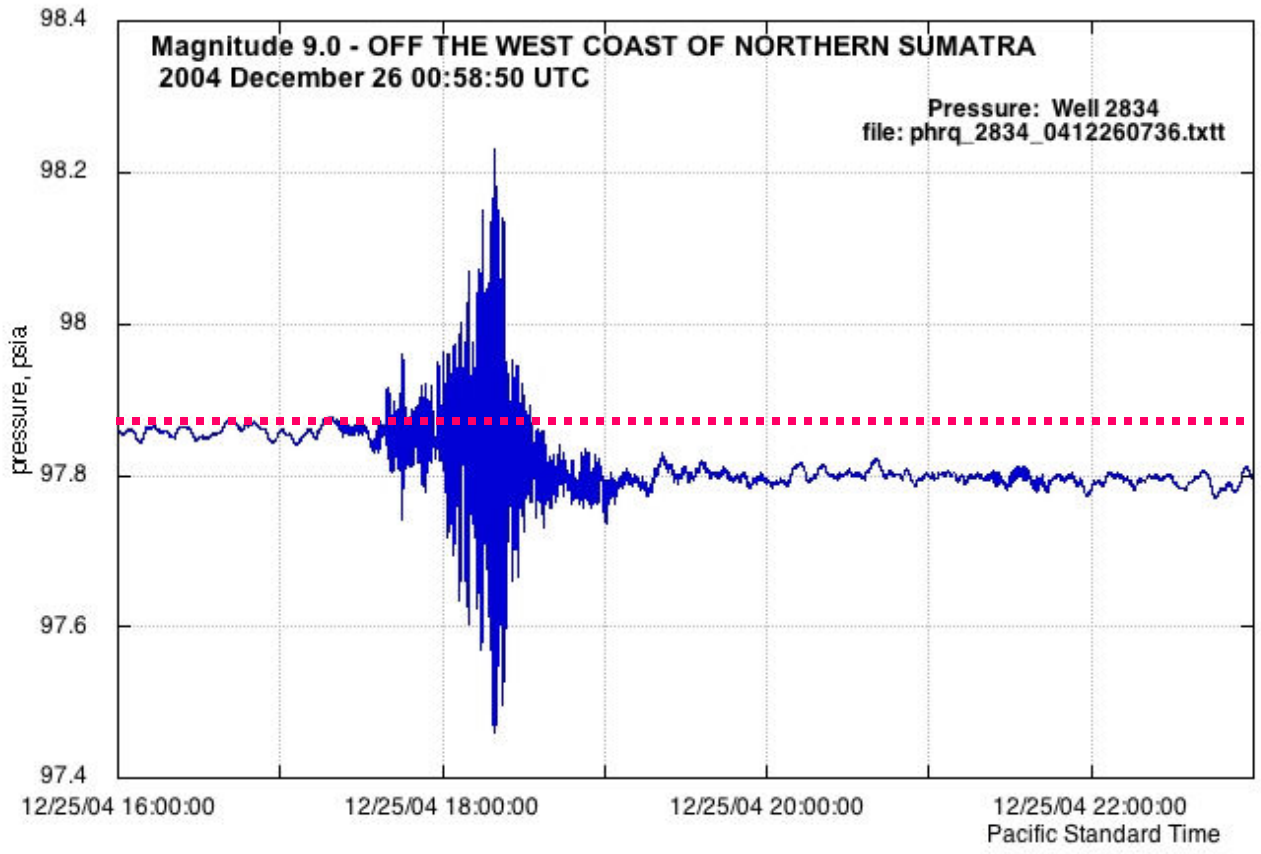
Capturing Sumatra Effects in CA.



- The Sumatra Earthquake occurred in the Indian Ocean.
- The effects were felt world-wide.
- Using an Sandia HT tool, the USGS captured this change in a geothermal reservoir.

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Geothermal Plans for 2007??

1St Priority: Add HT Batteries to our HT SOI Tool

2nd Priority: Seismic-Pressure tool for hydraulic fracturing measurements inside the well

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Add HT Batteries to our HT SOI Tool

Objectives:

A) To merge Sandia's existing high-temperature (HT) wireline tool technology with new HT battery technology.

The geothermal industry requires reliable logging and drilling tools able to operate at very high-temperatures for an extend time within the well. Last year, Sandia started working with two service companies and two tool builders to commercialize Sandia's wireline high-temperature logging tool.

This will enable:

Lower cost memory tool operation

Allow bottom hole monitoring without wirelines

Significant reduction in operational risk.

B) To provide American HT electronic component manufactures the opportunity to demonstrate their technology within the globe drilling market.

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HT Batteries

- The battery 'GAP'
  - Commercial batteries are limited to 200°C
    - Will detonate in an over temperature condition
- Candidates for HT Batteries to fill the 200-250°C gap.
  - Safe Lithium
  - Electrochemical Systems
  - Russian
  - Sandia on 2 Molten Salt Technologies

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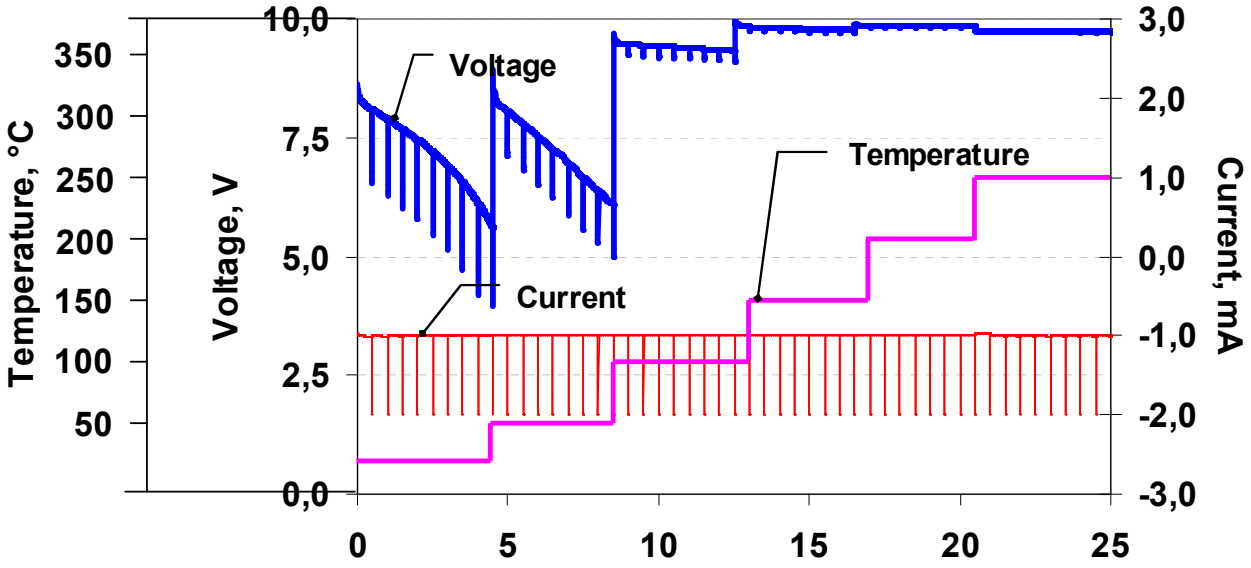
Solid-State Russian Battery

- Keep-alive current 25C to +250C
- Potential tool power above 150C
- Save for people and the environment
- R & D 100



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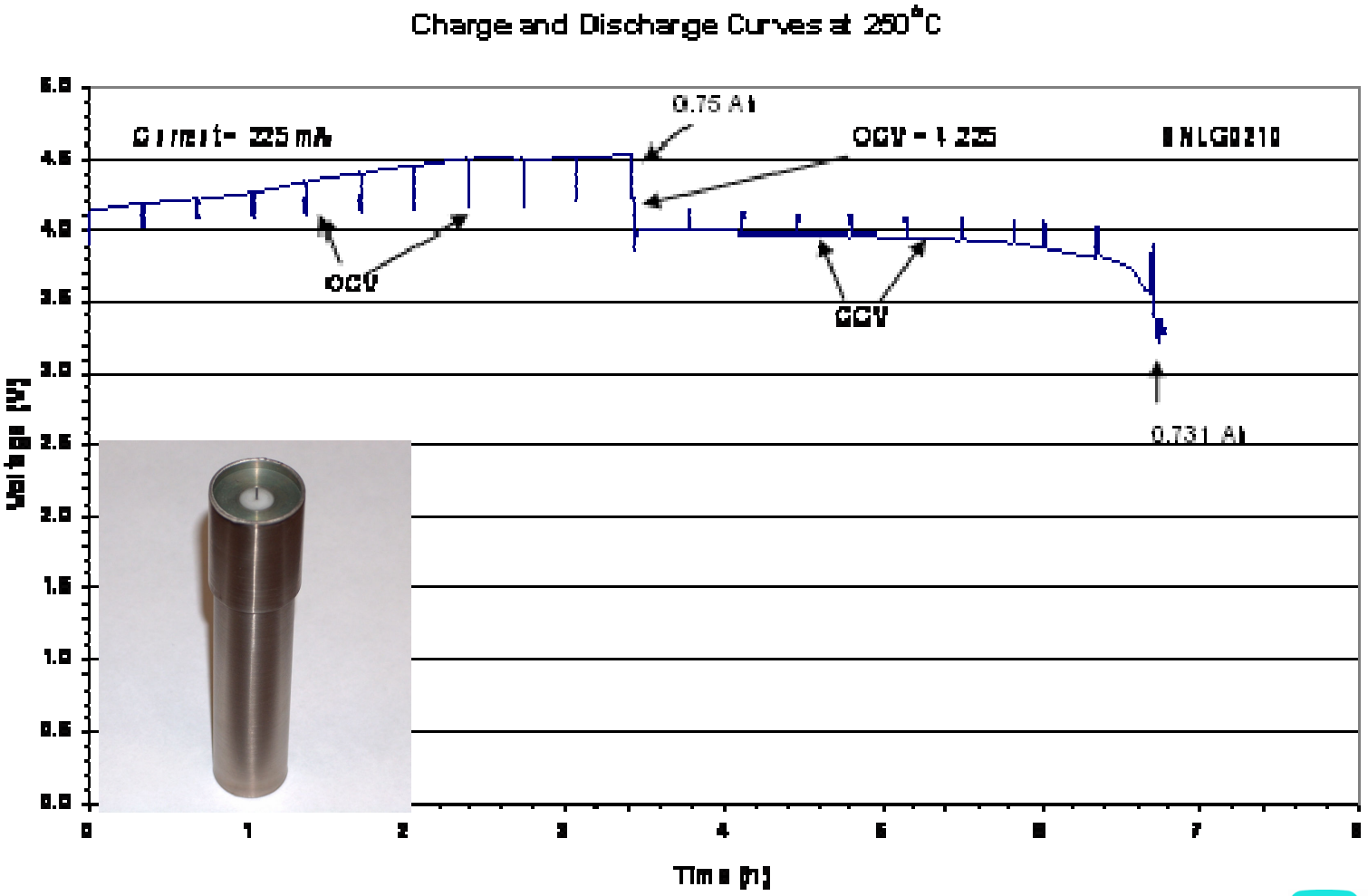
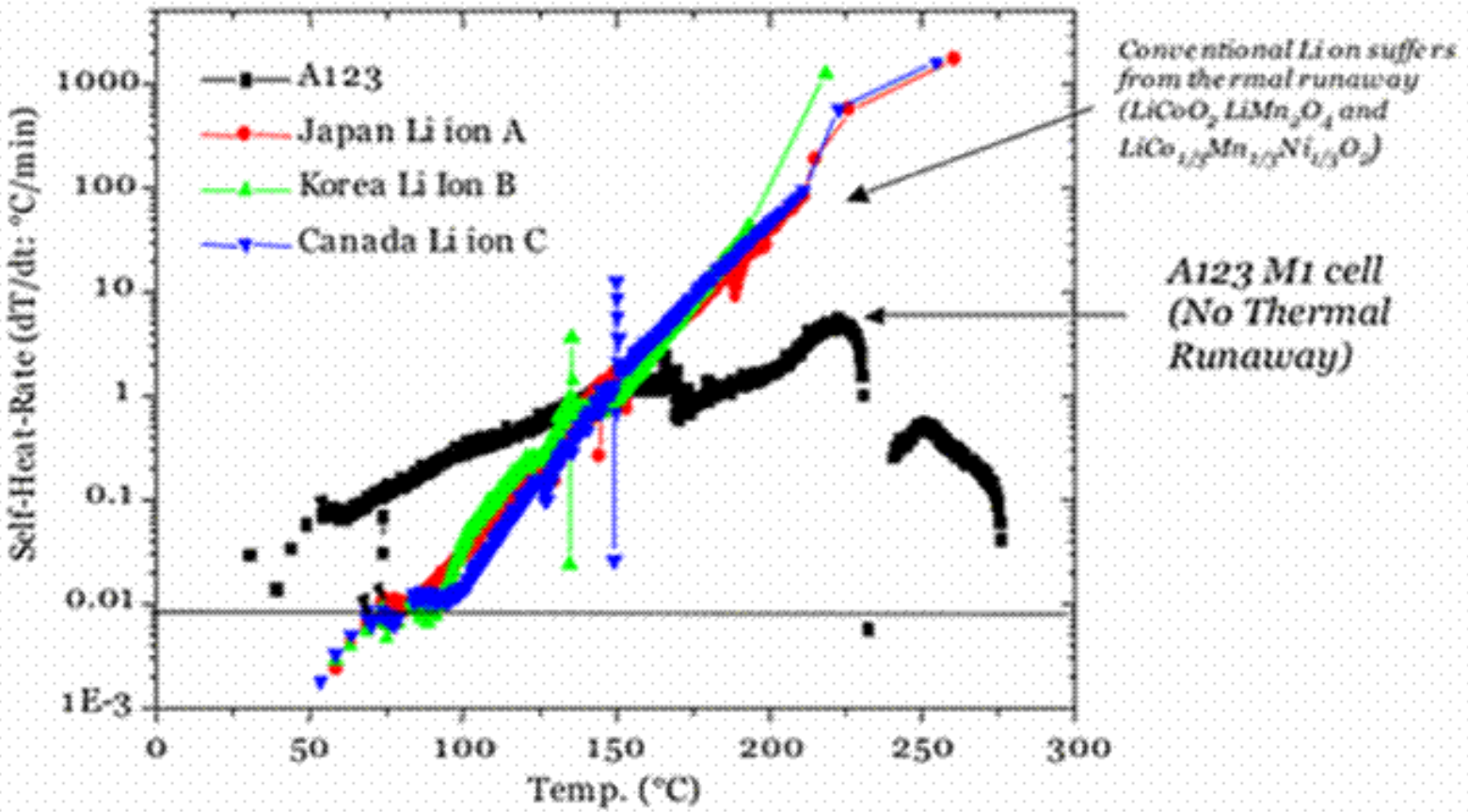
250C Electrochemical Batteries



Safe Lithium Batteries



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Seismic-Pressure Tool

Objectives:

A) To design and fabricate a high-temperature HT tool needed to capture seismic and fast pressure response data as geothermal wells are fractured using hydraulics to stimulate production.

Tool targeted requirements:

1. Three axis, 1 uG/ 500 Hz seismic sensitivity
2. 20K psi pressure >10 psi relative response @ 10 samples/sec
3. 20K psi pressure measurement with absolute accuracy of 10 psi
4. Continuous operation at 250C

B) Same as before

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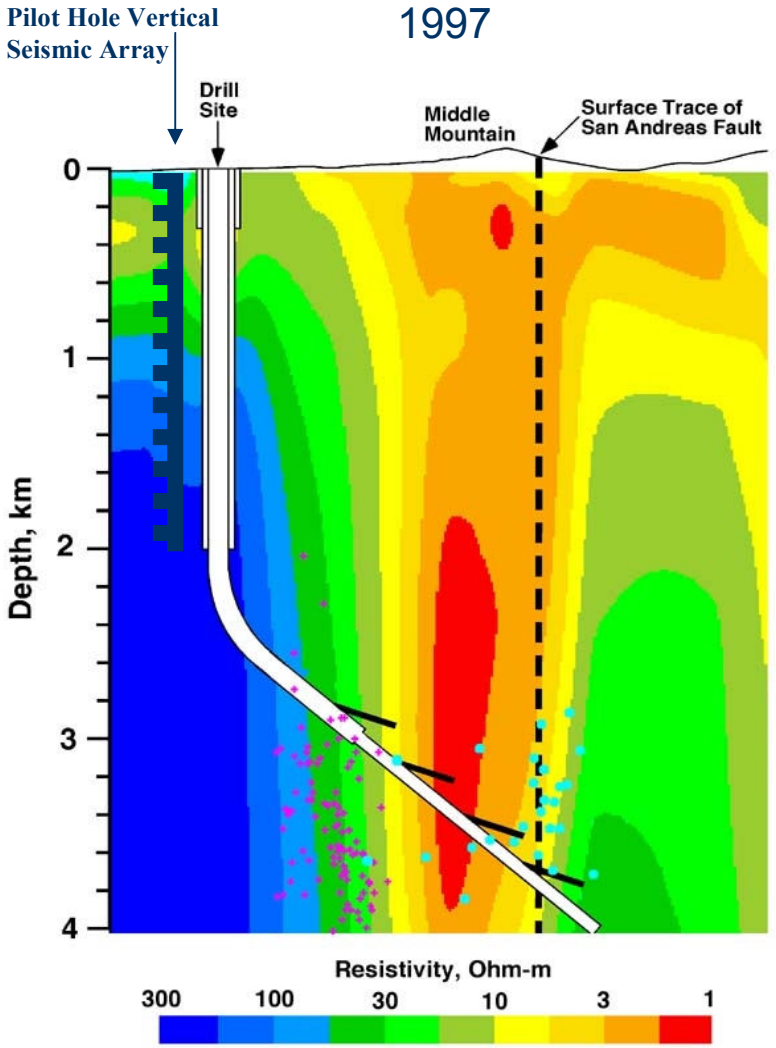
Why in the Well Seismic?

Unsworth, M., Malin, Egbert, Booker, *Geology*, 1997



- Data from SAFOD.
- Blue dots are the same seismic events using a different model
  - 1000 ft difference in location!
  - Future tools measuring seismic from inside the well can greatly fracture location

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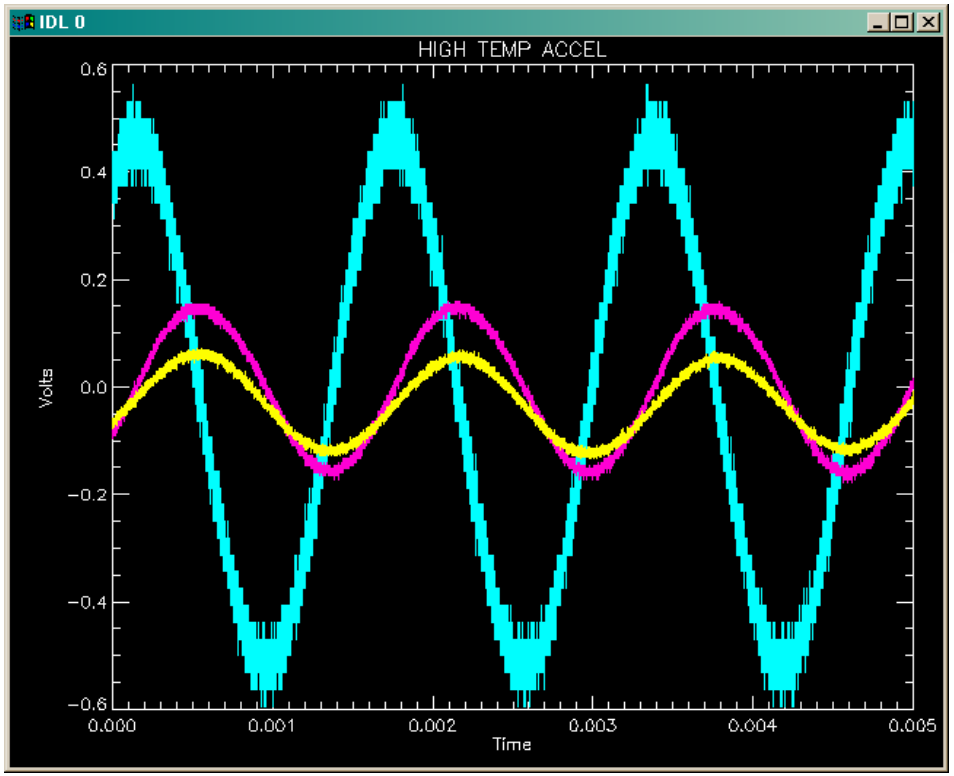
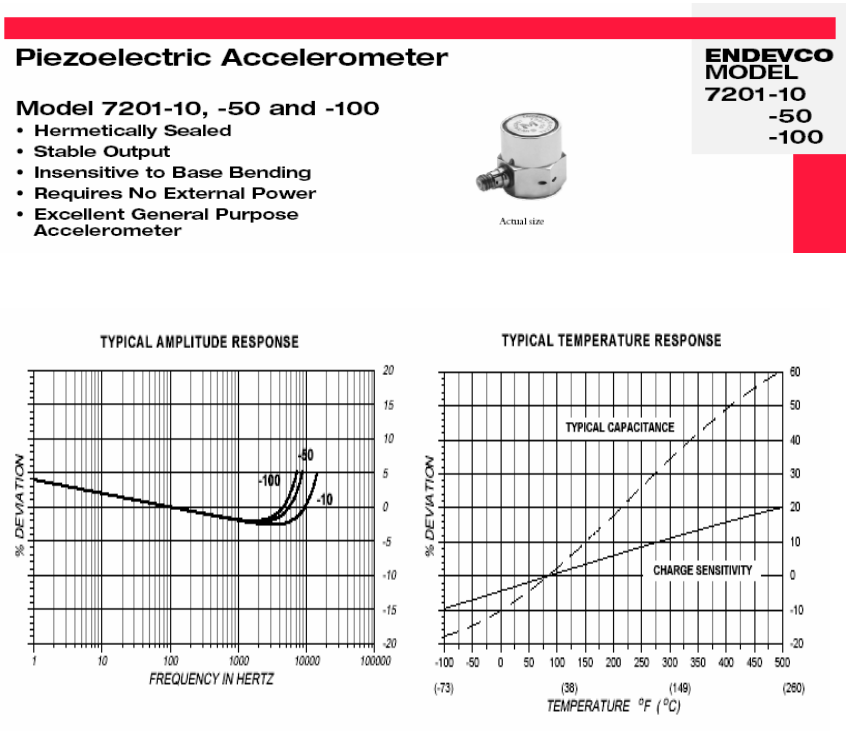
The Accelerometer





Above is the default seismic sensor

•There are 3 other possibilities underdevelopment

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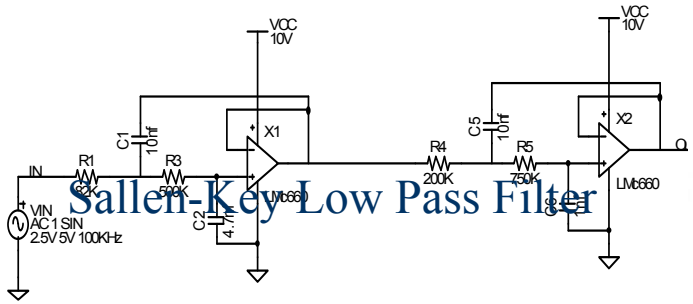
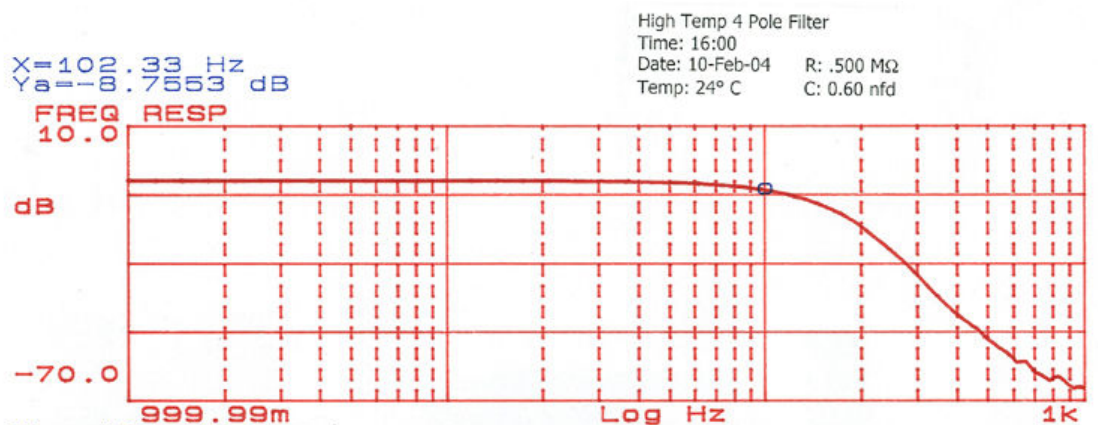
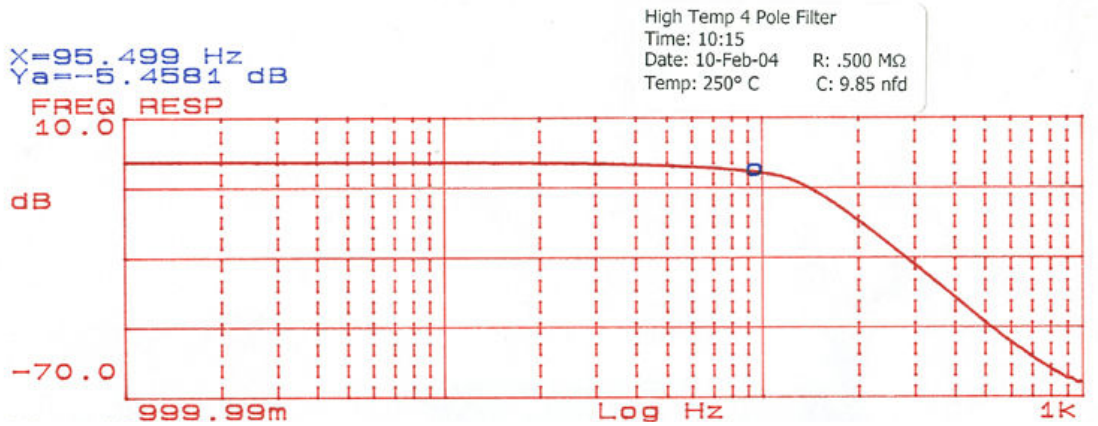
Low Pass Filter Performance Results







Actual circuit used Honeywell Quad Op-Amp showing stable frequency response up to 250C.

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HT MWD-DWD Tools

1. Designed new SiC face seals
2. Evaluated magnetometer sensors
3. Designed new SiC-SOI Mud pulse circuit
4. Designed new turbine regulator

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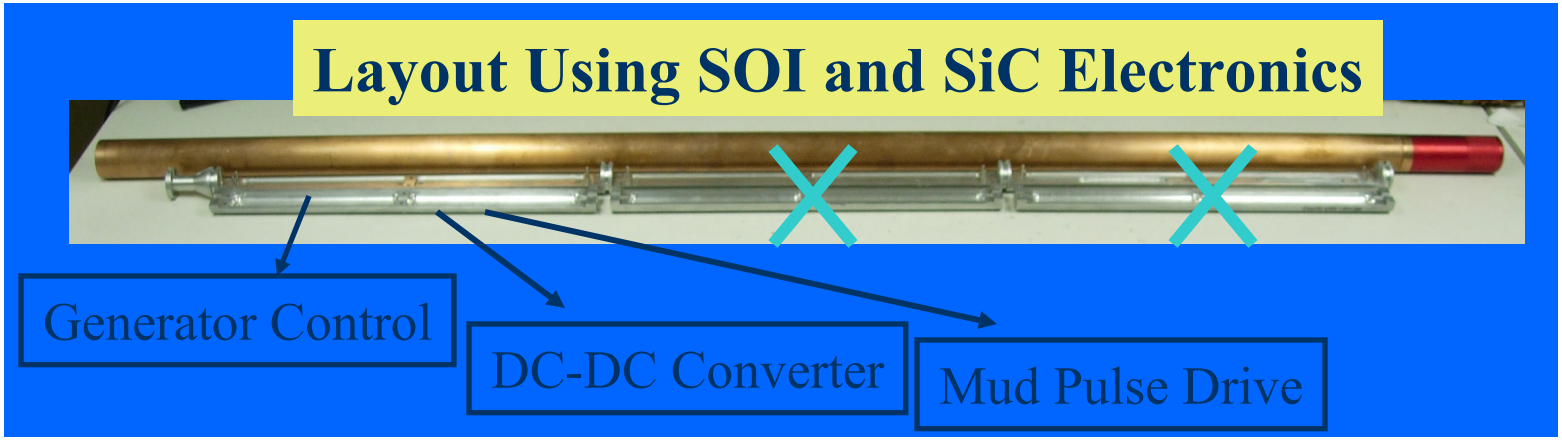
What's NEW?

- Sandia's HPHT turbine regulator using HT SOI and SiC electronics
  - 1/3 the size of the old 200C Si switcher
  - Operates up to 230C+
  - Commercial systems reduce energy loss by 30-50%
- In 3-5 years SiC technology will dominate the electronics industry for power electronics!!!



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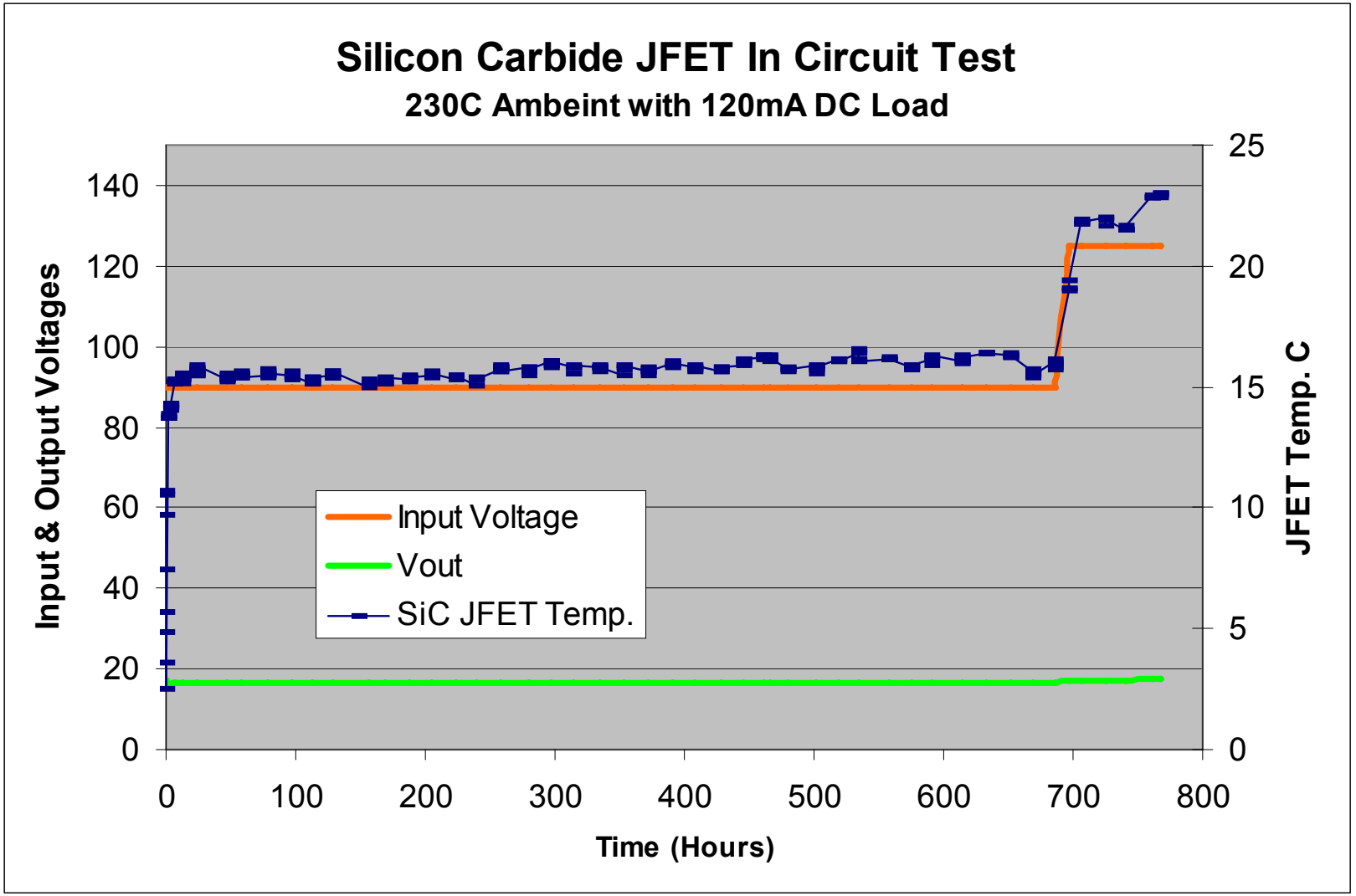
MUD Turbine Reg. Testing



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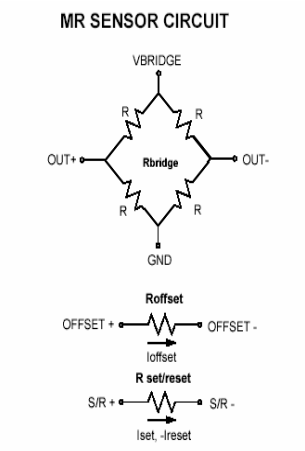
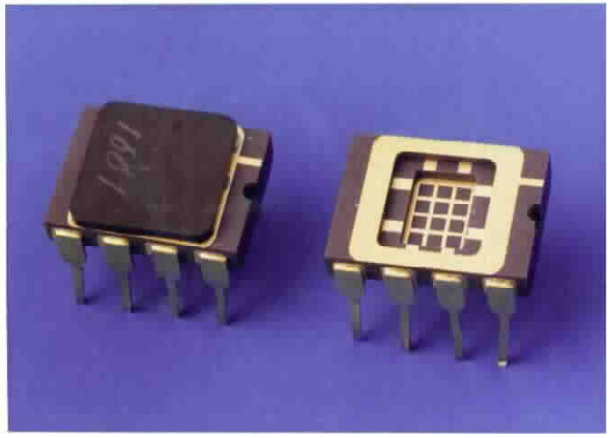
HT Magnetometers

Honeywell



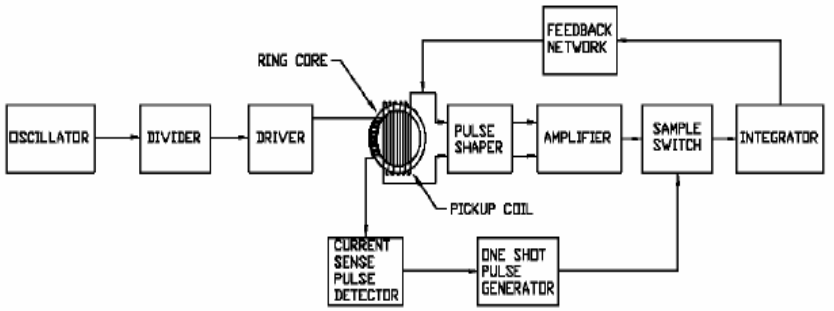
FEATURES

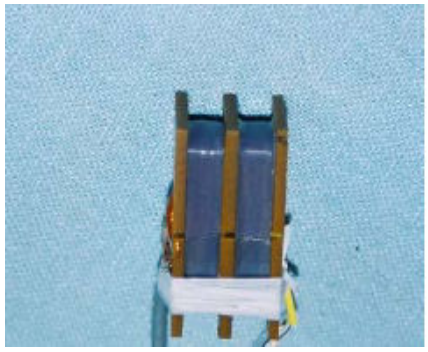
- Ceramic Dip Package
- Reliable For -55 to +225°C Operation
- ±2 Gauss Field Range (HTMC1001D
  ±6 Gauss Field Range (HTMC1021D)
- 1mV/V/Oersted Sensitivity (Room Temp)
- Patented On-Chip Straps Require Low Voltage Set/Reset Pulse

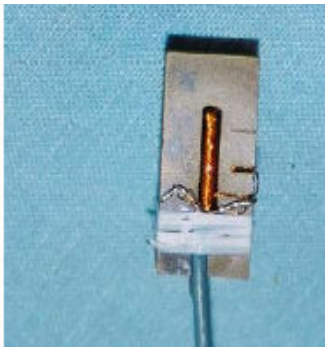


Flux Gate

Designed by Diamond Research and Development
Steven Rountree
Tested up to 225C







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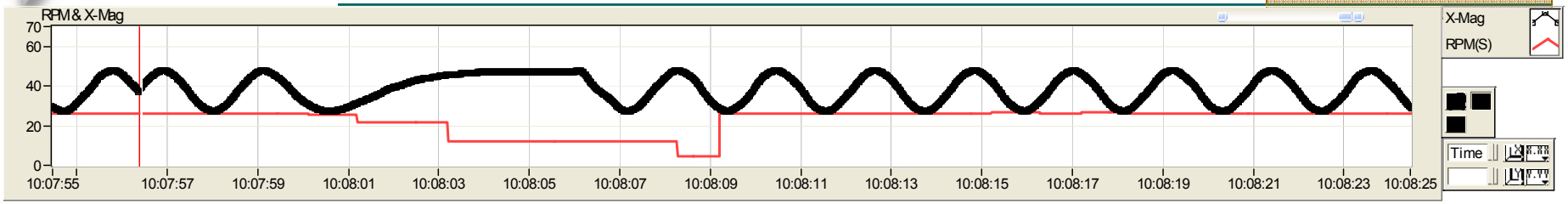
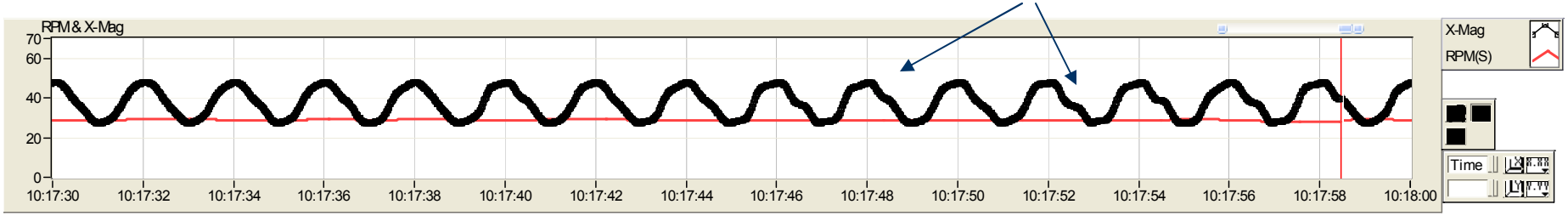
225C DWD Tool Drilling Test

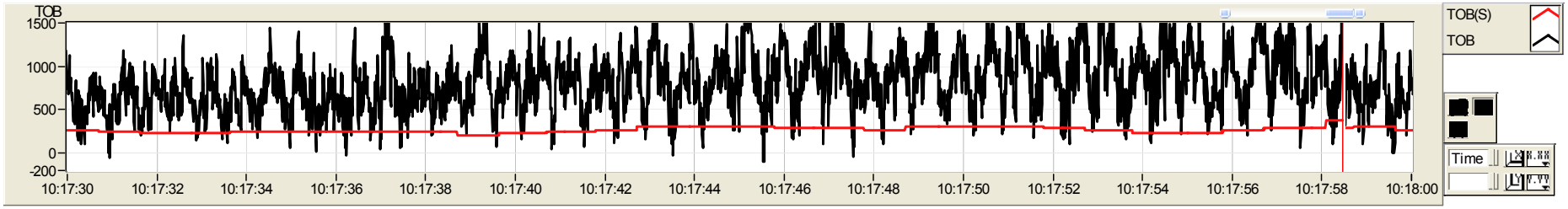


Above: Magnetometer data shows windup of drill pipe while reaming down to bottom of hole

Below: Magnetometer data shows drillpipe is sticking as it rotates

Magnetometer is showing stops in RPM





Downhole bit torque measurements repeat the mag. data.

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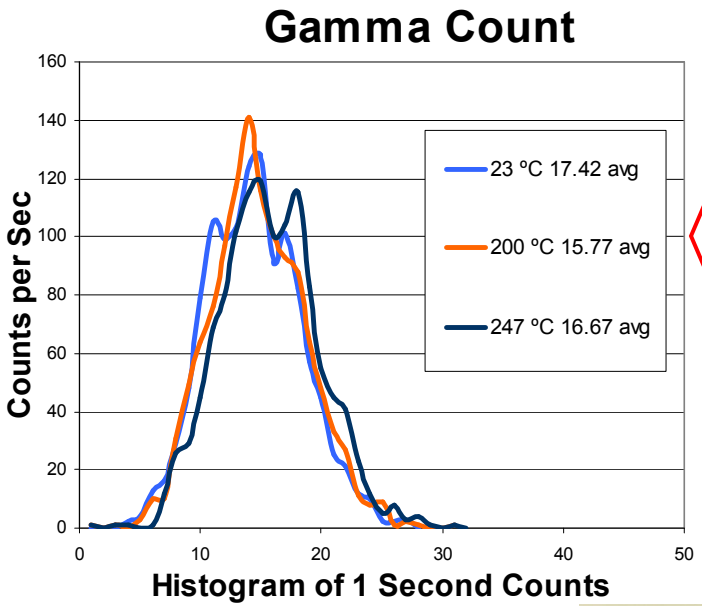
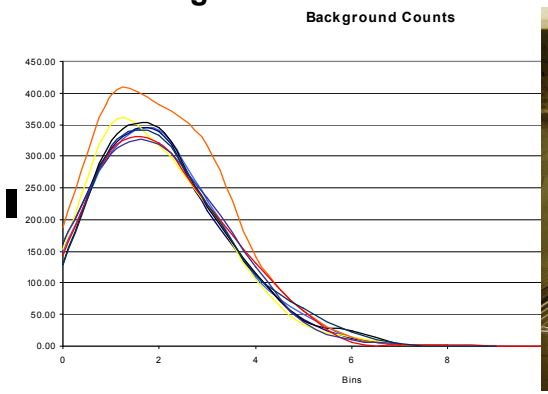
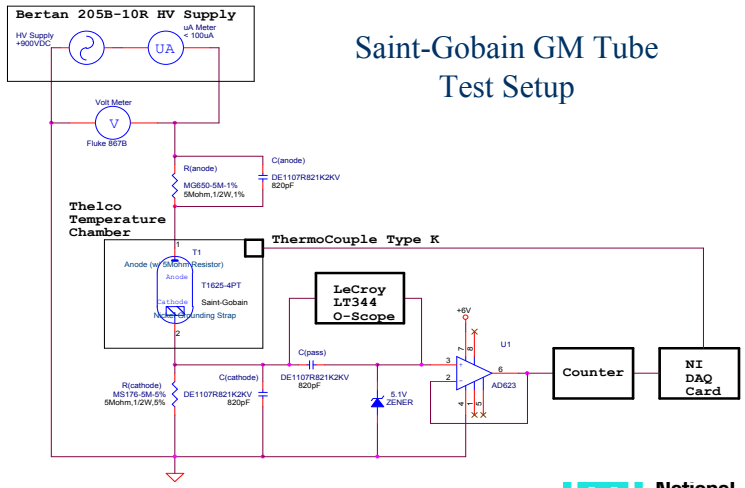
Adding Gamma



The first data of a new HT Geiger-Muller gamma sensor. This sensor is needed to build a 250°C Press/Temp/Spinner/Gamma tool. One of the most common logging tools used within the industry.





Saint-Gobain GM Tube Test Setup

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HT MWD Conclusions

- Potential Improvements for 250C MWD tools
  - GE's Spectra-gamma
  - Reduced tool size
    - Potential MEM inclination sensor
    - SS magnetometer
  - Rechargeable batteries
  - Enhanced magnetic for dynamic bit measurements
  - Improved power converters

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FEEDBACK

- Service company interest in:
  - A. HT Batteries
  - B. HT MWD + Gamma + Bit Measurements
  - C. HT Lead-Free Solders
  - D. Other

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Conclusion

- Sandia is working with the SAE to develop standards for reliability testing of new high-temperature electronic components needed to.
  - Improve energy efficiency of power systems
  - Reduce weight of aircraft and hybrid vehicles
  - Improve long-term reliability
- The next SAE meeting on this topic is hosted by Airbus, April 24 - 26, 2007, Toulouse, France
  - http://www.sae.org/servlets/aerostd/committeeHome.do?comtID=TEAAE7

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- Time for Questions?

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The Sandia Team: Electric Design

- Randy Normann and Joseph Henfling
- Sandia Drilling & Instrumentation Dept
- We have been working to develop HT tools for 8+ years. We have a number of commercial success stories for a 350C PTS tool, 300C Fluid-Steam Sampler and now unheat-shielded 250-300C PT tool.
- http://www.sandia.gov/geothermal/

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An outsider working with the Sandia team on utility power electronics

- Michael Ropp
- Associate Professor of Electrical Engineering, South Dakota State University
- Working with Sandia's Solar Energy Systems, Solar Technologies, and Energy Storage groups, and the Drilling and Instrumentation Department
- Areas of activity:
  - High-reliability modular power electronics for utility-scale applications
  - Improved means for controlling power systems using power electronics and communications
  - Integration of renewable energy resources into power systems

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The Sandia Team: Electrical Interconnection

- Paul Vianco
- Metals Processing Department
- Part of the Materials and Process Science Center, performs research and development studies in the area of metals melting and casting at the Liquid Metal Processing Laboratory. http://www.sandia.gov/materials/sciences/1861.htm
- Paul has experience in designing reliable solder electrical interconnects.

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The Sandia Team: MEMS

- Seethambal “Sita” Mani
- MEMS Technology Department
- Integrated Microsystems provides customer focused engineering services required for the development of micro sized products based on emerging micro technologies. While our focused developmental areas are dedicated to our mission of National Security we also partner with industry and government.
- Sita is working on this project along with others in a joint effort with the U of Texas at Austin. This joint project is looking at what sensors are the most beneficial for the production life of a well.

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