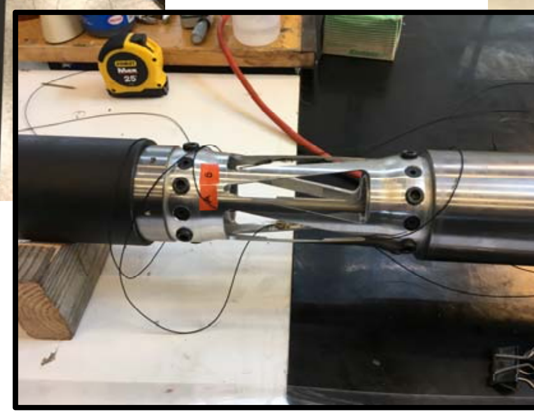
COLLAB
A PATH TO FORGE
U.S. DEPARTMENT OF ENERGY



Collab Task 5: Flow Test Characterization and Drillback (Experiment 1)

Project Officer: Lauren Boyd

November 13, 2017

Task 5 PI: Tim Johnson

EGS Collab

Relevance to Industry Needs and GTO Objectives

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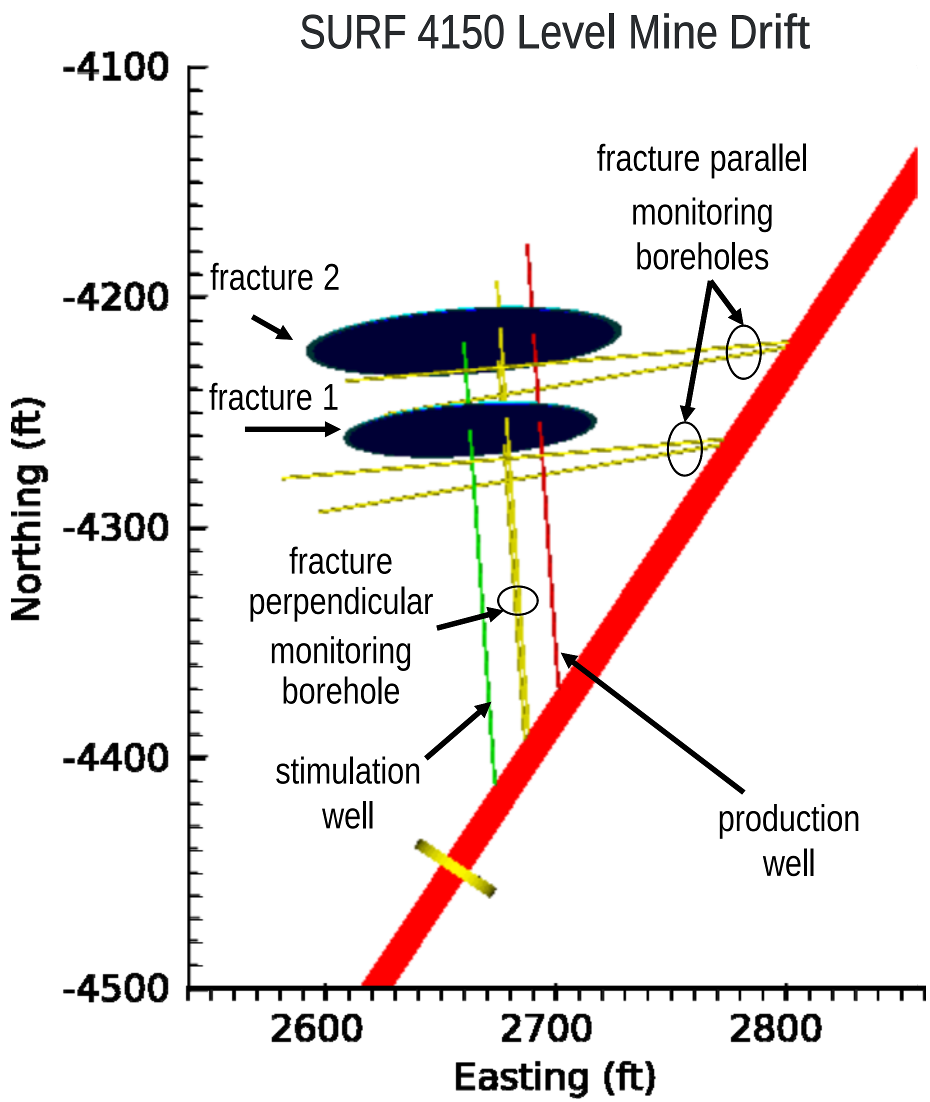
Objective: Provide high resolution THMC-G data sets for EGS model calibration and validation

Goals:

- quantify fracture network spatial heterogeneity
- constrain flow and heat transfer performance
- understand fracture stress-permeability response
- understand geophysical signatures of fracture generation and flow
- provide insight into coupled processes (i.e. cooling induced stress)

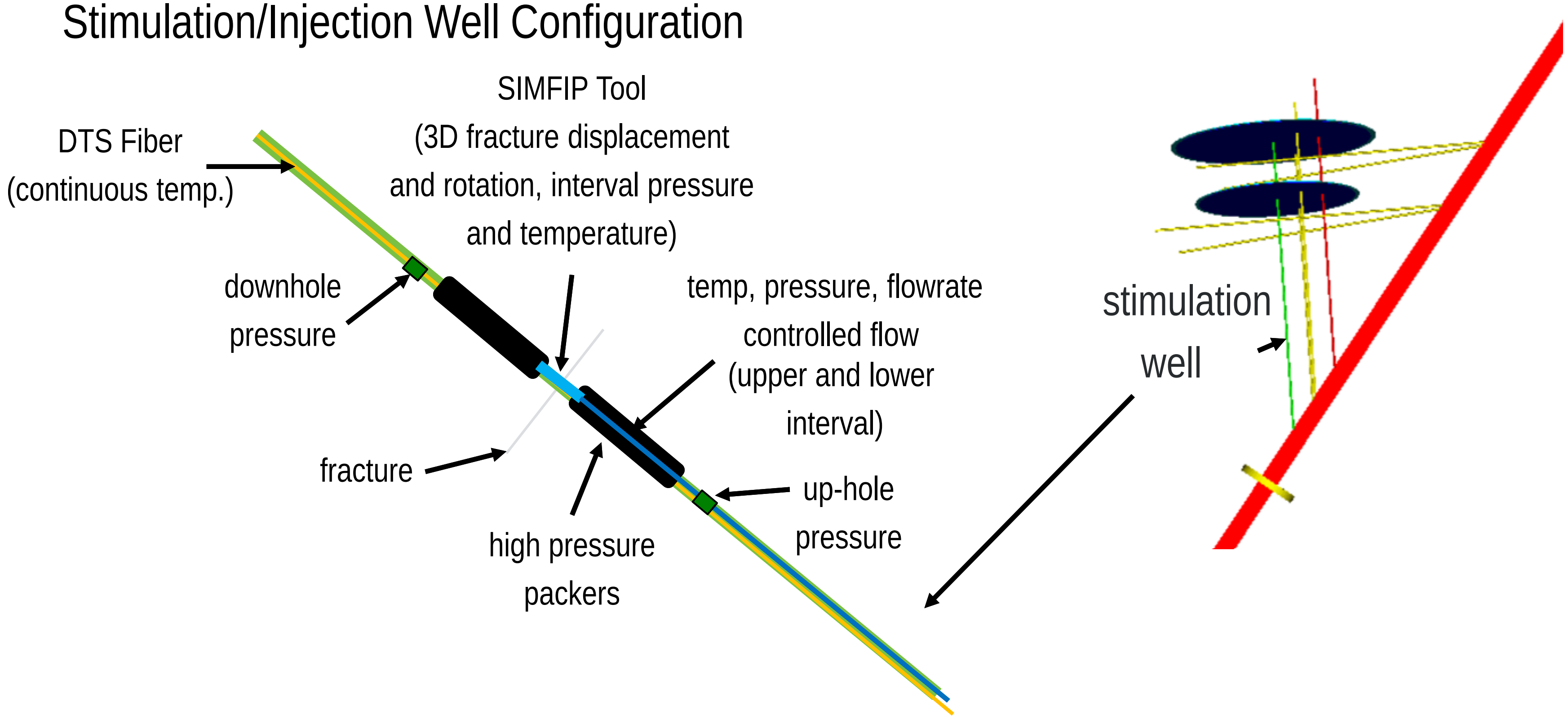
Achieved through a series of precisely controlled and comprehensively monitored flow tests, guided by model predictions, validated by post-test drill-back.

Stimulation and Flow Test
Downhole Monitoring
System Overview



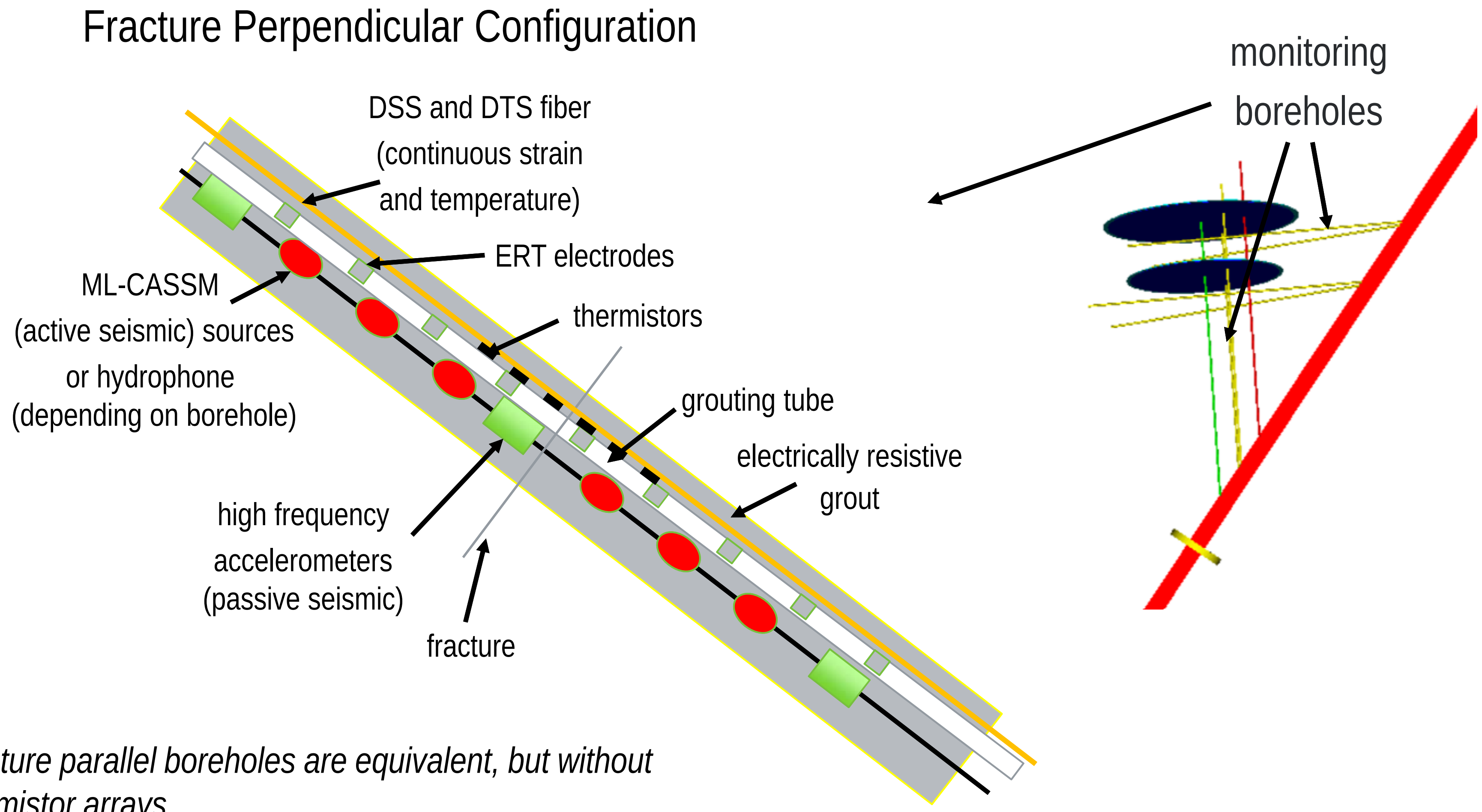
Downhole Monitoring System: Stimulation and Production Wells

Stimulation/Injection Well Configuration



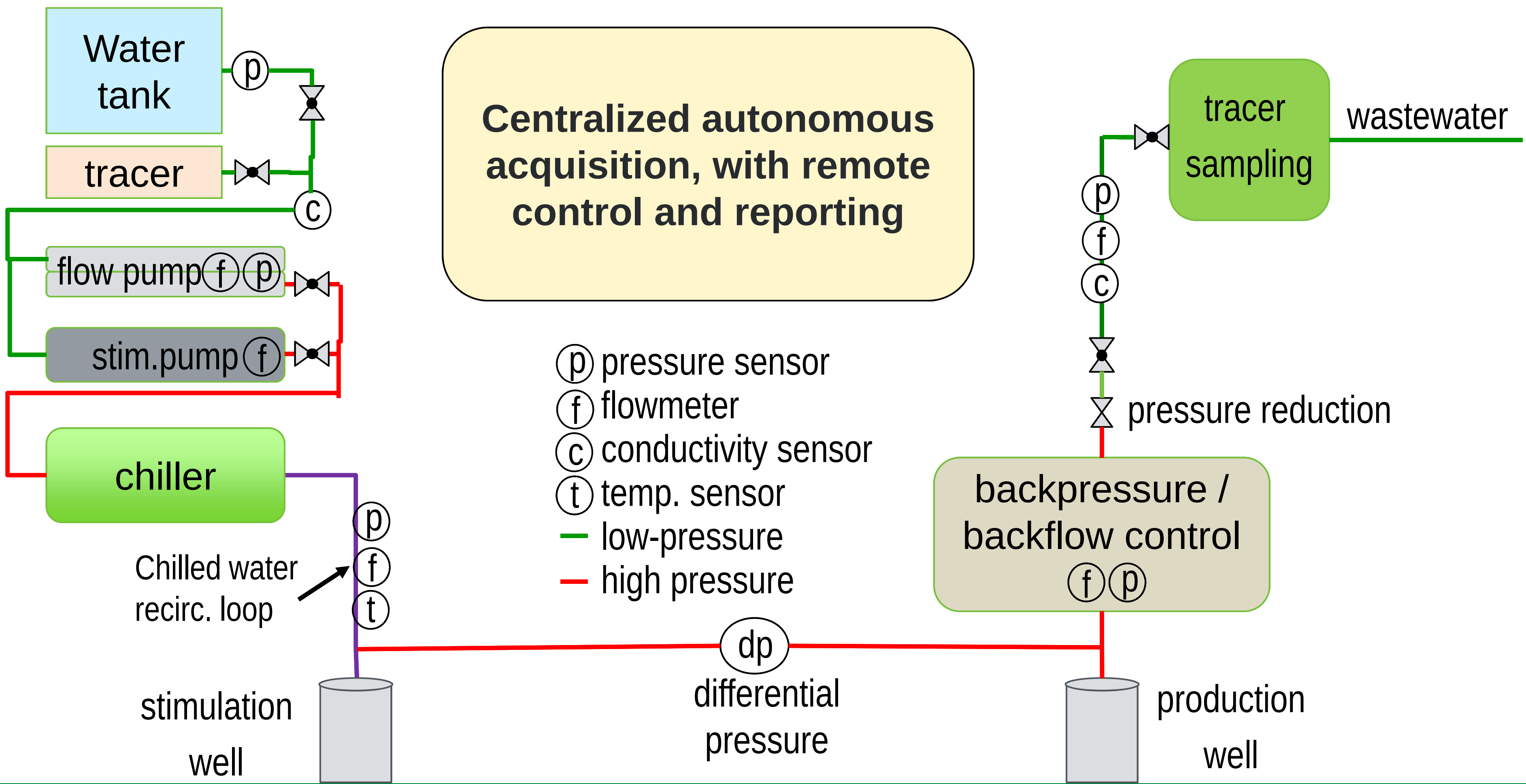
- *production well is equivalent, with backpressure and backflow control.*

Downhole Monitoring System: Monitoring Boreholes



- *fracture parallel boreholes are equivalent, but without thermistor arrays*

Inter-well Uphole Flow, Pressure, and Temperature Control System



Sequence of well controlled and comprehensively instrumented flow tests: each with a specific objective

1) Step rate flow/pressure test (task 5a)
2) Constant rate tracer flow test (task 5a)
3) Long-term heat transfer test (task 5a)
4) Geophysical tracer test (task 5a)

(Test 1-4 repeated for fracture 2, task 5b)

5) Dual fracture, inter-well flow test (tasks 5c and 5d)

Drillback Validation

1) Post-testing drillback validation (task 5e)

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Test 1: Step Rate Flow/Pressure/Extension Test

Objective

- Investigate the relationship between fracture stress, aperture, and permeability.
- Determine pressure limits for future tests.

Description

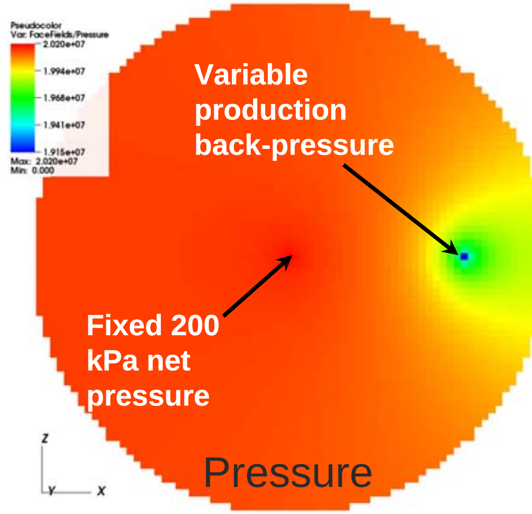
- Precise step modifications in injection well pressure and production well backpressure.

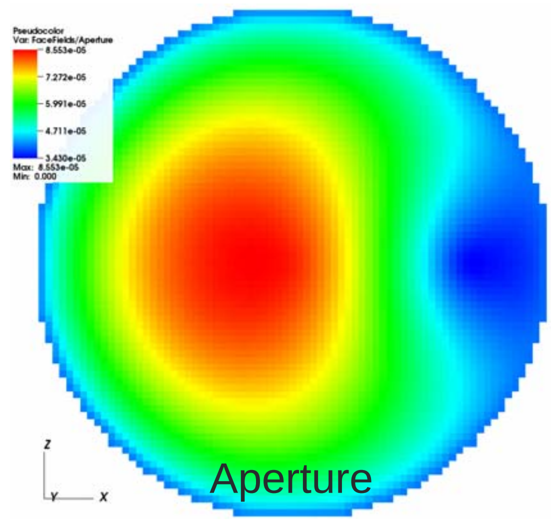
Data sets

- Injection and production well: pressure, flowrate, interval temp, distributed temp., aperture
- Monitoring wells: active & passive seismic, distributed fiber temp. and strain, point temp., ERT

Data Usage

- Validate hydro-mechanical models, constrain monitoring responses to aperture modulation





Courtesy Pencheng Fu, Randy Settgast, Joe Morris

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Test 2: Constant flow rate tracer test

Objective

– Investigate relationship between pressure/aperture, residence time and flow path

Description

– Constant pressure-flow tests with tracer tests (saline, fluorescent, DNA).

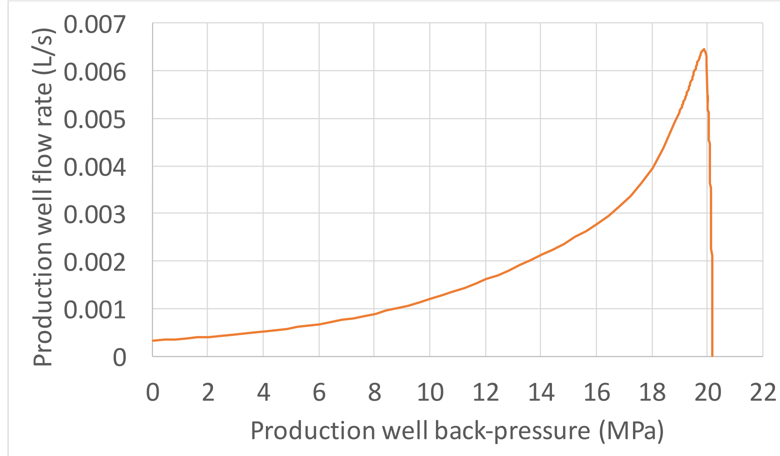
Data sets

– Inj./Prod. wells: pressure, flowrate, interval temp, distributed temp., aperture, tracer concentration

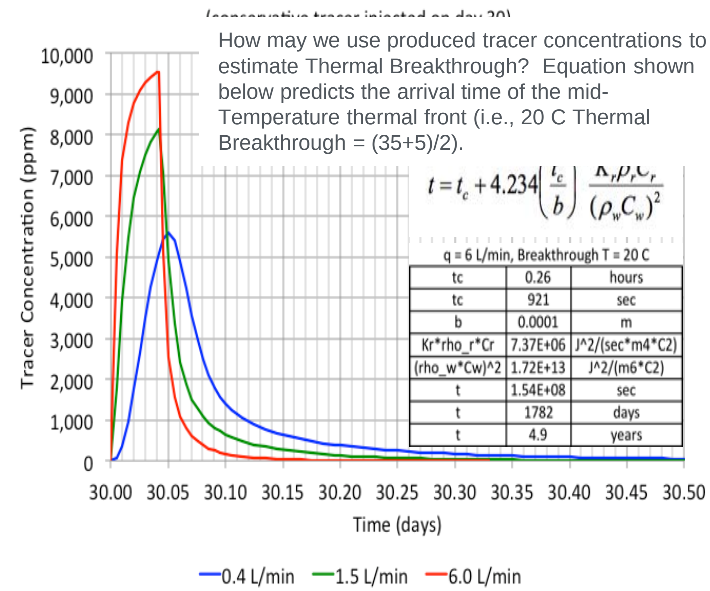
– Monitoring wells: active & passive seismic, distributed fiber temp. and strain, point temp., ERT

Data Usage

– Validate flow-path predictions, support heat transfer modeling, evaluate monitoring responses



Courtesy Pencheng Fu, Randy Settgast, and Joe Morris



tc	0.26	hours
tc	921	sec
b	0.0001	m
Kr*rho_r*Cr	7.37E+06	J^2/(sec*m4*C2)
(rho_w*Cw)^2	1.72E+13	J^2/(m6*C2)
t	1.54E+08	sec
t	1782	days
t	4.9	years

Bud Johnson, Phil Winterfield and Yu-Shu Wu

Test 3: Heat Transfer Flow Test

Objective

- Comprehensive heat transfer performance data: thermo-mechanical response, effects of cooling on stress, aperture and permeability

Description

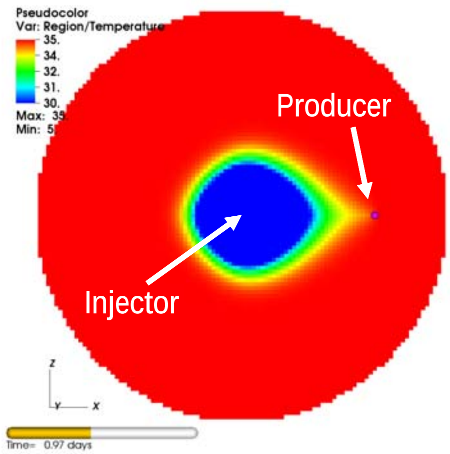
- Long term, constant rate, cold-water circulation test with tracers

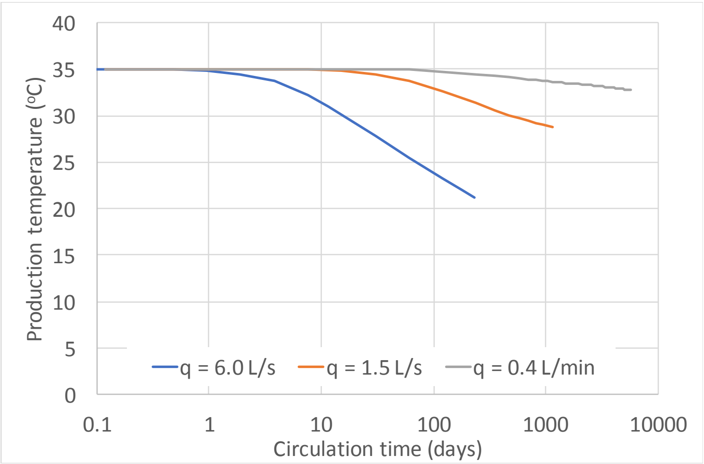
Data sets

- Injection and production well: pressure, flowrate, interval temp, distributed temp., aperture, tracer conc. at production
- Monitoring wells: Distributed temp. and strain, point temp., ERT, active seismic

Data Usage

- Validate THM-G model predictions. Validate monitoring capability predictions.





Courtesy Pencheng Fu and Joe Morris

Test 4: Geophysical Tracer Test

Objective

- Image fracture flow paths vs. stress/aperture

Description

- Saline/electrically anomalous fluid circulation + tracers

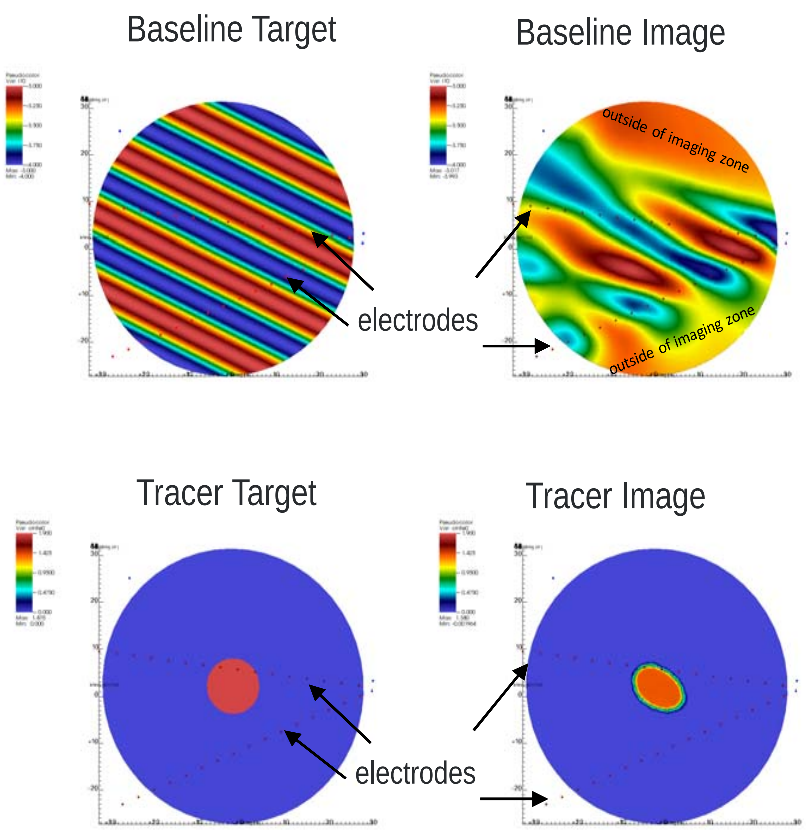
Data sets

- Injection and production wells: pressure, flowrate, interval temp, distributed temp., aperture, tracer conc. at production
- Monitoring wells: Time-lapse ERT, point and distributed temp. and strain.

Data Usage

- Validate residence time, flow path predictions. Validate monitoring capability predictions.

ERT Feasibility Modelling



Test 5: Combined and Zonal Isolation Flow Tests

Objective:

– Predict, demonstrate, and evaluate isolation of fracture zones and simultaneous flow and pressure control.
– Compare isolated and non-isolated behavior.

Description:

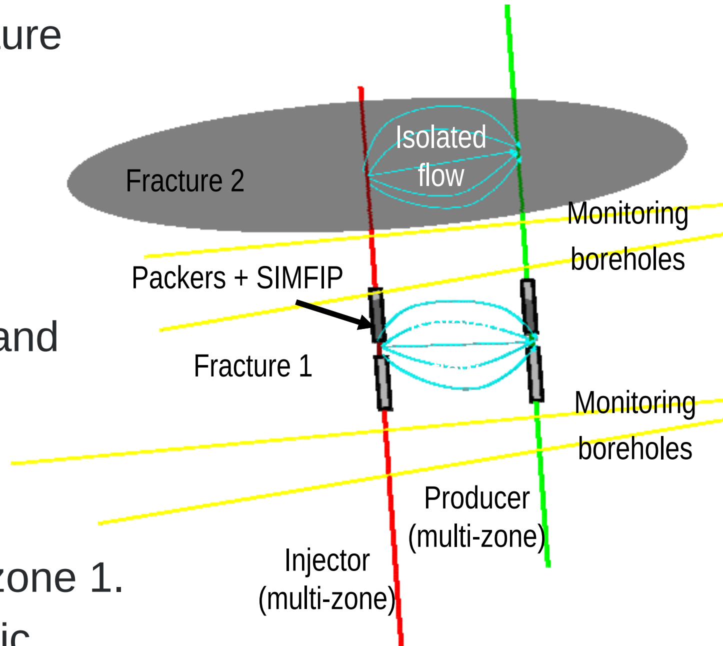
– Model driven combined and independent pressure and flow manipulation of fracture zones

Data sets:

– Pressure, flowrate, temp in each zone, aperture in zone 1.
– Monitoring wells: cross-hole seismic, passive seismic, distributed fiber temp. and strain, point temp., ERT

Data Usage

– Hydro-mechanical model validation of multi-fracture flow and control.
– Monitoring response validation



Up-hole dual zone control system

Technical Accomplishments and Progress

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Participate in kickoff meeting; task 5 lead presentation & team feedback	Accomplished Original	3/31/17
Task 5 Workplan (full team collaboration) for incorporation into PMP	Accomplished Original	6/30/17
Deliver to LLNL : task 5 infrastructure and equipment requirements, monitoring wellbore & spacing req's for ERT	Accomplished Original	7/31/17

Technical Accomplishments and Progress: Autonomous Precision Flow Test System

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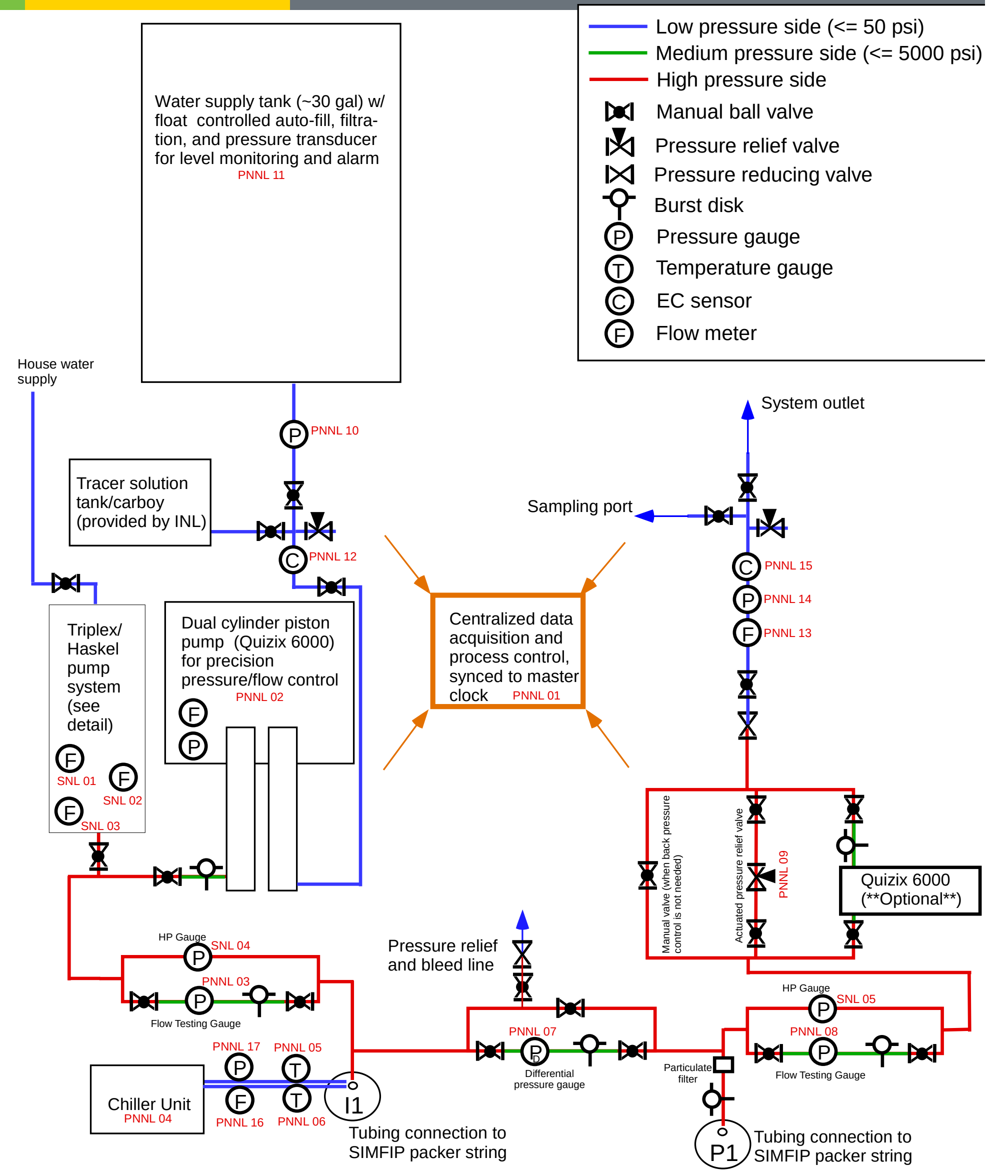
- Precise, automated flow and pressure in production and monitoring wells.
- Precision monitoring of pressure, flow and temp.
- Precision temperature control (downhole recirc. loop)
- Dual zone
- Monitoring system timing integrated with flow system.
- Remote control operation and monitoring
- Adaptable to address unexpected contingencies (e.g. larger flow rates, leak off)
- Hardened for mine conditions



Research Collaboration and Technology Transfer

Roland Horne (Stanford U.)

- DNA Tracers

Bud Johnson (NREL), Phil Winterfied and Yu-Shu Wu (CSM)

- Chemical tracer analysis

Tom Doe and Mark McClure

- Analysis of fracture flow and leak-off

Future Directions

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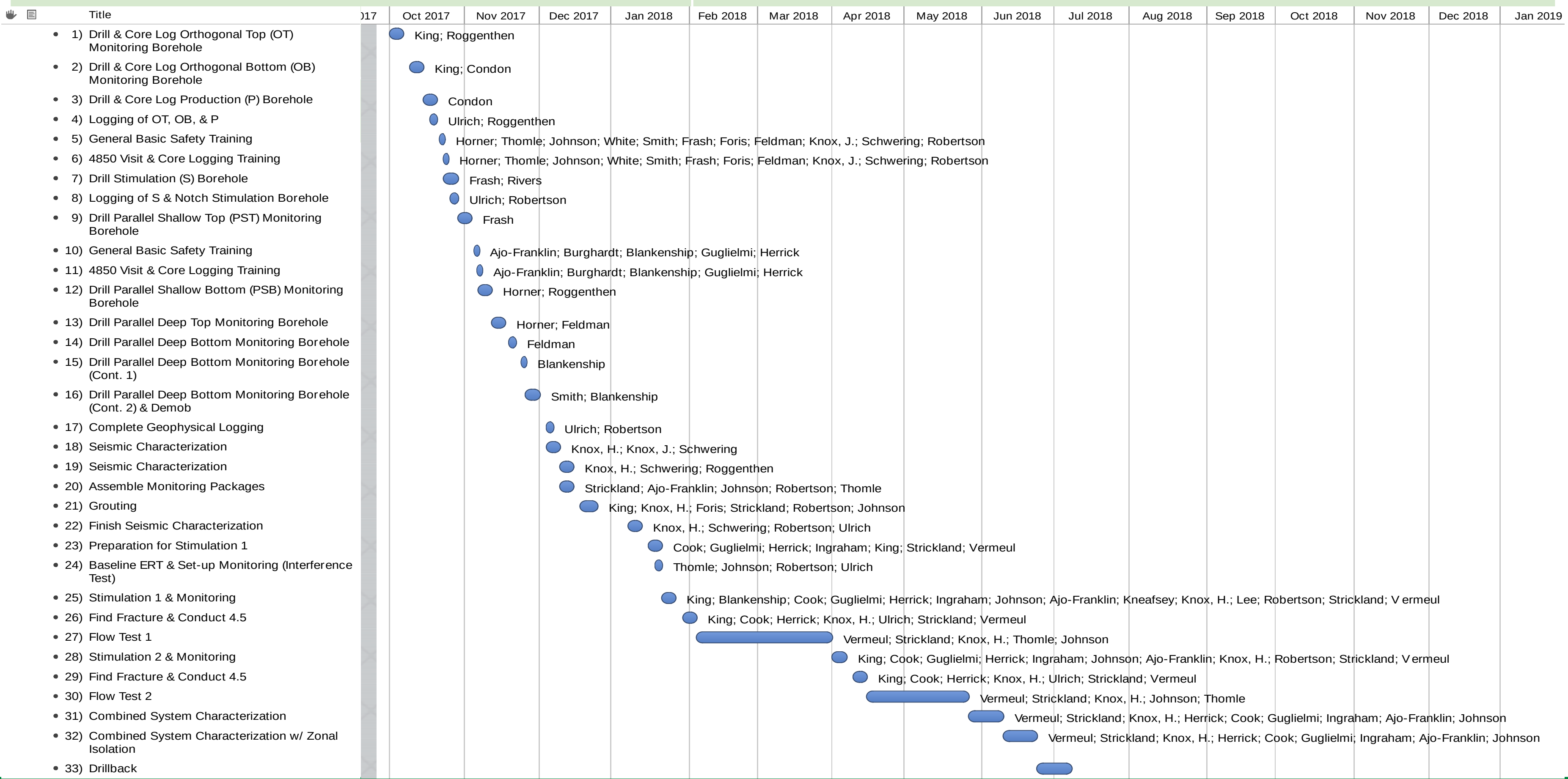
Milestone or Go/No-Go	Status & Expected Completion Date
Complete flow tests for Experiment 1, fracture set 1 and submit data to the EGS Collab database	September 30, 2018



Summary

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Task 5 will provide:

Precisely controlled and comprehensively monitored flow tests, guided by model predictions, validated by post-test drill-back.

- *Enables assessment of THMC-G predictive capability: Critical for validation of EGS computational tools*
- Fractures will be characterized by:
  - dimension, geomechanical properties, hydrogeologic properties, heat transfer properties, and geophysical properties
- Enables assessment of field tools for characterization
- Comprehensive THMC-G community data set to facilitate advancement of EGS systems will be made generally available