

Laboratory and Field Testing of Two Rotational Seismometers

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Overview

- Two each of commercial rotational velocity sensors, Eentec Model R-1 and PMD Model RSB-20
 - Lab Testing
 - Field Testing
 - Earthquake Monitoring
 - Ambient Monitoring in Buildings
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Acknowledgements

- Willie Lee
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 - George Liu of IES
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 - NEES@UCSB – Jamie Steidl
 - NEES@UCLA
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Eentec R-1 specs

- Triaxial rotational velocity sensor
 - Electrochemical technology (magnetohydrodynamic)
 - 0.05 – 20/50 Hz bandwidth
 - 50V per radian/sec
 - ~0.1 radian/sec clip
 - ~micro radian/sec noise (108dB specified)
 - 20mA from 9-14VDC power
 - 12 x 12 x 9cm
 - 1kg
 - Watertight (NEMA-4)
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PMD RSB-20 (prototype) specs

- Triaxial rotational velocity sensor
- Electrochemical technology (magnetohydrodynamic)
- 0.01 – 50 Hz bandwidth
- 50V per radian/sec
- ~0.1 radian/sec clip
- Sub-micro radian/sec noise (144dB specified)
- 28mA from 9-14VDC power
- 16 x 16 x 16cm
- 2kg
- Watertight

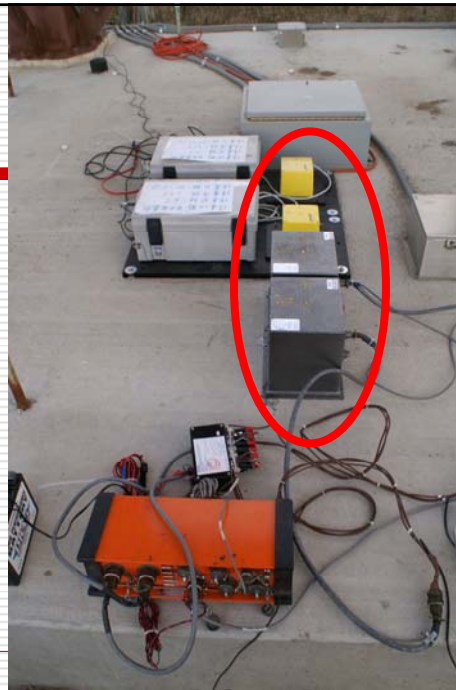


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5

Sensor Testing, Aug.-Nov. 2006

- Electronic, Noise, Shake Table Testing at UCLA
- Field Testing at NEES@UCSB's Garner Valley Array
- Temporary deployments in 2 UCLA buildings
- Connected to K2 Accelerographs and Q330 Dataloggers



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6

Basic Testing

Test	R-1 #122	RSB-20 #10602
Startup Current @12VDC	~ 100mA	~ 400mA
Steady-State Current @12VDC	25mA	35mA
Voltage step sensitivity	no	yes
Clip Recovery	Tens of seconds	minutes
Warm-up Time	Several Minutes	~ 10 Minutes

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7

Shake Table Testing

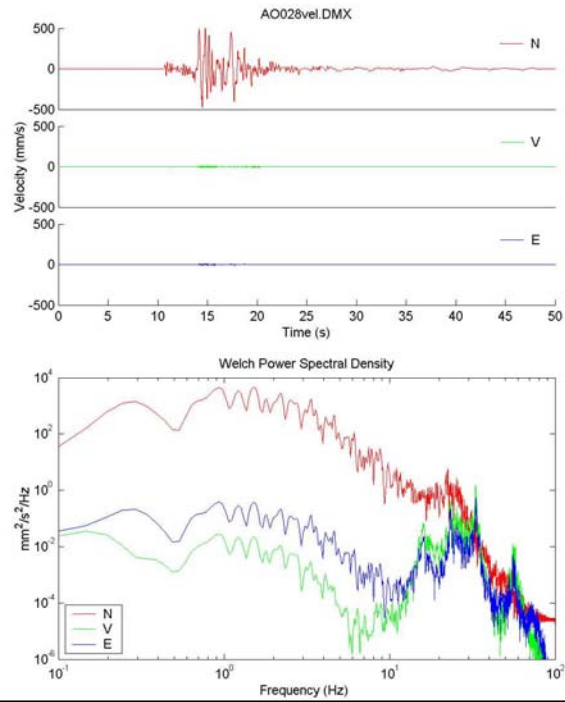
- UCLA 1-D linear shake table
- Purpose: Look at cross-axis & large motion response
- Also intended to develop rotational fixture, but these sensors are too sensitive (0.1 rad/sec is SMALL)
- Findings: Cannot separate table rattling effects from potential cross-axis

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8

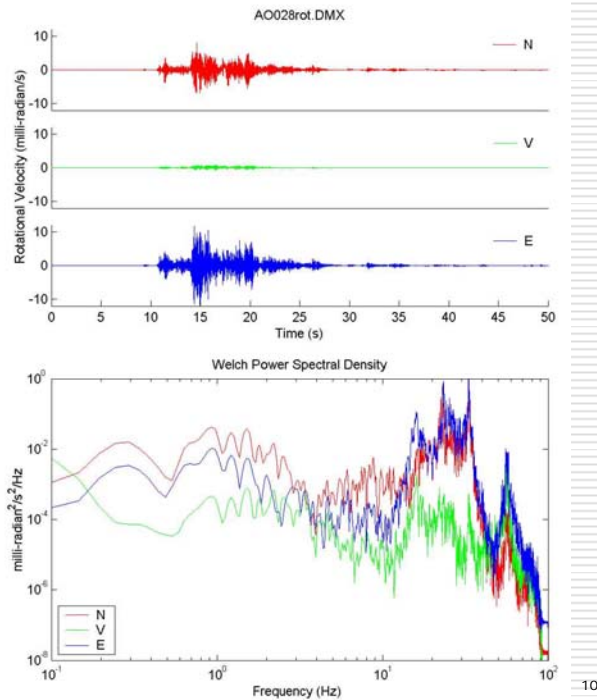
Shake Table Accelerations for Simulated Earthquake

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Measured Rotation Signals for Simulated Earthquake (R-1)

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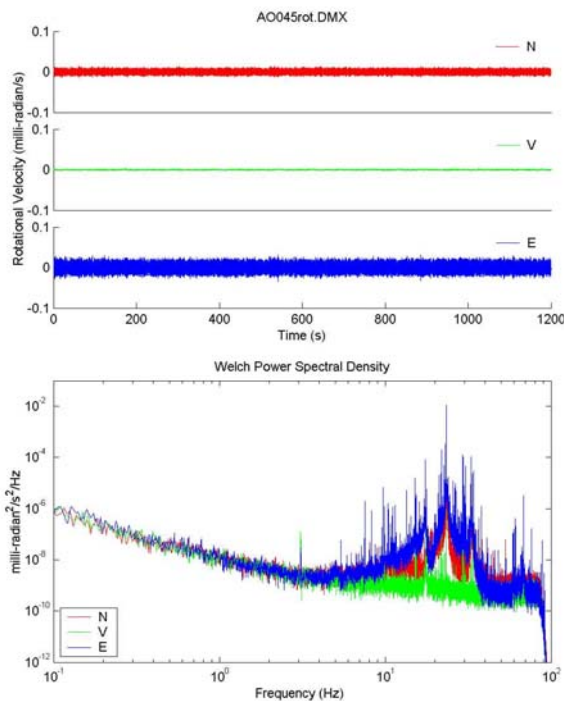
Sensor Noise (R-1)

- Measured in building basement in urban area, so is an upper bound

- R-1 Noise < 0.01 milli-radian/sec rms

- RSB-20 instability prevented long-duration noise measurement

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11

Field Deployment

- On SFSI test structure at the GVDA array
- Two K2 19-bit accelerographs w/internal accelerometers & external rotation sensors
- Ambient & triggered monitoring for ~6 weeks
- Forced vibration testing with small shaker and hammer

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12

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- 3D Geotechnical Arrays at 2 permanent field sites in Southern California
- Soil-Foundation-Structure-Interaction (SFSI) Test Structure

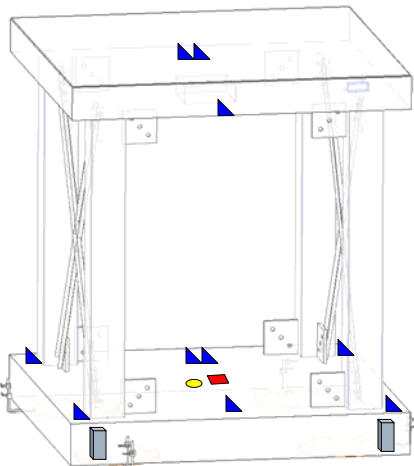
- Real earthquake data
- Test bed for geotechnical and geophysical methods
- Location for active experiments in a well-characterized field setting



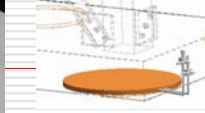
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13

SFSI Test Structure Instrumentation



Pressure Cell and Sensor



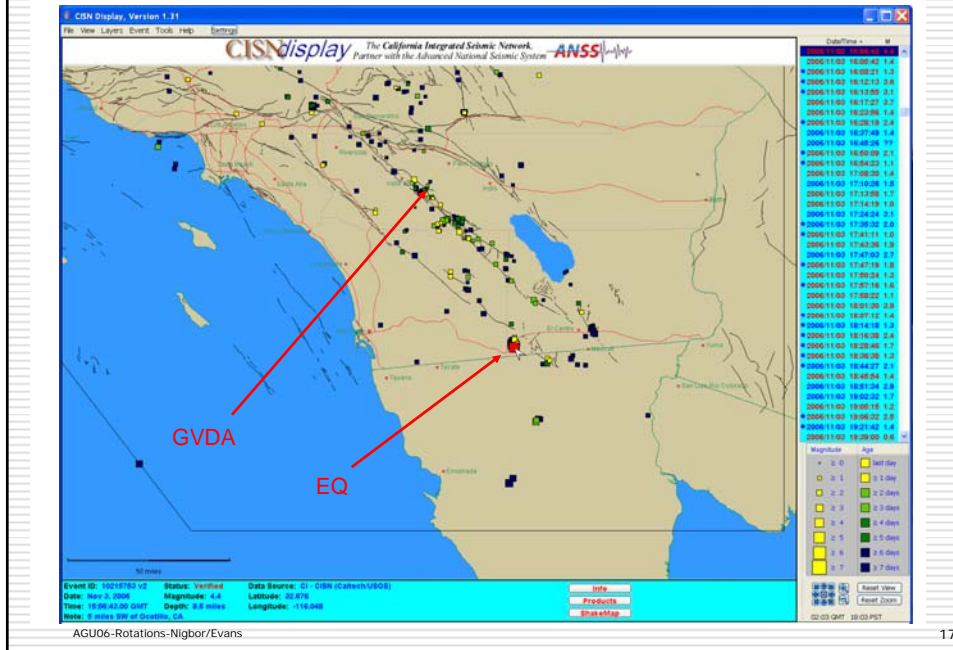
- ▲ Uni-axial Accelerometer
- Tri-axial Accelerometer
- Rotation Sensor
- ▭ Displacement Transducer

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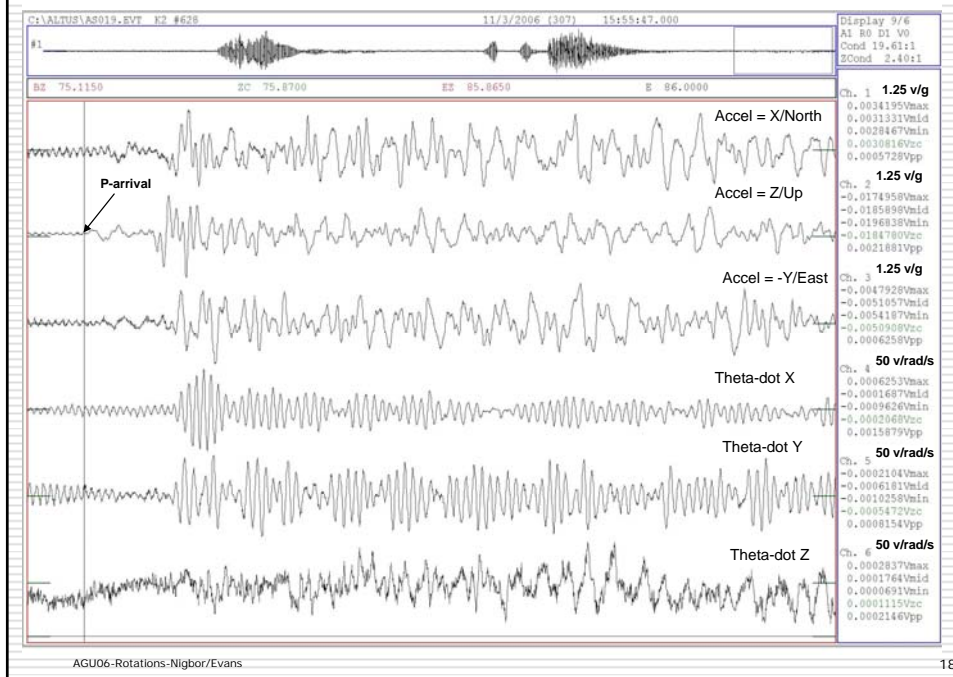
14

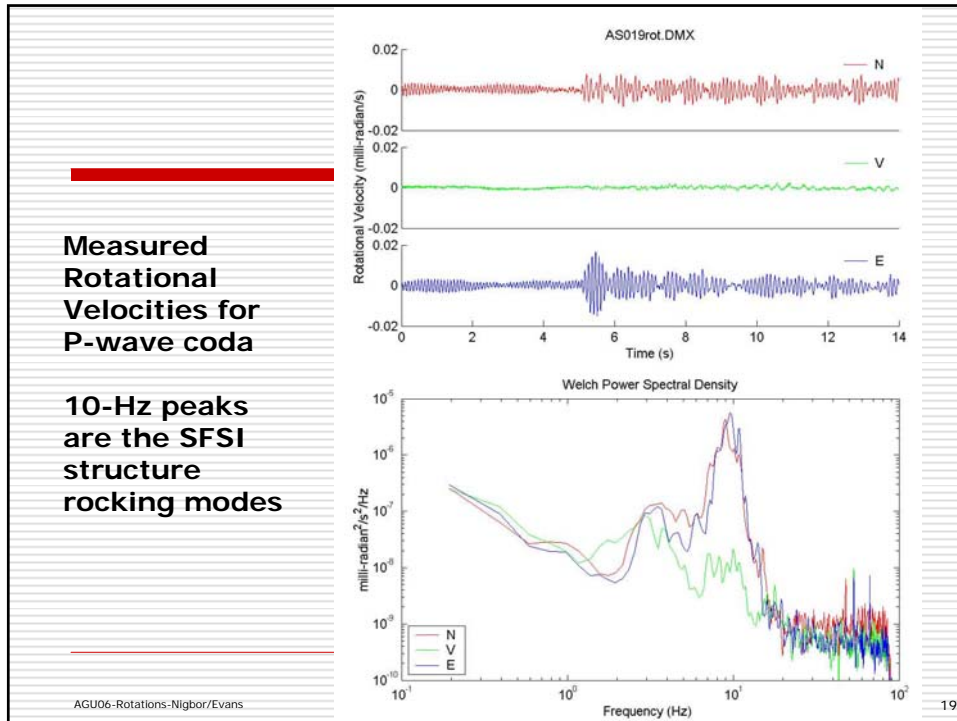


M4.4 Earthquake, 11/3/2006 15:56:43 GMT, ~120km from GVDA



File AS019.evt, System 2: M4.4 event subset (P-coda only)

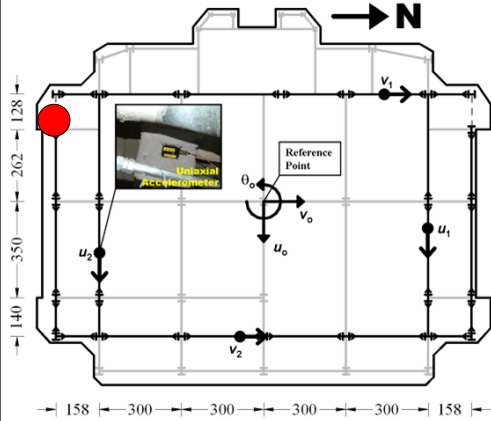




Structural Response Measurements

- Boelter Hall at UCLA
- Factor Building at UCLA
- Temporary deployments at each to measure ambient vibrations
- R-1 with 24-bit datalogger (Q330) works well

Factor Building: ANSS-Instrumented w/72 accelerometers

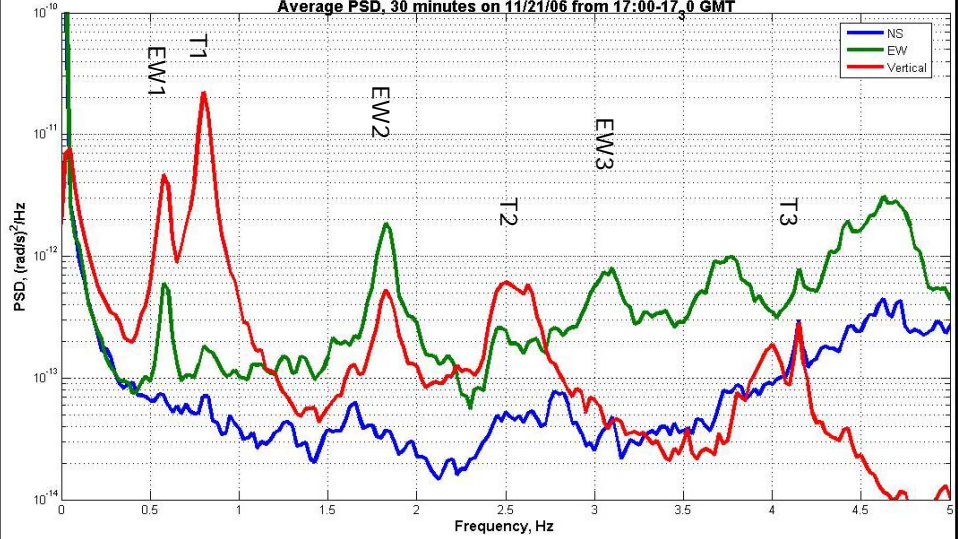


● Rotation sensor location on 15th floor

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21

Factor Building Ambient Rotations, 15th Floor SW Corner
Average PSD, 30 minutes on 11/21/06 from 17:00-17:30 GMT



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22

Summary

- **Two samples each of the Eentec R-1 and PMD RSB-20 (prototypes) were tested in lab and field for ~3 months**
- **These are highly-sensitive rotational broadband seismometers, and must be treated more like broadbands than strong motion sensors**
- **R-1 performance was good**
- **The RSB-20 prototypes had some instability issues that hindered testing – the manufacturer is working on solutions**
- **Cross-axis and more rigorous performance testing will require special rotational test fixtures (rotational shake tables) to isolate individual rotational components of motion**
- **An earthquake and ambient & forced structural vibrations were measured – analysis is in progress**