Enabling Cost Effective High Quality Seismic Monitoring of Unconventional Reservoirs with Fiber Optics
DOE contract DE-FE0031780

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MagiQ Technologies, Inc.

U.S. Department of Energy
National Energy Technology Laboratory
Oil & Natural Gas
2020 Integrated Review Webinar
Program Overview

– DOE Funding: $2.5M
– Cost Share total: $625k
– Performance Period: 10/1/2019 – 9/31/2021
– Project Participants:
  • MagiQ Technologies, Inc. (prime)
  • HighPeak Energy – field operator
  • Microseismic, Inc. – deployment/acquisition
Program Overview

– Overall Project Objectives

• produce a narrow diameter, high temperature, reliable optical seismic sensor system and demonstrate it in a field test an unconventional basin

• perform a suite of data acquisition activities which will be analyzed to provide information on the reservoir and well operations including active surveys and passive seismic and microseismic monitoring

• demonstrate the ability to cost-effectively provide useful data in a challenging environment
• Accurate geophysical data with reliable, transparent analyses are essential for profit and safety.
• DOE pushing for better understanding of well dynamics in fractured wells to improve safety and efficiency.
• State of the art seismic wireline tools are bulky and require maintenance, so downhole sensor deployments are temporary, labor intensive, and disrupt production operations.
• **DEPLOYMENT COST > HARDWARE COST**
Background: optical accelerometers

- ‘Mass on a spring’ design moves under acceleration, stretching optical fibers
- Flexure offers high directionality (>30dB below 100 Hz), high linear dynamic range
- Multiple designs with different specs have been field tested and verified by comparison to geophones and accelerometers.
- All parts are passive and survive decades at high temperatures.
Background: MagiQ Sensor System

- The interrogator includes all electronics, while sensors can be kilometers away, connected by rugged optical cables.
- Supports 10 3C sondes per fiber, many fibers per cable.
- Field tested to be robust against laser noise and transmission line pickup.
We will assemble an array of 3C optical sondes on a rugged downhole cable and deploy it in a commercial well. It will be used to acquire active and passive surveys, allowing geophysical analyses and comparisons to commercial sensors.

Project schedule:
Oct. 1, 2019: project start
April 30, 2020: Design review and Go/No-Go
April 30, 2021: Field readiness review
Sept. 31, 2022: Field test completed
Success criteria:

a. Outfit a field site with an optical sensor system meeting program requirements.

b. Provide useful, high quality data to contribute to the understanding of unconventional reservoirs.

c. Specific analysis goals TBD, may include time lapse images of the reservoir and surrounding regions, estimates of stimulated reservoir volume, and maps of microseismic events.

Project risks and mitigation strategies:

a. Mature designs, prior field tests and a field readiness review mitigate technical risks.

b. The pandemic and its economic impacts add schedule risk due to uncertainty among our vendors and partners, but we are on schedule for now.
Major Outcomes to report

• **We are on schedule for this program**
  - We completed a field test in January (funded by related contract DESC0015781); where we delivered a working system completed a deployment in a well-characterized test environment.
    - The system performed as expected, and we learned lessons about field integration and workflow. The data was processed using standard seismic techniques, providing results that compared well with commercial products.

• **We continue developing relationships with industry partners and potential customers.** These relationships have informed our target specs and ongoing plans.
Sensor assembly

- Sensor “core” elements are machined from tungsten and wound with fiber.

- The cores are assembled and enclosed in a tube with welded flanges.

- The sensors are fluid filled for pressure balance and damping.

- Response testing occurs at each step
Completed Sonde

- Sensors were attached to fiber optic cable (6 fibers in a metal tube with armor and polymer jacket)

- Magnetic clamps (routinely used with DS-150 toolstrings) were attached to the sensors with adapters to allow independent clamping to the well.

- We experienced failures of the cable attachment methods, where the cable would mechanically come loose or fibers break.

- Modifications just before the test repaired sensors while changing to the “piggyback” configuration shown earlier.
Field test performed in Jan. 2020

Field test in collaboration with MSI, Aramaco Services Co, and Total SA, partly funded by Phase II SBIR DESC0015781

MagiQ produced and tested 4 sonde prototypes (1 Flexible Sonde and 3 Rigid Sondes).
-Narrow diameter, broadband sondes with response comparable to GeoSpace DS-150s

We also delivered an interrogation system with proprietary control software which interfaced with MSI’s commercial seismic QA and analysis workflow.

We used the data to generate a variety of seismic analyses and visualizations
Deployment from Wireline

MSI provided a DS-150 seismic toolstring and wireline truck for deployment. MagiQ sondes were deployed from a winch and strapped onto the wireline.
Deployment from Wireline

MagiQ Sonde

Geospace DS -150
Field Test Results and Lessons

- Deployment completed and tools extracted safely.
- Data collected at multiple depths and source points.
- System self-noise meets expectations is immune to interrogator/transmission line vibration pickup.
- Data shows the sensors met design targets and replicated the measurements of DS150 geophones also deployed in the well.
- Currently working on a journal article reporting detailed results.

- Lesson: Integration to toolstring is critical; late changes to the cable and hardware with limited time for testing affected signal quality and resulted in some sensor failures.
- Lesson: Data workflow must be fully tested prior to field test; some surprises lead to costly delays in QA/QC during field operations.
- The test also identified some minor interrogator bugs which have been fixed.
Sample Results

- Three sets of stacked VSP data traces were generated
  - Source point VP02, about 38 m from well head
  - Source point VP03, about 72 m from well head
  - Source point VP04, about 173 m from well head
Waveform Comparison to DS-150

- This is the first break of an extracted P-waveform, from each tool.

- The DS 150 and GLASS signatures show
  - the same structures
  - the same amplitudes
VSP comparison with DS-150

- Both data sets were used to estimate and subtract out the direct wave, showing matching residual wavefields.
Development Plan

This project will result in a field test of a commercial scale system (10 levels in a commercial well)

The resulting system will be reusable for additional tests or customer deployments to obtain feedback and increase industry visibility.

The interrogation system design is owned by MagiQ and allows for scaling up to hundreds of levels. The toolstring can be adapted for other environments and configurations.
Commercialization

Customers will include service providers and operators, with MagiQ providing hardware and/or services.

System Specs: competitive and scalable to large arrays

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<tr>
<th>Parameter</th>
<th>Units</th>
<th>Target Spec</th>
<th>Notes</th>
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<td>Scale factor</td>
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<td>Ratio of optical phase to acceleration</td>
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<td>dB</td>
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<tr>
<td>Off-axis isolation</td>
<td>dB</td>
<td>≥30</td>
<td>Demonstrated in lab environment</td>
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Our efforts to manufacture a commercial scale optical seismic sensor system are on schedule with mature designs and specifications based on recent customer feedback.

A recent field test from another DOE program has verified the key aspects of the design and provided valuable lessons.

The next 6 months will involve the actual fabrication and assembly work as we plan a field test with industry partners for late 2021, and (hopefully) customer adoption after that.
Appendix

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

Audrius Berzanskis, CEO

Rick Metzbower, Director of Engineering

Caleb Christensen, Chief Scientist (PI)

Partner Organizations:
- HighPeak
- MSI
- others

Task assignments

Program Requirements

DOE
Steve Henry, Program Manager
Gantt Chart

Start: Oct. 1, 2019
End: Oct 1, 2021

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<th>Task</th>
<th>Quarter</th>
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Preliminary Design Review

TODAY (Oct. 15)

Field Readiness Review

Field Test Complete