EGS Collab Project (Task 3/9): Refine Stimulation Test Design, Preliminary THMC Test Design Modeling, and Monitoring Design and Installation (EGS Experiment 1)

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This presentation does not contain any proprietary confidential, or otherwise restricted information.
Objective

• The focus of EGS Experiment 1/Task 3 will be upon delivering a robust plan for stimulation and flow testing with minimal risk
  – Identify and resolve competing objectives
  – Identify/anticipate roadblocks and interdependencies

• Demonstrating and setting stage for validation of software essential for FORGE and commercial-scale EGS

Innovation and novelty:

• Leverage multidisciplinary team across labs, industry, and academia
• Build a testbed for validation of stimulation, flow, and monitoring
• Take advantage of access to the rock
Relevance to Industry Needs and GTO Objectives

Task 3 is a Nexus for Exp. 1 Planning:

- Refine the stimulation tests design based on detailed site characterization (Task 2)

- Perform systematic sensitivity studies of pre-stimulation (fracturing) test modeling (Task 4)

- Perform initial THMC modeling of desired tests to support (Task 5)
Methods/Approach

• Utilize modeling and peer review across the Collab team to address every step of the experimental design

• To the extent possible, confidence is built through repeated analyses with
  – Different modeling approaches
  – Different contributors across the Collab team
  – Utilize COTS and research tools as appropriate

• Key issues:
  – Control near-wellbore tortuosity to ensure stimulation
  – Predict geometry of stimulation
  – Predict performance of flow test
  – Predict performance of monitoring systems
Technical Accomplishments and Progress

**Milestone: Refine Stimulation Test Design:**
Refined the test design based on available and collected information.

**Verification Method:**
Site 1 selected and testbed preparation initiated

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<tr>
<th>Original Planned Milestone/Technical Accomplishment</th>
<th>Actual Milestone/Technical Accomplishment</th>
<th>Date Completed</th>
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<tr>
<td>Refine Stimulation Test Design</td>
<td>Refine Stimulation Test Design</td>
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**Challenge:** Balancing readiness, availability, and characterization of test site with drift and stress orientation

**Solution:**
- Place boreholes according to stress state and model results
- Extensive modeling demonstrates system robustness

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**Borehole Key**
- Monitoring
- Stimulation
- Production

**Future blast door location**
200’ from Governor’s Corner
1st quarter of 2019
Technical Accomplishments and Progress
Evaluating notching to control stimulation

**Challenge:** Near wellbore tortuosity can prevent effective stimulation

**Solution:**
- Quantify notch geometry required to overwhelm such effects
- Results indicate notching apparatus should be effective
Technical Accomplishments and Progress

Predict performance of the packer system

Challenge: Will packer inflation impact fracture initiation?

Solution:

- Finite element models indicate up to 2 MPa of axial tensile stress increment in the wellbore wall near the packer ends.
- Magnitude of this stress increment attenuates quickly.
- Unlikely to affect fracture initiation from a notch
- Within range tolerated by tool
Technical Accomplishments and Progress
DEM indicates minimal seismic risk

**Challenge:** Quantify seismic risk during stimulation

**Solution:**
- Multiple discrete element realizations build confidence
- Results consistent with and build upon kISMET experience

Total Energy Released = 0.153 MJ
Total Energy Released = 0.16 MJ
Technical Accomplishments and Progress
Built confidence in fracture extent

- **Challenge:** Predict expected aperture and fracture extent
- **Solution:** Compare multiple methods, range of assumptions
  - Observe excellent agreement among radically different modeling approaches
    - DEM, FEM
    - Semi-analytic
- Aperture ~0.1 mm
**Challenge:** Quantify the impact of thermal gradients due to ventilation

**Solution:**
- Analysis indicates potential for significant thermal gradient due to cooling from drift
- 3D stress modeling quantifies the stress gradient

![Diagram showing thermal gradient over time](image)
Challenge: How might thermal stress influence stimulation?

Solution:

- Multiple analyses indicate stress gradient will encourage growth toward drift
- Producer borehole well placed for draining and arresting fracture growth
- V&V: Well characterized stress gradient over “statistical” heterogeneity
Technical Accomplishments and Progress
Evaluated geophysical performance

**Challenge:** Predict geophysical monitoring system performance

**Solution:**
- Rapid, multiple investigations and communication of results across the team
- Results inform placement of boreholes and geophysical layout
Research Collaboration and Technology Transfer

• Design process directly involves academics and industry:
  – Mark Zoback (Stanford) – Stress measurement, stimulation borehole orientation, fracture geometry, breakout analysis
  – Tom Doe (Golder) – Stress measurement and hydraulic fracture growth
  – Mark McClure (McClure Geomechanics) – Hydraulic fracturing, diagnostic fractures, fast running analysis tools
  – Ahmad Ghassemi (OU) – Hydraulic fracture modeling
  – Participate/present in weekly project meetings

• Technology transfer is most immediately to FORGE
• Much of software used is available under license
• Learnings will influence the design of EGS in the future
• Conf. papers: GRC, Stanford Geothermal Workshop
• Journal publications planned
Future Directions: Exp. 2 with Task 9

• Lessons learned from Exp. 1/Task 3 will influence Exp. 2/Task 9

Possible examples:
• Should spatial variability in temperature be a factor in site selection?
• Utilize viscous fluids and proppant to attain greater aperture for subsequent flow (also a consideration for Exp. 3)
• Will the notching technique need improvement?
• Should new monitoring be added, existing approaches modified, or dropped?

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<tr>
<th>Go/No-Go</th>
<th>Status &amp; Expected Completion Date</th>
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<tr>
<td>Site selected for Exp. 2</td>
<td>On track for “Go”: Preliminary evaluation complete and expect site selection final by 3/31/18</td>
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Summary Slide

- We have effectively engaged as a team to guide the design of a robust, relevant test bed
- Design is balanced:
  - Validation goals of the experiment
  - Successful stimulation
  - Fracture intersection with producer well
  - Successful monitoring of fracture growth and subsequent flow
- This has required close teamwork among stimulation, flow, and modeling teams
- Benefited from rapid cross-verification and peer-review
- Demonstrating and setting stage for validation of software essential for FORGE and commercial-scale EGS