Hydraulic Fracturing Test Site (HFTS)

DE-FE0024292

Jordan Ciezobka

Gas Technology Institute (GTI)

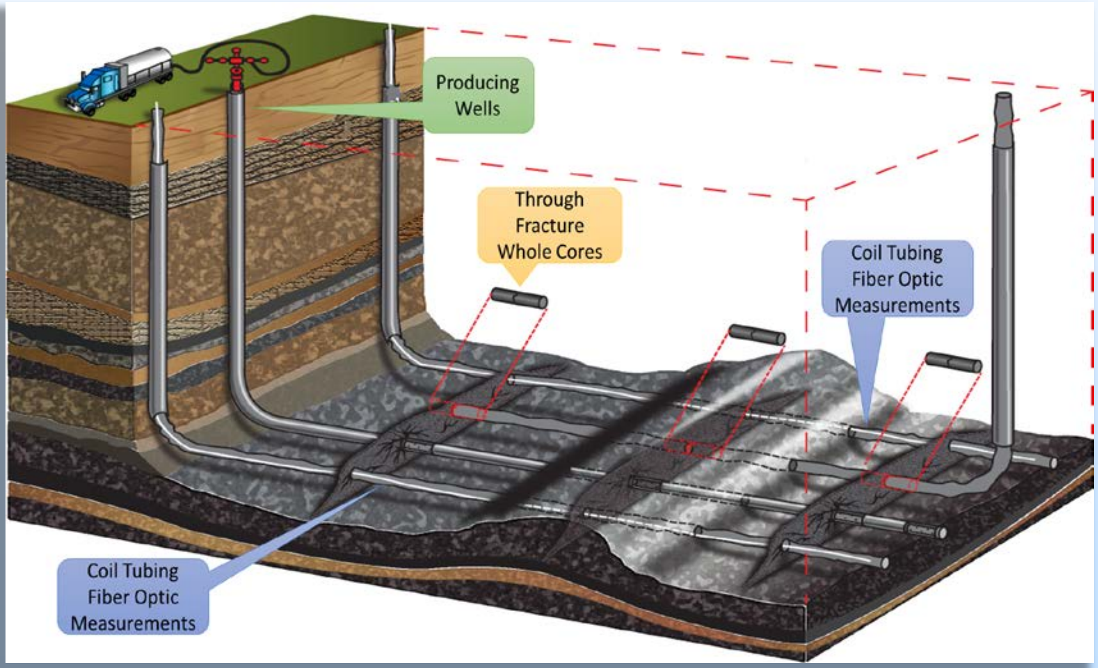
U.S. Department of Energy - National Energy Technology Laboratory
Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting
August 28, 2019

Presentation Outline

- Project Overview
- Test Site Location
- Current Status
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Summary
- Appendix

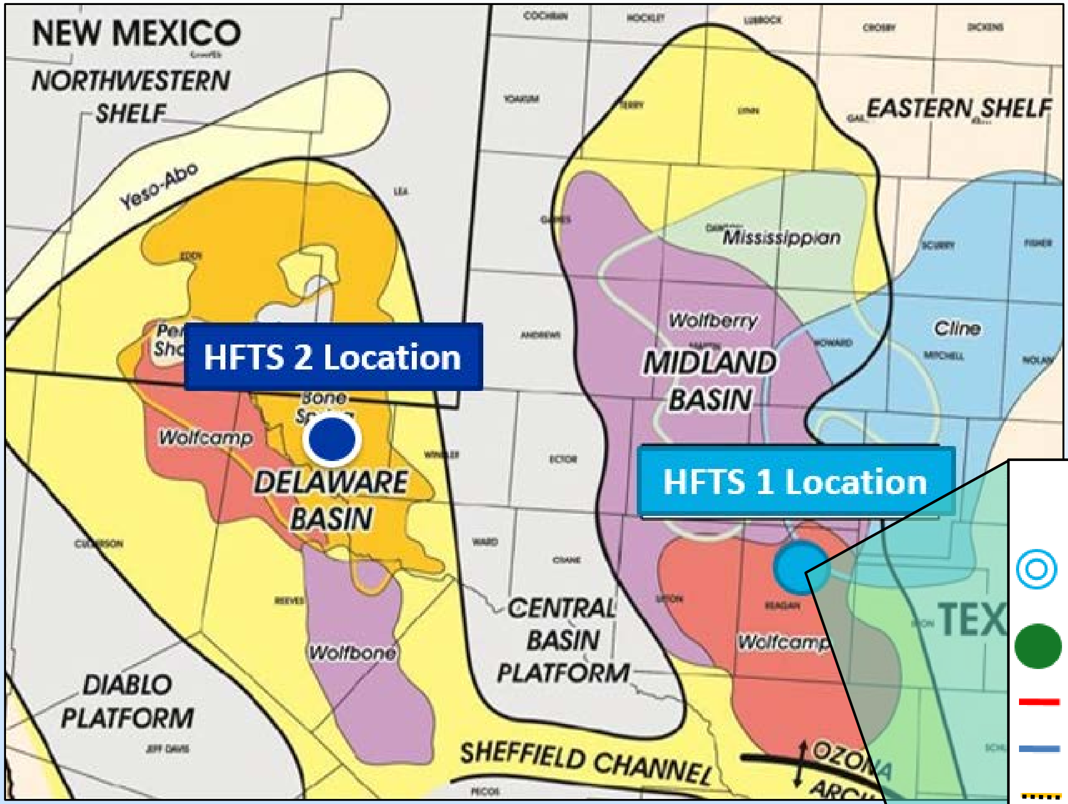
Hydraulic Fracturing Test Site: Project Overview

Comprehensive $30-million JIP research program



- Capture fundamental insights of fracturing process
- Acquisition of nearly 850 feet of through-fracture whole core
- Physical observation of created fractures and proppant distribution
- Field and lab test of shale EOR; huff-and-puff using field gas

Test Site Location: Phase 1

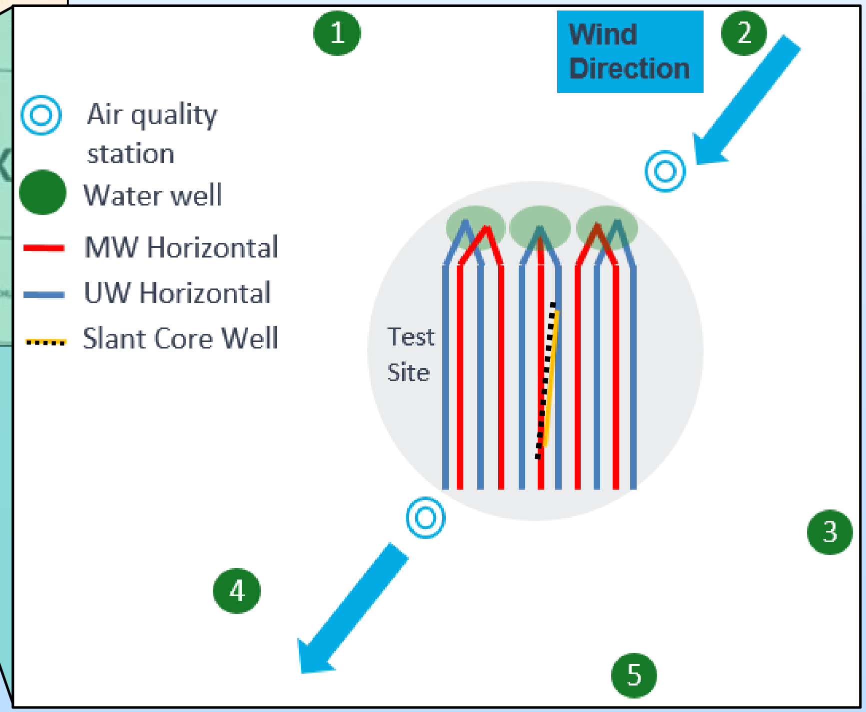


Study Area

Permian-Midland Basin

Reagan County

Upper & Middle Wolfcamp



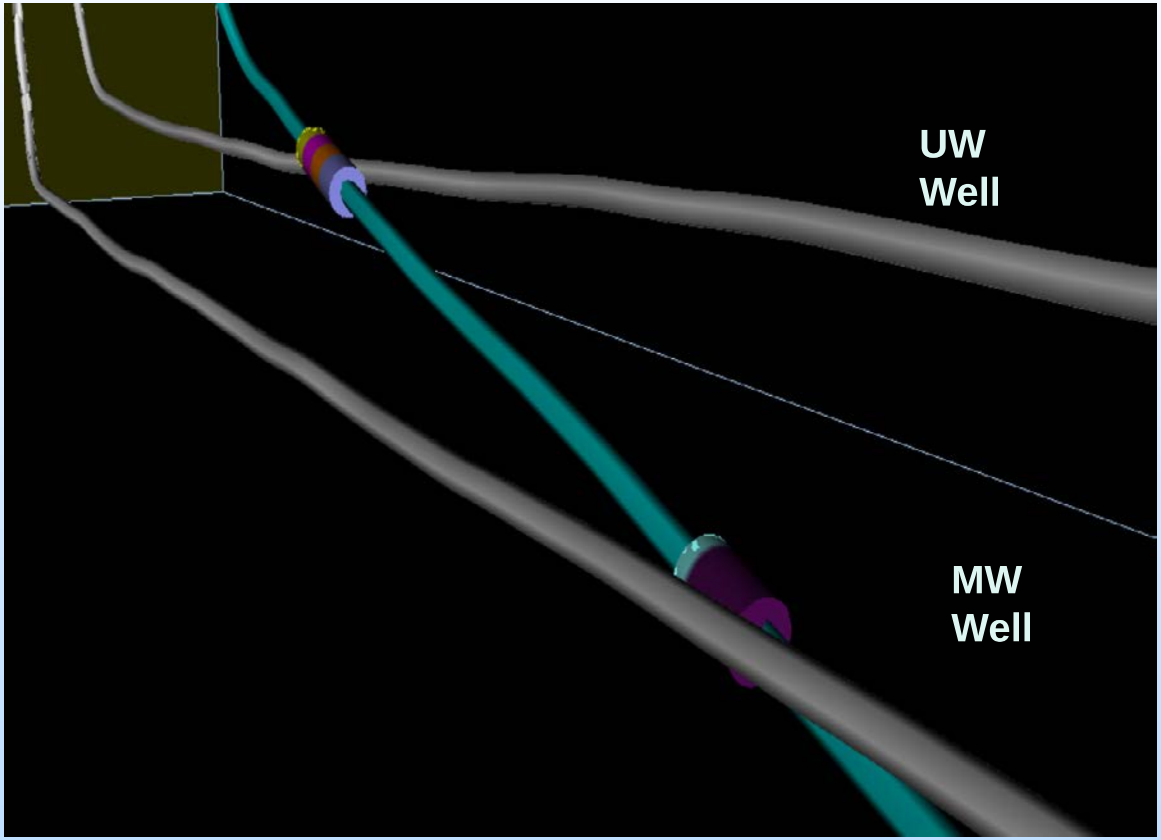
6 UW & 5 MW 10,000' Wells

Current Status

- Phase 1 field data acquisition complete
  - Data analysis and integration ongoing
  - Extracting fracture information from 3D laser scans
- Phase 2 EOR field pilot
  - Drilled and instrumented 2nd slant core well
  - Cyclic gas injection using field gas (huff and puff) evaluation ongoing

SRV Core Through Well #1

- Nearly 600 feet of SRV core
  - Upper & middle Wolfcamp
  - Core description – 2 teams
  - Proppant analysis
  - CT scanned entire core
- Advanced open hole logs
  - 5,100' lateral length
  - Quad Combo, including spectral gamma and image log (OBMI)
- Discrete pressure gages



Hydraulic Fractures in Core – Variable Morphology

Complex breaks, irregular patterns, stepping planes

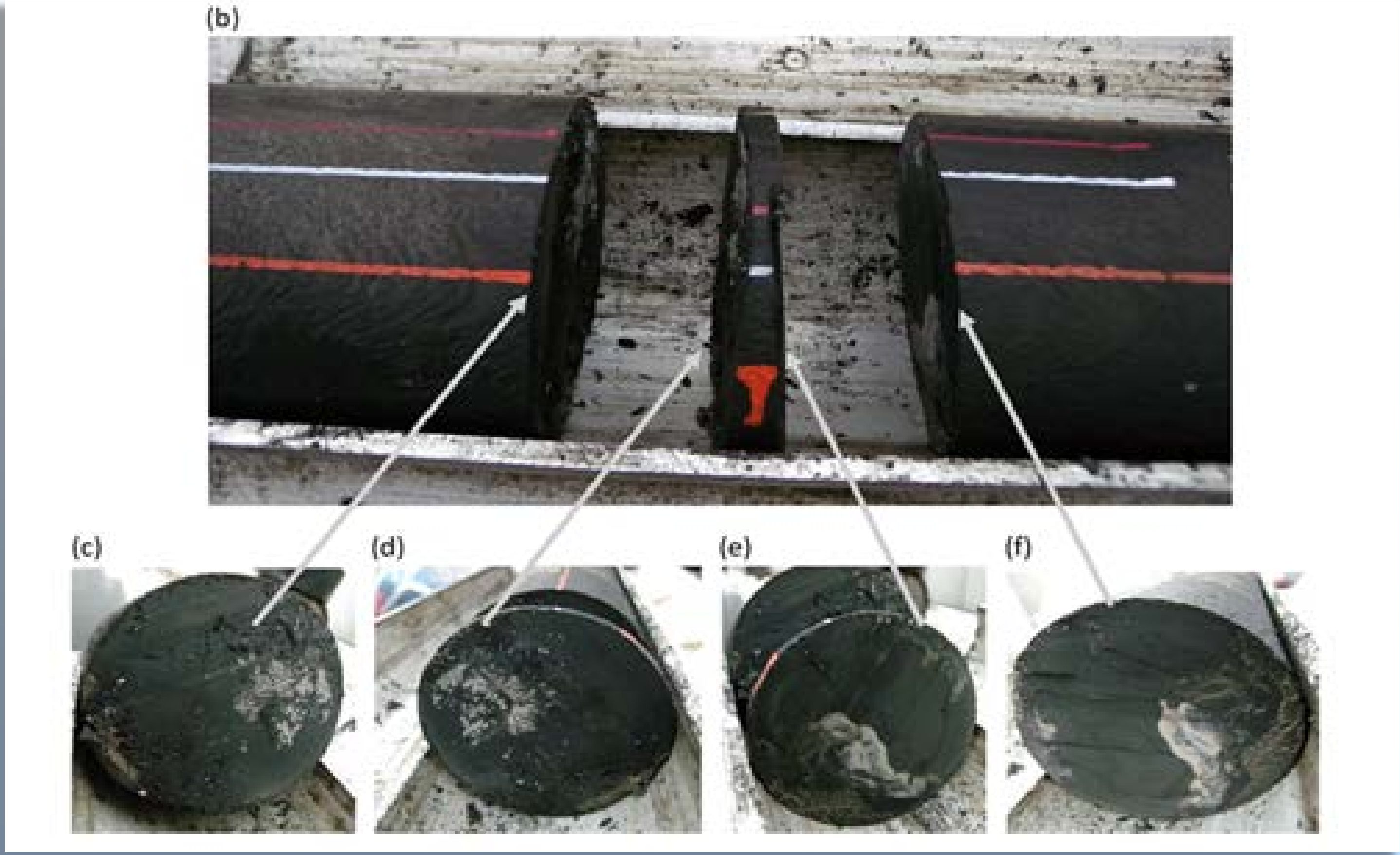





Smooth planar surfaces


Hydraulic Fractures in Core

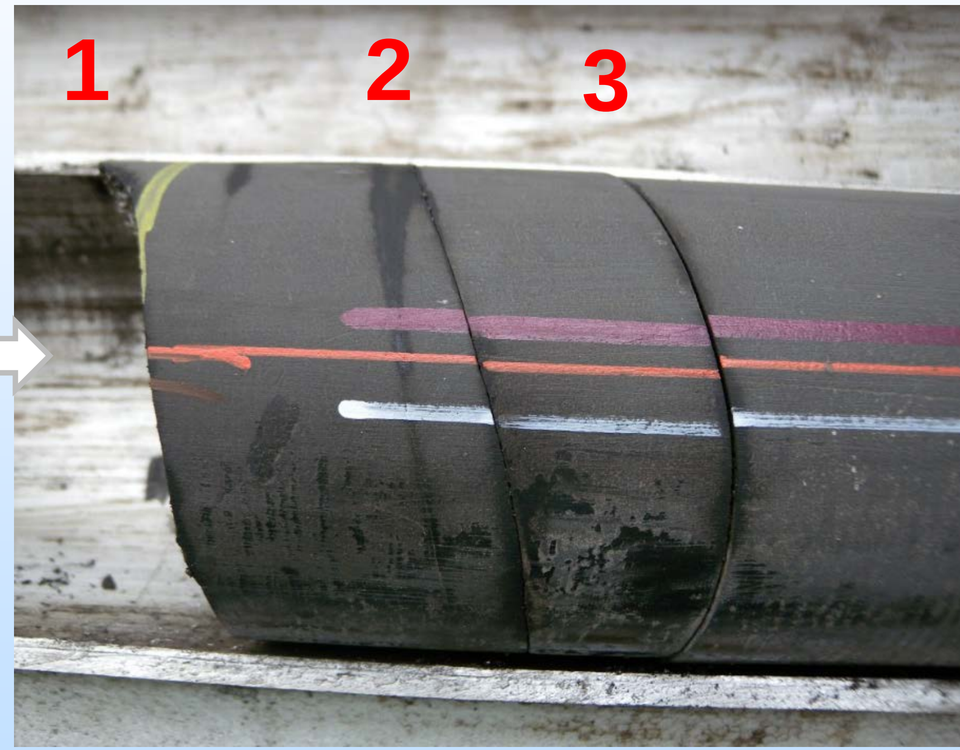
Doublet – 2 competing fractures



URTEC - 2902624

Hydraulic Fractures in Core

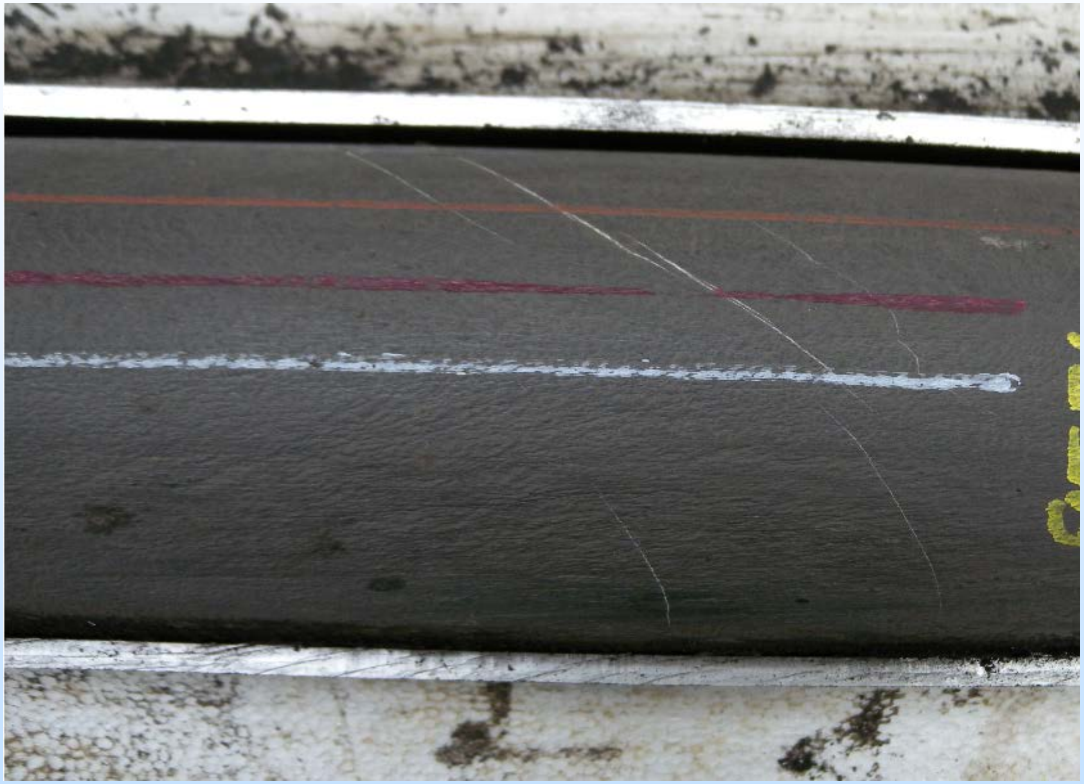
Triplet – 3 competing fractures



- Which fracture came first, second, third?
- Same time?
- How can we tell: orientation, surface features from 3D laser scan?

Natural Fractures in Core

- Discontinuous NF's
- Useful section for modeling discrete fracture network at this scale
- Used to calibrate & QC the image log, and compare to CT scans



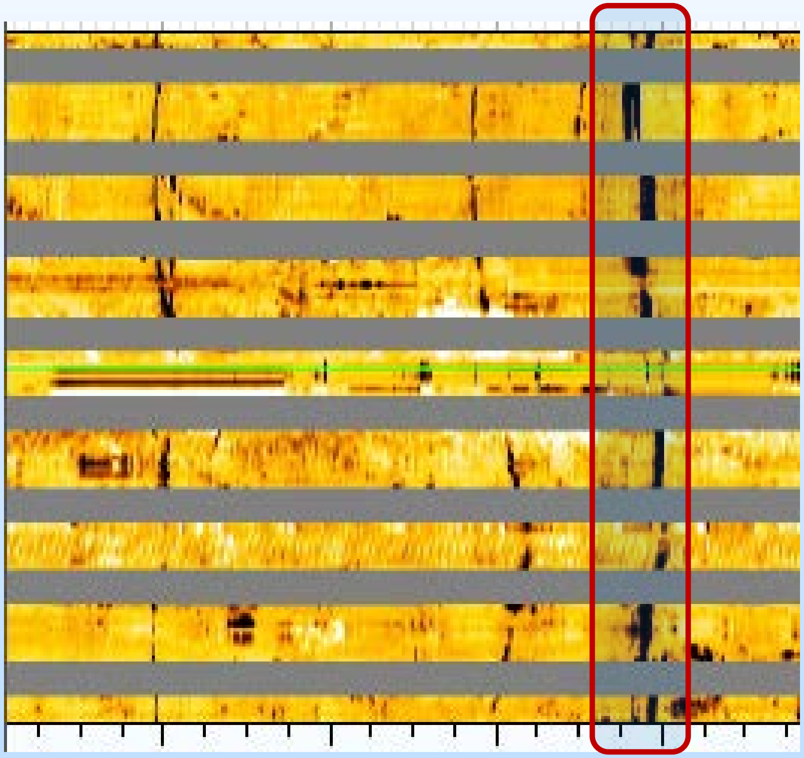
Proppant Pack in Core

Tortuous path for proppant?

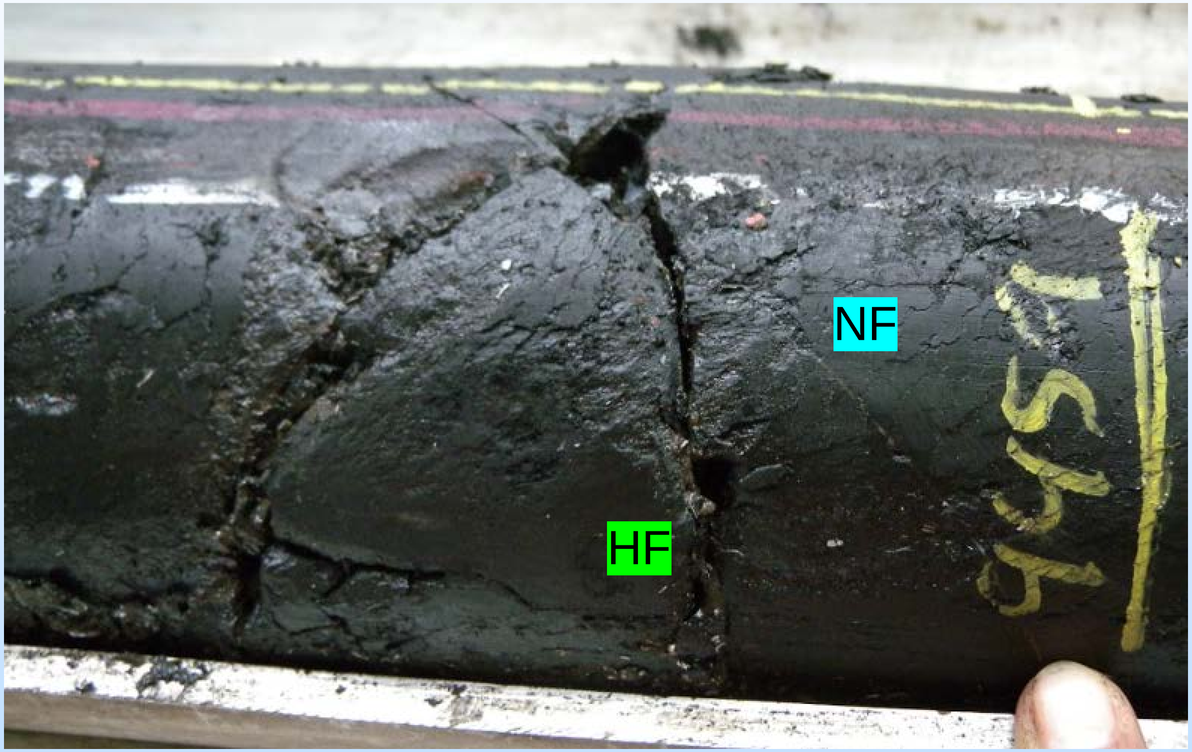
Proppant Pack in Image Log

Most open fractures captured in image log

- Sealed fractures difficult to discern



Proppant in HF/NF Complex



3D Laser Scans of Fractures

Permanently preserve fracture features, 50µm

- “Digital magnifying glass”

Scans used for systematic interpretation, to determine

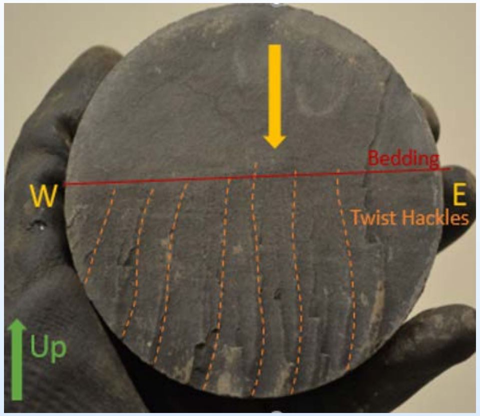
- propagation features, complexity measures, roughness, etc.

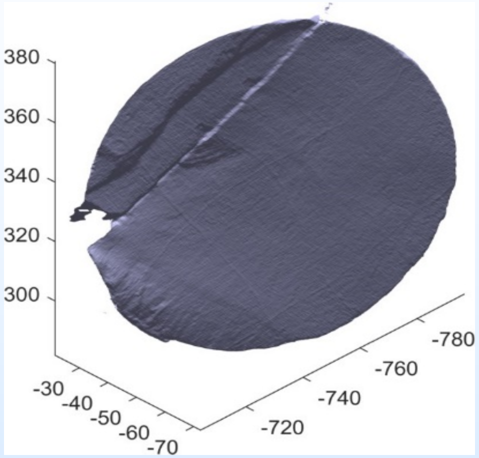
3D Laser Scans of Fractures

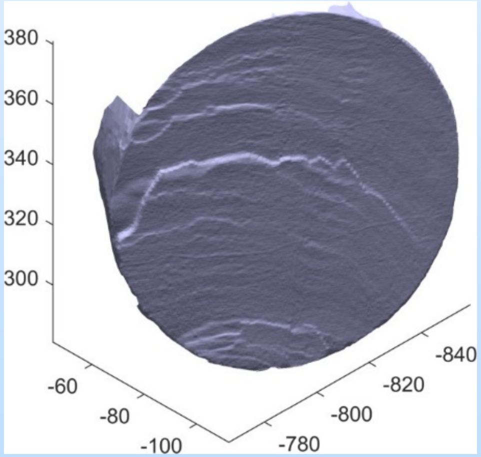
Ongoing Work

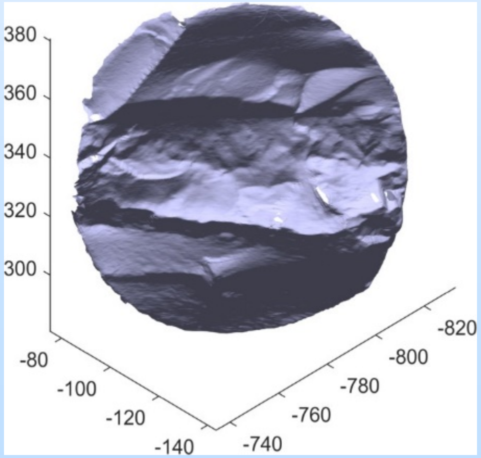
- Evidence of local stress shadow variation from:
  - competing fractures
  - nearby proppant packs
- Impact of fracture features on proppant distribution

Image Courtesy ConocoPhillips

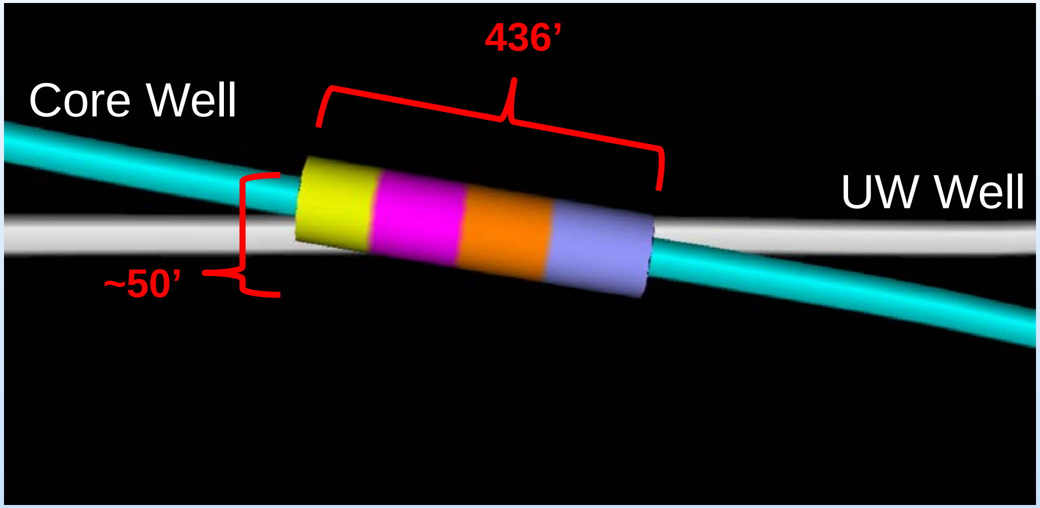


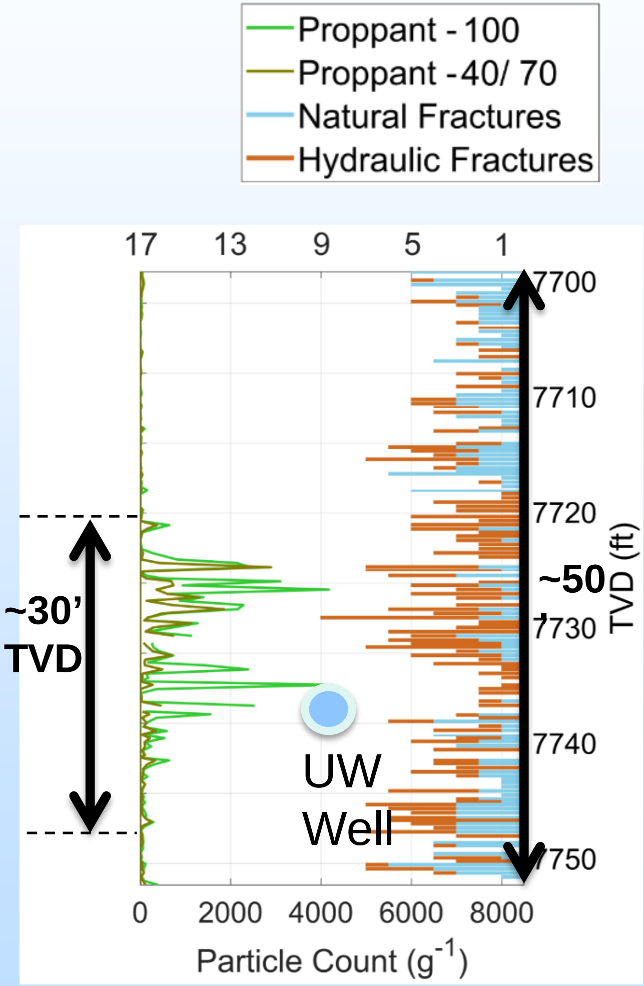






Vertical Proppant Distribution





Lessons Learned

- Fracture quantity and complexity far beyond what current simulators/models can predict.
- Vertical proppant distribution measured in core only a fraction (5%) of measured microseismic geometry
- Multiple proppant packs found, others likely washed out during coring, indicating inefficient proppant placement.
- Far-field created fractures (100 ft away) are multiple in number, non-uniform in distribution with fracture clusters and voids
- Well communication at 660’, however fracture and proppant distribution incomplete between wells
- The upper and lower Wolfcamp formations vary considerably; the upper with multiple times more hydraulic and natural fractures, leading to very different fracture half lengths, spacing implications

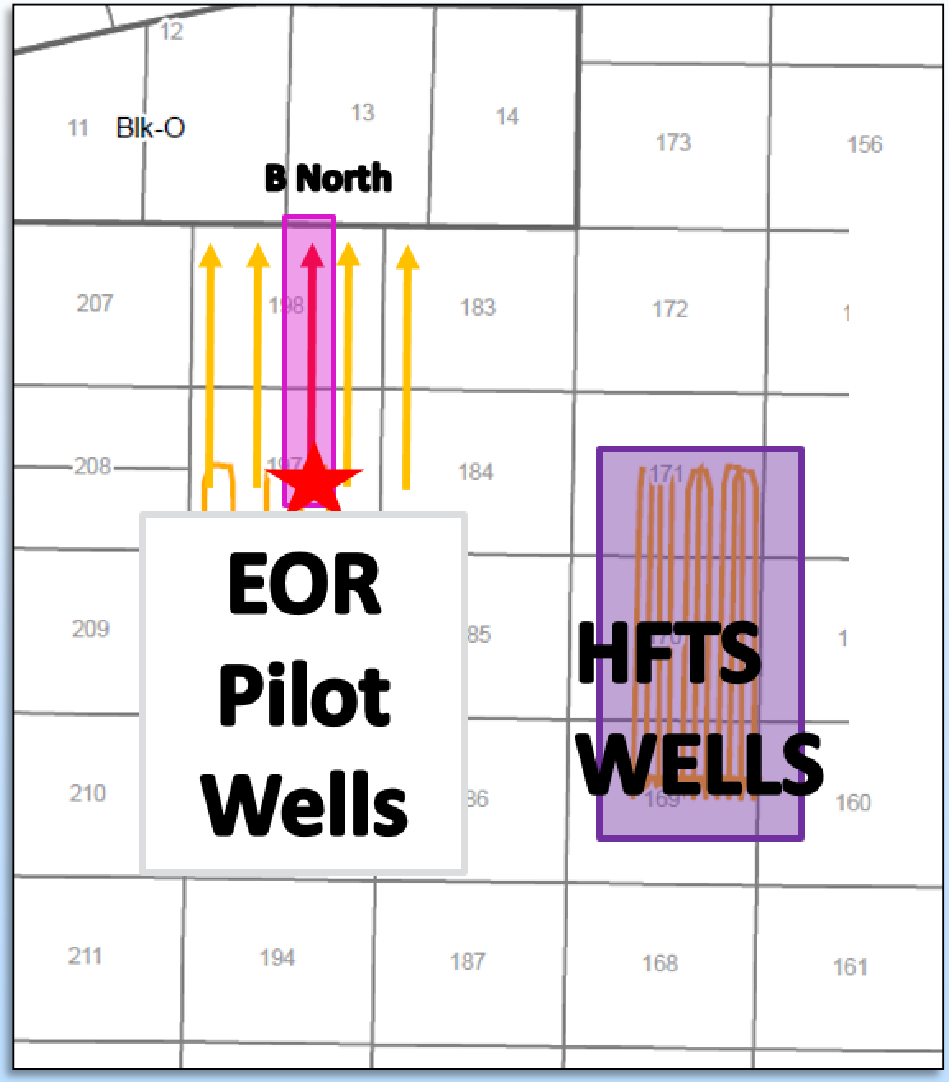
Image courtesy: Laredo Petroleum

Phase 2 – EOR

Huff-and-Puff Field Pilot in the M. Wolfcamp

2nd Slant Core Well

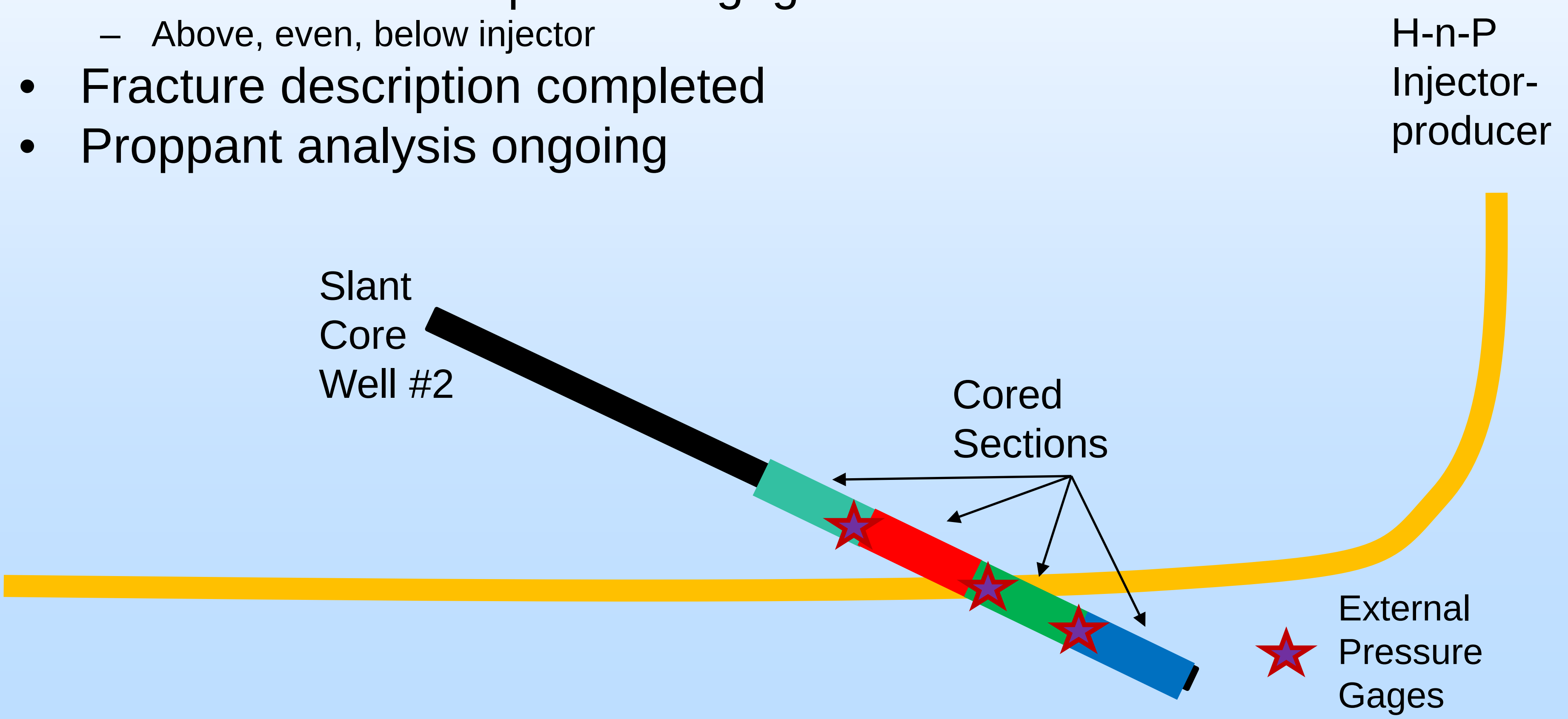
Phase 2: EOR Pilot Details



- 6 well pilot (1 injection, 5 monitor)
- Lab Studies
  - PVT analysis, MMP, etc.
  - Core flooding
- 3D reservoir simulations
- Diagnostics
  - Time-lapse geochemistry
  - BH gages
  - Passive seismic monitoring
  - FO logs
- 2nd slant core well
  - Open and cased hole logs
  - Pressure gages

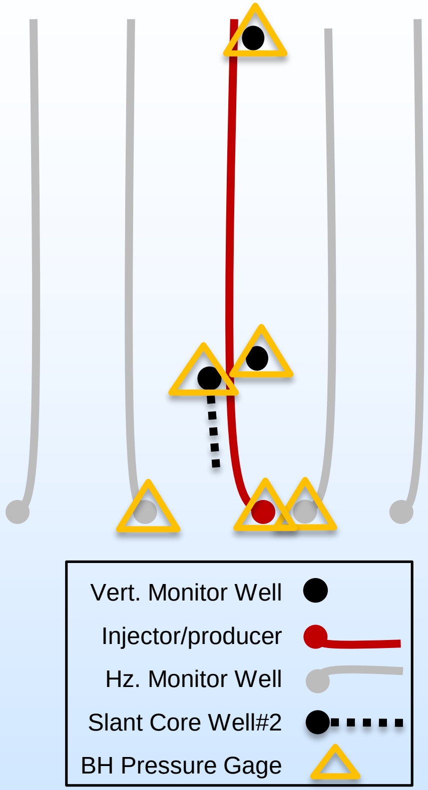
Slant Core Well #2

- Drilled in December 2018
- Recovered 260’ of core
- 53 deg inclination
- Installed 3 isolated pressure gages
  - Above, even, below injector
- Fracture description completed
- Proppant analysis ongoing



H-n-P Pilot Details

HP Compressor, Image Courtesy Laredo



- Completed gas injection, currently producing
- Evaluating diagnostic and production data

Ongoing Synergies and Opportunities

- NETL deployed geophones at HFTS EOR site to monitor LPLD signals
- NETL performing core flooding using HFTS core and reservoir fluids
- HFTS data and core used in other DOE projects
- Collaborate with other NETL field test sites; in the Marcellus, EagleFord, HFTS #2, etc.

Project Summary

- We have captured fundamental insights of fracturing
- Hydraulic fractures do not grow into fresh water zones
  - No evidence of fracturing or reservoir fluids migrating into aquifer
  - Substantiated with fracture diagnostics and aquifer fluid sampling
- Propped fracture dimensions are very different from hydraulic fracture dimensions
- No impact on local air quality during hydraulic fracturing
  - Potential for elevated emissions during flowback if using open systems
- We will continue to analyze and integrate various datasets to get a deeper understanding of the fracturing process
- We are exploring EOR methods to improve resource recovery

Acknowledgements

Thanks to Department of Energy (DOE), National Energy Technology Laboratory (NETL), Laredo Petroleum, and all of the HFTS Sponsors. Also thanks to Gary Covatch – NETL, Matt Magguire ,Cassandra Oeth & Ben Hubbert – Laredo, Julia Gale – BEG, Debotyam Maity - GTI for all of their work on the project.

Images Courtesy: DOE/NETL, Laredo, GTI

Appendix

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

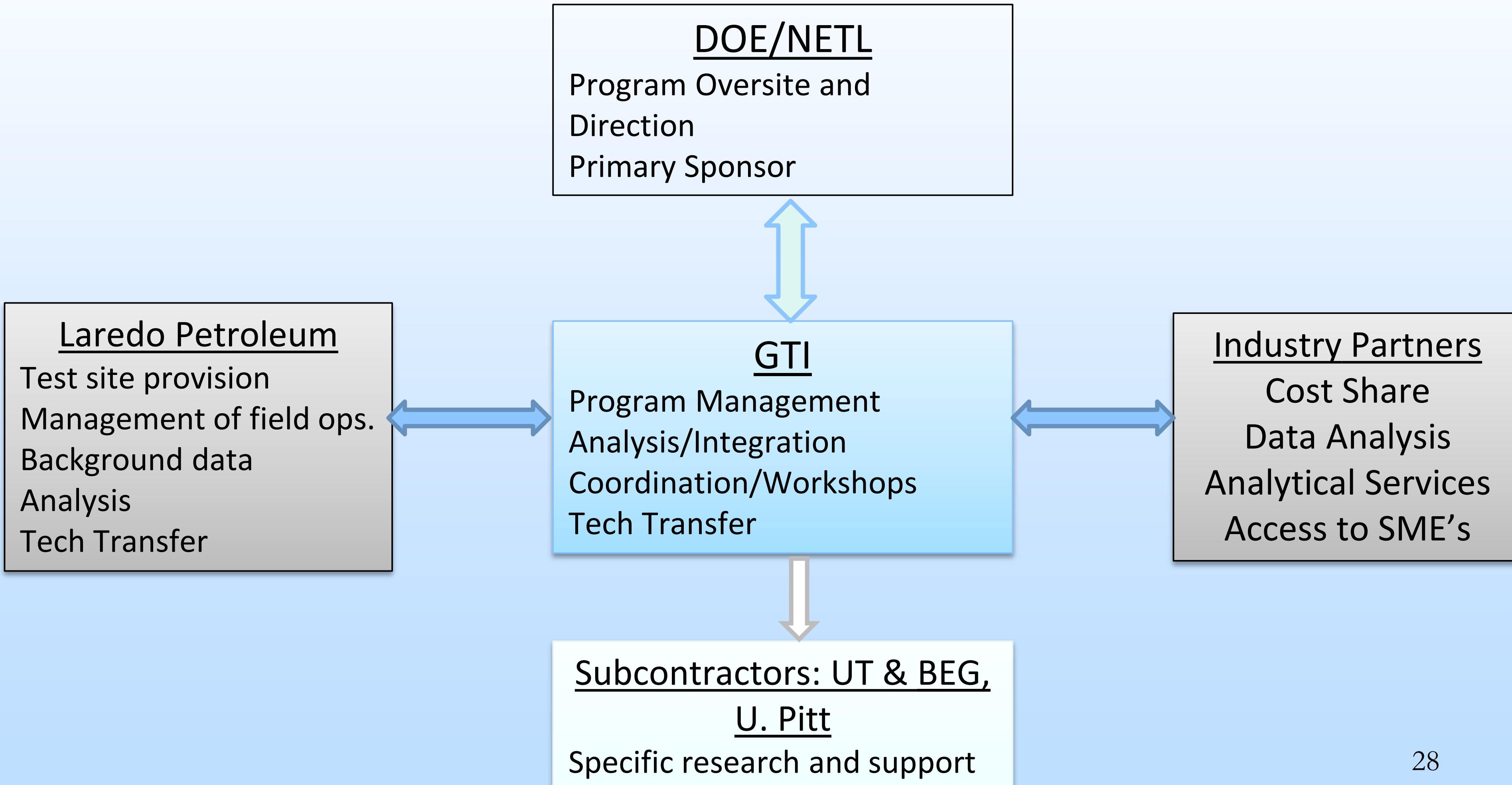
Benefit to the Program

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

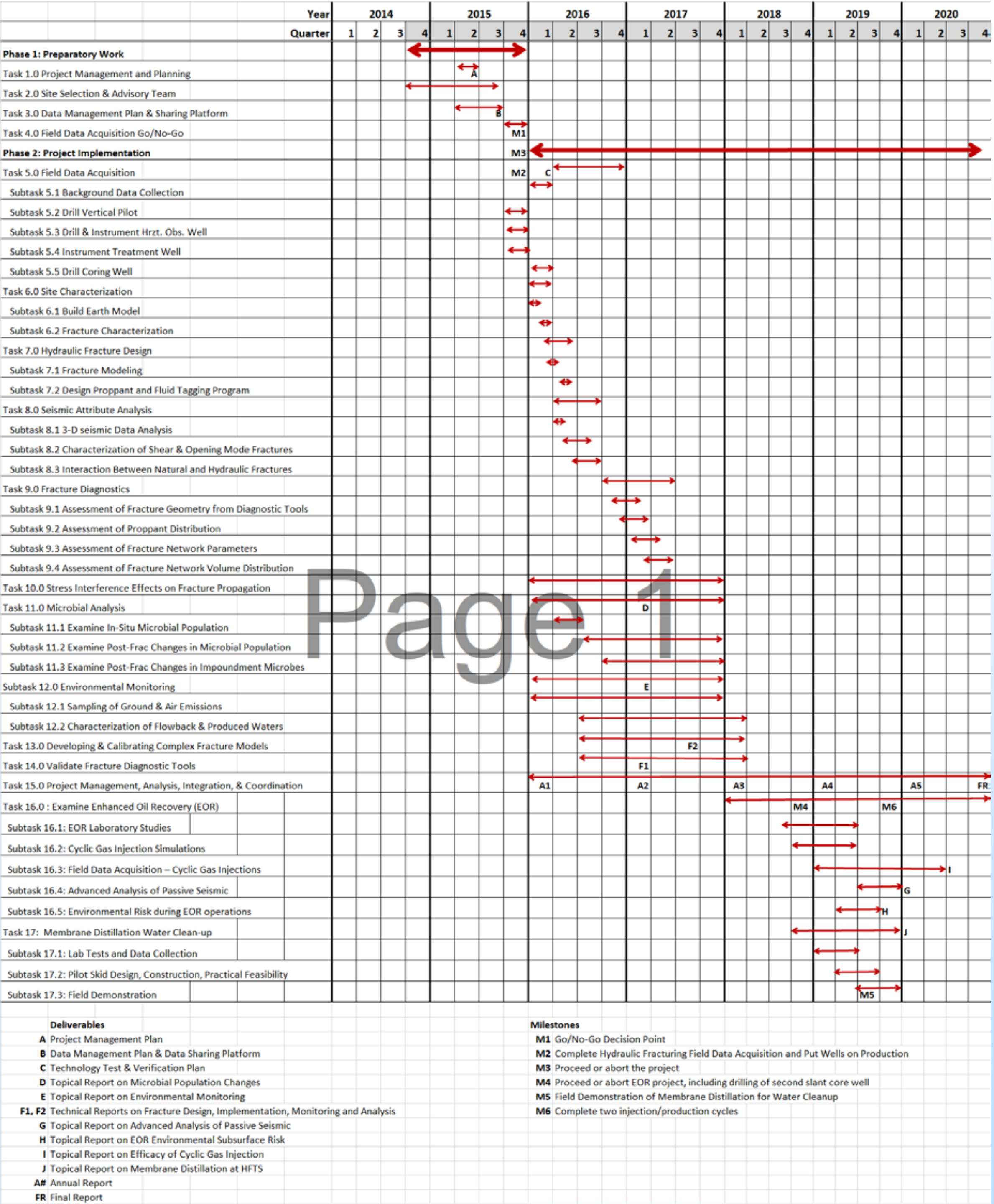
Project Overview
Goals and Objectives

- 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
  - Improve fracture models
  - Conclusively determine maximum fracture height

Organization Chart



Gantt Chart



Year
2014
2015
2016
2017
2018
2019
2020
Quarter
1 2 3 4
Phase 1: Preparatory Work
Task 1.0 Project Management and Planning
Task 2.0 Site Selection & Advisory Team
Task 3.0 Data Management Plan & Sharing Platform
Task 4.0 Field Data Acquisition Go/No-Go
Phase 2: Project Implementation
Task 5.0 Field Data Acquisition
Subtask 5.1 Background Data Collection
Subtask 5.2 Drill Vertical Pilot
Subtask 5.3 Drill & Instrument Hrzt. Obs. Well
Subtask 5.4 Instrument Treatment Well
Subtask 5.5 Drill Coring Well
Task 6.0 Site Characterization
Subtask 6.1 Build Earth Model
Subtask 6.2 Fracture Characterization
Task 7.0 Hydraulic Fracture Design
Subtask 7.1 Fracture Modeling
Subtask 7.2 Design Proppant and Fluid Tagging Program
Task 8.0 Seismic Attribute Analysis
Subtask 8.1 3-D seismic Data Analysis
Subtask 8.2 Characterization of Shear & Opening Mode Fractures
Subtask 8.3 Interaction Between Natural and Hydraulic Fractures
Task 9.0 Fracture Diagnostics
Subtask 9.1 Assessment of Fracture Geometry from Diagnostic Tools
Subtask 9.2 Assessment of Proppant Distribution
Subtask 9.3 Assessment of Fracture Network Parameters
Subtask 9.4 Assessment of Fracture Network Volume Distribution
Task 10.0 Stress Interference Effects on Fracture Propagation
Task 11.0 Microbial Analysis
Subtask 11.1 Examine In-Situ Microbial Population
Subtask 11.2 Examine Post-Frac Changes in Microbial Population
Subtask 11.3 Examine Post-Frac Changes in Impoundment Microbes
Subtask 12.0 Environmental Monitoring
Subtask 12.1 Sampling of Ground & Air Emissions
Subtask 12.2 Characterization of Flowback & Produced Waters
Task 13.0 Developing & Calibrating Complex Fracture Models
Task 14.0 Validate Fracture Diagnostic Tools
Task 15.0 Project Management, Analysis, Integration, & Coordination
Task 16.0 : Examine Enhanced Oil Recovery (EOR)
Subtask 16.1: EOR Laboratory Studies
Subtask 16.2: Cyclic Gas Injection Simulations
Subtask 16.3: Field Data Acquisition – Cyclic Gas Injections
Subtask 16.4: Advanced Analysis of Passive Seismic
Subtask 16.5: Environmental Risk during EOR operations
Task 17: Membrane Distillation Water Clean-up
Subtask 17.1: Lab Tests and Data Collection
Subtask 17.2: Pilot Skid Design, Construction, Practical Feasibility
Subtask 17.3: Field Demonstration
Deliverables
A Project Management Plan
B Data Management Plan & Data Sharing Platform
C Technology Test & Verification Plan
D Topical Report on Microbial Population Changes
E Topical Report on Environmental Monitoring
F1, F2 Technical Reports on Fracture Design, Implementation, Monitoring and Analysis
G Topical Report on Advanced Analysis of Passive Seismic
H Topical Report on EOR Environmental Subsurface Risk
I Topical Report on Efficacy of Cyclic Gas Injection
J Topical Report on Membrane Distillation at HFTS
A# Annual Report
FR Final Report
Milestones
M1 Go/No-Go Decision Point
M2 Complete Hydraulic Fracturing Field Data Acquisition and Put Wells on Production
M3 Proceed or abort the project
M4 Proceed or abort EOR project, including drilling of second slant core well
M5 Field Demonstration of Membrane Distillation for Water Cleanup
M6 Complete two injection/production cycles

Bibliography

- Perry, K., Ciezobka, J., Maity, D., & Eisenlord, S. (2017). The Hydraulic Fracture Test Site (HFTS) a West Texas Research Experiment for New Hydraulic Fracturing Technology in the Wolfcamp Formation. International Gas Union Research Conference. Rio de Janeiro, Brazil.
- James Courtier, Karen Chandler, Danny Gray, Shaun Martin, Randy Thomas, Joe Wicker, Jordan Ciezobka, (2017) Best Practices in Designing and Executing a Comprehensive Hydraulic Fracturing Test Site in the Permian Basin, URTeC: 2697483
- Courtier, J., Gray, D., Smith, M., Stegent, N., Carmichael, J., Hassan, M., & Ciezobka, J. (2016, September). Legacy Well Protection Refrac Mitigates Offset Well Completion Communications in Joint Industry Project. In SPE Liquids-Rich Basins Conference-North America. Society of Petroleum Engineers
- Ciezobka, J., Courtier, J., & Wicker, J. (2018). Hydraulic Fracturing Test Site (HFTS)–Project Overview and Summary of Results. Unconventional Resources Technology Conference (URTEC).
- Gale, J. F., Elliott, S. J., & Laubach, S. E. (2018). Hydraulic Fractures in Core From Stimulated Reservoirs: Core Fracture Description of HFTS Slant Core, Midland Basin, West Texas. Unconventional Resources Technology Conference (URTEC).
- Maity, D., Ciezobka, J., & Eisenlord, S. (2018). Assessment of In-situ Proppant Placement in SRV Using Through-Fracture Core Sampling at HFTS. Unconventional Resources Technology Conference (URTEC).

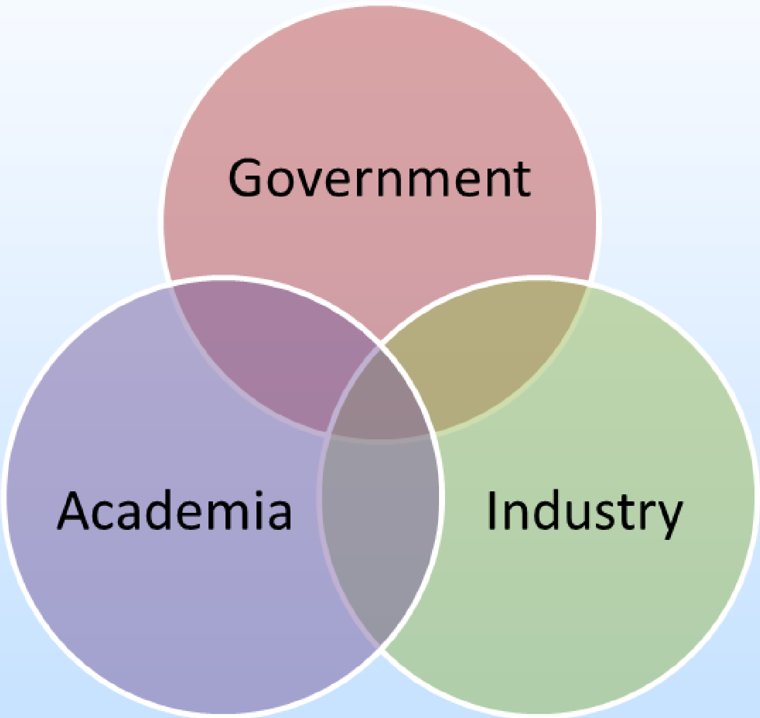
Bibliography

- Elliott, S. J., & Gale, J. F. (2018). Analysis and Distribution of Proppant Recovered From Fracture Faces in the HFTS Slant Core Drilled Through a Stimulated Reservoir. Unconventional Resources Technology Conference (URTEC).
- Campbell, W., Wicker, J., & Courtier, J. (2018). Natural and Hydraulic Fracture Density Prediction and Identification of Controllers. Unconventional Resources Technology Conference (URTEC).
- Wood, T., Leonard, R., Senters, C., Squires, C., & Perry, M. (2018). Interwell Communication Study of UWC and MWC Wells in the HFTS. Unconventional Resources Technology Conference (URTEC).
- Kumar, A., Seth, P., Shrivastava, K., Manchanda, R., & Sharma, M. M. (2018). Well Interference Diagnosis through Integrated Analysis of Tracer and Pressure Interference Tests. Unconventional Resources Technology Conference (URTEC).
- Stegent, N. A., & Candler, C. (2018). Downhole Microseismic Mapping of More Than 400 Fracturing Stages on a Multiwell Pad at the Hydraulic Fracturing Test Site (HFTS): Discussion of Operational Challenges and Analytic Results. Unconventional Resources Technology Conference (URTEC).
- Wang, I. H., Fairfield, R., Courtier, J., Gray, D., & Lee, S. (2018). Using Stage Level Microseismic Analysis to Gain Insight Into Fracture Efficiency and Completion Effectiveness. Unconventional Resources Technology Conference (URTEC).

Bibliography

- Wicker, J., Courtier, J., Campbell, T., Lee, S., Fairfield, R., & Trowbridge, S. (2018). Using Stage Level Microseismic Analysis to Correlate and Ground Truth Cored Hydraulic Fractures. Unconventional Resources Technology Conference (URTEC).
- Kumar, A., Chao, K., Hammack, R. W., & Harbert, W. (2018). Surface Seismic Monitoring of Hydraulic Fracturing Test Site (HFTS) in the Midland Basin, Texas. Unconventional Resources Technology Conference (URTEC).
- Maity, D. (2018). Microseismicity Analysis for HFTS Pad and Correlation With Completion Parameters. Unconventional Resources Technology Conference (URTEC).
- Eisenlord, S., Hayes, T., & Perry, K. (2018). Environmental Impact Analysis on the Hydraulic Fracture Test Site (HFTS). Unconventional Resources Technology Conference (URTEC).
- Wang, Shugang, et al. "Learnings from the Hydraulic Fracturing Test Site (HFTS)# 1, Midland Basin, West Texas-A Geomechanics Perspective." SPE/AAPG/SEG Unconventional Resources Technology Conference. Unconventional Resources Technology Conference, 2019.

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
  - 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

Project Progress and Major Milestones

Secure Funding and Test Site → Design Testing Program → Field Data Acquisition & Diagnostics → Slant Core Well → Data Analysis & Integration → Continue Field Data Acquisition → Data Analysis & Integration → Initial Confidenti-ality Period Expires

2015 → 2016 → 2017 → 2018

- Secured Test Site Laredo Petroleum
- Environmental baseline completed
- Completed hydraulic fracturing –put wells on production
- Drilled slant core well
- 1st interference test
- Core viewing workshop
- 2st interference test
- Learnings workshop
- 3D Laser Scans of core
- Design of EOR Field Pilot
- EOR Pilot

Lessons Learned

– Careful planning and operational de-risking helps ensure project tracks on budget and on time

– Multi-disciplinary teamwork critical for successful execution – peer review

– Multi agency involvement provides access to SME's and allows early adoption of learnings, leading to efficient technology transfer

– A balance between science and practical issues is key to success when collaborating with various stakeholders