Hydraulic Fracturing Test Site 2 (HFTS 2)

DE-FE00231577

Jordan Ciezobka

Gas Technology Institute (GTI)

U.S. Department of Energy

National Energy Technology Laboratory

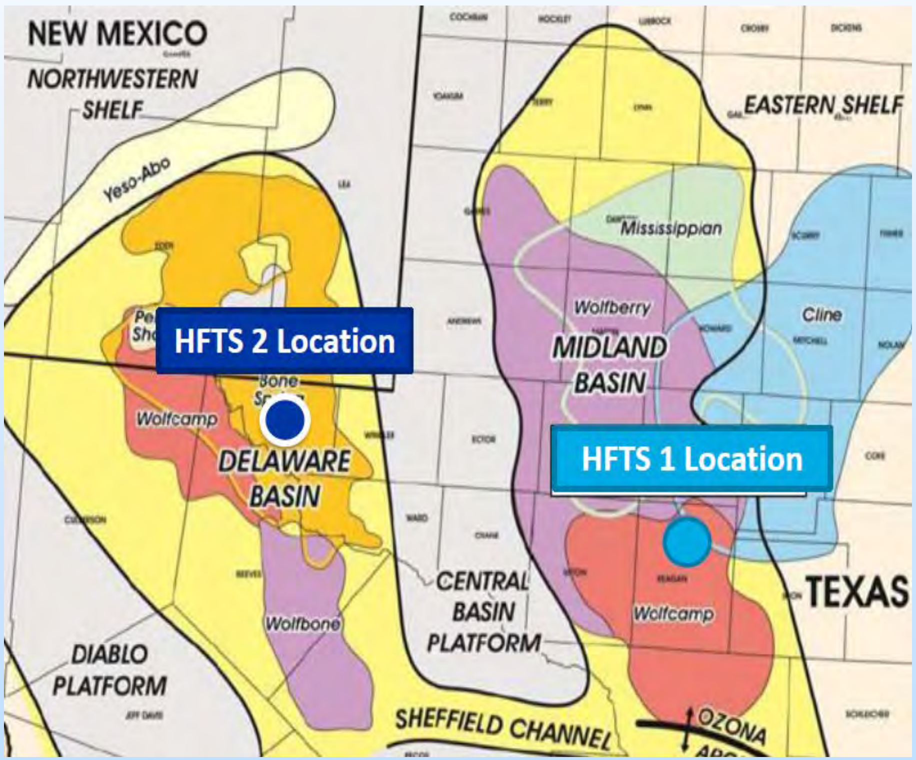
Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration: Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 15, 2018

Presentation Outline

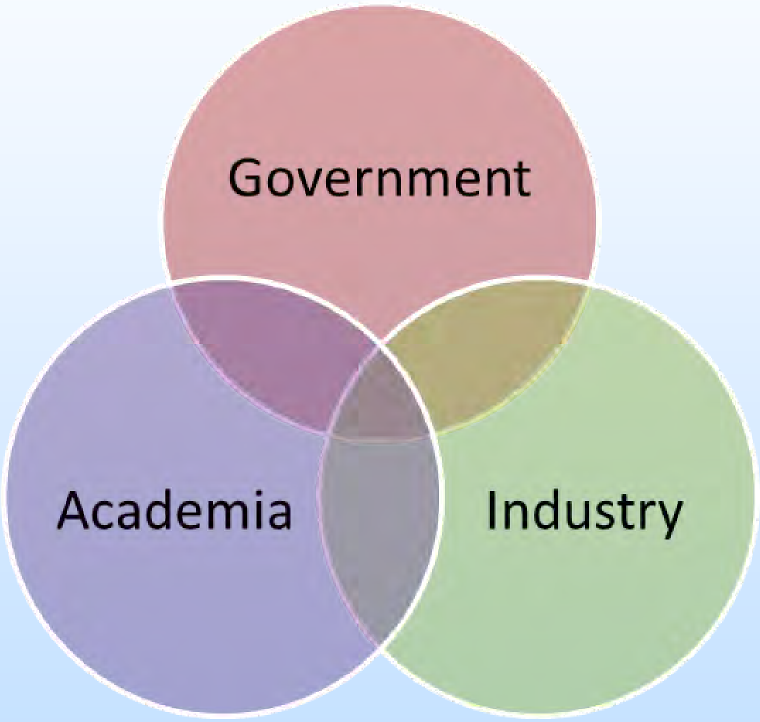
- HFTS#2 Overview
- Review of Test Site Location and Details
- Project Status and Timing
- Technical Status
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Summary
- Appendix

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 multiple industry partners providing financial support
- Site host to be Anadarko and Shell – Joint effort
- $20+ 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.

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

Organization Chart

NETL / DOE

- Program Oversite and Direction
- Tech Transfer

Site Host: Anadarko/Shell

- Provision of site
- Management of Field Operations
- Background data
- SMEs
- Tech Transfer

Gas Technology Institute

Management

- Program Management
- Coordination / Meetings / Workshops
- Schedule and Budget Management
- Management of Subcontractors

Technical

- SMEs
- Analysis
- Project / Data integration
- Tech Transfer

Industry Partners

- Cost Share ($ / in kind)
- SMEs
- Analytical Services
- Specific Research
- Tech Transfer

Subcontractors

- Specific Research
- Tech Transfer

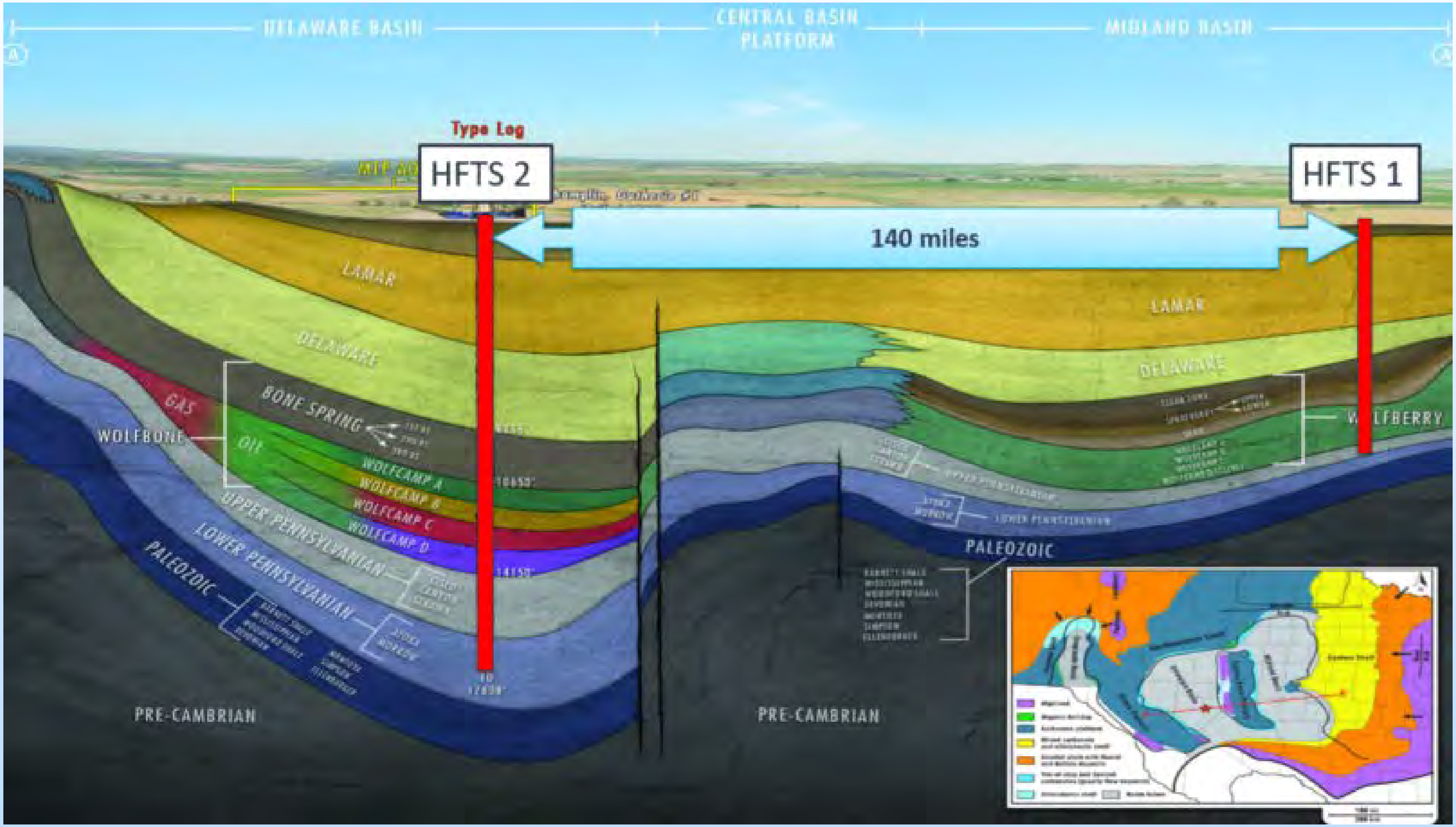
Subcontractors

- Bureau of Economic Geology
- Desert Research Institute
- Stanford SLAC National Accelerator Laboratory

Current Status & Timing

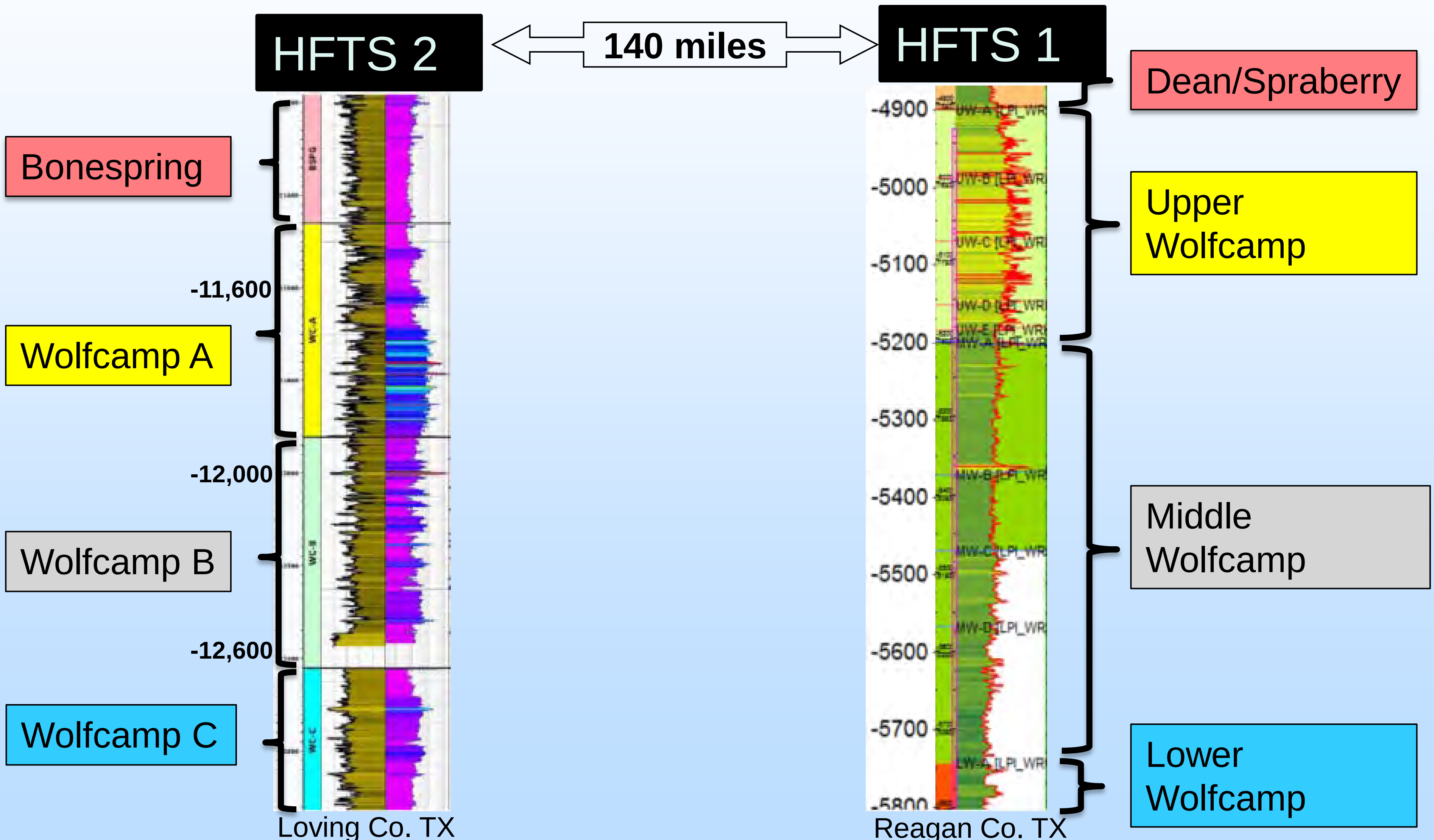
- Funding by U.S. Department of Energy, National Energy Technology Laboratory (DOE/NETL) awarded to GTI on 3/9/18
  - DOE share: $7,799,052
  - Performer share: $12,590,025 towards minimum scope of work
- Five of the eight well test program have already been drilled and none are completed
  - Remaining three wells will spud in November 2018
- Wells schedule to be completed by June 2019
- Finalizing site agreement with Anadarko – Participation agreements will follow immediately

Overview of the Permian Basin



Background Image Courtesy: Tarka.com

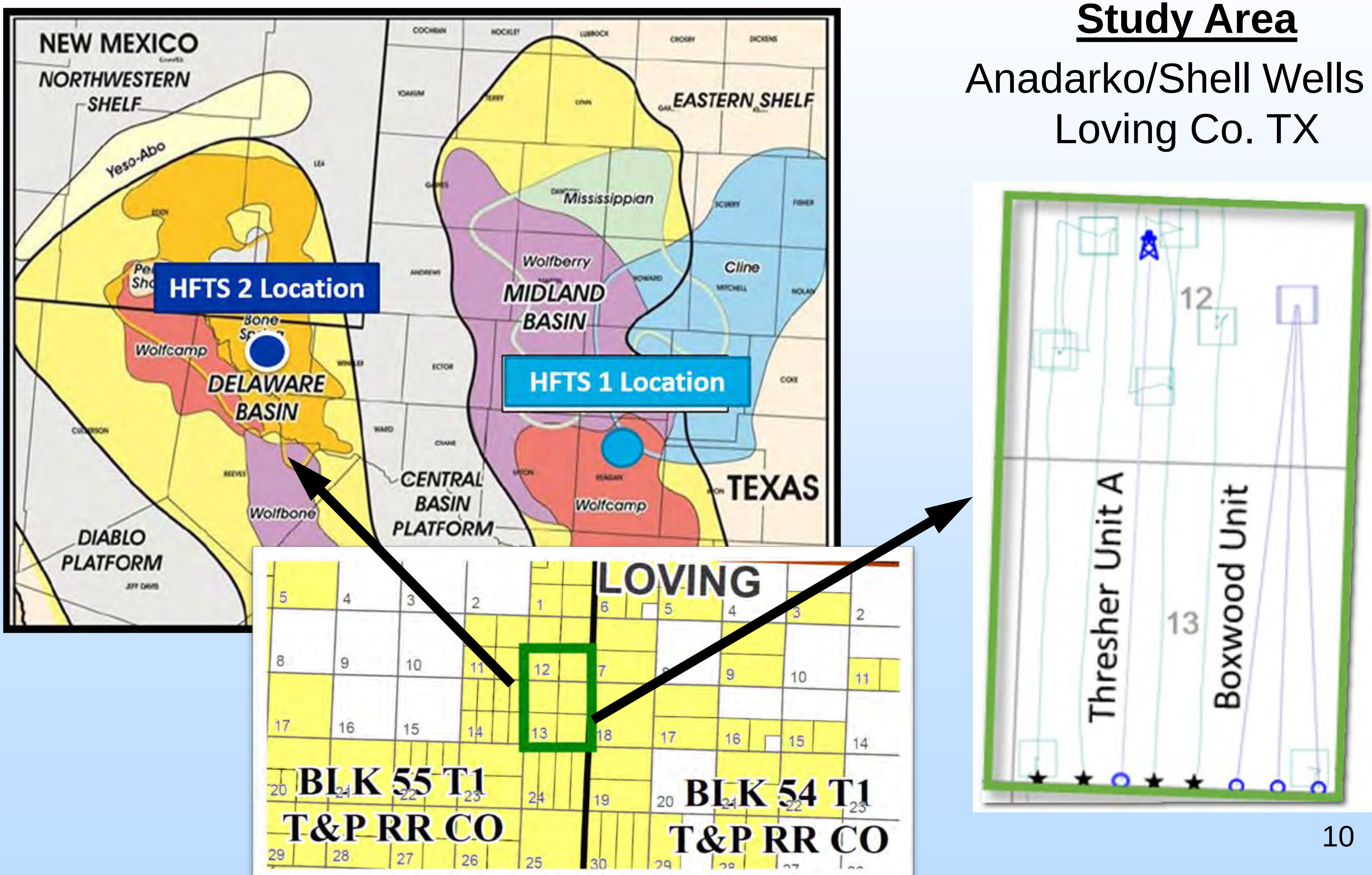
Stratigraphy Across the Permian Basin



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

Test Site Location

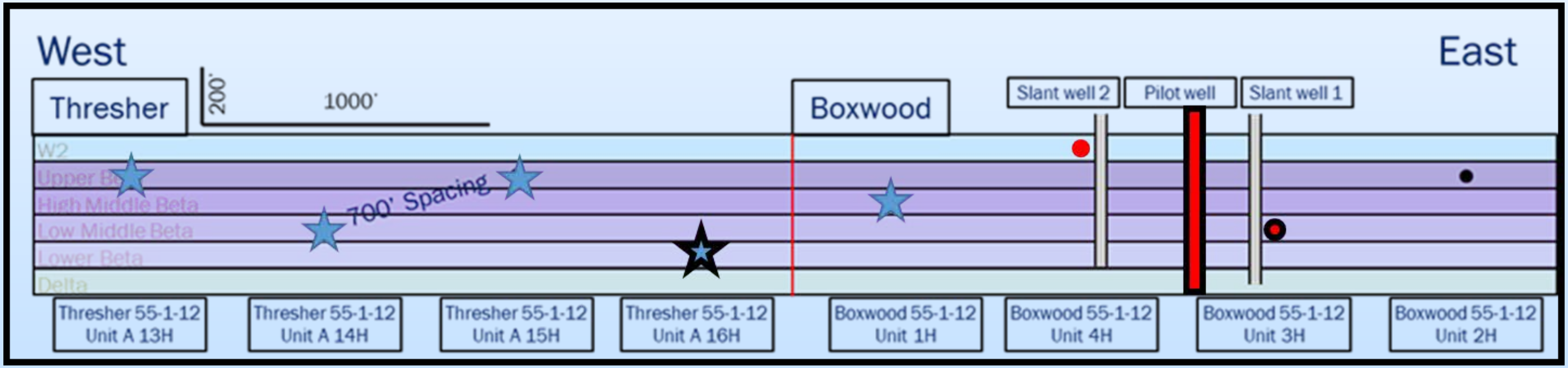


Study Area

Anadarko/Shell Wells in Loving Co. TX

Development/Diagnostics Plan

Eight Wells Spaced at 700’ Absolute/Hypotenuse spacing. 660’ Horizontal, 200’ Vertical. Wolfcamp A: W2 Alpha & Beta.



Drilled
Fiber
Microseismic

Diagnostic Plan – Tier 1
~$20 Million – 8 Participants

Characterize the SRV

- Microseismic monitoring in Thresher 16H, Boxwood 3H and pilot well
- Obtain whole core on 1st slant well adjacent to Boxwood 3H (Lower Middle Beta) through 3-4 stages based on diagnostics captured during completions (~500 – 1,000' of core)
- DFIT in the toe of all wells
- Lateral Quad combo with OBMI logs in Boxwood 2H, 3H, and 4H

Pre-Completion, Geological & Petrophysical Characterization

Vertical whole core in the pilot well from BS3 through Upper Delta

- Advanced mudlogging
- Routine core analysis
- Geomechanical analysis
- CMR/NMR
- Quad combo with OBMI and dipole sonic

Production Analysis & SRV/DRV Evolution

- Geochemistry on pilot well core chips
- Time lapse geochemistry on Boxwood 2H, 3H and 4H
- Surface PVT from all producing wells in the test
- Permanent downhole pressure gauges in all producing wells in the test. External pressure gauge at the heel and at the toe of the Boxwood 3H and 4H

Characterization of the Completion

- DAS/DTS fiber in Boxwood 3H, 4H and pilot well
- Varied completions designs testing the impact of water volumes on SRV development
- Completion fluid tracing

Diagnostic Plan – Tier 2+
$35+Million – 18 Participants

Characterize the SRV

- Obtain whole core from a 2nd slant well adjacent to Boxwood 4H (W2 Alpha) through 3-4 stages
- Sidetrack 1st and/or 2nd slant wells to further sample the extent of the frac dimensions
- Tiltmeter on pilot well

Pre-Completion, Geological, and Petrophysical Characterization

- Intense geomechanical sampling and analysis outside of landed zones
- Cased hole logs in Boxwood 1H

Production Analysis & SRV/DRV Evolution

- TEC line with bottom hole pressure gauge on pilot well
- Install casing on slant wells and install isolated bottom hole pressure gauges
- Time Lapse PLTs on Boxwood 3H and 4H

Characterization of the Completion

- Proppant tracing
- Seven external isolated pressure gauges on pilot well from BS3 through Upper Delta
- Downhole camera on Boxwood 3H to measure perforation hole size after the completion

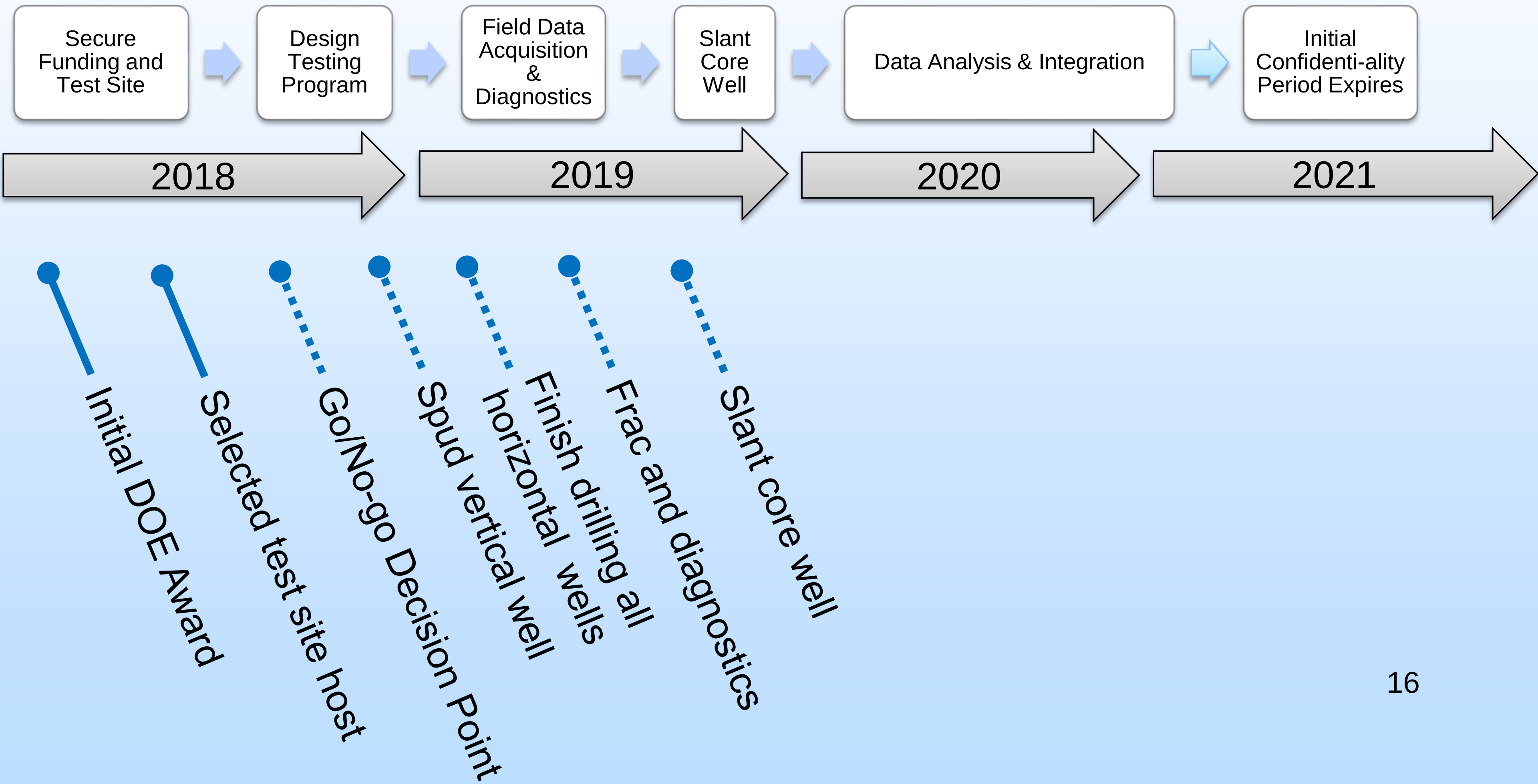
Field Testing Upgrades

- Will test up to 5 horizons simultaneously at HFTS #2. Tested only 2 at HFTS#1.
- Dedicated vertical observation well
- Delaware wells flow longer than Midland due to higher pressure, provides opportunity to run production logs if fiber does not provide enough resolution
- Will monitor HFTS#1 EOR experiment and plant seed for similar program in the Delaware if enough industry interest
- Slant core well learnings – more core

Diagnostic Learnings from HFTS 1 and Upgrades

- Increase colored proppant from 5 to 20% in offset treatment wells. While we saw colored proppant in the core, there was not enough of it to conclusively tell where it came from or if it was a specific color.
- Explore adding smaller colored proppants which will travel further out.
- Plan to sample core sludge and test for chemical tracers (oil and water) pumped in offset treatment well. We were able to detect chemical tracers in core sludge, however the samples were already washed during proppant analysis and only a couple samples were available for this testing.
- Will not do cross-well seismic (cost to benefit was low)
- Install fiber and measure fluid injection and production points. Was not able to this in HFTS 1.

Project Progress and Major Milestones



Accomplishments to Date

- Executed DOE contract
  - Submitted PMP, DMP, and SOPO
- Secured field test site, jointly hosted by Anadarko and Shell
  - Large background data package
- Hosted project industry outreach meeting in Houston, over 60 people attended
- Hosted a dedicated HFTS#2 booth at the URTeC conference
- Developed a preliminary diagnostic SOW based on test well package, tiered budget approach
- Industry sponsors, some signed, multiple others in contract negotiations (Participation Agreement), about 2 dozen interested

Lessons Learned: Carried over from HFTS #1

- Public Private Partnership’s leverage funding and expertise, and allow for fast dissemination of learnings and technology adoption.
- Significant planning required for complicated experiments (core well).
- Outreach to the consortium and teamwork among the consortium was essential for the successful execution of the project.
- No EHS incidents, cored 598’ in 6 runs with 99.4% recovery.
- Significant sharing of data and analyses amongst the team.
- Significant learnings to date, many more to come - Data will be looked at for years if not decades; data integration task needs to be defined.
- Each shale is different, multiple test sites needed across U.S.

Synergy Opportunities

- Collaborate with other NETL field test sites; in the Marcellus, EagleFord, HFTS #1, etc.
- NETL Long wave seismic measurement
- NETL core analysis
- NETL emissions van

Project Summary

- Test site to be jointly hosted by Anadarko Petroleum and Shell E&P
  - 8 well package in Loving county TX
- Substantial Anadarko/Shell E&P existing proprietary hydraulic fracturing and well performance data sets available for participants – value significantly exceeds the $1.5 million participation fee
- Significantly enhanced diagnostic and experimental design compared to HFTS#1 in South Midland Basin
- Support from Shell’s large instrumentation history
- Desire to leverage other companies’ experiences
- Unique opportunity for extremely robust integrated data acquisition

Appendix

– These slides will not be discussed during the presentation, but are mandatory.

Benefit to the Program

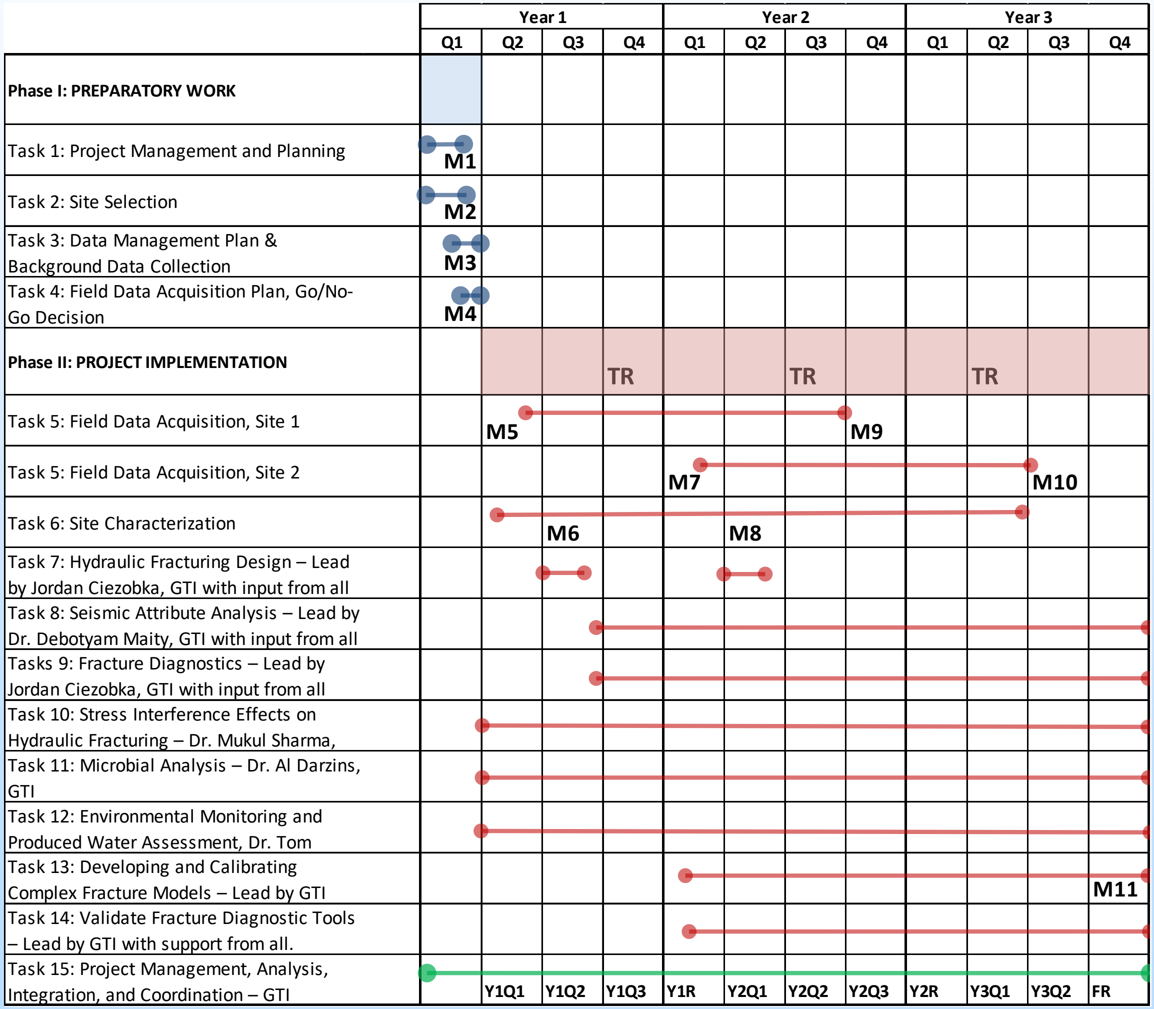
- The research project is focused on **environmentally prudent development of unconventional resources & enhanced resource recovery.**
- The HFTS#2 is a collaborative, comprehensive hydraulic fracturing diagnostics and testing program in horizontal wells at a dedicated, controlled field-based site. The 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 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



Quarterly Report 1, Year 1	Y1Q1
Quarterly Report 2, Year 1	Y1Q2
Quarterly Report 3, Year 1	Y1Q3
Annual Report, Year 1	Y1R
Quarterly Report 1, Year 2	Y2Q1
Quarterly Report 2, Year 2	Y2Q2
Quarterly Report 3, Year 2	Y2Q3
Annual Report, Year 2	Y2R
Quarterly Report 1, Year 3	Y3Q1
Quarterly Report 2, Year 3	Y3Q2
Quarterly Report 3, Year 3	Y3Q3
Final Report	FR
Topical Reports	TR

Critical Path Milestones

Milestone 1 - Project Management Plan Approval
Milestone 2 - Test Site Selection
Milestone 3 - Launch Data Sharing Platform
Milestone 4 - Completion of Field Data Acquisition Plan
Milestone 5 - Commencement of Field Data Acquisition Site #1
Milestone 6 - Completed Earth Model for Site #1
Milestone 7 - Commencement of Field Data Acquisitions Site #2
Milestone 8 - Completed Earth Model for Site #1
Milestone 9 - Conclusion of Field Data Acquisition Site #1
Milestone 10 - Conclusion of Field Data Acquisitions Site #2
Milestone 11 - Calibrating Complex Fracture Models

Bibliography

- None

Acknowledgements

Thanks to Department of Energy (DOE), National Energy Technology Laboratory (NETL), Anadarko and Shell