Enabling Cost Effective High Quality Seismic Monitoring of Unconventional Reservoirs with Fiber Optics

DOE contract DE-FE0031780

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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

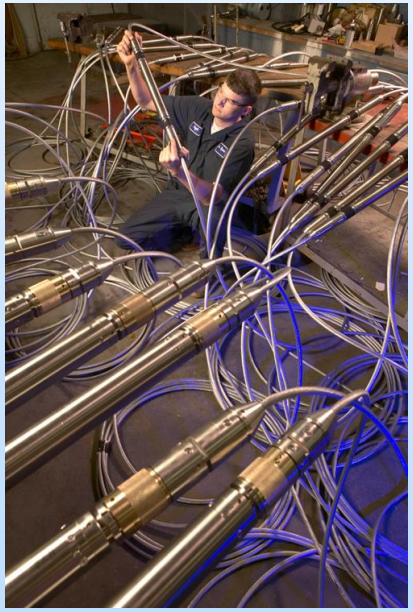
– Overall Project Objectives

- 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

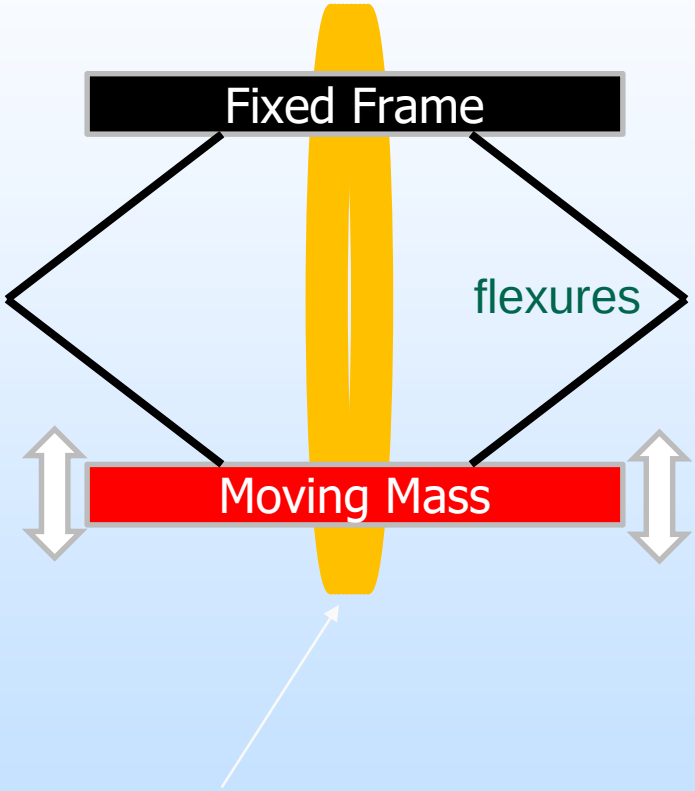
Background: Industry Need

- 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



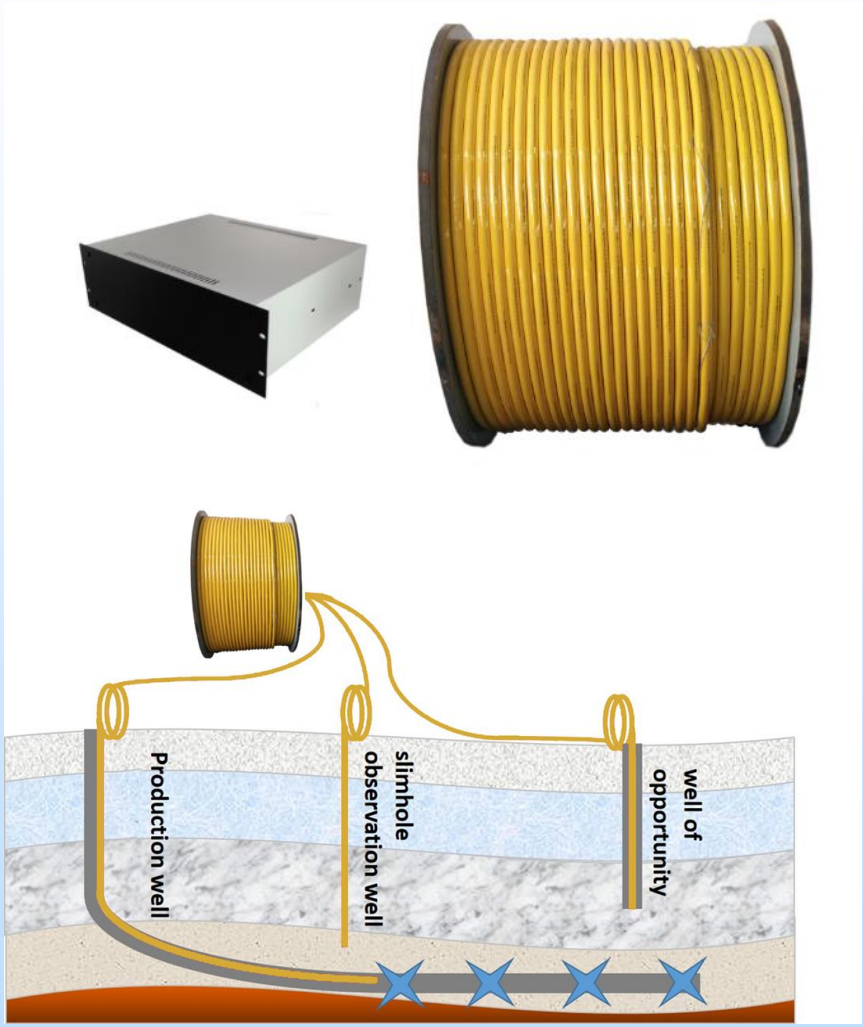
Background: optical accelerometers



- ‘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.



Technical Approach/Project Scope

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

Technical Approach/Project Scope

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.

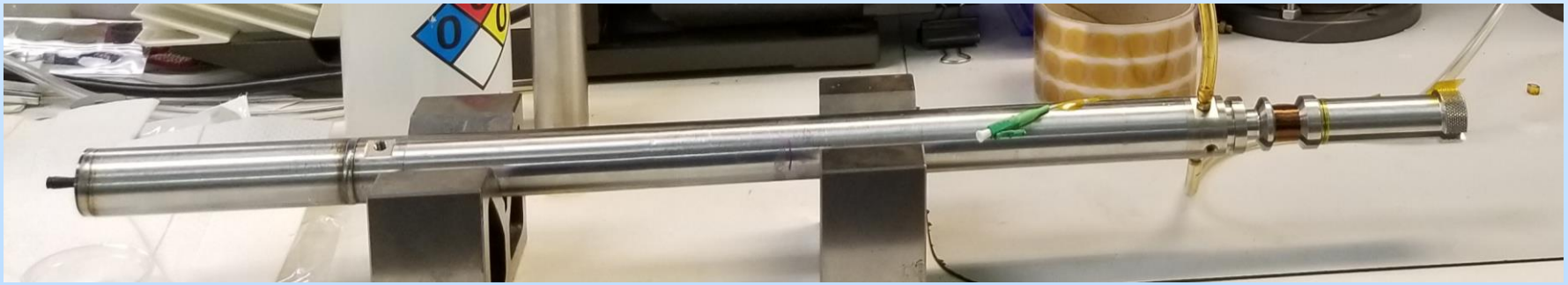
b. The pandemic and its economic impacts add schedule risk due to uncertainty among our vendors and partners, but we are on schedule for now.

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

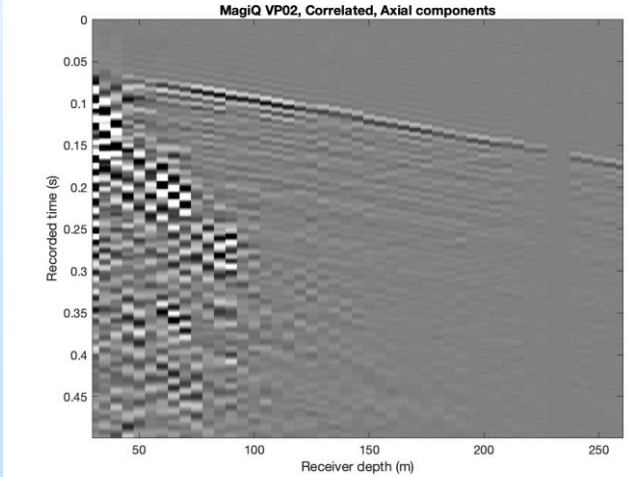
- Sensor “core” elements are machined from tungsten and wound with fiber.
- The cores are assembled and enclosed in a tube with welded flanges.
- The sensors are fluid filled for pressure balance and damping.
- Response testing occurs at each step



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

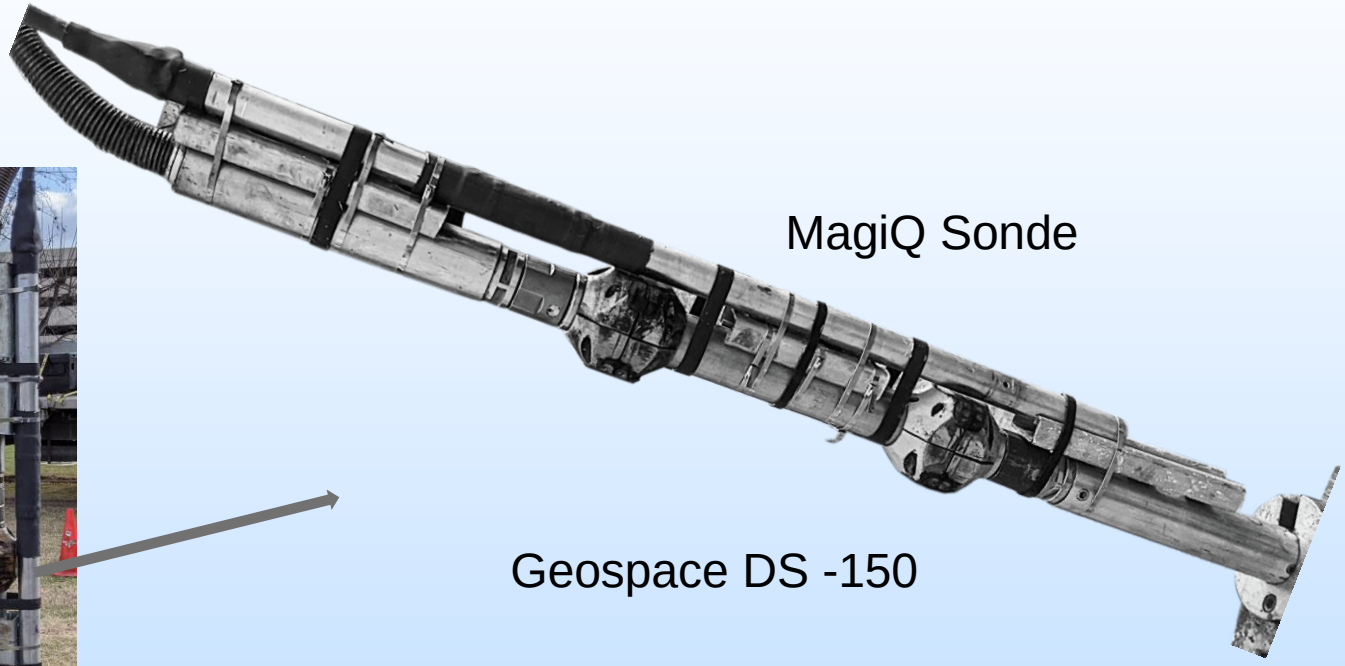
We also delivered an interrogation system with proprietary control software which interfaced with MSI's commercial seismic QA and analysis workflow.

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

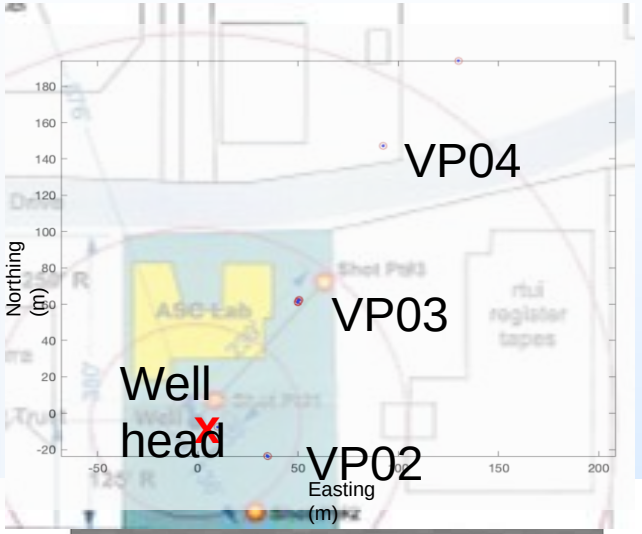
Field Test Results and Lessons

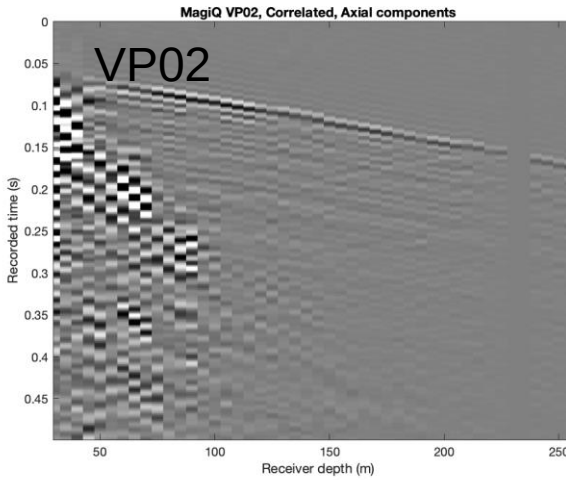
- **Deployment completed and tools extracted safely.**
- **Data collected at multiple depths and source points**
- **System self-noise meets expectations is immune to interrogator/transmission line vibration pickup.**
- **Data shows the sensors met design targets and replicated the measurements of DS150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

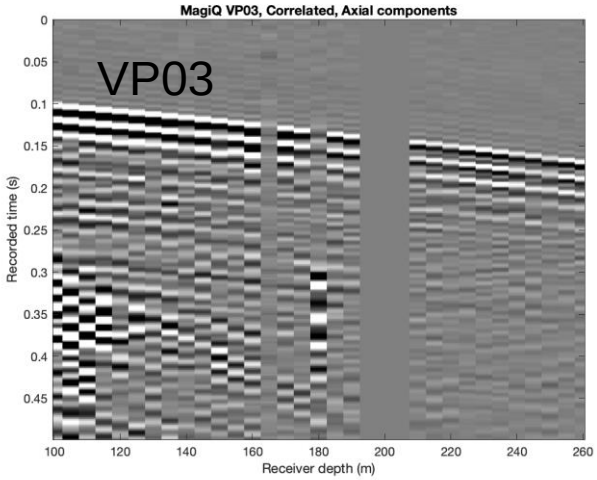
- **Lesson: Integration to toolstring is critical; late changes to the cable and hardware with limited time for testing affected signal quality and resulted in some sensor failures**
- **Lesson: Data workflow must be fully tested prior to field test; some surprises lead to costly delays in QA/QC during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

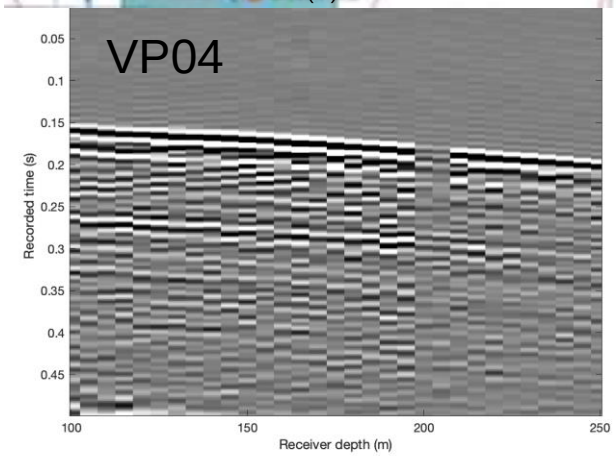
Sample Results

- 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

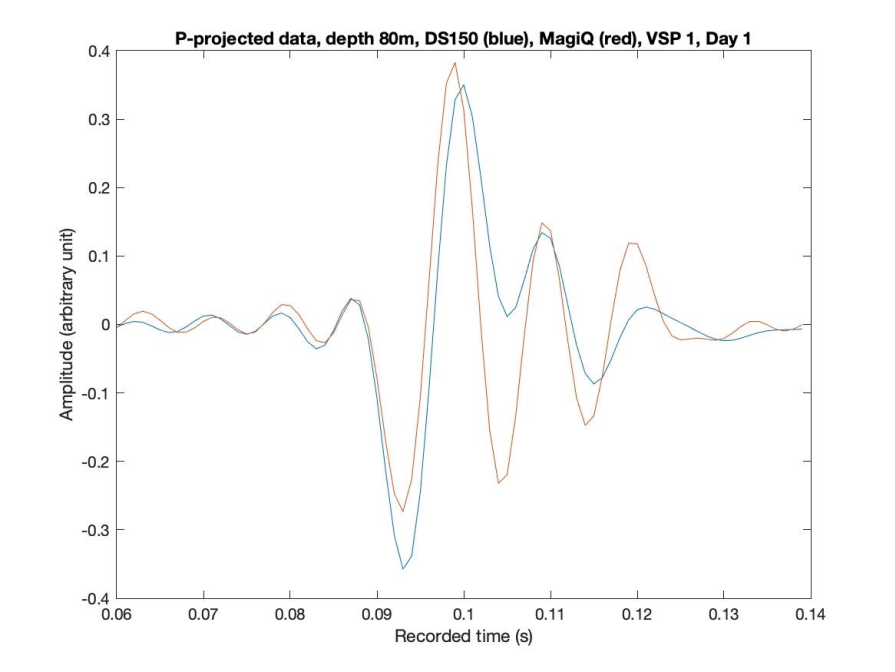








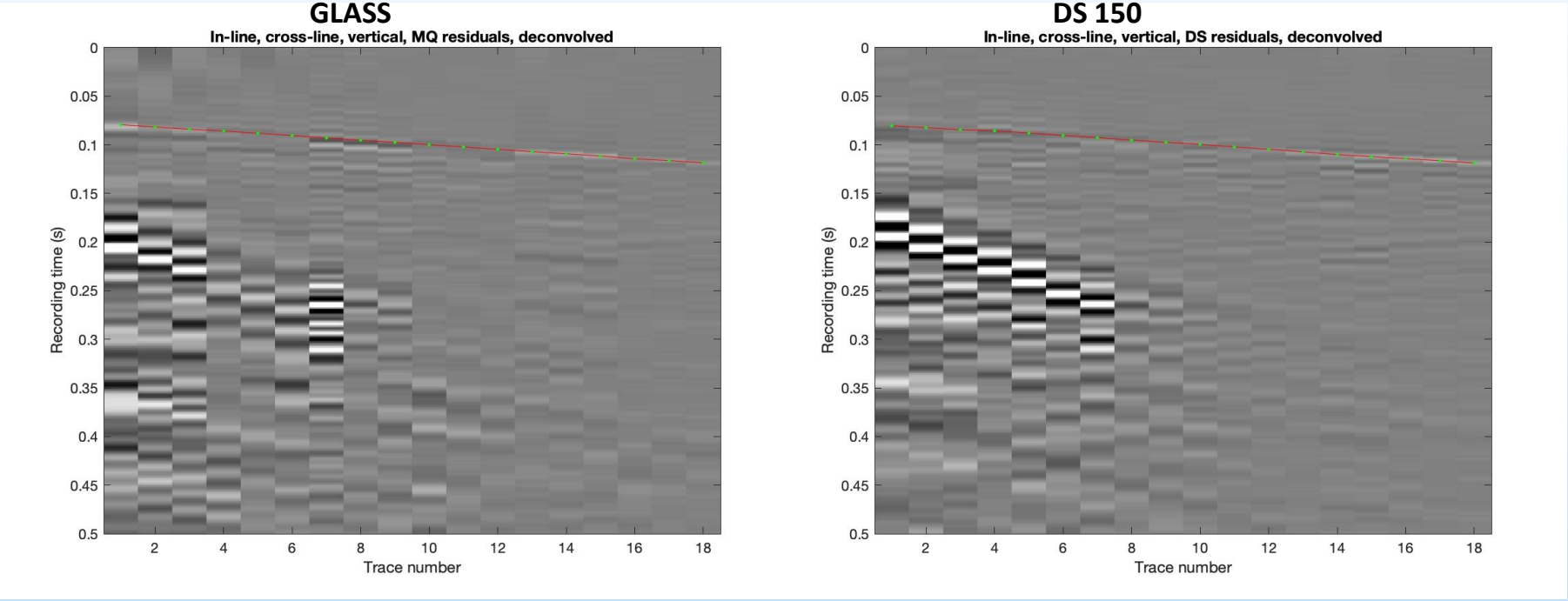
Waveform Comparison to DS-150



- 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

Parameter	Units	Target Spec	Notes
Environmental			
Max Operating Temperature	°C	+150	
Min Operating Temperature	°C	0	
Max Non-Operating Temperature	°C	+200	
Min Non-Operating Temperature	°C	-20	
Max Pressure	atm	≥400	
Length	mm	≤1,000	
Diameter	mm	≤25.4	
Bandwidth	Hz	0.1 - 1000	
Scale factor	dB re rad/g	≥49	Ratio of optical phase to acceleration
Scale factor uniformity	dB	±3.0	
Off-axis isolation	dB	≥30	Demonstrated in lab environment

Summary Slide

Our efforts to manufacture a commercial scale optical seismic sensor system are on schedule with mature designs and specifications based on recent customer feedback

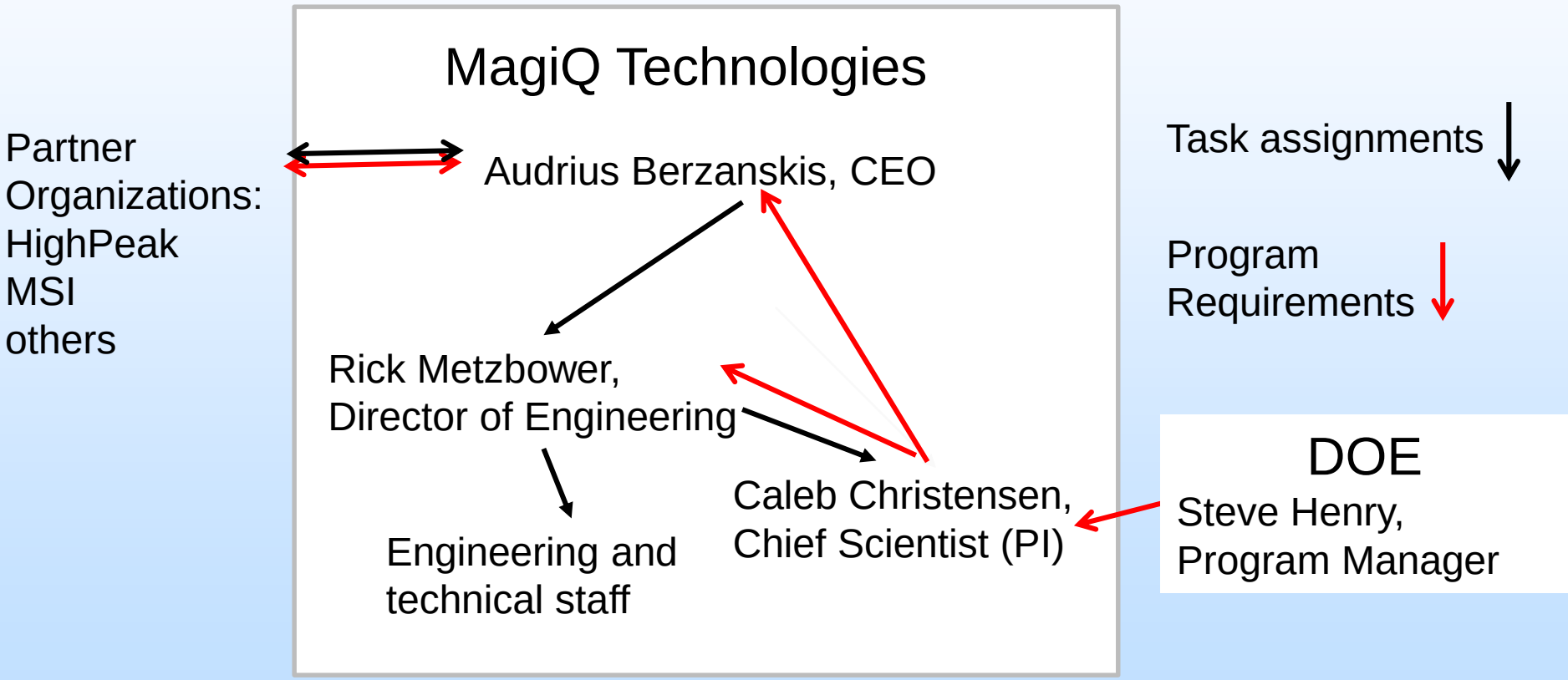
A recent field test from another DOE program has verified the key aspects of the design and provided valuable lessons.

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.

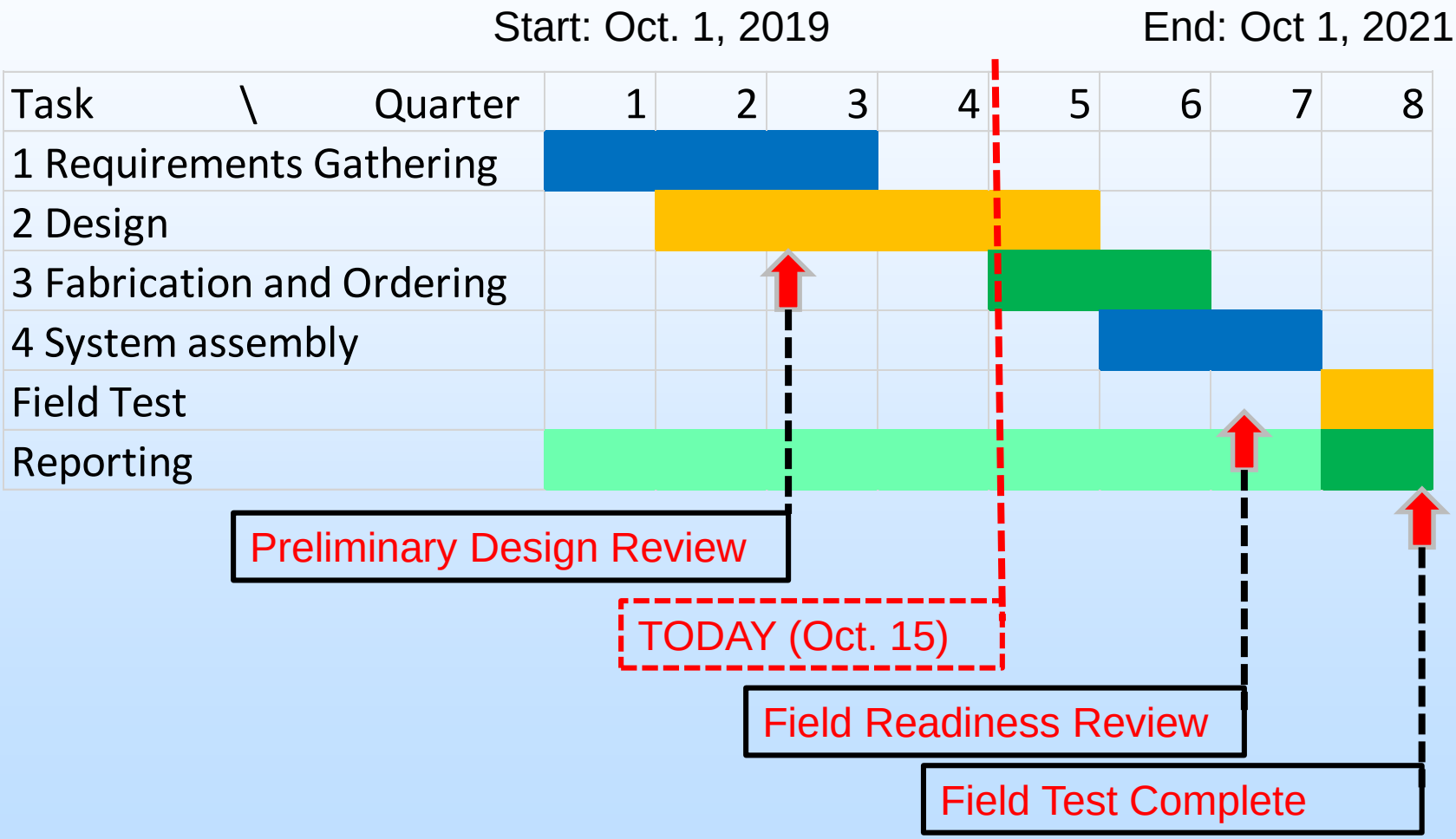
Appendix

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

Organization Chart



Gantt Chart


Start: Oct. 1, 2019
End: Oct 1, 2021
Task \ Quarter
1
2
3
4
5
6
7
8
1 Requirements Gathering
2 Design
3 Fabrication and Ordering
4 System assembly
Field Test
Reporting
Preliminary Design Review
TODAY (Oct. 15)
Field Readiness Review
Field Test Complete