Hydraulic Fracturing Test Site (HFTS)

DE-FE0024292

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

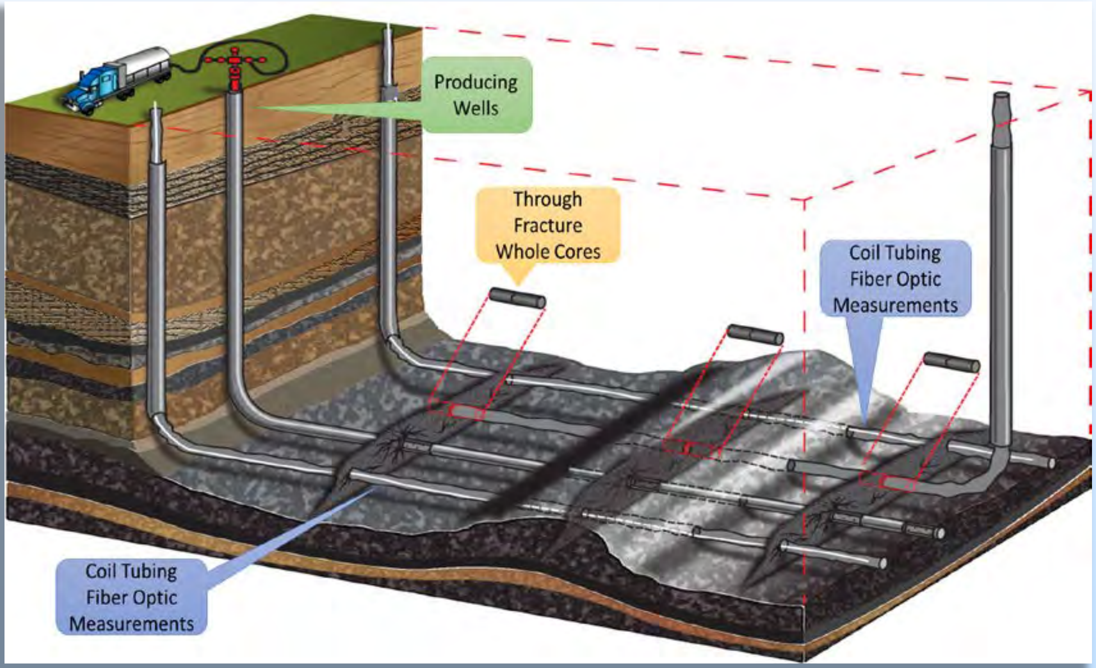
August 15, 2018

Presentation Outline

- HFTS Overview
- Review of Test Site Location and Details
- Project Progress
- Technical Status – Summary of research results presented at URTeC
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Summary
- Appendix

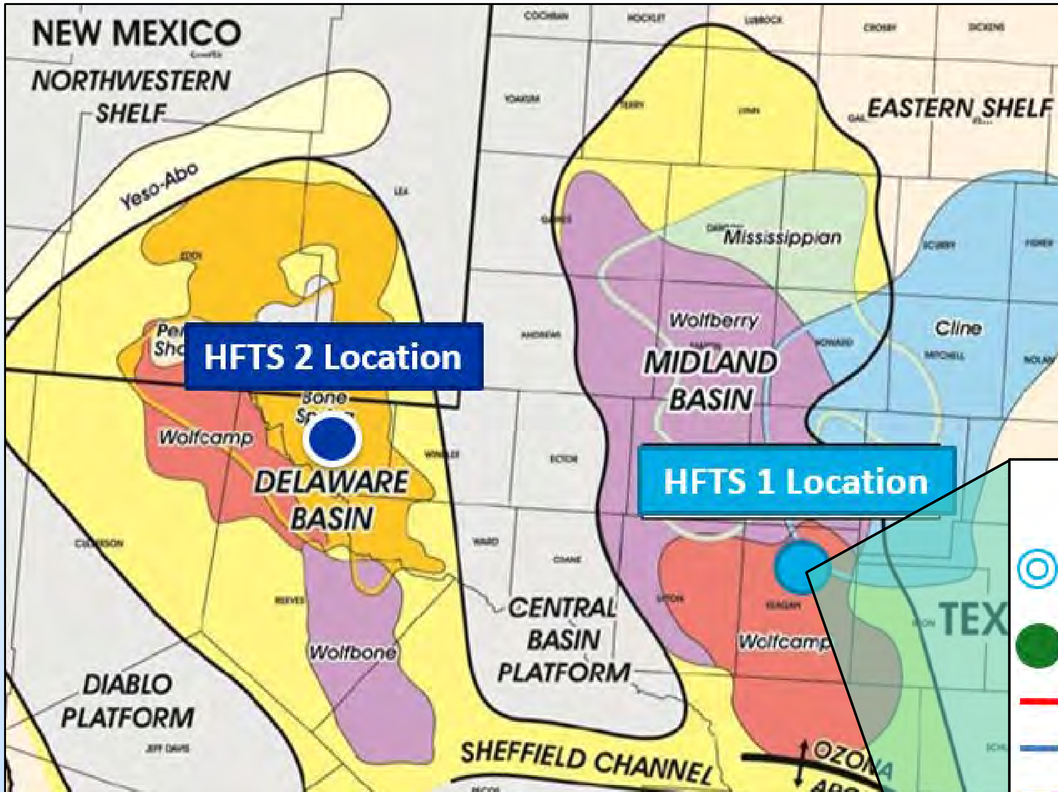
Hydraulic Fracturing Test Site: Project Overview

Comprehensive $25-million JIP research program



- Capture fundamental insights of fracturing process
- Acquisition of nearly 600 feet of through-fracture whole core
- Physical observation of created fractures and proppant distribution

Test Site Location

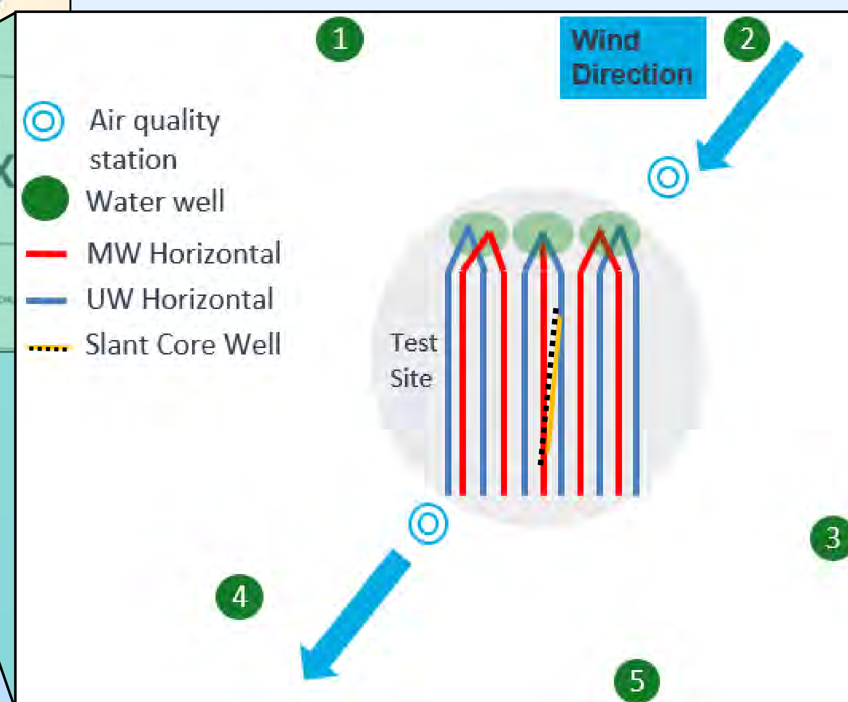


Study Area

Permian-Midland Basin

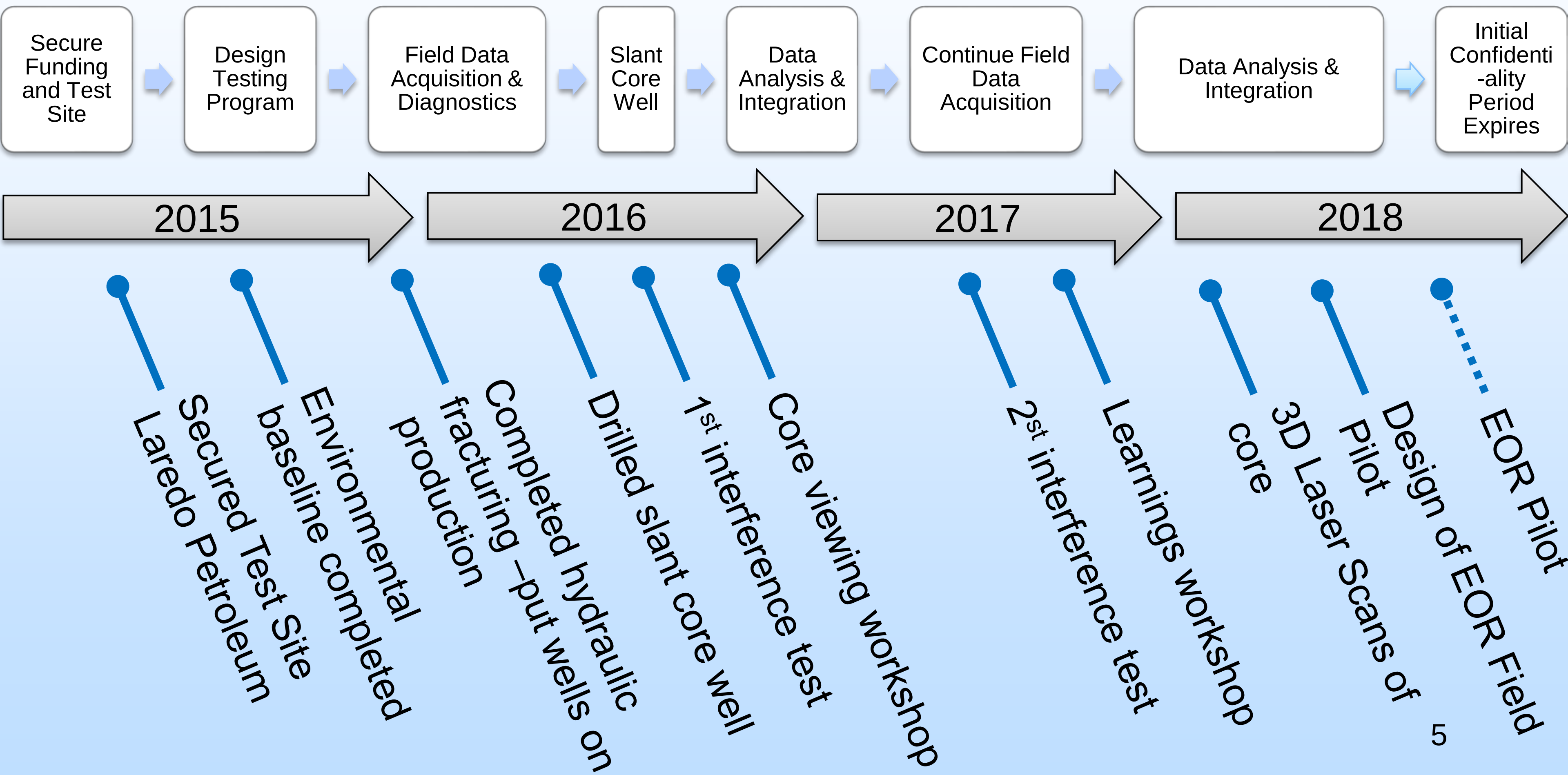
Reagan County

Upper & Middle Wolfcamp



6 UW & 5 MW 10,000’ Wells

Project Progress and Major Milestones

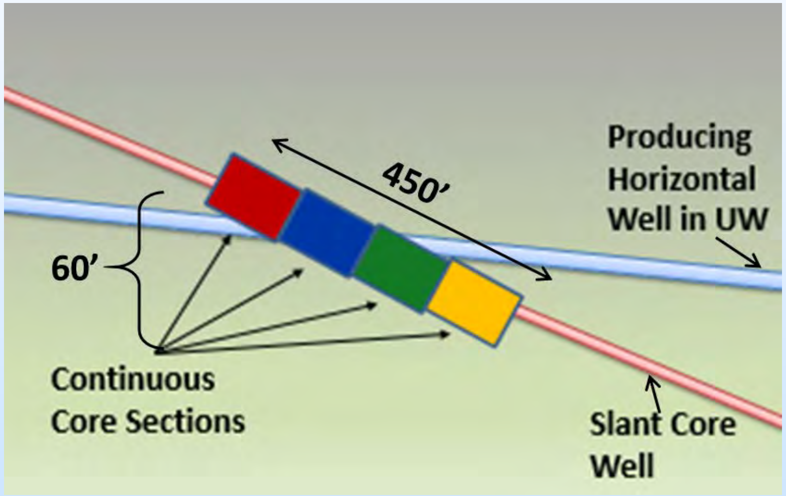


Technical Status

- Research results presented at the Unconventional Resources Technology and exhibition Conference (URTeC)
  - Houston, Texas, June 2018
- 13 papers in 2 special sessions over 2 days
- Summary of selected results presented here

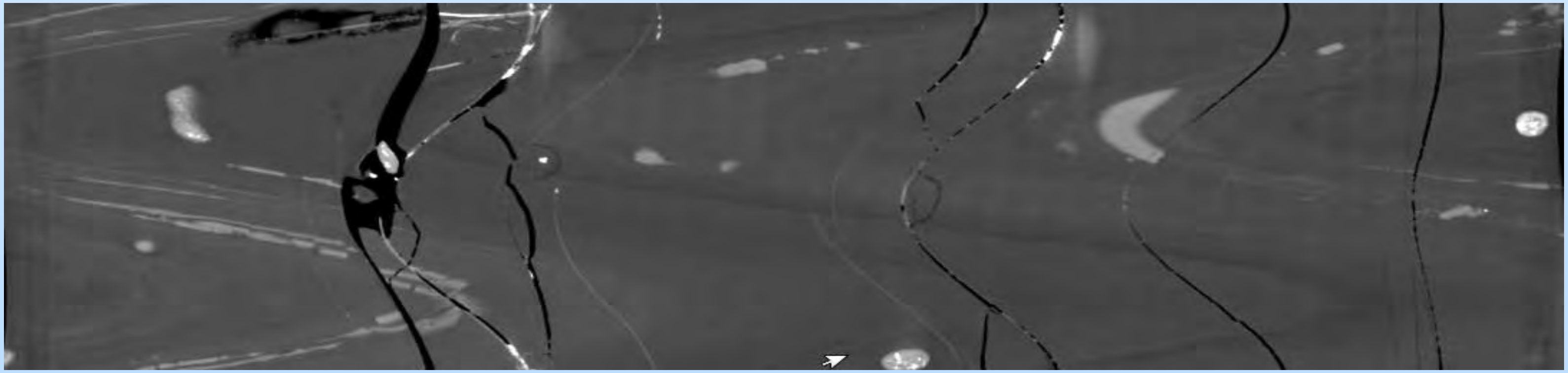
Through Fracture Core Highlights

Recovered ~440 feet in UW
Recovered ~160 feet in MW

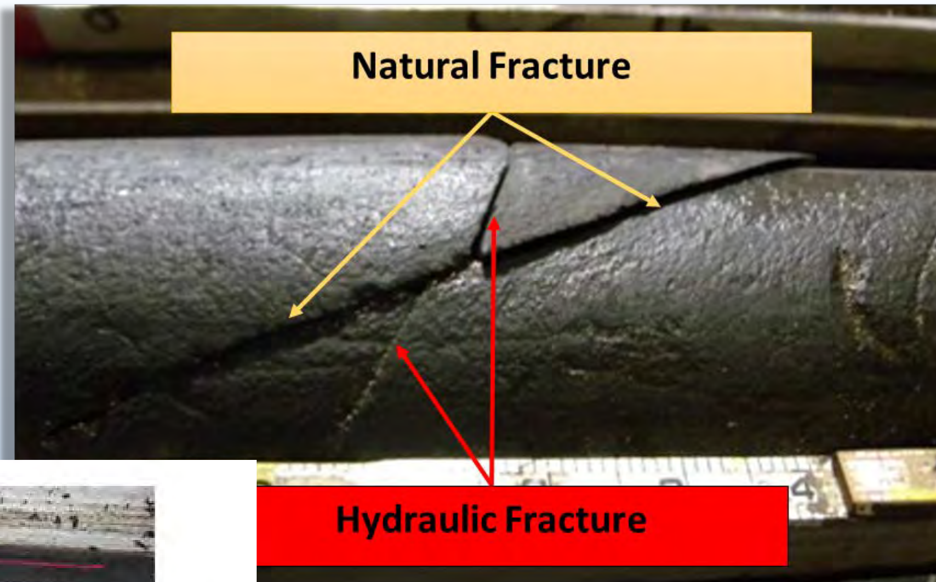


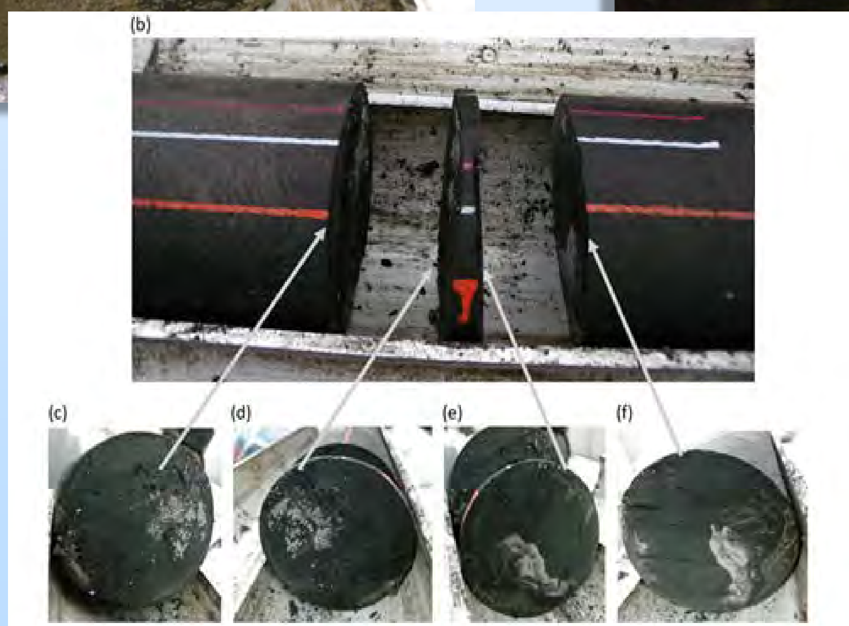
- Complexity beyond current simulator capability
- Patchy proppant distribution
  - Thick proppant packs to single grains
- Clear features on fracture faces of fracture propagation mechanisms

URTeC - 2937168



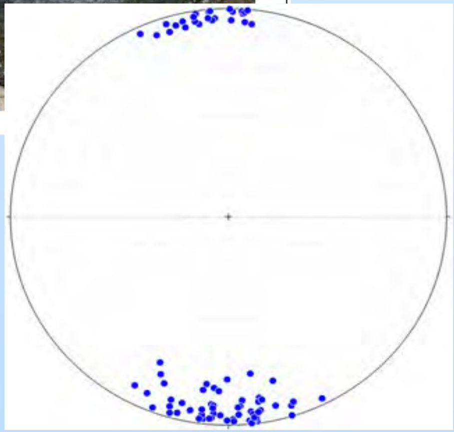
Fracture and Proppant Features Captured in Core





UW 5X # fractures than MW

Hydraulic Fractures in Core

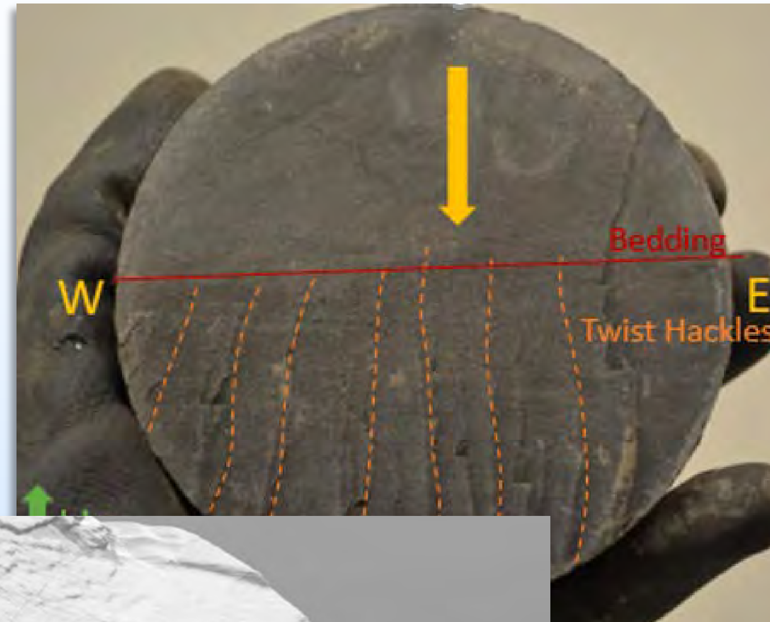


- Variable morphology
  - ~E-W Trending
  - Smooth planar surfaces trending
  - Complex, irregular groups of planes or stepping planes

URTeC - 2902624

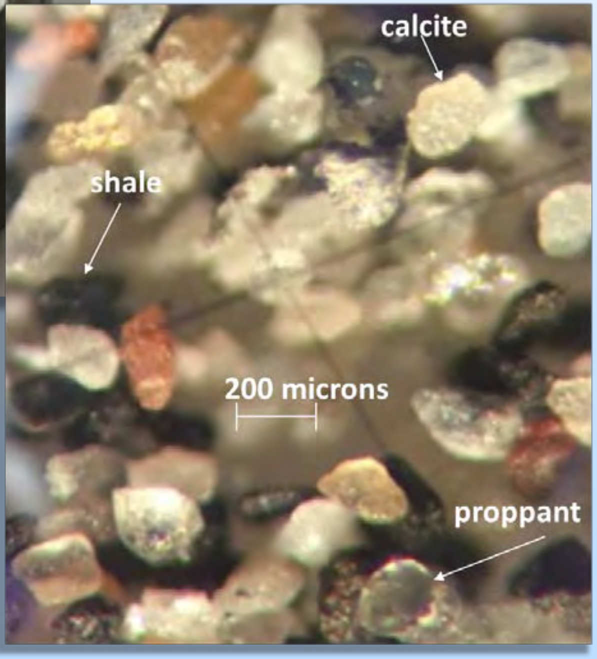
3D Laser Scans of Fractures

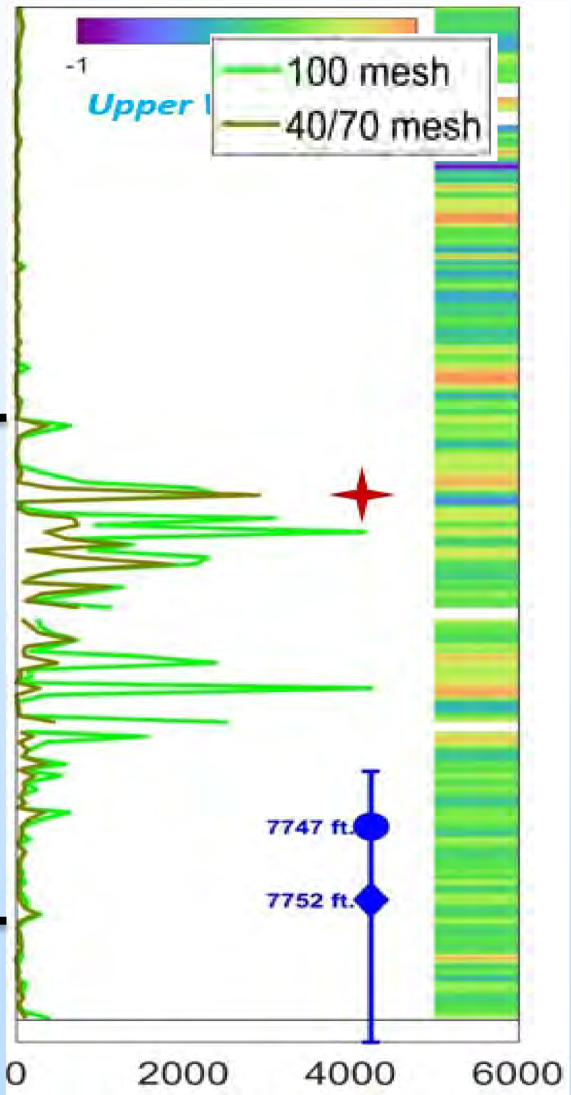
- Permanently preserve fracture, 50µm
- “Digital magnifying glass”
- Allows systematic interpretation, either visual or machine learning
  - Fracture type
  - propagation direction and mechanism



Subsurface Proppant Results-UW

Vertical Height 30’
~5% of MS height

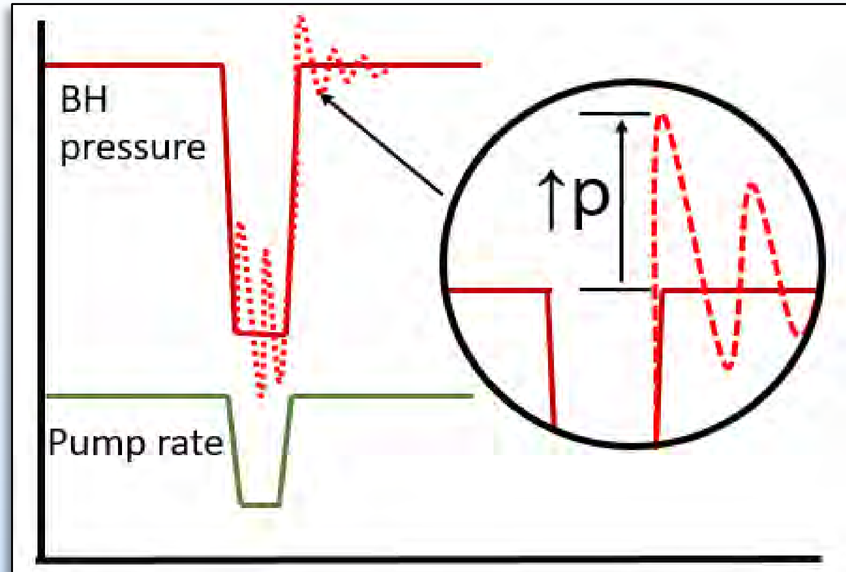




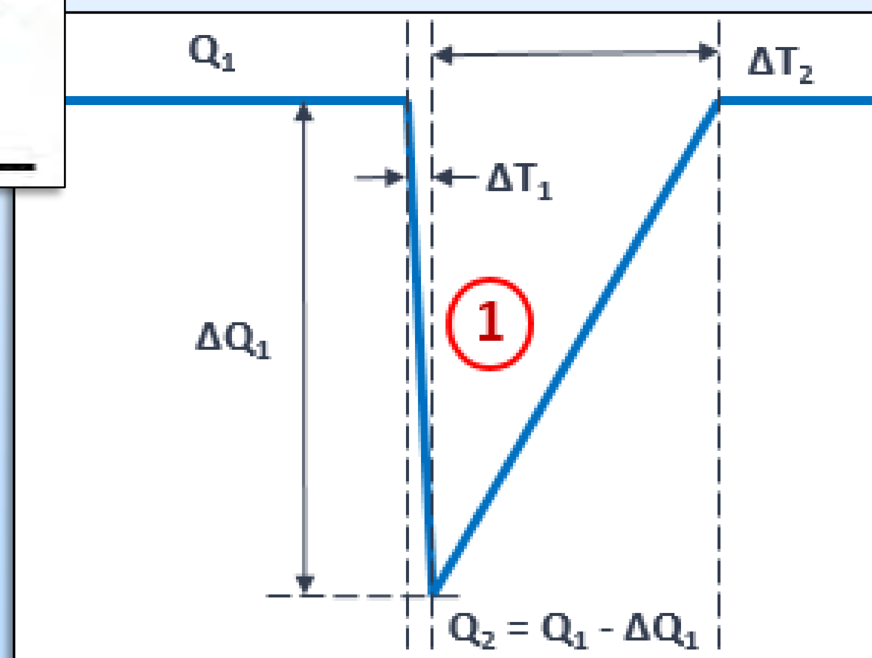
Developed methods to detect and quantify proppant

URTeC - 2902364

Variable Rate Fracturing



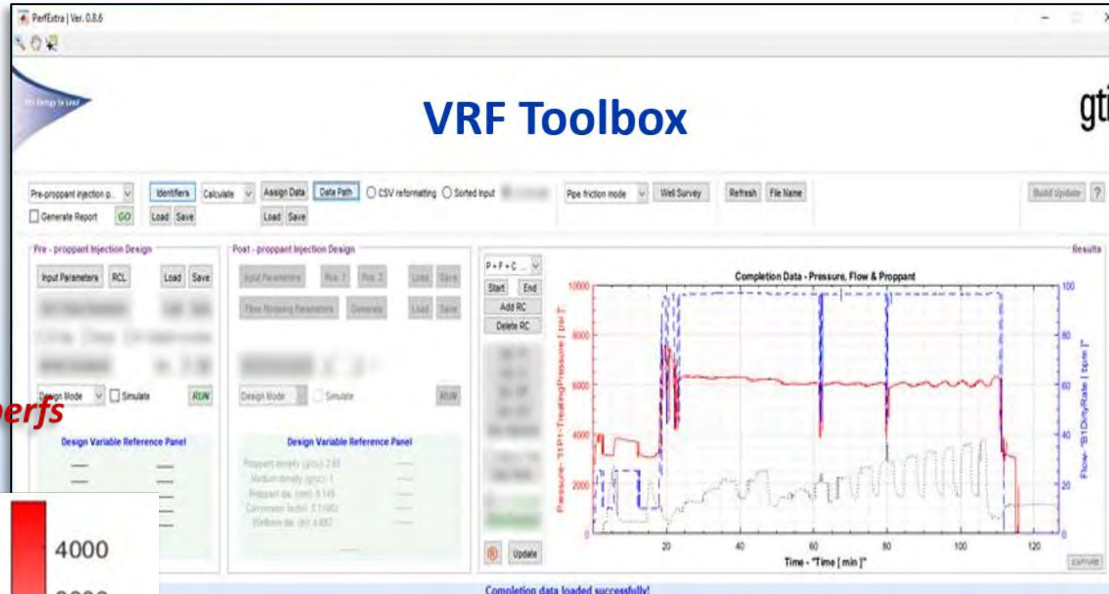
- Engineered rate pulses to create pressure pulses which temporarily raise the treating pressure and open perforations

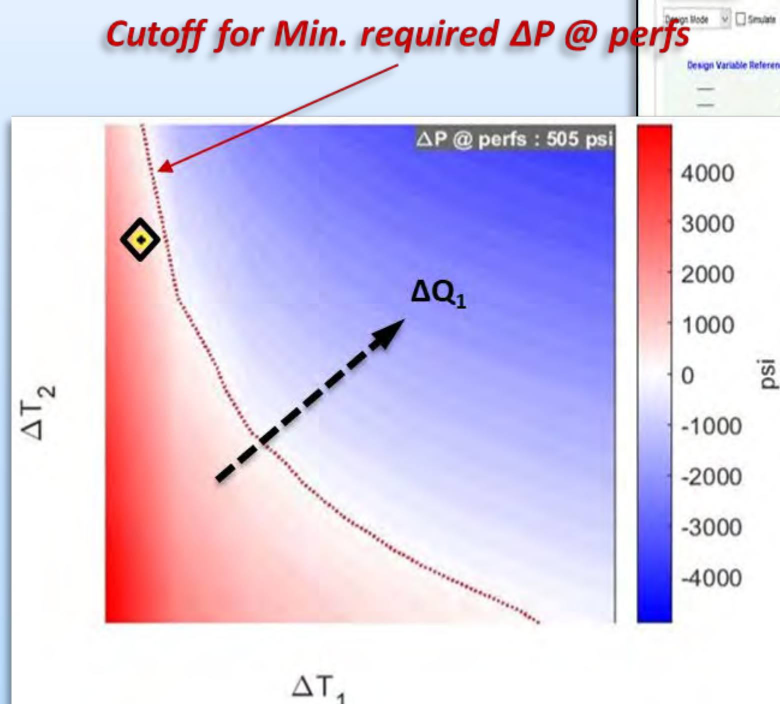


- Determine parameters of rate pulse to obtain a desired $\Delta\uparrow p$

Variable Rate Fracturing Toolbox

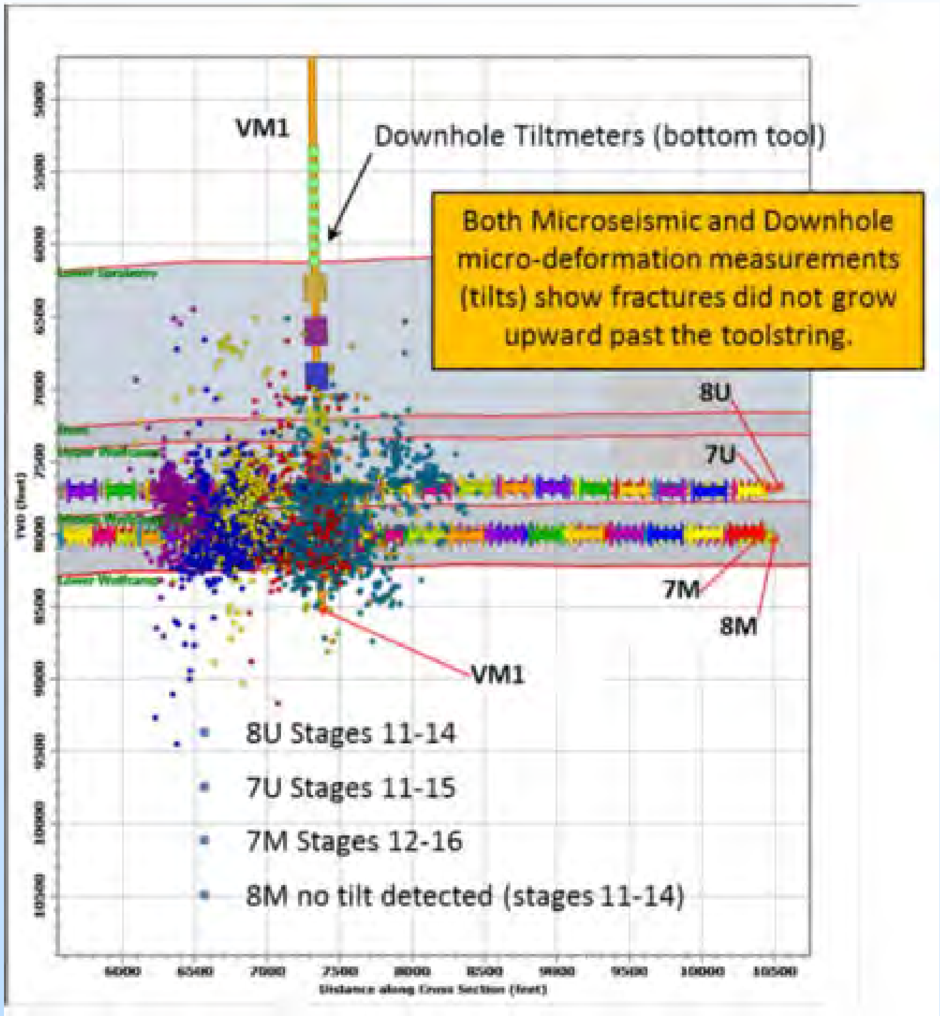
- Toolbox used to design and optimize VRF rate pulses

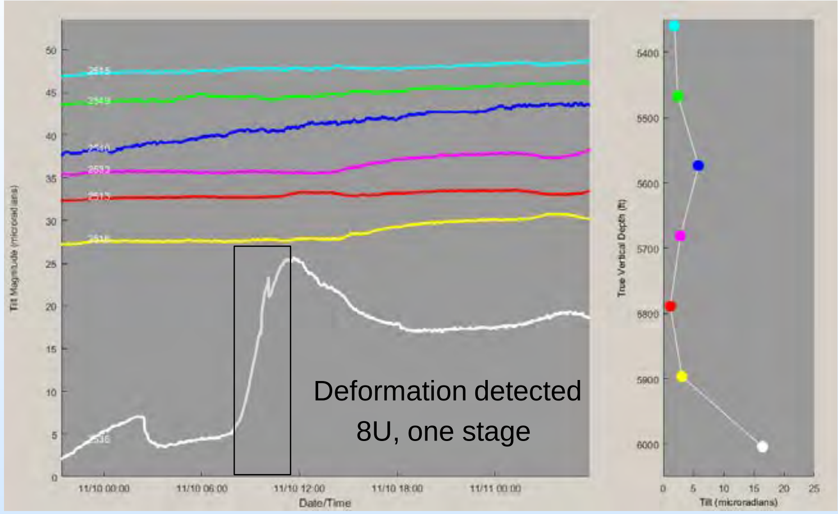




- VRF well had ~20% uplift in production (cum BOE) versus 3 adjacent MW wells after 14 months
- Implemented under license in many other Permian wells

Hydraulic Fractures Limited in Height





- Tiltmeters showed response only three times during fracturing, 1 example shown
- Response only on lowest tilt
- Confirms hydraulic fractures do not grow into fresh water zones

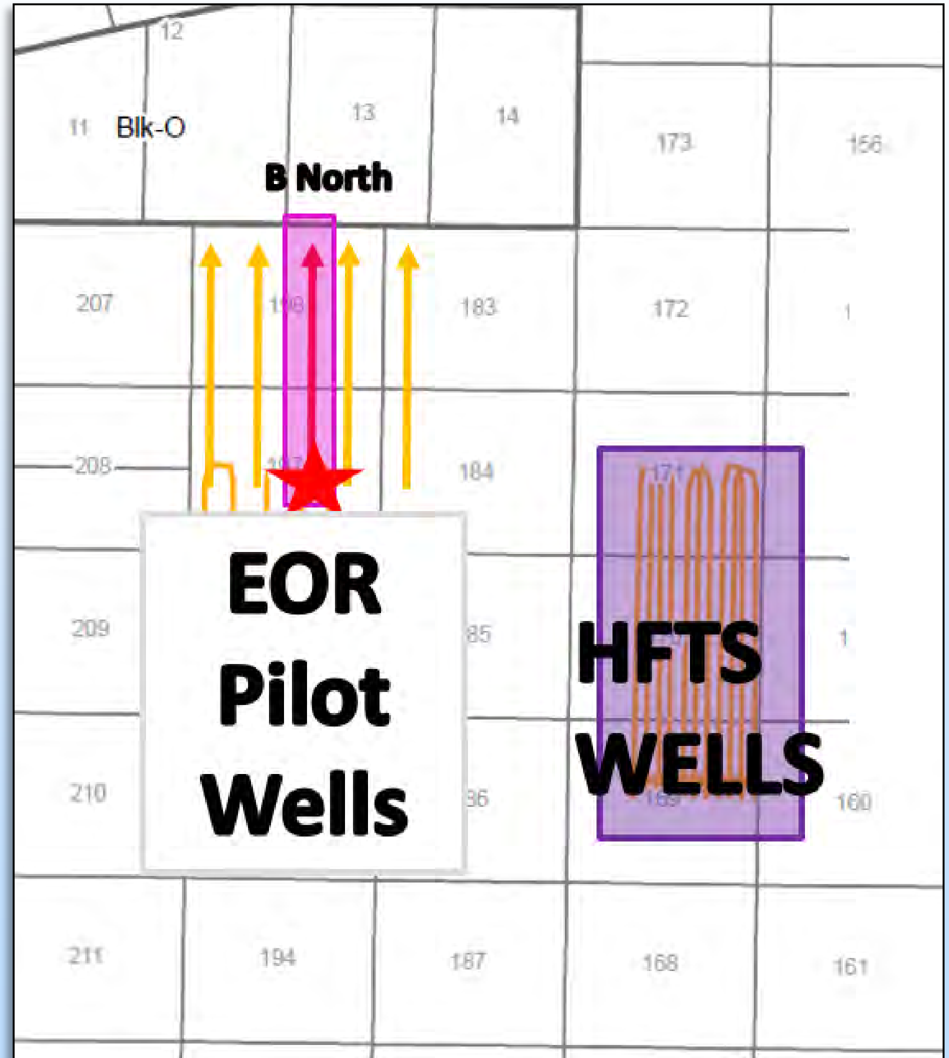
Top 10 Learnings

- Created hydraulic fractures are very complex and beyond all current fracture modeling capability. A new approach to fracture modeling is being developed as a result of this program.
- Variable rate fracturing provides a significant (20%) uplift to production by improving perforation effectiveness.
- Vertical proppant distribution is measured to be 5% of the dispersion indicated by microseismic measurements. Unique core well data indicates multiple mini-screenouts and thick proppant packs, limiting proppant distribution. This correlates with rapidly declining rates of production.
- The upper and lower Wolfcamp formation vary considerably; the upper with five times the created and natural fractures. Future fracture designs need to be customized in order to maximize resource recovery in these different geologies.
- Far field created fractures are multiple in number – challenging current thinking that fractures in the far field join to a singular fracture.
- Water and air impact from an 11 well Permian basin pad was minimal: there was no effect on shallow aquifers. Microseismic and tilt meter surveys indicate fractures do not grow into fresh water zones.
- Significant hydraulic well-to-well communication at 660 ft. spacing indicates well spacing is too close for current completion designs, especially within the middle Wolfcamp. Proper well spacing and completion design will eliminate the need to drill some wells.
- No obvious production communication is observed between wells in the upper and middle Wolfcamp formations.
- The rapid downhole formation of multiple tons of sulfide from sulfate could result in corrosion, sour gas formation and iron sulfide precipitation, interfering with oil and gas production.
- Industry trends to longer wellbores, more proppant and closer perforation spacing results in significantly increased near-term production; but not optimum well design from an NPV perspective.

Phase 2 EOR Overview

- Design and perform an Enhanced Oil Recovery (EOR) field pilot utilizing produced gas to perform a series of Huff-n-Puff treatments, leveraging:
  - HFTS data and results
  - Consortium expertise
  - NETL EOR capabilities
- Significant staff dedication and project management from Laredo and financial support from HFTS JIP and DOE/NETL
- Estimated total project value exceeding $35MM; including wells, facilities, and research
- Work commencing in Q3 2018 – 2 year project

EOR Pilot Details



- 6 well pilot (1 injection 5, monitor)
- Lab Studies
  - PVT analysis
  - Core flooding
- 3D cyclic gas injection and production simulations
- Diagnostics
  - Tracers,
  - BH gages
  - Passive seismic monitoring
  - Geochemistry
- New slant science/observation well
  - SRV Cores
  - Open and cased hole logs
  - Pressure gages

Accomplishments to Date – Short List

- Formed a successful public-private partnership
- Executed over 450 fracture stages in 13 wells, most monitored with advanced diagnostics
- Collected air and water emission data before, during, and after hydraulic fracturing
- Improved well performance by implementing Variable Rate Fracturing
- Collected ~600 feet of through fracture whole core
  - 3-D Laser scanned fractures
- Developed an EOR pilot, starting in Q3, 2018

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

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

- 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

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

DOE/NETL
Program Oversite and Direction
Primary Sponsor

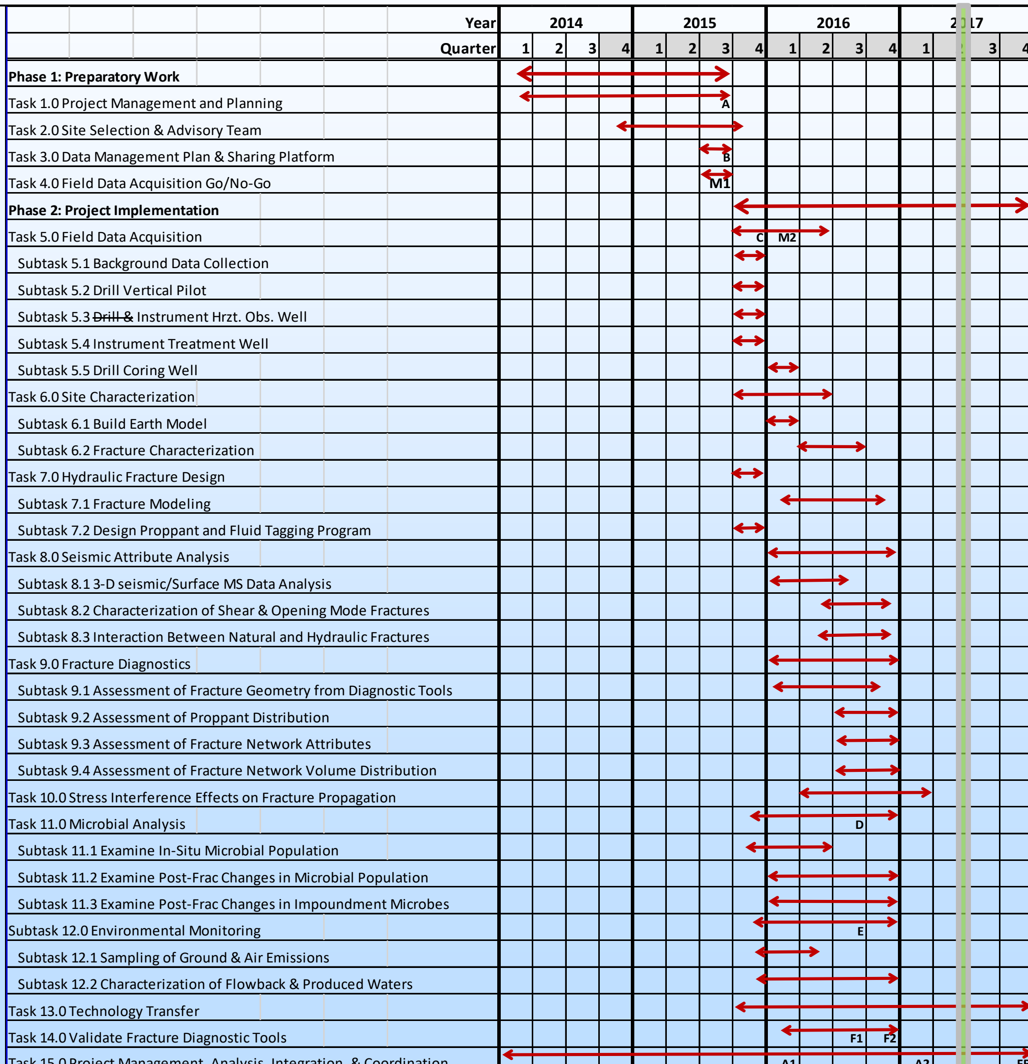
Laredo Petroleum
Test site provision
Management of field ops.
Background data
Analysis
Tech Transfer

GTI
Program Management
Analysis/Integration
Coordination/Workshops
Tech Transfer

Industry Partners
Cost Share
Data Analysis
Analytical Services
Access to SME's

Subcontractors: UT & BEG
Specific research and support

Gantt Chart



	Milestones & Deliverables
A	Project Management Plan
B	Data Management Plan & Data Sharing Platform
M1	Go/No-Go Decision Point
M2	Complete Hydraulic Fracturing Field Data Acquisition and Put Wells on Production
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
A1, A2	Annual Report
FR	Final Report

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).

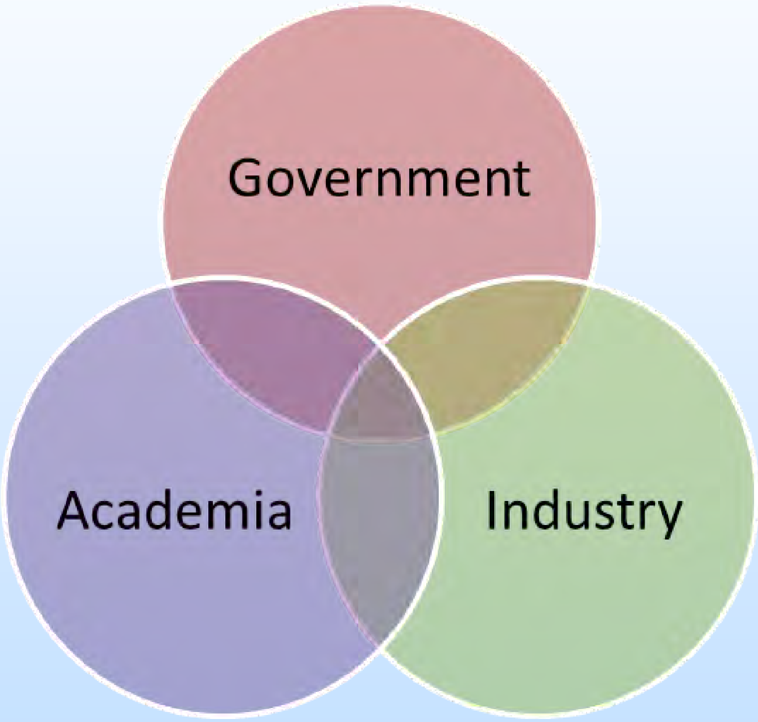
Bibliography

- 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).

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

Site Host

Sponsors and Participants

Acknowledgements

Thanks to Department of Energy (DOE), National Energy Technology Laboratory (NETL), Laredo Petroleum Inc., U.S. Core Laboratories, Devon, Discovery Natural Resources, Encana, Energen, ConocoPhillips, Shell, Halliburton, Chevron, TOTAL, ExxonMobil and SM Energy, Pioneer

Images Courtesy: DOE/NETL, Laredo, GTI