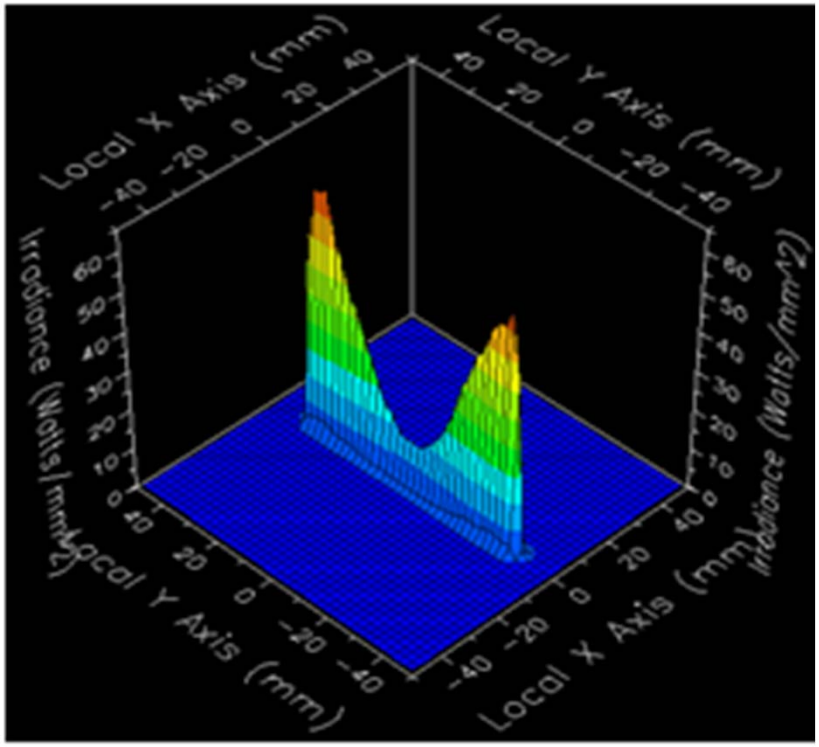

Microhole Drilling: Application of Low Weight-on-Bit Drilling Technologies

Project Officer: Eric Haas

Total Project Funding: $3M

November 14, 2017

SAND2017-10569 C

Principal Investigator (Jiann Su)

Sandia National Laboratories

Track One

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Relevance to Industry Needs and GTO Objectives

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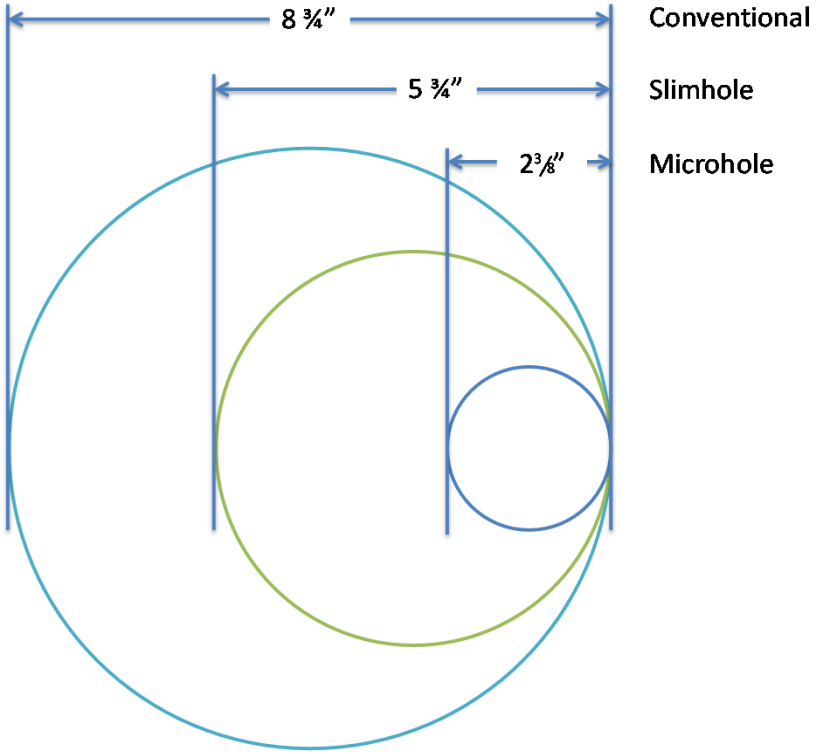
- Microhole uses
  - Exploration
  - Monitoring & evaluation
- Microhole benefits
  - Smaller footprint
  - Rapid mobilization/de-mob
  - Higher-resolution imaging
  - Lower cost
- Help to realize potential of microborehole drilling (up to 70% savings)
- Enable economical access



Methods/Approach

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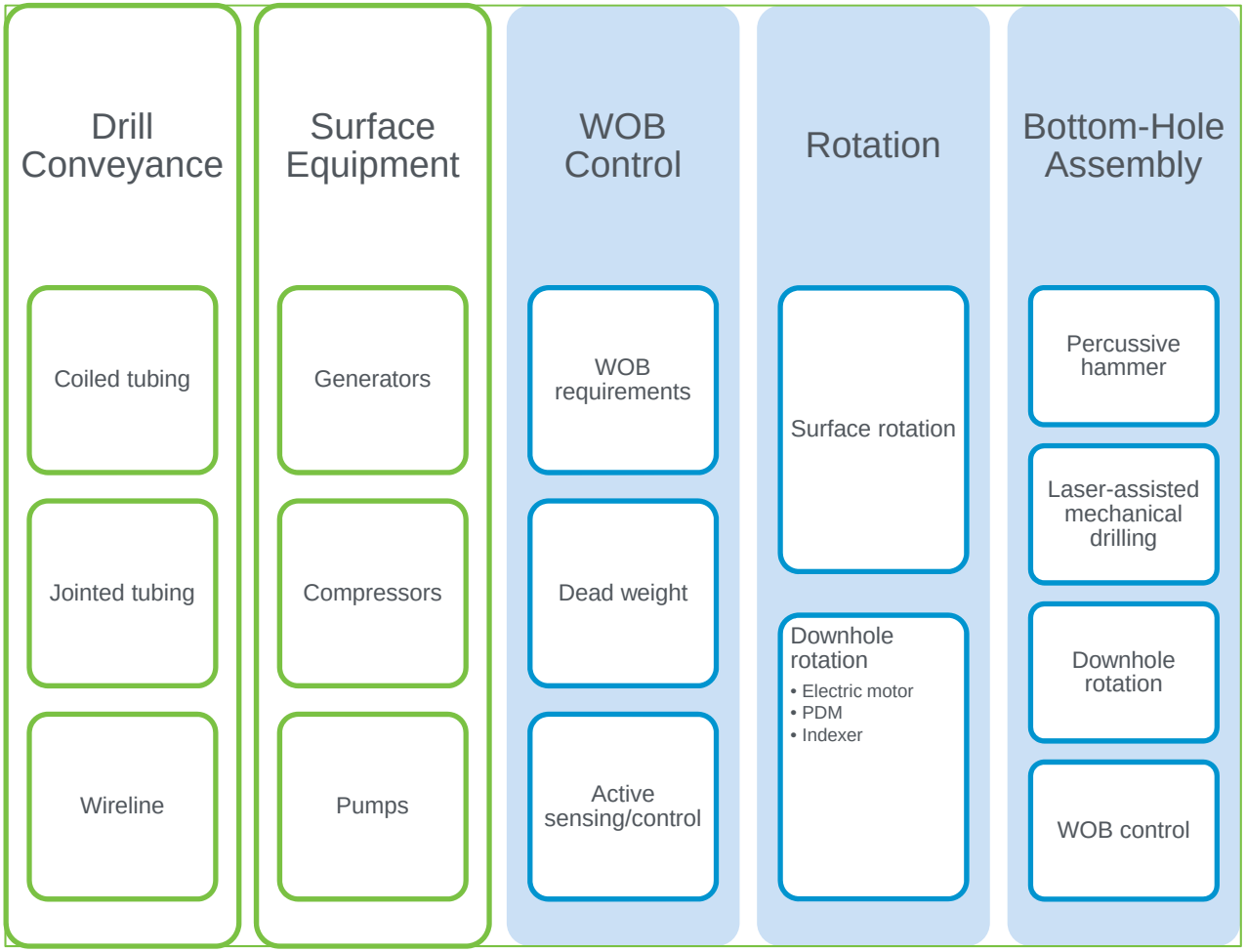
- Define microhole
- Validate and establish proof-of-concept low WOB drilling technology
- Develop WOB control strategies & techniques for microhole drilling
- Develop downhole rotation for low WOB drilling
- Help to realize economic and technical promise of microhole drilling
- Build on previous microhole drilling efforts
- Leverage previous DOE investments



Microhole Modeling Results
Productivity Index

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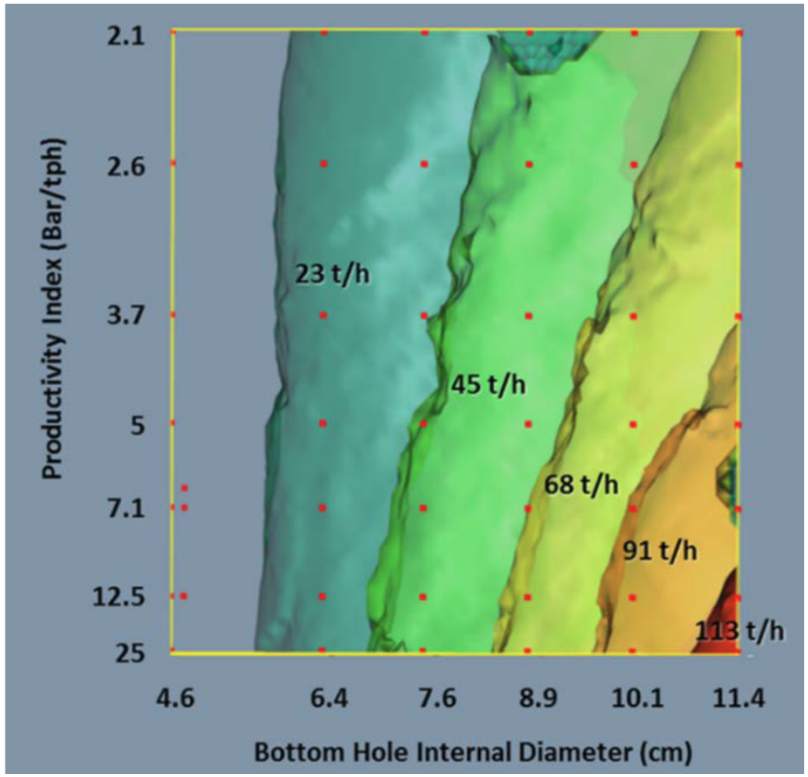
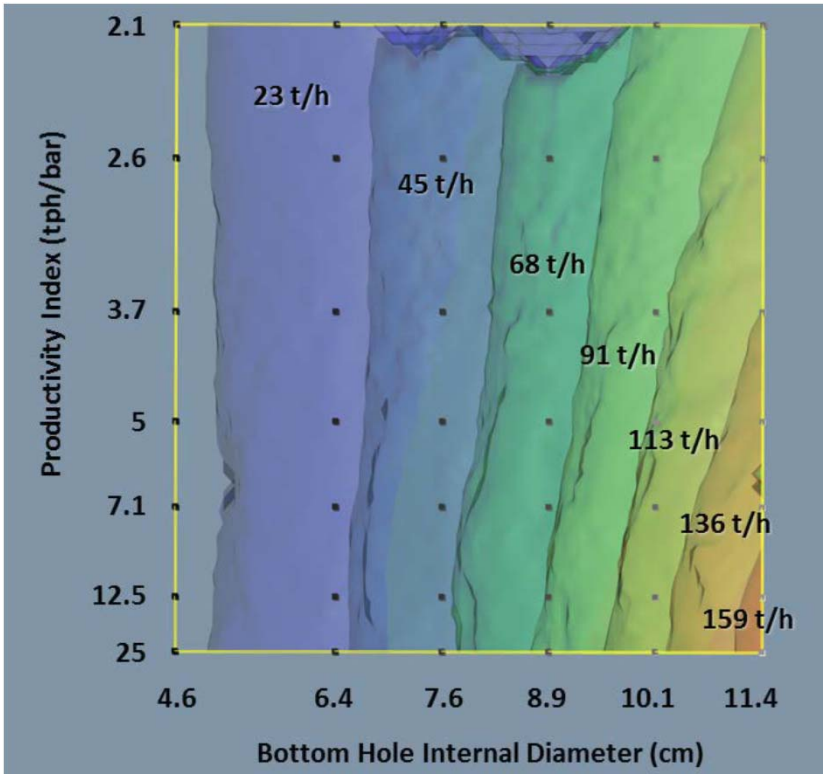
3000 ft borehole



>3.0”

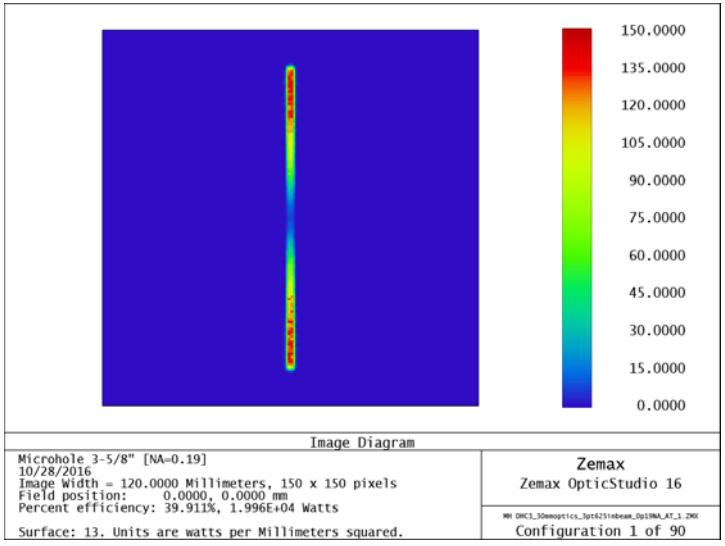
6000 ft borehole

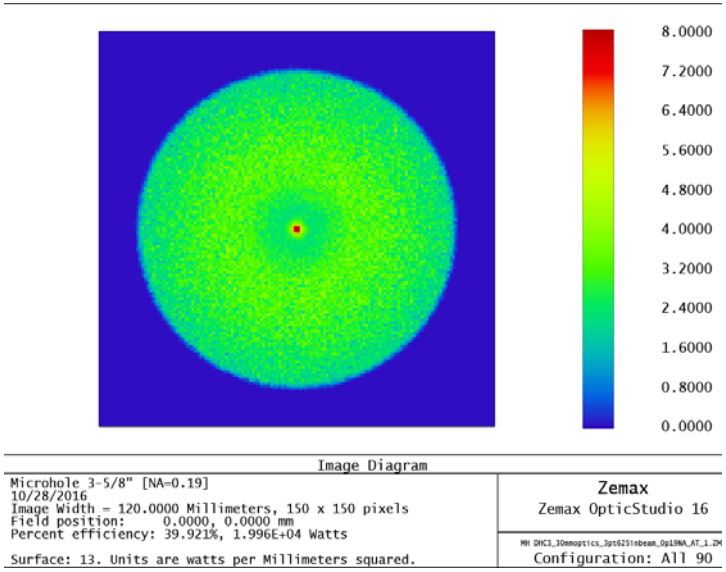


> 4.5”

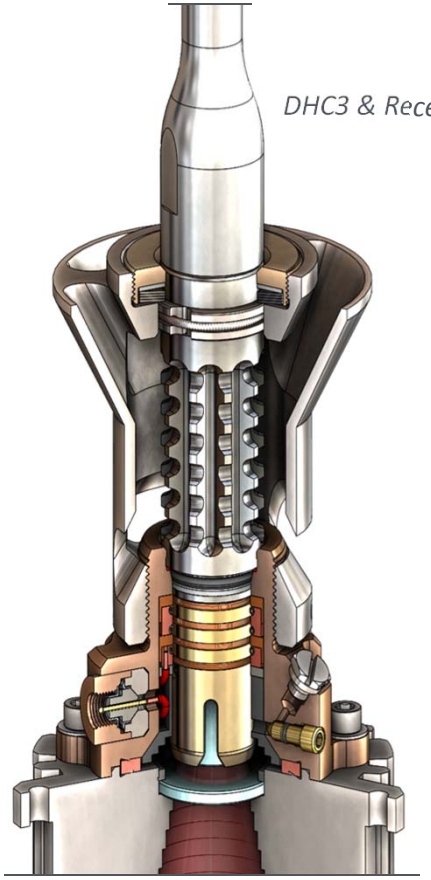
Targeting 3.5” – 4.5” range

Task 3.1 Laser-Assisted Mechanical Drilling





- Accommodate higher power, deeper downhole tools
  - Up to 60kW throughput power
  - Air or liquid cooling
  - High pressure/temperature hermetic seal
- Enable plug & play tool architecture
  - Integrated electrical power and telemetry to tool
  - Integrated tool air purge in receptacle
- Enhance feedback
  - Working position interlock
  - Faster temperature sensor
  - Integrated stray light sensor



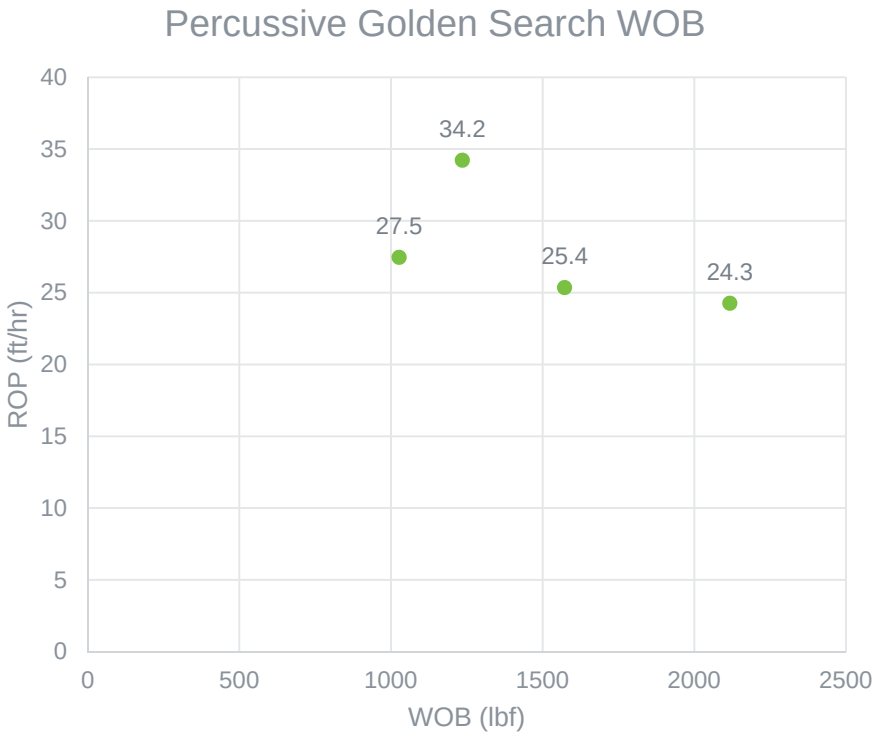
DHC3 & Receptacle

FORO ENERGY

Task 3.2 Percussive Hammer

- Utilizing COTS hammers to establish low WOB drilling requirements
- 3” hammer, 4” bit
- Tested hammer with coated piston and feed tube
- Identified design modifications for elevated temperature

Task 4.1 WOB Control (Algorithm)

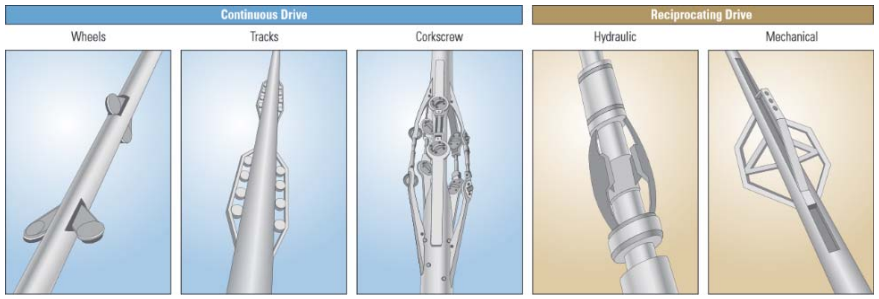


- Drill-off (man vs. machine)
  - Depth: 39”
  - Pressure: 175 psi
- Static WOB Setting
  - WOB: 4000 lbf
  - ROP: ~27 ft/hr
- GS Optimized WOB
  - WOB: GS optimized
  - ROP: ~33 ft/hr

~20% improvement in ROP

Task 4.1 WOB Tool Options

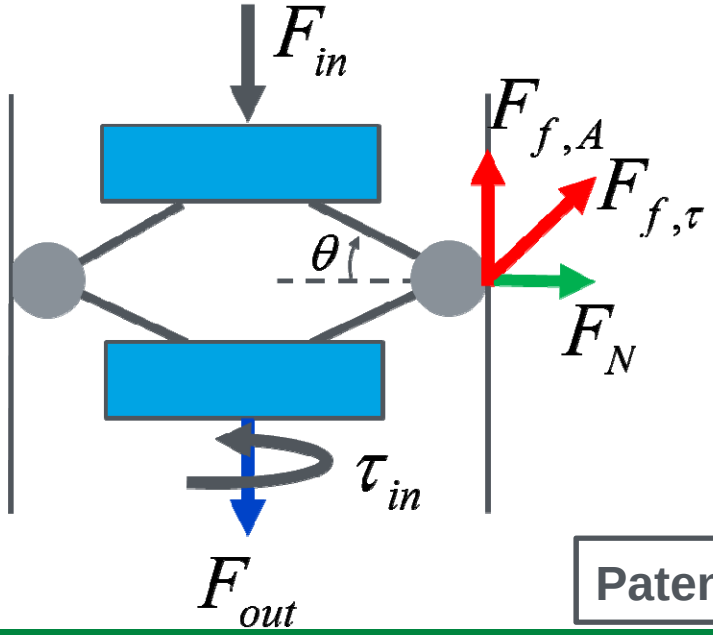
Dead Weight (aka drill collars)

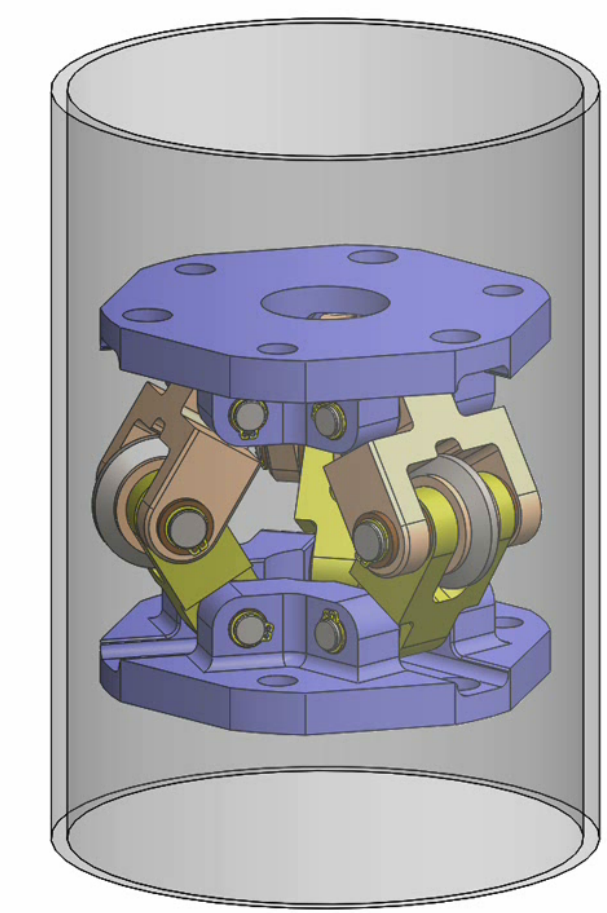


- Advantages
  - Passive component
  - Flexible configuration
  - Conventional drilling method
  - Cost-effective
- Disadvantages
  - Potentially long BHA
  - Dense material may be brittle (e.g. Tungsten)

WOB Tool Design

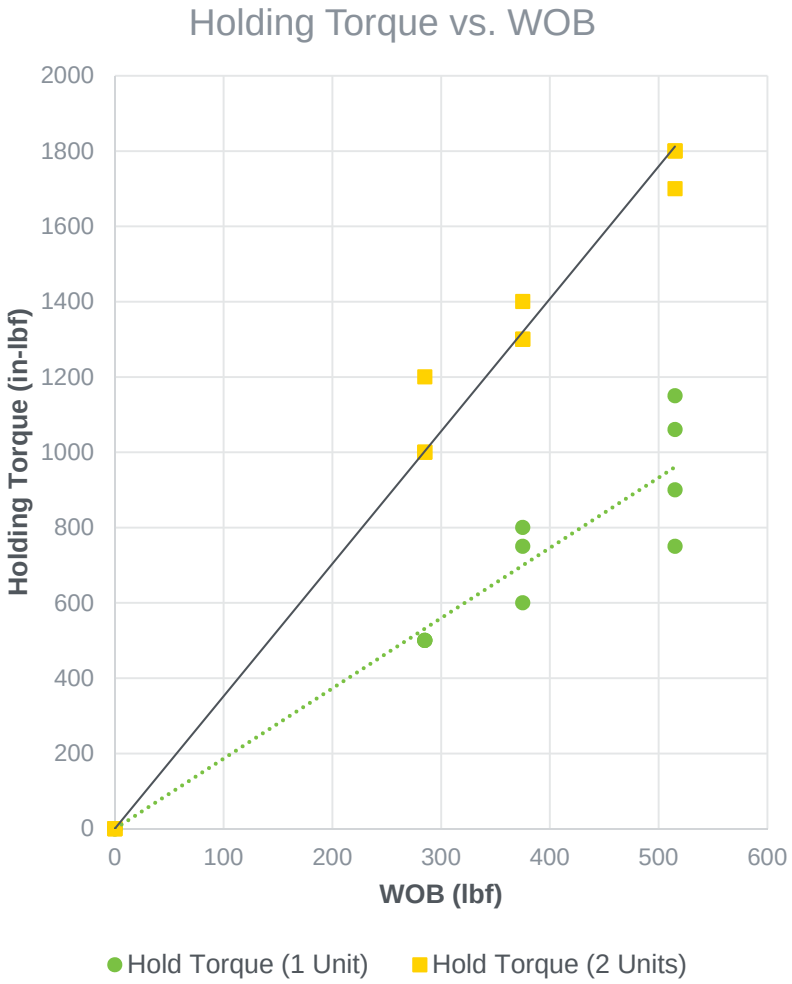
- Utilizes conventional drill collar for WOB
- Allows axial movement while reacting torsion (differential friction between rolling and sliding)
- Modular design (multiple units to amplify lateral forces)

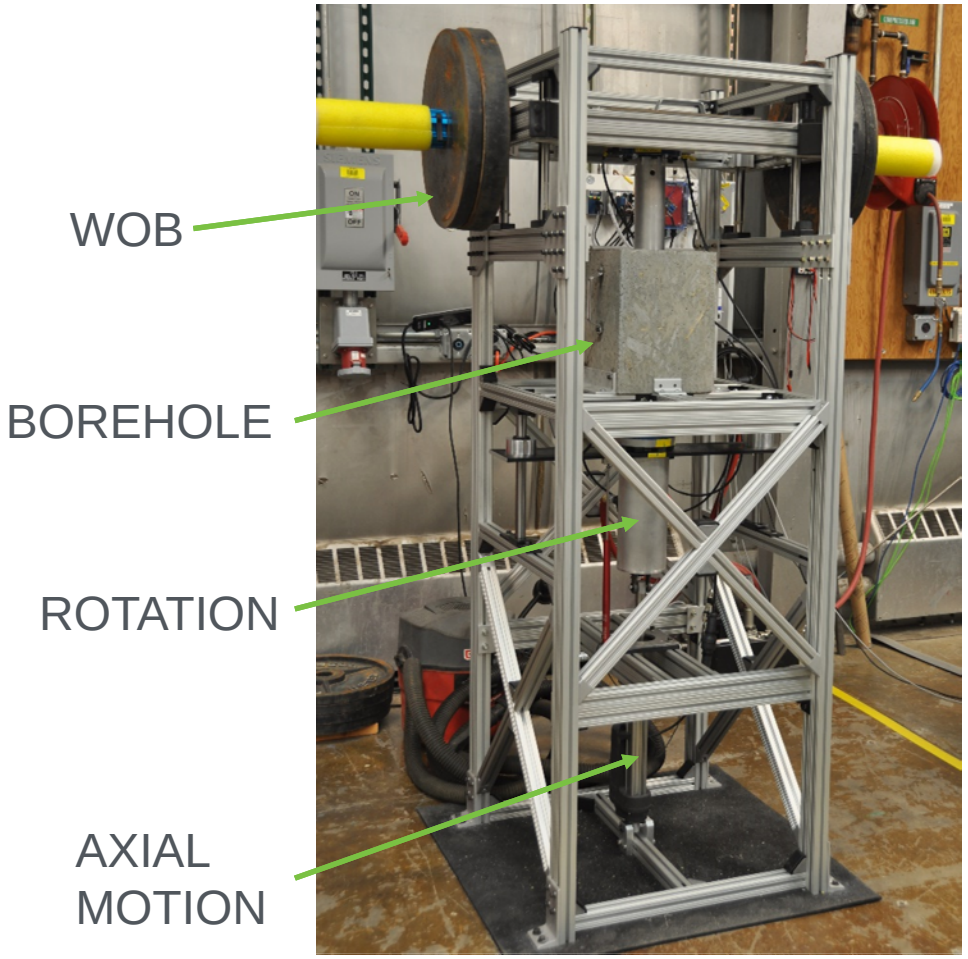




Patent application submitted

WOB Module Testing





Task 4.2 Integrated Motor and Hammer

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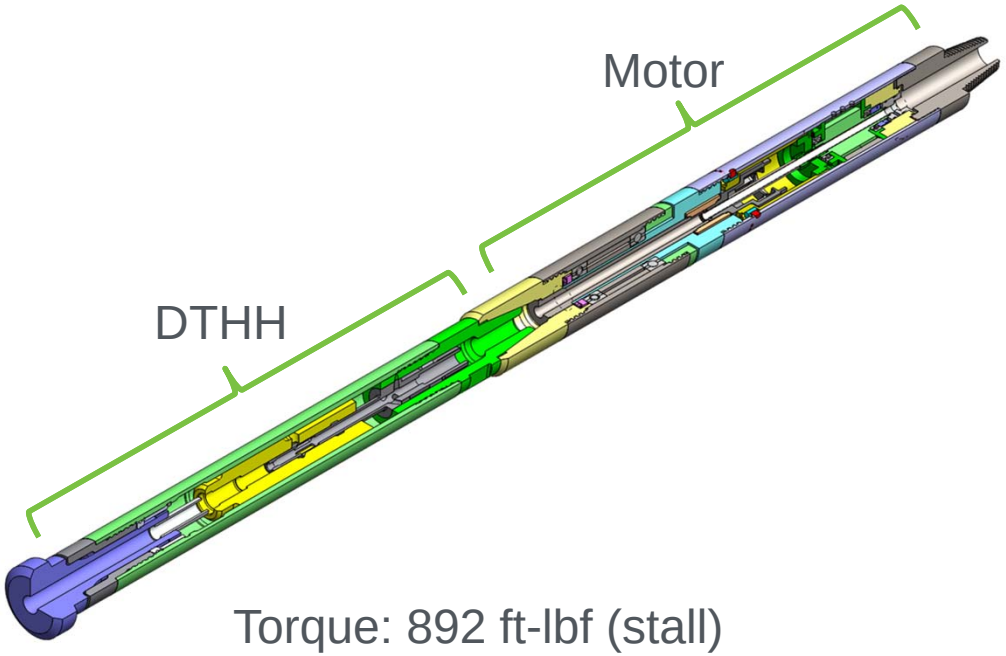
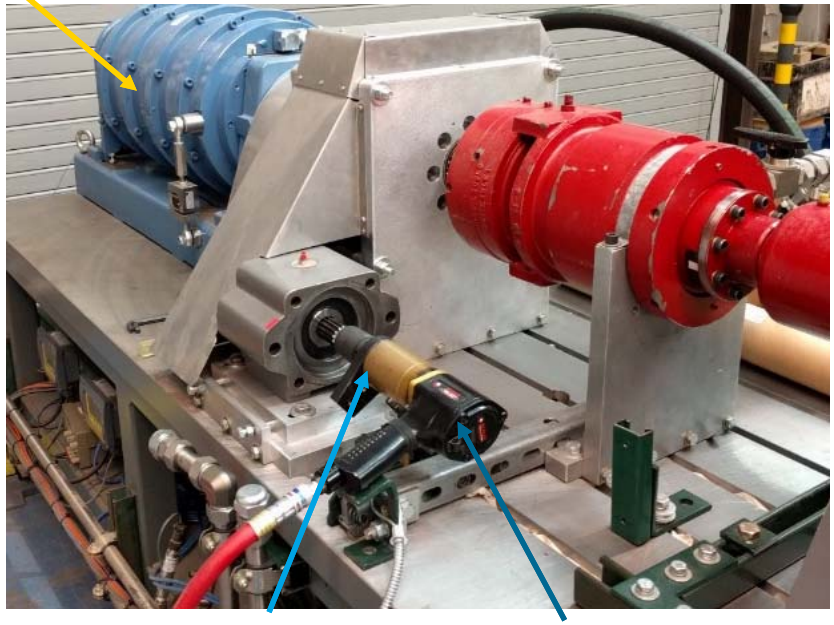
Integrated Hammer and Motor



Torque: 892 ft-lbf (stall)
Dimensions: ~3” OD x 30”

RadTorque Pneumatic Motor



Patent application submitted

Technical Accomplishments and Progress

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- Conducted resource assessment modeling with Geothermal Resources Group to define useful microholes
- Implemented weight-on-bit control optimization algorithm leveraging Sandia LDRD
- Designed and tested prototype WOB control/anti-rotation hardware (lead to patent application)
- Designing and building integral downhole rotation for percussive hammers (lead to CRADA with CMW)
- Tested small-diameter percussive hammers without lubrication
- Completed small-diameter laser-assisted mechanical drilling design utilizing DHC-3 connector for high-pressure/temperature seal

Milestone	Description	Completion Date	Status
~~FY16~~	~~Specify requirements for low WOB drilling bottom hole assembly (BHA) and identify and demonstrate technologies capable of meeting system level performance targets~~ ~~Verification Method: Analysis~~	~~Q4 FY16~~	~~Complete~~
-	~~Quarterly Progress Measures~~ ~~- Complete literature review of microhole drilling cost drivers~~ ~~- Complete necessary partnership agreements to perform work~~ ~~- Complete microhole resource assessment modeling~~ ~~- Complete requirements definition for downhole tools~~	- ~~Q1 FY16~~ ~~Q2 FY16~~ ~~Q3 FY16~~ ~~Q4 FY16~~	 ~~Complete~~ ~~Complete~~ ~~Complete~~ ~~Complete~~
FY17	~~Design and complete build of small diameter, low WOB drilling tools. (3" diameter percussive hammer, 3" laser-mechanical optics package and drill)~~ Verification Method: Inspection, analysis, limited lab tests	Q4 FY17	
Go/No-Go	Quarterly Progress Measures ~~- Identify downhole rotation and WOB control options~~ ~~- Preliminary designs for downhole tools are complete and ready for fab~~ - Designs for low WOB tools are in production - Low WOB tools production is complete	 Q1 FY17 Q2 FY17 Q3 FY17 Q4 FY17	 Complete Complete In progress In progress
FY18	Build, integrate, and conduct initial prototype lab test bottom hole assembly (BHA) (drill, rotation, WOB control) Verification Method: Demonstrate rapid ROP and path towards compelling commercial economics in a laboratory test frame.	Q4 FY18	
	Quarterly Progress Measures - Select and acquire rotation option for BHA - Implement WOB control - Successfully integrate BHA components - Test integrated low WOB BHA	 Q1 FY18 Q2 FY18 Q3 FY18 Q4 FY18	 In progress In progress
FY18	Submit final report to DOE	Q4 FY18	

Research Collaboration and Technology Transfer

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- CRADA with Charles Machine Works to co-develop integral downhole rotation tool for use with percussive hammers
- DOE Technology Commercialization Fund (TCF) award to develop downhole rotation with Charles Machine Works
- Patent application for the weight-on-bit (WOB) control mechanism

Future Directions

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- Continued lab testing
- Limited field testing
  - Blue Canyon Dome in Socorro, NM
  - 5” OD x 4.25” ID casing 35’
  - 4” ID x 20’ open hole
- Continued collaboration with partners

Mandatory Summary Slide

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- Addressing limitations of previous efforts in microhole drilling
- Developing new technology as well as leveraging existing technology
- Garnered additional interest from new commercial partner
- Project following proposed schedule

Acknowledgements

- Sandia National Labs (Ani Mazumdar, Steve Buerger, Adam Foris, Elton Wright)
- Geothermal Resources Group (Dennis Kaspereit)
- Atlas Copco Secoroc (Dale Wolfer)
- Foro Energy (Ian Lee, Brian Faircloth)