The Monte Cristo Range Mw 6.5 Nodal Geophone Rapid Deployment

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Abstract

The Nevada National Security Site deployed 48 nodal geophones within 34 hours of the Monte Cristo Range (MCR) Mw 6.5 earthquake that occurred at 11:13 UTC May 15, 2020. The first geophone was planted within 16 hours of the main shock and a series of four deployments were conducted to maintain near continuous recording from May 15 – August 19, 2020. The systems were deployed along roads. The main line trending east-west for 15 km and a north-south line running 3 km along Highway 95 with approximately 500 m station spacing. The east-west line parallels a significant section of the ENE striking sinistral mainshock rupture. The systems recorded at 500 sps with orientation of the inline channel to the North and leveled vertically. Each deployment had fewer than two systems fail and collected a half terabyte of data, for a total of two terabytes of data over three months. Much of the energetic aftershock period was recorded on the dedicated nodal array near the main fault offsets of the MCR earthquakes. The main shock and subsequent large events were recorded by an additional nodal array that was already deployed at the Nevada National Security Site (NNSS) at ~200 km epicentral distance. These complementary data sets provide a unique opportunity to demonstrate the use of geophones for deployment and the recording of significant events. The initial review of data shows that for every initial cataloged event there are likely a dozen additional events that can be visually identified on the geophone data. We are developing a micro seismic localization algorithm that detects additional events in the subsurface that do not correspond to published events. We will continue to refine event locations and develop an improved velocity model for the event region.

Deployment

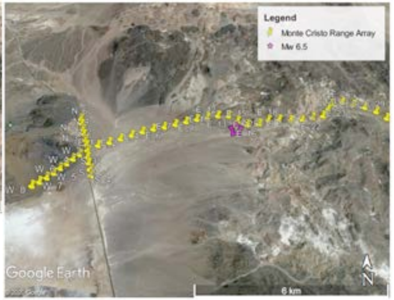
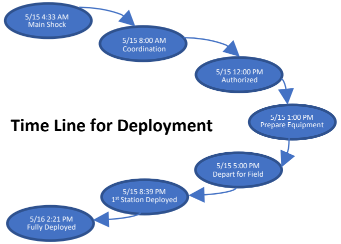


Figure 1. (Top) Relative location of the deployment to Las Vegas, the NNSS, and epicenter. (Right) The nodal geophone deployment with respect to the main shock.



Time Line for Deployment

Figure 2. Typical deployment for the Inova Hawk Nodal system, consisting of a buried Dynamic Technologies DT-Solo 5Hz 3 component geophone (inset), Hawk Data recorder and Lithium Ion battery pack.

Events

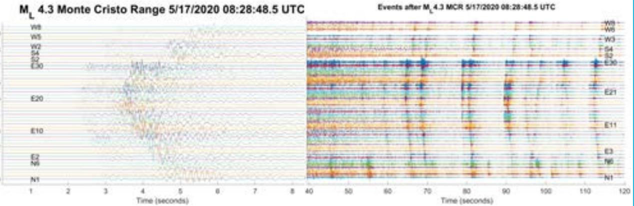


Figure 3. Waveforms from an aftershock (left) from the Monte Cristo Range sequence. (Right) The minute after the aftershock and multiple events that are not cataloged can be visually observed.

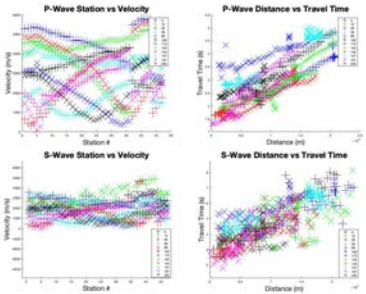


Figure 4. Initial review of P and S Wave picks, plotted versus distance and velocity to each station.

Table 1. Reviewed earthquakes.

Event #	Time	Latitude	Longitude	Depth	ML
3	2020-05-19T00:09:39.034Z	38.1965	-117.7213	8.3	2.6
12	2020-05-19T01:10:01.194Z	38.1778	-117.7907	9.2	1.9
26	2020-05-19T02:13:33.249Z	38.1567	-117.9561	6.7	3.4
39	2020-05-19T03:43:22.820Z	38.1443	-117.8902	8.2	3.5
68	2020-05-19T05:53:22.880Z	38.1918	-117.9583	4.5	2.3
103	2020-05-19T08:26:04.144Z	38.1447	-118.0344	0.1	2.4
113	2020-05-19T09:08:33.875Z	38.1782	-117.8017	10.5	4.3
125	2020-05-19T09:48:50.239Z	38.1368	-118.0631	6.3	3.9
144	2020-05-19T10:58:43.114Z	38.1776	-117.7921	8.4	4
157	2020-05-19T12:38:31.260Z	38.0195	-117.821	17.9	2.3
167	2020-05-19T13:21:34.610Z	38.1681	-117.9551	4.8	3.3
243	2020-05-19T22:12:45.639Z	38.1755	-117.8535	8.1	4.6

Table 2. Deployment schedule.

	On Date	Off Date
Collect 1	May 15, 2020	June 4, 2020
Collect 2	June 4, 2020	June 29, 2020
Collect 3	June 29, 2020	July 20, 2020
Collect 4	July 20, 2020	August 19, 2020

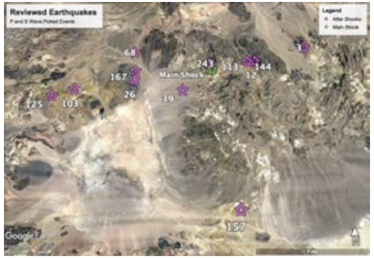


Figure 5. After shocks that were processed for P and S Wave arrival times.

Acknowledgements

The nodal array would not have been possible without Jesse Bonner's vision and dedication to secure the funding to purchase the system. Joe Sears, Jerry Hawe and Tim Rearich all provided support to open the facility, on their day off, to mobilize the equipment. The quick action to approve the deployment by the NNSS Administration was also crucial to make the deployment possible. The deployment was funded by Mission Support and Test Services, LLC and the equipment was purchased under Contract No. DE-NA0003624 with the U.S. Department of Energy National Nuclear Security Administration, for the office of Defense Nuclear Nonproliferation Research and Development (NA-22).

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Additional Data

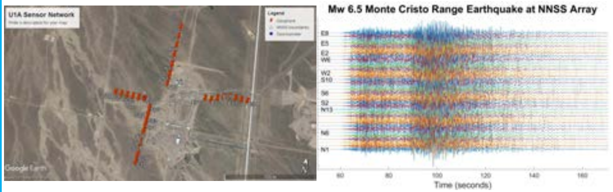

Figure 6. Deployment of Inova Hawks at U1a (left), that captured the main shock (right).

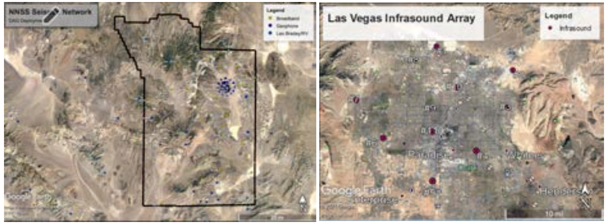

Figure 7. Stations across the NNSS and surrounding area that were recording during the Monte Cristo Range sequence.

Conclusions

Data collected during these deployments will be a wealth of information as we continue to look at how to respond to significant events. As we look to rapidly deployable systems, having a coordination avenue, as well as, the equipment ready to go could provide a substantial savings in time. While the sixteen hours from event to first geophone plant is a typical response, we should be able to reduce the coordination time significantly. This leaves about a four hour equipment preparation and the time to transport to the epicenter as the primary controllers for response time. The initial hours after a major event are when a significant amount of the initial seismicity is generated Comparing our visual observations to the reported events, the geophone network will be able to contribute a significant number of additional events to the locatable database. The multilateration analytic identified potential activity in the subsurface that did not correlate to known events. In addition, the technique demonstrated that longer duration signals may be generated. We will explore these signals to determine if a geophysical explanation can be established to identify the source and mechanism of these correlated events. This data set will provide multiple opportunities to discover new features in earthquake sequences, improve the local velocity model, identify smaller events, constrain the event depths, and develop subsurface imaging techniques.

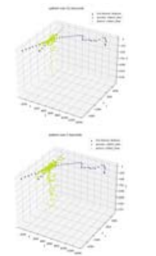

Figure 8. The multilateration correlator results for the 2 second window (left) and 32 second window (right). The majority of the correlations are on the surface, possibly due to traffic in the area. However, there are signals down to 1.5 km in depth.