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Istituto Nazionale
di Oceanografia e di Geofisica Sperimentale

Technical evaluation of the Cludinico (CLUD) seismic station in relation to the CTBTO draft "Operational Manual for Seismological Monitoring and the International Exchange of Seismological Data"

1. STATUS

General

The Cludinico (CLUD) seismic station is actively part of the North-Eastern Italy seismic network run by the *Istituto Nazionale di Oceanografia e di Geofisica Sperimentale* (OGS). For reference see the OGS Archive System of Instrumental Seismology (OASIS) at the following link: http://oasis.crs.inogs.it/.

Location and access

The station is located in a vault, a former coal mine approximately 300m from the small village of Cludinico at about 600m altitude in the mountain area of the Friuli Venezia Giulia Region. The temperature in the vault is stable at 15°C. The road to the village is accessible all year long. The path from the village to the station however is difficult for the transportation of heavy equipment and occasional snow. The drive from Udine takes approximately 1 h. Following are the location map and the entrance of the vault.

Borgo Grotta Gigante 42/C
34010 Sgonico (Trieste)
Tel. +39 040 2140215
Fax +39 040 327455
Cod. Fisc. E Partita IVA: 00055590327
CEE IT 00055590327
E-mail: mailbox@ogs.trieste.it
http://www.inogs.it

Coordinates

Latitude: 46.4569 N Longitude: 12.8814 E Elevation: 635 m

The station is registered at the International Seismological Center (ISC) station registry:

From: station_reg@isc.ac.uk

To: dpesaresi@inogs.it

Subject: Station Registration for CLUD

Date: Fri, 18 Feb 2011 11:29:45 +0000

Provisional Station Details

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-- Station code: CLUD

-- Station name: Cludinico

-- Region: Italy

-- latitude: 46.4569

-- longitude: 12.8814

-- elevation: 635.00

-- depth: 0.00

-- open: 2011/02/15

-- close:

-- remark: Quanterra Q330 acquisition system Nanometrics Trillium T120 very broad seismometer Kinemetrics Episensor accelerometer station is installed in a vault

-- institution: Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS

-- network: TRI

-- title: Damiano Pesaresi

-- email: dpesaresi@inogs.it

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Instrumentation: data logger

The data acquisition system is a Quanterra Q330 24-bit high resolution with 132 dB dynamic range. The sampling rate is 100 sps. Technical characteristics are shown in Attachment A.

Instrumentation: seismometer

The seismometer is a 3-component broad-band Trillium T120 sec installed on a pier and thermally shielded. Technical characteristics are shown in Appendix B.

Power Supply

The station runs on reliable AC mains. There is limited local backup power supply capabilities.

Data transmission

The station is connected in real time with a satellite link using public IP addresses. Two data links send data to the OGS data center in Udine and to the regional Civil Defense headquarters in Palmanova.

Performances

The station provide data very regularly. Following is a quick check of data availability over the period of one month:

rt@antmac:~$ rtoutage -N -p -s "sta=='CLUD'" -t -z db/ogs 1/1/2018 1/31/2018

CLUD:HHZ 12:34 hours

CLUD:HNZ 12:34 hours

Missing average of 12:34 hours of data from 2 channels (1/1 stations reporting)

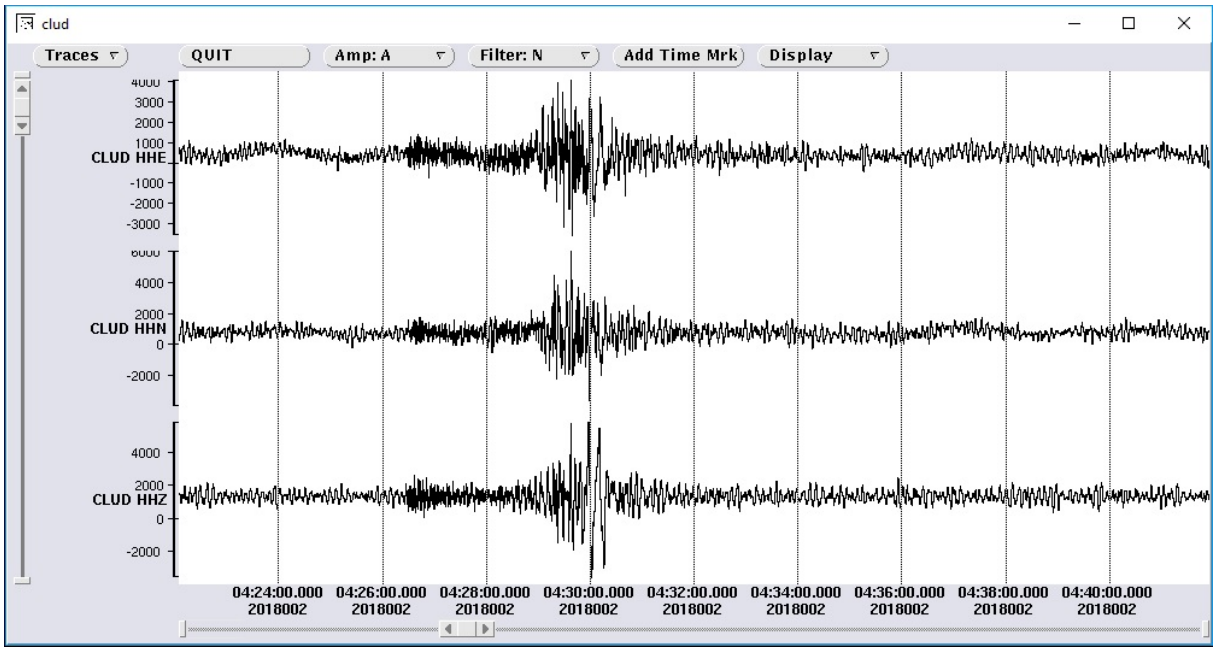
98.25% data recovered over 30 days

Largest gap = 3:11 hours

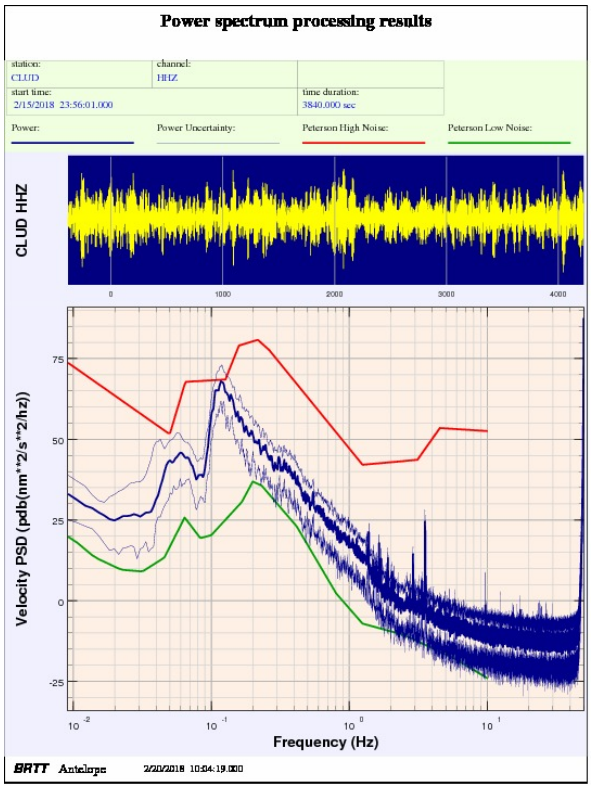
> Network Performance 2592000 seconds

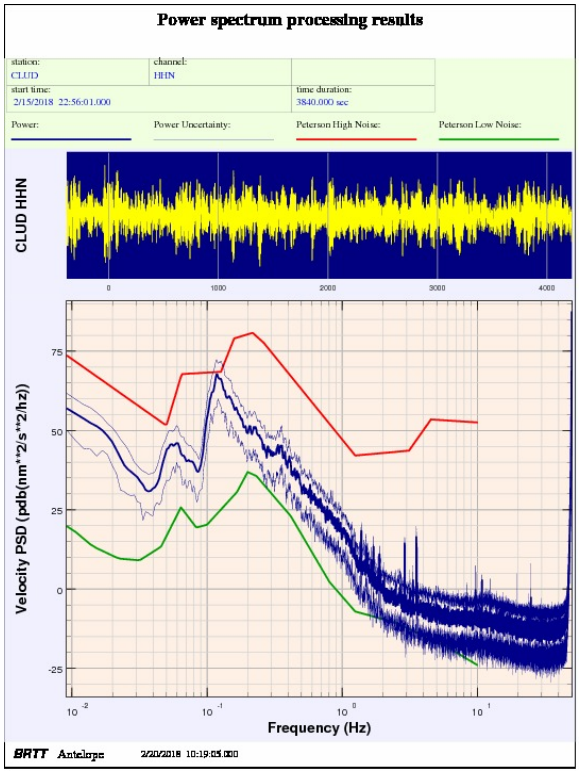
% OX 1 sta 2 chan 90482 seconds **98.25%**

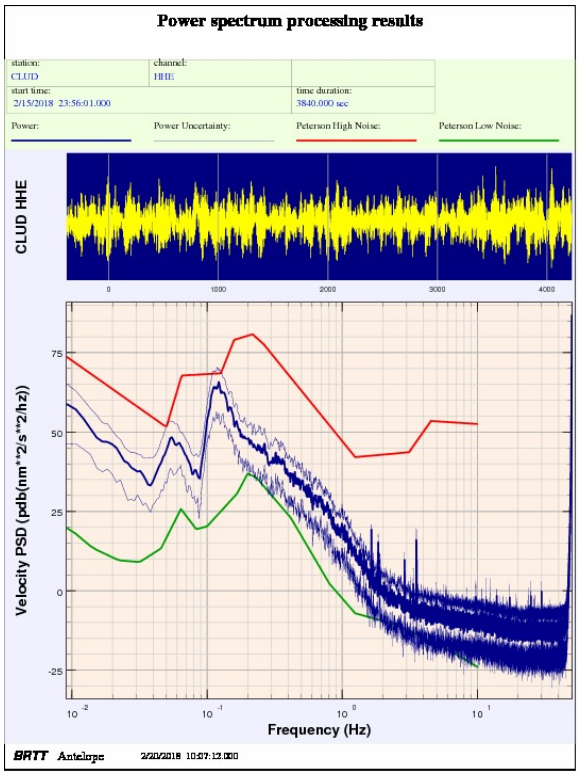
Station routinely contribute to the OGS real time seismic monitoring. Following is the recording of a M=5 earthquake in Greece (data available):



Recorded seismic noise at the station (data available) is shown here for the 3 channels HHZ HHN and HHE:







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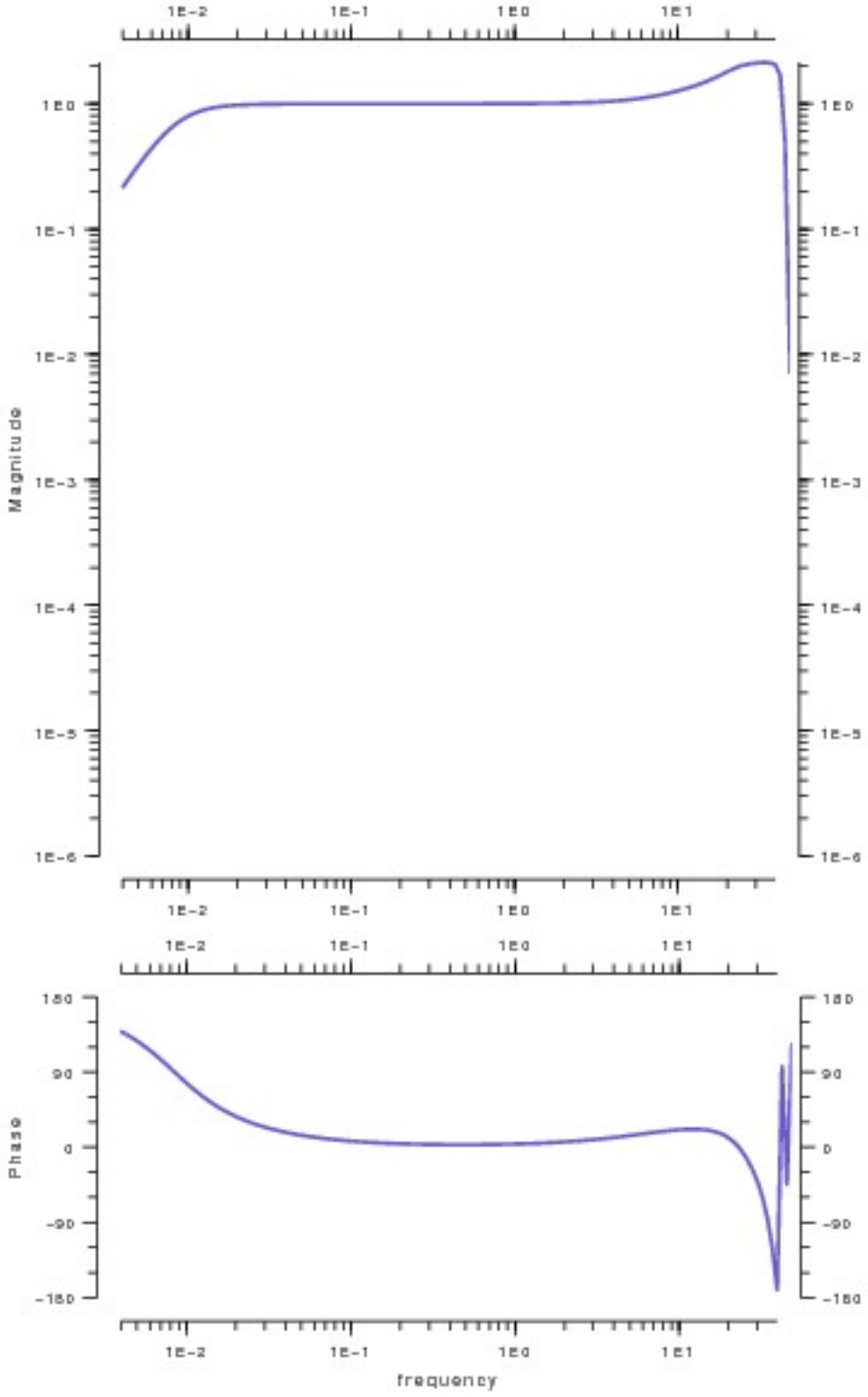
Following is the station velocity response in amplitude and phase:



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2. COMPLIANCE

Instrumentation

Characteristics	*Minimum Requirements*	*Station Characteristics*	*Status*
Sensor type	Seismometer	Nanometric Trillium 120P	OK
Station type	3C or array	3C	OK
Position	Borehole or vault	Vault	OK
3 C Pass Band	SP: 0.5 - 16 Hz + LP: 0.02 - 1 Hz or BB: 0.02 - 16 Hz	BB 0.0083 – 175 Hz	OK
Sensor response	flat to velocity or acceleration over the pass band	Flat to velocity over the passband	OK (see specs and figure above)
Seismometer noise	< 10 dB below minimum-earth noise at the site over the pass band	At least 10 dB below minimum background noise	Noise recordings above and sensor specs, TBC
Calibration	within 5% in amplitude and 5° in phase over the pass band	Better than 5% in amplitude and 5° in phase	OK (Technical specs)
Sampling rate	SP, BB: > 40 samples/s LP: > 4 samples/s	All data channels 100 sps	OK
Resolution	18 dB below the minimum local seismic noise	18 dB below the minimum local seismic noise	Noise recordings above and technical

			specs, TBC
System Noise	< 10 dB below the noise of the seismometer over the pass band	At least 10 dB below the requirement for the sensor over the passband	Noise recordings above and technical specs, TBC
Dynamic range	> 120 dB	> 132 dB	OK (tech spec)
Absolute timing accuracy	≤ 10 ms	< 10 ms	OK (tech spec)
Operation temperature (°C)	-10° C to 45 °C	-20ºC to +50ºC (T120P) -20 to +50° (Q330)	OK (moreover Vault temperature is 15° constant)
Precision on station location	< 100 m absolute for stations (WGS84)	< 100 m	TBC
Seismometer orientation	< 3°	< 3°	OK

Power Supply

Although the station run on reliable AC mains, a better backup system is necessary to handle extra instrumentation (see below).

Data transmission

Station is already equipped with a satellite using public IPs. Therefore, it is here suggested to realize a VPN connection from the station through the existing satellite connection to the International Data Center (IDC) of the CTBTO in Vienna like many other CTBTO IMS stations.

Delay in transmission to IDC	≤ 5 min	< 5 min expected	TBC (existing satellite)

Authentication and data format and protocol

Station is lacking authentication and CTBTO data format and protocol (AutoDRM, CD1.1). Therefore, it is suggested to provide the station with the CTBTO Standard Station Interface (SSI) as many other CTBTO IMS Auxiliary seismic stations, including the Italian AS050 Valguarnera VAE. This shall comply with the Data frame length, Buffer at station or at NDC, Data format, data signature, tamper detection for critical components and the GCI interface as required. Also, it shall allow remote routine calibration as per the characteristic required.

Security

The station instrumentation inside the vault needs a fence to protect it from occasional visitors of the mine. Such a fence could then be equipped with anti-tamper devices.

Others

Works must be done at the station to solve the problem of humidity.

QUANTERRA

Q330

VERY LOW-POWER HIGH-RESOLUTION NETWORK-AWARE SEISMIC SYSTEM

A New Performance Standard

The Q330 is an advanced 3 or 6 channel broad-band, high resolution seismic system incorporating Quanterra's proven IP networking technology into a very low-power field package. The Q330 uses Quanterra's exclusive patented (US Patent 4866442, Japan Patent 2787445, others pending) ultralow-power delta-sigma 24-bit A/D with DSP, 32MB RAM, GPS receiver, power management, sensor command/control, and an advanced telemetry application for reliable data delivery.

Streamlined Remote Administration

The Q330 supports real-time data telemetry to a central site or connection via hard-wire or radio (burst or continuous) to a local low-power recording system, or both simultaneously.

FEATURES

Low Power

Incorporating the latest low-power technology, the Q330 achieves integrated capability with an average power requirement of ~0.5 Watts, including recorder & GPS!

Internet-Ready Industry Standards

The telemetry protocol use industry standard stateless IP communications, enabling the use of off-the-shelf IP equipment and service providers. Serial IP and Ethernet 10BaseT are built-in.

Comprehensive Sensor Control

The Q330 is a seismological instrument, not a digitizer alone. Sensor control interface, including calibration, and sensor identification-tag support is built in.

SPECIFICATIONS

Channels	Standard 6-channel Q330-6
Auxiliary Channels (Opt.)	4/8 DI/SE 16-bit 1sps. Full scale range ±50V
Dynamic Range	132-135 dB wideband RMS typical. Typical band-limited 136 dB
Format	32-bit integer, Level 2 compressed 1-second packets
Input Range	40V P-P at gain=1
Gain	Selectable per channel: 1,30
Filtering	Linear or Minimum Phase FIR.
Sample Rate	200, 100, 50, 40, 20, 10, 1 Other rates available.
Time Base	Precision TCXO, locked to GPS. No adjustment.
DSP/CPU	ADSP-2189M
Telemetry	Full Duplex, efficient positive acknowledge with error control. UDP/IP over serial and Ethernet. Burst or continuous. Operates with major application software.
Temperature	Fully specified -20 to +50° C Operative -40 to +70° C

Continued

QUANTERRA

SPECIFICATIONS

Sensor Control	Calibrate step, sine, or random. Recenter, on-command
Operational Data	Temperature, DC voltage, GPS status, Sensor boom position (6 channnels)
Memory	32MB RAM standard
Network	IEEE 802 10Base-T Ethernet UDP/IP Protocol Stack
Serial Ports	2 serial telemetry and 1 console ports up to 115kbaud.
Wireless	IrDA interface supported.
Power	<0.6 W avg. 12VDC 3-channel <0.8 W avg. 12VDC 6-channel
Physical	Sealed, Aluminum, 14 X 4 X 6 in., 8 lbs., Rubber endcaps, visible status and fault indicators.

USA- 325 Ayer Rd. Harvard, MA
Tel (978) 772-4774 I www.kinemetrics.com
10-10-16

Trillium BROADBAND SEISMOMETER

Trillium 120P

The Trillium 120P is an exceptional seismometer having an instrument self noise 4 dB above the NLNM at 100 seconds and below the NLNM up to 10 Hz.

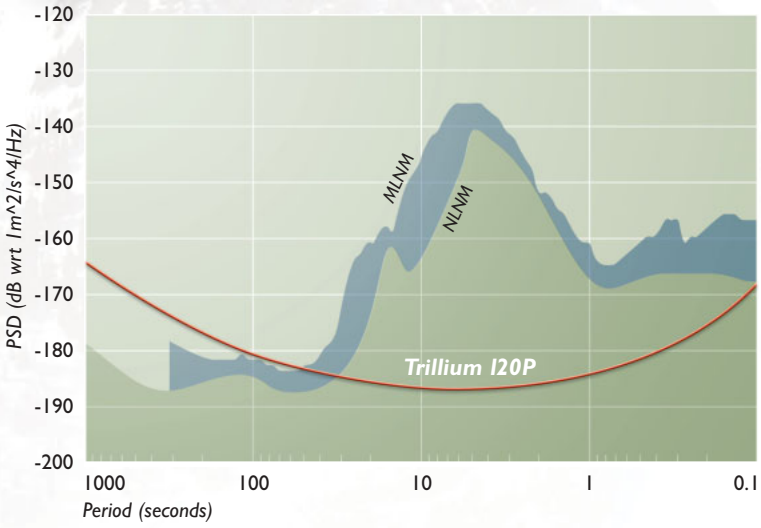
This instrument incorporates the same symmetric triaxial design and suspension system as the highly successful Trillium 40. The design employs fewer parts than traditional sensors and offers improved temperature stability. The robustness and reliability of the mechanical suspension is well proven: with over 500 Trillium units operating in the field, there have been no mechanical failures.

The very low self-noise of the Trillium 120P makes it ideal for local, regional and teleseismic studies in both observatory and portable applications. Portable network users will appreciate the low power consumption and reliable operation over a temperature range of ±45°C without re-centering.

The 120P is the smallest of the Trillium seismometers.

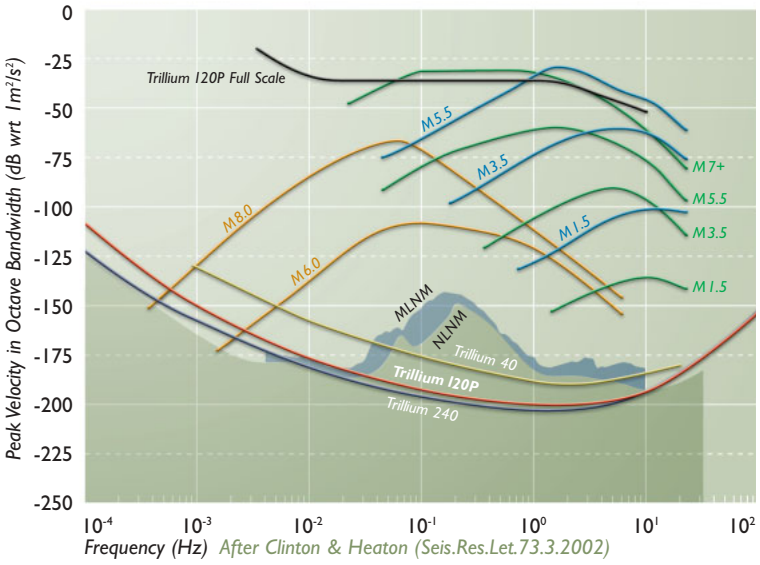
Trillium 120P Self Noise Performance

Seismometer self noise plotted against NLNM (after Peterson, 1993) and MLNM (after McNamara and Buland, 2004)



Nanometrics INC.
SEISMOLOGICAL INSTRUMENTS

The Earthquake Spectrum



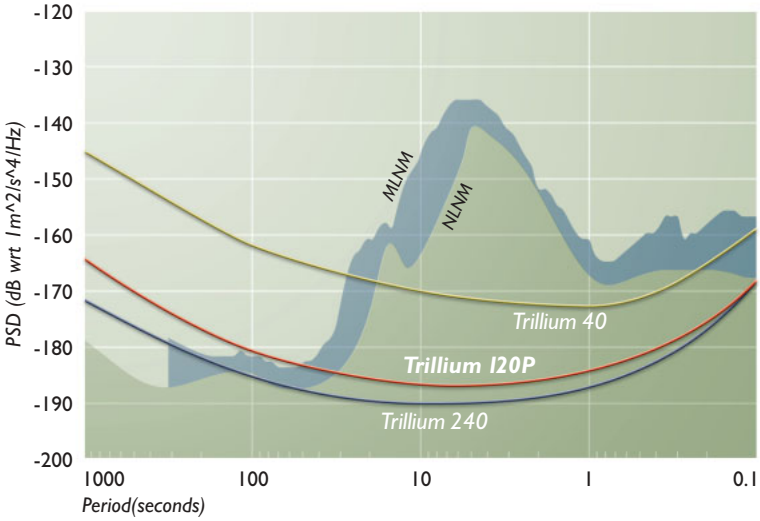
After Clinton & Heaton (Seis.Res.Let.73.3.2002)

Earthquake Categories

Local events	<~10km	Several seconds to 30Hz
Regional	>~10km	30 seconds to 10Hz
Teleseismic	>~3000km	3600 seconds to 2 seconds

Note: Sensor noise floors and earth noise models have been converted to equivalent peak amplitudes using a full octave bandwidth assuming Gaussian distribution and 95% probability.

Self Noise Performance Plots



Seismometers self noise plotted against NLNM (after Peterson, 1993) and MLNM (after McNamara and Buland, 2004)

References

New Low-Noise Model (NLNM) *from Peterson (1993)*
Observation and Modeling of Seismic Background Noise

PDF Mode Low-Noise Model (MLNM) *from McNamara and Buland (2004)*
Ambient Noise Levels in the Continental United States

Event Magnitudes *from Clinton and Heaton (2002)*
Potential Advantages of a Strong Motion Velocity Meter Over a Strong Motion Accelerometer

Technical Specifications Trillium 120P

Specifications subject to change without notice.

➤ Technology

Topology	Symmetric triaxial
Feedback	Force balance with capacitive transducer
Mass centering	Operates over full temperature range without manual re-centering; Manual centering control included
Leveling	Integrated bubble level; Adjustable locking leveling feet
Alignment	Vertical scribe marks for N/S; Precision N/S guide in top of cover for straight-edge, line or laser level; Precision holes for 5/16" alignment rod for E/W

➤ Performance

Self noise	See graph
Sensitivity	1201 V·s/m ±0.5%
Bandwidth	-3 dB points at 120 s and 175 Hz
Transfer function	Lower corner poles within ±0.5% of nominal provided; High frequency poles and zeros within ±5% of nominal provided
Clip level	>15 mm/s up to 1.5 Hz
Temperature	±45°C without re-centering

➤ Interface

Connector	19-pin MIL-C-28642, mounted in base
Velocity output	40 V peak-to-peak differential; Selectable XYZ or UVW mode
Mass position	Three independent voltage outputs
Calibration input	Single voltage input with one active high control signal per channel; Calibration in XYZ or UVW, selectable via control lines
Serial port	For retrieval of sensor response information and instrument control

➤ Power

Supply voltage	9 to 36 volts DC isolated input
Power consumption	650 mW typical at 15 V input
Protection	Reverse-voltage protection; Auto-resettable over-current protection (no fuse to replace)

➤ Physical

Diameter	21.0 cm
Height	20.9 cm to 21.8 cm depending on leveling feet extension
Weight	7.2 Kg
Handling	Detachable lifting handle included

➤ Environmental

Operating temp.	-20°C to +50°C
Humidity	0 to 100%
Shock	20 g half sine, 5 ms without damage, 6 axes; No mass lock required for transport
Packaging	Rated to IP68 and NEMA 6P for outdoor use

Nanometrics INC.
SEISMOLOGICAL INSTRUMENTS

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