Hydraulic Fracturing Test Site 2 (HFTS 2)
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Presentation Outline

• Project Overview
• Project Progress
• Background Data
• Industry Participation
• Test Site Location and Well Details
• Technical Status
• Accomplishments to Date
• Synergy Opportunities
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Hydraulic Fracturing Test Site #2: Project Overview

- Field-based hydraulic fracturing research program in west Texas, Permian (Delaware) Basin
- Public-private partnership with NETL and 16 industry partners providing technical support and cost sharing
- Site host Anadarko (Shell interest owner)
- $30 million of new hydraulic fracturing research
- Advanced diagnostics including coring through hydraulically fractured reservoir, fiber optics, pressure monitoring, proppant quantification, etc.
- Goal is to define/mitigate environmental impact and optimize HF and well spacing
Project Progress and Major Milestones

- 2018
  - Secure Funding and Test Site
  - Design Testing Program
  - Field Data Acquisition & Diagnostics
  - Slant Core Well

- 2019
  - Data Analysis & Integration

- 2020
  - Initial Confidentiality Period Expires

- 2021
  - Slant Core Well
  - (Sep/Oct)
  - Frac and diagnostics
  - Finish drilling all horizontal pilot hole
  - Drill vertical pilot hole
  - Go/No-go Decision Point
  - Selected test site host
  - Initial DOE Award
Background Data

- 20 Wolfcamp A Wells
- Generic Data
  - Daily drilling and completions reports
  - Final directional surveys; Final as-built plats
  - Wellbore, casing BHA/bit specs/diagrams
- Completion Information
  - Well test report, frac stimulation reports
  - Stage lengths, cluster spacing, proppant/fluid
- Daily Production Data
  - Oil, gas, water, pressures, choke sizes
- Vertical Core with Conventional Core Analysis
  - Photographs, Hyperspectral Scanning, XRD & Thin Section Analysis, High Resolution SEM
  - Geochemistry, Rock mechanics, Fresh State NMR
  - Wireline Quad Combo-Dipole Sonic and OBMI
- Petrel Based Earth Model
HFTSII – Delaware Participants

- Technical Advisory Group
- 6 Technical Committees with Chairs
  - Formation Evaluation
  - Completions
  - Microseismic
  - Instrumentation
  - Slant Core Well
  - Data Integration and Modeling

Currently 126 SMEs
Test Site Location

Loving County Texas Block 55
LOVING COUNTY, TEXAS

"America's emptiest County" - New York Times
2012 Population Estimate ~ 71 Residents

FACTS ABOUT LOVING COUNTY:
- There's no school in Loving County. Children are bused 33 miles east to Wink.
- Mentone has no water (it has to be hauled in), no bank, no cafe, no doctor, no cemetery.

Source: Ralph Blumenthal, NY Times; Wikipedia; rootsweb.ancestry.com

Loving County was named for Oliver Loving, a trail-blazing cattleman.

One person for every 9 square miles lives in Loving County!

Mentone ~ only town in the county

FUNMAPUSA.NET
Test Site Wells

New Drilled Wells (3 FO)
- **Pad 2**: Boxwood 55-1-12 Unit 2H/3H/4H
- **Pad 5**: Boxwood 55-1-12 Unit 5PH

Existing Drilled Wells
- **Pad 1**: Boxwood/Redbud 55-1-12 Unit 1H
- **Pad 3**: Thresher 55-1-12 Unit A 13H/14H
- **Pad 4**: Thresher 55-1-12 Unit A 15H/16H

Producing “Parent” Wells
- **Pad 6**: Bitterroot 54-1-18 1H/2H

Image Courtesy: APC
Wells & Diagnostic Instrumentation

5 Wolfcamp Alpha and Beta Targets

- Vertical Pilot Hole with Permanent Fiber Optic and P/T Gages
- Horizontal Test Well
- Horizontal Test Well with Permanent Fiber Optic
- Permanent P/T Gage at Toe and Heel of Horizontal Well
- Permanent P/T Gage in Vertical Well
- Conventional MSM Array in Vertical and Horizontal wells
- Planned Slant Core Well

*Slant core well trajectory is notional at this time.*
Extensive Use of FO Diagnostics

Leveraging Shell’s expertise and equipment

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Image courtesy of Shell, Anadarko
Testing of Various Completions

• Base design
• Aggressive Limited Entry (ALE)
• ALE with tapered perforations
• Extreme Limited Entry (ELE)
• Extended Stage Length (ESL) with ALE
• ESL with tapered perforations and ALE
• Tight clusters with normal stage length
• Tight clusters with shorter stage length
• Single entry to calibrate DAS strain and amplitude
Cross Well Strain Monitoring

First known cross-well strain survey using a vertical and horizontal FO array
Accomplishments to Date

• Drilling
  • All wells drilled
  • Recovered vertical core on pilot hole (540ft of 750ft, 72%), failed core catcher
  • Installed 8 external P/T gauges on pilot hole
  • Ran fiber on Boxwood 3H, 4H, and 5PH
  • Logged 3 laterals and pilot hole, RSWCs for missed core section
Accomplishments to Date

• Completions
  • DFITs monitored 4 wells (Thresher 13H, 14H, 15H and Boxwood 2H)
  • Cable mapped fiber wells and ran gyro on Boxwood 3H to facilitate future slant well closer proximity
  • Monitored fracs with Microseismic tools placed in 3 wells: Boxwood 3H, Boxwood 5PH and Thresher 16H
  • Recorded FO Microseismic data
  • All wells frac’d, over 260 fracture stages in 8 wells

• Production
  • All Boxwood wells tubed up and on production
Planned Slant Core Well

- 76 degrees coring inclination
- >800’ feet of slant core (~200’ vertical coverage)
- Advanced OH logs
- Discrete P/T gauges
Synergy Opportunities

- Collaborate with other NETL field test sites; in the Marcellus, EagleFord, HFTS #1, etc.
- Support ongoing DOE HF research
- Explore NETL and other NL’s laboratory capabilities for potential collaboration using HFTS II core and field data
Project Summary

- Secured test site with Anadarko and Shell
- Substantial background data set
- Signed on 14 industry participants
- Significantly enhanced diagnostic and experimental design compared to HFTS#1 in Midland Basin
- Drilled and cored a vertical pilot hole
- Installed fiber in 3 wells
- Planning to spud core well in September/October 2019
- Unique opportunity for extremely robust integrated data acquisition
Acknowledgements

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Appendix

- These slides will not be discussed during the presentation, **but** are mandatory.
Benefit to the Program

• The research project is focused on **environmentally prudent development of unconventional resources & enhanced resource recovery.**

• The HFTS#2 is a collaborative, comprehensive hydraulic fracturing diagnostics and testing program in horizontal wells at a dedicated, controlled field-based site. The program emulates the field experiments DOE/NETL and GRI performed in vertical wells in the 1990s (Mounds, M-Site, SFEs). Technology has since advanced into long horizontal, multi-stage shale wells creating a new set of challenges and unanswered questions. HFTS will conduct conclusive tests designed and implemented using advanced technologies to adequately characterize, evaluate, and improve the effectiveness of individual hydraulic fracture stages. Through-fracture cores will be utilized to assess fracture attributes, validate fracture models, and optimize well spacing. When successful, this will lead to fewer wells drilled while increasing resource recovery.
Project Overview
Goals and Objectives

• The primary goal of the HFTS 2 is to minimize current and future environmental impacts by reducing number of wells drilled while maximizing resource recovery.

• Objectives
  – Assess and reduce air and water environmental impacts
  – Optimize hydraulic fracture and well spacing in a multi horizon stacked pay resource
  – Improve fracture models
# Gantt Chart

## Critical Path Milestones
- Milestone 1 - Project Management Plan Approval
- Milestone 2.1 - Secured Test Site
- Milestone 2.2 - Approved Field Testing Program and a "GO"
- Milestone 2.3 - Approved Data Management Plan
- Milestone 3.1 - Acquire background data
- Milestone 3.2 - Drill vertical observation well
- Milestone 3.3 - Complete hydraulic fracturing
- Milestone 3.4 - Collect through fracture cores
- Milestone 3.5 - Install discrete pressure gages
- Milestone 3.6 - Completion of field data acquisition
- Milestone 4 - Completed Earth Model
- Milestone 5 - Final approved tracer program
- Milestone 6 - Establish environmental baseline
- Milestone 7 - Completion of environmental monitoring

## List of Reports
- Quarterly Report 1, Year 1
- Quarterly Report 2, Year 1
- Quarterly Report 3, Year 1
- Annual Report, Year 1
- Quarterly Report 1, Year 2
- Quarterly Report 2, Year 2
- Quarterly Report 3, Year 2
- Annual Report, Year 2
- Quarterly Report 1, Year 3
- Quarterly Report 2, Year 3
- Quarterly Report 3, Year 3
- Final Report
- Topical Reports
Bibliography

- None
Public Private Partnership

- Leveraged investment in a dedicated, controlled field experiment
  - Access to producing and science wells explicitly designed for hydraulic fracturing diagnostics, environmental monitoring, data collection and technology testing
  - Use of multiple near-well and far-field diagnostics and verification with through fracture cores
  - Access to many subject matter experts
  - Early adoption of learnings by industry participants – technology transfer
  - Balanced science and practical issues

- Data available to public upon of expiration of confidentiality period
Overview of the Permian Basin

Background Image Courtesy: Tarka.com
HFTS Locations – Significant Geologic and Geomechanical Differences

• There is ~150 miles between the basins, which are separated by a central basin platform creating different geologic settings.
• Vertical depth of Delaware basin is deeper - double in some cases to that of the Midland basin.
• Provenance and burial history of the sediments is different resulting in different geomechanical properties of the rock.
• Fracture height growth is likely markedly different between the two areas with very little agreement amongst industry as to the created hydraulic fracture height.
• Pore pressure in the Delaware is higher and in some areas double that of the Midland basin (.70 to .75 in Delaware)
• Higher GOR in the Midland
• Significant difference of opinion as to HF job design in the Delaware