Metrozet M2166-VBB
Very Broadband Triaxial Seismometer System

Observatory-Grade Triaxial Seismometer

High Performance Sensor Modules (Vertical: M2166-VSM, Horizontal M2166-HSM)
- **360 Second to 15 Hz Velocity Passband**
- **Velocity (BRB) Scale Factor: 2400 V-sec/m**
- **DC to 360 Second Acceleration Passband**
- **Acceleration Scale Factor: 8000 V/gal**

- **Lock/Unlock Via Four Simple Screws**

Modular Design
- **Separate Horizontal and Vertical Sensor Modules (non-Galperin Architecture)**
- **Remote Electronics with Separate Cabling for Each Sensor Axis**
- **Each Sensor Element Individually Trimmed:**
  - **Provides 360 Second/0.71 Damping Corner and 2400 V-sec/m Scale Factor**
  - **Independent of Electronic Module/Channel**

Separate Electronics Module (M2166-EM)
- **Based upon Proven Metrozet STS1-E300 Design**
- **Connectors Designed for Simplified Recording via Quanterra Q330HR**
- **Remote From Sensor (up to 20 feet) to Minimize Thermal Effects**
- **Identical E/N/Z Channels (Fully-interchangeable)**
- **Comprehensive Remote Control Capability:**
  - **Sensor Configuration (10 sec/360 sec; Damp/Undamp)**
  - **Complete Motor Control (Including AUTOCENTER)**
  - **Automated Calibration Features (Velocity and Acceleration Sweeps/Steps/Sines)**
  - **Full Diagnostic Readout of System Parameters**
  - **Accessible via RS-232, USB, or Ethernet**
- **Fully-potted cabling (based on Souriau 851 series)**
- **Full-isolated power input +9-36V**

Integrated Triaxial Package (M2166-TSP)
- **Monolithic Design Utilizing Wielandt/ASL "Warpless Baseplate" Concept**
- **Separate Vacuum Housing for Each Sensor Module**
- **Simplified Installation and Orientation**
  - **Kinematic Mounting Features for Precise Azimuthal Alignment of H Sensors**
  - **Integrated Cable Connection Boards**
  - **Simple, Global Tip/Tilt and Azimuth Adjustment During Installation**

Nickel-Plated Aluminum Vacuum Housing Design for High Reliability
  - **Vacuum Manifold Integrated Within Baseplate**
  - **Metal Valve**
  - **Manual Pressure Gauge**
- **Integrated Magnetic Shield for Vertical Sensor (Required for Any Compensated VBB Sensor)**

Single-Axis Vertical Sensor System Also Available

21143 Hawthorne Blvd., #456
Torrance, CA 90503
310-371-0256
866-823-0339
www.metrozet.com

Full Sensor System

Metrozet M2166-VBB Triaxial Seismometer System: Integrated triaxial sensor package (M2166-VBB-TSP) at left. M2166-EM Electronics Module at right. Each sensor axis is connected to electronics via dedicated cable. The electronics connect to a 3 or 6-channel Q330HR recorder via the connectors on the front side of its box.

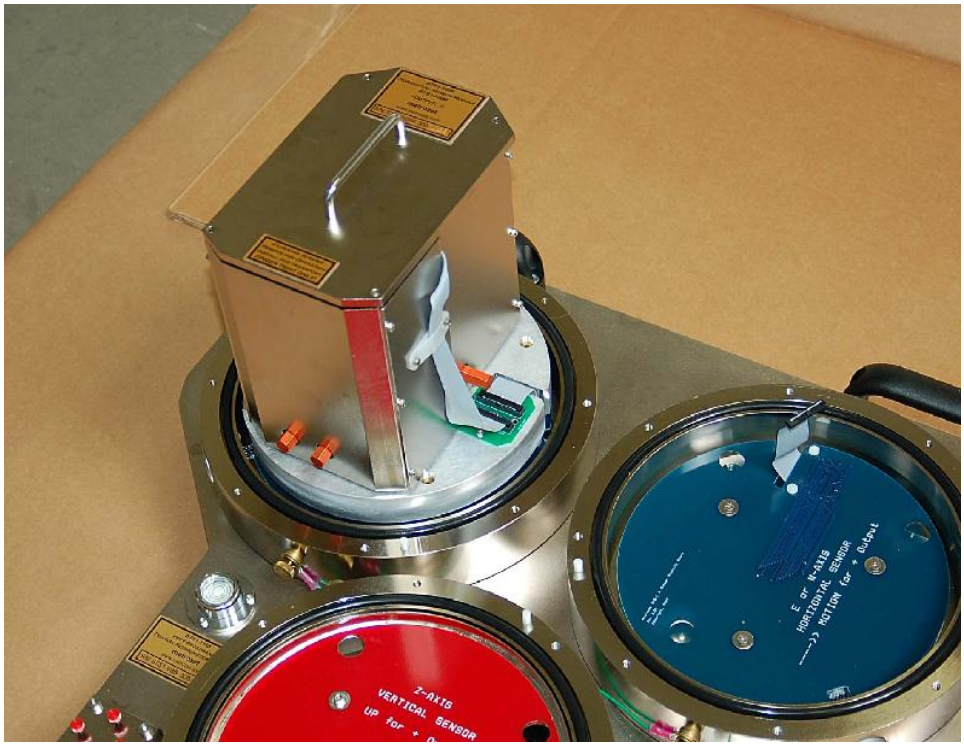
M2166-EM Electronics Module

Metrozet M2166-EM Electronics Module. The output SIGNAL connectors (CHA and CHB) are visible at the lower left corner. At the top are the three SENSOR connectors. The CONTROL connection is visible on the left side. At the bottom right are the CAL, CONTROL, and POWER
connectors.

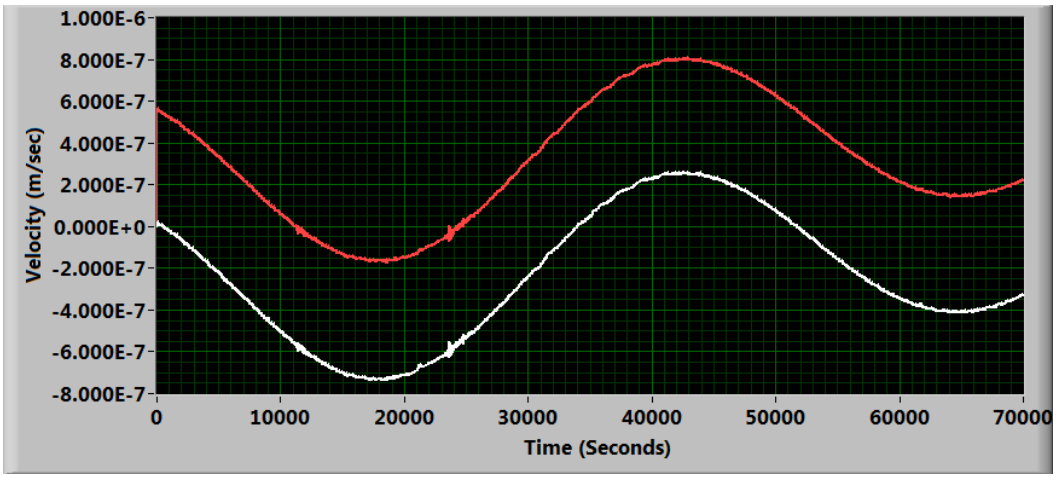
Sensors and Sensor Mounting

Triaxial package with shielded vertical sensor installed in front chamber. Sensor installation and connection is greatly simplified through the use of integrated cabling boards (blue E sensor board shown at back left). Sensor alignment accuracy and repeatability provided by kinematic mounting features integrated within each chamber. The front chamber includes an integrated magnetic shield.

Triaxial package with shielded horizotal sensor installed in E chamber



Incoherent (Self-Noise) Measurements

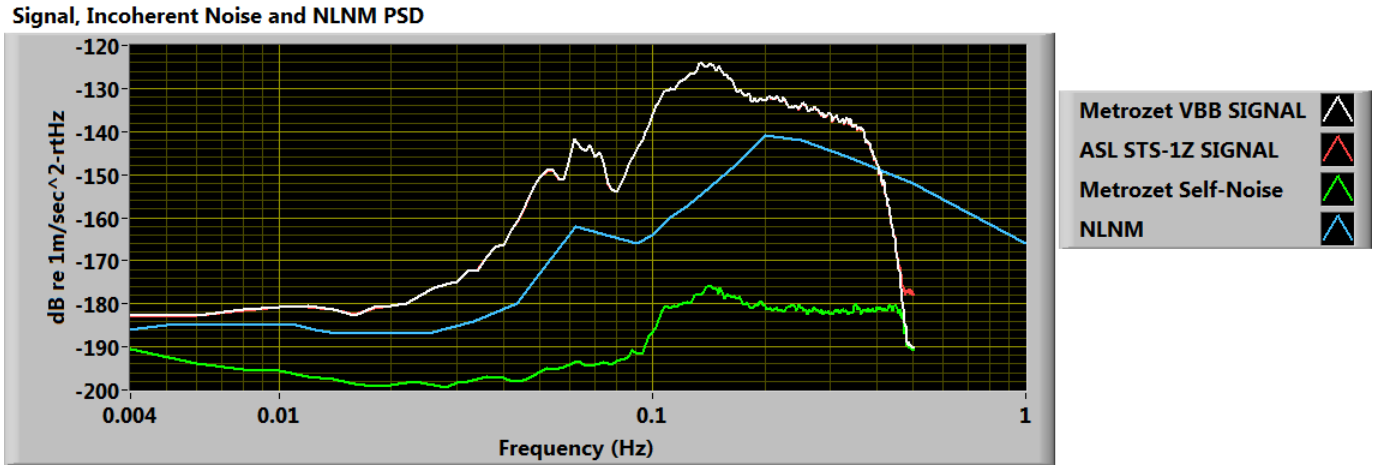


White: Metrozet VBB Vertical Sensor

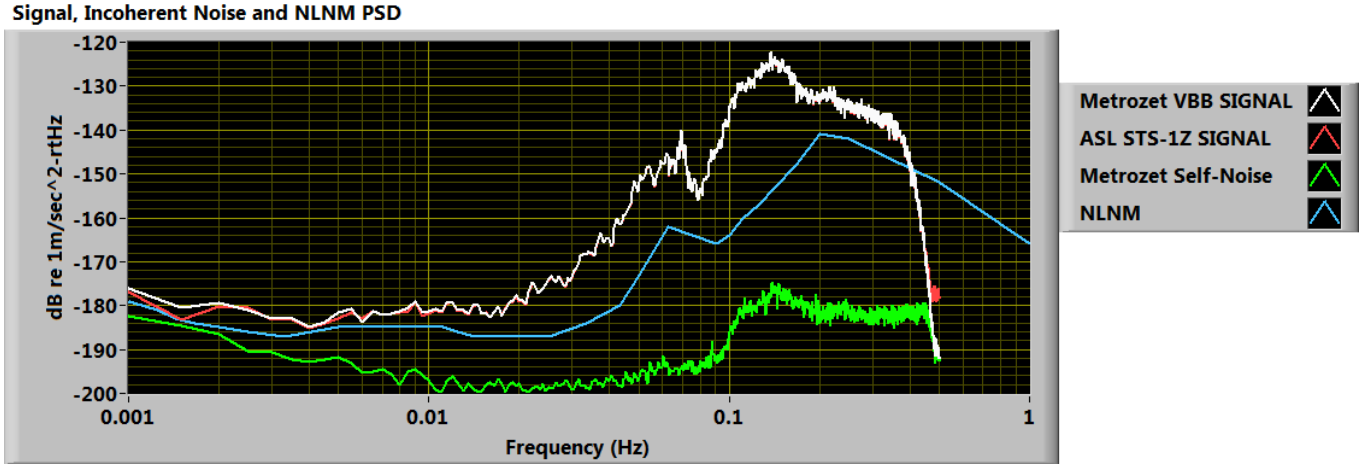
Red: Reference STS-1 Vertical Sensor (Original)

Power Spectral Density:

500 Second Pieces, 80 averages, 0% overlap;



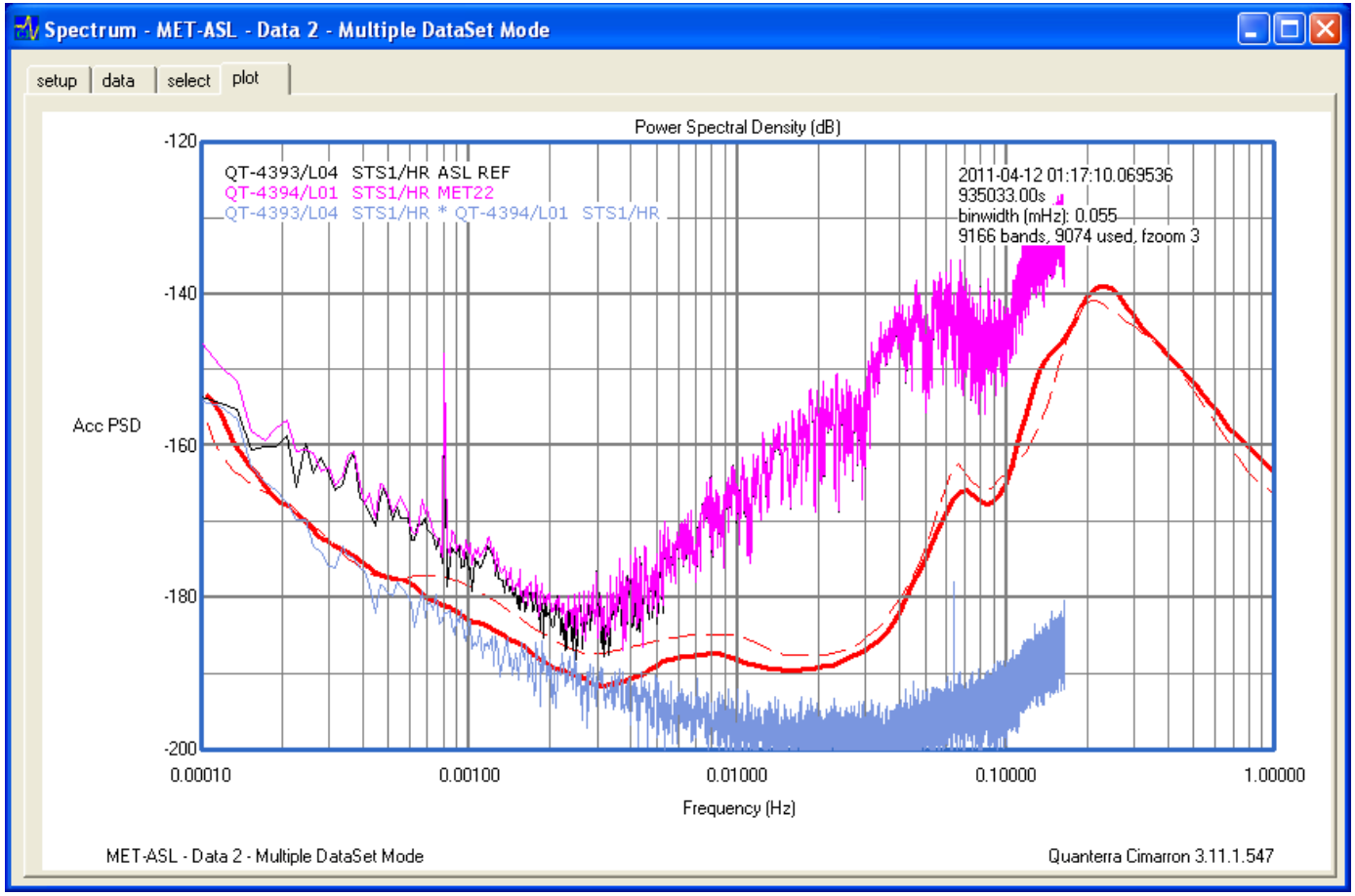
2000 Second Pieces, 20 averages, 0% overlap



Incoherent Noise Equivalent to Original STS-1 Sensor!

Normal Mode Recording, M9.0 Tohoku Event: One Month After Event

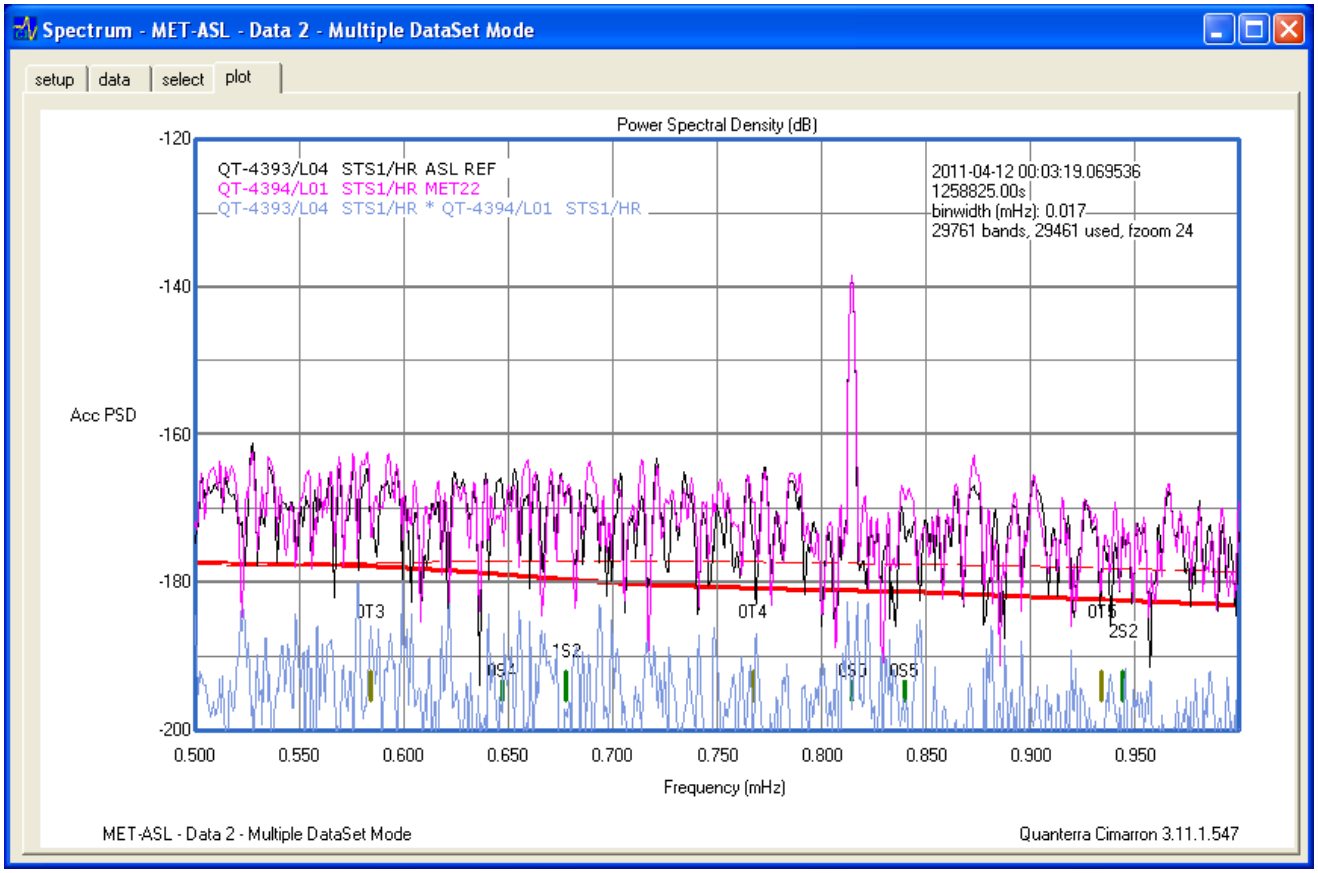
${}_0S_0$Mode (0.82 mHz) recorded at USGS Albuquerque Seismological Laboratory (ASL)



Pink: Metrozet M2166-VBB Prototype Vertical sensor in ASL cross-tunnel
Black: ASL Reference Vertical Sensor (sand-packed) in ASL cross-tunnel
Blue: Calculated incoherent noise between sensors (identical sensor approximation)
Dotted Red Line is NLNM
Solid Red Line is Berger, Ekstrom, Davis (BDE) Noise Model

Normal Mode Recording, M9.0 Tohoku Event: One Month After Event

Zoom to $_0S_0$ Peak



Data courtesy of Quanterra, Inc.

Use of data does NOT signify approval or endorsement of this product by the USGS, or by ASL

Metrozet M2166-VBB: Detailed Specifications

General System Specifications

Specification	Value
Axes Orientation	E(X), N(Y), UP(Z)
Sensor Format	Two (2) horizontal sensors, one (1) vertical sensor Sensors modules are removable from package (swappable)
Scale Factor	Velocity (BRB) Output: 2400 V-sec/m differential Acceleration (LP) Output: 8000 V-sec^2/m differential Boom Position Output: 4000 V-sec^2/m single-ended
Nominal Low Corner Frequencies	Horizontal and Vertical Sensors: 0.00278 Hz (360 seconds), Normal Operation 0.1 Hz (10 seconds), Setup Nominal Damping: 0.707 of critical 2nd Order High Pass
Nominal High Frequency Corner Frequencies	15 Hz with damping 0.7 of critical
Full-Scale Range	Velocity (BRB) linear to +/-8 mm/sec
Self Noise	Below NLNM and GSN Noise Minimum between 0.001Hz and 5 Hz. See Figure 10 for low frequency incoherent self noise PSD data
Intermodulation Distortion (IMD)	Under -80 dB for 1.00 and 1.05 Hz signals at 10% of full-scale velocity
Uniformity	Exchange of electronics boxes and/or sensor modules will maintain corner frequency, damping, and scalar responsivity, to within 1%
Total System Weight/Size	~150 pounds; 24" x 24" Footprint x 17" High
Operating Temperature Range	5^{o}C to 35^{o}C +/-8^{o}C without mass re-centering

M2166-EM Electronic Module Specifications

Specification	Value
Format	Electronics supports up to 3 fully-independent sensor channels Nominally configured as E, N, and Z. Single and dual-axis versions available
Nominal Low Corner Frequencies	360 seconds, Normal Operation 10 Seconds, Setup Nominal Damping: 0.707 of critical
Analog Output Ranges	Approximately +/-23V Differential for BRB and LP Approximately +/-11.5V Single-Ended for Boom Position
Uniformity	Exchange of electronics boxes will maintain corner frequency, damping, and scalar responsivity, to within 1%
Sensor Control Functions	*Via serial command strings:* Independent control of each sensor's low corner frequency: 360 sec Default, 10 sec in Setup Mode Independent control of each sensor's low corner frequency damping: 0.707 of critical Default, undamped in Setup Mode *Via Digitizer:* Switch to 10 second setup mode via assertion of 10_SECOND_ENABLE line from digitizer; orange LED indicator when enabled
Motor Control Functions	*Via serial command strings:* Independent monitoring of each sensor's motor limit switch Independent control of each sensor's centering motor: ON/OFF/Direction One-step "Autocenter" for each sensor *Works seamlessly with both horizontal and vertical STS-1 sensors* *Via Digitizer:* Autocenter of each sensor via assertion of AUTOCENTER_ENABLE line from digitizer; yellow LED indicator when enabled
Calibration Functions	*Via serial command strings:* Direct connection of external signals to sensor CAL coils Signal conditioning circuitry for converting raw CAL signals into acceleration or velocity-equivalent stimuli External input of remote CAL signals into signal conditioning circuit Internal generation of CAL signals via 16-bit DAC Internally-generated step, sine sweep, and sine (0.01 Hz, 0.1 Hz, and 1 Hz) Optional "Auto CAL" function: CAL Stimulus connected to E SIGNAL connector E or N sensor output connected to N SIGNAL connector Z sensor output connected to Z SIGNAL connector *Via Digitizer:* Digitizer-supplied calibration stimulus injected into sensor calibration coil in velocity-equivalent mode, via assertion of CAL_ENABLE line from digitizer; green LED indicator when enabled
Diagnostic Functions	*Via serial command strings:* Digitization of internal signals via 24-bit ADC (remote diagnostics) Connection of internal signals to analog differential output lines (local diagnostics) Signals Monitored: E/N/Z BRB+/- E/N/Z LP+/-

Diagnostic Functions (continued)	E/N/Z Boom Position E/N/Z Motor Limit Switch State Analog Power +/- (regulated power used by sensors) Input Power +/- Module Temperature (via internal temperature sensor) DAC Voltage Auxiliary Analog Input 0 and 1 Auxiliary Digital Input 0 and 1
Fail-Safe Mode	All sensors set to 360 second corner frequency, with damping engaged All motor, calibration, and diagnostic functions disconnected from sensor electronics Fail-safe entered upon power-up (or power reset), after 3600 second inactivity timeout, or via remote command
Native Command Interface	RS-232, 9600 baud, 8 data bits, 1 stop bit, No parity Full-duplex, no hardware handshaking
Connector Names (quantity) and Functions	SIGNAL (2) CHA: Differential BRB (E,N,Z), single-ended boom position (E,N,Z), and input of external calibration signals CHB: Differential LP signals (E, N, Z) SENSOR (3): Individual connectors for each sensor Analog sensor signals, digital motor control signals, and CAL coil signals CONTROL(1): Power inputs, RS-232, analog output of selected internal signals, Auxiliary analog inputs, and auxiliary digital inputs
Connector Types	All are Souriau 851-series CHA SIGNAL: 851-07C16-26P50-A7-44, 26-pin CHB SIGNAL: 851-07C16-26P50-A7-44, 26-pin SENSOR(3): 851-07C16-26S50-A7-44, 26-socket POWER: 851-07C10-98P50-A7-44, 6-pin CONTROL: 851-07C14-18S50-A7-44, 18-socket CAL: 851-07C12-10P50-A7-44, 10-pin
Input Power	9-36V Unregulated into isolated DC-DC converter Approximate 5W total consumption
Physical	Package Size: 13.75”W x 7.25”H x 15”D Weight:30 pounds

M2166-TSP Triaxial Sensor Package Specifications

Specification	Value
Package weight/size	~85 pounds; 24" x 24" Footprint x 17" High
Sensor Mounting Ports	Three (3): Two horizontal and one vertical port
Tip/Tilt Control	Three (3) of 9/16" x 32 TPI leveling screws with insulating feet
Sensor Module Mounting	Kinematic (cup, slot, flat) features to accept sensor legs
Package Alignment Aids	Azimuth Alignment block with precision bores aligned with horizontal sensor axes; package edges also very well-aligned with H sensor axes Bull's-eye level for tip/tilt alignment
Internal Sensor Mounting Plate Alignment Accuracy	Relative azimuth alignment of horizontal sensors: +/- 2 mrad Tip/Tilt : +/-500 micro-radians between surface normal and local gravity
Global Composite Alignment Accuracy	5 mrad between horizontal sensor axes and azimuth alignment fixture 1 mrad between vertical sensor axis and local gravity
Axis Non-orthogonality	Under 5 mrad
Carrying Handles	Four handles on periphery of package
SENSOR Cable Connections	3 of 851-hermetic bulkhead receptacles on package sealing rings 851-07A16-26P50-A7-44-EP
Sensor Wiring Boards	Two (2) Blue colored boards for horizontal sensors One (1) Red colored board for vertical sensor Boards contain through holes for sensor mounting feet and ribbon cables for electrical connection to sensor modules Ribbon cable is Samtec TCSD-13-D-04.00-01-F-N
Environmental Protection	Vacuum-tight pressure housing and use of pressure-compensating "warpless baseplate" design Integrated magnetic shield in vertical sensor mounting port
Vacuum Manifold	Integrated with baseplate Includes mechanical vacuum gauge Doubly-redundant quick-disconnect vacuum pumping port Accepts McMaster-Carr 8636T223 hose coupling
Ground Isolation and Connection	Entire package is galvanically isolated from pier via alumina balls in leveling screws Explicit package ground connection via thumb screws on baseplate and on sealing rings

M2166-VBB Sensor Modules

M2166-VSM Vertical Sensor Module

Specification	Value
Module Size	8.0" diameter x 10.5" Height
Mounting Feet	Three (3) brass feet, factory set for vertical alignment
Integral Shields	Physical (non-hermetic) shield to protect sensor mechanics during shipment and handling 6061-T651 Aluminum, nickel plated
Carrying Handle	Mounted on top of sensor
Mechanical Pendulum Design	Hinged boom with temperature-compensated astatic leaf spring Approximate 6 second mechanical free period
Temperature Coefficient of Acceleration	At or below 20 micro-g/^{o}C in range of 5^{o}C to 25^{o}C
Boom Displacement Sensing Method	Capacitive sensor
Alignment Accuracy of Sensor	Under 500 micro-radians between sensitive axis and local gravity
Sensor Locking	Four (4) orange locking screws inserted finger-tight for shipment or transport
Boom Centering	Motorized centering assembly moves small mass on boom to balance sensor over range of +/-3 mg about nominal factory acceleration (9.796) Microswitch to ensure mechanical de-coupling of centering motor from boom Design is passively protected against over-travel
On-board Electronic Components	Capacitive preamplifier (6 mW total power dissipation) Feedback setting resistors and capacitors Relays for 10 sec/360 second switching, damping control Relay for calibration signal connection (normally open relay)
Electrical connection	2 mm, 26 contact shrouded connector Samtec STMM-113-02-S-D
Grounding	CASE_GND wire in SENSOR cable is connected to body of sensor Electronics EXT_ANALOG_GND wire in SENSOR cable is also connected to body of sensor Sensor body is connected to STS1-VBB-TSP package through sensor's brass mounting feet

M2166-HSM Horizontal Sensor Module

Specification	Value
Module Size	8.0" diameter x 9.5" Height
Mounting Feet	Two (2) brass feet, and a single polished stainless steel foot Factory set for proper mechanical free period
Integral Shields	Physical (non-hermetic) shield to protect sensor mechanics during shipment and handling 6061-T651 Aluminum, nickel plated
Carrying Handle	Mounted on top of sensor
Mechanical Pendulum Design	Hinged boom configured in as horizontal garden-gate pendulum Approximate 6 second mechanical free period
Boom Displacement Sensing Method	Capacitive sensor
Alignment Accuracy of Sensor	+/- 1 mrad between sensitive axis and mounting feet
Sensor Locking	Four (4) orange locking screws inserted finger-tight for shipment or transport
Boom Centering	Motorized centering assembly tilts sensor over a range of +/-2 mrad by adjusting height of polished steel leveling foot Microswitch to ensure mechanical de-coupling of centering motor from boom Microswitches to prevent over-travel of adjustment stage
On-board Electronic Components	Capacitive preamplifier (6 mW total power dissipation) Feedback setting resistors and capacitors Relays for 10 sec/360 second switching, damping control Relay for calibration signal connection (normally open relay)
Electrical connection	2 mm, 26 contact shrouded connector Samtec STMM-113-02-S-D
Grounding	CASE_GND wire in SENSOR cable is connected to body of sensor Electronics EXT_ANALOG_GND wire in SENSOR cable is also connected to body of sensor Sensor body is connected to STS1-VBB-TSP package through sensor's brass mounting feet

M2166-VBB Cabling

Specification	Value
CHA and CHB SIGNAL Cable (White Overmold)	Dual-ended cable compatible with Q330HR connection Electronics-end: 851-06E16-26S50-A7-44, 26-socket Q330HR-end: 851-06E16-26P50-A7-44, 26-pin CHA: Conventional broadband sensor connections, including: E/N/Z BRB Velocity signals (differential) E/N/Z Boom position signal (single-ended) AUTOCENTER_ENABLE, 10_SECOND_ENABLE, and CAL_ENABLE lines CAL Input (differential) from digitizer ANALOG_GND DIGITAL_GND CASE_GND (1M series impedance between ends) CHB: E/N/Z LP Acceleration signals (differential) ANALOG_GND Same cable can be used for either connection 12-twisted pair cable with internal shields Neoprene-jacket 6 meter length
SENSOR Cable (Orange Overmold)	Dual-ended cable between M2166-EM and M2166-TSP package Electronics-end: 851-06E16-26P50-A7-44, 26-pin Package-end: 851-ET16-26S50-A7-44, 26-socket rotating body 13-twisted pair cable with internal shields Neoprene-jacket 6 meter length
POWER Cable (Red Overmold)	Single-ended cable that connects to M2166-EM POWER Connector Electronics-end: 851-06E10-98P50-A7-44, 6-socket POWER+/POWER_RTN/CASE_GND Twisted-triad (16 AWG) conductors with internal shield Neoprene-jacketed 12 meter length

CAL Cable (Green Overmold)	Single-ended cable that connects to M2166-EM CONTROL Connector Electronics-end: 851-06E12-10S50-A7-44, 10-socket CAL_OUTPUT (differential) CAL_INPUT (differential) CAL_GND 4-twisted pair cable with internal shield Neoprene-jacketed 6 meter length
CONTROL Cable (Blue Overmold)	Single-ended cable that connects to M2166-EM CONTROL Connector Electronics-end: 851-06E14-18P50-A7-44, 18-pin Connections to: RS-232: TX/RX/GND Auxiliary ANALOG INPUT (0 and 1)/ANALOG_GND Auxiliary DIGITAL INPUT (0 and 1)/DIGITAL_GND 3.3V External Digital Power/DIGITAL_GND CONTROL_OUTPUT (Differential) EXT_RESET Line for processor 8-twisted pair cable with internal shield Neoprene-jacketed 6 meter length
Environmental Isolation	Connectors are fully-potted and overmolded for hermetic isolation and mechanical ruggedness
Electrical Test Parameters	<5 ohms continuity on conductors >40M isolation (at up to 40V HiPot) between conductors