

MSHA's Trapped Miner Seismic Location System

By

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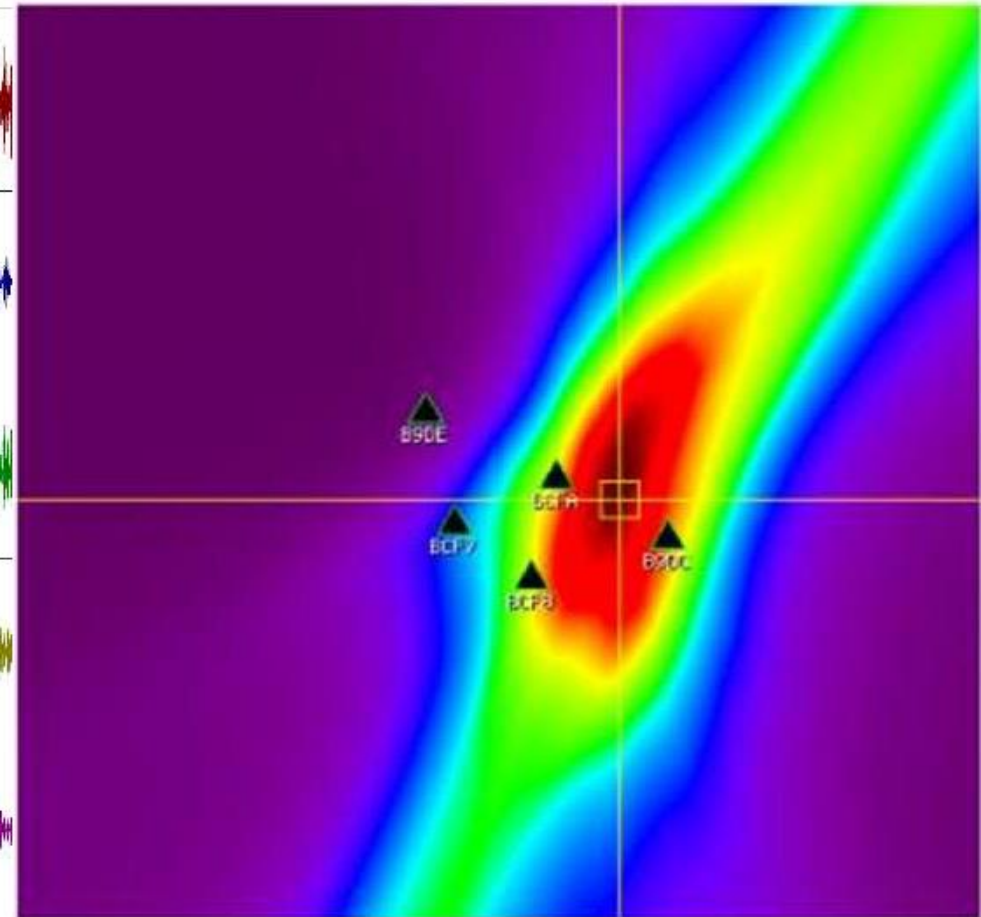
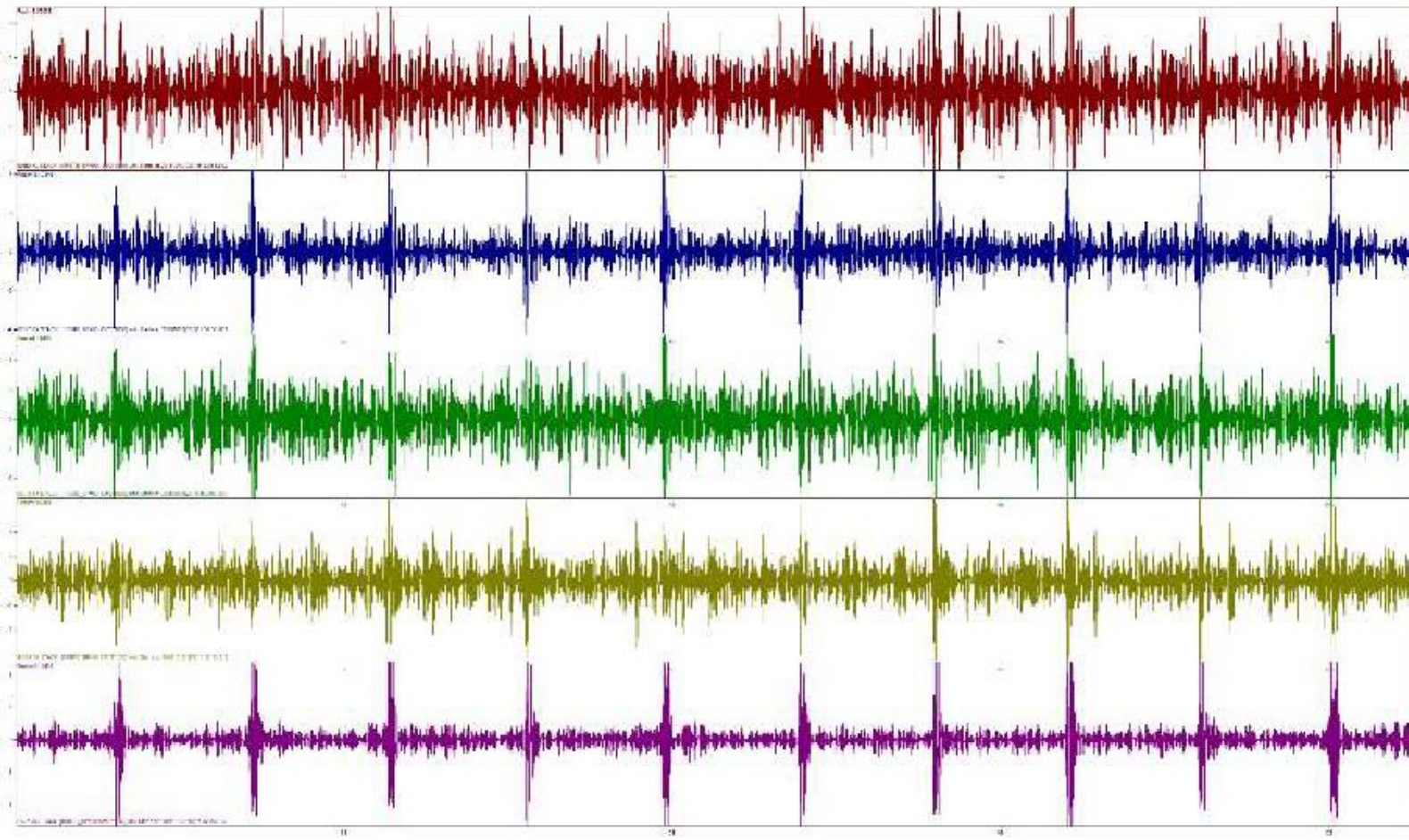
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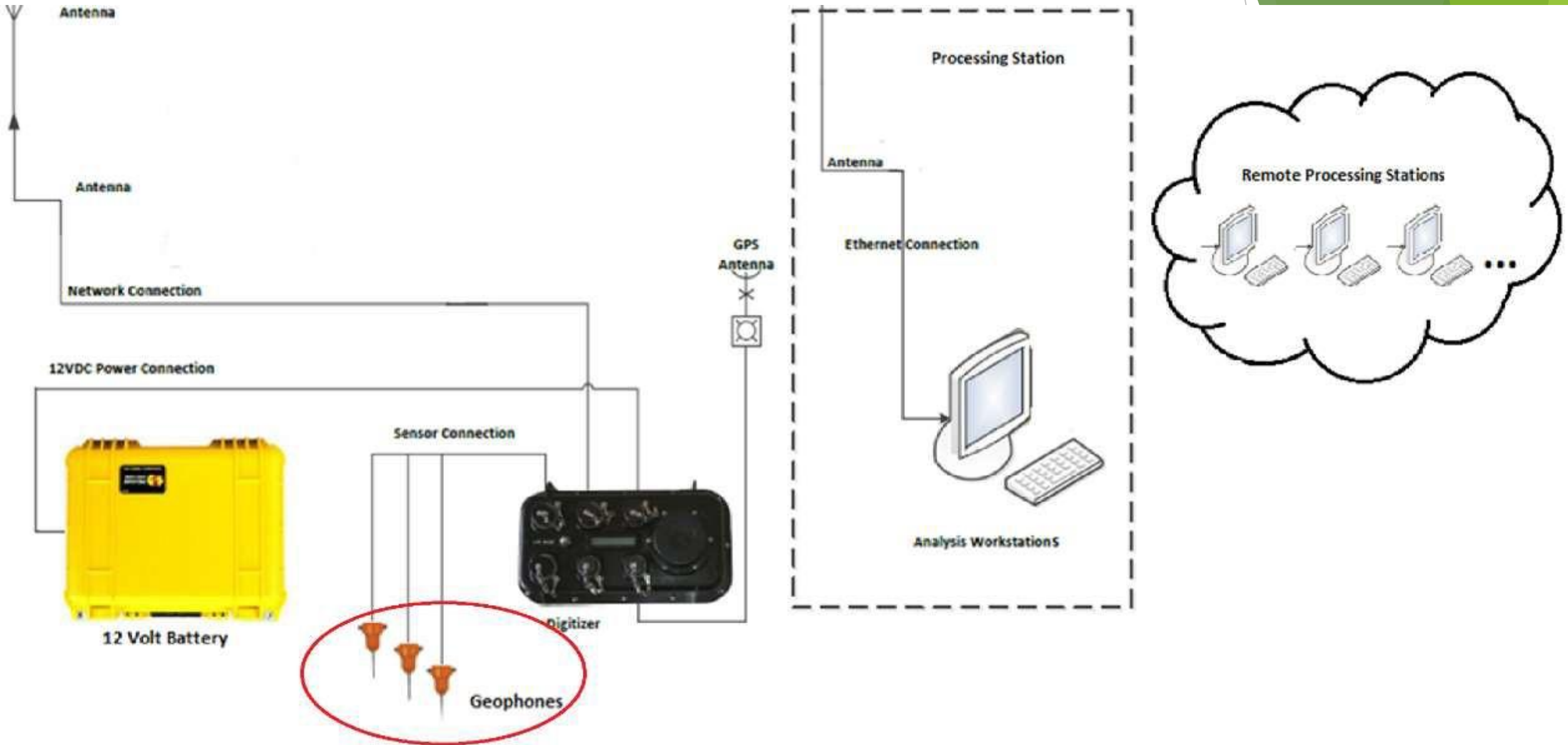


Objective - Detect and Locate Missing Miners

The seismic location system is capable of detecting and locating seismic vibrations produced by trapped miners



Test Setup Diagram



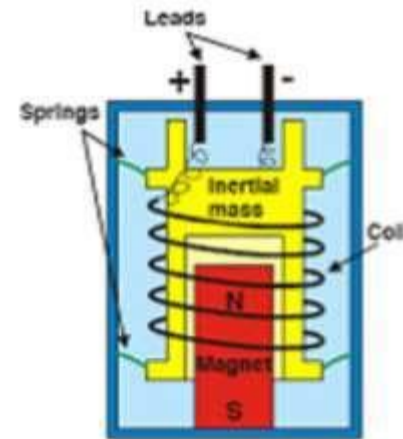
Geophone



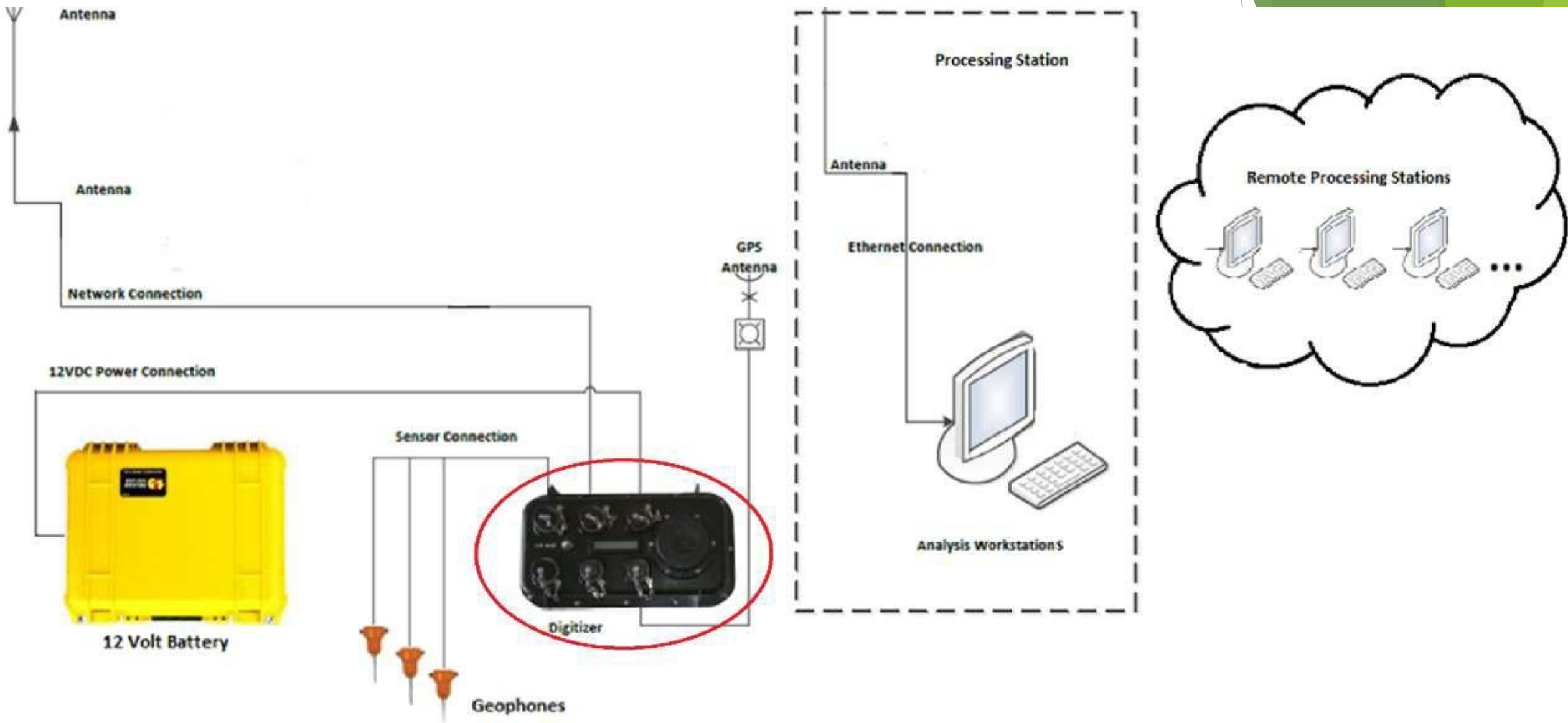
Sep 22, 1791 - Aug 25, 1867 (age 75)

Michael Faraday was a British scientist who contributed to the study of electromagnetism. His main discoveries include the principles underlying electromagnetic induction.

- ▶ Instrument that couples to the earth
- ▶ Faraday
- ▶ Induction
- ▶ Geophones, microphones, hydrophones



Test Setup Diagram



Digital Acquisition Unit

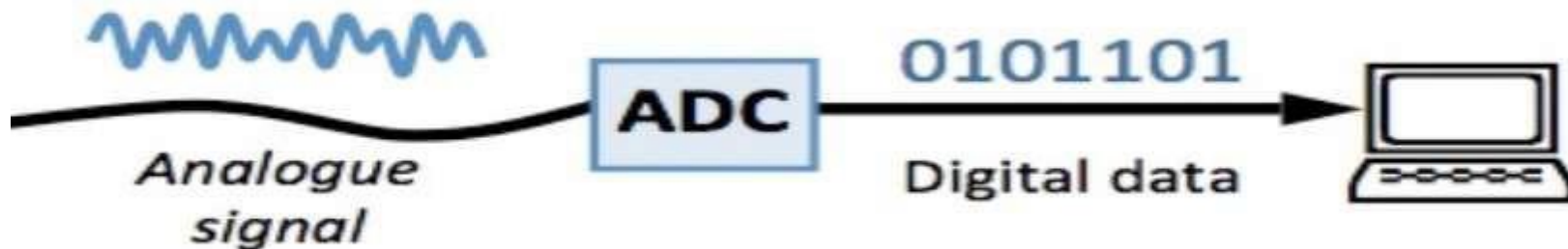
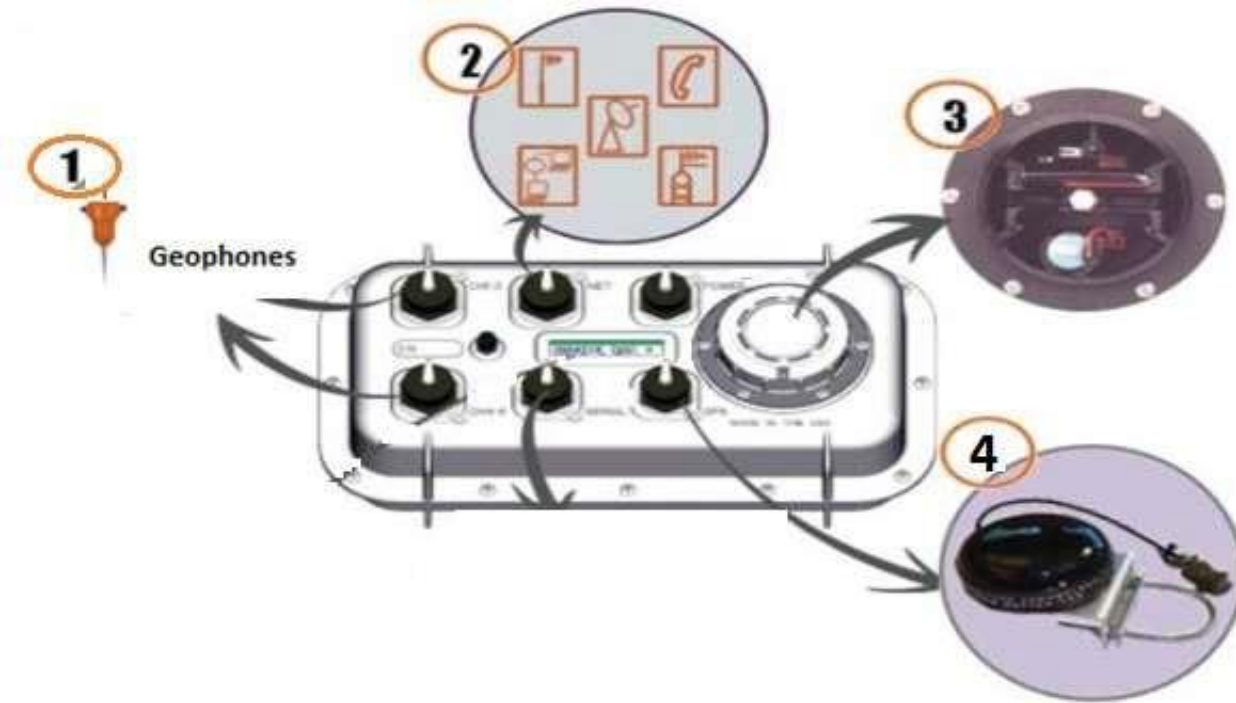
Functions of the DAU include:

Receive analog signals from the Geophone set

Send data to primary processing station

On Board Storage

Location



19s/1000sps
.019sec

-30.2282
-71.7967
-103.537
-130.02
-129.921
-119.788
-101.25
-57.881
-23.1702
9.45695
45.407
59.2681
56.7974
47.0665
27.5475
-6.17688
-39.0419
-72.6529
-98.4227

Harry Nyquist

Engineer



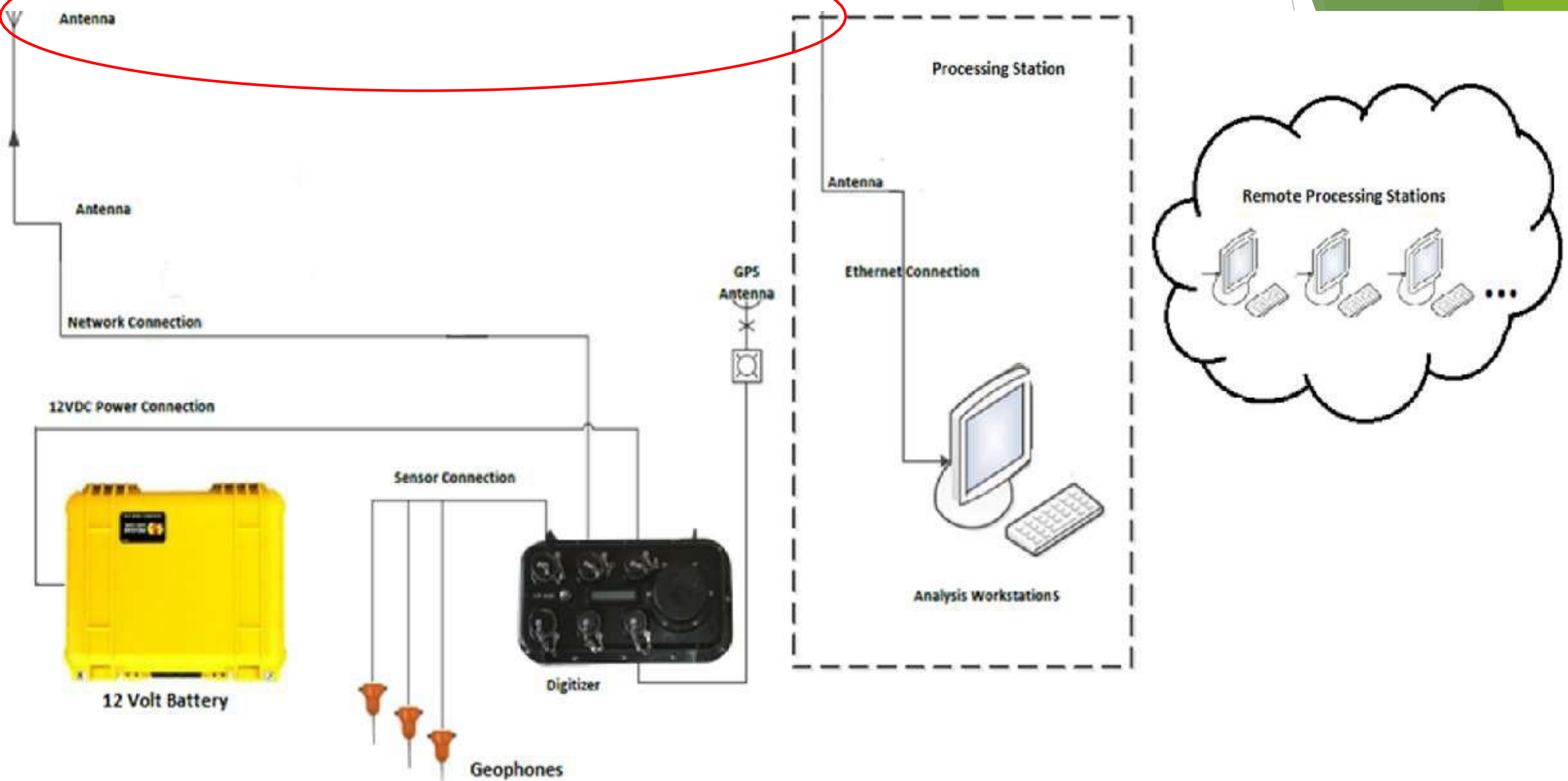
February 7, 1889 - April 4, 1976

Harry Nyquist was a Swedish-born American electronic engineer who made important contributions to communication theory

Digital Acquisition Unit

- ▶ 1000 samples per second
- ▶ Nyquist Theorem
 - ▶ The Nyquist Theorem, also known as the sampling theorem, is a principle that engineers follow in the digitization of analog signals. For analog-to-digital conversion (ADC) to result in a faithful reproduction of the signal slices, called samples, of the analog waveform must be taken frequently. The number of samples per second is called the sampling rate or sampling frequency.
 - ▶ Suppose the highest frequency component, in hertz, for a given analog signal is f_{\max} . According to the Nyquist Theorem, the sampling rate must be at least $2f_{\max}$, or twice the highest analog frequency component.

Test Setup Diagram



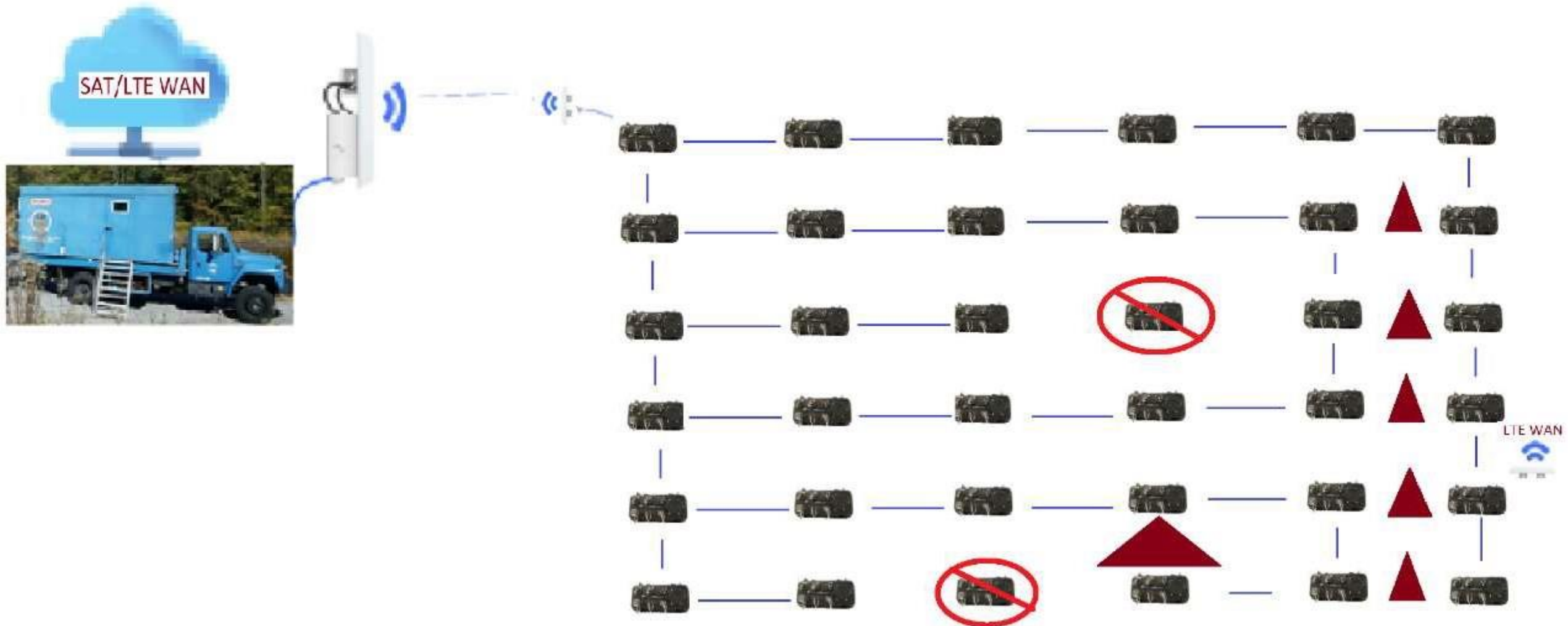
LAN Communications

From Arrays to Primary Processing Station

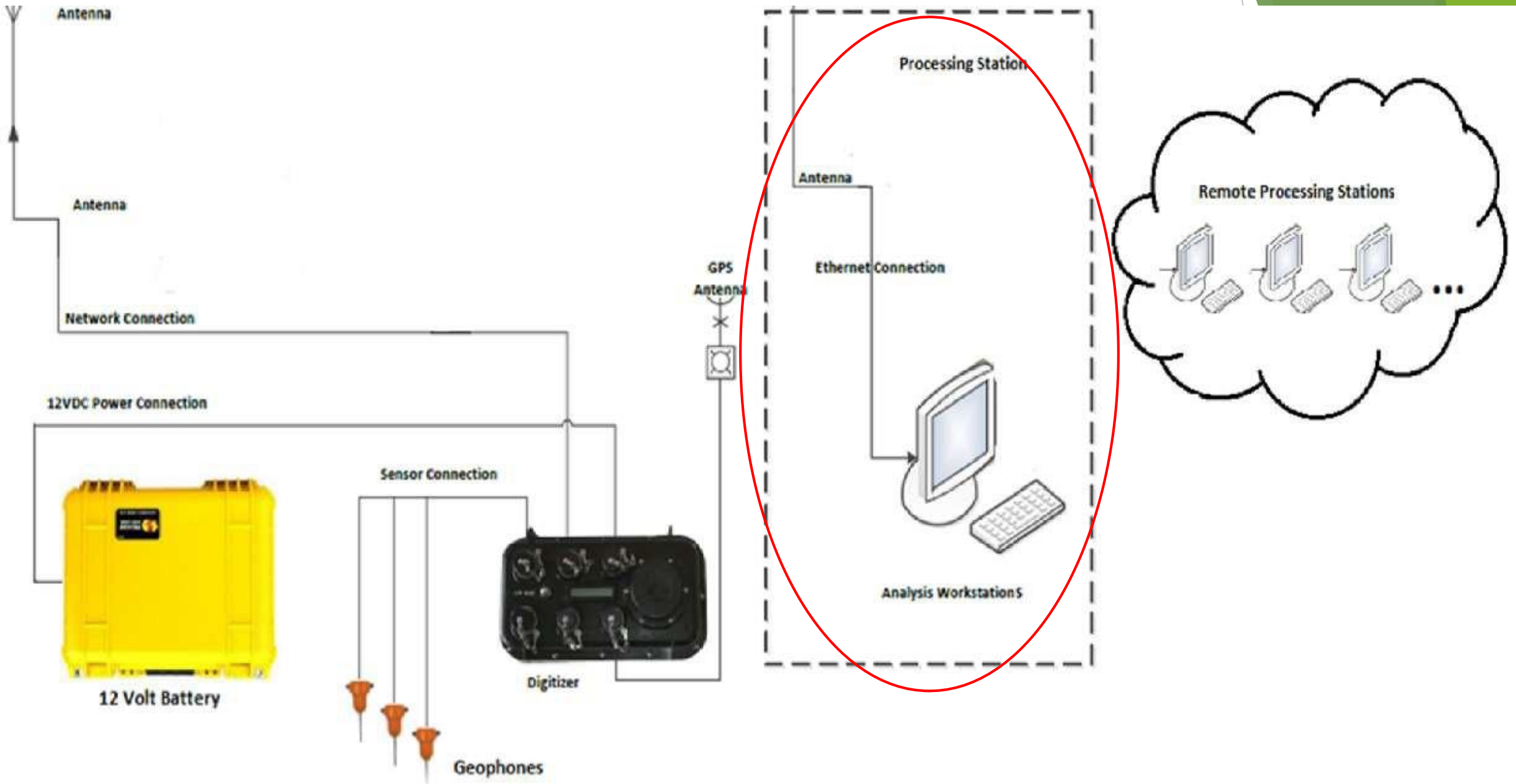
- ▶ Point to multipoint ptmp
- ▶ 902-928Mhz Unlicensed Band
- ▶ Frequency Scanning Anti-interference TDMA



Seismic Network with Self Healing Mesh, Wan mesh injection and Satellite



Test Setup Diagram



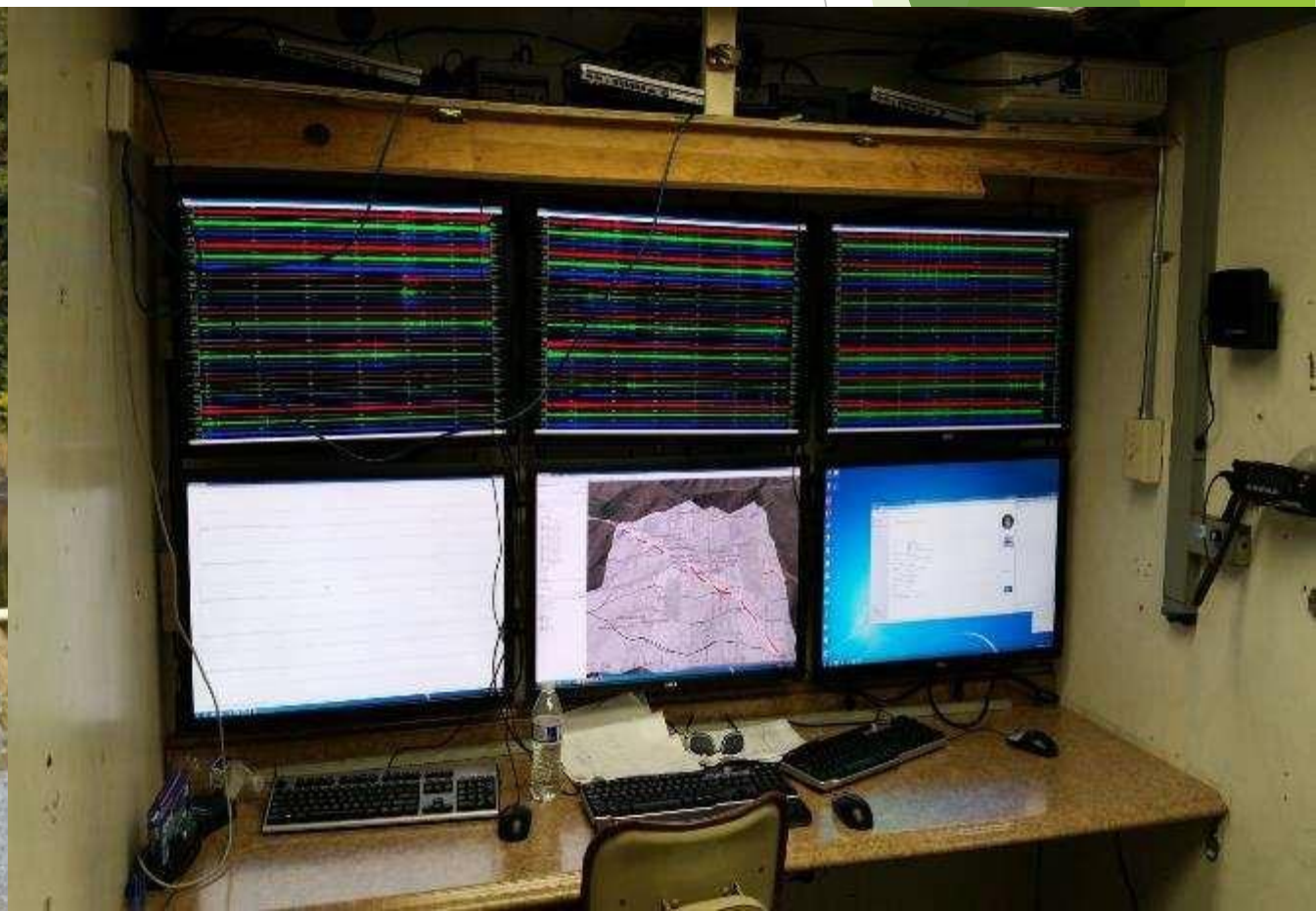
Primary Processing Station

Receive Seismic Data via Base Station Antenna

Process digitized seismic data

Forward data to remote processing stations

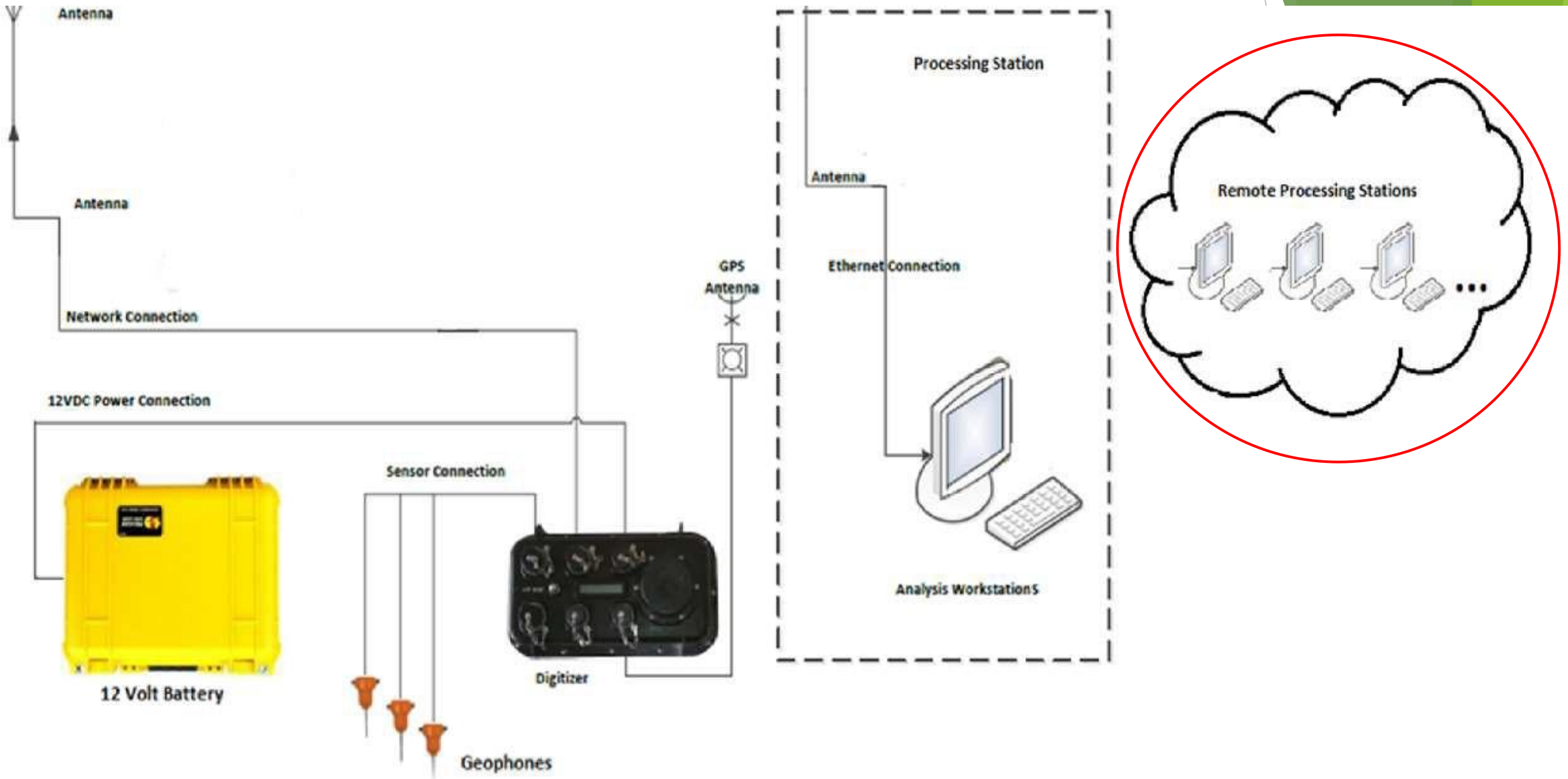
Computers and Monitors for Analysis



WAN Communications

- ▶ Hotspot
- ▶ Mesh injection
- ▶ Satellite
 - ▶ Link to remote processing stations
 - ▶ Supplemental Data
 - ▶ Video/Voice Communications with other Operations

Test Setup Diagram



Remote Processing Stations

- ▶ Process Data
- ▶ From Anywhere



Time Critical Element 1 (Assume trapped Miner)

Site Arrival

We are located in Bruceton, PA approximately 25 mins from Pittsburgh.

Arriving on site quickly is of utmost importance.

We must consider the quickest way to get onsite from Pittsburgh. Options would include driving, commercial flights, and military flights or transport.

Ideally, initial deployment would be accomplished via the nearest MSHA location equipped with a seismic system, a decentralized model to reduce deployment time and increase a miner's chance of survival.

Time Critical Element 2 (Assume trapped Miner)

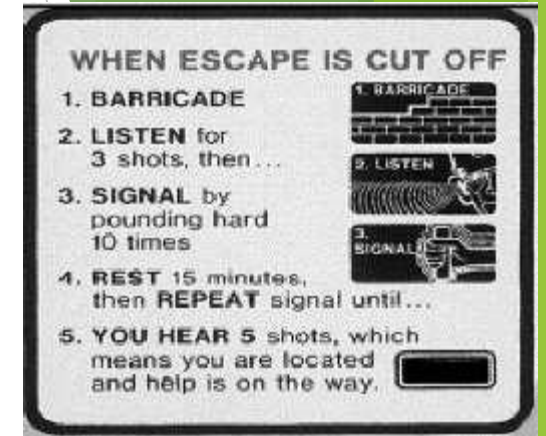
System Deployment

Main factors include:

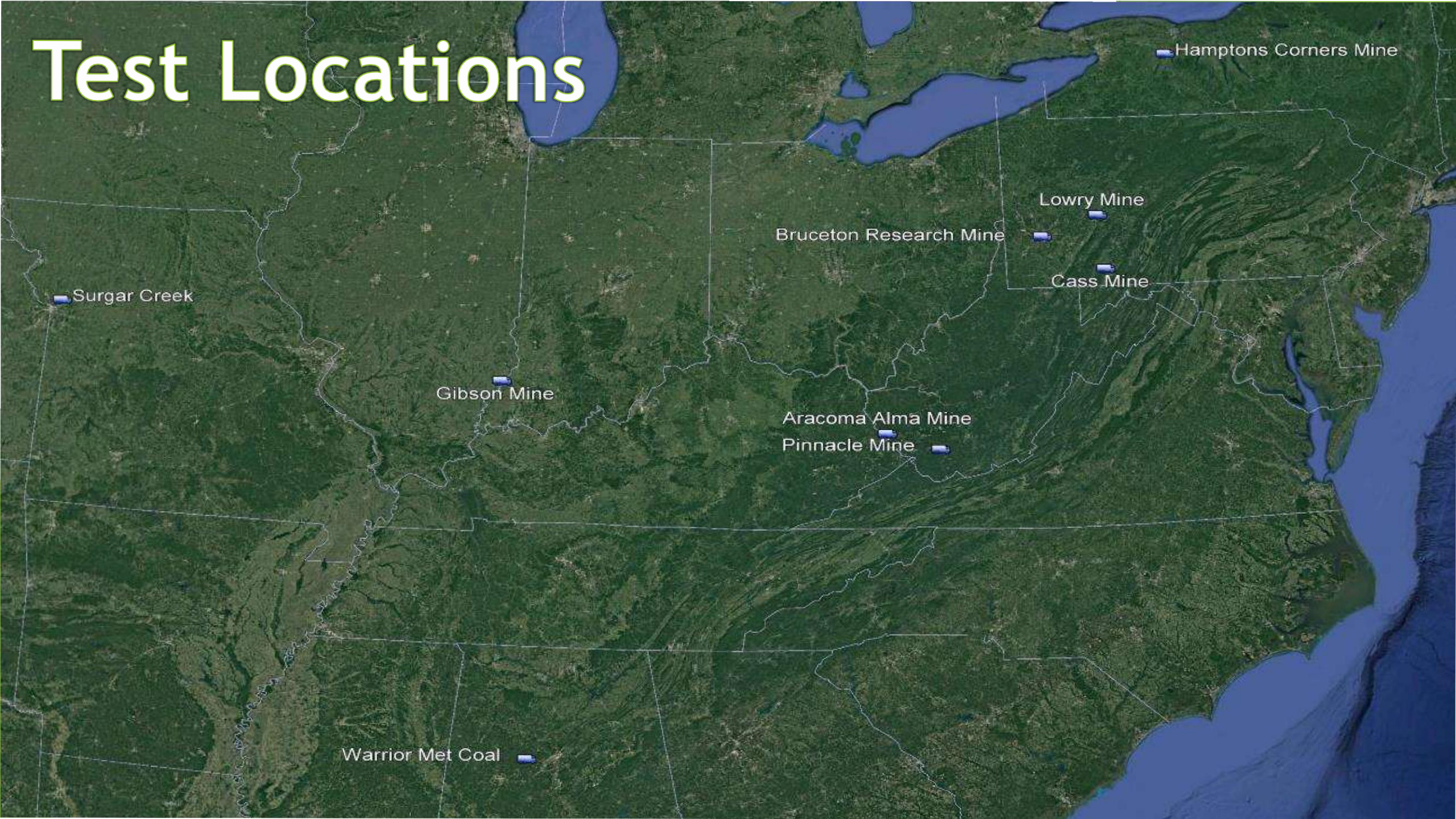
- ▶ Location, Terrain
- ▶ Number of people available
- ▶ Equipment available to supplement deployment, i.e. by foot w/ shovels vs using UTVs, augers, etc.

Time Critical Element 3 - Seismic Generation

- ▶ The system is dependent on a Miner to produce a seismic signal that travels through the earth.
- ▶ Testing has shown that hitting on bare roof produces a good signal. However, it may be beneficial to hit a roof bolt if the roof is loose or sparse.
- ▶ Due to the unpredictable circumstances, miners should be trained to use any available tool to produce a THUD... i.e., powerful low frequency signal. Their life likely depends on it. Training should include examples such as the use of a crib block, front loader, etc... Miners are well known for being creative geniuses. They should be trained with a mind set.
- ▶ Miners also need to be aware of our location and deployment time so they can conserve energy prior to creating a seismic signal - Alternatively, they could wait for us to signal to inform them we are ready to listen - this technique requires testing.
- ▶ We need to decentralize and have at least one person trained per seismic location office to reduce travel/setup time and have all trained personnel process data remotely if not on site during an emergency!
- ▶ Miners do need retrained.



Test Locations



Aracoma

Williamson, WV



Pinnacle

Pineville, WV



Lowry Indiana, PA



Hamptons Corner Geneseo, NY

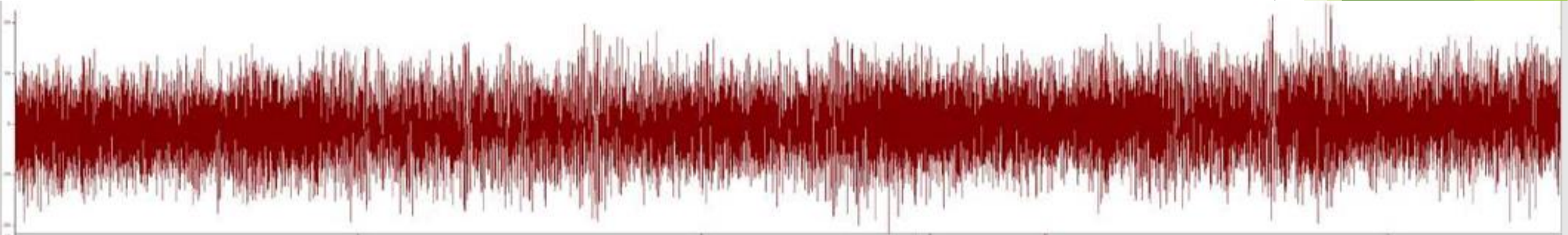


Gibson Princeton, IN



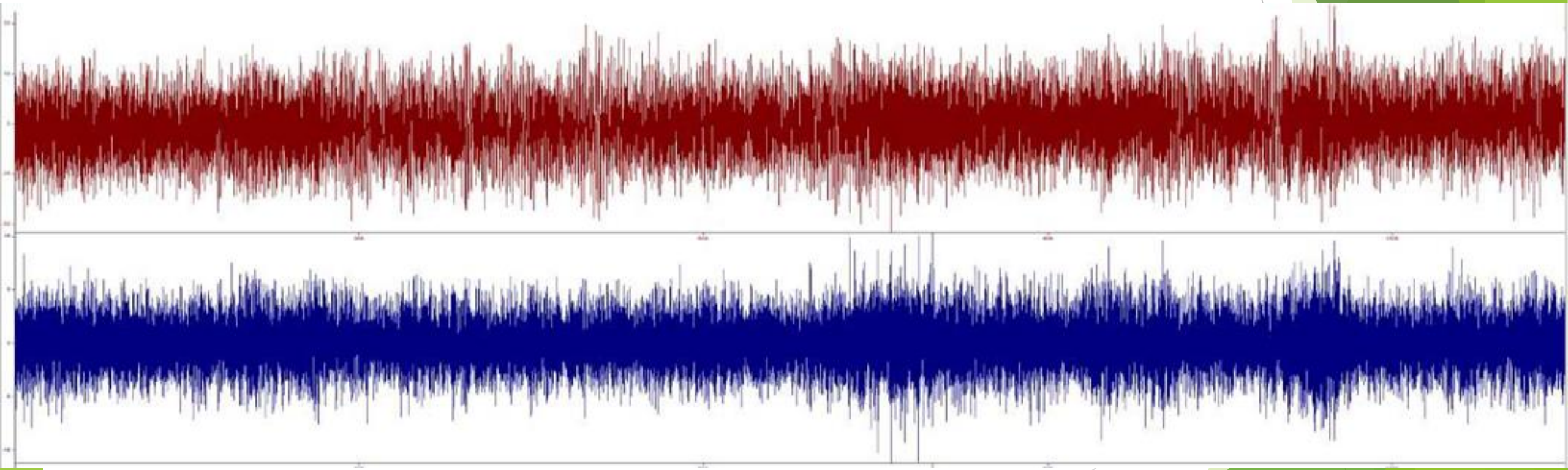
Signals

Seismic data can be processed with digital filtering and noise reduction techniques to hone into the signal of interest, isolating it from other seismic noise in the vicinity.



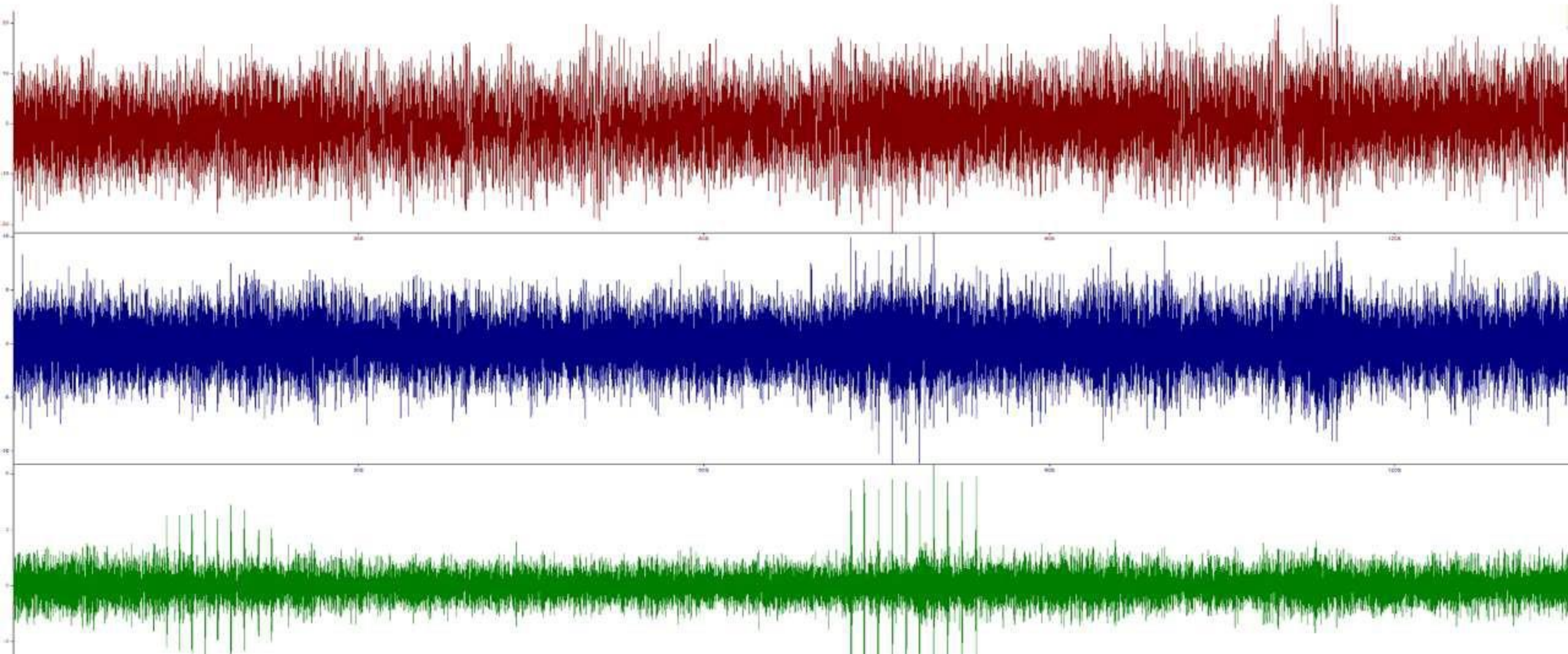
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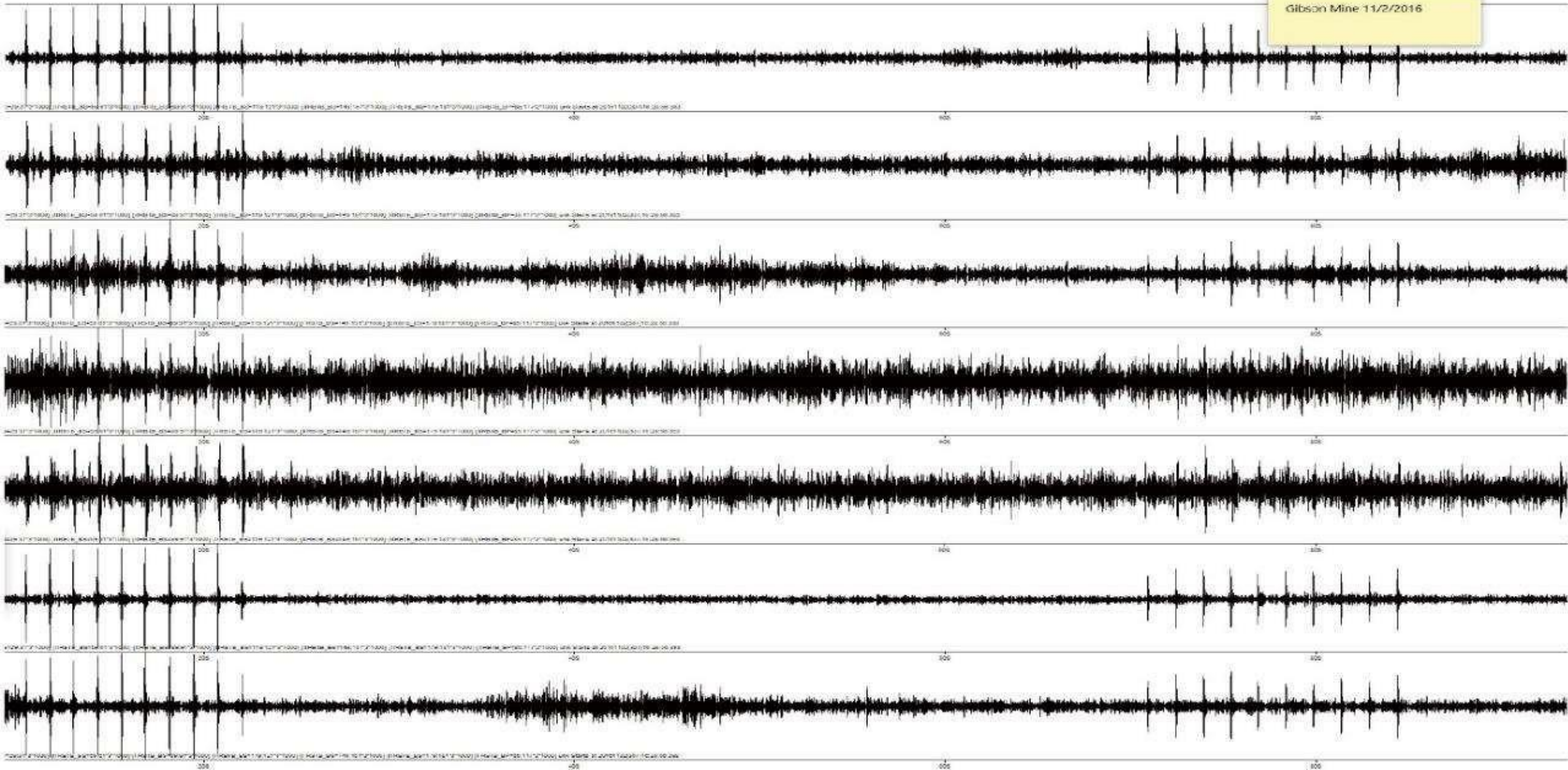
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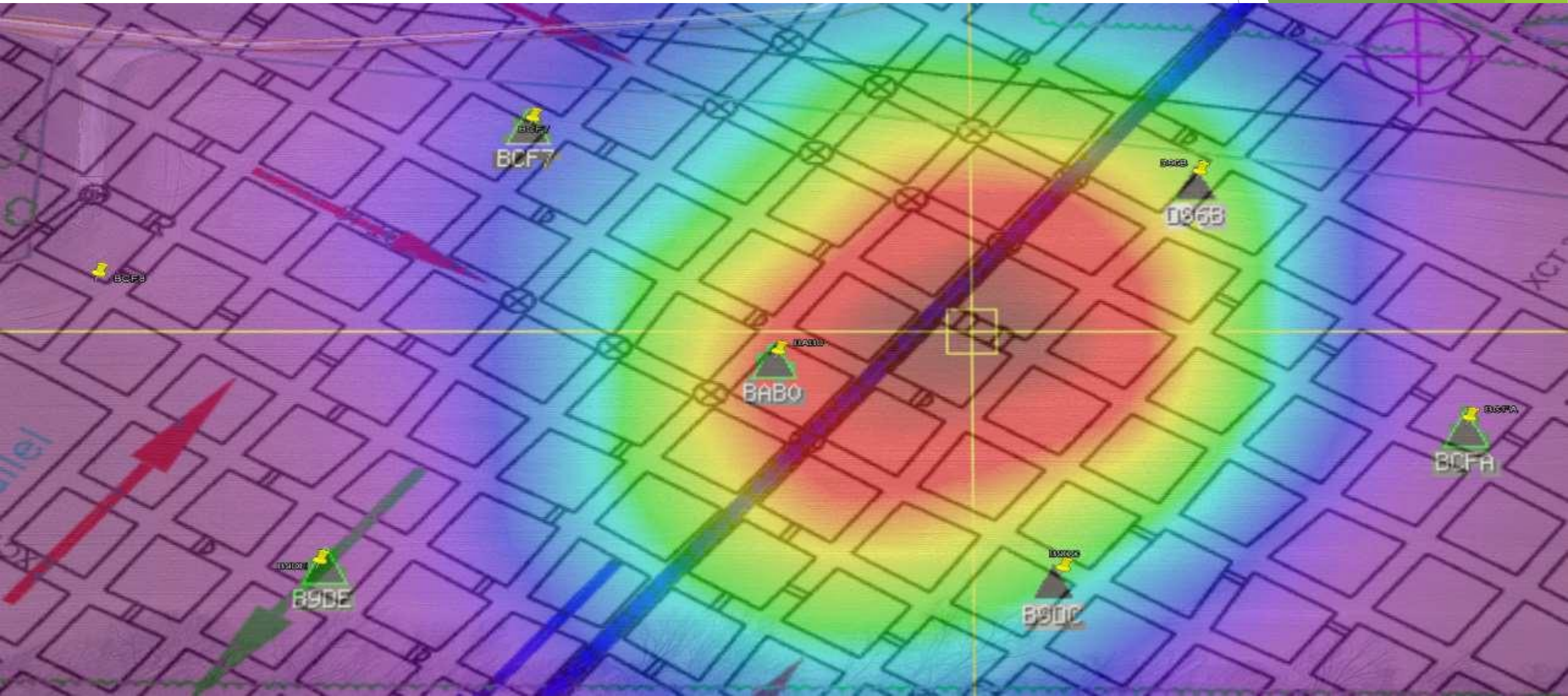
Signals

Gibson Mine 11/2/2016



Mapping and Location

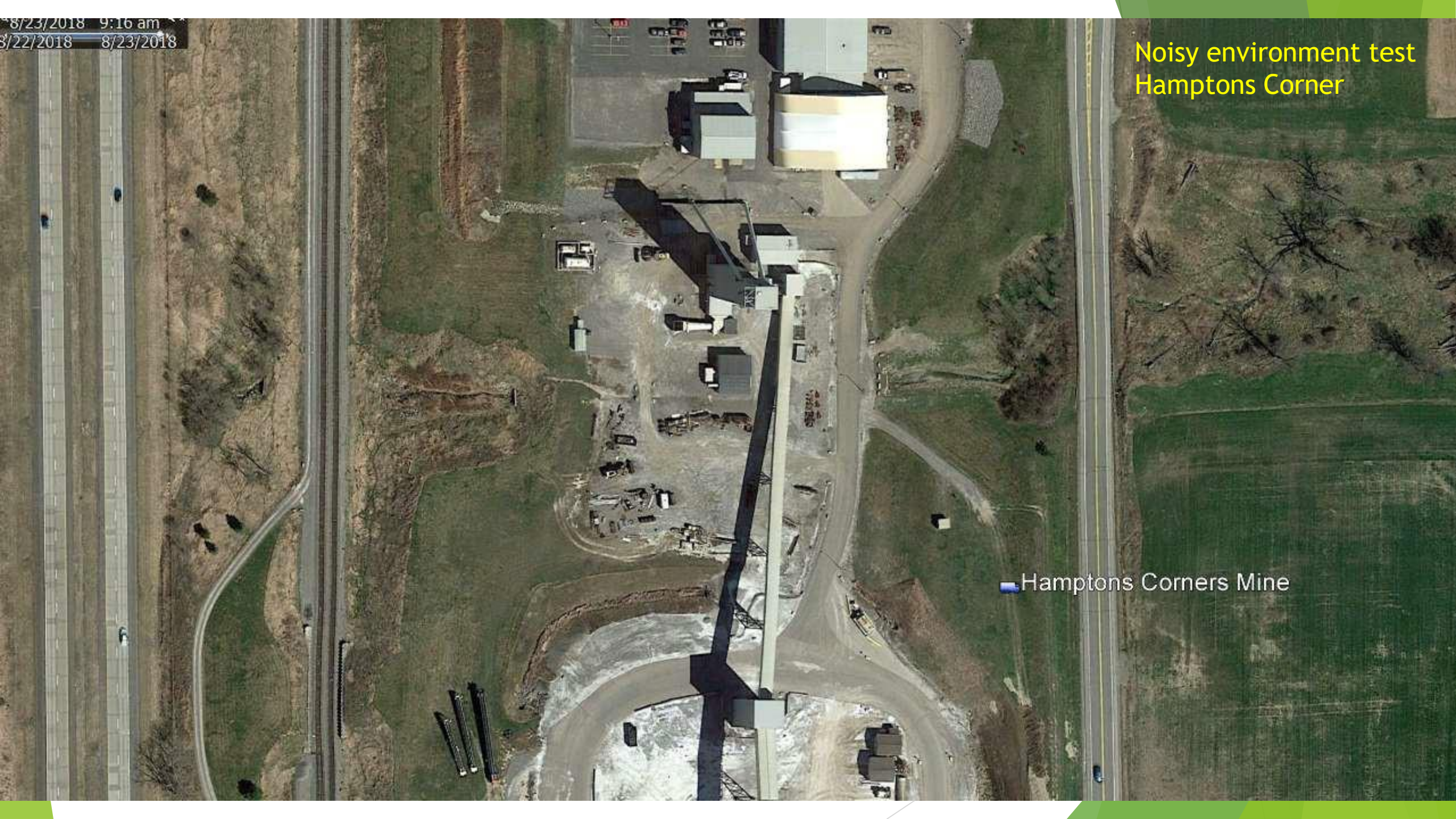
A miners location can be derived based on the seismic signals time difference of arrival and/or beamforming at each subarray.



8/23/2018 9:16 am
8/22/2018 8/23/2018

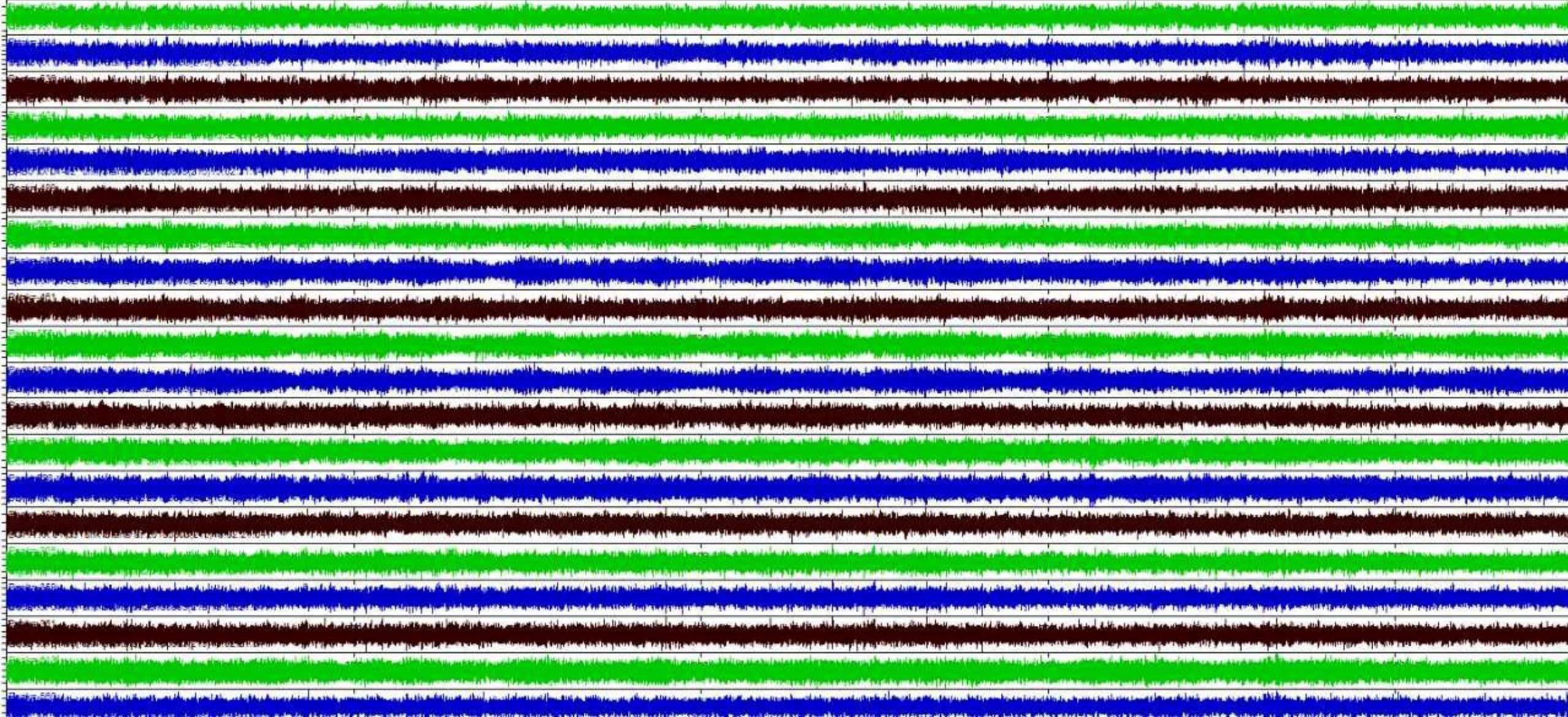
Noisy environment test
Hamptons Corner

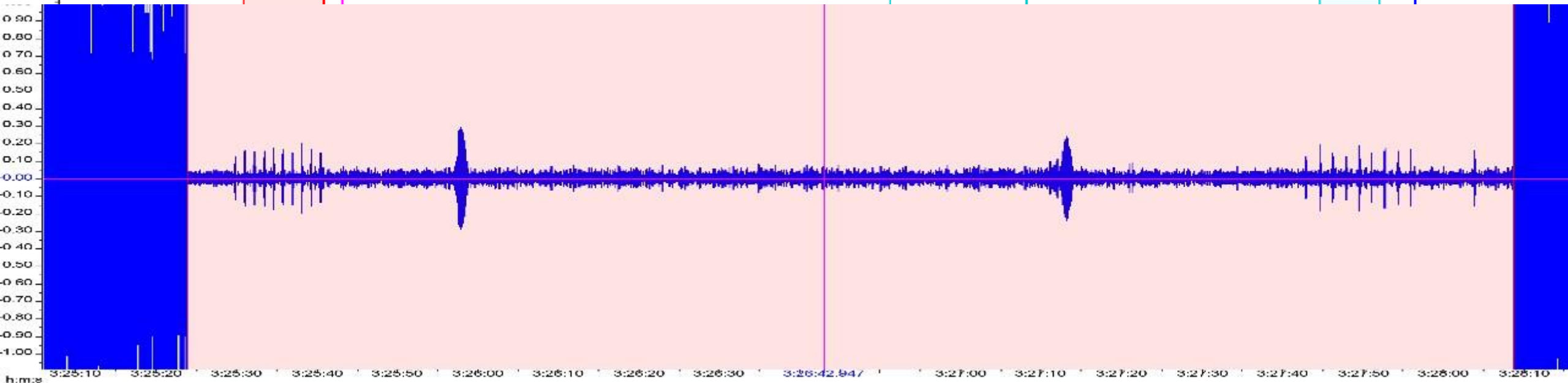
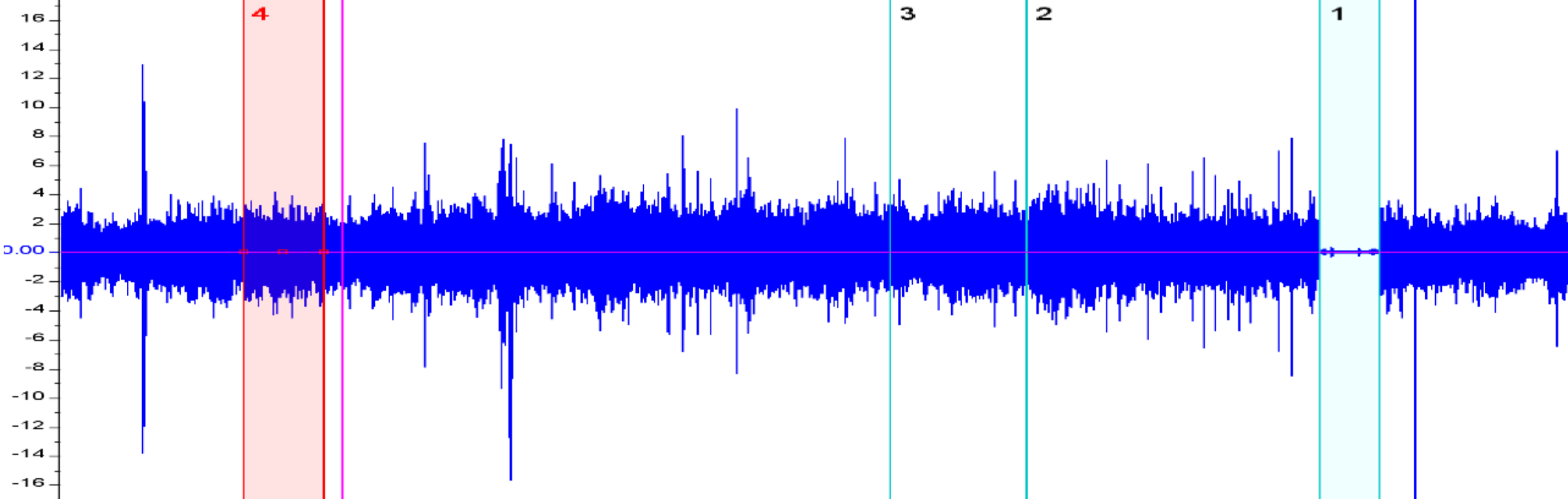
Hamptons Corners Mine



Typical Starting Point

Typically in deeper mines or mines with a lot of noise, reduction and filtering techniques will be required to extract the signals from within the noise.





Tham Luang Nang Non cave
Chiang Rai province Thailand



Cave entrance

Base Where group may be located

Approximately 6 mile drive from the cave entrance
to a possible seismic base.

Elevation profile from approx. 1350ft to 3400ft



1000ft from possible seismic base to the believed location of the boys.

Elevation profile from approx. 3400ft to 3700ft

Where group may be located

59 ft ↓ 0.0%

Image © 2018 DigitalGlobe

Image © 2018 CNES / Airbus

Google earth

Imagery Date: 11/15/2017 lat 20.374097° lon -99.849218° elev 3213 ft eye alt 5039 ft



How to Signal from inside the cave?

- ▶ Seismic signals could have originated from pounding or other means. The initial plan was to evaluate the possibility of having one of the divers signal once inside or bring in a signaling device located on site.

Seismic Tests

Aracoma Alma Mine – Williamson, WV

Overburden of 350ft

Pinnacle Mine – Pineville, WV

Overburden of 1,100ft

Sugar Creek - Kansas City, MO

Overburden of 120ft

Cass #1 Mine – Garrett, PA

Overburden 200ft

Hamptons Corner Mine – Mt. Morris, NY

Overburden 1,300ft

Lowry – Homer City, PA

Overburden 400ft, interseam mine at 200ft

Gibson Mine – Carmel, IN

Overburden of 500ft

Warrior Met Coal – Adger, AL

Overburden of 1700ft

PSHTC – Bruceton, PA

Overburden of 100ft

“If all other means of communications fail in the event of a mine disaster and you are trapped underground, we will be listening for you.”

Contact Information

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