



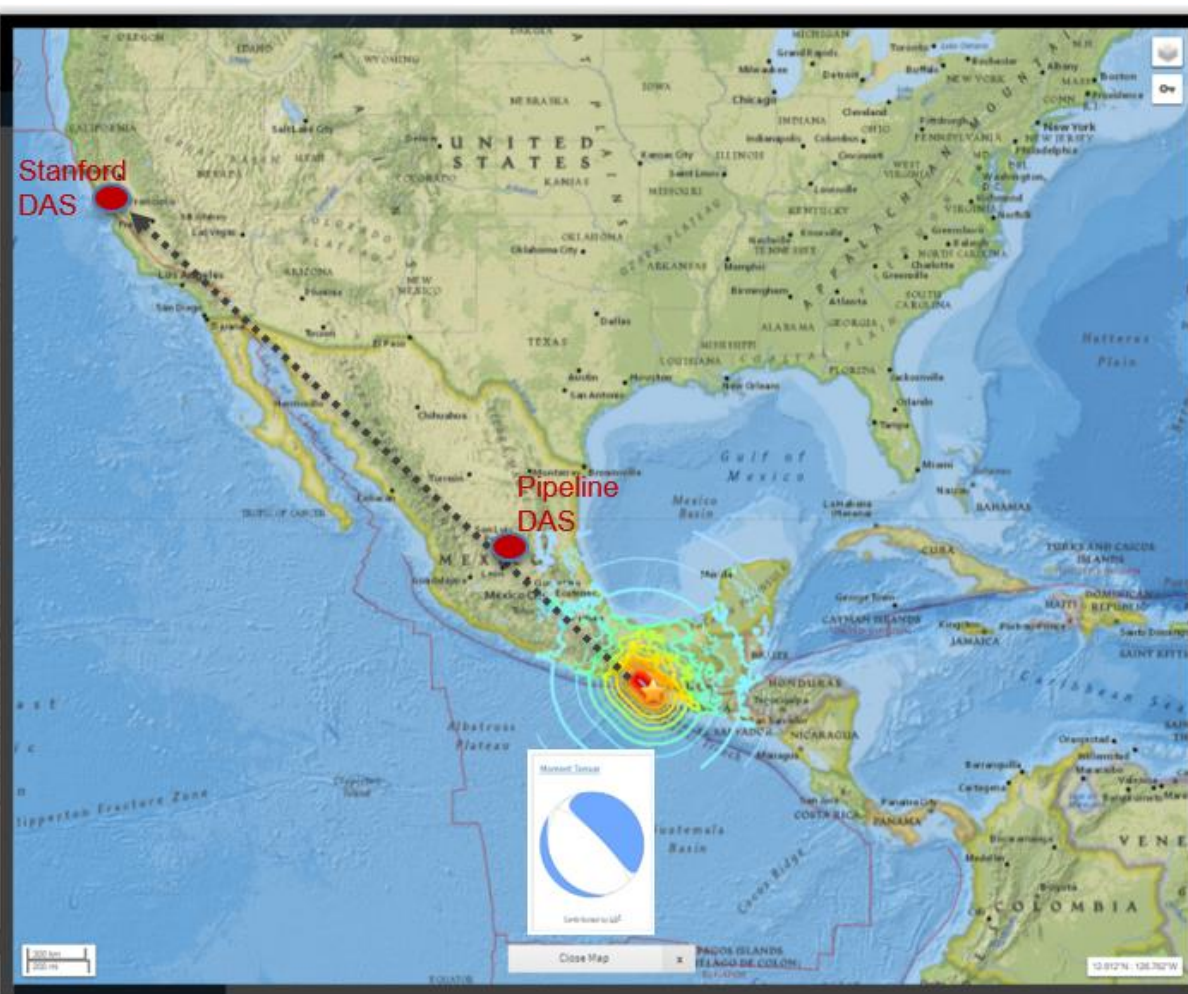
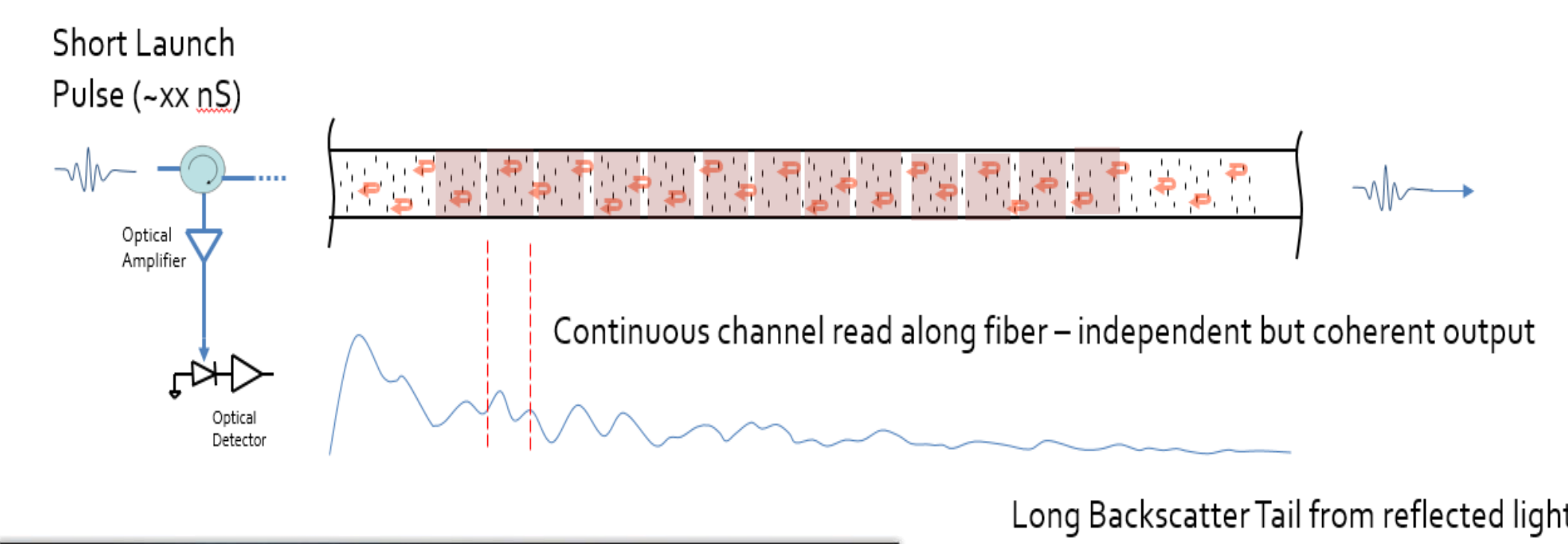
**ABSTRACT**

Distributed Fiber-Optic Sensors (DFOS) for Seismic monitoring are commonly used to understand seismic profiles in well bores and in one dimensional surface measurements. Recently they have been used to monitor and measure the effect of earthquakes with the prospect of exploiting existing telecoms infrastructure as an early warning system for seismicity in the San Andreas fault systems. Advances in interrogator design increase the performance of such devices by lowering the system noise floor in the long-period (sub-Hz) region with dedicated designs indicating a route to performance significantly below the general seismic noise floor. A typical sensor can deliver ~40km of quantitative strain sensing with ~10m resolution. Additionally, ~25,000km of installed monitoring capability now exists of installed simpler vibrational monitoring capability in a wide range of geographic locations with extended baselines that routinely delivers earthquake evidence to asset owners such as pipelines or railroads.

We propose to 1) augment the standard CTBT network with pre-existing sensor networks to assist with origin time and epicenter estimation and 2) provide dedicated high-sensitivity and dense-sampling sensors that could surpass the capabilities of existing point sensors/arrays and achieve large spatial coverage with a lower through-life cost for full explosion analysis.

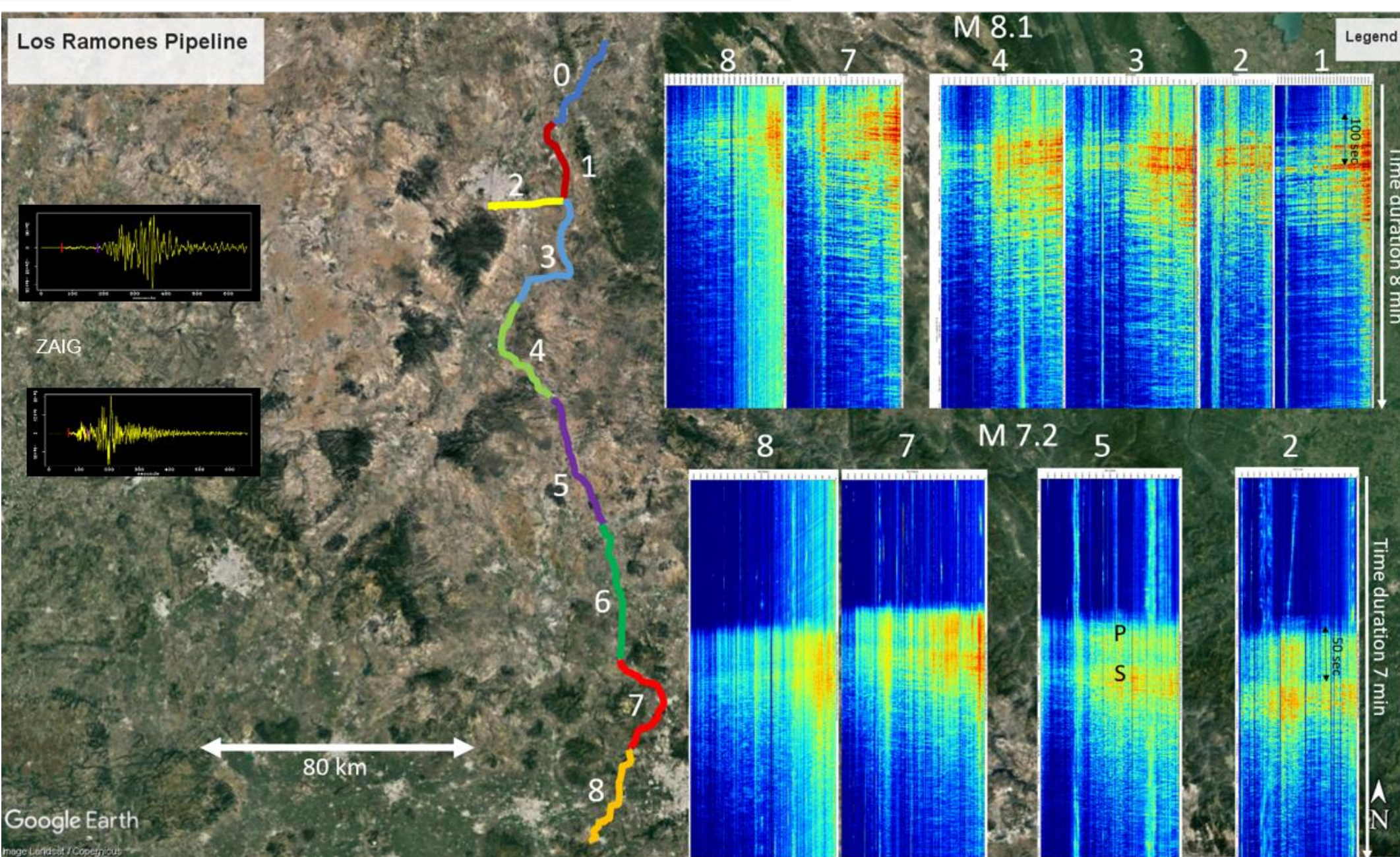
**INTRODUCTION TO DISTRIBUTED SENSING**

In a Distributed Rayleigh Backscatter Sensing (DRS) pulses of light are transmitted by an interrogation unit (IU) into a standard telecoms optical fiber. A small fraction of the light is reflected from the fiber and returns to the IU. The transmitted light is designed to create a series of virtual interferometers that each cover a certain section of fiber, typically 2-100m long. The system is able to measure fiber length changes of the order of an atomic radius as well as acoustic or vibrational signals in each such section of the fiber, with a typical frequency range of 0-1000 Hz, delivering thousands of sequential sensors in each 40km cable.



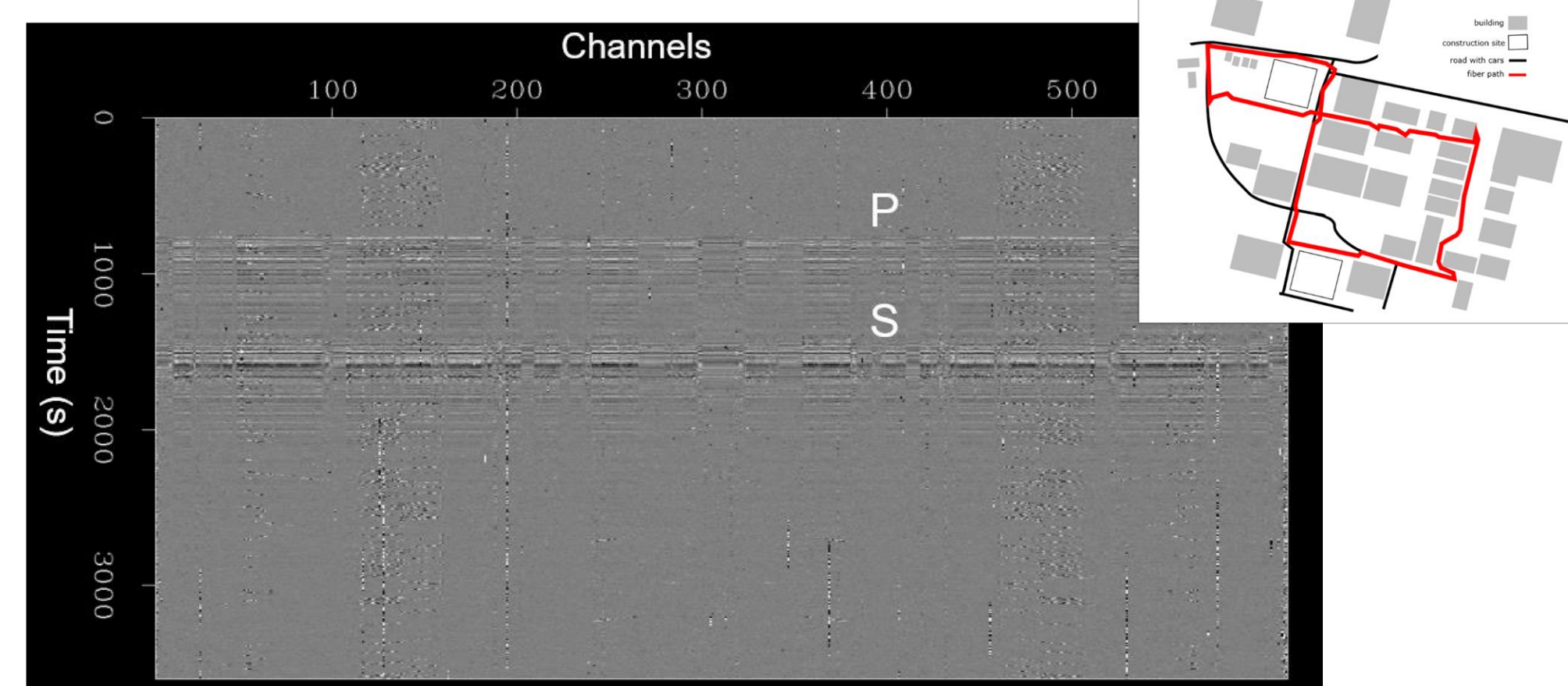
M8.1 Mexico earthquake with source mechanism inversion.

Closer to the epicenter a 30,000 channel array next to a pipeline, detects and records accurate arrival times of M8.1 and 7.2 earthquakes.

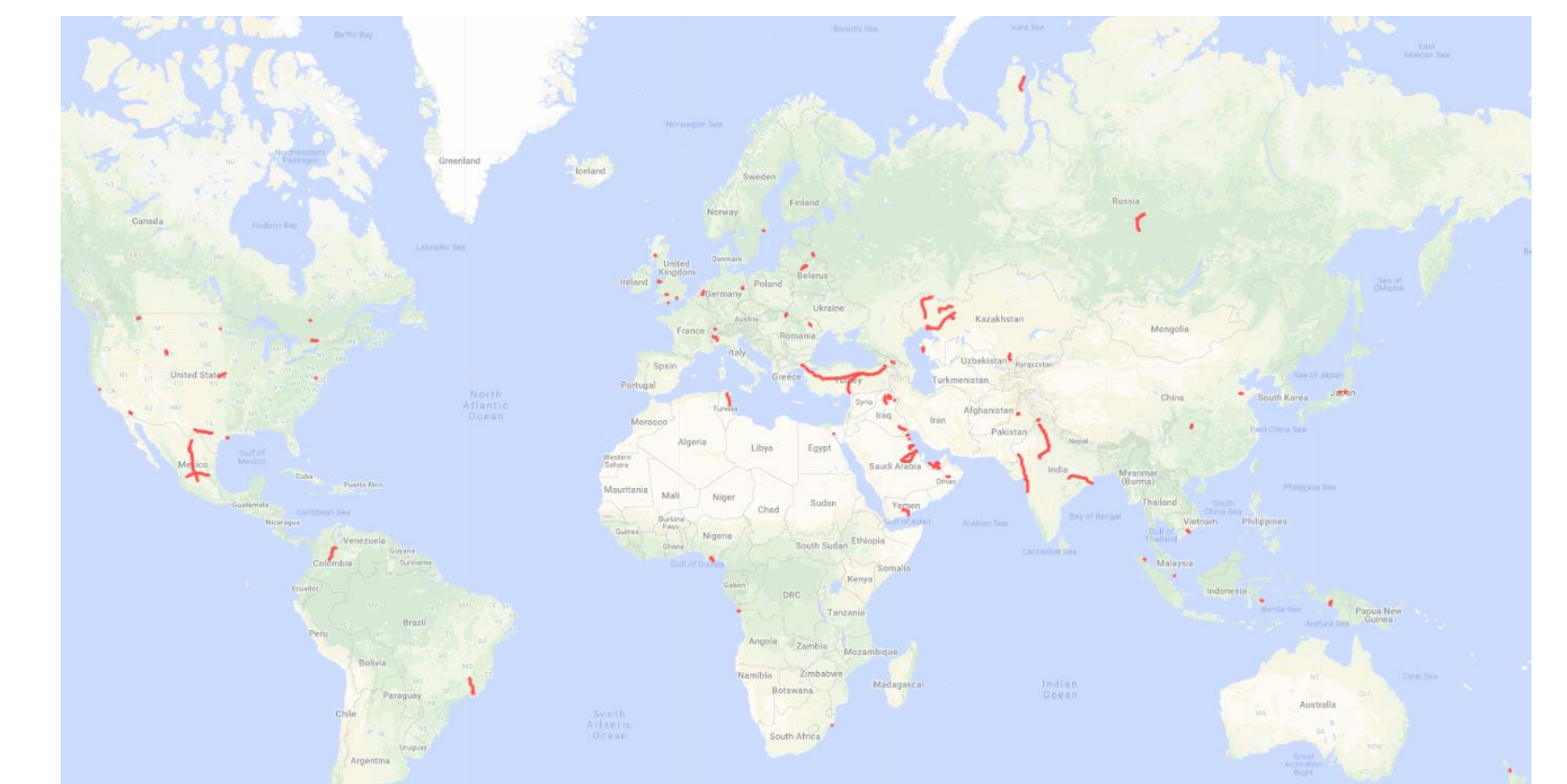
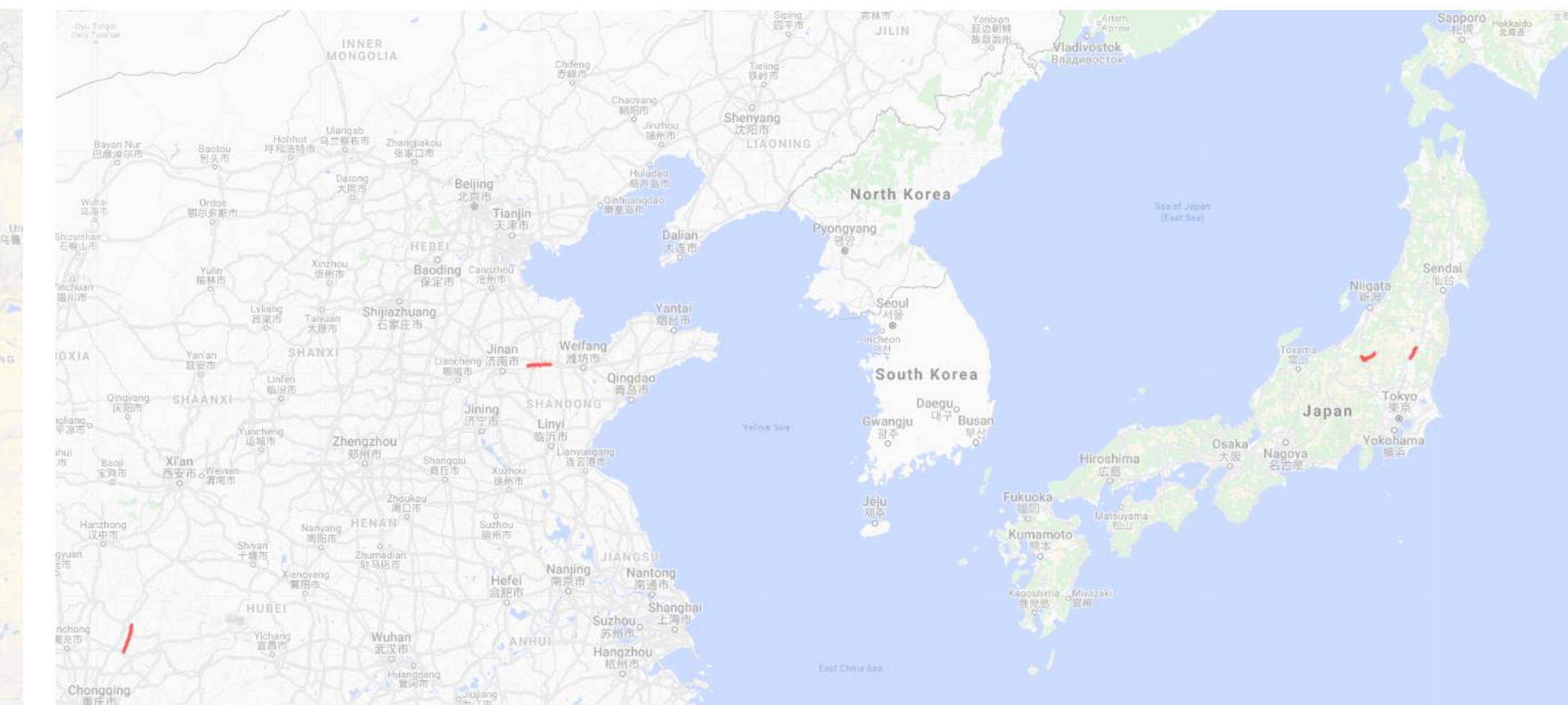
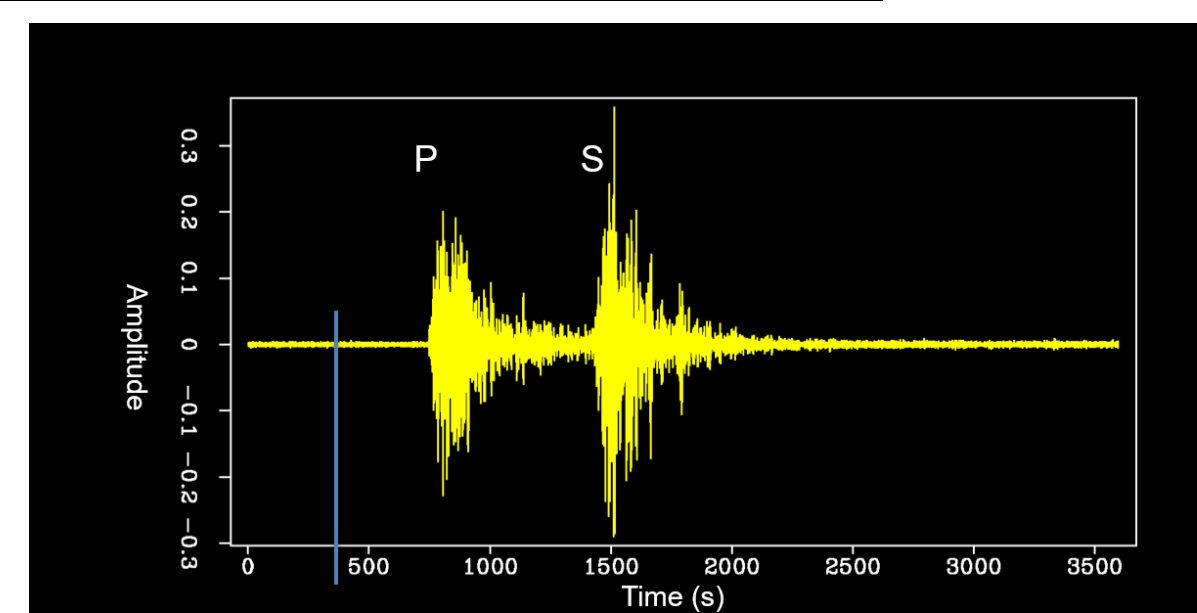


**Estimation of Event Location, Origin time and Source Mechanism**

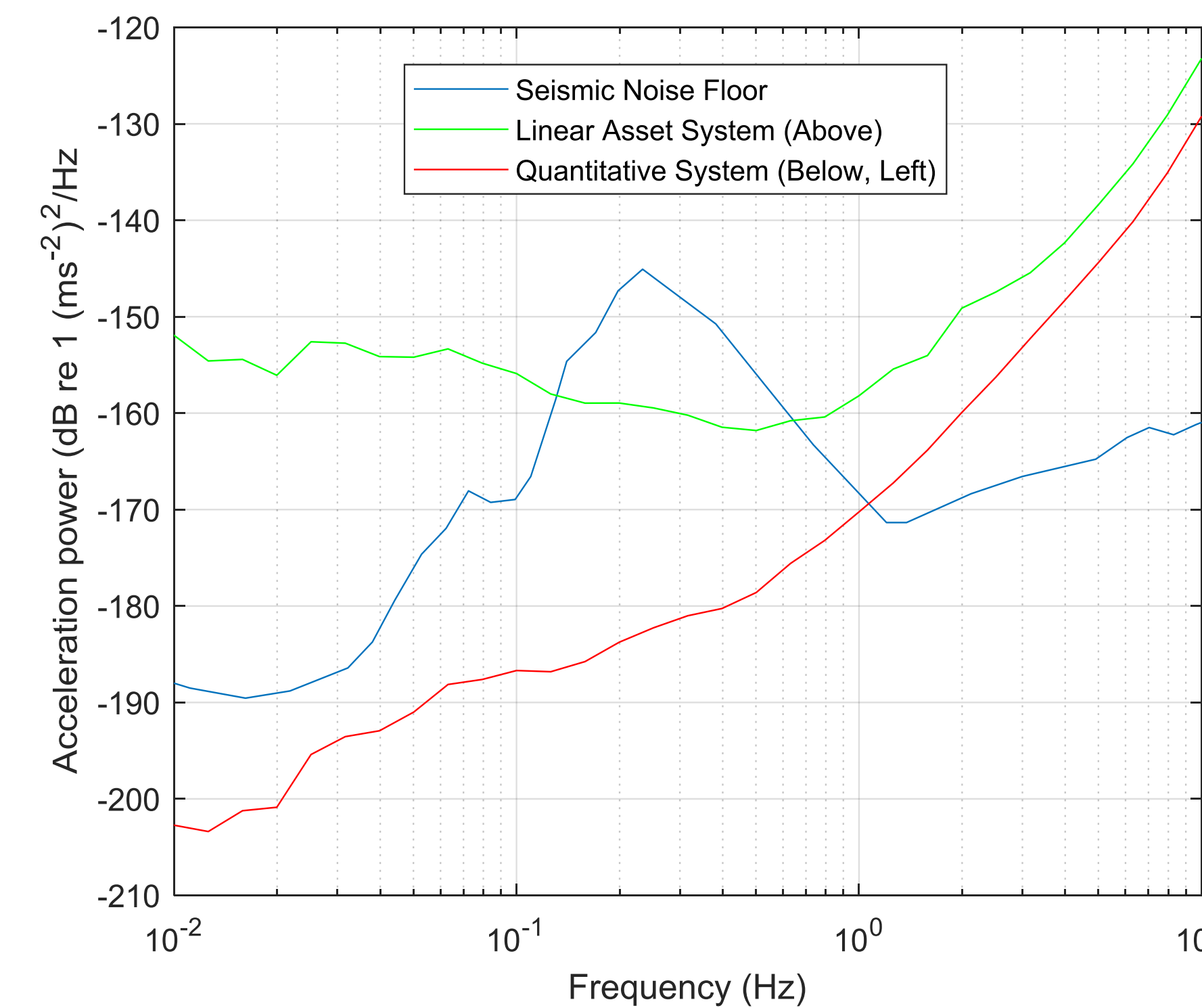
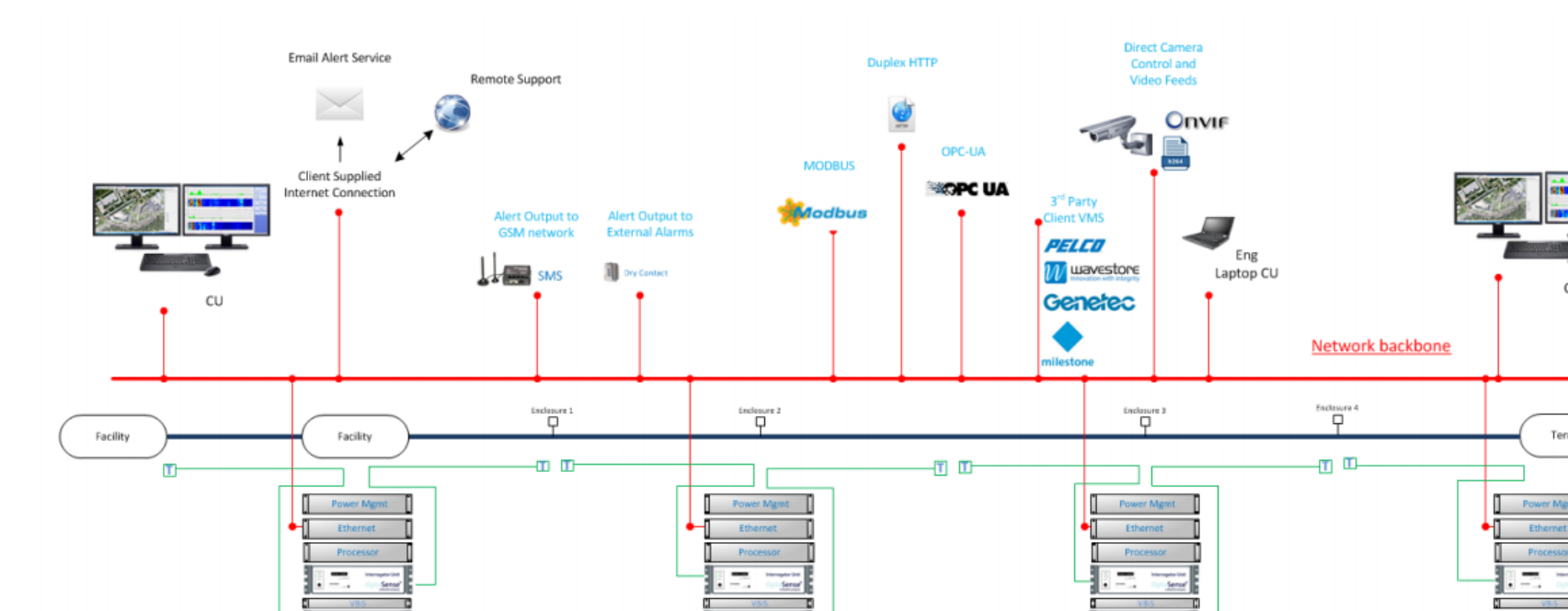
Sets of exiting global network stations are traditionally used for event detection, timing, location and source mechanism estimation. While the coverage is global, usually the individual stations tend to be far from the event itself. Utilizing distributed fiber-optic sensors in large numbers could provide better coverage and improve origin time and location estimation. The fiber-optic systems can be used as coherent sensor arrays, allowing us to apply array processing algorithms to enhance arrival signals and provide high-resolution estimates of arriving wave forms. Accurate time picks can be provided as additional input to the standard epicenter location algorithms. Accurate amplitude information can provide additional input to moment tensor inversion in source mechanism estimations for discrimination between earthquakes and nuclear explosions.



A consistent signal is observed across the 600 channel sensor array, and array-processed single trace.



Distributed, Extended Architecture of sensor coverage



The map above shows the locations where the OptaSense systems are currently being used to monitor linear assets such as roads, pipelines and railways lines. They are operated in many different global locations including some where nuclear tests might potentially be carried out. Data could be easily extracted from these existing systems as an initial demonstration of their seismic monitoring capability, while higher quality data could be obtained by installing additional quantitative interrogation units in an array.

**SYSTEM NOISE FLOOR**

The system noise of our DAS systems are compared with the seismic background as measured by the Global Seismographic Network (GSN).

Our existing linear asset systems have a noise level below the seismic background between 0.1 and 0.5Hz and in all frequencies benefits from their very long baseline.

A next-gen quantitative system, will have a much lower noise floor especially at lower frequencies. It is predicted that this will be below the seismic background for all frequencies below 1 Hz.

**CONCLUSIONS**

- Distributed Acoustic Sensing using fiber-optic cables can be used as a long baseline sensor system to measure low frequency seismic strain signals with exceptional sensitivity.
- Opportunistic data is available to give more precise and definitive information of the origin of seismic signals.
- With more advanced sensors, existing cable, or relatively cheap cable installation can be used to give a unprecedented seismic array of many thousands of sensors covering hundreds or thousands of kilometres.
- At frequencies below 1 Hz, the predicted sensitivity is below the seismic noise floor with appropriate gauge lengths.

**REFERENCES**

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- Berger et al, 2004, Ambient earth noise: A survey of the Global Seismographic Network, JGR, vol 109, B11307.
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