Hydraulic Fracturing Test Site (HFTS)

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Jordan Ciezobka

Gas Technology Institute (GTI)

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Presentation Outline

- Benefit to Program
- Goals and Objectives
- HFTS Background, Overview, and Sponsors
- Test Site
- Field Data Acquisition
- Core Well
- Summary
- Synergy Opportunities
- Appendix

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

HFTS Background

- The duration of HFTS project and activities, and GTI overall investment timeline is approaching 6 years (2010 – to present).
- In support of the HFTS project GTI sponsored 3 workshops in 2013 (Houston, Pittsburgh, Webex) with Industry to identify research needs and develop project support. Over 60 companies attended and provided feedback
- An HFTS strategy report was completed under a specific task of an RPSEA project in 2014.
- NETL award in 2014 initiated the HFTS program

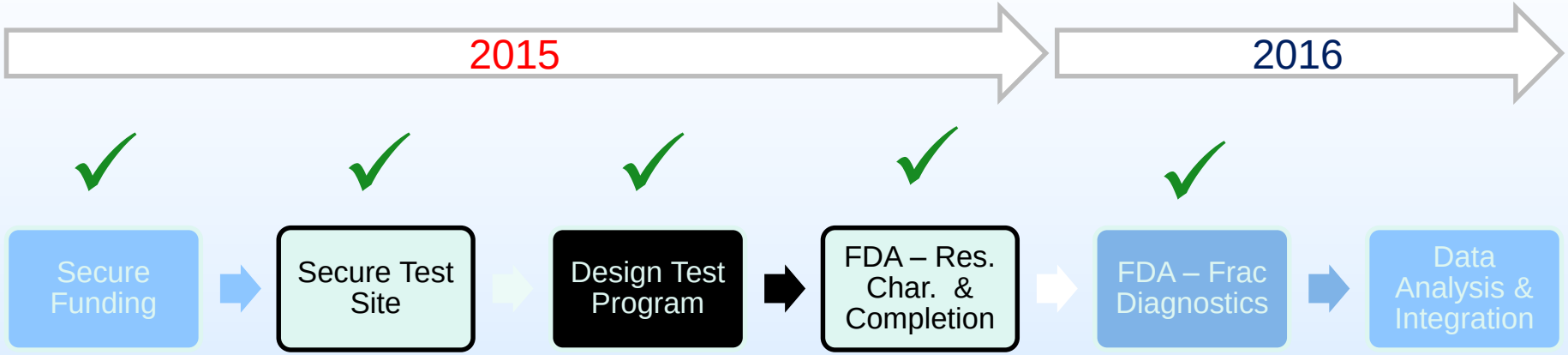
HFTS Overview

- Field-based hydraulic fracturing research program in West Texas, Permian Basin
- Public-private partnership with NETL and multiple industry partners providing financial support
- Laredo Petroleum is site host
- $22 million of new hydraulic fracturing research “piggy backing” on 11 horizontal wells over 400 fracture treatments, over $100 million in background data
- Advanced diagnostics including coring through hydraulically fractured reservoir
- Potential to reduce the number of wells required to develop West Texas Resources by thousands

List of Current HFTS Sponsors and Participants

- Site Host – Laredo Petroleum
- Sponsors ($1.5MM)
  - NETL ($7.5MM)
  - Encana
  - Devon
  - TOTAL
  - Energen Resources
  - Discovery Nat. Res
- Sponsors Continued
  - Halliburton
  - CoreLabs
  - ConocoPhillips
  - Shell
- Performing Universities
  - UT
  - BEG

HFTS Progress Review



- DOE/NETL
- 9 Participants
- >$22 MM cash and in-kind

- Laredo Petro.
- Permian Basin
- Wolfcamp
- 13 test wells
- 86 background well

- Testing Priority Matrix

- Logs, cores
- Pressure monitoring
- Fracture diagnostics
- Production Surveillance
- Environmental sampling

- Ground truth
- Cores
- Logs
- Pressure monitoring

- GTI
- UT
- BEG
- Laredo
- JIP

HFTS Specific Tasks

- Evaluate and confirm environmentally safe operating procedures
- Determine fracture geometry and confirm maximum height growth
- Evaluate subsurface controls and operational impacts on hydraulic fracture geometry and completion efficiency
- Evaluate inter-well interference
- Understand stimulated rock volume & reservoir depletion over time
- Identify and evaluate the distribution and effectiveness of geological frac barriers
- Evaluate pressure front barriers created in stimulation sequence
  - Refracs and zipper/simul fracs
- Test alternative frac designs in different wells in a relatively consistent geological setting
- Test production performance by stage/perf cluster post stimulation

Test Site Location
Extensive Nearby Science Data

Background data from
87 Nearby Wells

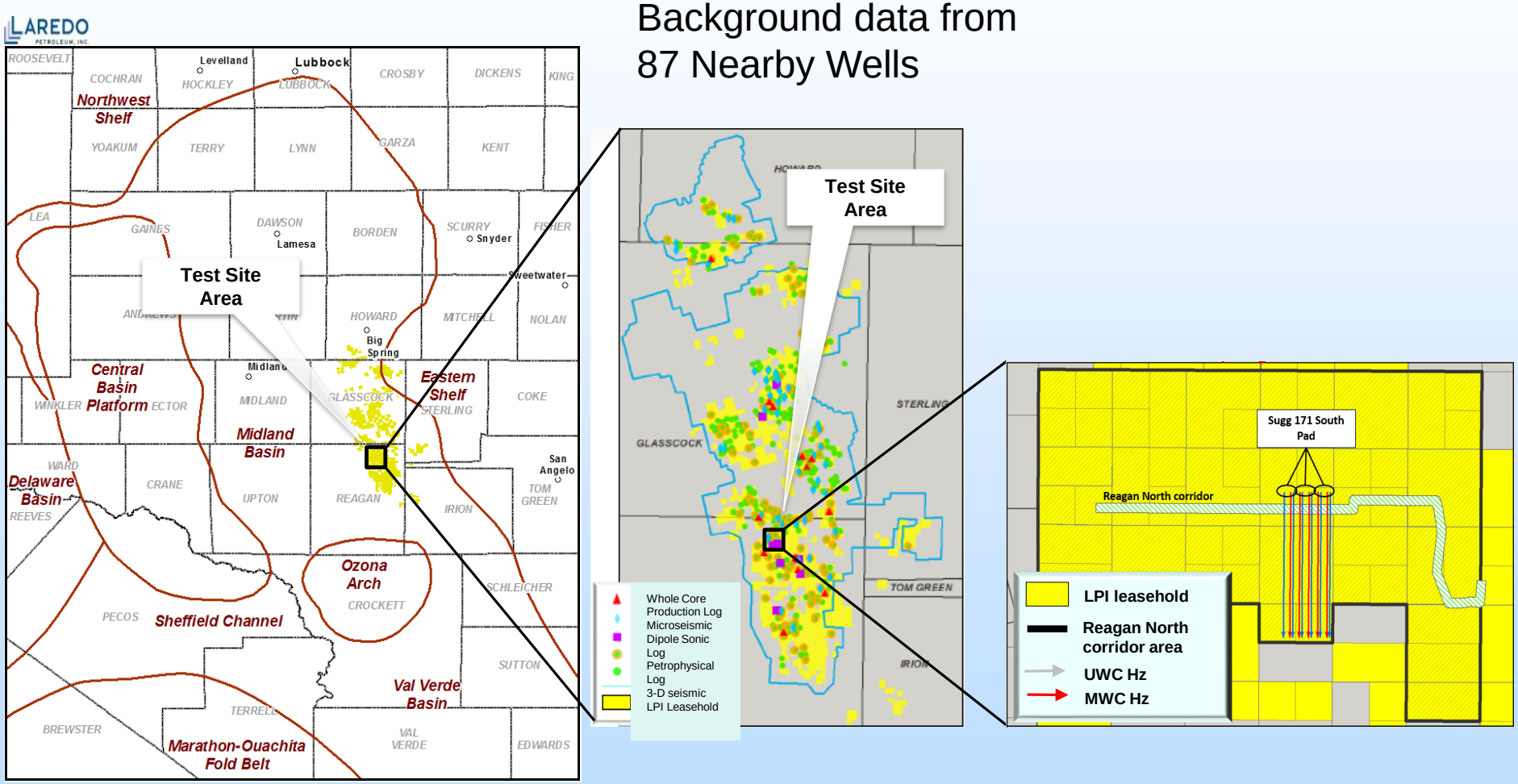
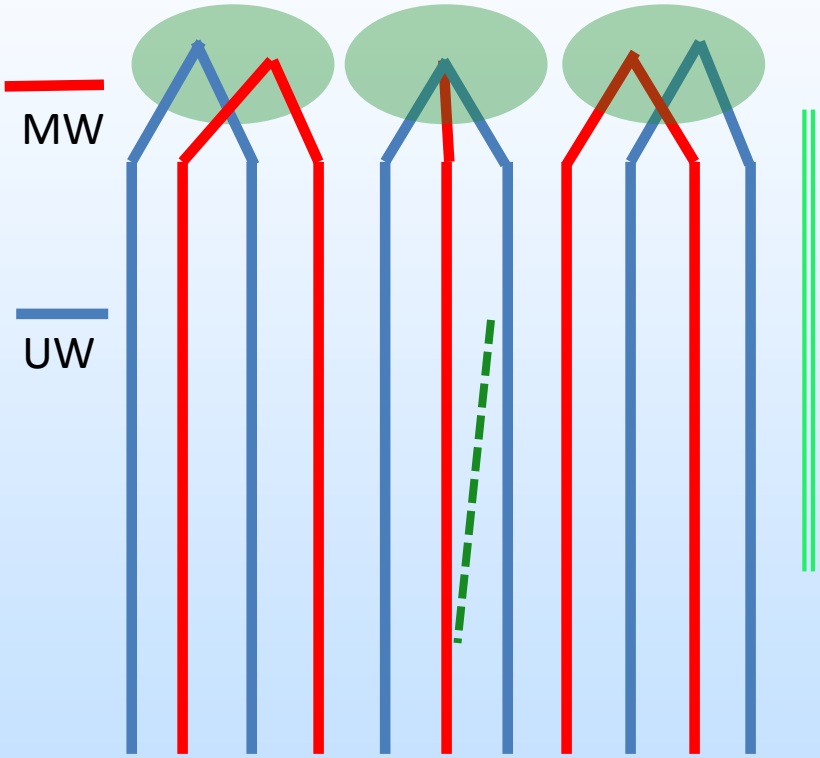
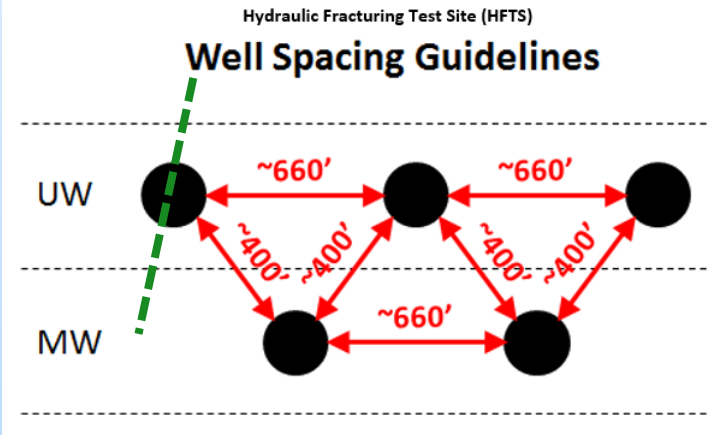


Image Courtesy: Laredo Petroleum

Well Layout Details

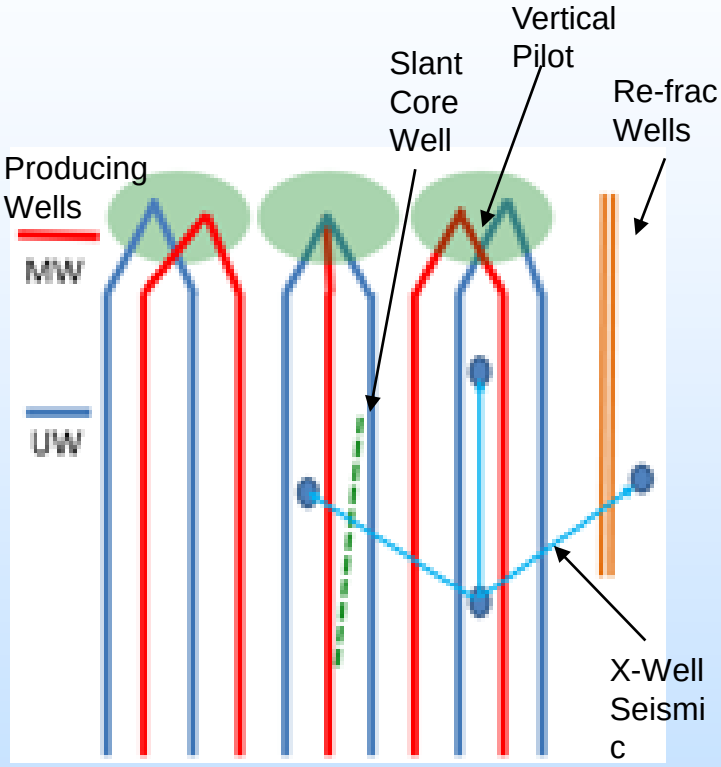


- **11 Extended reach horizontal wells, 10,000’ South laterals**
- **6 wells in Upper Wolfcamp**
- **5 wells in Middle Wolfcamp**
- **Chevron Spacing Pattern**



Progress Review – Field Data Acquisition

- Drilled Vertical Pilot below lower WC
  - 110 Sidewall rotary cores
  - 50 pressurized, 60 non pressurized,
  - Logs, Quad combo and image log
  - 14 micro DFIT's in open hole
- Open hole horizontal logs in 2 wells adjacent to core well
  - Quad Combo and image
- Completed 13 wells with over 450 frac stages
  - 11 in-field wells, 2 offset re-frac wells
  - RA, oil and water tracers, colored proppants
  - Microseismic monitoring inc. vertical and horizontal borehole arrays, tiltemeter array,
  - Surface microseismic, specific to a variable rate hydraulic fracturing test
  - Vertical Seismic Profile (VSP)
- Vertical BH pressure monitoring in 3 wells near the core well
- 4 toe DFIT's in cased horizontals
- Numerous frac design tests
- 2 Fiber Optic coil tubing production logs
- BH pressure gages in all producing wells, including refrac wells
- Environmental Sampling – Air, Water, Microbial: Reservoir Fouling, Corrosion
- PVT analysis completed from two adjacent wells to core well



Sidewall Rotary Core Analysis

- **Regular Rotary Cores (60)**
  - White Light / UV Photos
  - MicroCT Scans (35)
  - Thin Sections (20)
  - XRD/GRI (15)
  - Mechanical Properties (18)
  - Relative Perm (5)
  - Preserve (5)
- **CoreVault Rotary Cores (50)**
  - White Light / UV Photos
  - **NMR (50)**
  - MicroCT Scans (50)
  - **Gas Comp/Solvent Extraction (25)**
  - Thin Sections (25)
  - XRD/GRI (23)
  - Mechanical Properties (4)
  - Relative Perm (5)
  - Preserve (5)
  - Ingrain PoreHD (10)

Slant Core Well Objectives

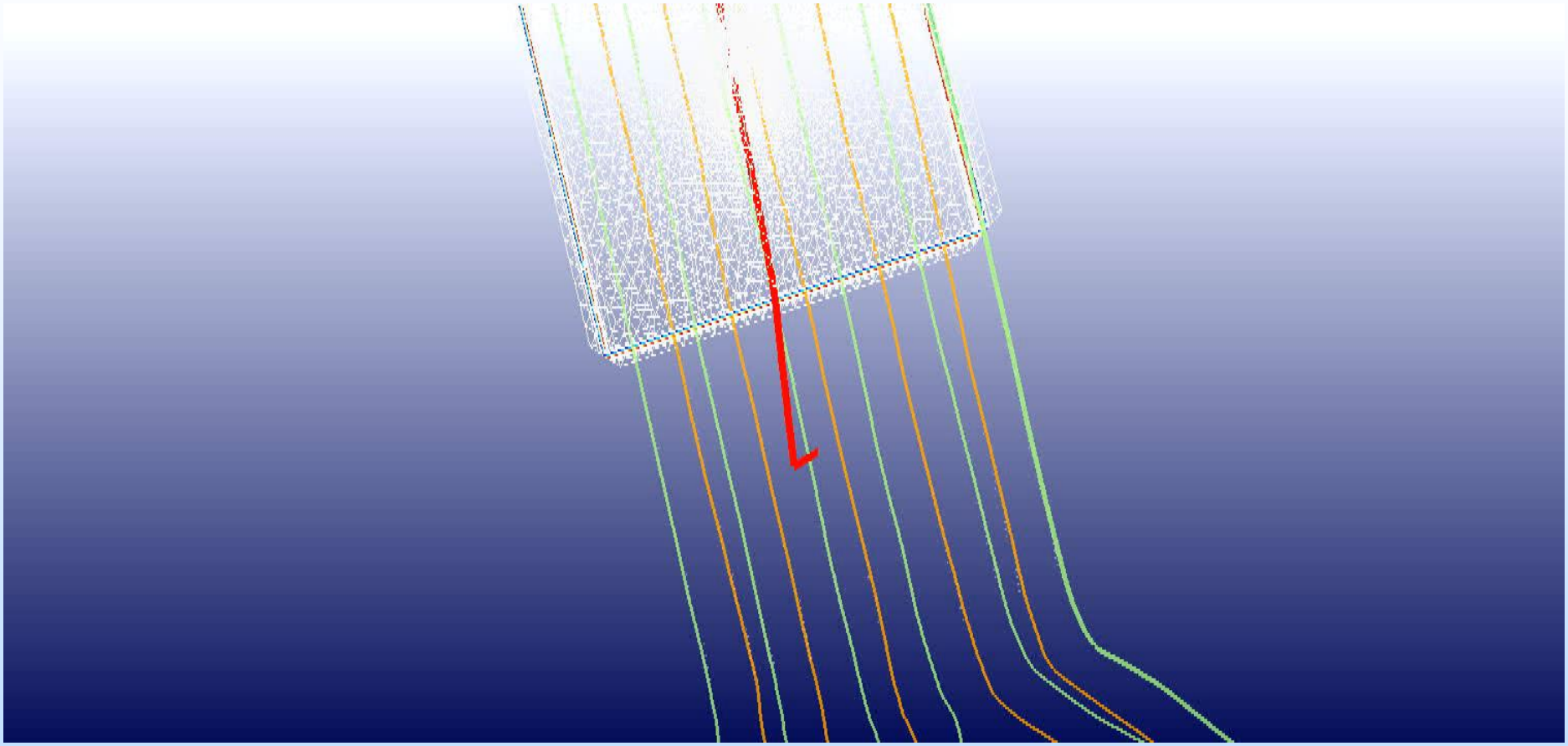
- Demonstrate vertical extent of hydraulic fractures
- Characterize observed hydraulically stimulated fractures in the wellbore to assist with frac design, well spacing, & interference objectives
- Validate fracture attribute data
  - Geometry, complexity, conductivity, etc…
- Conduct pressure monitoring during production lifetime

Slant Core Well

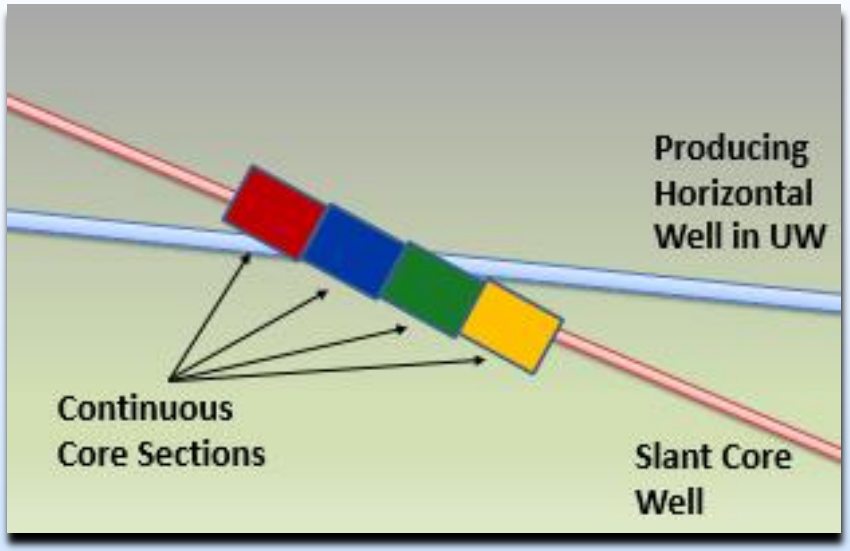
- Completed Slant Core Well
  - 600 feet of whole core through two hydraulically fractured reservoirs
    - Upper Wolfcamp
    - Middle Wolfcamp
  - CT scanned all cores
  - Logged and cased well
    - Quad Combo, including spectral gamma and Image log
  - Mass Spectroscopy analysis in entire slant lateral
  - Core description ongoing
  - Ran 8 isolated bottom hole pressure gages to monitor reservoir depletion through created fractures

Image Courtesy:
Baker Hughes

Core Well Trajectory

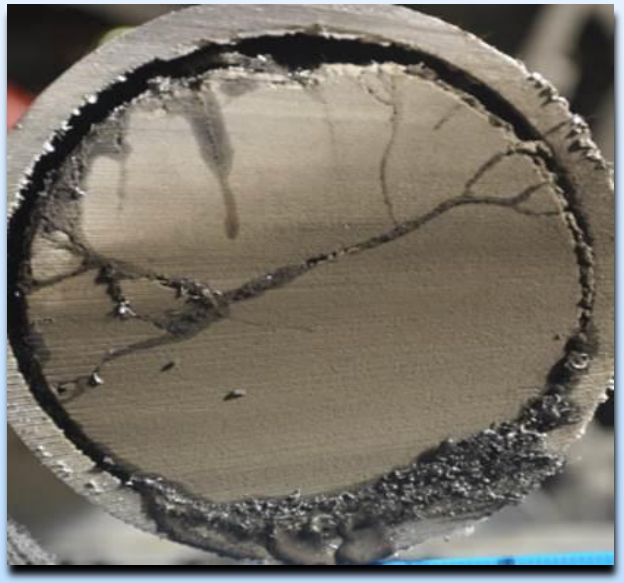


Slant Core Well Highlights



> Insights expected to increase resource recovery and spur new technology development

> Results challenge industry assumptions and understandings



Project Summary

- Continue Field Data collection
  - Interference testing, Pressure Monitoring, Production Monitoring, Environmental Sampling
- Complete core description & develop methods for proppant detection in fracture surfaces and drilling sludge in core sleeves
- Transition from Field Data Acquisition to analysis and integration of data
- Collaborative efforts of world class subject matter experts will culminate in redefining hydraulic fracturing understanding while leading to optimal resource development
- Elevate the learnings of HFTS and extrapolate the environmental impacts of precision well spacing and increased hydraulic fracturing efficiency on ground water resources to West Texas basins in a changing climactic landscape
- Ultimate goals of this effort is to conduct science and research that has the power to influence society, policy, and regulations for protecting the environment, water resources, and helping the shale oil and gas industry thrive.

Synergy Opportunities

- Collaborate with other field test sites
- Incorporate and test latest fracture models and diagnostic interpretation, i.e UT
- Continue to grow the public-private partnership that enabled the implementation of this project

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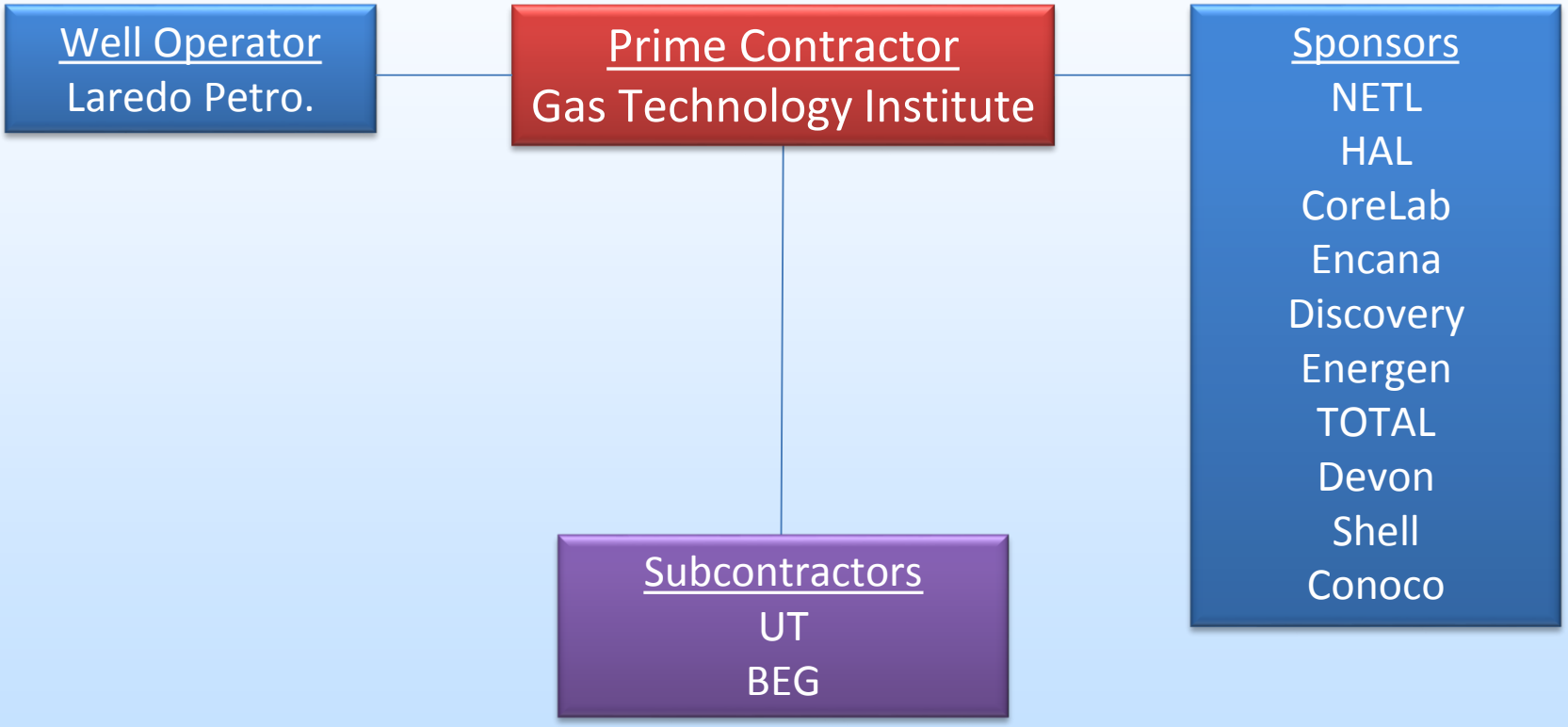
Excellent example of a very successful public-private partnership and can serve as a model for future experiments. It would not have gone forward without NETL support; but with that support the industry joined, tripling the size of the experiment and enabling a one of a kind dataset.

Image Courtesy: Laredo

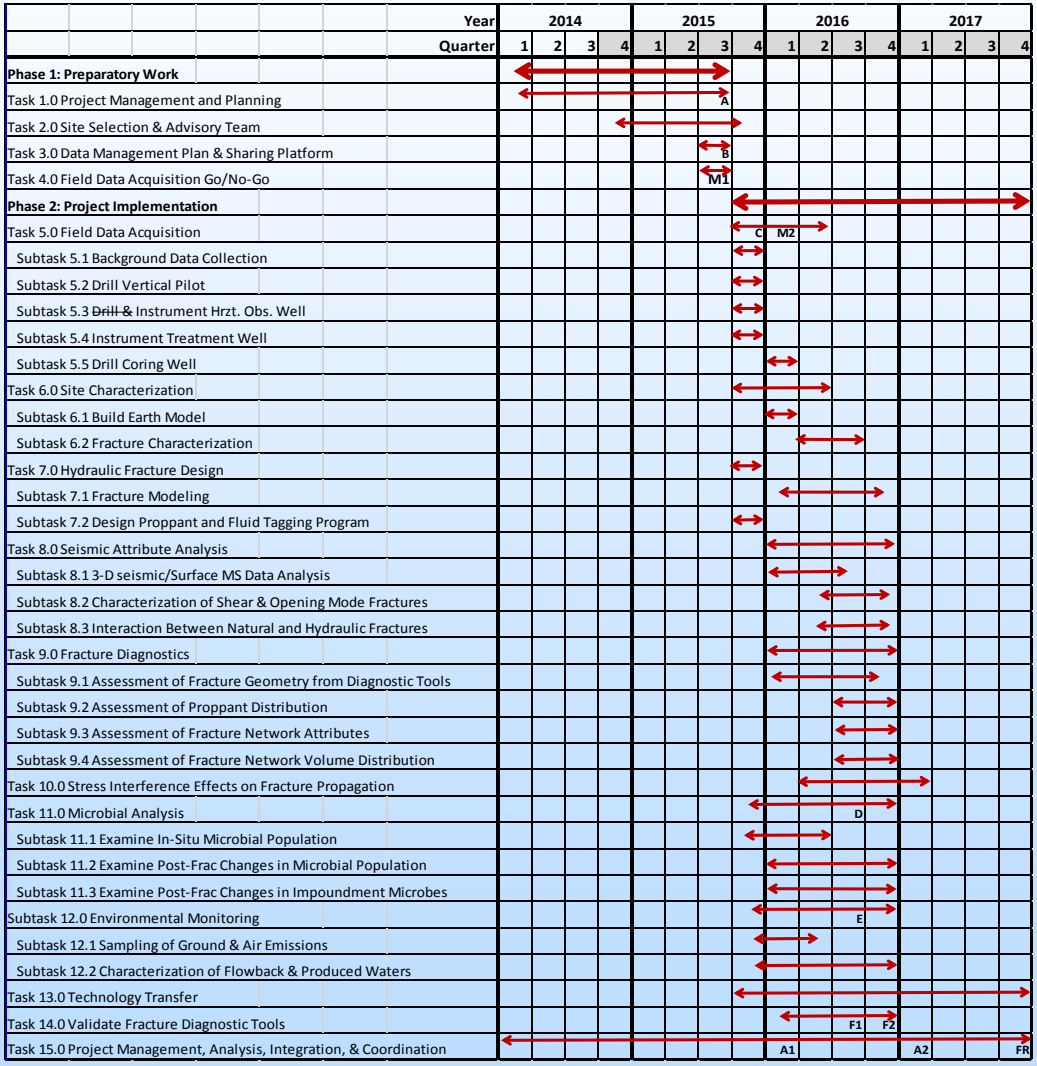
Appendix

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

Organization Chart



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

- None