nees@UCLA

The George E. Brown, Jr. Network for Earthquake Engineering Simulation

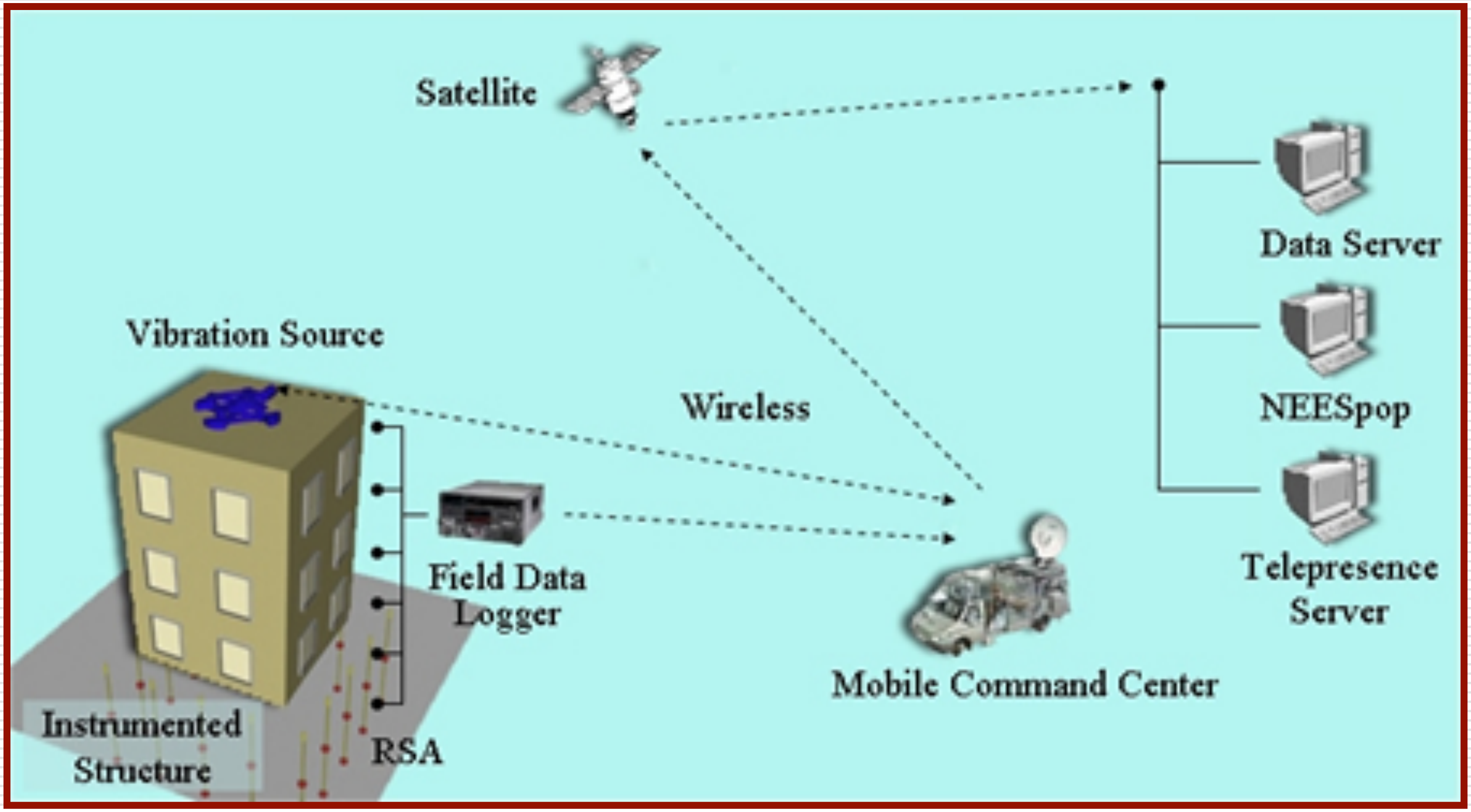
NEES@UCLA – A Community Resource for Field and Laboratory Testing

Robert Nigbor

NEES@UCLA

August 23, 2011

NEES@UCLA: Advanced Dynamic Field Testing of Civil Structures



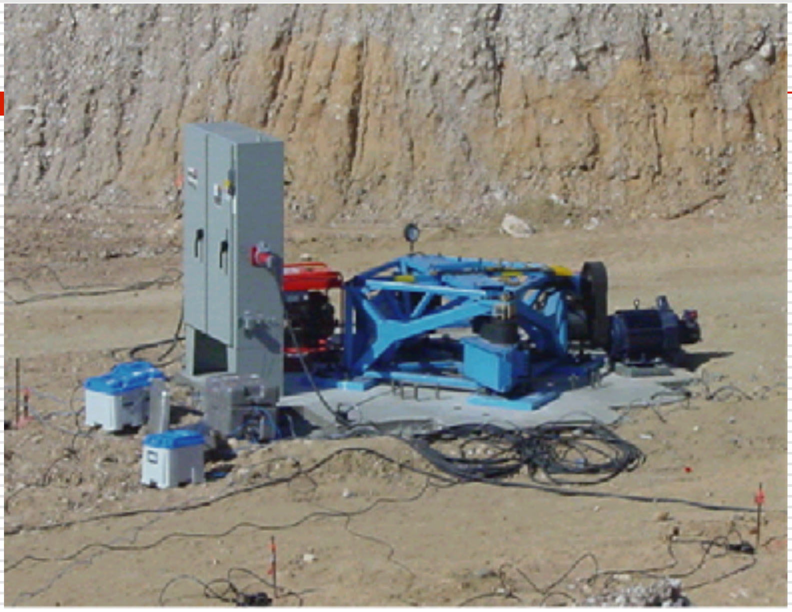
Who are we?

- Principal Investigators are:
  - John Wallace
  - Jon Stewart
  - Robert Nigbor
- Professional Staff:
  - Steve Keowen – Mechanical engineer
  - Alberto Salamanca – Instrumentation
  - Steve Kang – IT
  - Sophia Poulos– Instrumentation
  - Erica Eskes - Administration

Equipment Portfolio

- **Vibration sources (shakers)**
- **Data acquisition & sensors**
- **CPT Truck & RSA**
- **High performance mobile network**

Vibration Sources



- **Eccentric mass shakers**
  - MK14A (1x)
    - omni-directional, 0 to 4.2 Hz & 15 kips
  - MK15 (2x)
    - uni-directional, 0 to 25 Hz & 100 kips
    - Synchronized – 200 kips
  - AFB
    - Uni-directional, 0 – 20 Hz & 10 kips
    - Fits in a pickup truck and elevator
- **Linear inertial shaker**
  - Digital controllers
  - 15 kips, ± 15 inches & 78 in/s

Data Acquisition and Sensors

- Kinemetrics
  - Q330 data loggers (120 channels total)
  - Episensor accelerometers
  - 24-bit, large dynamic bandwidth ~135 dB
  - GPS time synchronization
  - Wireless telemetry using 802.11a/b
- National Instruments
  - SCXI/PXI combo chassis (96 channels)
  - 16 bit resolution
  - GPS time synchronization
  - Strain gauges, displacement transducers

High Performance Mobile Network

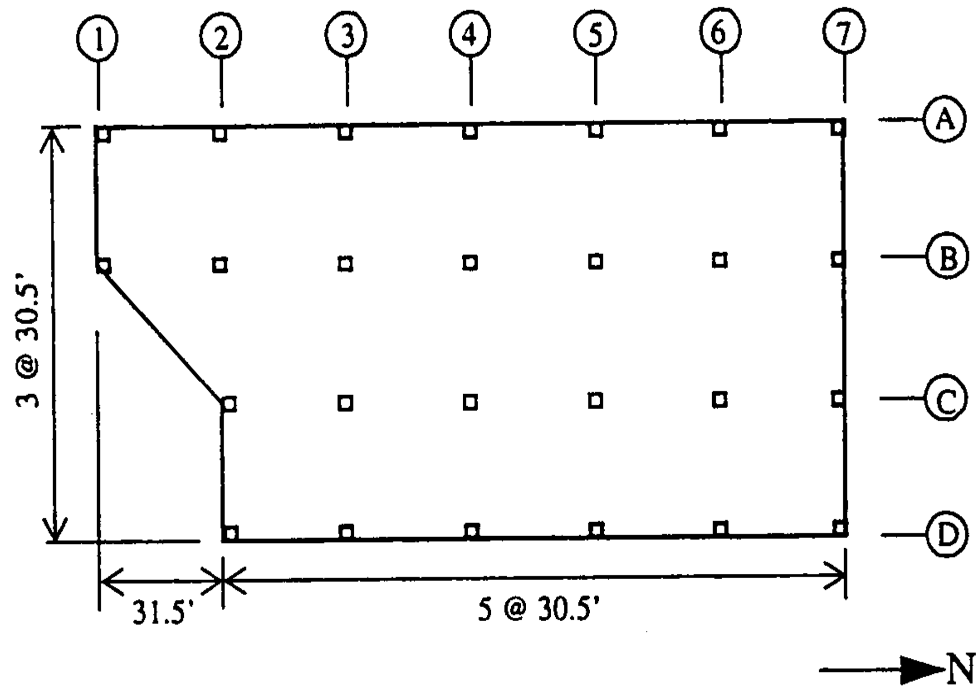
- **Mobile Command Center**
  - T1 satellite uplink (1.54 Mbps)
  - UNIX workstations
- **Networking Equipment**
  - Wireless Field-LAN
  - Campus-LAN
  - Satellite transmission system

UCLA Four Seasons Project

- Forced-Vibration Testing
  - Sherman Oaks, California
  - 4-story RC Building (1977)
- Damaged (yellow tag) in Northridge earthquake
  - Empty, to be demolished
- Complete System Test
  - Shakers/Sensors & DAQ (200 sensor channels)
  - Mobile command center
  - Satellite, Tele-presence

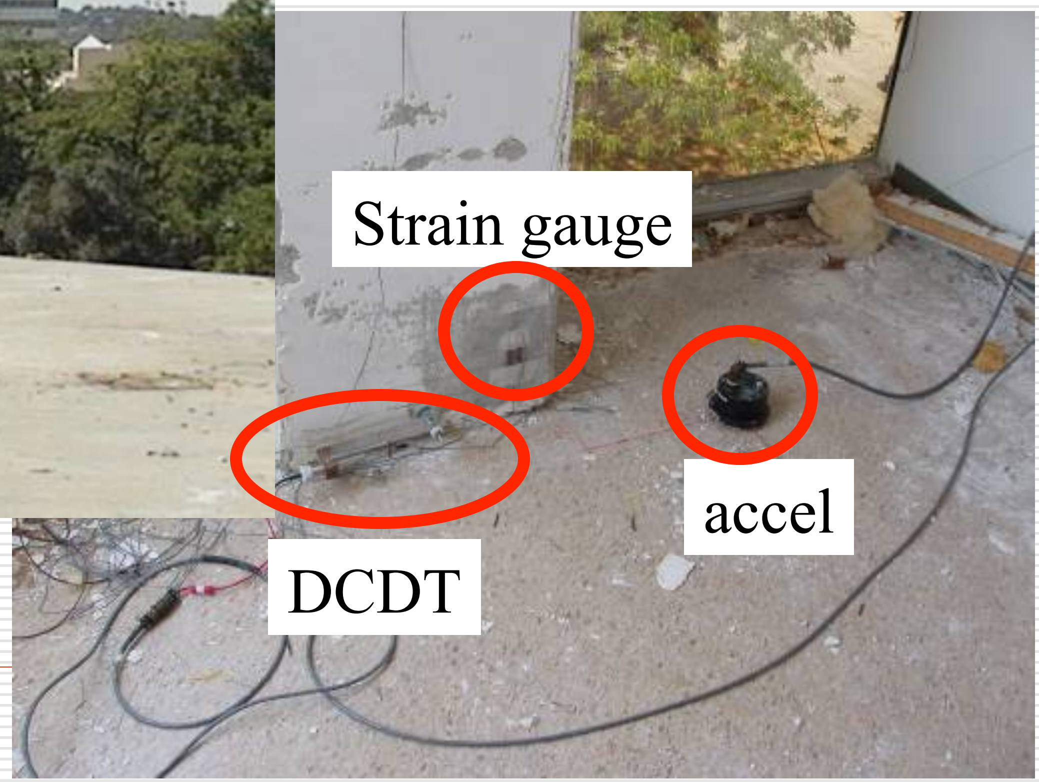
Building Description

- Perimeter Moment Resisting Frame
  - Beam : 24”x30”
  - Column : 24”x24”
- Gravity Load :
  - Post-tensioned slab with drop panels (8 ½”)
  - interior columns
- Bell caisson foundation

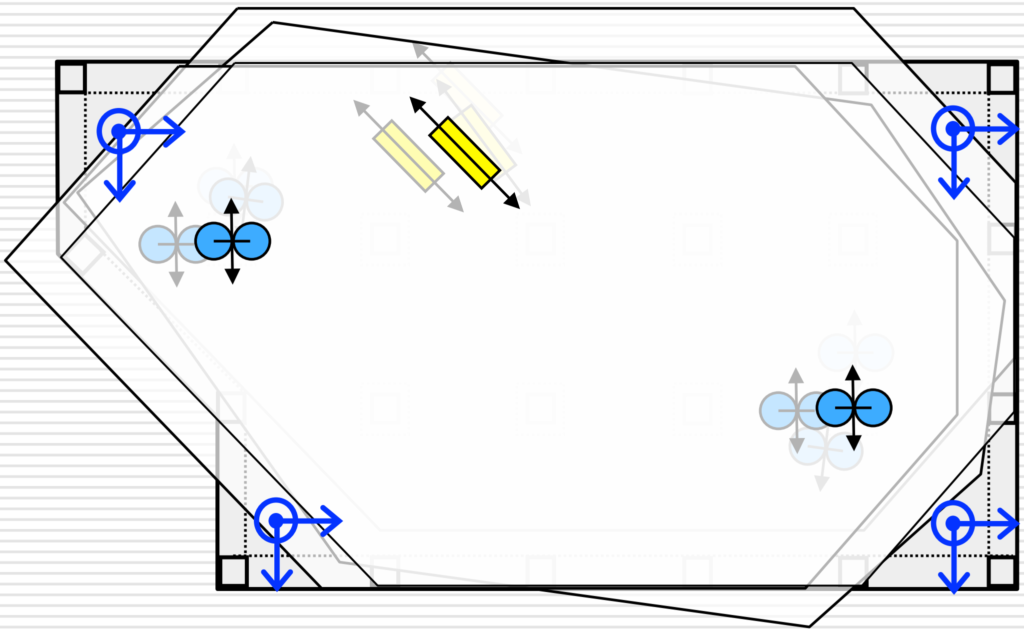


Typical Floor Plan

Four Seasons Building Vibration Tests



Building Shaking Example: Four Seasons Building



UCLA's large shakers:

100,000 lbs dynamic force each

Earthquake-Level Shaking

Caltrans Field Testing at the Caltrans-UCLA Test Site (105 & 405)

Caltrans 9-Pile Group

Caltrans 9 Pile Group

Basic Nonlinear Stiffness Curve (up to 3/4”)

LAX Theme Building Assessment

Los Angeles World Airports
LAX - Theme Building Restoration

nees@UCLA

GWA

miyamoto. STRUCTURAL & EARTHQUAKE ENGINEERING

VCA Engineers Inc.

CSA Constructors

Events and Chronology

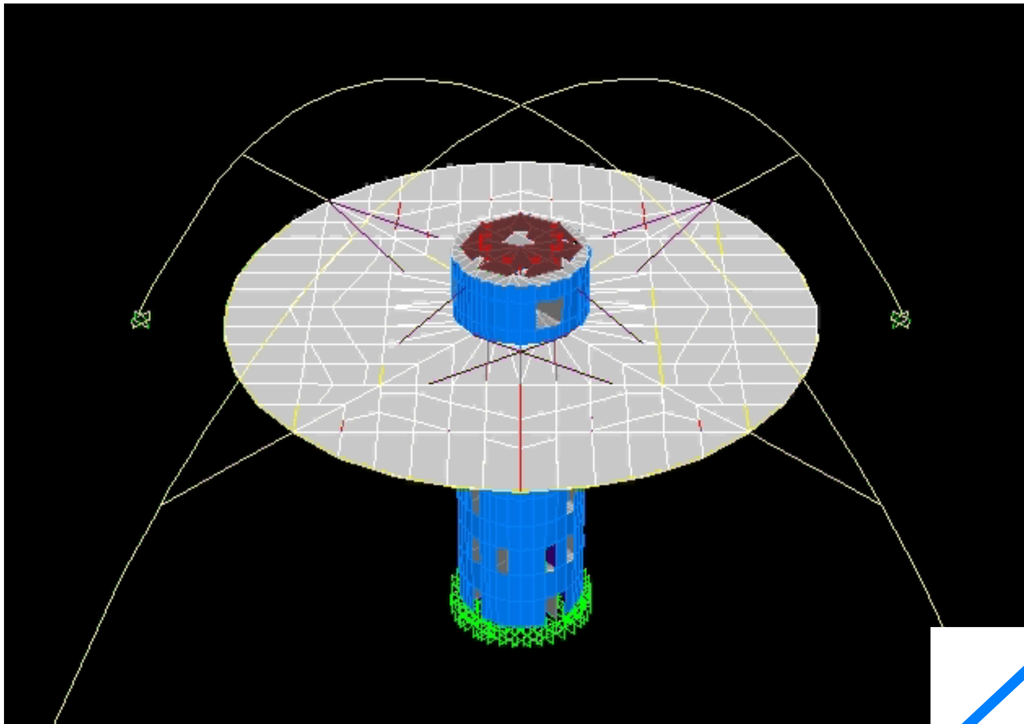
- Corrosion Failure
- Restaurant Closed
- Reconstruction Design
- Emergency Abatement
- Abatement & Demo Completed
- Restaurant Reopened
- Building Permit
- Construction Starts
- Construction Completed
- Re-Opening Ceremony

2/07 3/07 4/07 4/07 9/07 11/07 2/08 6/08 5/10 6/10

NEES@UCLA Tests **NEES@UCLA Tests**

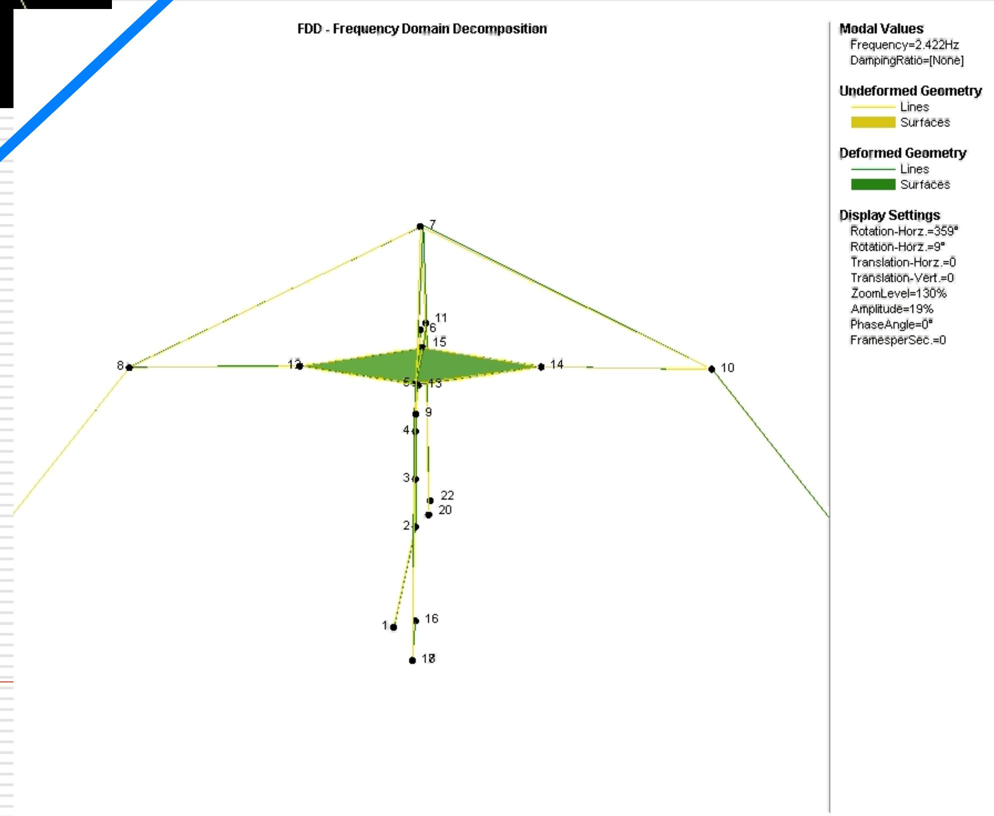
LAX Theme Building EMA

- EMA = “Experimental Modal Analysis”
- The purpose of EMA is to measure the dynamic properties of a real structure for comparison with and validation of computer models of the structure
- EMA is common in mechanical & aerospace engineering, not so common in civil engineering



Design Simulation

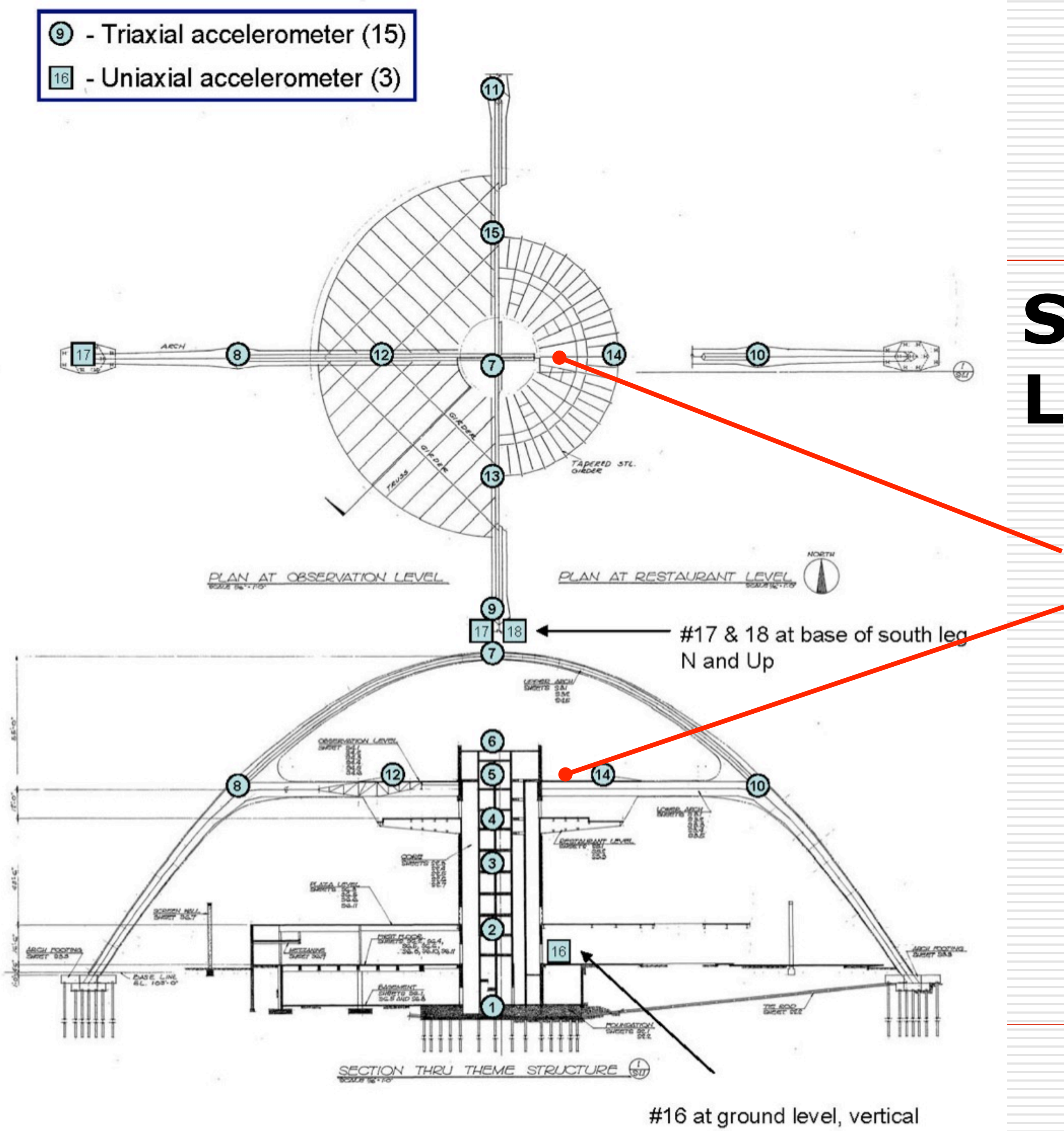
Experimental Validation

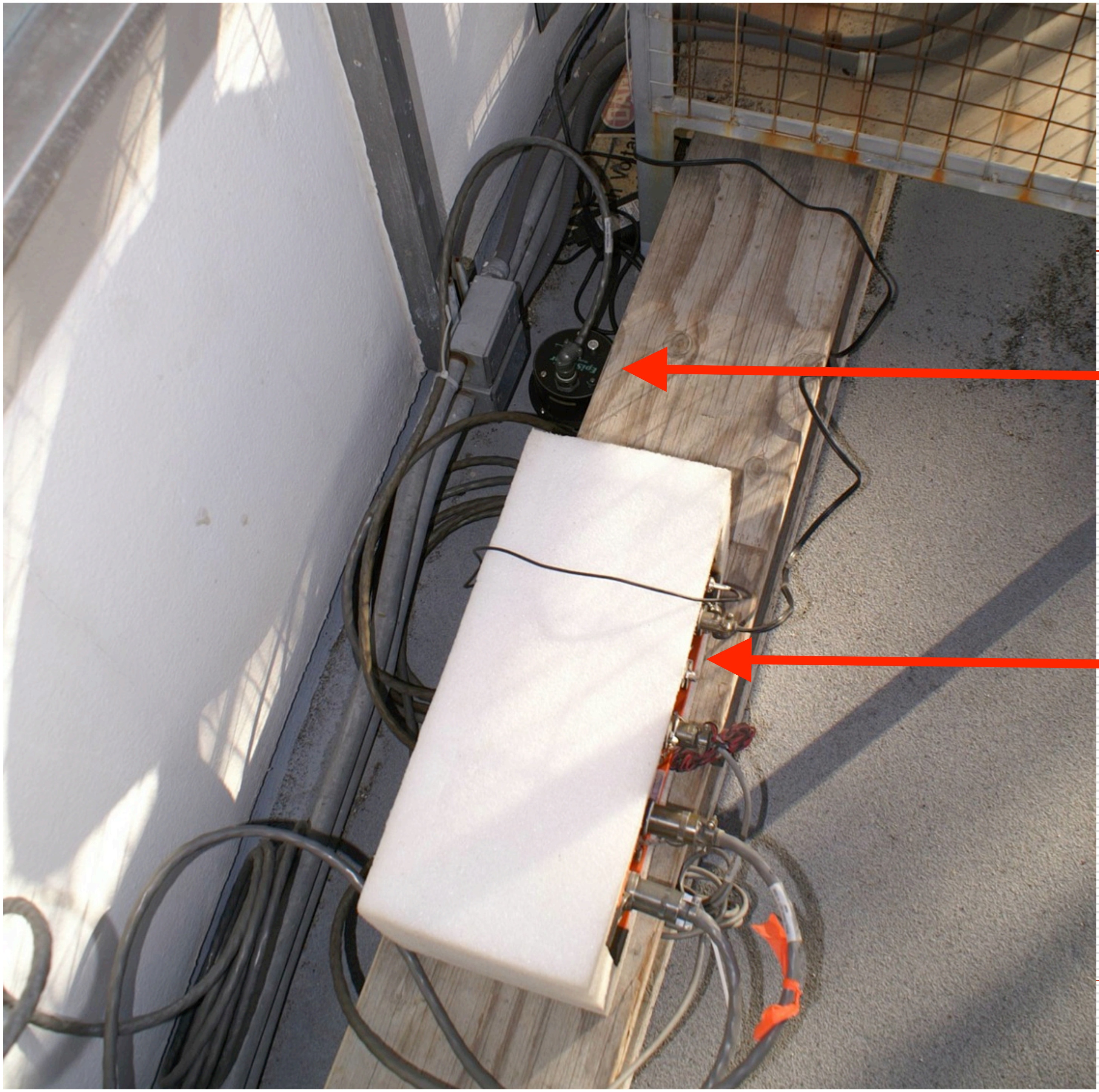


Measurements

- UCLA's small shaker, with 10,000 lb maximum force, installed on east side of observation deck. Force set to (100 x f^2) lbs.
- 51 channels of accelerometers installed at 18 locations
- Very high resolution digital recording to measure ambient through earthquake levels (micro-g to 2g)

Sensor Locations





Sensor

Recorder

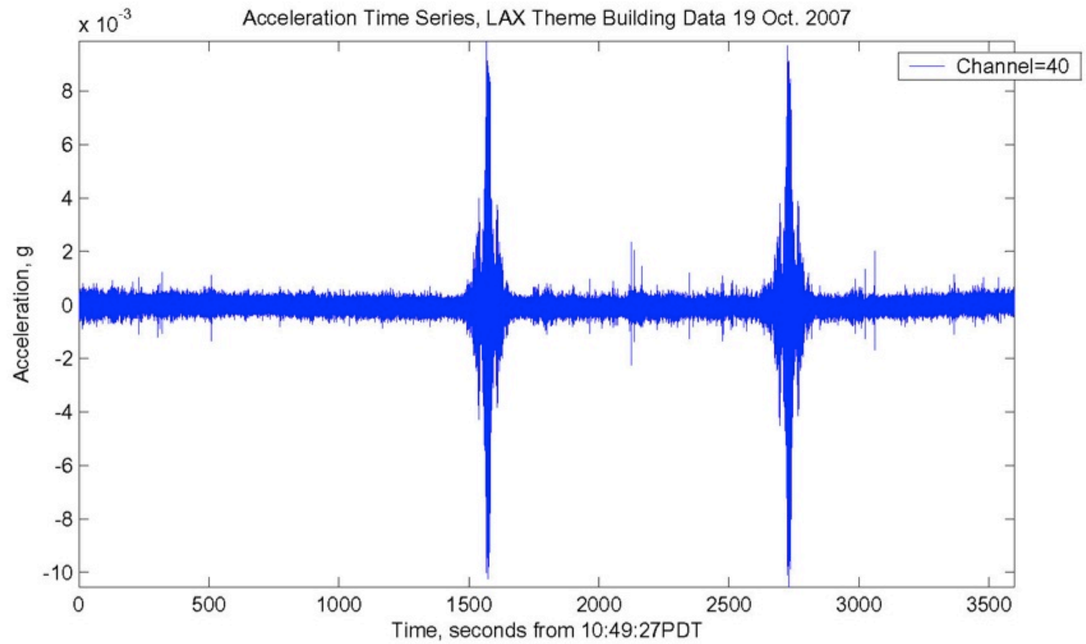
Data Recording

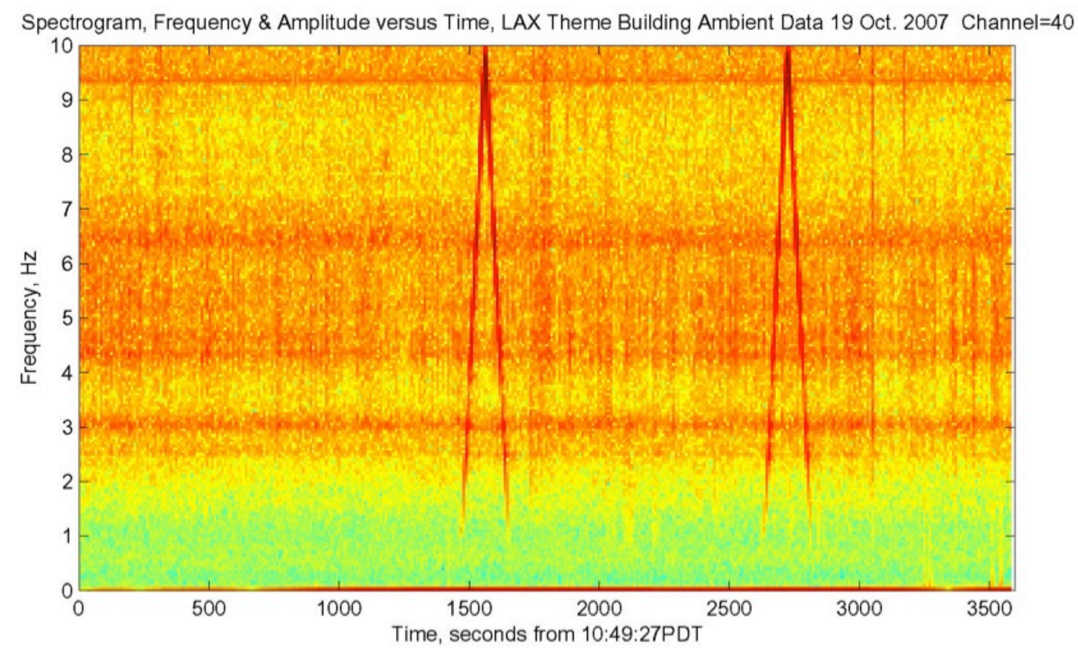
- Thursday Oct. 18: Installation
- Friday Oct. 19: E-W (X) shaking
- Friday–Sunday: Ambient Vibration, Santa Ana winds on Saturday Oct. 20 evening to 20 mph
- Monday Oct. 22: N-S and E-W shaking
- Monday–Friday: Ambient vibration, continuous

Sample Data:

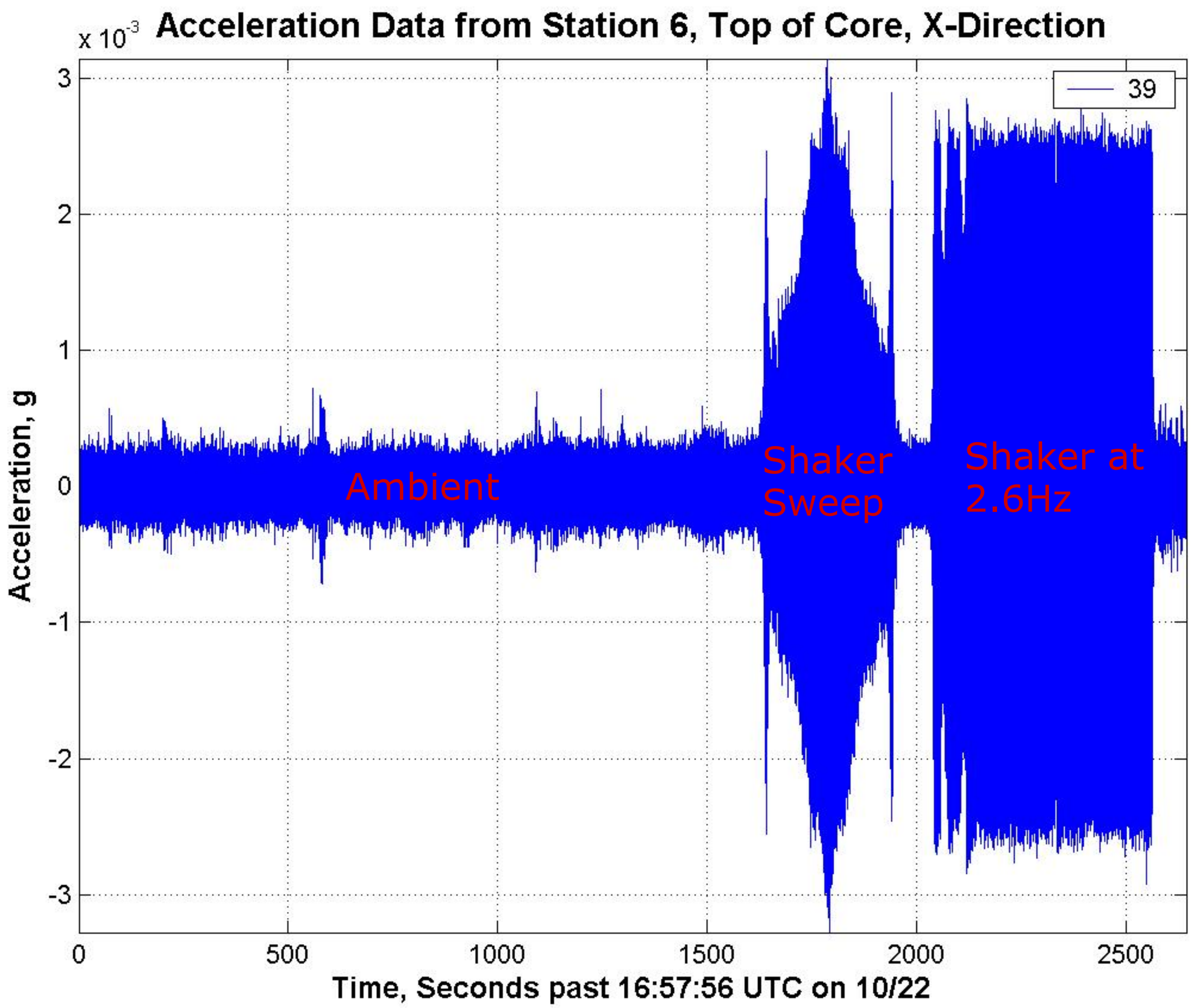
Location 14, observation deck, vertical, 1-hour, ambient & shaking

Peak~0.01g

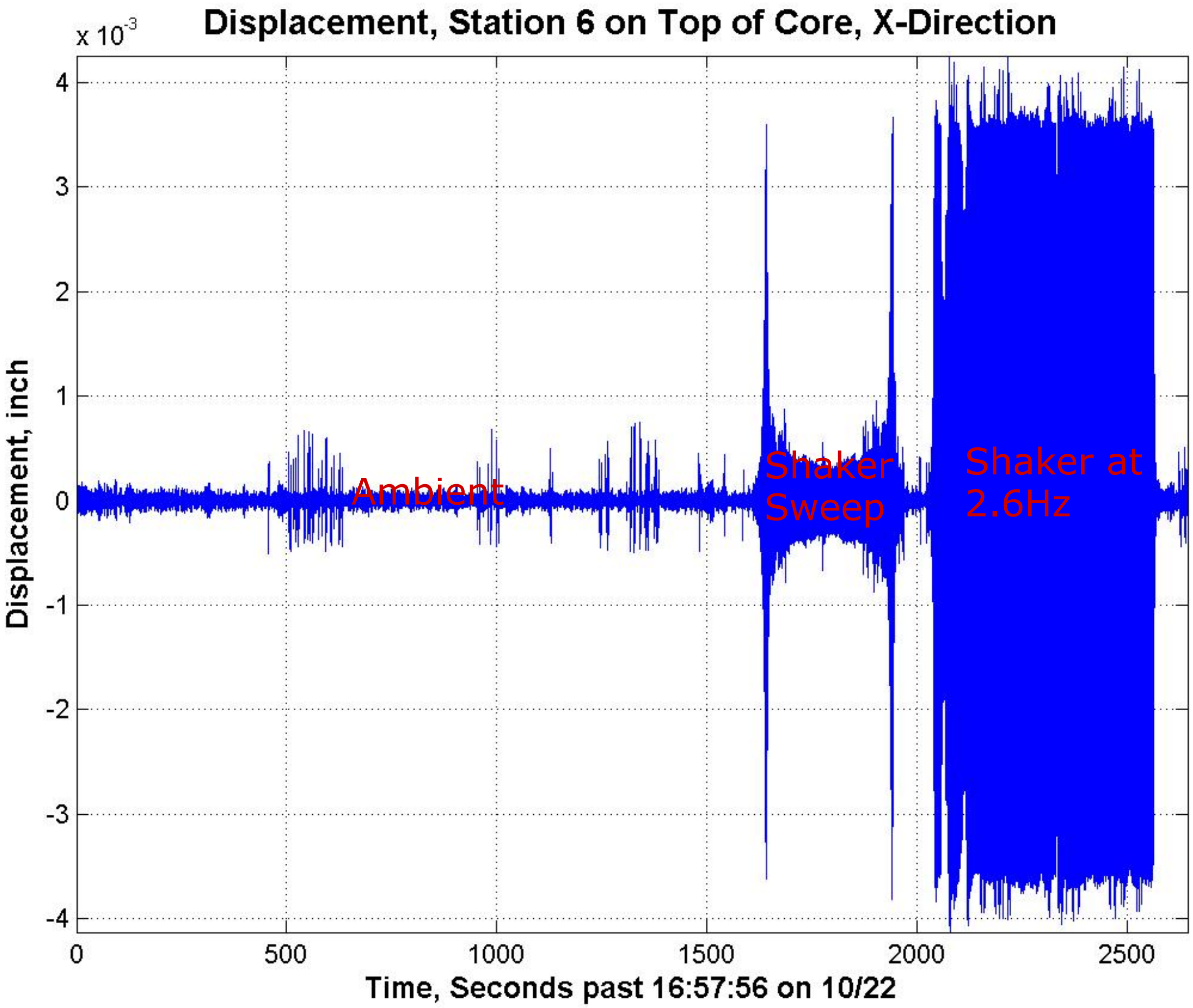




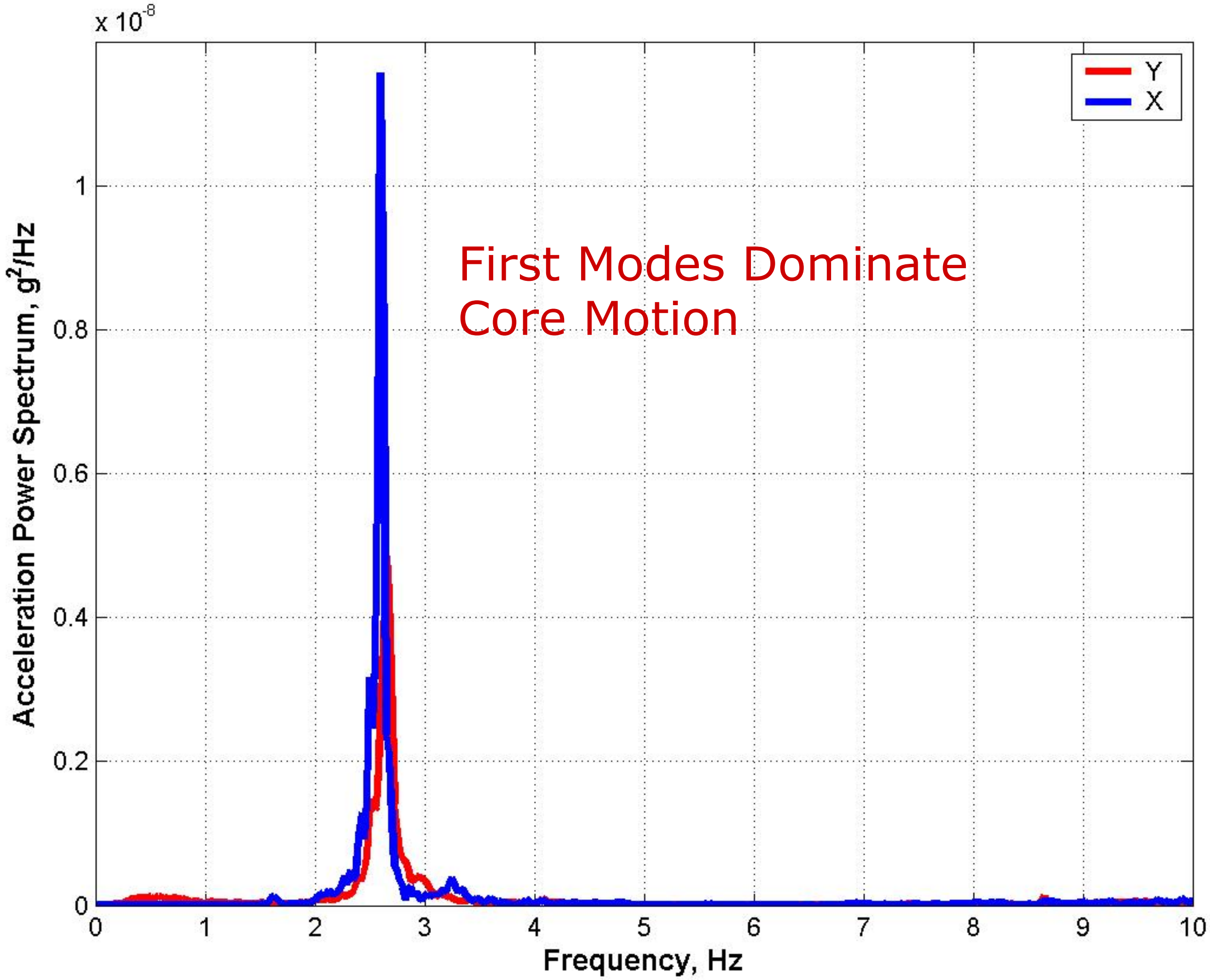
Sample Data, Acceleration (g)



Sample Data, Displacement (inch)



Sample Ambient Vibration Spectra, Top of Core, X and Y Directions



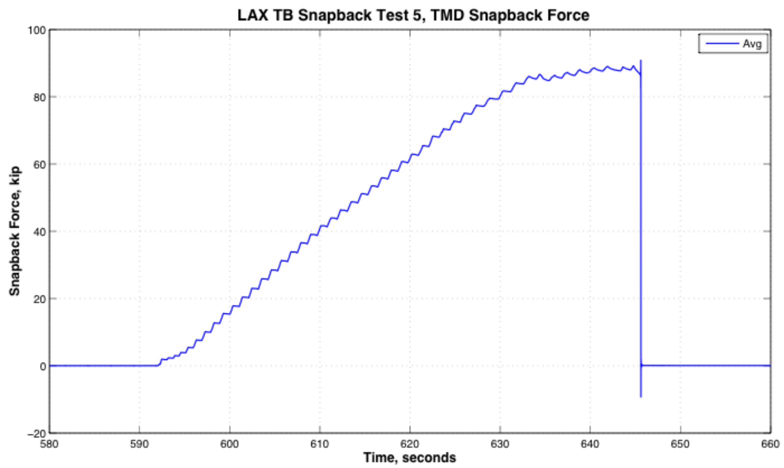
2007 Pre-Retrofit Results

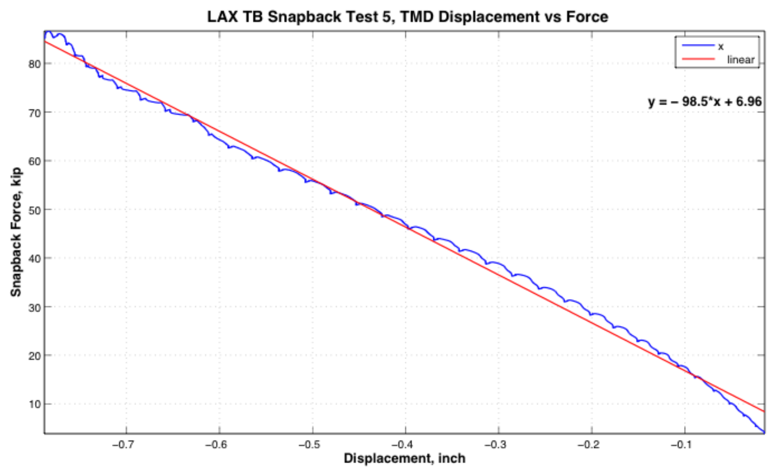
Frequency	Shape	Damping, Ambient	Damping, Shaker
2.4 Hz	N-S	1%	5%
2.6	E-W	2%	5%
4.7	Torsion + Legs		

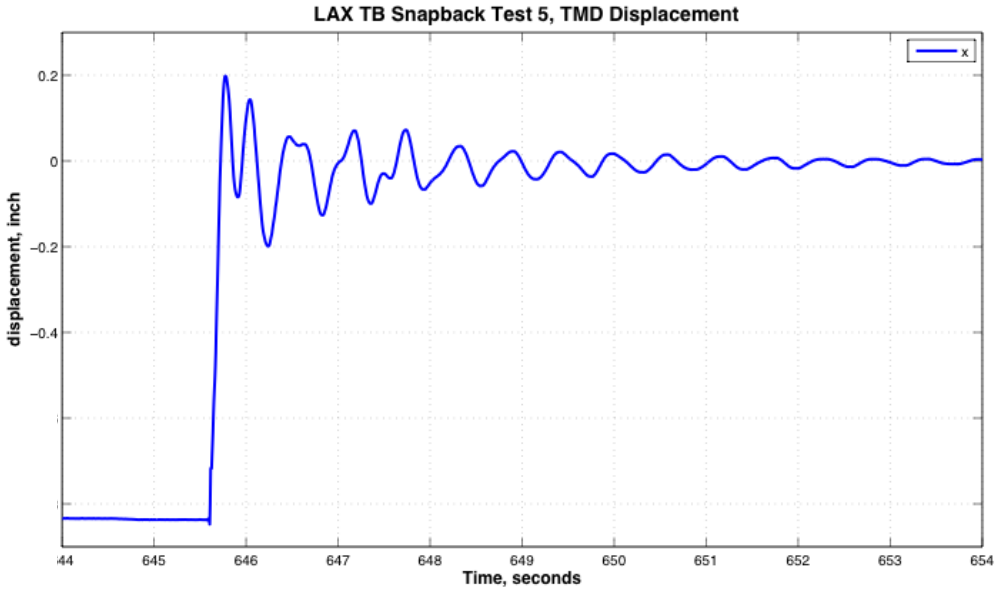
2010 Post-Retrofit Results

Frequency	Shape	Damping, Ambient	Damping, Shaker
1.8 Hz	N-S	1%	tbd
1.9	E-W	2%	tbd
4.7	Torsion + Legs		

Tuned-Mass Damper 90-Kip Snapback Tests





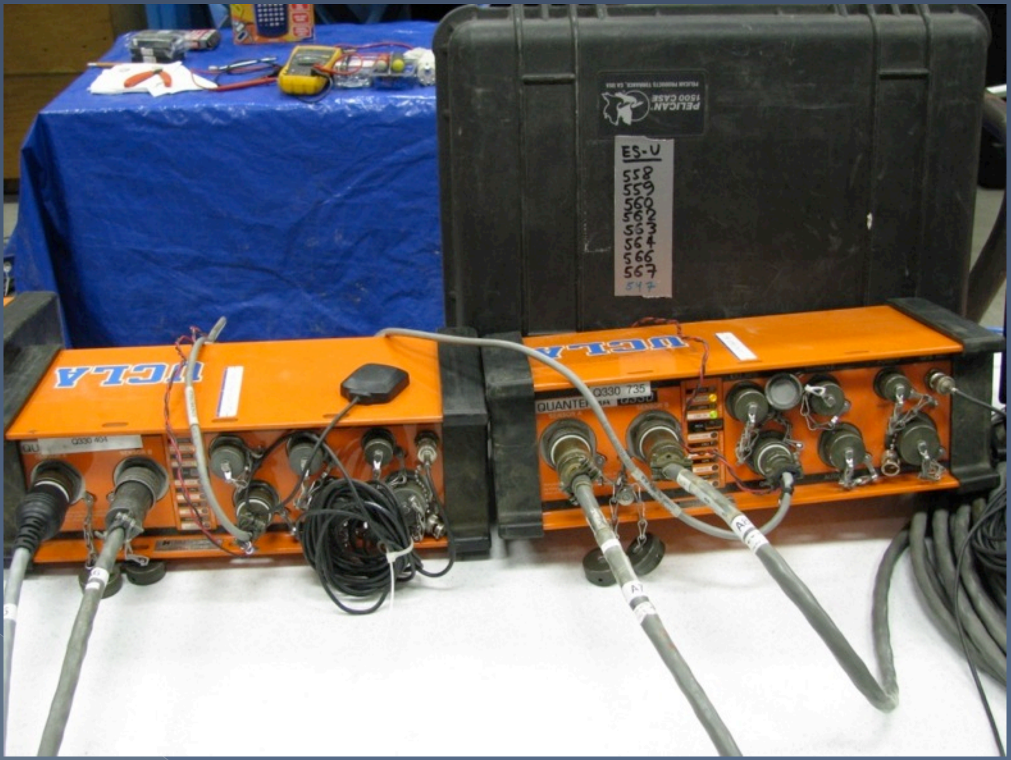


NEES Aftershock Monitoring of Reinforced Concrete Buildings in Santiago, Chile

following the February 27, 2010 Mw=8.8 Earthquake

Project Collaborators and Contributors:
Aziz Akhtary (Grad Student Researcher, CSU Fullerton)
Juan Carlos de la Llerra (Dean, Catholic University of Chile, Santiago)
Anne Lemnitzer (Assist. Prof, Cal State Fullerton)
Leonardo Massone (Assist. Prof. , Univ. of Chile, Santiago)
Bob Nigbor (NEES@UCLA co-PI & Manager)
Derek Skolnik (Sr. Project Engineer, Kinemetrics)
John Wallace (Professor, UCLA and NEES@UCLA PI)

Preparation of Instrumentation Layouts
Equipment provided by NEES@UCLA



Instrumentation used:

Instrumented Buildings

Located in Santiago, Chile

Buildings selected based on:

-Access and permission

-EERI Recon Team input

-Typical design layouts representative for Chile and the US

-Local collaborator for building selection: Juan Carlos de la Llerra

Ambient Vibration
2 Aftershocks

Ambient Vibration
30 Aftershocks

Ambient Vibration
4 Aftershocks

Ambient Vibration

Chile RAPID Instrumentation Team

US Team Members:
Anne Lemnitzer (CSUFullerton)
Alberto Salamanca (NEES @ UCLA)
Aditya Jain (Digitexx)
Marc Sereci (Digitexx; EERI team member)
John Wallace (UCLA, Instrumentation PI)

Local Graduate Student Members :
Matias Chacom, (Pontificia Universidad Católica de Chile)
Javier Encina, (Pontificia Universidad Católica de Chile)
Joao Maques, (Pontificia Universidad Católica de Chile)

Local Faculty Collaborators
Juan C. De La Llera M. (Pontificia Universidad Católica de Chile)
Leonardo Massone (University of Chile, Santiago)

CO-PIs on the NSF Rapid Proposal
Robert Nigbor (UCLA)
John Wallace (UCLA)

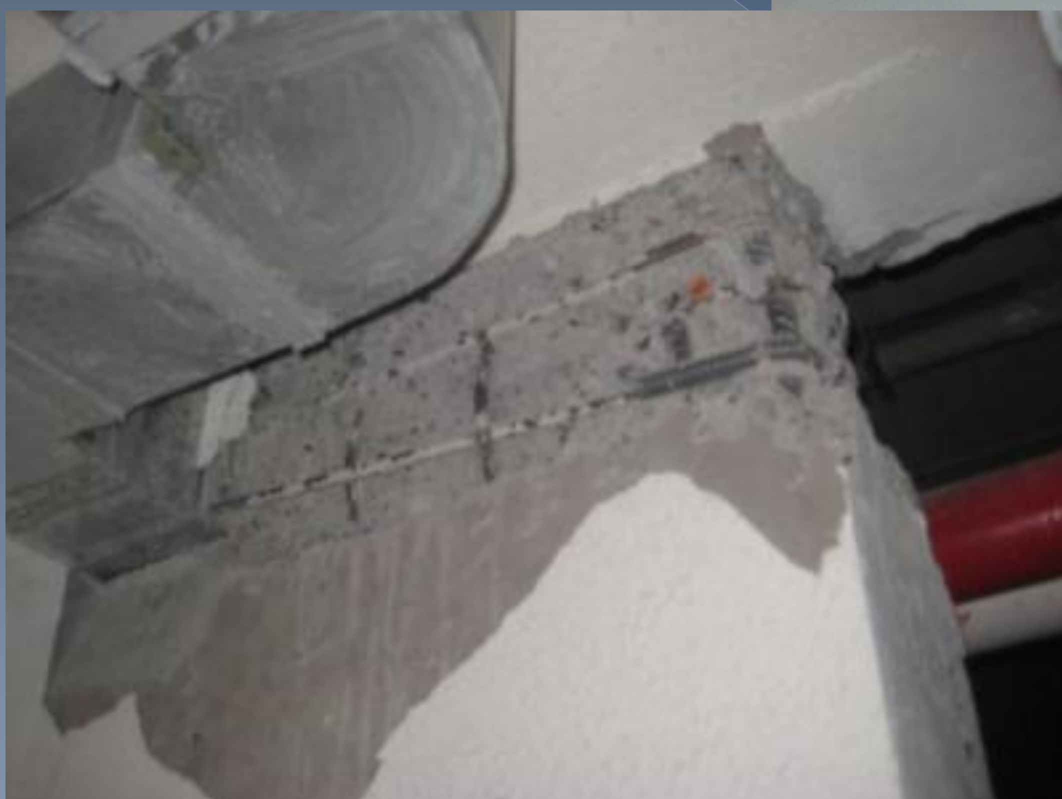
Building B:

-10 story RC residential building
- Structural system: Shear Walls
-Post Earthquake damage:

I. Shear wall failure,
II. Column buckling,
III. Extensive non-structural failure,
IV. slab bending & concrete spalling

Observed Damage in the 10 story shear wall building:

Repetitive Damage at the -1 level (Parking level):
Wall-Slab intersections



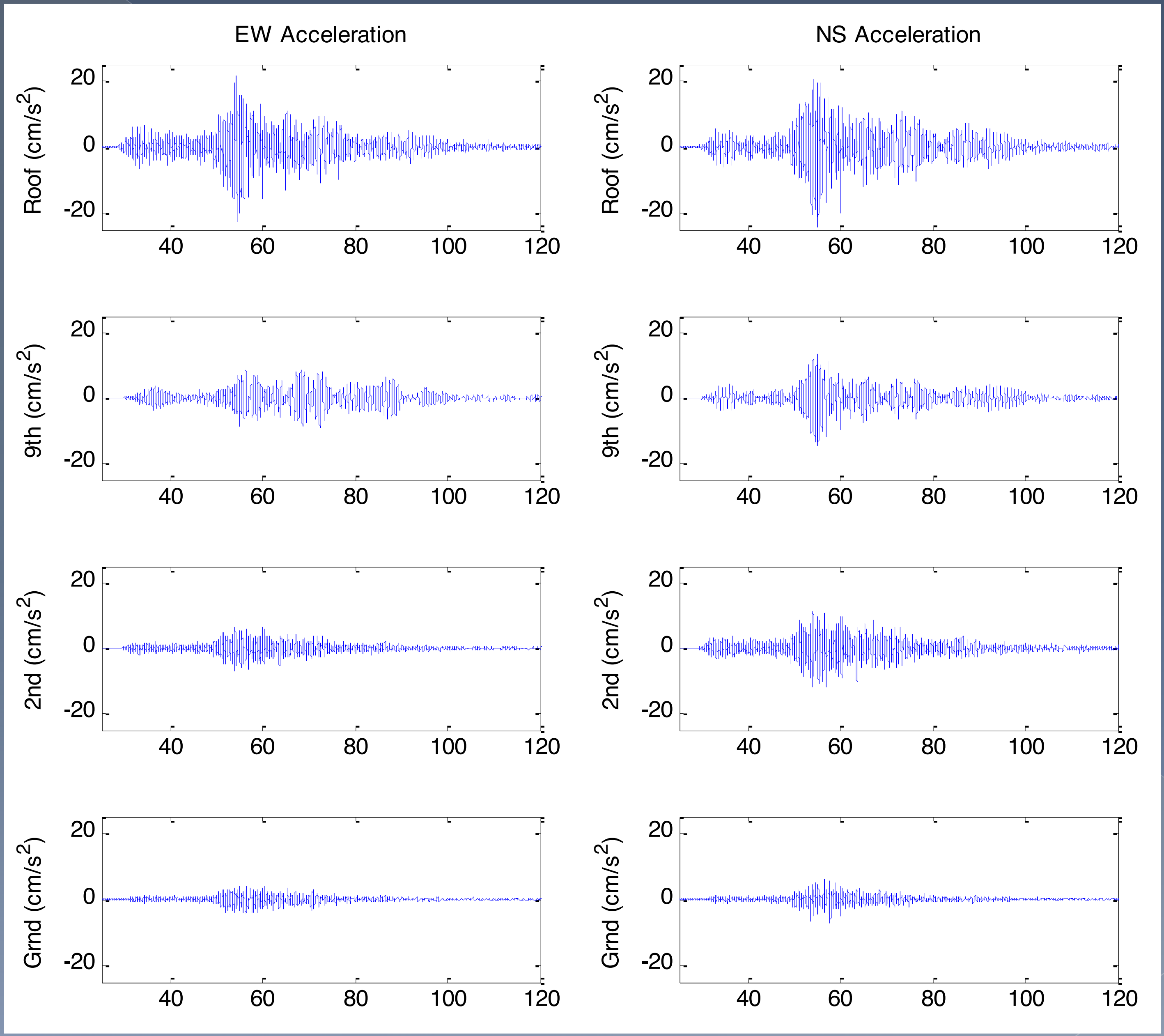
1^{st} floor shear wall damage

1st floor shear wall damage

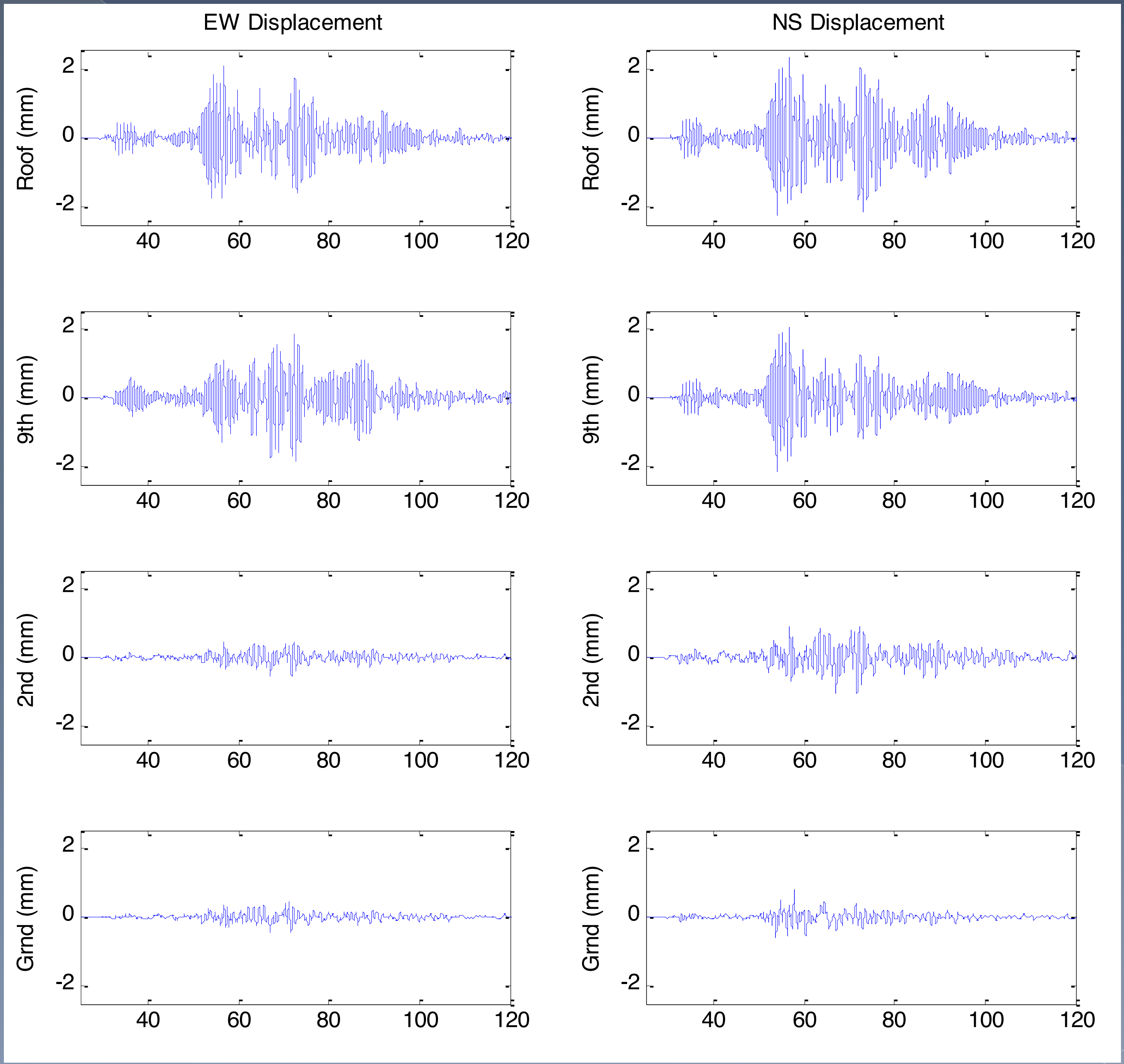
Column buckling at first floor

Shear Wall Instrumentation with LVDTs

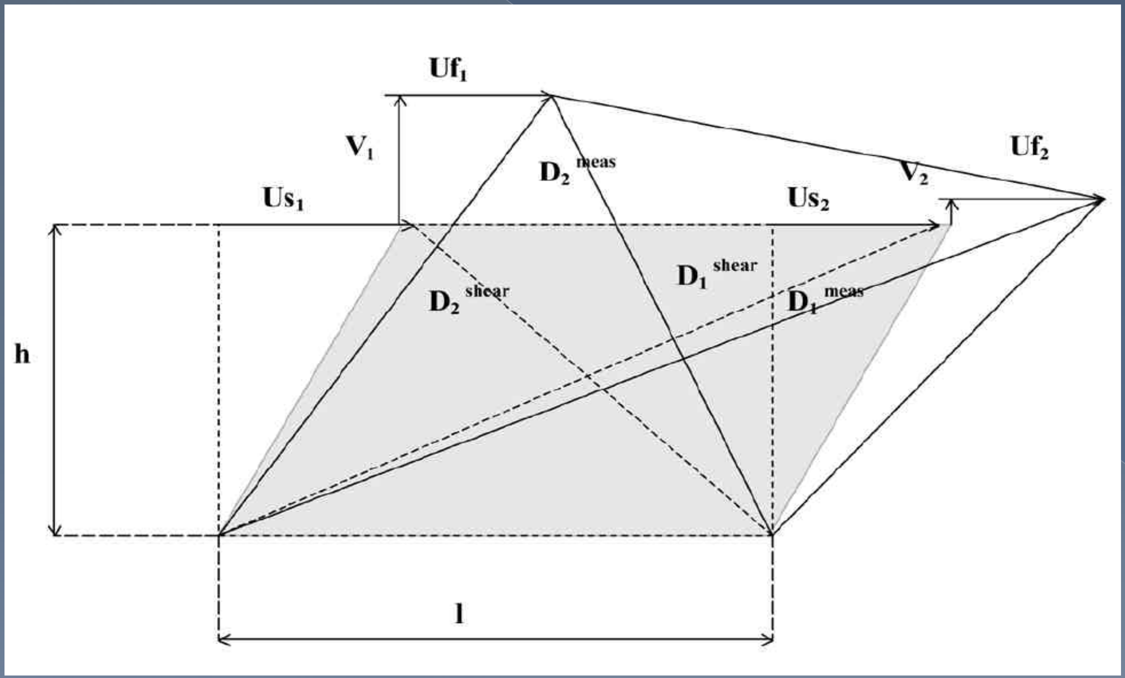
Story Accelerations 2010 05/02 14:52:39 UTC M5



Story Displacements



Shear and Flexure Deformations



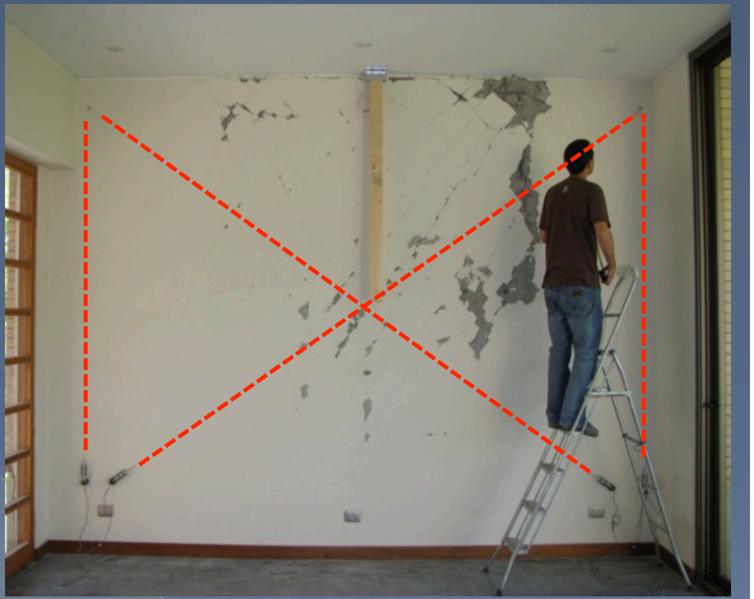
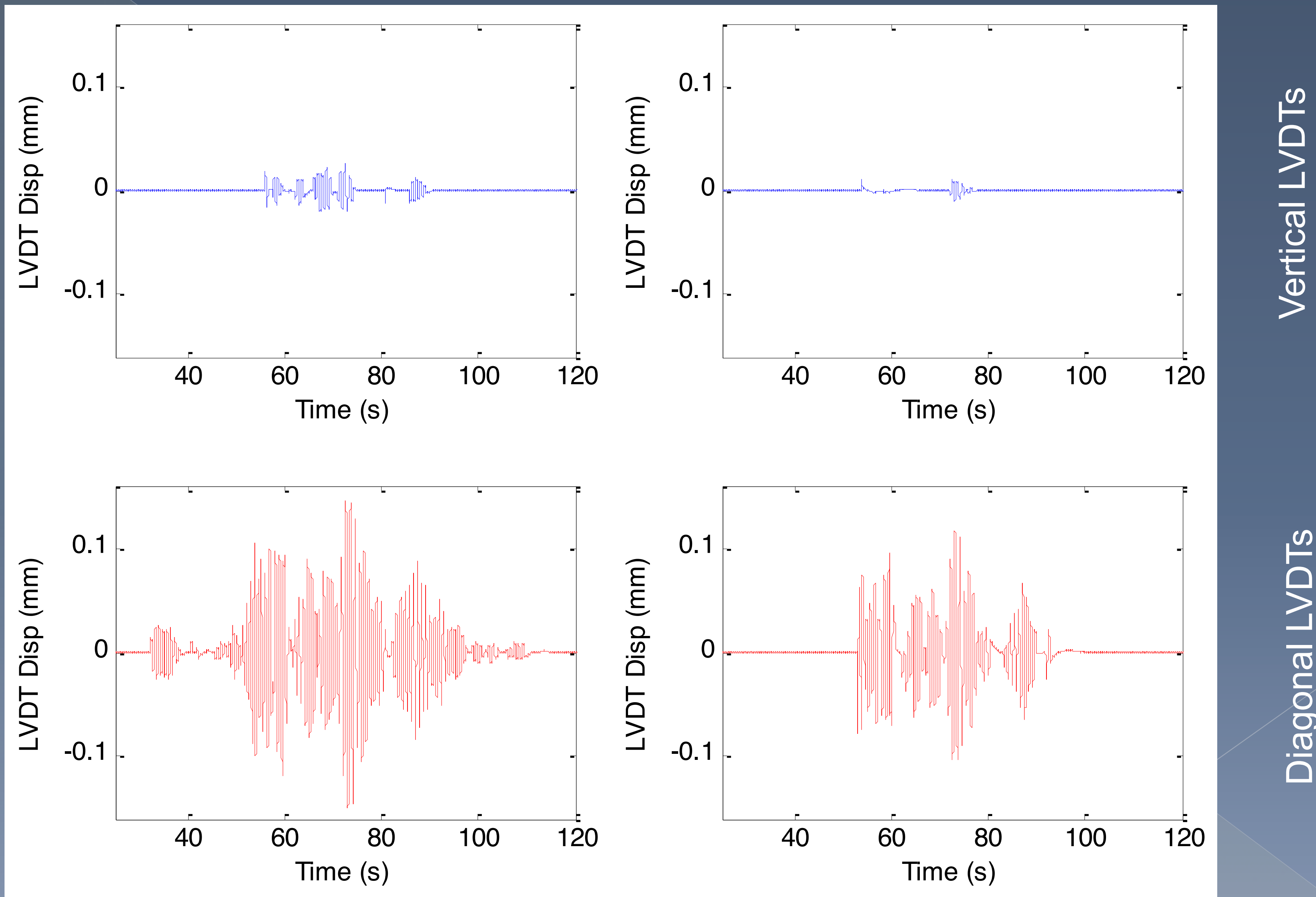
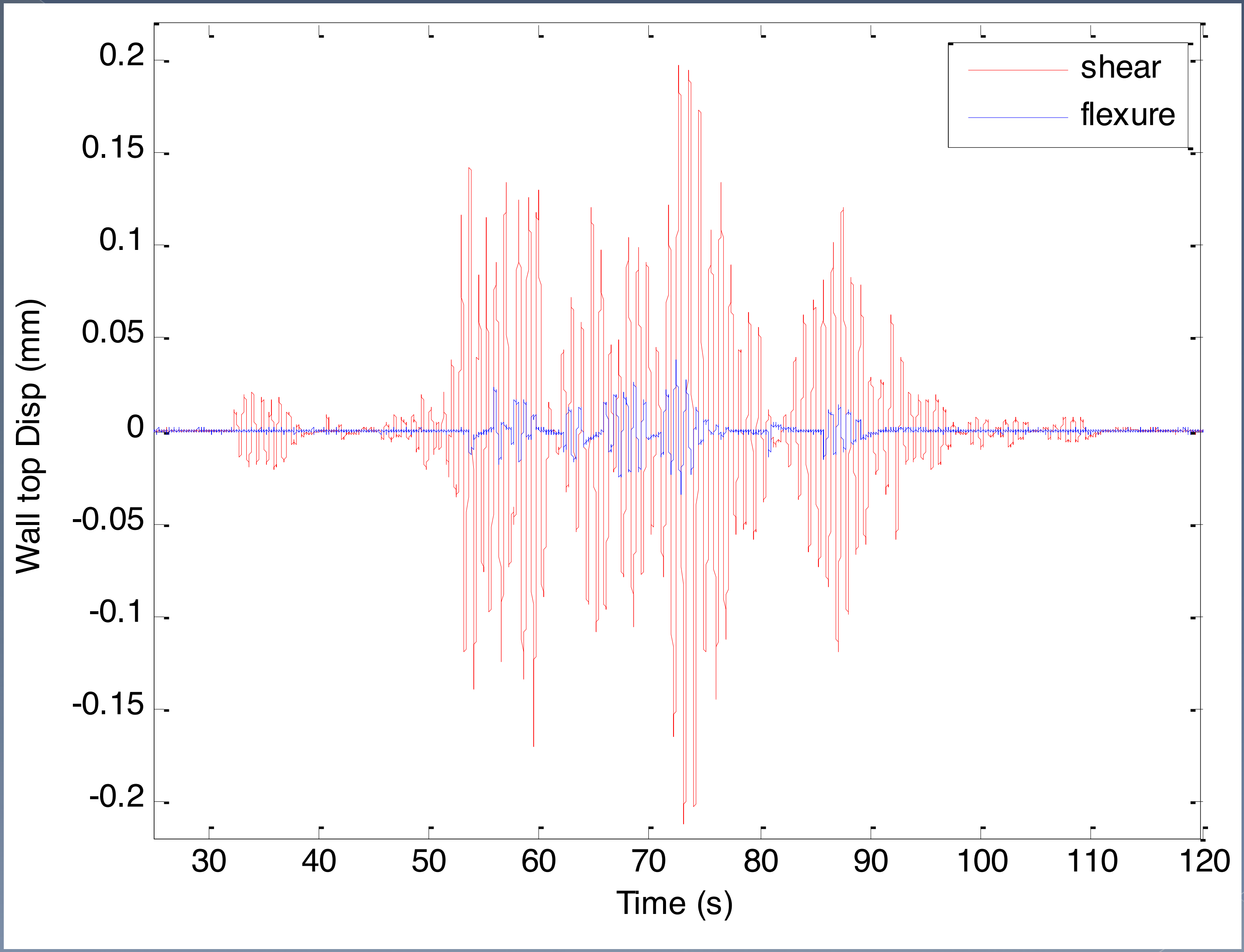


Figure 4: Shear-flexure interaction for a wall subject to lateral loading. (adapted from Massone and Wallace, 2004)

LVDT Measurements



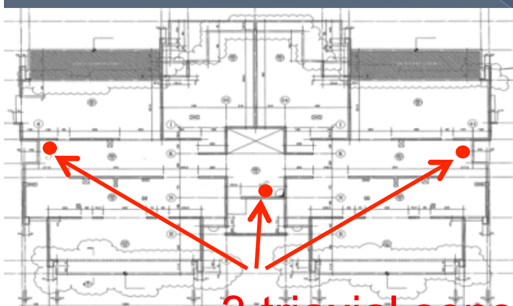
Shear and flexure deformations

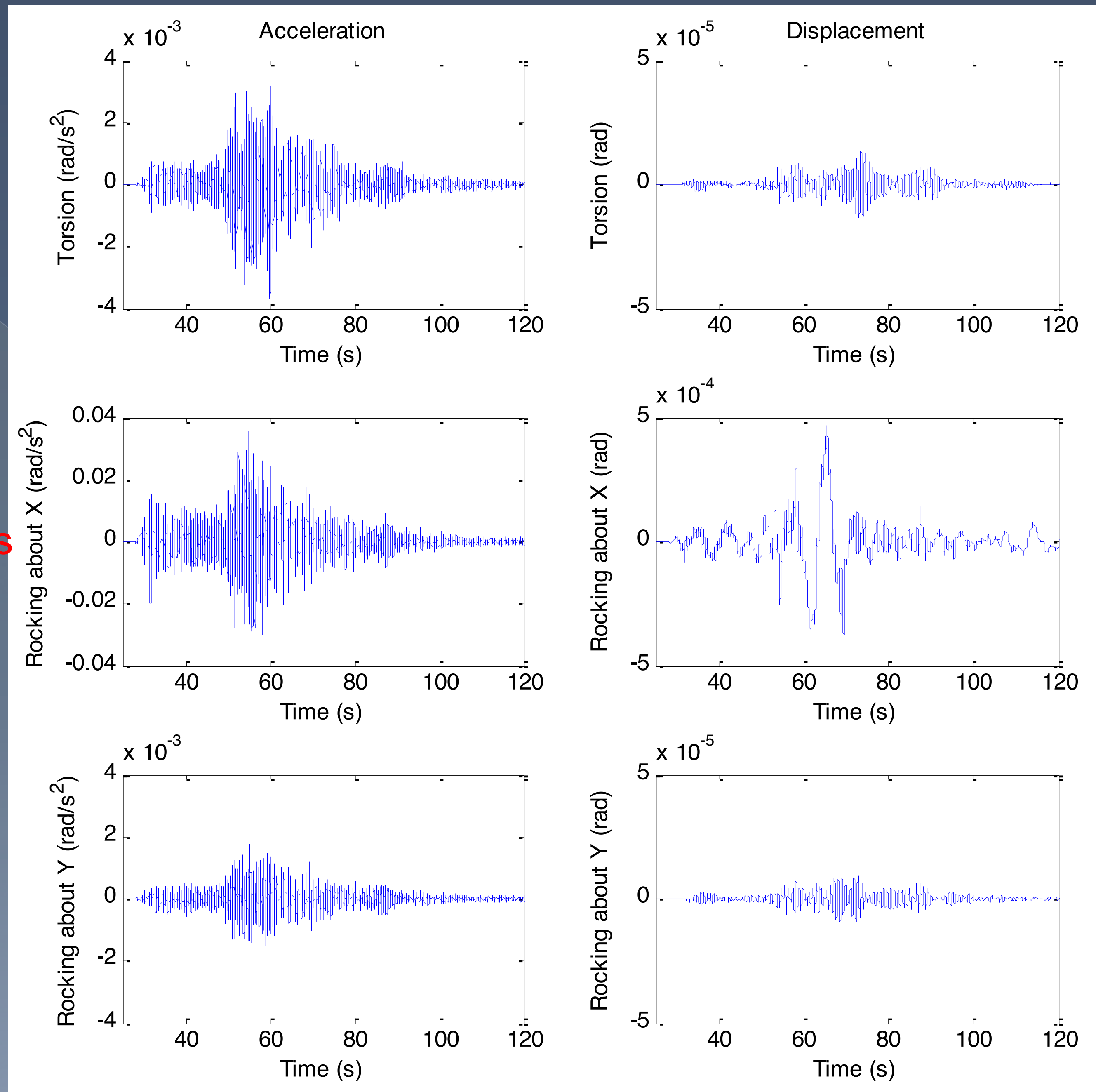


The rotation for flexure was taken at the base of the wall (so the top displacement is multiplied by the wall height), which is the largest value expected for flexure. If we assume that the flexure corresponds to a rotation at wall mid-height, the flexural component should be multiplied by 0.5.

2nd floor responses

Torsion and rocking

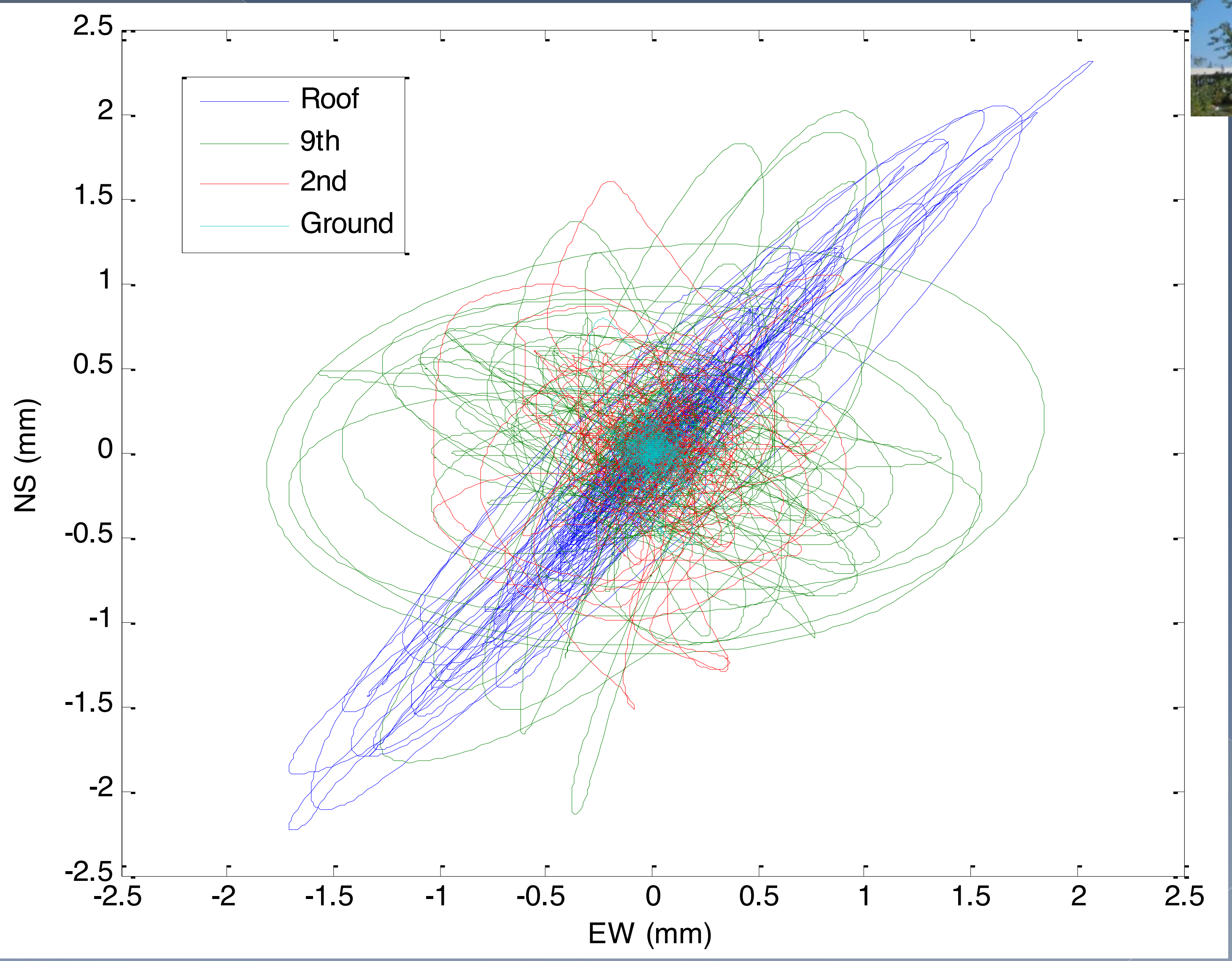




NOTE CHANGE IN SCALE FOR X-AXIS ROCKING

Rocking about the x axis = orientation of shear wall (corresponds to shear wall cracking)

Particle Motion



Lessons Learned in Chile & Turkey Deployments

- Airport regulations (invitation letters, label equipment as non stationary)
- Trigger and record mechanisms (Continuous for short duration, triggered for longer)
- Instrumentation cabling (<100m, Power supplies)
- Time Frame (ambient + aftershocks, can be 1-day or months)
- Battery power is workable
- Local collaboration essential (building access, installation, translations)
- Equipment Transportation (baggage is simple if possible)

Experimental Modal Analysis and Aftershock Monitoring for Two Christchurch Structures

Jose Restrepo, UCSD
David Deutsch, USC
Bob Nigbor, NEES@UCLA
Matt Schoettler, UCSD
Sahin Tasligedik, Univ. of Canterbury

August 4, 2011


ibis
SAKS & SUCH
Handbags
& Luggage
BAGS
& LUGGAGE
hotel ibis
111


Palazzo
del Marinaio
PALAZZO
108


WENDY'S
WENDY'S
WENDY'S
WENDY'S
P
5
At Any Time

Two Structures

- St. George Hospital Carpark
  - 5-level parking garage
  - Modern reinforced concrete construction
  - Damaged shear walls
  - Being repaired
  - Not in use until repairs completed
- Ibis Hotel
  - Inside Central Business District “Red Zone”
  - 9-story hotel building
  - Modern reinforced concrete construction
  - Extensive damage
  - Will be repaired


P8
P7
15

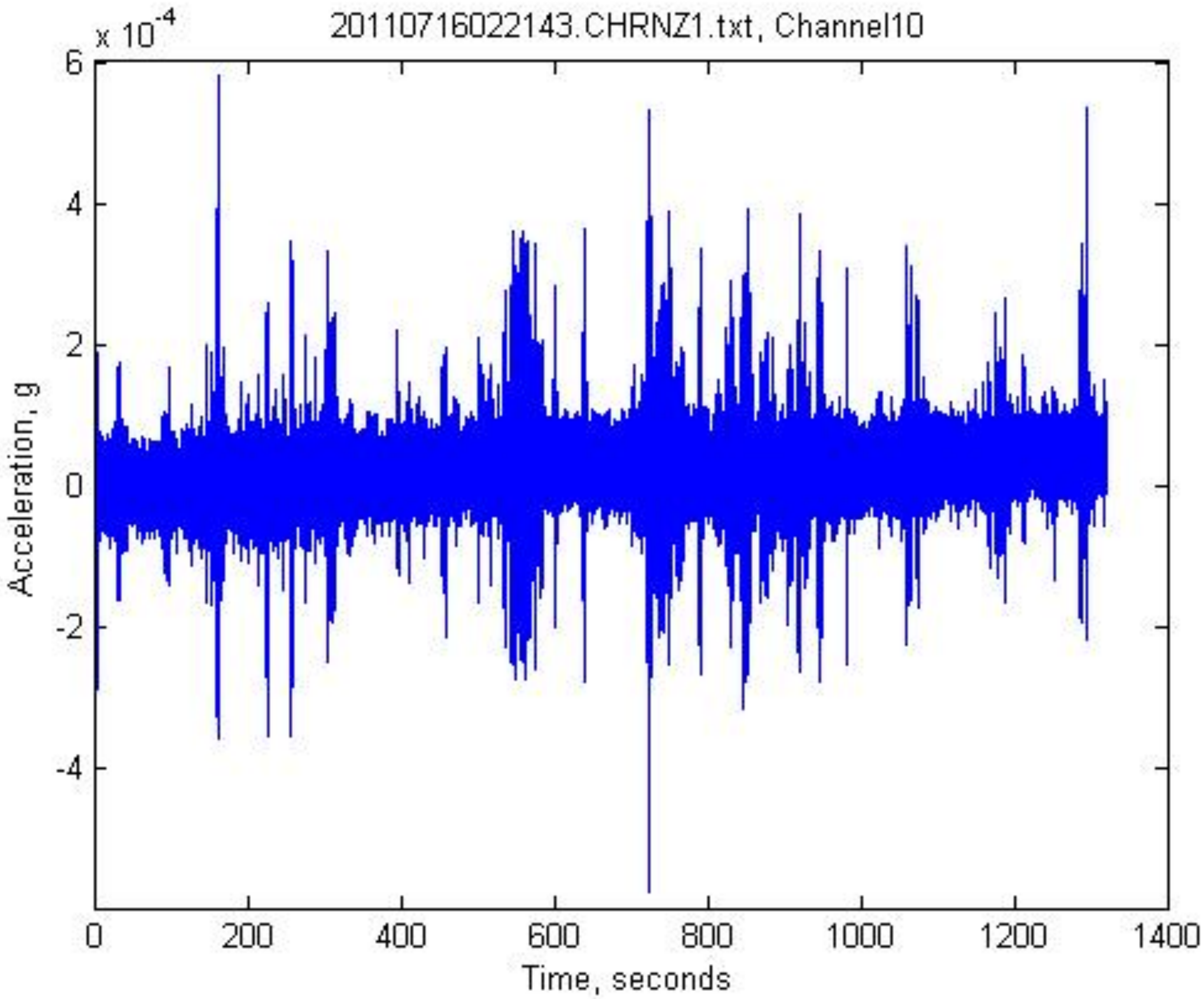

ibis
ibis
IBM


K5

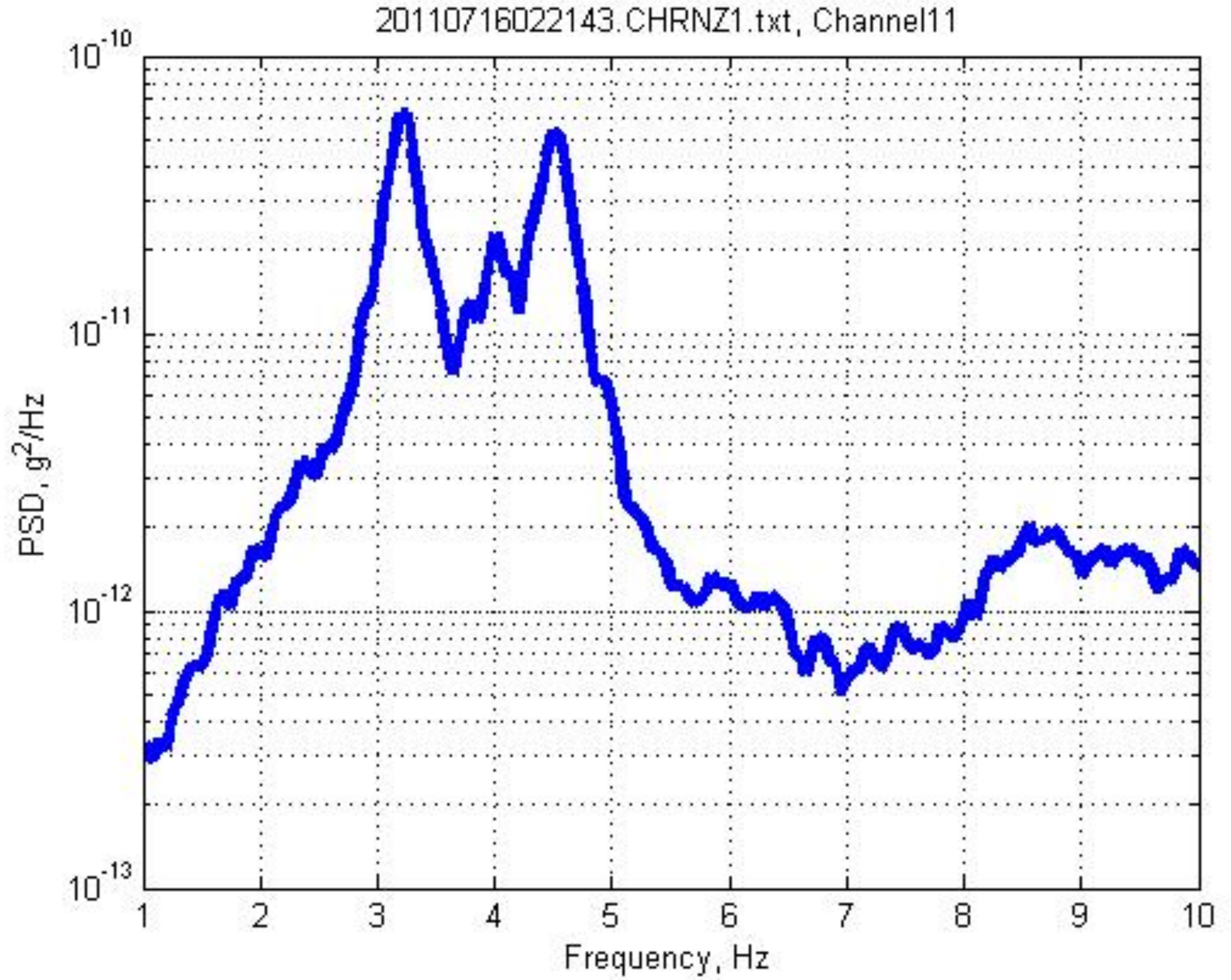
SGCP Measurements

- 12-channel system only
- 7 configurations for ambient vibrations, every corner of structure XYZ with CP5 level reference
- 20 minutes of ambient data per configuration
- Earthquake monitoring over 2 nights, 7 aftershocks recorded

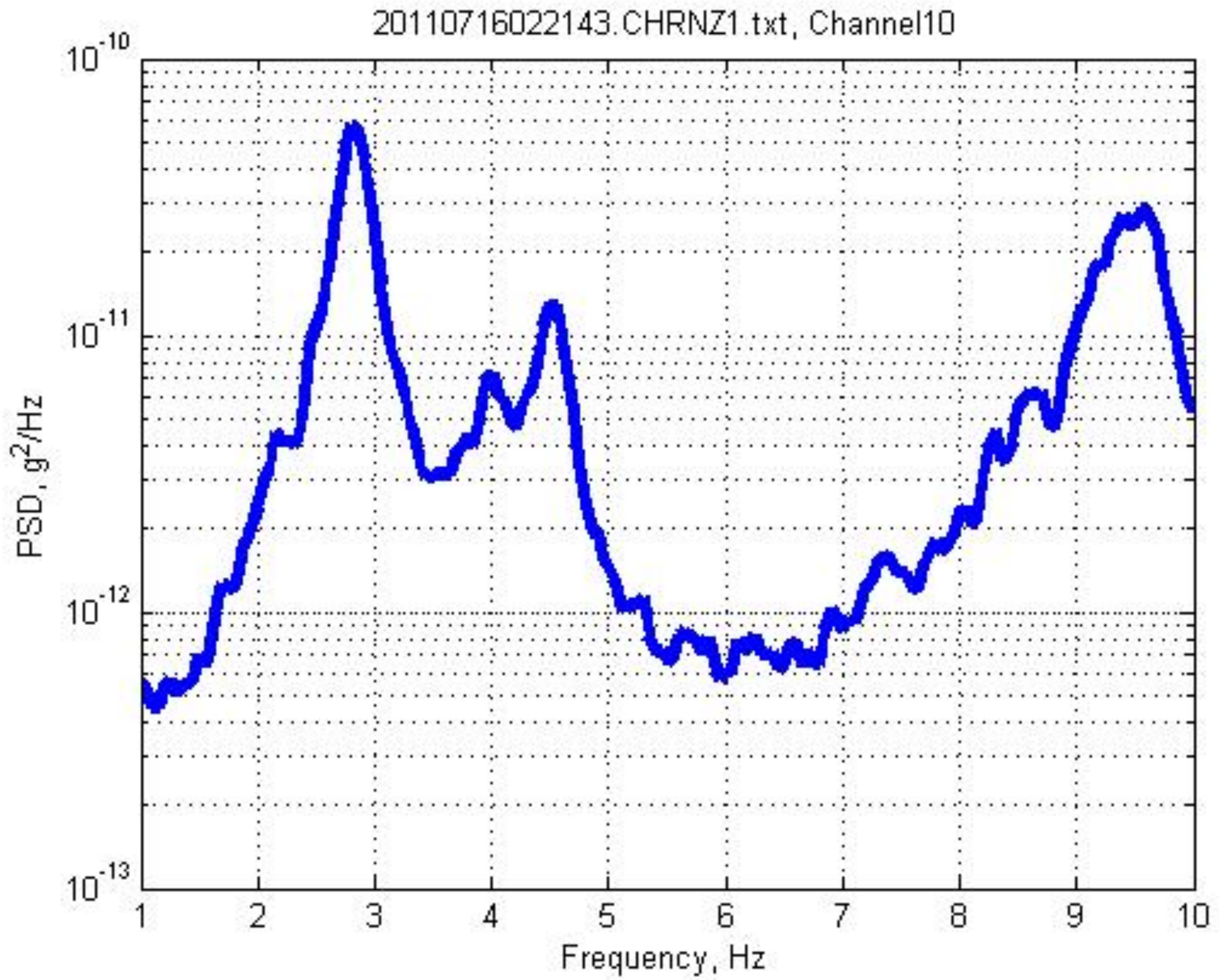
Sample ambient accelerations CP5 Column G2, Y



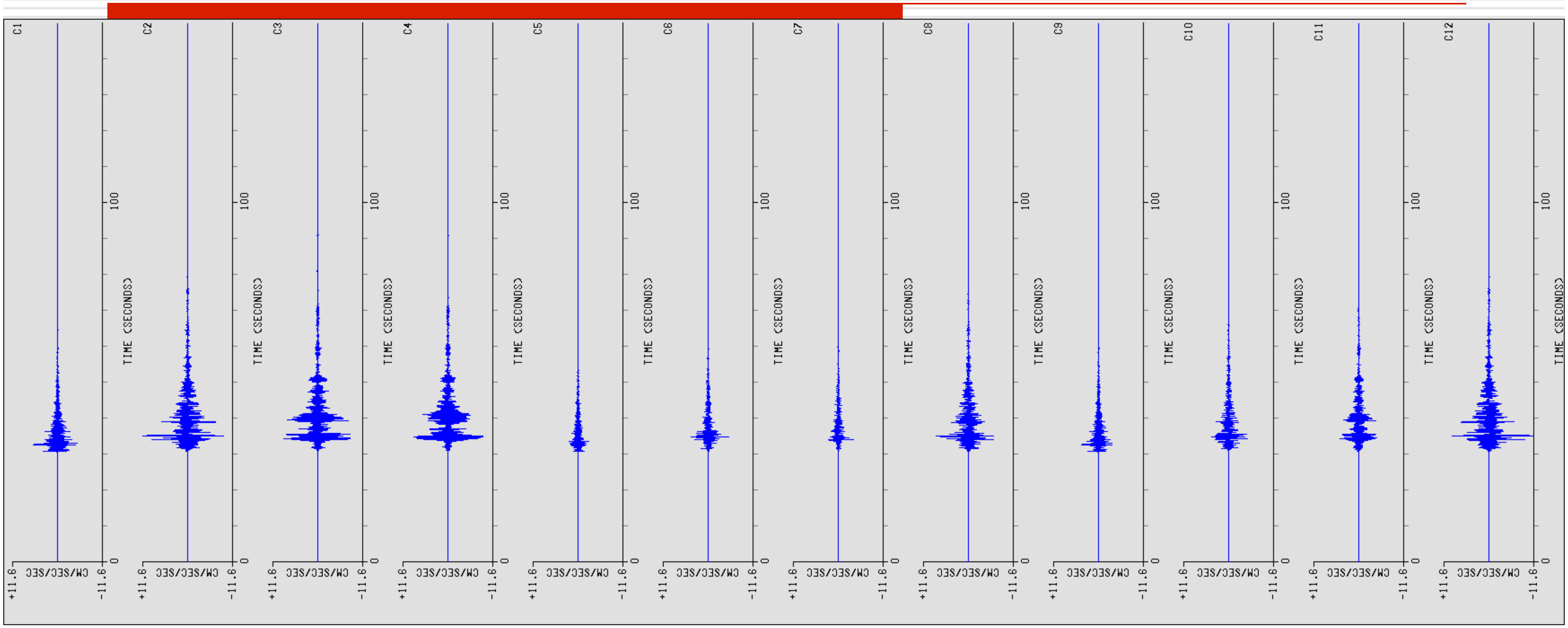
Sample PSD, X-direction, CP5 Column G2



Sample PSD, Y-direction CP5, column G2



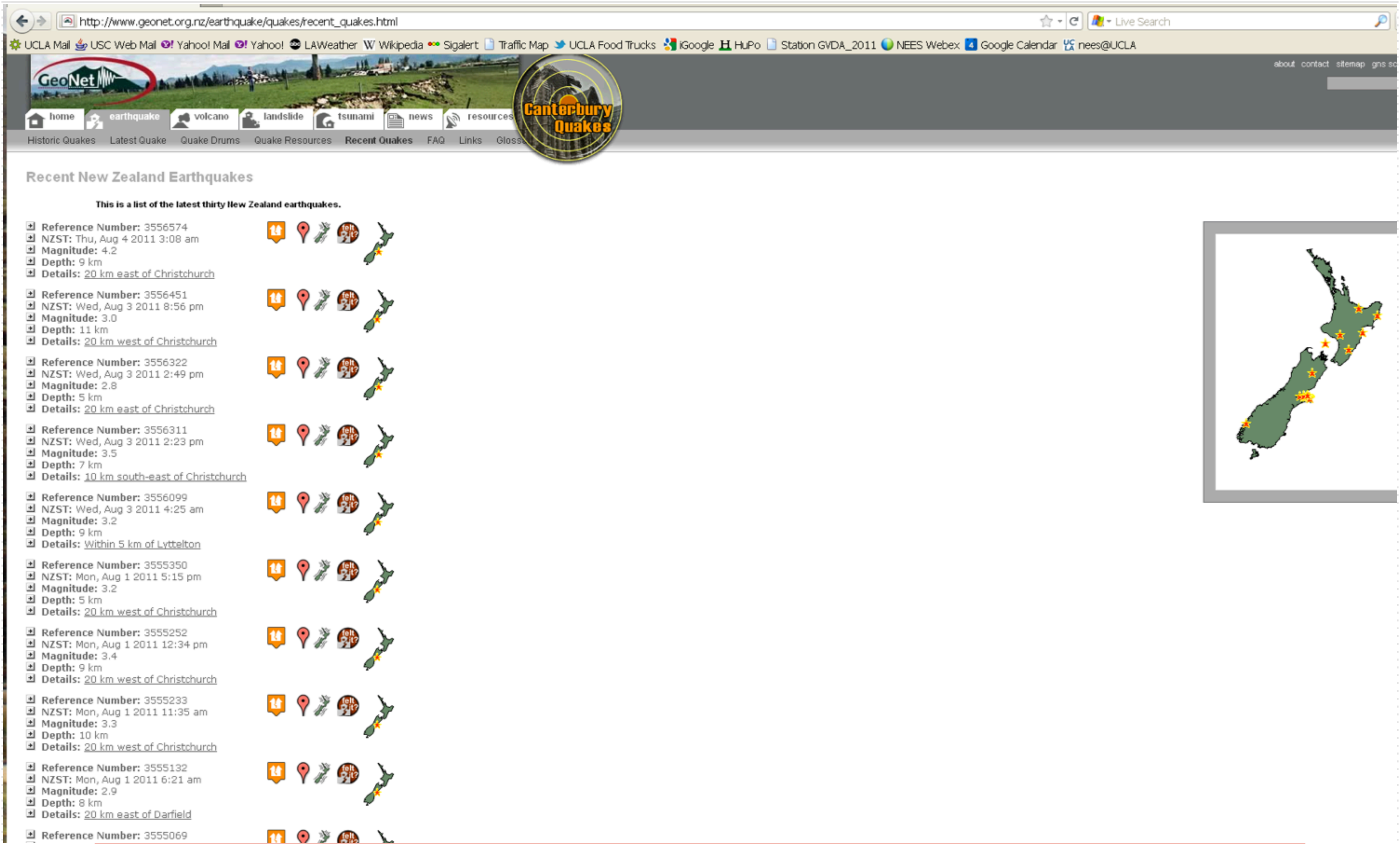
Earthquake Data
(130 sec, 11.8 cm/s/s)



CP7 ZYX CP6 Z B ZYX CP6 Y CP3 ZYX CP6 X

Preliminary Ambient Results, SGCP

Frequency Hz	Period Sec	Shape Qualitative	Damping Preliminary
2.9	.34	N-S 1	3%
3.2	.31	E-W 1	2%
4.5	.22	Torsion	
9.1	.11	N-S 2	
10	.1	E-W 2	


http://www.geonet.org.nz/earthquake/quakes/recent_quakes.html
UCLA Mail USC Web Mail Yahoo! Mail Yahoo! LAWeather Wikipedia Sigalert Traffic Map UCLA Food Trucks iGoogle HuPo Station GVDA_2011 NEES Webex Google Calendar nees@UCLA
GeoNet
home earthquake volcano landslide tsunami news resources
Historic Quakes Latest Quake Quake Drums Quake Resources Recent Quakes FAQ Links
Canterbury Quakes
Recent New Zealand Earthquakes
This is a list of the latest thirty New Zealand earthquakes.
Reference Number: 3556574
NZST: Thu, Aug 4 2011 3:08 am
Magnitude: 4.2
Depth: 9 km
Details: 20 km east of Christchurch
Reference Number: 3556451
NZST: Wed, Aug 3 2011 8:56 pm
Magnitude: 3.0
Depth: 11 km
Details: 20 km west of Christchurch
Reference Number: 3556322
NZST: Wed, Aug 3 2011 2:49 pm
Magnitude: 2.8
Depth: 5 km
Details: 20 km east of Christchurch
Reference Number: 3556311
NZST: Wed, Aug 3 2011 2:23 pm
Magnitude: 3.5
Depth: 7 km
Details: 10 km south-east of Christchurch
Reference Number: 3556099
NZST: Wed, Aug 3 2011 4:25 am
Magnitude: 3.2
Depth: 9 km
Details: Within 5 km of Lyttelton
Reference Number: 3555350
NZST: Mon, Aug 1 2011 5:15 pm
Magnitude: 3.2
Depth: 5 km
Details: 20 km west of Christchurch
Reference Number: 3555252
NZST: Mon, Aug 1 2011 12:34 pm
Magnitude: 3.4
Depth: 9 km
Details: 20 km west of Christchurch
Reference Number: 3555233
NZST: Mon, Aug 1 2011 11:35 am
Magnitude: 3.3
Depth: 10 km
Details: 20 km west of Christchurch
Reference Number: 3555132
NZST: Mon, Aug 1 2011 6:21 am
Magnitude: 2.9
Depth: 8 km
Details: 20 km east of Darfield
Reference Number: 3555069

Next Up in August–
Christchurch Women's Hospital

Thanks!

- For more information:
  - http://nees.ucla.edu
  - http://www.nees.org
  - nigbor@ucla.edu