Improving Gas Well Drilling and Completion with High Energy Lasers

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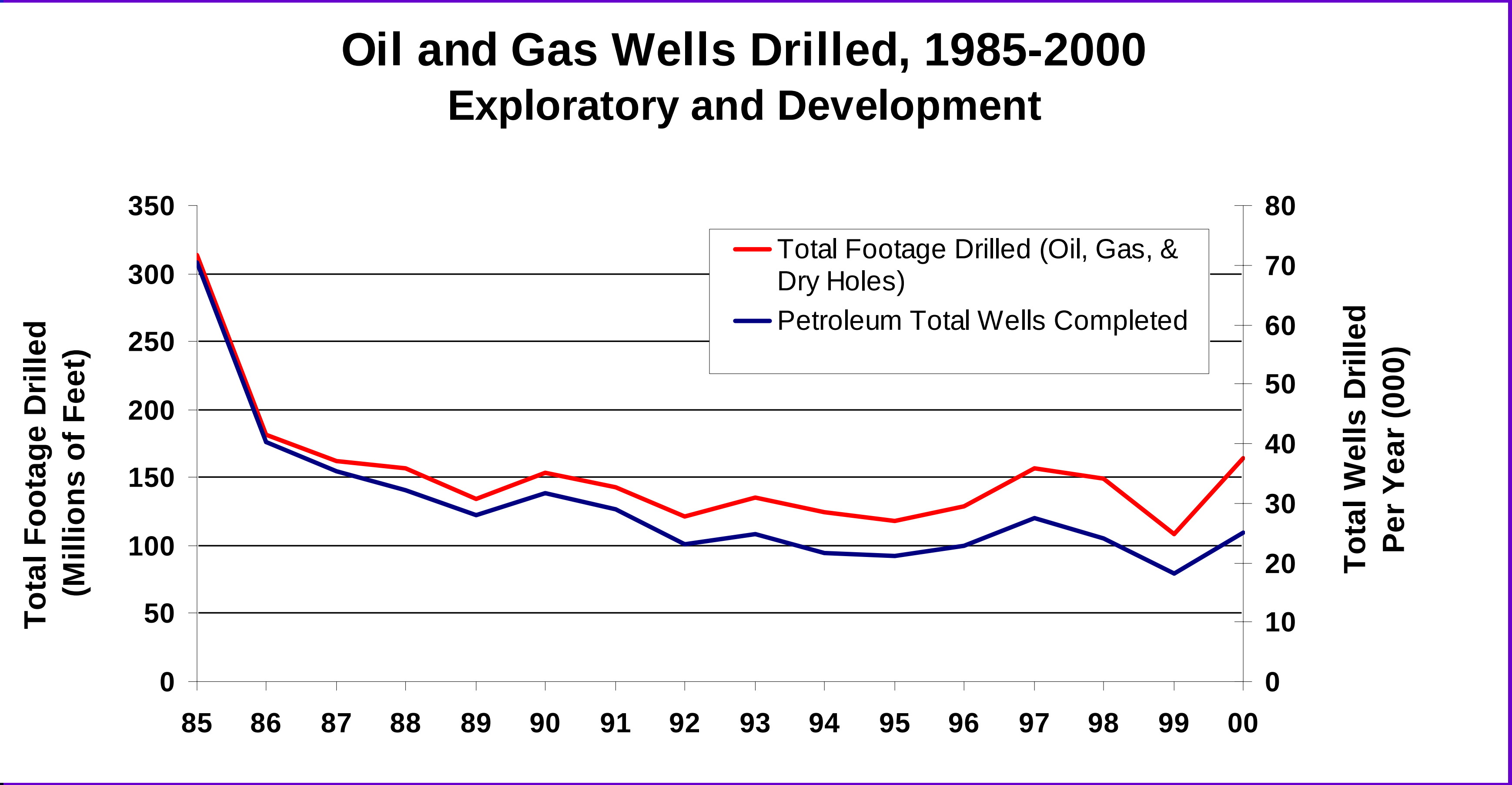
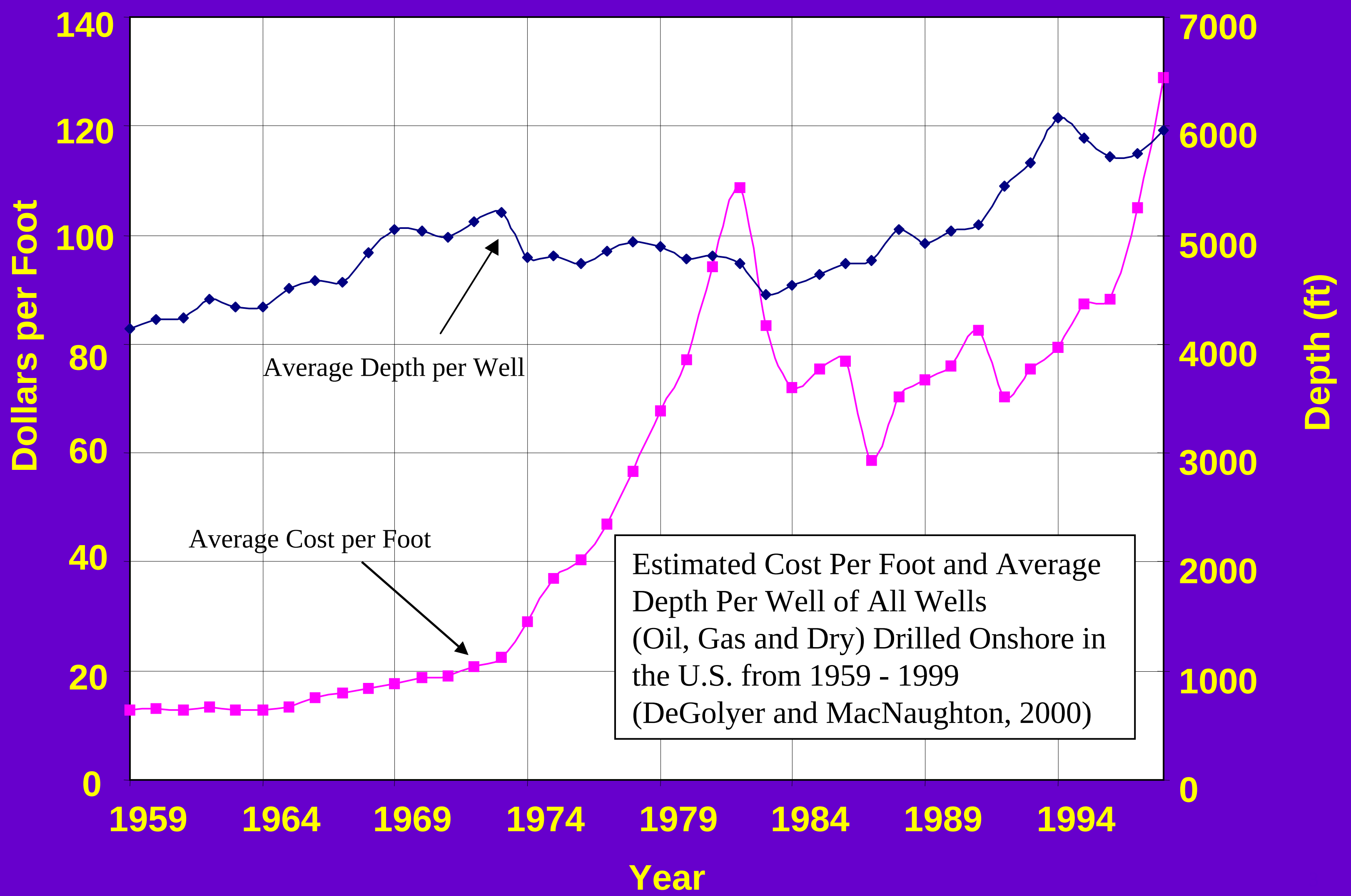
Drilling for Oil and Gas in the US



Drilling for Oil and Gas in the US



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Drilling for Oil and Gas in the US

- **1990 GRI Study on Drilling Costs**

Major Categories	% of Total Time
Making Hole	48
Changing Bits And Steel Casing	27
Well & Formation Characteristics	25
Total Drilling Time	100%

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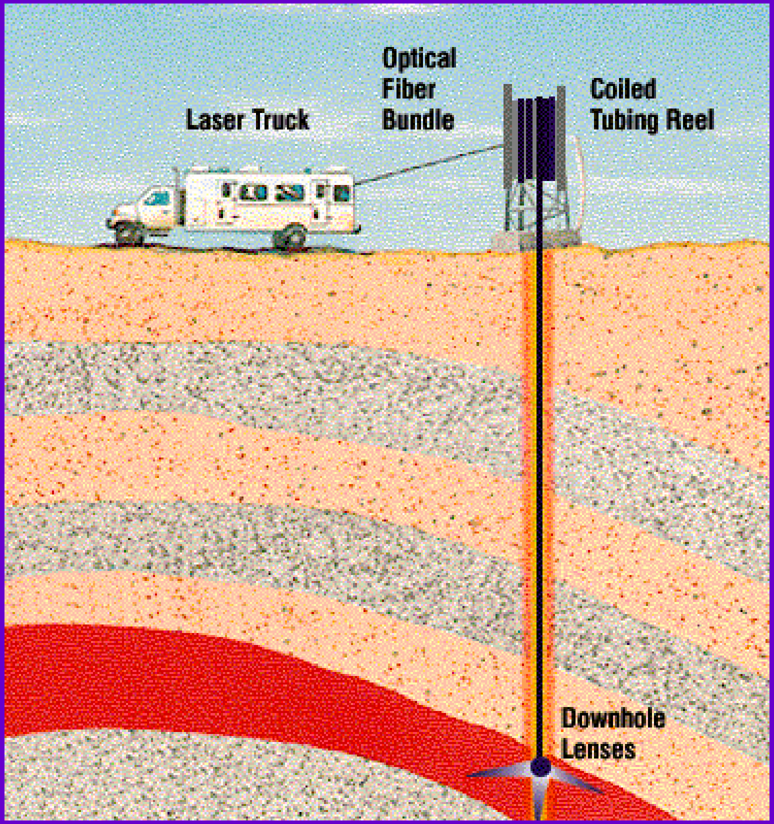
High-energy Laser Applications



Lasers could play a significant role as a vertical boring & perforating tool in gas well drilling

System Vision

- Laser on surface or within drilling tubing applies infrared energy to the working face of the borehole.
- The downhole assembly includes sensors that measure standard geophysical formation information, as well as imaging of the borehole wall, all in real time.
- Excavated material is circulated to the surface as solid particles

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System Vision

- When desired, some or all of the excavated material is melted and forced into and against the wall rock.
- The ceramic thus formed can replace the steel casing currently used to line well bores to stabilize the well and to control abnormal pressures.

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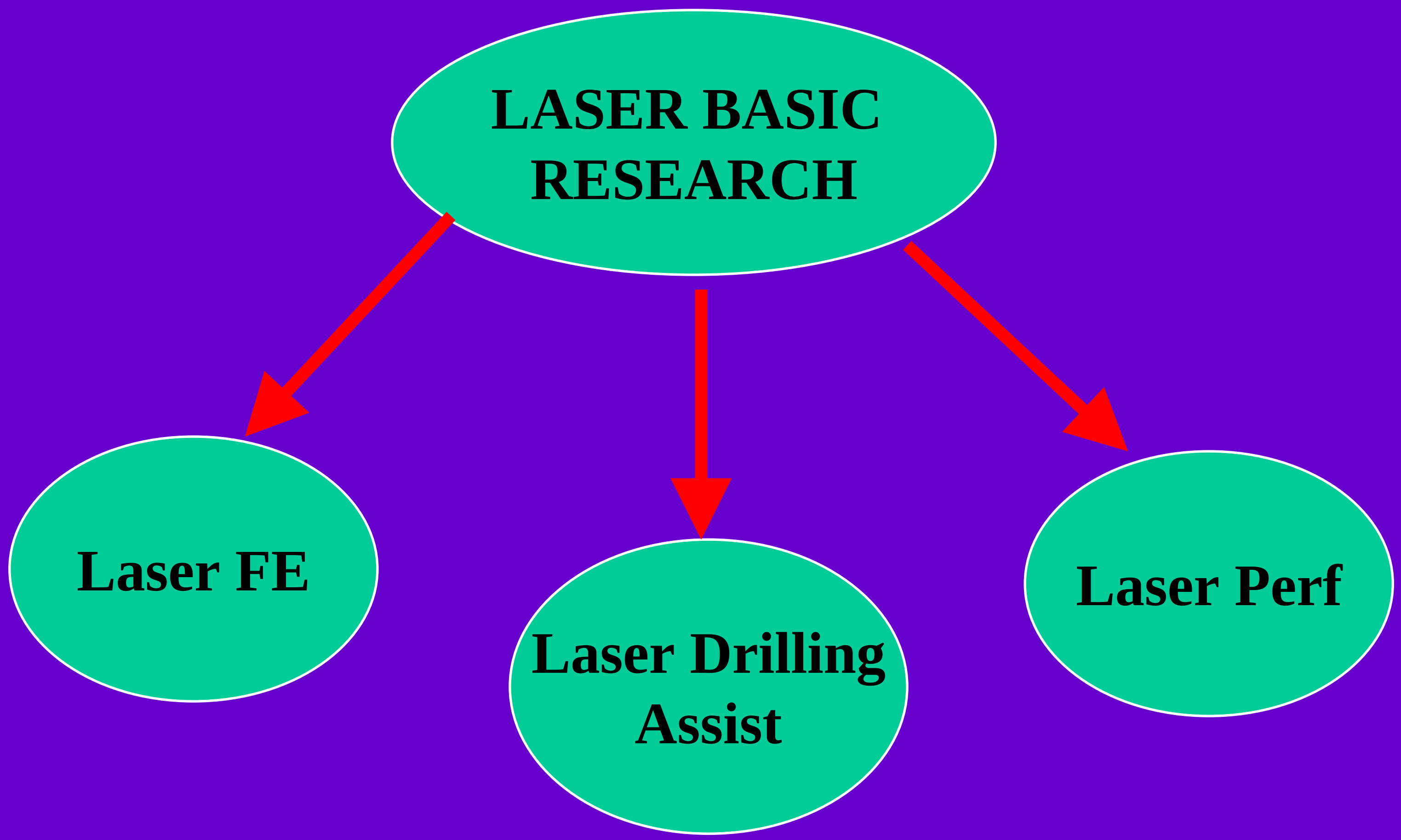
System Vision

- When the well bore reaches its target depth, the well is completed by using the same laser emergy to perforate through the ceramic casing.
- All this is done in one pass without removing the drill string from the hole.

Laser Product Development



Off Ramp: Perforating Tool

- Proposal Submitted to Service Industry Partner
- Purpose
  - Complete or re-complete existing well using laser energy
- Requirements
  - Durable, reliable laser system
  - Energy delivery system
  - Purpose designed downhole assembly

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Preliminary Feasibility Study

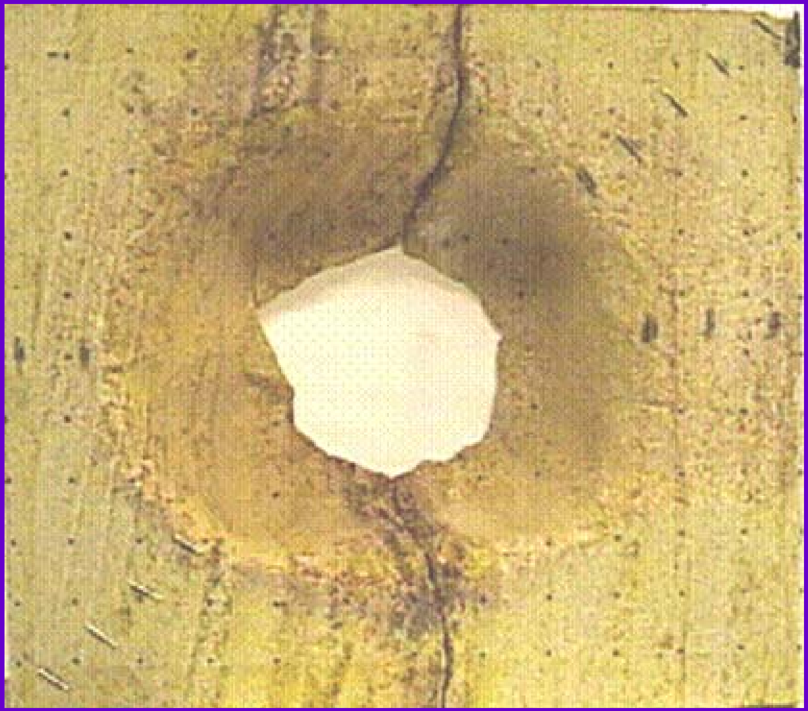
- Laser Drilling Experiments – 11/97
  - Basic Research – 2 years
- Three High-Powered Military Lasers
  - Chemical Oxygen Iodine Laser (COIL)
  - Mid Infra-Red Advanced Chemical Laser (MIRACL)
  - CO_2 Laser
- Various Rock Types Studied
  - Sandstone, Limestone, Shale
  - Granite, Concrete, Salt

MIRACL – Simulated Perf Shot

A two-inch laser beam is sent to the side of a sandstone sample to simulate a horizontal drilling application.

MIRACL – Simulated Borehole Shot

After a four-second exposure to the beam, a hole is blasted through the sandstone sample, removing six pounds of material.



GRI-Funded Study Conclusions

- **Previous Literature <u>Overestimated</u> SE**
- **Existing Lasers Able to Penetrate <u>All</u> Rock**
- **Laser/Rock Interactions Are a Function of Rock and Laser (Spall, Melt or Vaporize)**
- **Secondary Effects Reduce Destruction**
- **Melt Sheaths Similar to Ceramic**

Study Conclusions Indicate Additional Research is Warranted

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Laser Drilling Team – Phase I

Gas Technology Institute

DOE NETL

Argonne National Laboratory

Colorado School of Mines

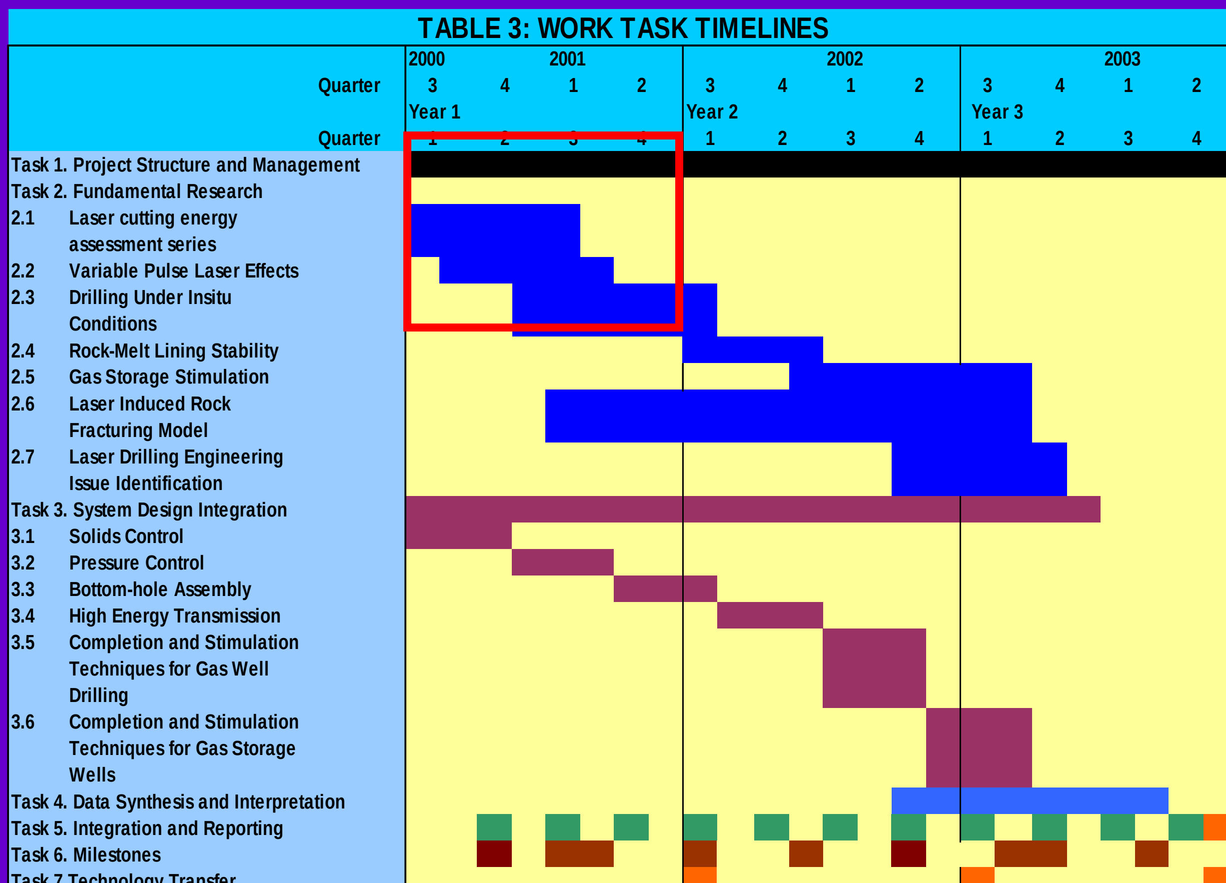
Parker Geoscience Consulting

Halliburton Energy Services

PDVSA-Intevep, S.A

Drilling With The Power Of Light

- DOE Cooperative Agreement DE-FC26-00NT40917
  - Original Proposed Tasks and Timeline



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First Phase (FY-01) Objectives

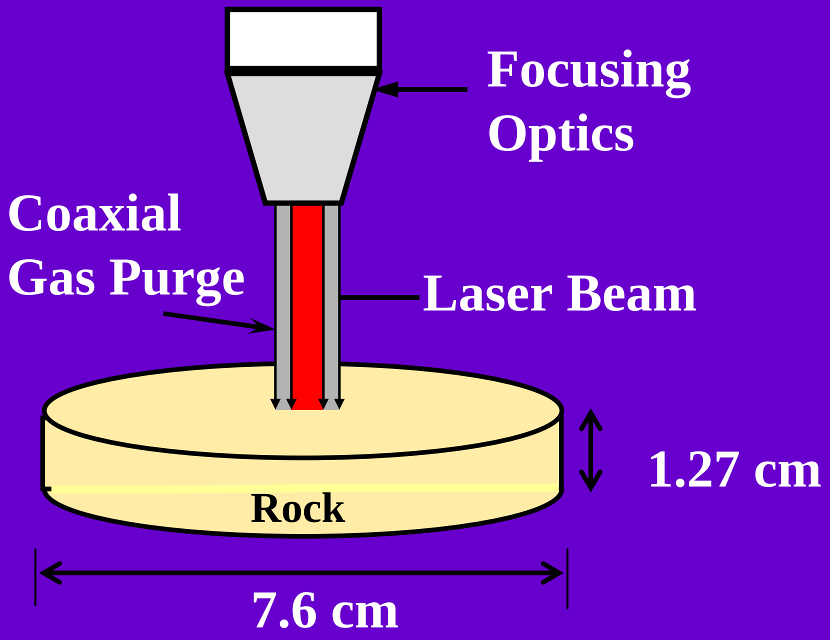
- **Accepted Phase 1 Task List**
  1. **Laser cutting energy assessment**
  2. **Variable pulse laser effects (Nd:YAG)**
  3. **Lasing through liquids**

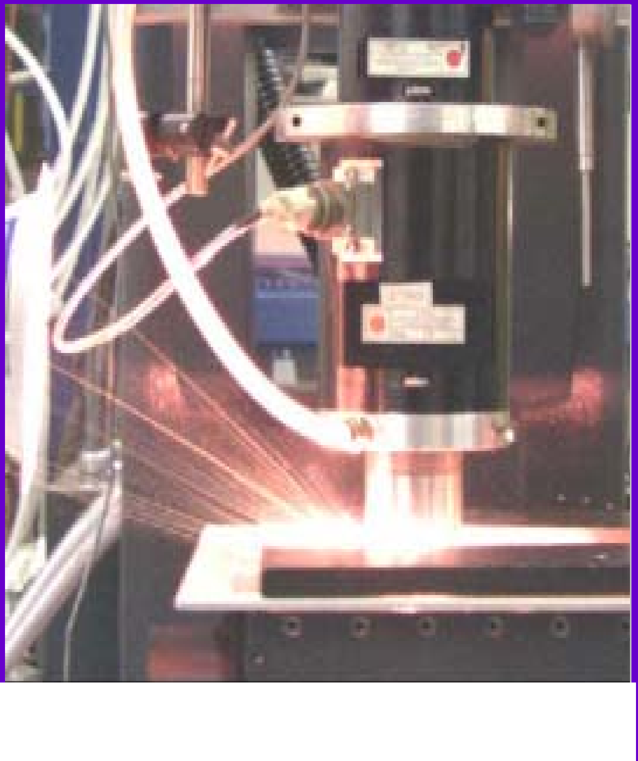
TABLE 3: WORK TASK TIMELINES

		2000	2001		
	Quarter	4	1	2	3
		Year 1			
	Quarter	1	2	3	4
1.0	Project Structure and Management				
1.1	Laser cutting energy assessment series				
1.2	Variable Pulse Laser Effects				
1.3	Conduct Lasing Through Liquids				
1.4	Topical Report				

Phase I Laser: 1.6 kW Nd:YAG

Neodymium Yttrium Aluminum Garnet (Nd:YAG)





Conclusions: GTI/DOE Phase I

- **SE for Shale 10x Less Than SS or LS**
- **Pulsed Lasers <u>Cut Faster</u> & With <u>Less Energy</u> Than Continuous Wave Lasers.**
- **Fluid Saturated Rocks Cut Faster Than Dry Rocks.**
  - **Possible Mechanisms Include:**
    - **<u>More Rapid Heat Transfer</u> Away From the Cutting Face Suppressing Melting**
    - **Steam <u>Expansion</u> of Water**
    - **Contributing to Spallation**

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Conclusions: GTI/DOE Phase I

- **Optimal Laser Parameters Observed to Minimize SE for Each Rock Type**
- **Shorter Total Duration Pulses Reduce Secondary Effects from Heat Accumulation**
- **Rethink Laser Application Theory – Rate of Application: Blasting vs Chipping**
- **Unlimited Downhole Applications Possible due to Precision and Control (i.e., direction, power, etc.)**

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DOE-GTI/NGOTP-ANL Phase 2 In Progress

- Continuation of SE Investigations
  - Effects at In-Situ Conditions
  - Effects of Multiple Bursts and Relaxation Time
  - Observations at Melt/Vapor Boundary

Supporting Slides Detailing Phase I Work

Laser Cutting Energy Assessment

- Measure specific energy (SE)
  - Limitation of variables
    - SS, shale and LS samples
    - Minimize secondary effects
  - Identify laser-rock interaction mechanisms (zones)
    - Spall, melt, vaporize

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Just Enough Power

- Conducted Linear Tests
  - Constant Velocity Beam Application (dx)
  - Constant Velocity Focal Change (dz)
- Five Zones Defined in Linear Tests
- Identified Zones Judged Desirable for Rapid Material Removal
  - Boundary Parameters Determined for Spall into Melt Conditions

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Laser/Rock Interaction Zones

- Zone Called Thermal Spallation Judged Desirable for Rapid Material Removal
- Optimal Laser Parameters Were Determined to Minimize:
  - Melting
  - Specific Energy (SE) Values
  - Other Energy Absorbing Secondary Effects, and
  - Maximize Rock Removal
- Short Beam Pulses Provided "Chipping" Mechanism Comparable to Conventional Mechanical Methods

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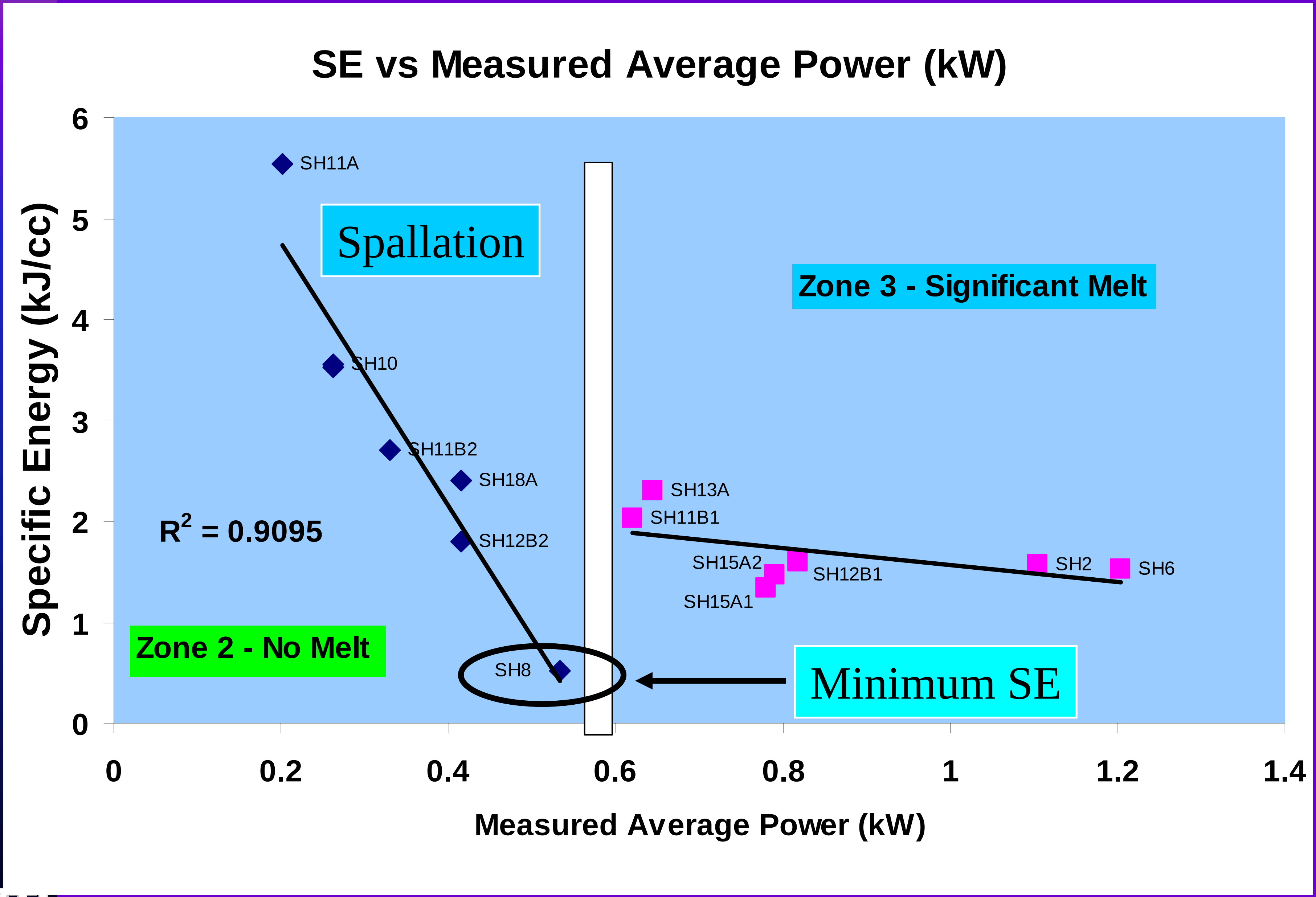
Zonal Differences

- SE differs greatly between zones
- Shale shows clear SE change between melt/no melt zones
- Much analysis remains to understand sensitivities of different variables

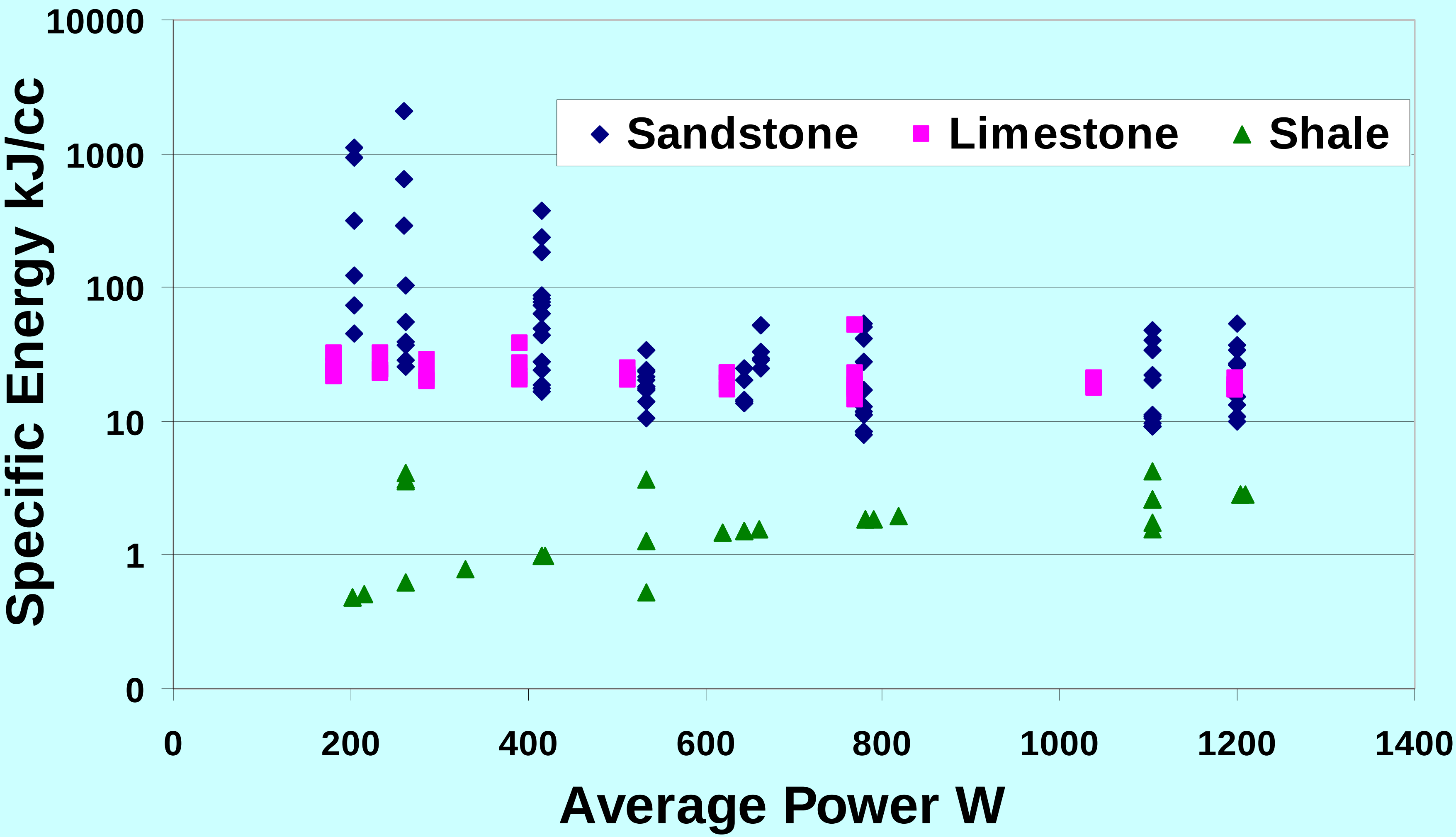


SE vs Measured Average Power (kW)
Specific Energy (kJ/cc)
Measured Average Power (kW)
0
1
2
3
4
5
6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
SH11A
Spallation
Zone 3 - Significant Melt
SH10
SH11B2
SH18A
SH13A
SH11B1
R2 = 0.9095
SH12B2
SH15A2
SH12B1
SH2
SH6
SH15A1
Zone 2 - No Melt
SH8
Minimum SE

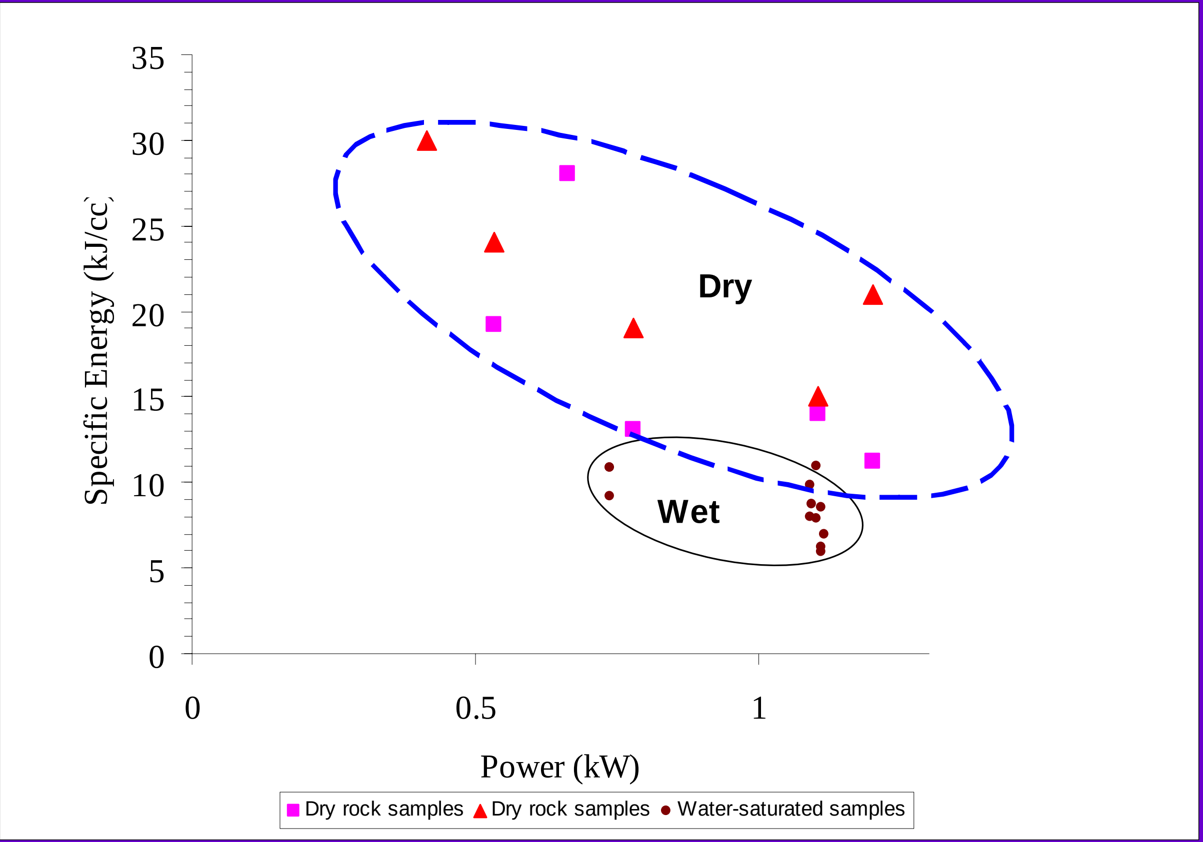
Lithology Differences

- Differences between lithologies more pronounced when secondary effects minimized
- Shale has lowest SE by an order of magnitude.
- Sandstone and limestone remain similar, as in CW tests

All ND:YAG Tests



SE Values: Wet vs. Dry Samples



Atmospheric Conditions