Verification Testing of Trillium 360
a New Seismometer for Global Seismology

ABSTRACT
Test results for Trillium 360 show this seismometer can resolve the Peterson New Low Noise Model down to 300 seconds period. This has been confirmed at multiple sites: Pifon Flat (California), Albuquerque Seismological Laboratory (New Mexico) and Nanometrics (Ottawa, Canada), and in different types of installations using different unit form factors (see Figure 1). The Pifon Flat deployment captured the March 2, 2016 Mw=7.9 Indonesian event and showed a response coherent with reference sensors including an STS-3 at periods down to 0.0015 Hz. At frequencies below 0.0015 Hz the reference sensors showed a noncoherent spurious response, i.e. noise in the presence of signal, whereas the Trillium 360 was relatively unaffected. Magnetic sensitivity has been measured to be <0.01 m/s/T. This enables low-noise performance even in an urban environment with thick sediments (at Nanometrics, Ottawa) since the seismometer can be emplaced in bedrock below surface sediments and away from surface noise. The T860 seismometer components are sufficiently miniaturized for deployment in a 6” borehole. This enables low-noise performance even in an urban environment with thick sediments (at Nanometrics, Ottawa) since the seismometer can be emplaced in bedrock below surface sediments and away from surface noise. The T860 seismometer components are sufficiently miniaturized for deployment in a 6” borehole. This enables low-noise performance even in an urban environment with thick sediments (at Nanometrics, Ottawa) since the seismometer can be emplaced in bedrock below surface sediments and away from surface noise.

Trillium 360 Borehole at Nanometrics (Ottawa, Canada)

Figure 4 shows total signals (in red) and non-coherent noise of the Trillium 360 seismometer components installed at 30 m depth in nearby boreholes. The coherence of the two signals shown in light blue represents the sum of the noise of the two sensors. Subtracting 3 dB yields the average noise shown in purple. Average noise (purple) is below the Peterson New Low Noise Model (black) down to 300 seconds (0.0033 Hz) and matches well with the Trillium 360 noise specification (green) up to 1.5 Hz. At higher frequencies the distance between the two lines causes some loss of coherence. Note that noise is in reasonable low despite the fact these sensors are installed in a major urban area. This is the benefit of installation depth. At this site noise levels are high within a 15 m surface sediment layer, but good performance is obtained in granite at 30 m.

Earthquake Spectrum at Pifon Flat

Seismometer response to ground motion must be highly linear, to avoid generating noise in the presence of signal. Figure 6 shows the response to a major earthquake at Trillium 360 and other reference sensors installed at Pifon Flat. Signals are well correlated between seismometers, above 1.5 Hz, but at lower frequencies there is a spurious response on some sensors unaffected by the earthquake. The Trillium 360 (black line) is approximately 4x quieter than the reference sensors at the lowest frequencies.

Magnetic Immunity

Immunity to magnetic fields is needed for low noise performance in the presence of solar geomagnetic activity. The USGS-GIR station for a Very Broadband Borehole Seismometer (April 16, 2016) included a specification for magnetic sensitivity of <0.06 m/s/T. The Trillium 360 better this specification by an order of magnitude as shown in Figure 7. Mean sensitivity to vertical field is <0.9, but even lower on X and Y to an accurate measurement was not obtained.

CONCLUSIONS
Availabilty of the Trillium 360 observatory-grade seismometer in Vault, Posthole, and Borehole form factors enables recapitalization of aging equipment and densification of global seismic networks with new stations in a variety of environments, taking advantage of recent advances in seismometry to realize better performance and greater versatility. Performance is enhanced, not only in the essential metric of self-noise, but also in linearity and dynamic range of real earthquake signals, magnetic immunity, and the reduction of surface temperature effects and site noise by means of down-hole or buried deployment.

REFERENCES