Hydraulic Fracturing Test Site 2 (HFTS 2)

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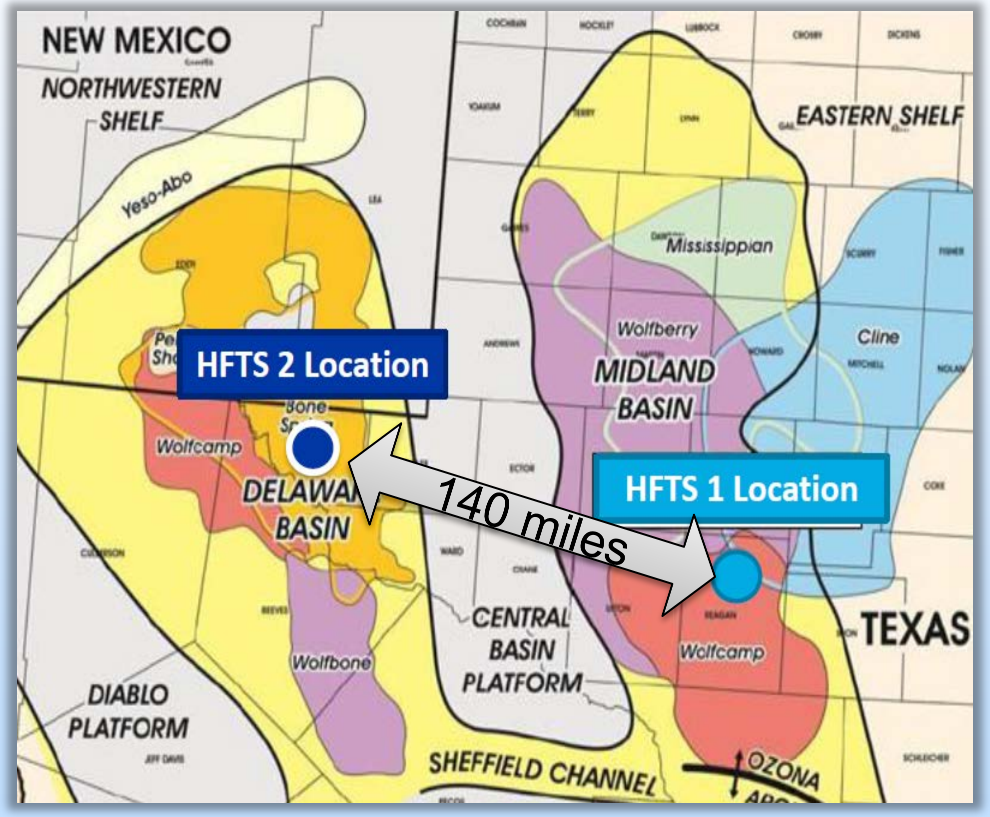
Presentation Outline

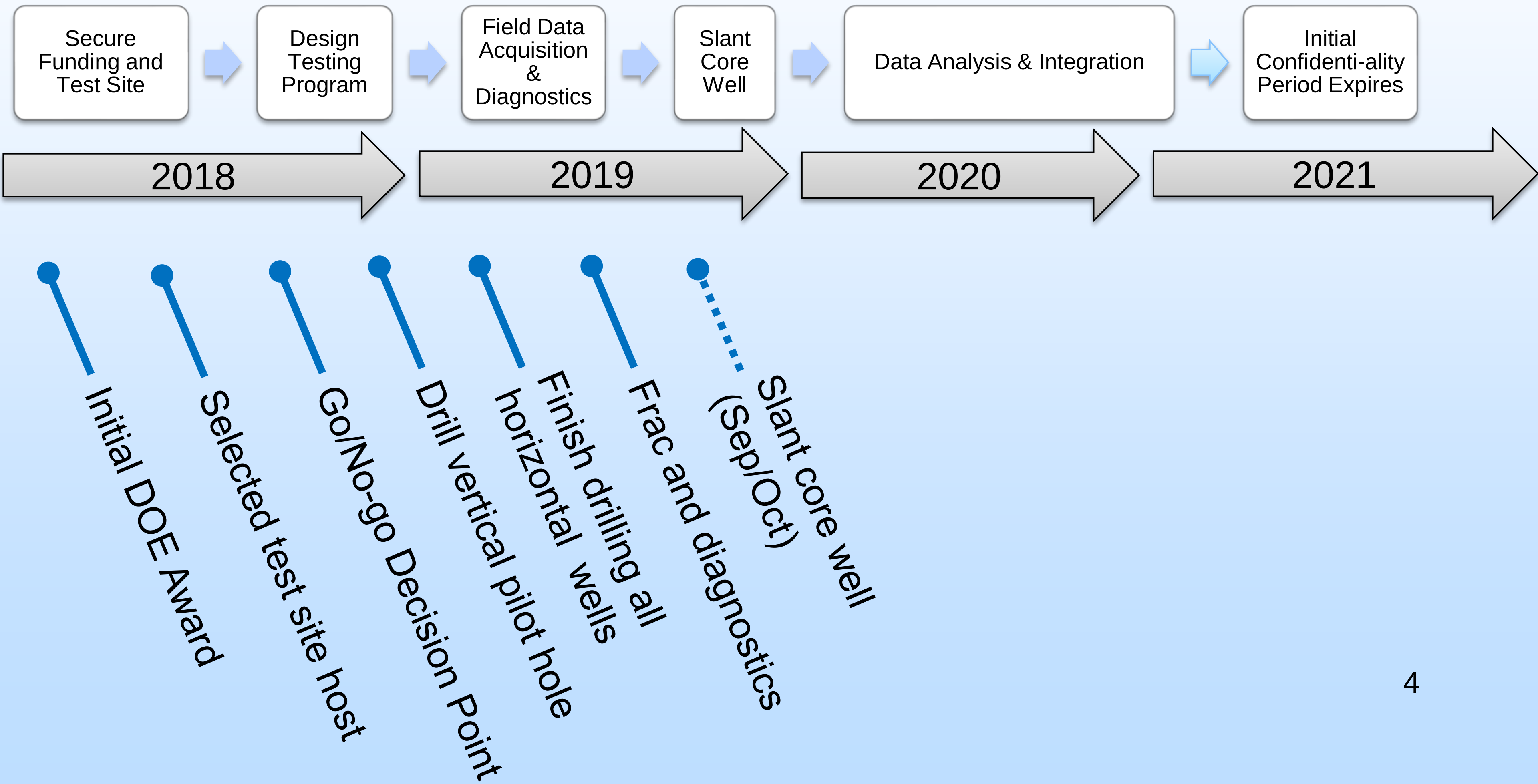
- Project Overview
- Project Progress
- Background Data
- Industry Participation
- Test Site Location and Well Details
- Technical Status
- Accomplishments to Date
- Synergy Opportunities
- Summary
- Appendix

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 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

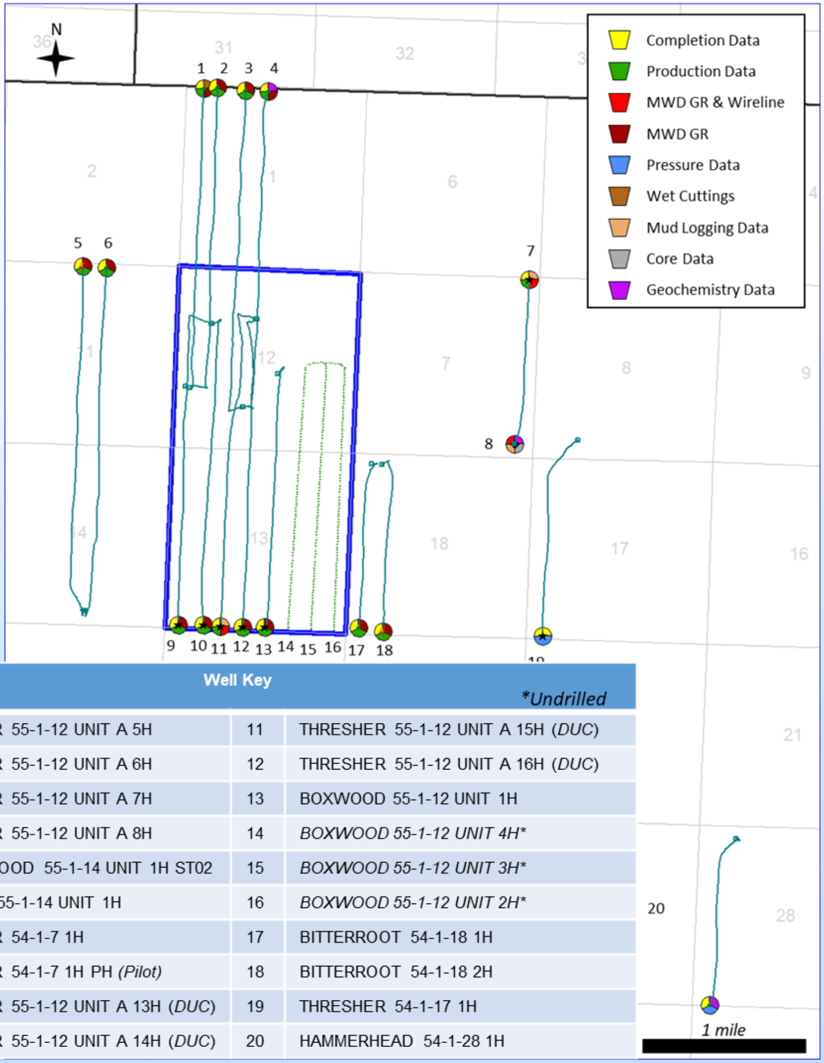
Project Progress and Major Milestones



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

HFTS Background Data Map



Well Key			*Undrilled
1	THRESHER 55-1-12 UNIT A 5H	11	THRESHER 55-1-12 UNIT A 15H (*DUC*)
2	THRESHER 55-1-12 UNIT A 6H	12	THRESHER 55-1-12 UNIT A 16H (*DUC*)
3	THRESHER 55-1-12 UNIT A 7H	13	BOXWOOD 55-1-12 UNIT 1H
4	THRESHER 55-1-12 UNIT A 8H	14	*BOXWOOD 55-1-12 UNIT 4H**
5	COTTONWOOD 55-1-14 UNIT 1H ST02	15	*BOXWOOD 55-1-12 UNIT 3H**
6	SEQUOIA 55-1-14 UNIT 1H	16	*BOXWOOD 55-1-12 UNIT 2H**
7	THRESHER 54-1-7 1H	17	BITTERROOT 54-1-18 1H
8	THRESHER 54-1-7 1H PH (*Pilot*)	18	BITTERROOT 54-1-18 2H
9	THRESHER 55-1-12 UNIT A 13H (*DUC*)	19	THRESHER 54-1-17 1H
10	THRESHER 55-1-12 UNIT A 14H (*DUC*)	20	HAMMERHEAD 54-1-28 1H

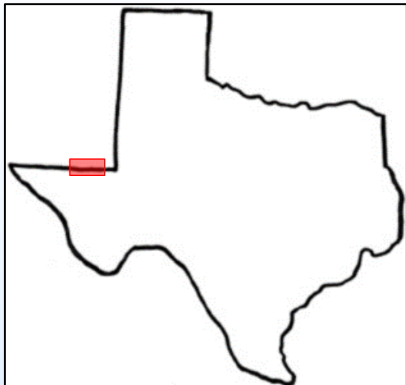
HFTSII – Delaware Participants

NETL/DOE
Anadarko
Blackstone
Borehole Seismic
BPX
Chevron
Cimarex
Concho
COP
Devon
Diamondback
Oasis
Oxy
PDC Energy
Shell
WPX
XTO

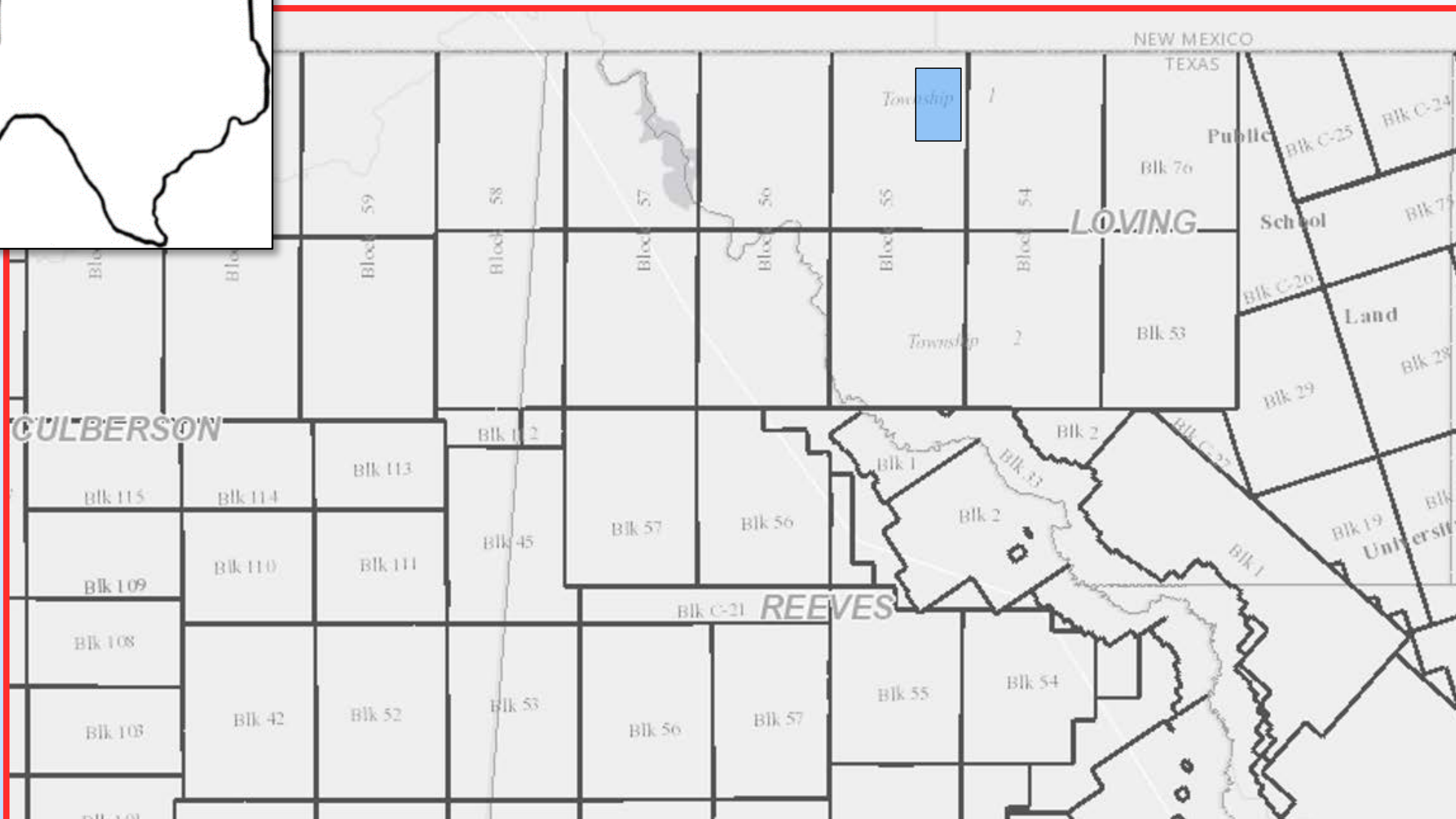
- Technical Advisory Group
- 6 Technical Committees with Chairs
  - Formation Evaluation
  - Completions
  - Microseismic
  - Instrumentation
  - Slant Core Well
  - Data Integration and Modeling

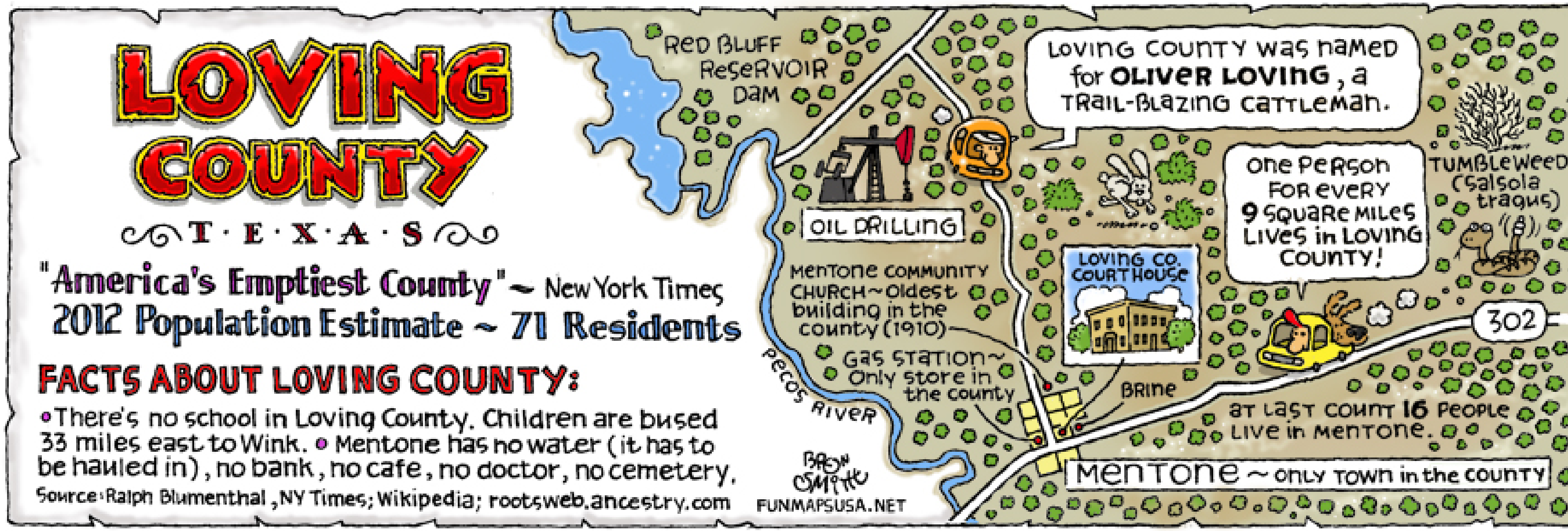
Currently 126 SMEs

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
RED BLUFF RESERVOIR DAM
OIL DRILLING
MENTONE COMMUNITY CHURCH ~ Oldest building in the county (1910)
GAS STATION ~ Only store in the county
PECOS RIVER
FUNMAPSUSA.NET
LOVING COUNTY was named for OLIVER LOVING, a TRAIL-BLAZING CATTLEMAN.
LOVING CO. COURTHOUSE
BRINE
ONE PERSON FOR EVERY 9 SQUARE MILES LIVES IN LOVING COUNTY!
TUMBLEWEED (Salsola tragus)
302
AT LAST COUNT 16 PEOPLE LIVE IN MENTONE.
MENTONE ~ ONLY TOWN IN THE COUNTY


MENTONE

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

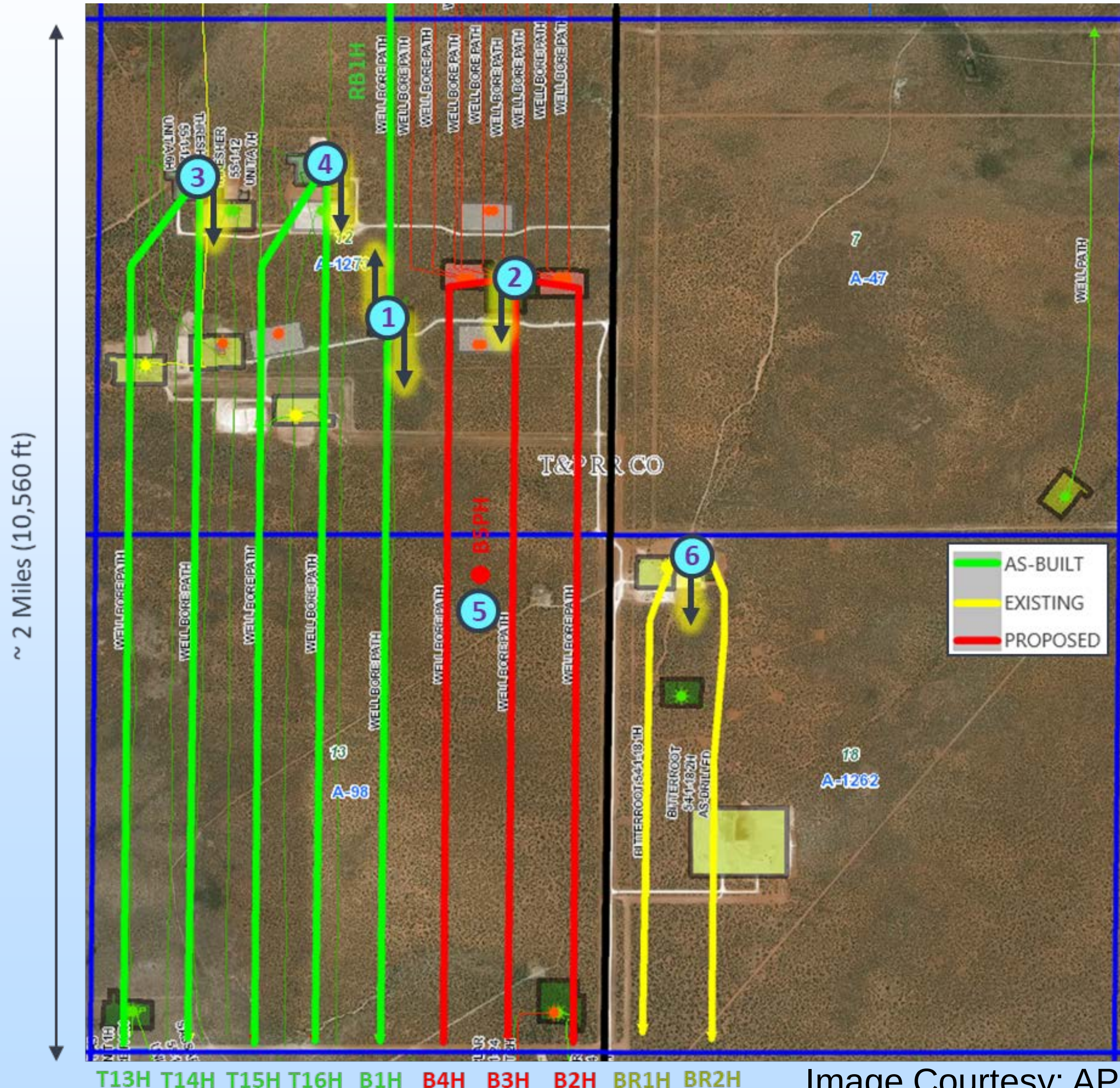
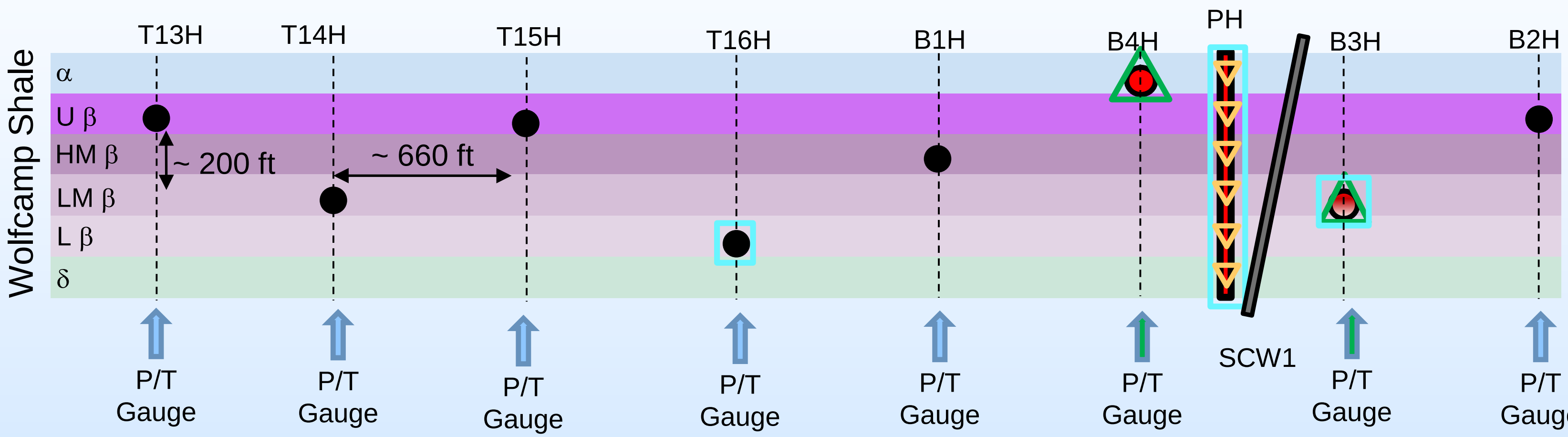


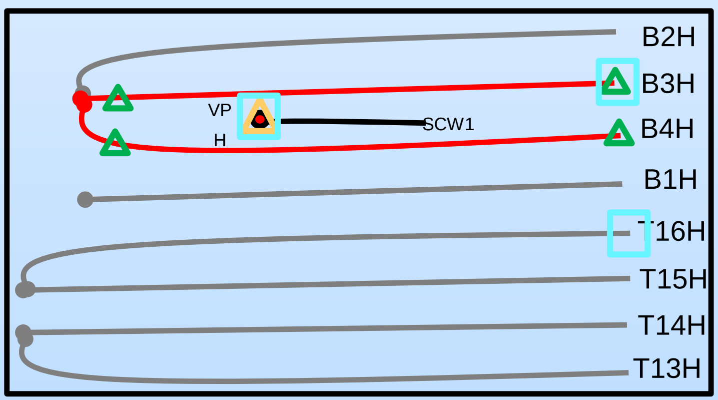
Image Courtesy: APC

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

FO Applications - GTI HFTS#2	
Installation	Ops Monitoring
	Cementing Ops & Curing
	Geothermal
Stimulation	Microseismic
	Cross-Well Stimulation Monitoring
	Stimulation Monitoring
	Stimulation Warmback
Post-Stimulation & Production	Qualitative Production Monitoring *2
	Flowing Pressure
	Lift Monitoring - TBD
	Pressure / Production Interference - TBD

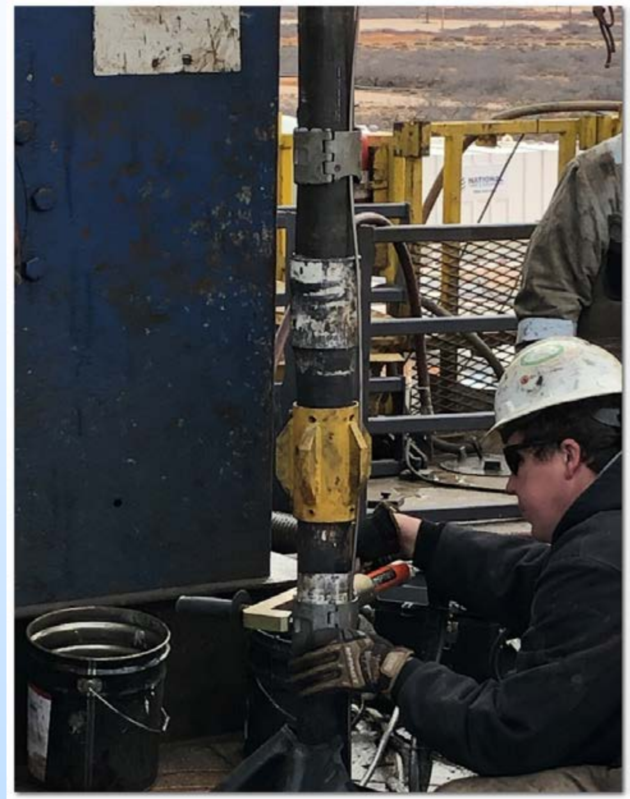
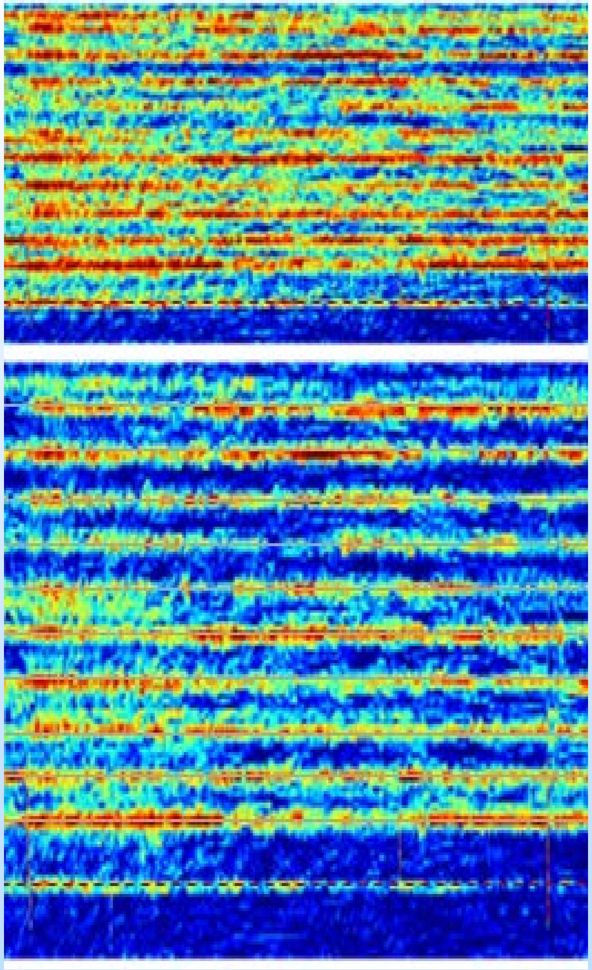


Image courtesy of Shell, Anadarko

Testing of Various Completions

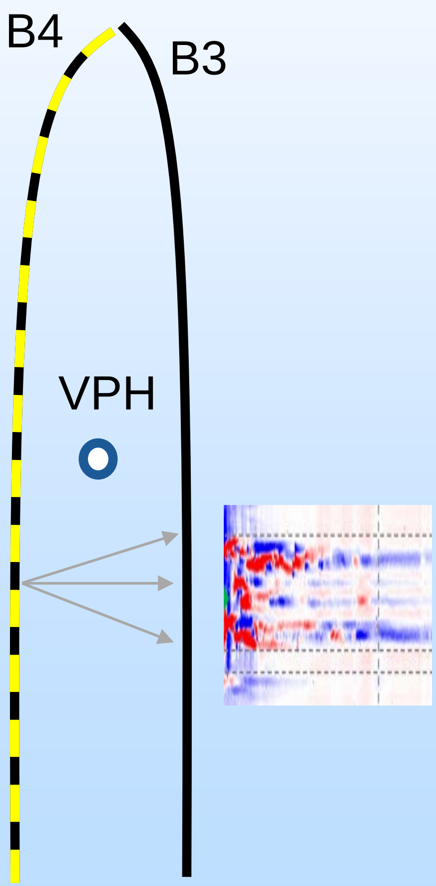
- Base design
- Aggressive Limited Entry (ALE)
- ALE with tapered perforations
- Extreme Limited Entry (ELE)
- Extended Stage Length (ESL) with ALE
- ESL with tapered perforations and ALE
- Tight clusters with normal stage length
- Tight clusters with shorter stage length
- Single entry to calibrate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

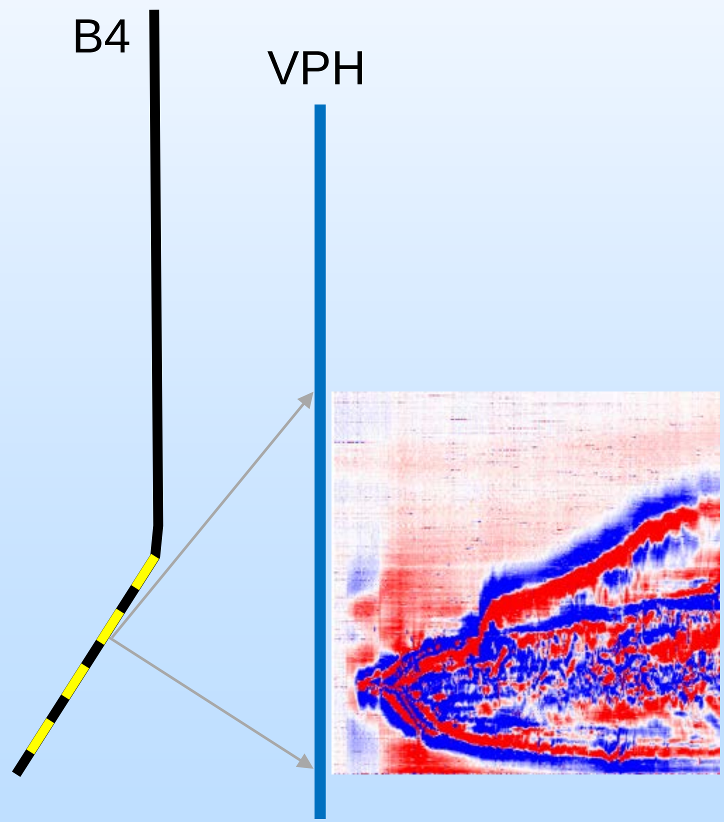
FO DAS Response



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

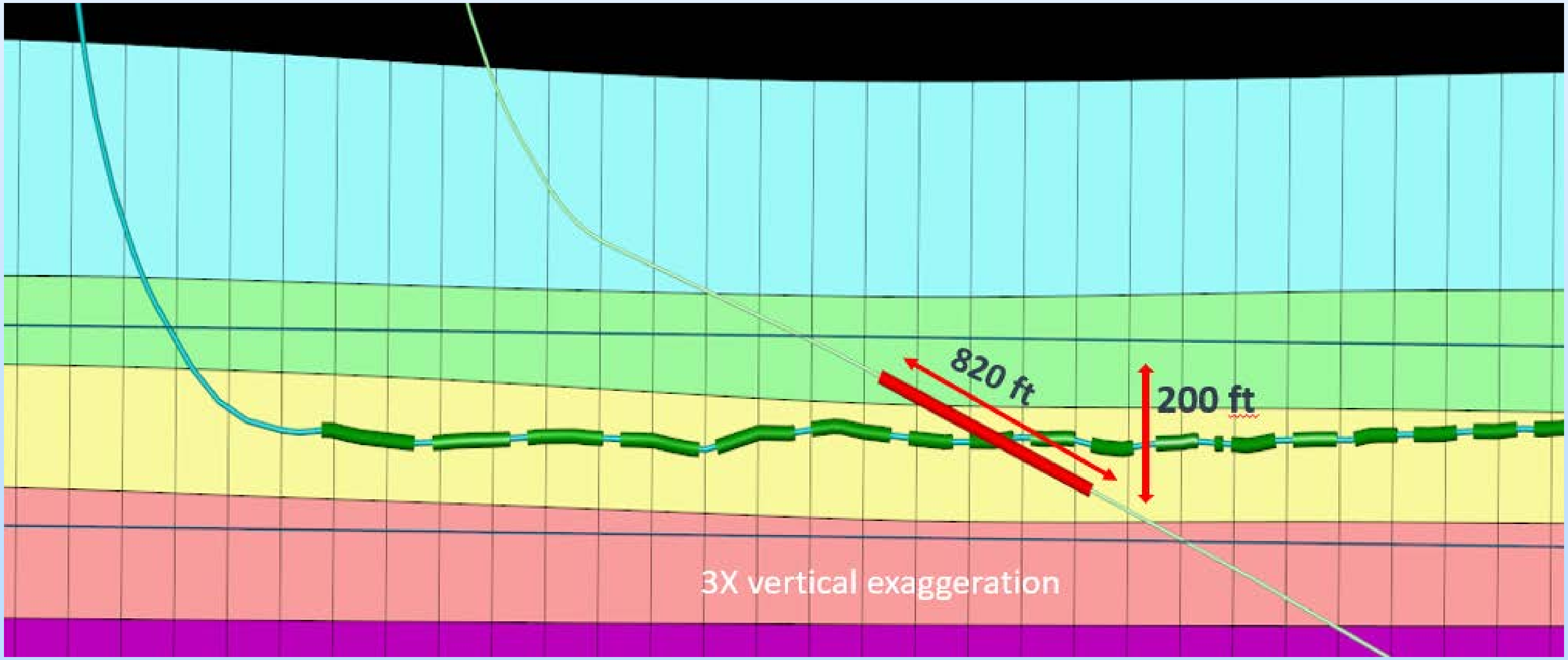


Image courtesy APC

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

Thanks to Department of Energy (DOE), National Energy Technology Laboratory (NETL), Anadarko and Shell, and all of the HFTSII Sponsors. Also thanks to Gary Covatch - NETL, Robert Anderson - APC, Jennifer Gujral – Shell , and Kent Perry – GTI, for all of their work on the project.

Site Host

Appendix

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

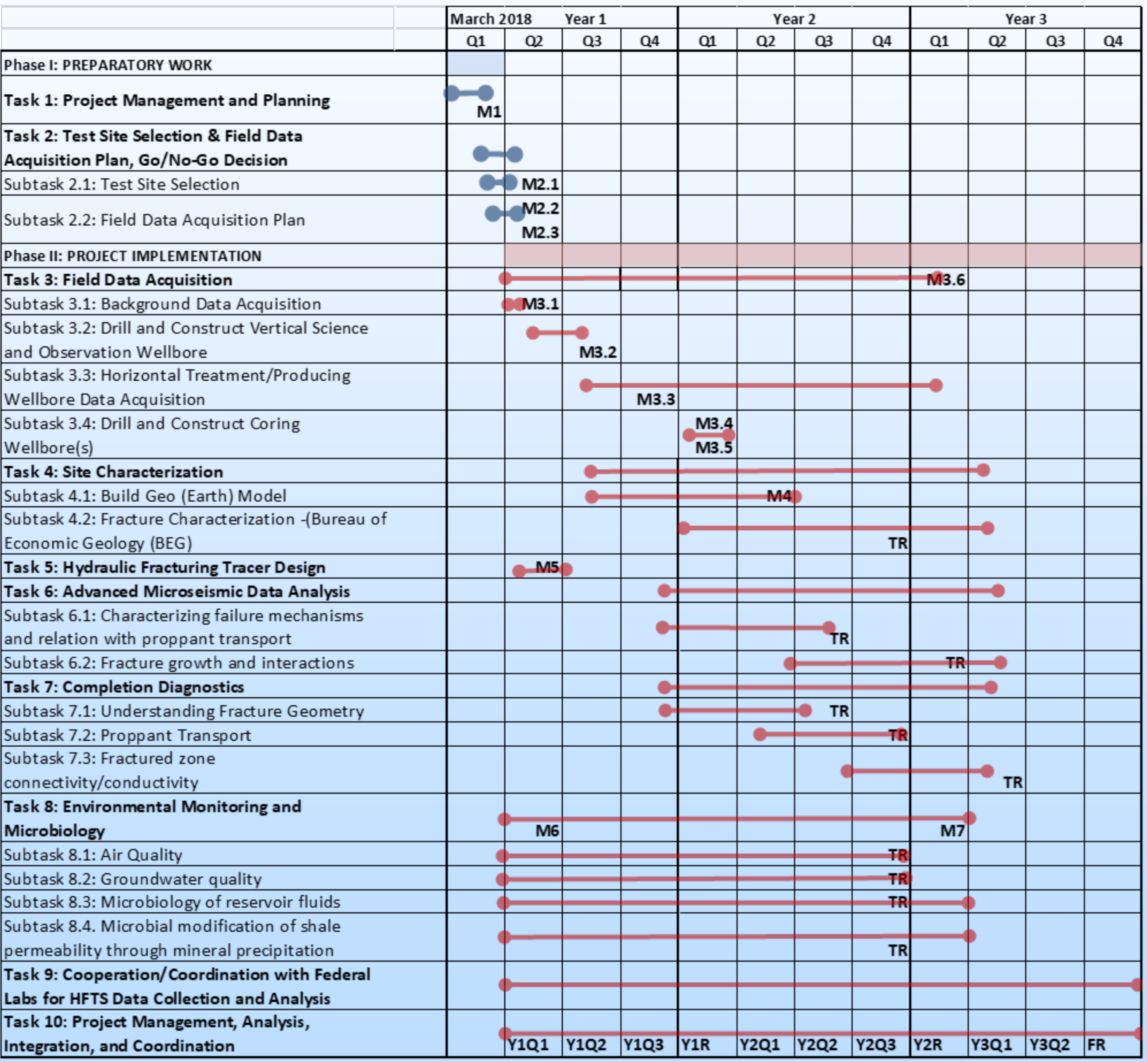
Benefit to the Program

- 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



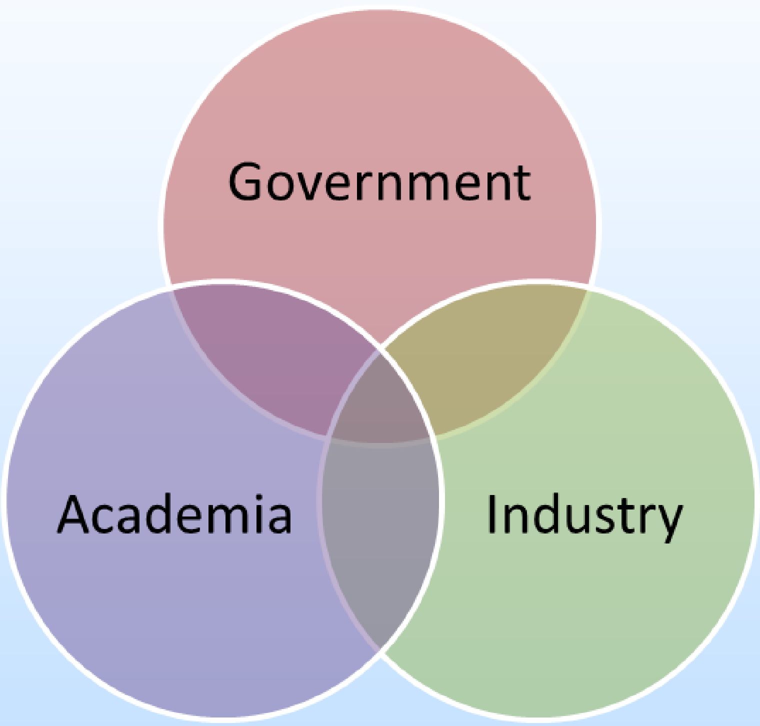
Critical Path Milestones
Milestone 1 - Project Management Plan Approval
Milestone 2.1 - Secured Test Site
Milestone 2.2 - Approved Field Testing Program and a "GO"
Milestone 2.3 - Approved Data Management Plan
Milestone 3.1 - Acquire background data
Milestone 3.2 - Drill vertical observation well
Milestone 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	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

Bibliography

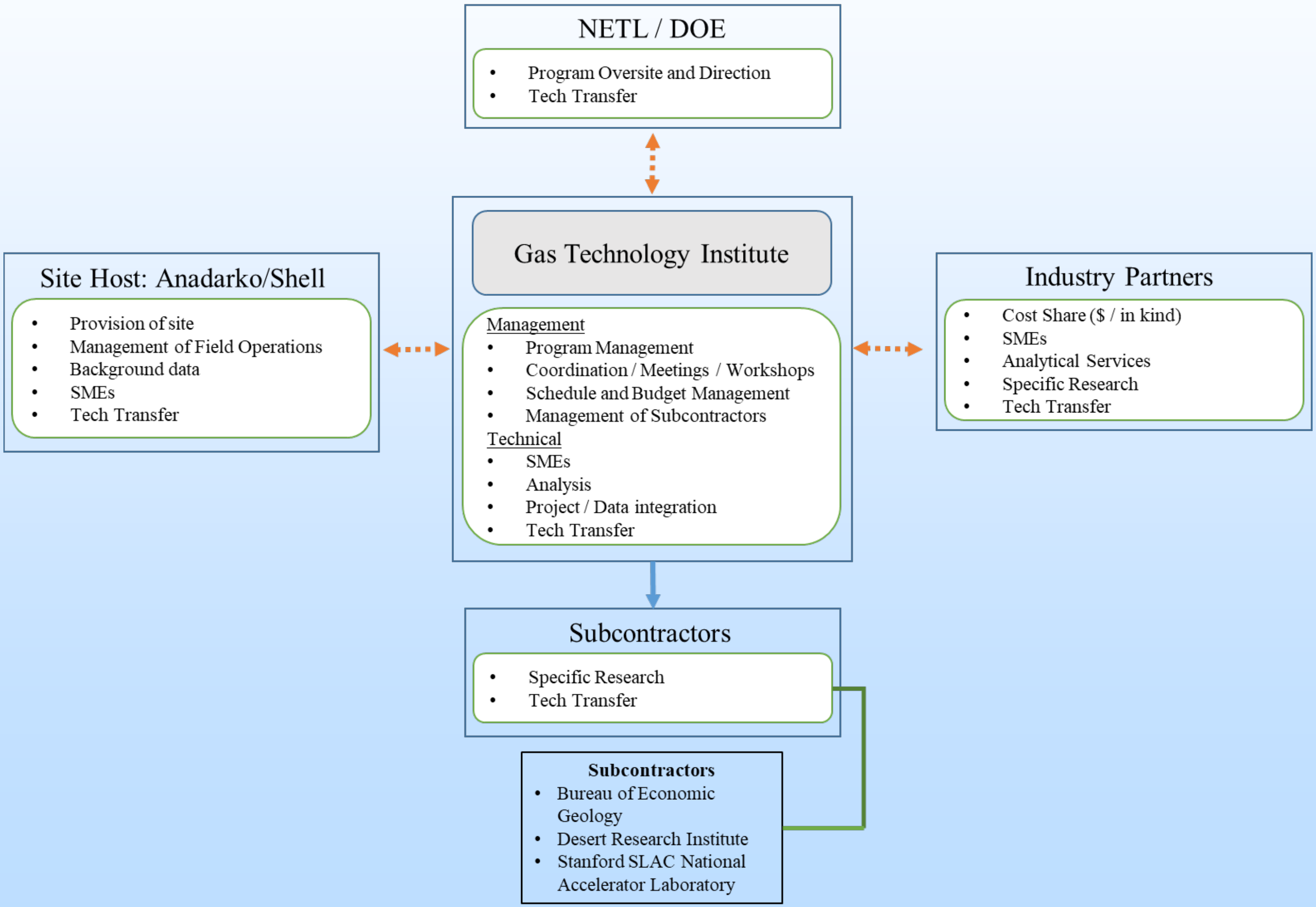
- None

Public Private Partnership

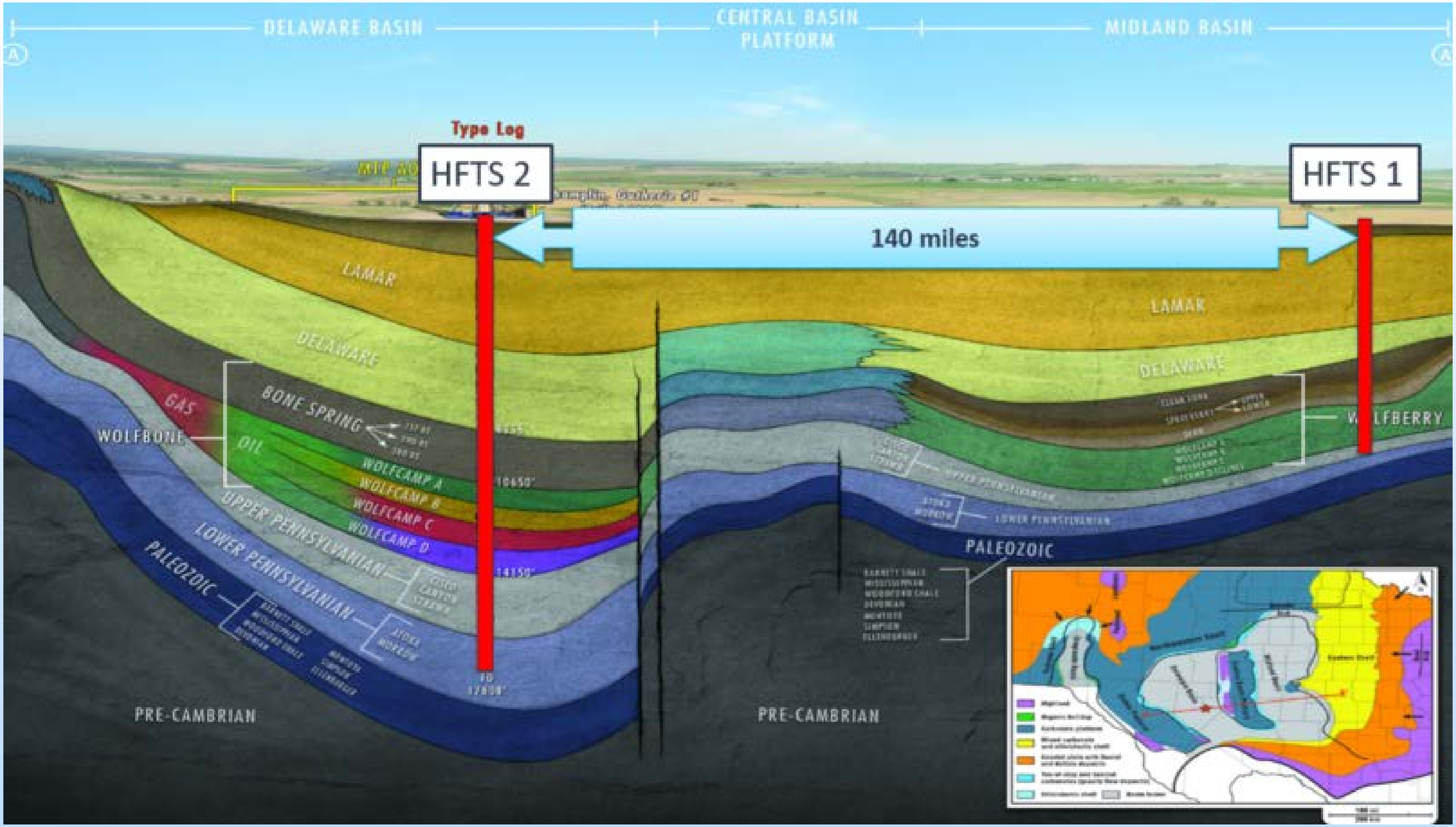


- Leveraged investment in a dedicated, controlled field experiment
  - Access to producing and science wells explicitly designed for hydraulic fracturing diagnostics, environmental monitoring, data collection and technology testing
  - Use of multiple near-well and far-field diagnostics and verification 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

Organization Chart



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