Automated High Power Permanent Borehole Seismic Source Systems for Long-Term Monitoring of Subsurface CO2 Containment and Storage

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U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

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Presentation Outline

- Technical Approach/Status
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Project Summary
- Appendix

Technical Status

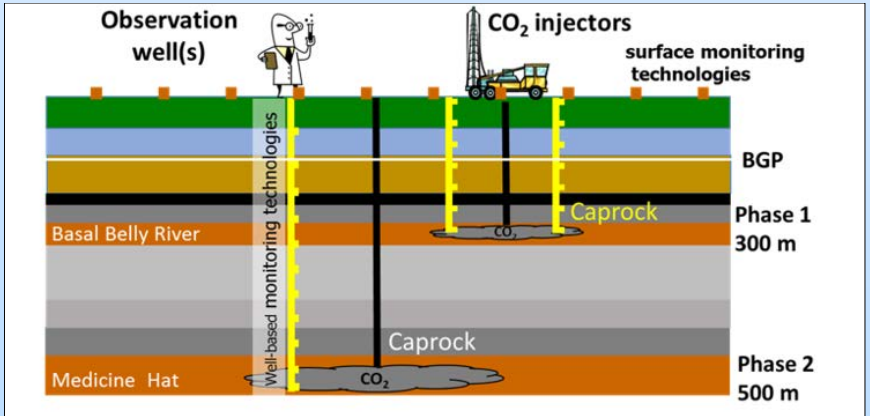
Problem & Proposed Solution

Problem:

- The geologic storage of CO_2 emitted from fixed sources, such as coal or gas power plants, is currently considered one of the prime technologies for short term (~50 year) mitigation of greenhouse gas emissions (Pacala and Socolow 2004).
- Subsurface storage of CO_2 is expected to require monitoring to verify that CO_2 remains effectively trapped underground (Benson et al., 2005).
- Previous field testing by LBNL has shown that continuous active-source seismic monitoring (CASSM) is a very effective technique for monitoring the size and location of the injected CO2 plume on an almost real-time basis (Daley et al., 2007). Existing seismic source technology lacks the power needed, is not practical or cost effective, and is not designed for permanent monitoring.

Proposed Solution:

- Demonstrate the Ability of GPUSA's Powerful, Permanent Vibratory Sources to Monitor Injected CO_2 at the Carbon Management Canada Field Research Station (FRS) site.



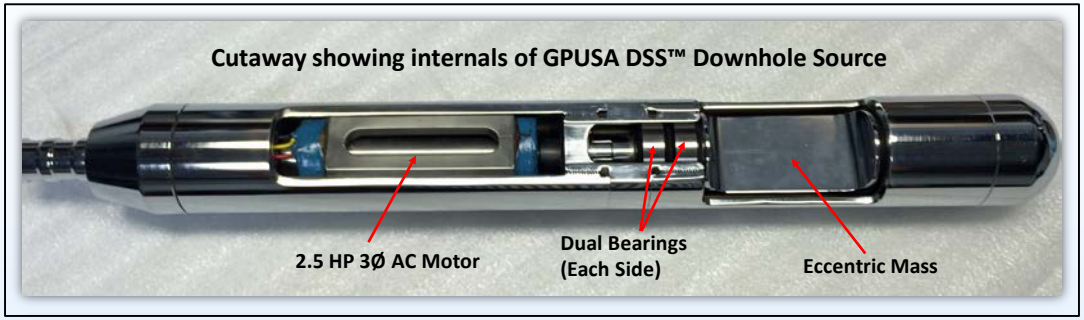
Schematic depth section of the FRS. Phase I is monitoring CO2 injection at 300 m depth; Phase II is monitoring CO2 injection at 500 m depth.

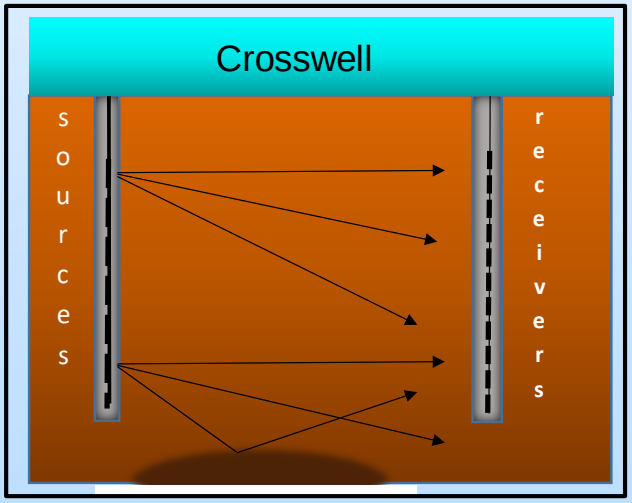
Technical Status

Technical Approach – Downhole Orbital Vibrator (DHOV)

DHOV for Cross Well Monitoring

- Can be permanent or retrievable
- Generates over 2200 pounds of vibrational force at 200 Hz.
- Will build six sources on a single downhole cable
- Clamp automatically releases upon energizing of DHOV



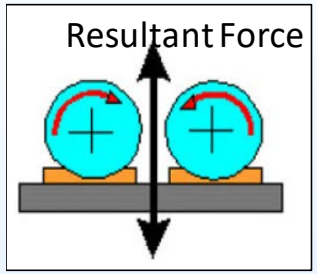


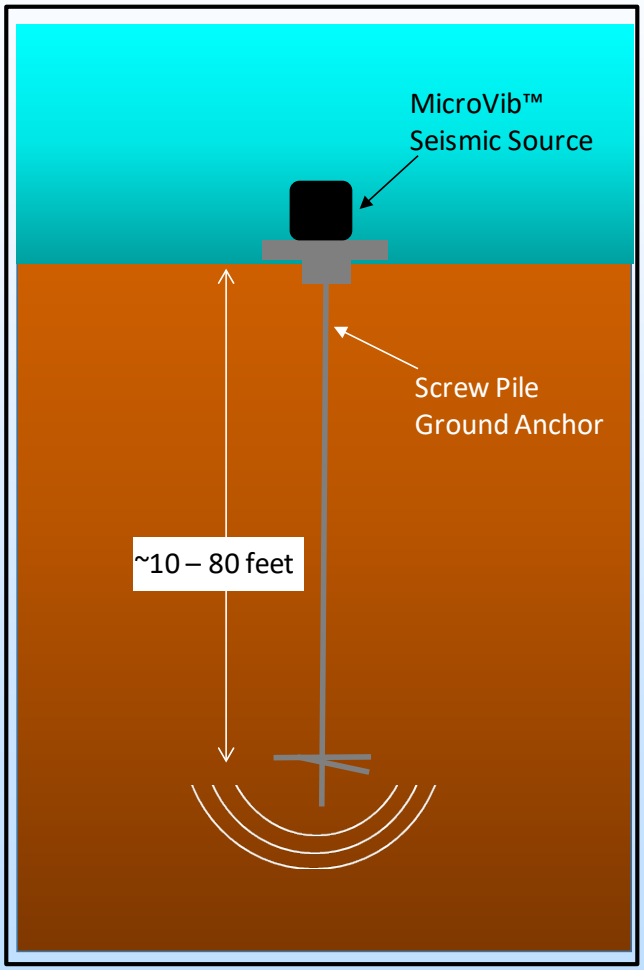
Technical Status

Technical Approach – MicroVib™ Linear Vibrators

MicroVib™ Linear Vibrators

- Generates linear vibration similar to Vibroseis
- **MV11K-100S** generates >11,000 lbf at 100 Hz
- **MV42P-200S** generates >4200 lbf at 200 Hz
- Designed for permanent installation
- Designed for installation atop helical pile



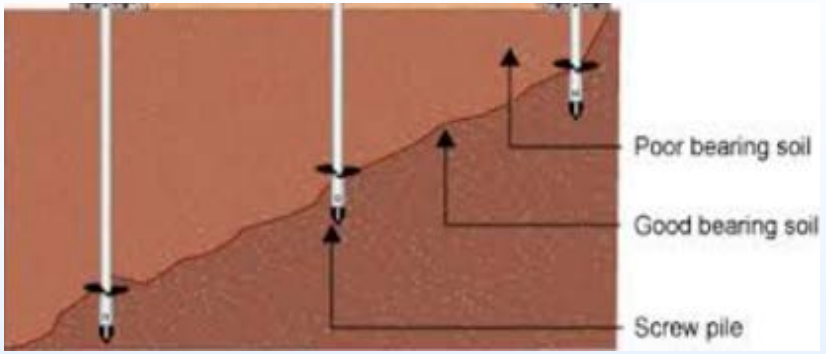


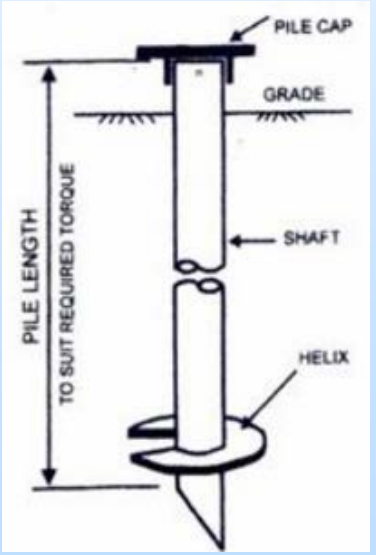
Technical Status

Technical Approach – Helical Pile Foundation Installation

MicroVib™ Installation via Helical Pile Foundation

- Minutes to install w/ immediate load bearing capability
- Designed for permanent installation, >30 year life
- Length/depth as required to engage load bearing soil
- Install at sites with limited access w/ minimal site disturbance
- Can bypass attenuating near-surface layers putting more energy on target





Technical Status

Technical Approach – Fully Automated Electronics

Electronics uses Latest Factory Automation Technology

- All operations are controlled via touch screen with pull down menus for sweep type/duration, frequency range, sweep interval, etc.
- Can be remotely operated over the internet
- Displays seismic source amplitude and spectrum via internally-mounted accel
- Includes external connections for synchronization pulses, time stamps, contact closure, etc.

Control electronics uses state-of-art factory automation and programmable logic technology

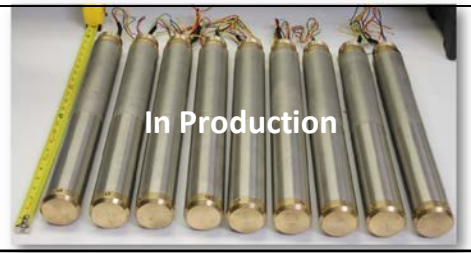
IP65 Enclosure provides protection from dust, oil and water wash down.

Electronics meets UL-508C standards for Industrial Control Equipment.

Accomplishments to Date

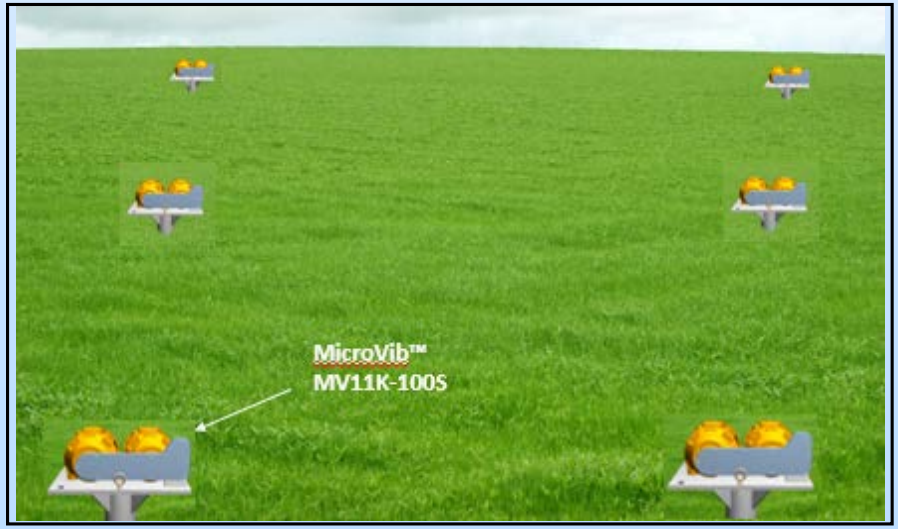
DHOV Design Updated:

- Integrated/tested internal digital accel
- Added downhole bow spring clamps
- Downhole self-releasing clamp device
- Tested in-house and at LBNL
- Transitioned to production



MicroVib™ Designs Updated:

- 2 versions built and tested in-house
- Scheduled for field testing early Aug.
- Added new helical pile installation method



Electronics Design Updated:

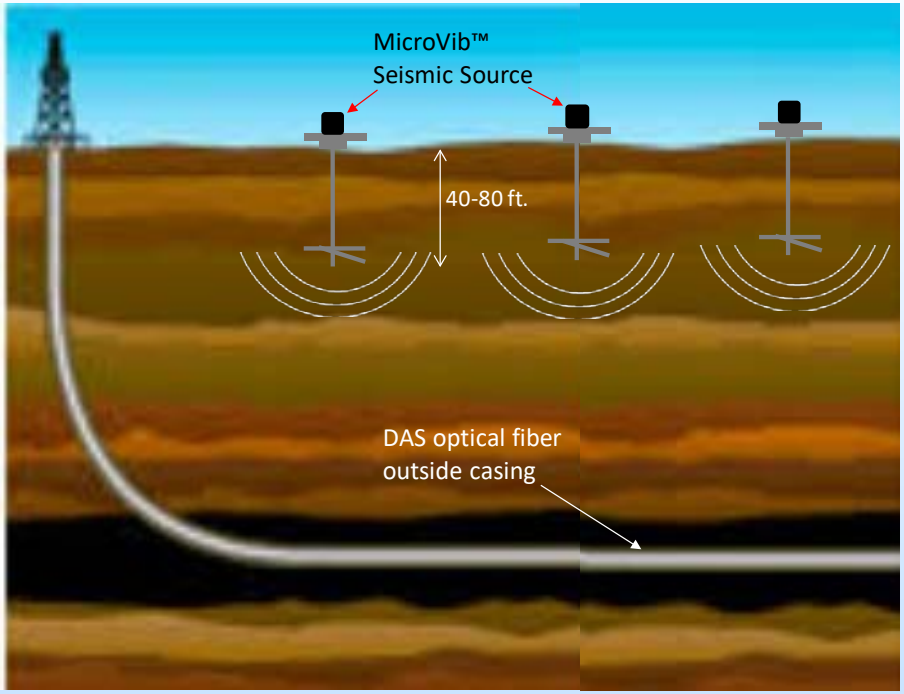
- Incorporated latest state-of-the-art VFD
- Upgraded touch screen graphics
- Selected contract manufacturer for build

Lessons Learned

- **Research gaps/challenges** – limited availability of test sites led to schedule delays
- **Unanticipated research difficulties** – None
- **Technical disappointments** – None to date
- **Changes that should be made next time**
  - Ensure availability of test sites early on
  - Find/schedule suitable alternate test sites as soon as possible
  - Perform testing of prototype hardware earlier to enable more time for the building of deliverable hardware/systems

Synergy Opportunities

- Any Project involving Seismic Monitoring may be a potential synergy opportunity for GPUSA's new Permanent Seismic Source Technology. Examples include:
  - Other carbon capture monitoring projects
  - Understanding fluid migration in shale
  - Monitoring fluids/gases in enhanced recovery operations
  - Monitoring steam chamber growth SAGD
  - Improving the seismic performance of distributed optical fiber systems
  - Making onshore 4D seismic more cost effective



GPUSA's new MicroVib™ using standard helical pile foundations can improve optical fiber performance in shale monitoring

Project Summary

Objective is to build and test new small, lightweight, seismic sources and demonstrate their superiority over existing technology at an actual $C0_2$ downhole storage site. Key expected findings include:

- Pound for pound, orbital vibrator sources can generate at least an order of magnitude more power than any comparable seismic source.
- Permanent orbital vibrator sources can also take advantage of the stacking of long duration sweeps for even greater performance.
- While all GPUSA sources take advantage of downhole placement to bypass attenuating near surface layers, the new helical pile foundation can provide this advantage from the surface.

Once commercialized, GPUSA's new permanent seismic sources are expected to revolutionize seismic surveys, making continuous or repeat seismic surveys (4D) cost effective and common place.

Thank You

Appendix

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

Benefit to the Program

Program goals being addressed: Expected to provide the ability to:

- Acquire reliable, real-time measurements of injected CO_2,
- Track and quantify uncertainty of spatial and temporal movement of the CO_2 plume through the storage reservoir
- Define the lateral extent and boundaries of the plume
- Demonstrate long-term stability of the CO_2 plume.

Project benefits statement: The goal of this project is to commercialize and validate in an operational field environment GPUSA's powerful, low cost, permanent, and automated borehole seismic source systems. These systems will enable continuous near real-time tracking and monitoring of injected CO2's plume, trajectory, and containment via crosswell and vertical seismic profile (VSP) techniques thereby meeting the Carbon Storage Program Goal to "Develop and validate technologies to ensure 99 percent storage permanence."

Project Overview
Goals and Objectives

Goals:

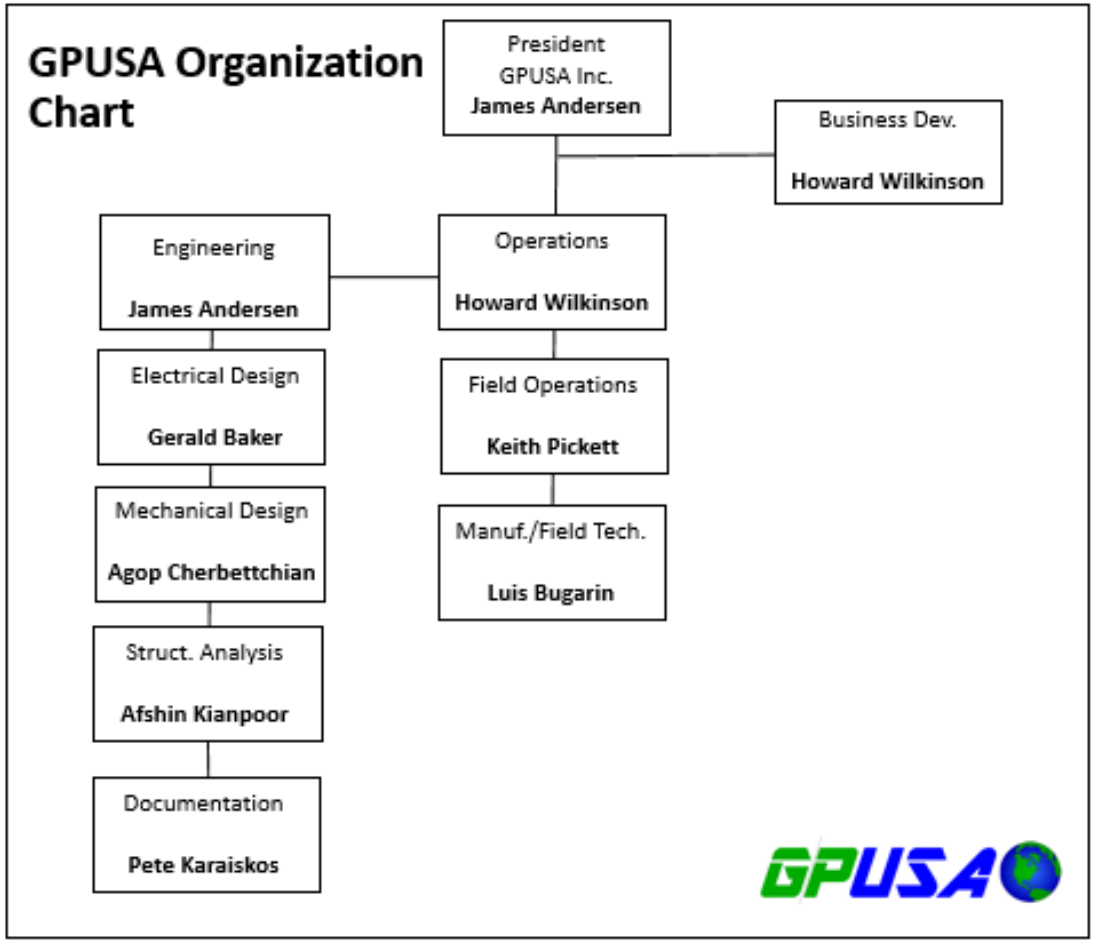
- Commercialize and validate in an operational field environment GPUSA's powerful, low cost, automated borehole seismic source systems.
- First build/test prototypes of each source, conduct design reviews, then build deliverable hardware incorporating design changes based upon testing
- Then successfully demonstrate at CMC the ability to permanently deploy and operate GPUSA's powerful sources downhole, bypassing the attenuation and filtering of the unconsolidated near surface layers to monitor injected CO_2

Progress Toward Goals:

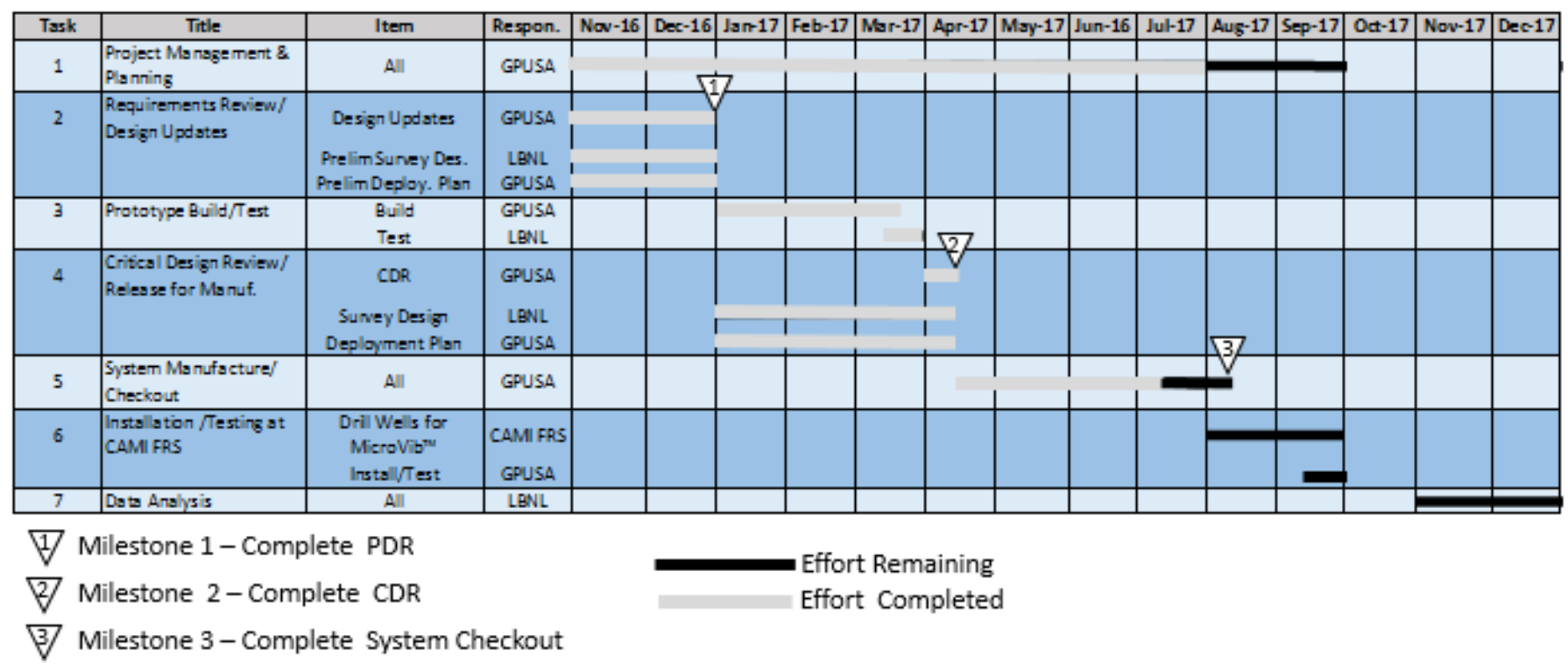
- Prototypes of each source (DHOV and MicroVib™) have been built and tested in-house, design reviews completed, designs have been updated
- DHOV has been tested in field (LBNL) and deliverable system is being built
- MicroVib™ planned for field testing early August, parts for deliverable systems on order or already in-house
- Electronics being built by contract manufacturer
- Planned ship date to CMC is August 20, 2017

Organization Chart

- Project team organization chart shown at right
  - GPUSA Inc. is Prime contractor and responsible for all hardware design and build
  - Lawrence Berkeley National Lab (LBNL) responsible for seismic testing and analysis
  - Carbon Management Canada is providing the FRS site and any alterations needed for installation.



Gantt Chart



Task	Title	Item	Respon.	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-16	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
1	Project Management & Planning	All	GPUSA														
2	Requirements Review/ Design Updates	Design Updates	GPUSA														
		Prelim Survey Des.	LBNL														
		Prelim Deploy. Plan	GPUSA														
3	Prototype Build/Test	Build	GPUSA														
		Test	LBNL														
4	Critical Design Review/ Release for Manuf.	CDR	GPUSA														
		Survey Design	LBNL														
		Deployment Plan	GPUSA														
5	System Manufacture/ Checkout	All	GPUSA														
6	Installation /Testing at CAMI FRS	Drill Wells for MicroVib™	CAMI FRS														
		Install/Test	GPUSA														
7	Data Analysis	All	LBNL														

Bibliography

- List peer reviewed publications generated from the project per the format of the examples below.

  - N/A