Collab Task 4: Stimulation in Stress Condition 1 (Experiment 1)

Project Officer: Lauren Boyd

Total Project Funding: PY 1 $9M, PY 2 $10.7M

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Sandia National Laboratories

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Relevance to Industry Needs and GTO Objectives

Objectives:

- Perform and monitor the multistage stimulation experiments based on pre-test computations
- Interpret the collected data, including by joint inversion, to understand the active processes and resulting features of the test(s)
- Conduct model validation studies for fracturing and stimulation

Impact:

- Comparison of post-test modeling using laboratory studies and field characterization to field tests quantified by field geophysical monitoring should allow us to validate and improve current predictive stimulation models.
- This approach provides us with an opportunity to better understand what level of detail of rock heterogeneities and what key processes/physics are needed for meso-scale hydraulic fracturing models.
- Furthermore, detailed analysis of the monitoring data will quantify the value of various geophysical methods in monitoring for and imaging of fractures.

Relevance to Industry Needs and GTO Objectives

Project Integration:

Pre-test modeling

- Pre-test simulations performed in Tasks 2 and 3 will be used to finalize the experimental design and monitoring plans, and provide opportunity for subsequent code validation. (previous presentations)
- Resultant fracture will be characterized during the flow tests in Task 5. (next presentation)

Post-test modeling

- Post-test modeling will be performed using new mechanical properties from laboratory tests, new *in situ* stress measurements, stimulation parameters, and interval deformation data monitored with the SIMFIP probe.
- Simulated fracturing model results will be compared to the stimulation process and to the interpreted and inverted spatial-temporal distributions of the microseismic events and their statistics.

Methods/Approach – Combined Stimulation & Flow System

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- Parallel pump options
  - Parameters determined through predictive modeling
- Centralized Data Acquisition w/ NPT (internal clock sync), PPS (timing signal), and Dual Recordings (accurate relative timing)
- Single system allows for streamlined ES&H documentation & pressure evaluation

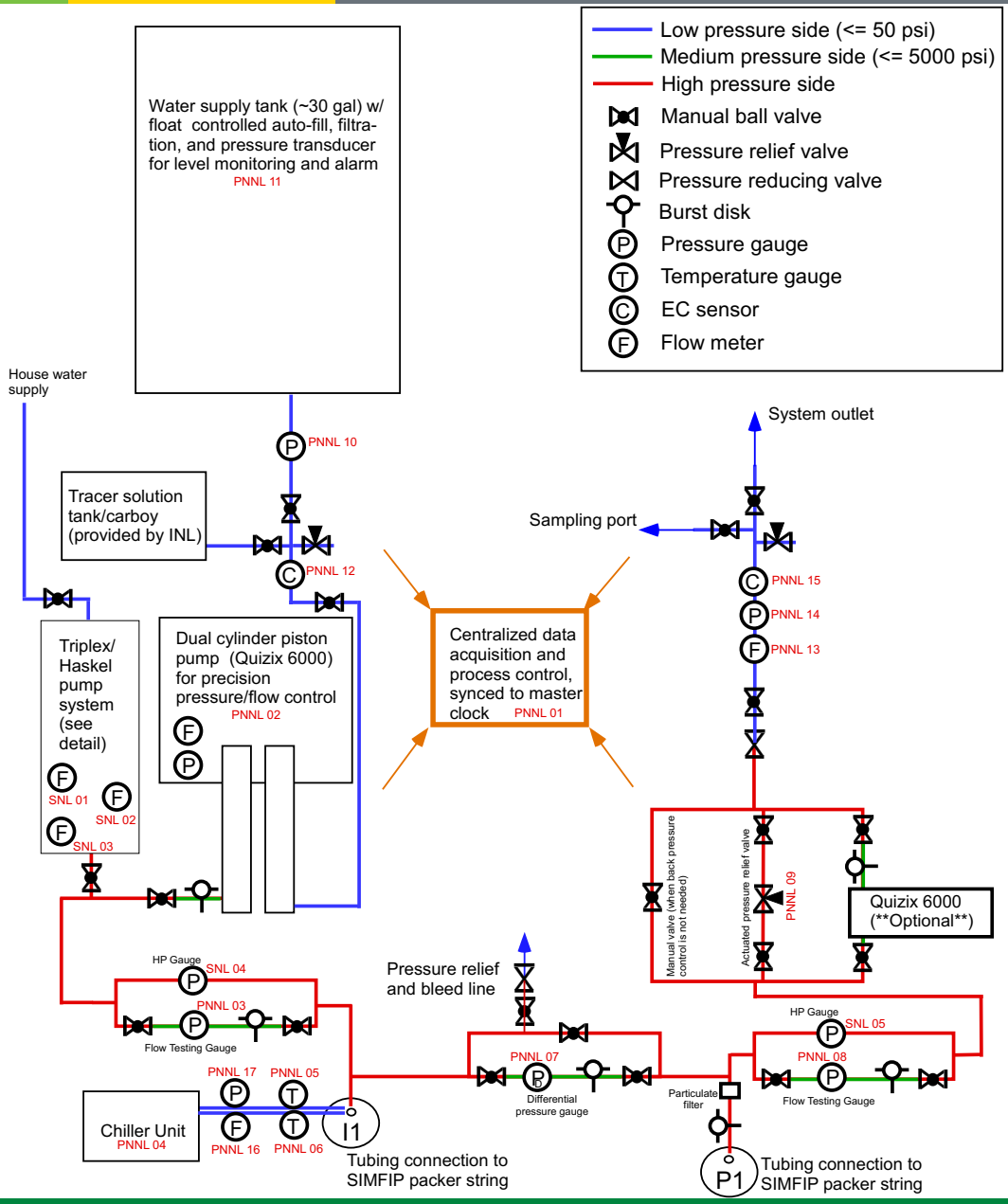

Figure by: V. Vermeul, C. Strickland, & C. Herrick

Methods/Approach – SIMFIP Tool

Measurement of near wellbore fracture properties in both stimulation and production wells.

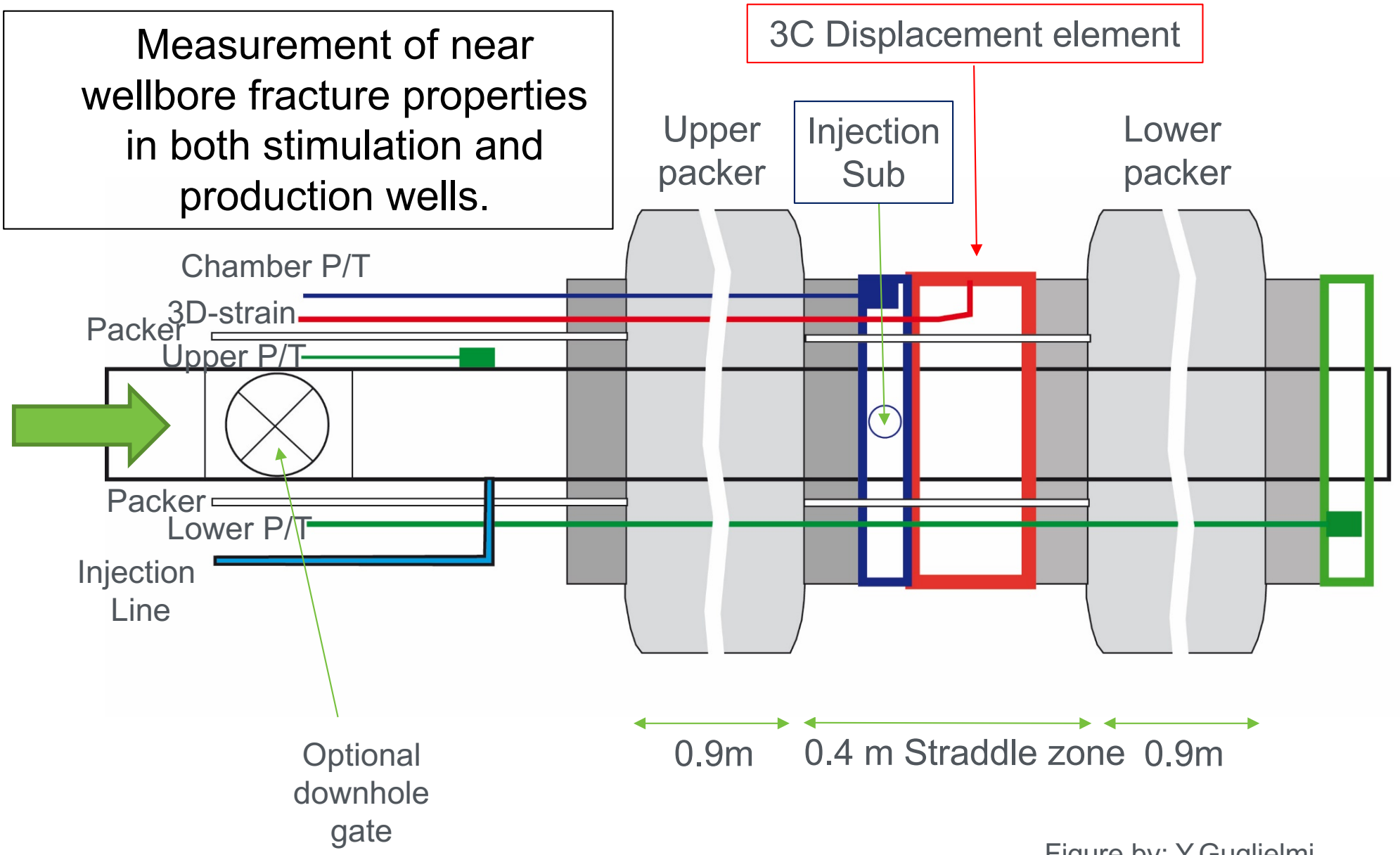

Figure by: Y.Guglielmi

Methods/Approach – Monitoring System

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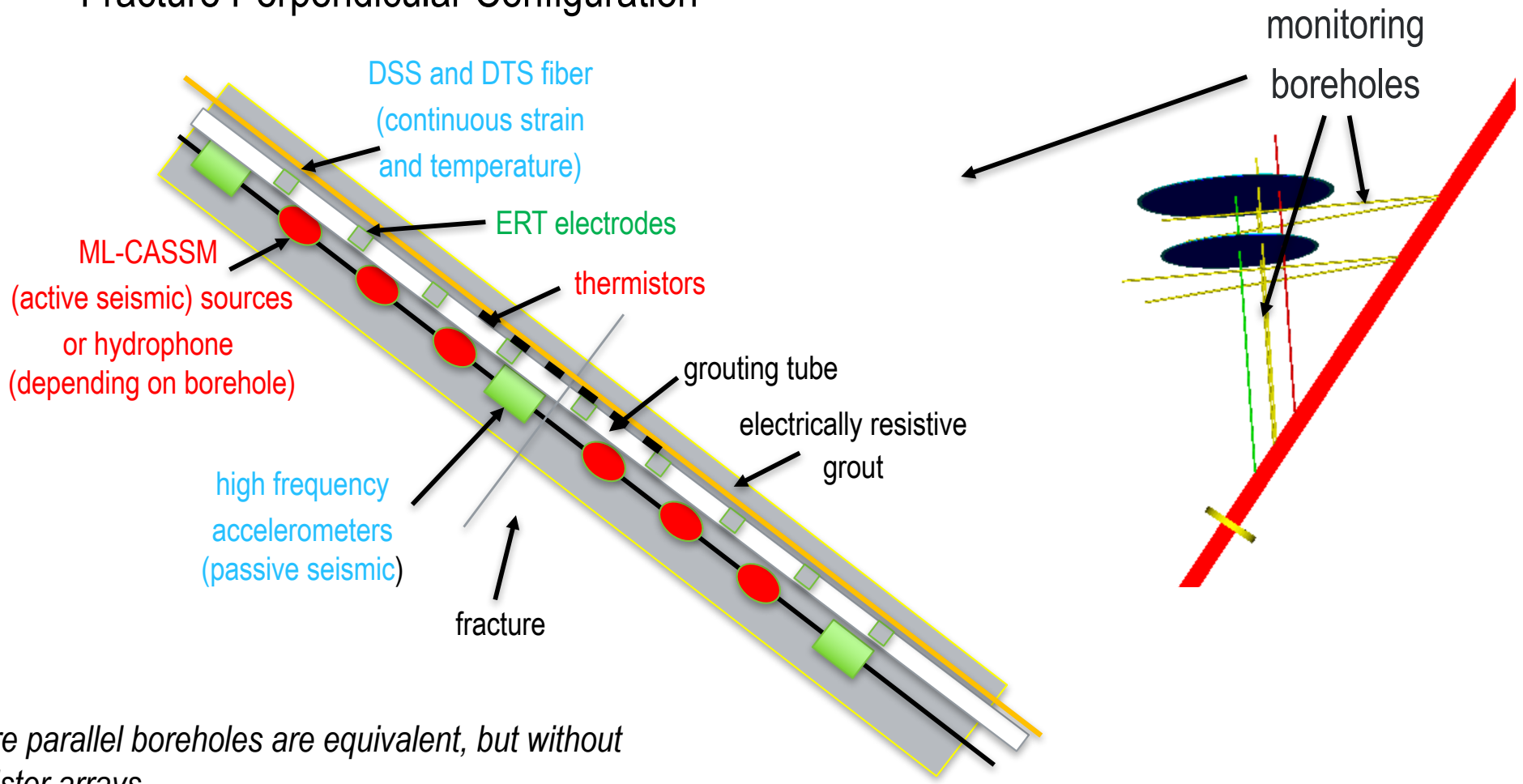
Downhole Monitoring System: Monitoring Fracture Growth, Imaging Fracture Extent, and Providing Ground Truth

Fracture Perpendicular Configuration



fracture parallel boreholes are equivalent, but without thermistor arrays

Figure by: J. Ajo-Franklin & T. Johnson

Methods/Approach – Predictive Modeling

In-situ stress changes caused by cooling contraction in the drift

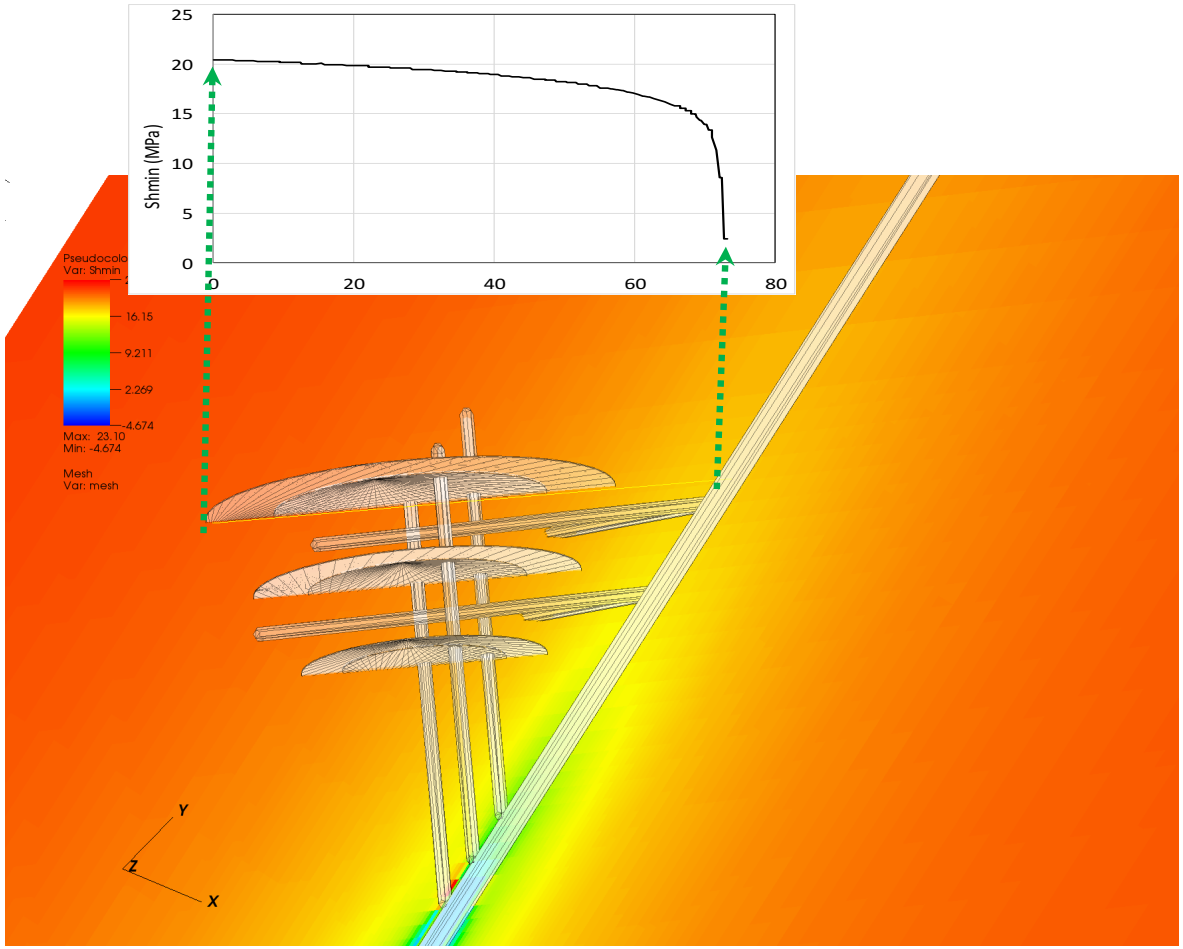


Figure by: P. Fu

- Modeling of break-down pressure led to notching recommendation
- Evaluation of Sh_{min} and resultant fracture shape informed monitoring design for the stimulation
- Evaluation of thermal effects of changes in stress help define the stimulation design

Technical Accomplishments and Progress

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Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Lead Task 4 (Stimulation Test - Permeability Enhancement Execution and Characterization (EGS Experiment 1). (Due 3/31/2017)	Accomplished Original	March 7, 2017
Prepare Task 4 workplan, coordinated, and compiled from contributions from labs and universities. (Due 5/31/2017)	Accomplished Original	May 31, 2017
Recommend the stimulation equipment and instrumentation, which will be heavily leveraged for the flow experiment. Integrate the SIMFIP tool into the production and injection well packer systems. (Due 9/30/2017)	Accomplished Original	September 1, 2017
Design and construct one new SIMFIP tool specifically for the project, and test in laboratory	In Progress	December 31, 2017

Technical Accomplishments and Progress
Borehole Notching

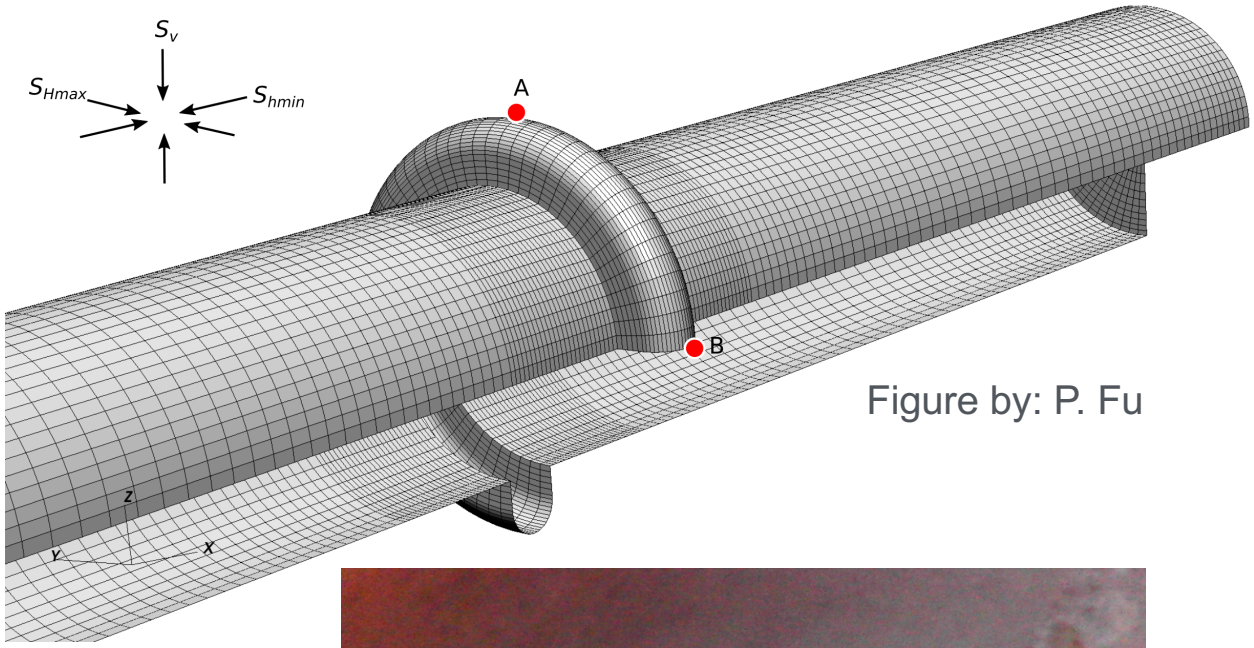


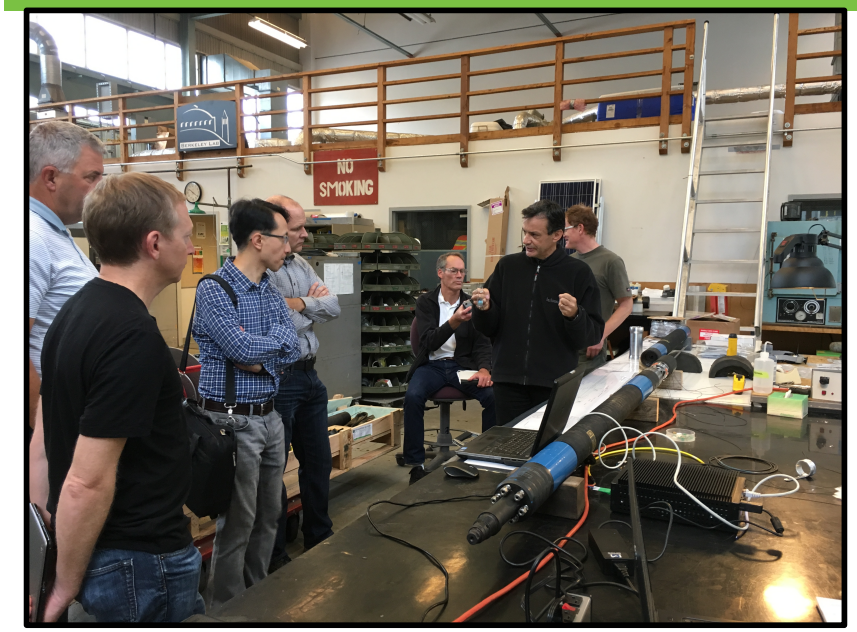
Figure by: P. Fu

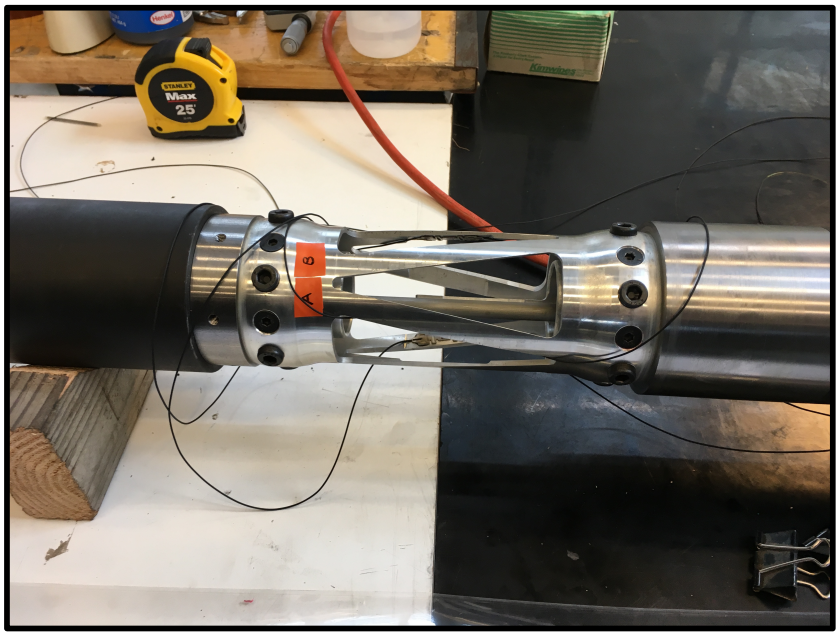
Figure by: J. Su

Without a notch an axial fracture was imminent.

- Tool:
  - Prototype was built rapidly
  - Geometry of resultant notch was reported to modelers
- Modeling:
  - Realistic notch in a borehole was meshed
  - Stress concentrations were computed and summarized
  - Design equations were derived

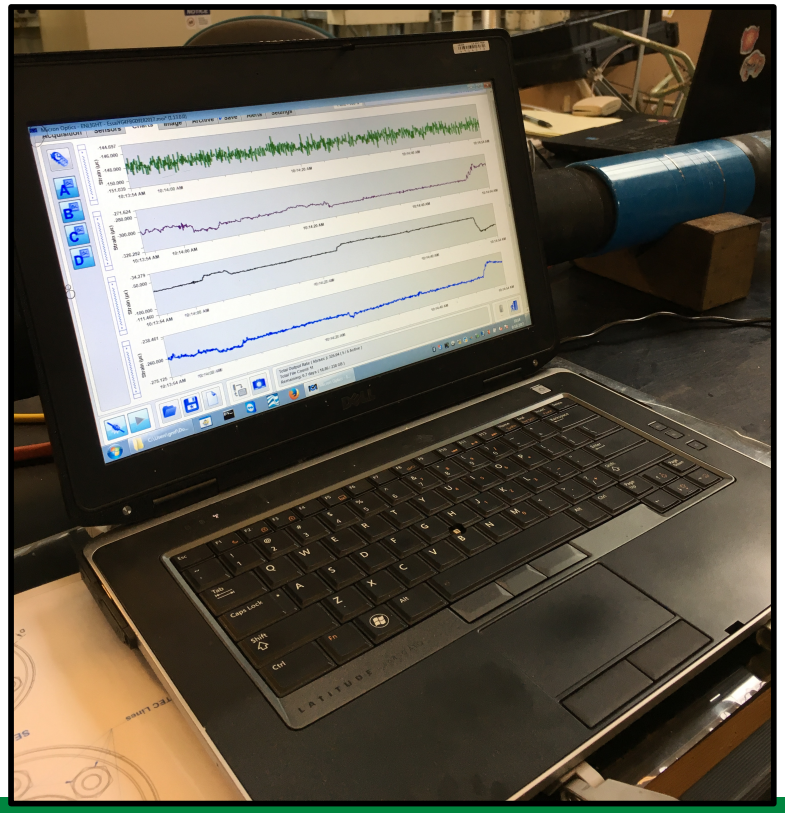
Technical Accomplishments and Progress
SIMFIP "Redesign"





SIMFIP Redesign:

- Incorporation of the tool into packer system
- Additional Straddle Packer Controls
- Multi-phenomenological Measurements



Technical Accomplishments and Progress Shakedown Test for Stimulation & Flow

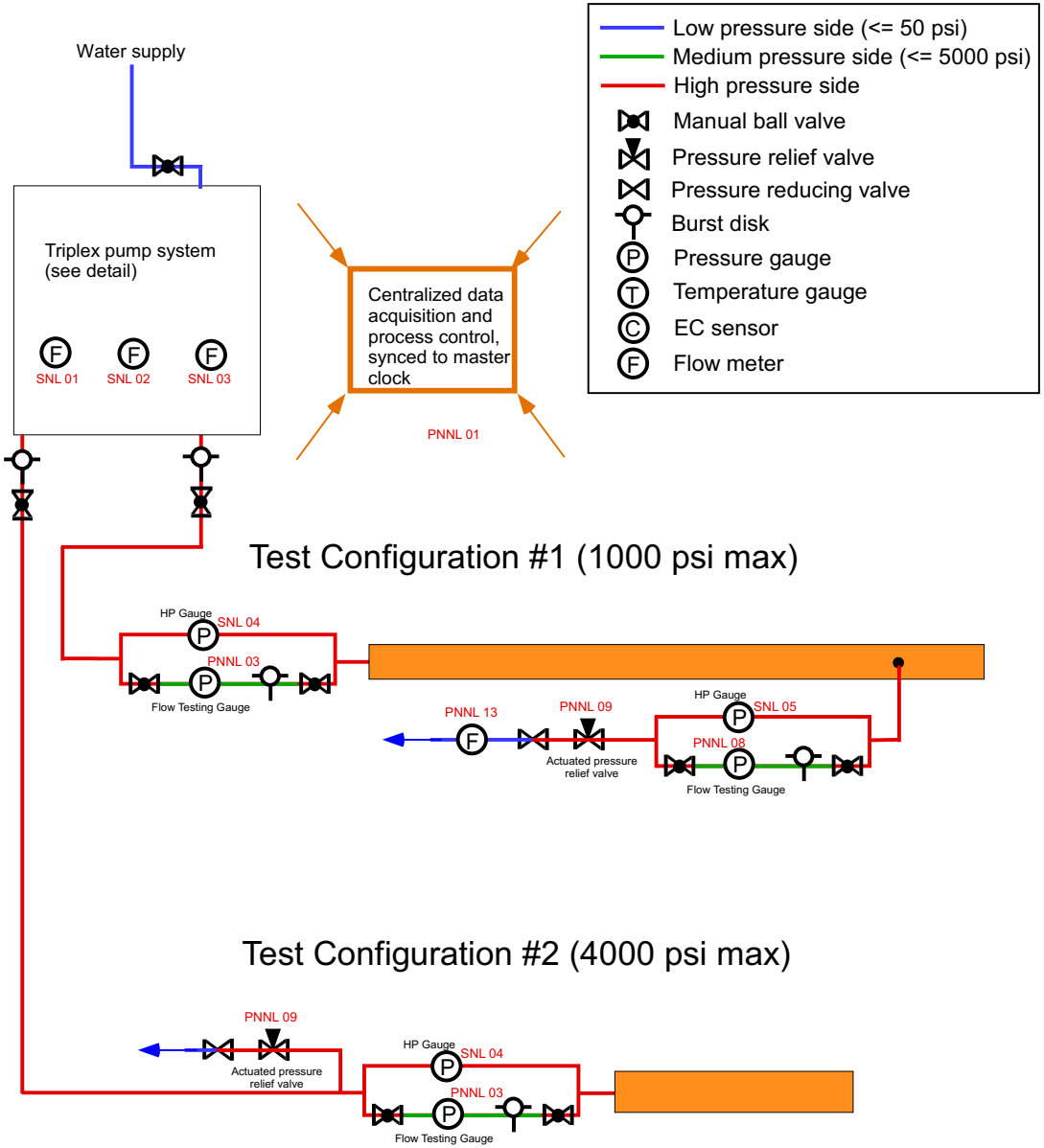


Figure by: V. Vermeul, C. Strickland, & C. Herrick

Design Questions:

- How long does it take to convey the packer? Does it all fit?
- Can we hook up the “whole” system?
- Can we pressurize the system to 1000 psi? How about 4000 psi?
- Can we flow the system?
- Data about packer inflation and interval pressurization for SIMFIP? What do the pressure test steps look like?
- Can we record flow, pressure, and SIMFIP simultaneously? (Relative timing test using Courtney’s system)
  - Chris pulls in Pressure (downhole & packer) and Courtney’s gauges
- Grout Coverage
- Triplex flow test (what kind of fluctuations will we get and how well can we control the pump.
- Convey Geophysical Tools

Research Collaboration and Technology Transfer

- Collaborations are being developed between University of Wisconsin, South Dakota School of Mines, University of Oklahoma, Stanford University, Golder Associates, McClure Geomechanics for stress measurements and fracturing advice relevant to Collab.
- Technology transfer is most immediately relevant to FORGE
- Learnings will influence fracture designs applicable to EGS in the future

Immediate Future Directions

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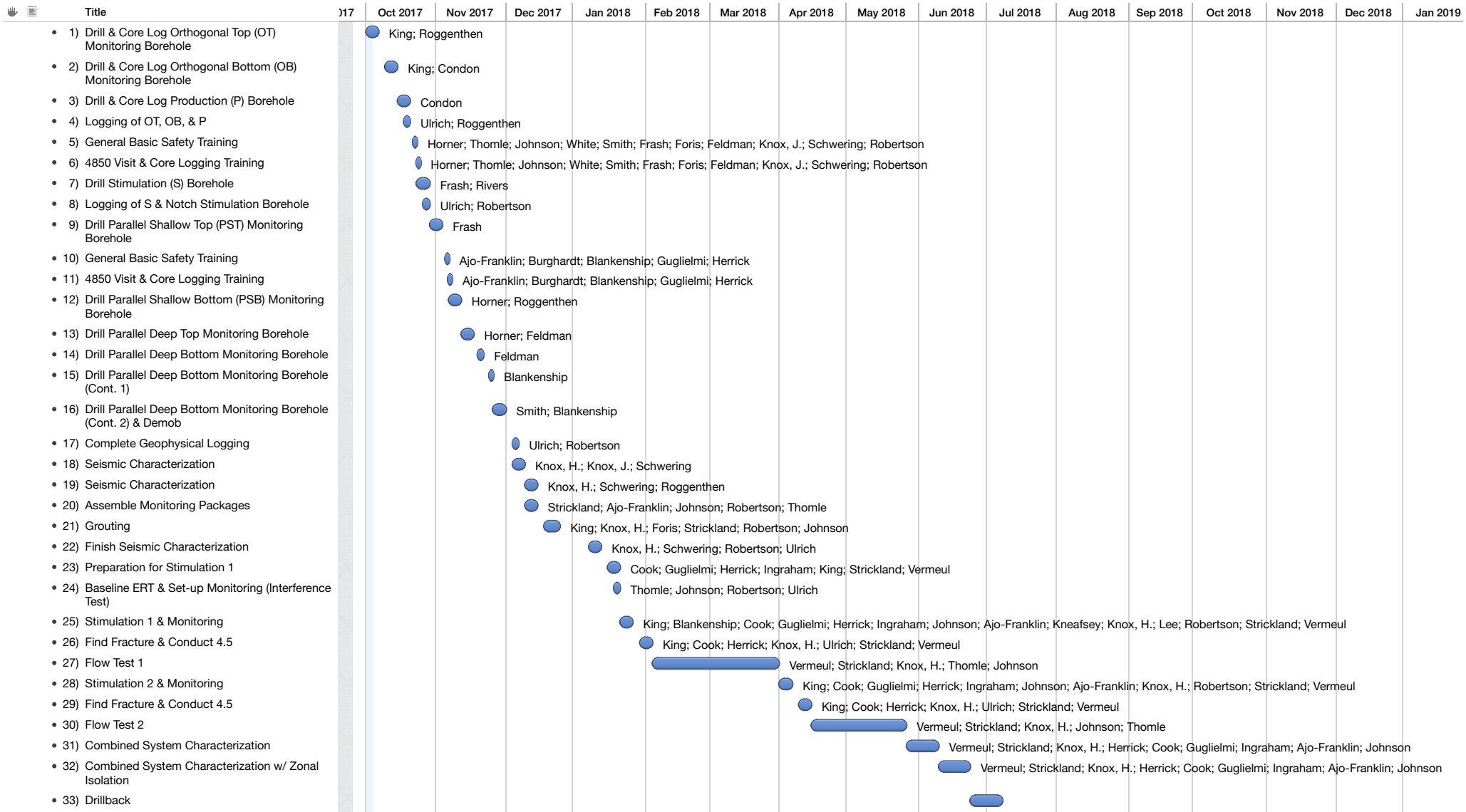
Finish Experiment 1!



Future Directions

Milestone or Go/No-Go	Status & Expected Completion Date
Organize and execute a multi-lab shakedown test of the stimulation and shared flow test equipment before it is mobilized to SURF. Test the pump connections, packer assemblies and the incorporation and integrity of the SIMFIP tool. System test pressures will be conducted up to 4000 psi. The test will also evaluate conveyance of the instrumented packer stings, which will aid in the development of the assembly and test protocol to be used at SURF. (Due 3/31/2018)	In Progress (12/1/2017)
Perform first stimulation at Experiment 1 site (Due 6/30/2018)	In Progress (6/30/2018)
Assist in setup for the flow tests through the first fracture at Experiment 1 site (Due 6/30/2018)	In Progress (6/30/2018)
Assist in performing the flow tests through the first fracture at Experiment 1 site (Due 9/30/2018)	In Progress (9/30/2018)

Mandatory Summary Slide

- Borehole notching tool, which was an unanticipated experiment requirement, is rapidly being developed and tested.
- Collab team has successful built a monitoring design that capitalizes on co-located multi-phenomenological measurements.
- Through close coordination, we have designed and built a single stimulation and flow system. This has an added benefit of leveraging ES&H across the labs.
- SIMFIP re-design is on track and should allow for state-of-the-art displacement measurements associated with the stimulation and flow tests.
- Modeling has been used to guide the design of the stimulation system, the borehole emplacement, the fracturing design, and the monitoring system.
- All of the tasks came together for a successful experiment review in September
- A shakedown test has been planned to vet the equipment before execution of Experiment 1 at SURF.