NHERI@UC San Diego 4^{TH} USERS TRAINING WORKSHOP

Workshop Program – Thursday Morning

7:30 - 8:00am	Registration/light breakfast
8:00 - 8:15am	Welcome, Introduction of each Attendee & Workshop Schedule (Prof. Joel Conte, UCSD)
8:15 - 9:15am	NHERI@UCSD: Facility Description and Capabilities (Prof. Joel Conte, UCSD)
9:15 - 9:30am	NHERI DesignSafe: user tools & support (Dr. Tim Cockerill, UT Austin)
9:30 - 10:00am	Nuts & Bolts: Instrumentation/DAQ, Cameras, IT Resources & Cybersecurity (Dr. Ozgur Ozcelik, Research Scientist, SOM, UCSD)
10:00 - 10:30am	Break
10:30 - 11:00am	Journey through a project (Structural) (Prof. Jose Restrepo, UCSD)
11:00 - 11:30am	Journey through a Project (Geotechnical) (Prof. Ahmed Elgamal, UCSD)
11:30 - 12:30am	Box Lunch (in the Forum) & bus to site (depart 12:30pm; arrive 1:00pm)

Workshop Program – Thursday Afternoon

1:00 - 2:15pm	Facility Tour and Demonstration by RAPID Center (depart 2:30pm; arrive at UCSD at 3:00pm) (Prof. Joel Conte, UCSD & Prof. Jeff Berman, Univ. of Washington)
3:00 - 3:30pm	Advances in Hybrid Simulation (Prof. Gilberto Mosqueda, UCSD)
3:30 - 3:50pm	Research Planning in a Nutshell (Prof. Tara Hutchinson, UCSD)
3:50 - 4:15pm	Payload Opportunities (Prof. Chia-Ming Uang, UCSD & Prof. Keri Ryan, Univ. of Nevada at Reno)
4:15 - 5:00pm	Education, Outreach and Training (EOT) (Prof. Lelli Van Den Einde) & Open Discussion (Q/A)
5:30 - 8:00pm	Dinner – Structural and Materials Building (SME) Courtyard

Workshop Program – Friday Morning

7:30 - 8:00am	Light breakfast
8:00 - 8:15am	Opening Remarks (Prof. Joel Conte, UCSD)
8:15 - 9:15am	Model Design and Dynamic Similitude (centrifuge-scale) & NHERI@UC Davis (Prof. Katerina Ziotopoulou & Dr. Dan Wilson, UC Davis)
9:15 - 10:00am	Model Design and Dynamic Similitude (1g/large scale) (Prof. John McCartney)
10:00 - 10:15am	Break
10:15 - 11:15am	NHERI RAPID@Univ. of Washington (Prof. Jeff Berman, Un. of Washington)
11:15 - 12:15am	NHERI SimCenter (Dr. Matt Schoettler, UC Berkeley)
12:15+	Lunch on the Terrace – Poster Session on the Terrace

Presenters

- Jeff Berman, Univ. of Washington
- Tim Cockerill, UT Austin
- Joel Conte, UC San Diego
- Ahmed Elgamal, UC San Diego
- Tara Hutchinson, UC San Diego
- John McCartney, UC San Diego
- Gilberto Mosqueda, UC San Diego
- Ozgur Ozcelik, UC San Diego
- Jose Restrepo, UC San Diego
- Keri Ryan (Univ. of Nevada, Reno)
- Benson Shing, UC San Diego
- Matt Schoettler, UC Berkeley
- Chia-Ming Uang, UC San Diego
- Lelli Van Den Einde, UC San Diego
- Dan Wilson, UC Davis
- Katerina Ziotopoulou, UC Davis

Objectives

- Familiarize prospective users of the NHERI@UC San Diego shake table with its simulation capabilities and performance characteristics and limitations.

- Introduce prospective users to the basics of large-scale shake table testing, including recommendations for how to plan for and execute successful large-scale shake table projects:
  - Pros and cons of shake table experiments
  - Experiment design and execution
  - Project management
  - Data acquisition, storage, retrieval, and interpretation

- Describe complementary research capabilities supported by NHERI@UC Davis, NHERI RAPID (University of Washington) and NHERI SimCenter.

- Provide workshop attendees with the knowledge necessary to prepare research proposals utilizing the NHERI Experimental Facility at UC San Diego, including a broader vision of utilizing other NHERI facilities, and the Educational and Community Outreach (ECO) aspect.

NHERI@UC San Diego: Facility Description and Capabilities

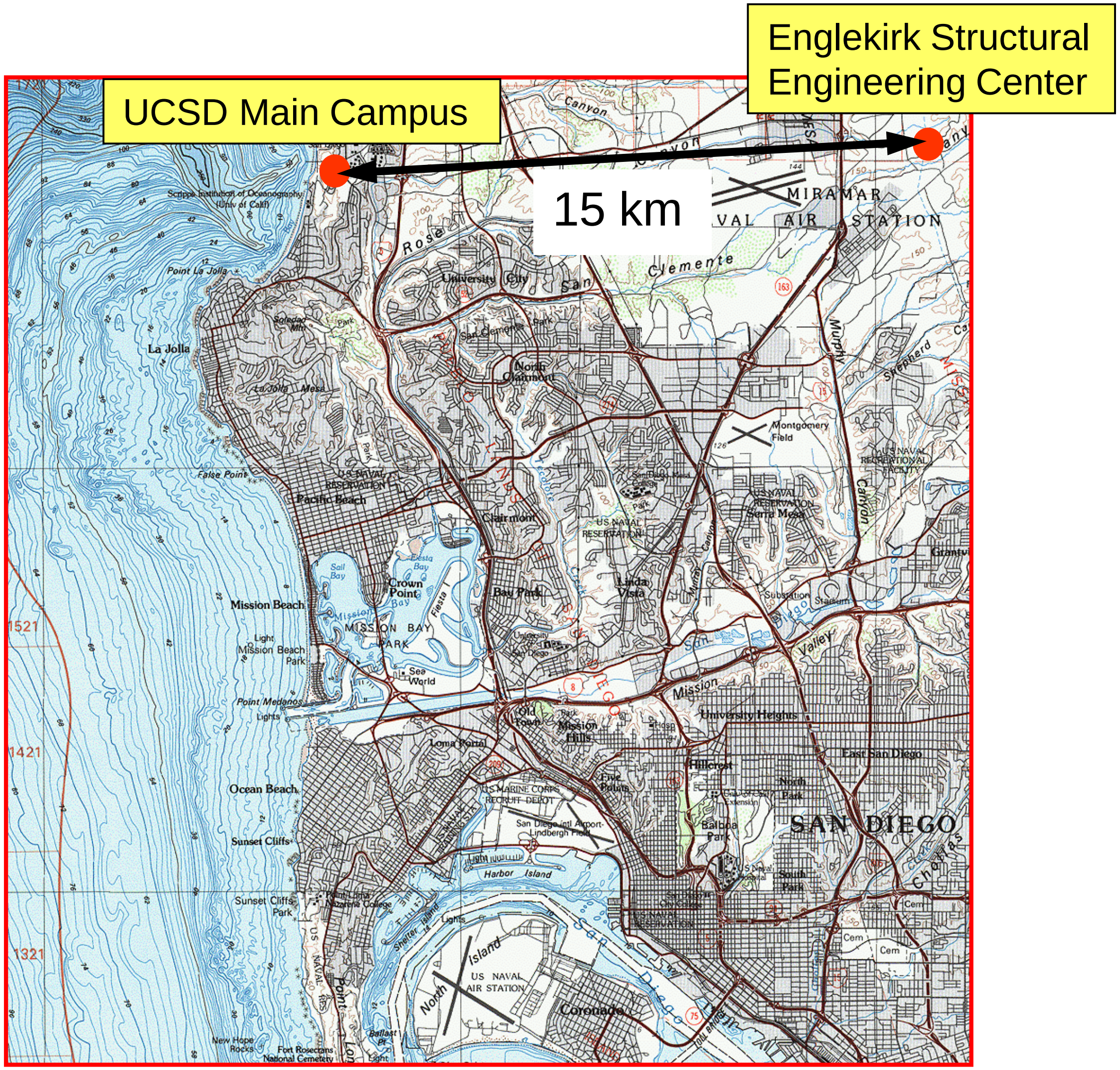
Joel Conte, Professor

University of California, San Diego

December 12, 2018

Natural Hazards Engineering Research Infrastructure (NHERI) Network

Englekirk Structural Engineering Center



Englekirk Structural Engineering Center

Soil-Structure-Interaction Facility

HYDRAULIC POWER SYSTEM BUILDING

BLAST/IMPACT TEST FACILITY

Large High-Performance Outdoor Shake Table (LHPOST)

IAS Accreditation of ESEC

INTERNATIONAL ACCREDITATION SERVICE®

CERTIFICATE OF ACCREDITATION

This is to attest that

ENGLEKIRK STRUCTURAL ENGINEERING CENTER

10201 POMERADO ROAD
SAN DIEGO, CA 92131

Testing Laboratory TL-356

has met the requirements of AC89, *IAS Accreditation Criteria for Testing Laboratories,* and has demonstrated compliance with ISO/IEC Standard 17025:2005, *General requirements for the competence of testing and calibration laboratories.* This organization is accredited to provide the services specified in the scope of accreditation maintained on the IAS website (www.iasonline.org).

This certificate is valid up to April 1, 2019.

This accreditation certificate supersedes any IAS accreditation bearing an earlier effective date. The certificate becomes invalid upon suspension, cancellation or revocation of accreditation. See www.iasonline.org for current accreditation information, or contact IAS at 562-364-8201.

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President

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Soil-Foundation-Structure Interaction Facility

Bridge Abutment - Soil Interaction
(Caltrans)

Pile – soil interaction
(Port of Los Angeles)

NHERI@UC San Diego
Shake Table Experimental Facility

NEES@UCSD Shake Table: 2004-2014

NHERI@UC San Diego Shake Table: 2016-2020

NHERI@UC San Diego Personnel

Joel Conte
PI
Site Admin.

Tara Hutchinson
Co-PI
Site User Services

Gilberto Mosqueda
Co-PI
Site Performance

Benson Shing
Co-PI
Site Operations

Lelli Van Den Einde
Co-PI
Education and
Community Outreach

José Restrepo
Senior Personnel

Enrique Luco
Senior Personnel

Ozgur Ozcelik
Res. Scientist,
Site Operations
Manager

Darren McKay
Res. & Dev.
Engineer, Shake
Table Operator

Robert Beckley
IT Manager

Alex Sherman
Site Foreman
Development
Technician

Jeremy Fitcher
Development
Technician

Outline

- Overview of NHERI@UC San Diego Shake Table Experimental Facility
  - Description of Facility
  - Performance Characteristics
  - Capabilities and Limitations
- Shake Table Dynamics and Control
  - Sources of Signal Distortion
  - Shake Table Controller
  - Fidelity in Signal Reproduction
- Select Set of Large-Scale Shake Table Tests Performed on the NHERI@UC San Diego Shake Table

Objectives of the NHERI@UC San Diego Site

- The **vision for the NHERI@UCSD Shake Table experimental facility** is rooted on **three critical needs** for advancing the science, technology, and practice in earthquake disaster mitigation and prevention:

  - Fundamental knowledge for understanding the **system-level behavior** of buildings, critical facilities, bridges, geo-structures, and other civil infrastructure systems during earthquakes, ***from the initiation of damage to the onset of collapse***.

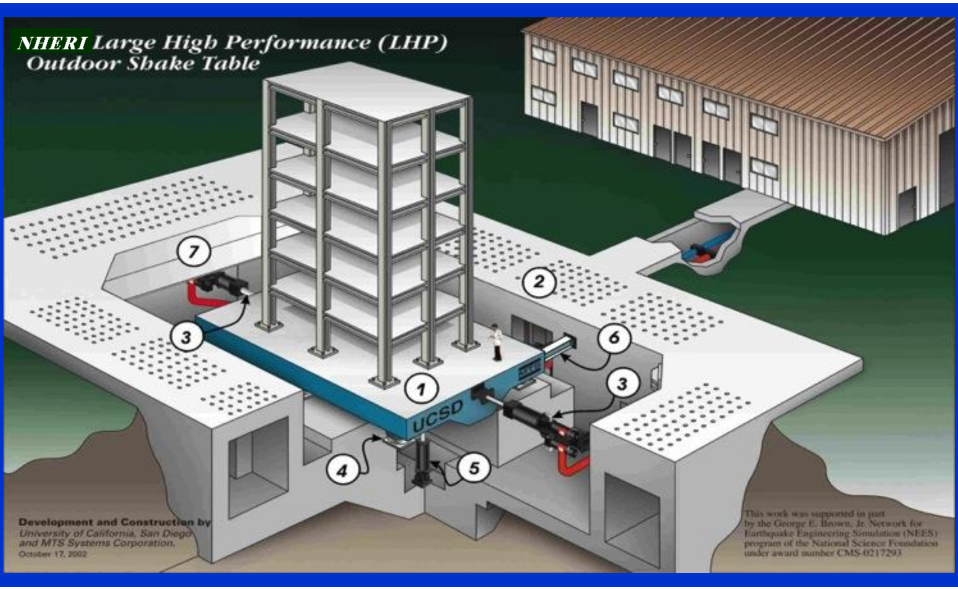
  - Experimental data to support the **development, calibration and validation of high-fidelity physics-based computational models** of structural/geotechnical/soil-foundation-structural systems that will progressively shift the current reliance on physical testing to model-based simulation for the seismic design and performance assessment of civil infrastructure systems.

  - **Proof of concept, benchmark and validation/verification tests** for seismic retrofit methods, protective systems, and the use of new materials, components, systems, and construction methods that can protect civil infrastructure systems against earthquakes.

Large High Performance Outdoor Shake Table (LHPOST)

- Designed to permit accurate simulation of severe earthquake ground motions and, particularly, strong near-source ground motions.
- Lack of height limitation allows testing of full- or very large-scale structural specimens.
- Table designed in 2001-2002, built in 2002-2004, and commissioned on October 1, 2004, as part of the NSF NEES Network.
- 30 major tests were performed in 14 years of operation:
  - Reinforced concrete buildings and bridge column
  - Precast concrete parking structure
  - Unreinforced and reinforced masonry building structures
  - Metal building structures
  - Woodframe dwellings and buildings
  - Wind turbine
  - Soil retaining walls
  - Underground structures (deep and shallow)

Large High-Performance Outdoor Shake Table

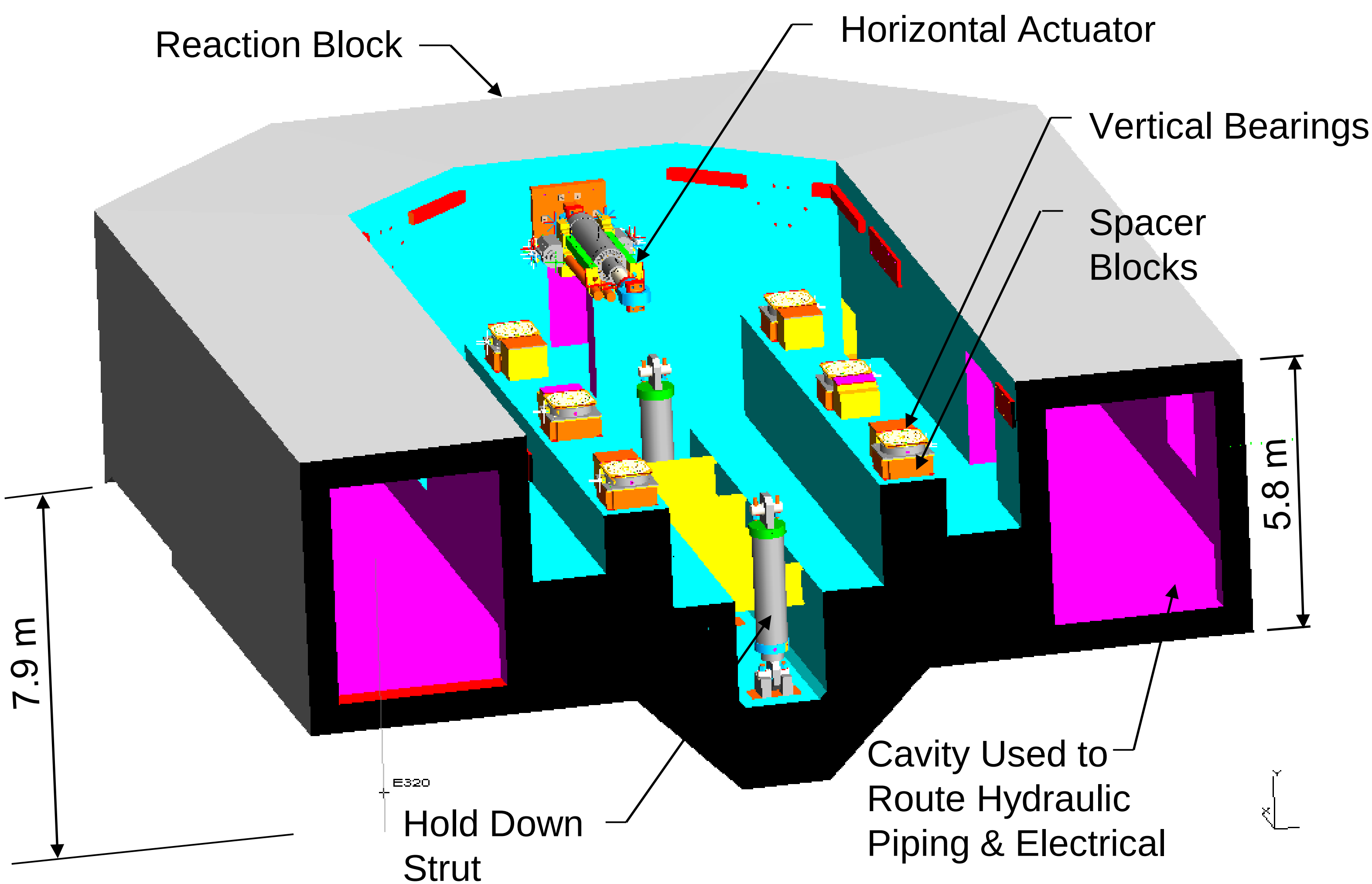


Performance Characteristics in Current 1-DOF Configuration	
Designed as a 6-DOF shake table, but built as a 1-DOF system to accommodate funding available	
Stroke	±0.75m
Platen Size	40 ft × 25 ft (12.2 m × 7.6 m)
Peak Velocity	**1.8 m/sec**
Peak Acceleration	4.7g (bare table condition); 1.2g (4.0MN/400 tons rigid payload)
Frequency Bandwidth	0-33 Hz
Horizontal Actuators Force Capacity	**6.8 MN (680 tonf)**
Vertical Payload Capacity	**20 MN (2,000 tonf)**
Overturning Moment Capacity	50 MN-m (5,000 tonf-m)

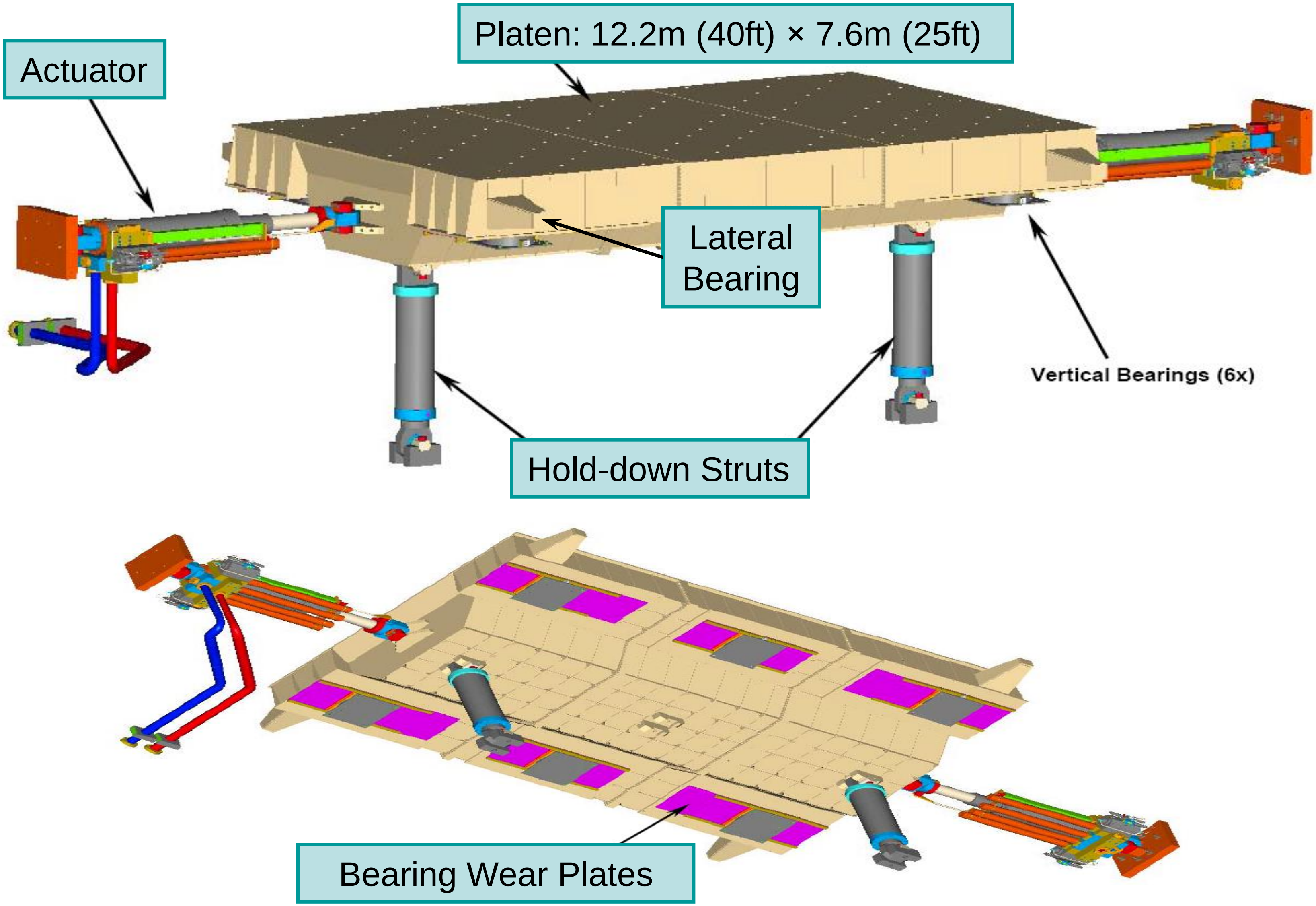
Capabilities/Provisions of NHERI@UCSD Site

- **Simulation of near-source earthquake ground motions** which involve large acceleration, velocity and displacement pulses.
- Seismic testing of **extensively instrumented large/full-scale structural specimens** under extreme earthquake loads at near real-world conditions.
- Seismic testing of **extensively instrumented large-scale geotechnical and soil-foundation-structural systems** by using the shake table in combination with large soil boxes.
- Basic capabilities for **hybrid shake-table testing**.
- **Education** of graduate, undergraduate, and K-12 students, as well as news media, policy makers, infrastructure owners, insurance and the general public, **about natural disasters** and the national need to develop effective technologies and policies to prevent these natural hazard events from becoming societal disasters.

Connection of Platen to Reaction Block



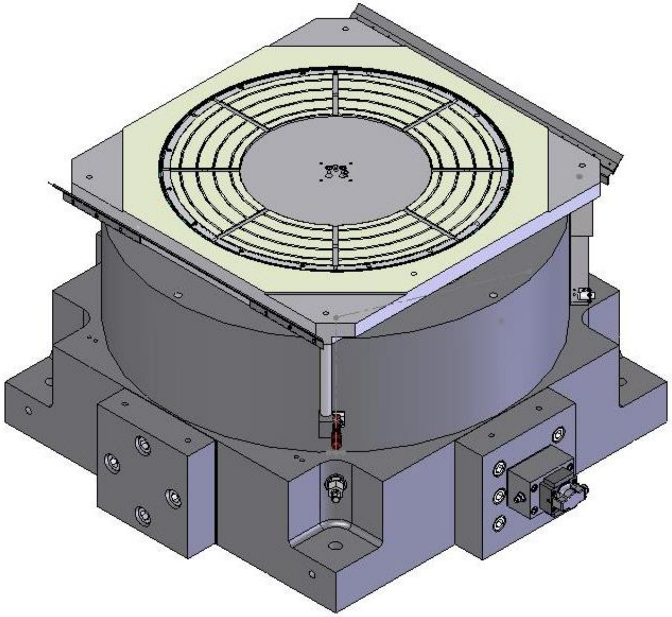
Platen, Actuators, Hold-Down Struts, and Bearing Wear Plates

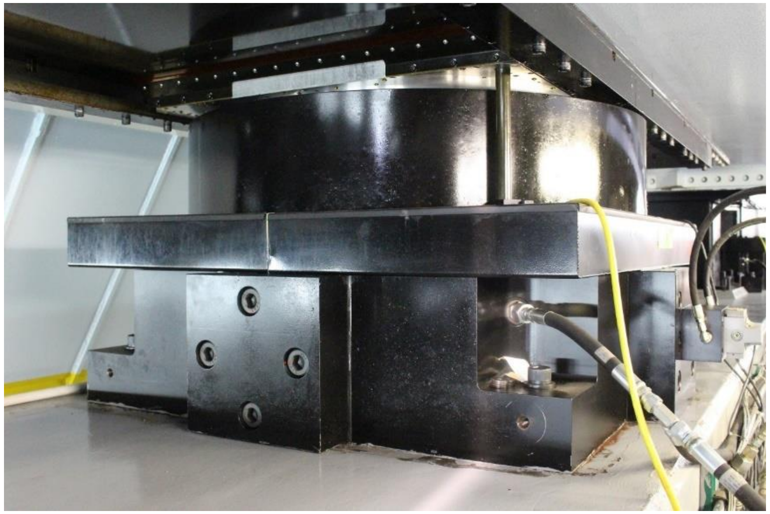


Technical Characteristics of Vertical Actuators

VERTICAL ACTUATORS SPECIFICATION		
	Bi-Axial Configuration	**4 or 6 DOF Configuration**
Piston Diameter	0.81 m	0.81 m
Piston Stroke	± 0.006 m	± 0.127 m
Piston Tilt	N/A	± 2°
Force Rating	20.7 MPa	20.7 MPa
Compression	10.0 MN	10.0 MN
Valve Flow	56.8 lit/min	18,927 lit/min

3-D Rendering of the Vertical Bearing



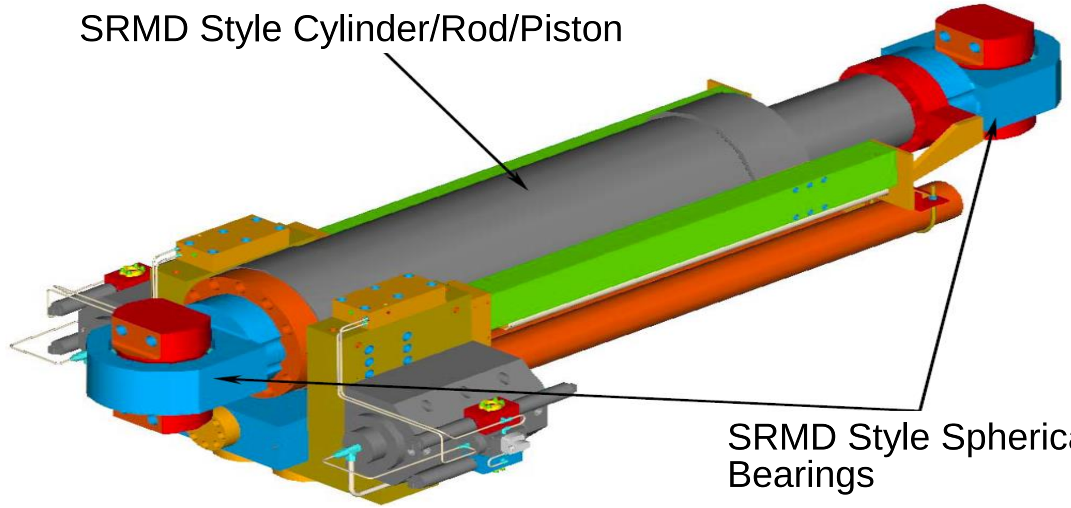


Technical Characteristics of Hold-down Struts

Hold-Down Struts (Qty. 2)	
Nitrogen Pressure	13.8 MPa
Uni-axial Stroke	2 m
Pin-to-Pin Length	3.3 m
Hold-down Force	**2.1 MN**
Effective Tension Area	0.15 m^2

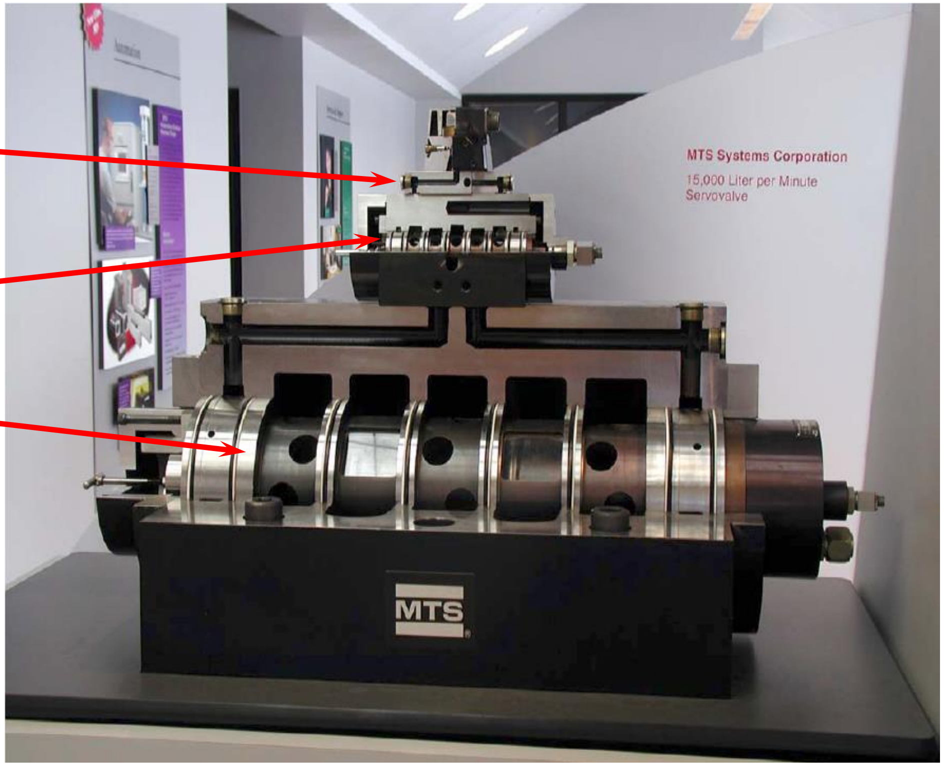
Technical Characteristics of Actuators

Actuators (Qty. 2)	
Stroke	**+/- 0.75 m**
Max. Velocity	**1.8 m/s**
Max. Acceleration (w/ 4MN Rigid Payload / Bare Table)	**1.25g / 4.7g**
Force Capacity (Tension / Compression)	**4.2 MN / 2.7 MN**
Rod Diameter	0.3048 m
Piston Diameter	0.5080 m
Total Effective Piston Area	0.332 m^2
Tension Area	0.2027 m^2
Compression Area	0.1297 m^2
Peak Extend Flow Rate	21,890 lt/m
Peak Retract Flow Rate	14,010 lt/m



Technical Characteristics of Servovalves

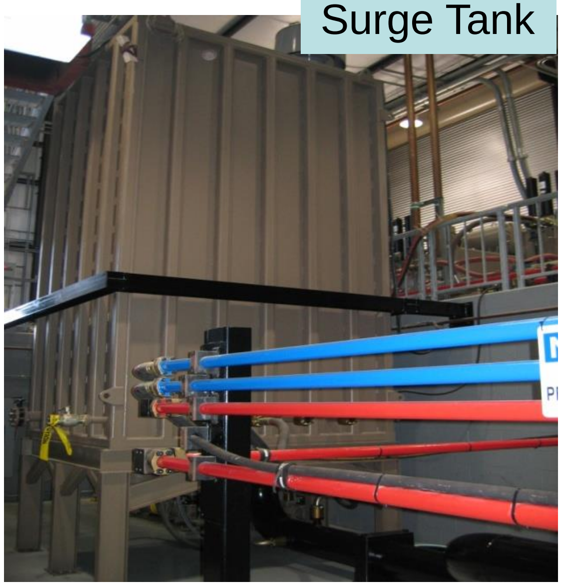
Servovalves (Qty. 2E+2W)	
Pilot 2nd Stage Rating (Manufacturer Moog)	**19 lt/min**
Pilot 3rd Stage Rating	**630 lt/min**
4th Stage Flow Rating	**10,000 lt/min**
Port Area Ratios	1:0.8:0.64:0.512
Valve Sleeve Windows Area Ratios	1:0.64



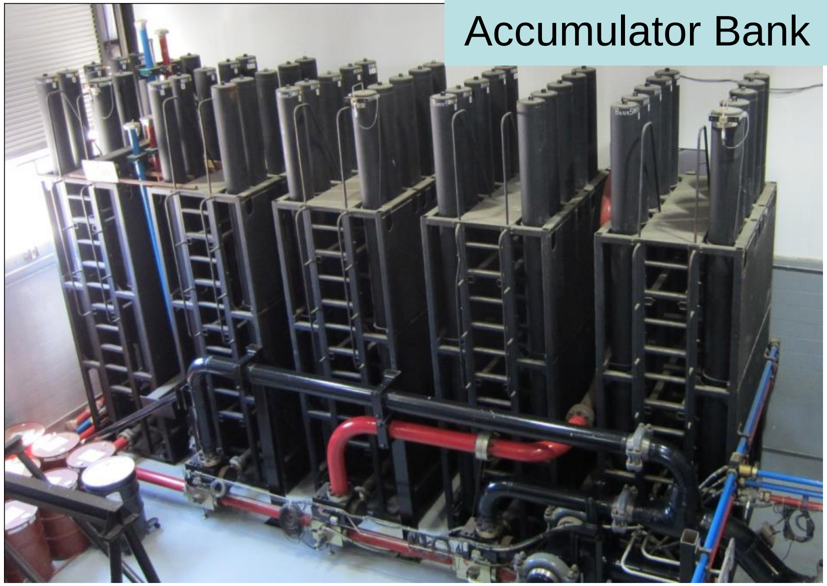
Technical Characteristics of Hydraulic Power System

Hydraulic Power System	
Accumulator Swept Displacement	**7.5 m**
Accumulator Bank Pressure	**35 MPa**
System Pressure	**20.7 MPa**
Blow-down Flow Rate	38,000 lt/min
HPU Flow Rate @ 35 MPa	431 lt/min
HPU Flow Rate @ 20.7 MPa	718 lt/min
Surge Tank Capacity	20,000 lt

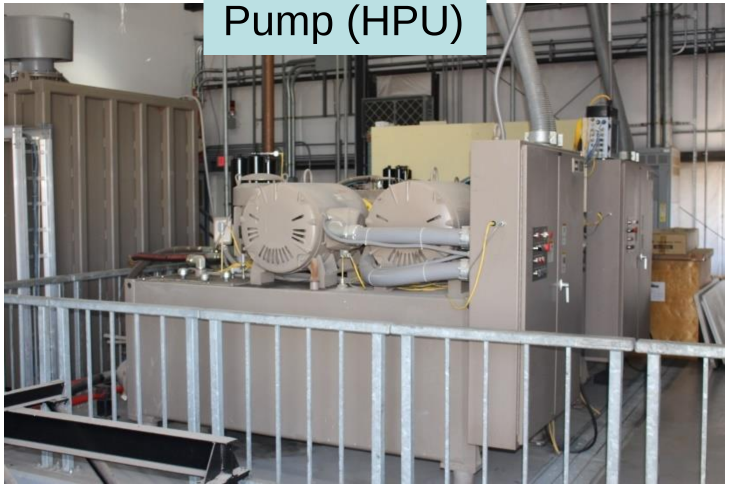
Surge Tank



Accumulator Bank



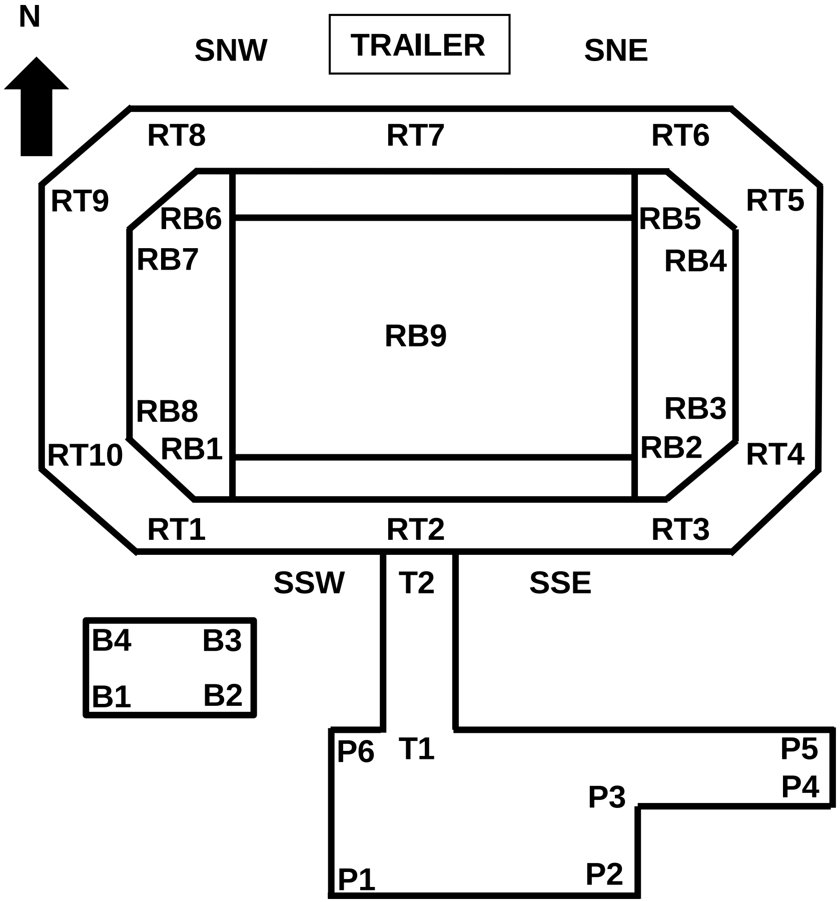
Pump (HPU)



Bare Table Commissioning Tests

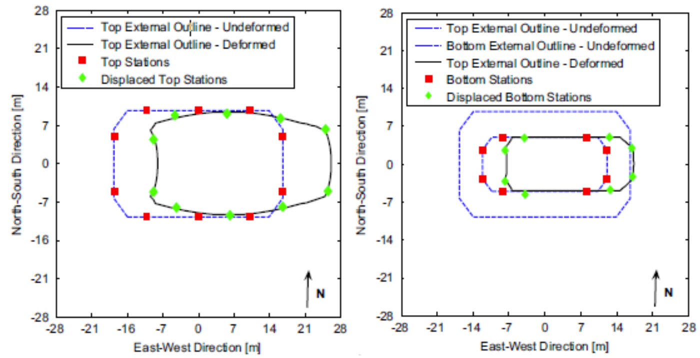
Forced Vibration Tests of the Reaction Mass at the NEES-UCSD Shake Table

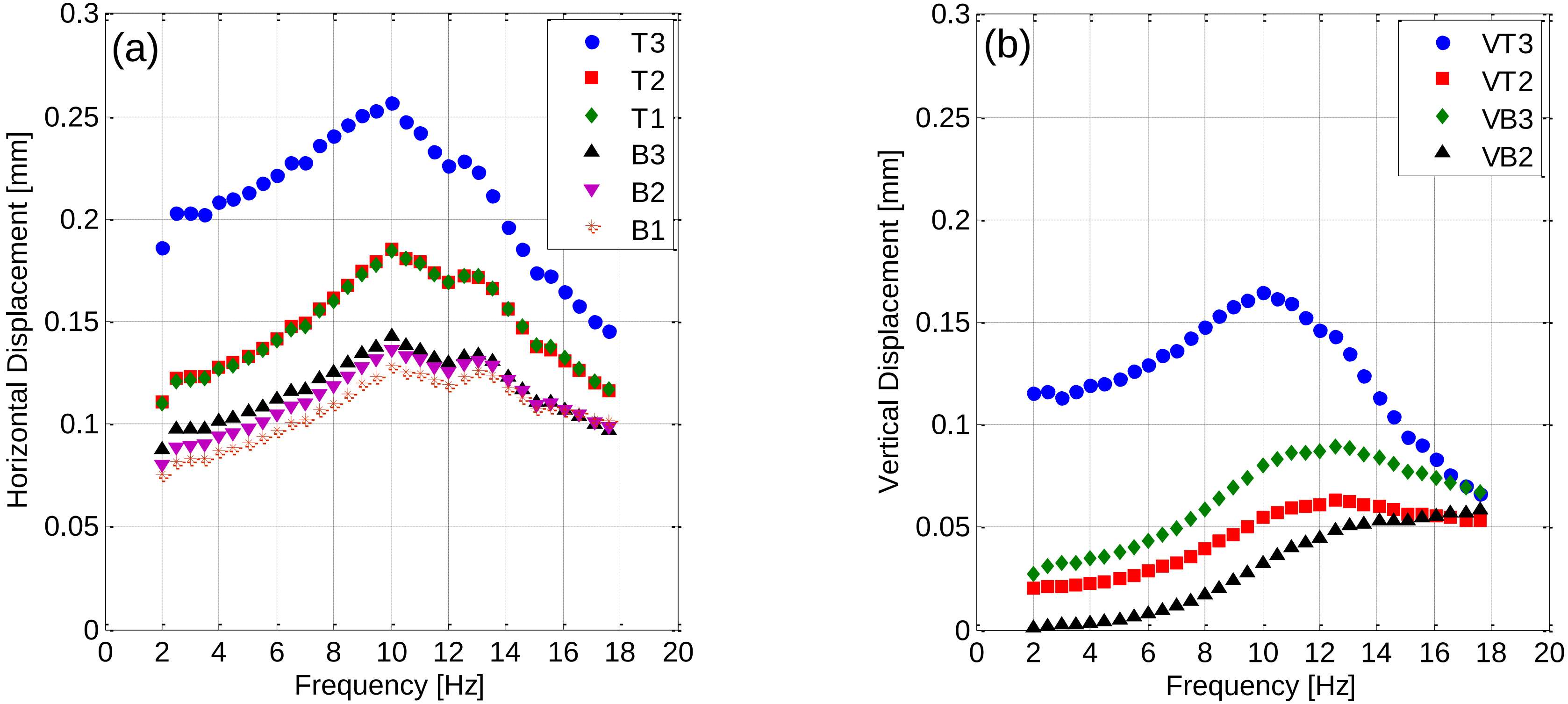
Commissioning Tests



Instrument locations on Reaction Block and adjacent foundations

Frequency Response Functions of Reaction Mass





Amplitudes of the EW (a) and vertical (b) frequency response functions of the reaction block for EW excitation. The results shown are based on Test 2 and correspond to scaled displacement amplitudes for a harmonic force of constant amplitude 6.8 MN.

Use of LHPOST in Combination with Large Soil Boxes

Laminar soil shear box:
6.7m (L) × 3.0m (W) × 4.7m (H)

Stiff soil confinement box:
10.0m (L) × 4.6 or 5.8m (W) × 7.6m (H)

- To investigate the seismic response of soil-foundation-structure systems
- To complement centrifuge tests in order to validate computational models
- To study the performance of underground structures, bridge abutments, earth retaining walls and slope stability in hillside construction
- To investigate soil liquefaction and its effect on the seismic response of soil-foundation-structure systems

Assembly of Laminar Soil Shear Box

Assembly of Stiff Soil Confinement Box

Disassembly of Stiff Soil Confinement Box

Staging Facility

- In an effort to increase throughput at the NHERI@UCSD facility, a reinforced concrete staging slab with dimensions of 13.4 m × 8.8 m × 0.914 m deep (44 ft × 30 ft × 3 ft deep) was built near the shake table.
- Small to moderate size specimens (weighing up to 100 tons) can be constructed on the staging area then lifted onto the shake table platen, or partial assembly of components for large specimens can reduce construction time.

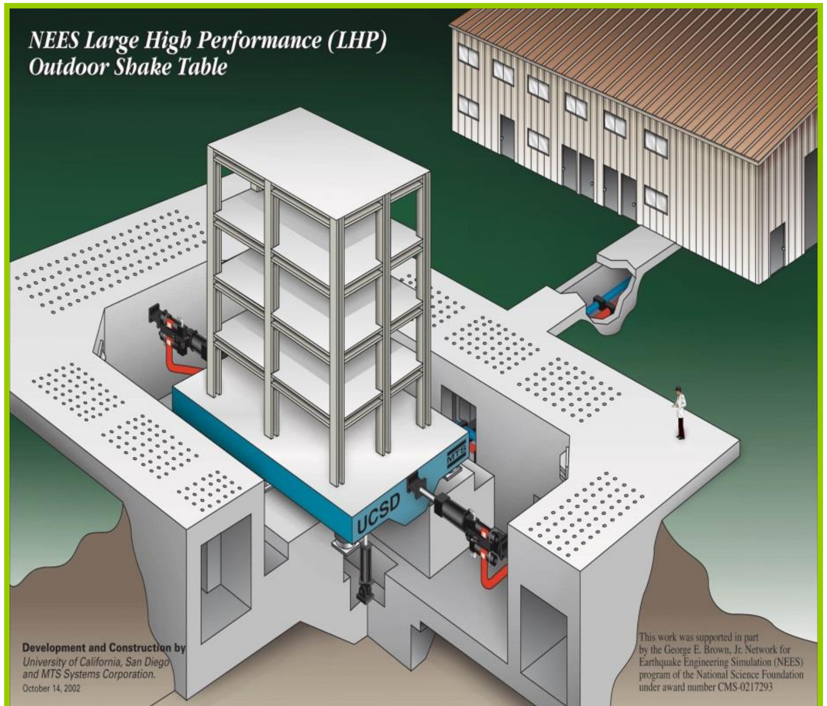
Staging Facility

Instrumentation Overview

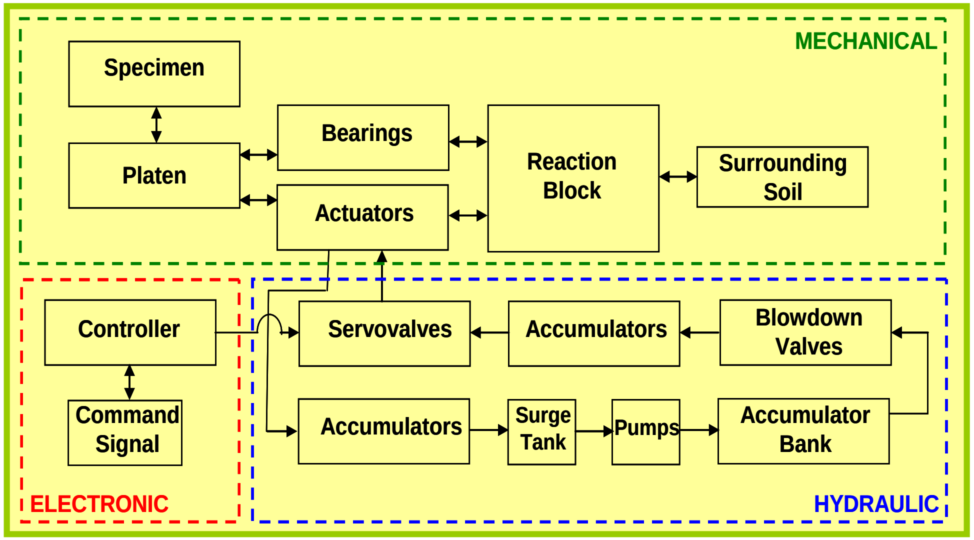
- Data acquisition system with over 600 channels that can be configured to accept:
  - Accelerometers
  - Linear displacement transducers
  - String potentiometers
  - Strain gauges
  - Load Cells
  - Soil Pressure Transducers
- High-speed cameras and GoPro cameras.
- GPS system providing dynamic displacement monitoring in three coordinates.
- Fully configured, end-to-end, live video streaming production system
- Calibration equipment for data acquisition systems and sensors.

Shake Table Dynamics and Control Fidelity in Signal Reproduction & Sources of Signal Distortion

Components and Interaction Diagram of LHPOST System

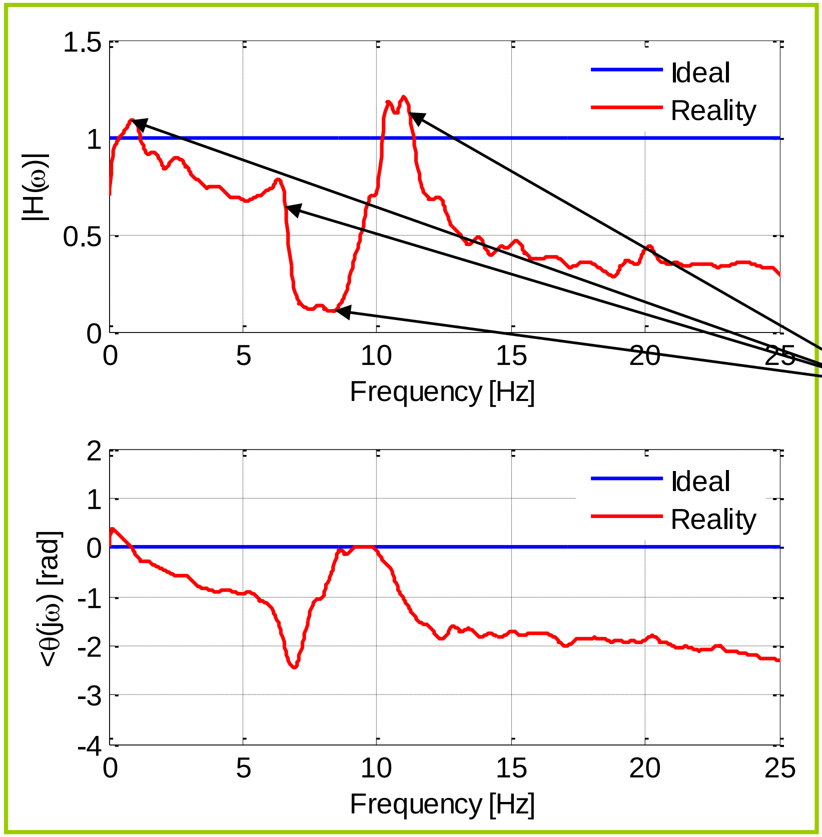


Components and Interaction Diagram



Components and Interaction Diagram of LHPOST System

- Ideal shaking table:
  - Reproduces commanded motion exactly
  - Is characterized by a transfer function with unit gain and zero phase shift over its entire operating frequency range under loaded table condition.

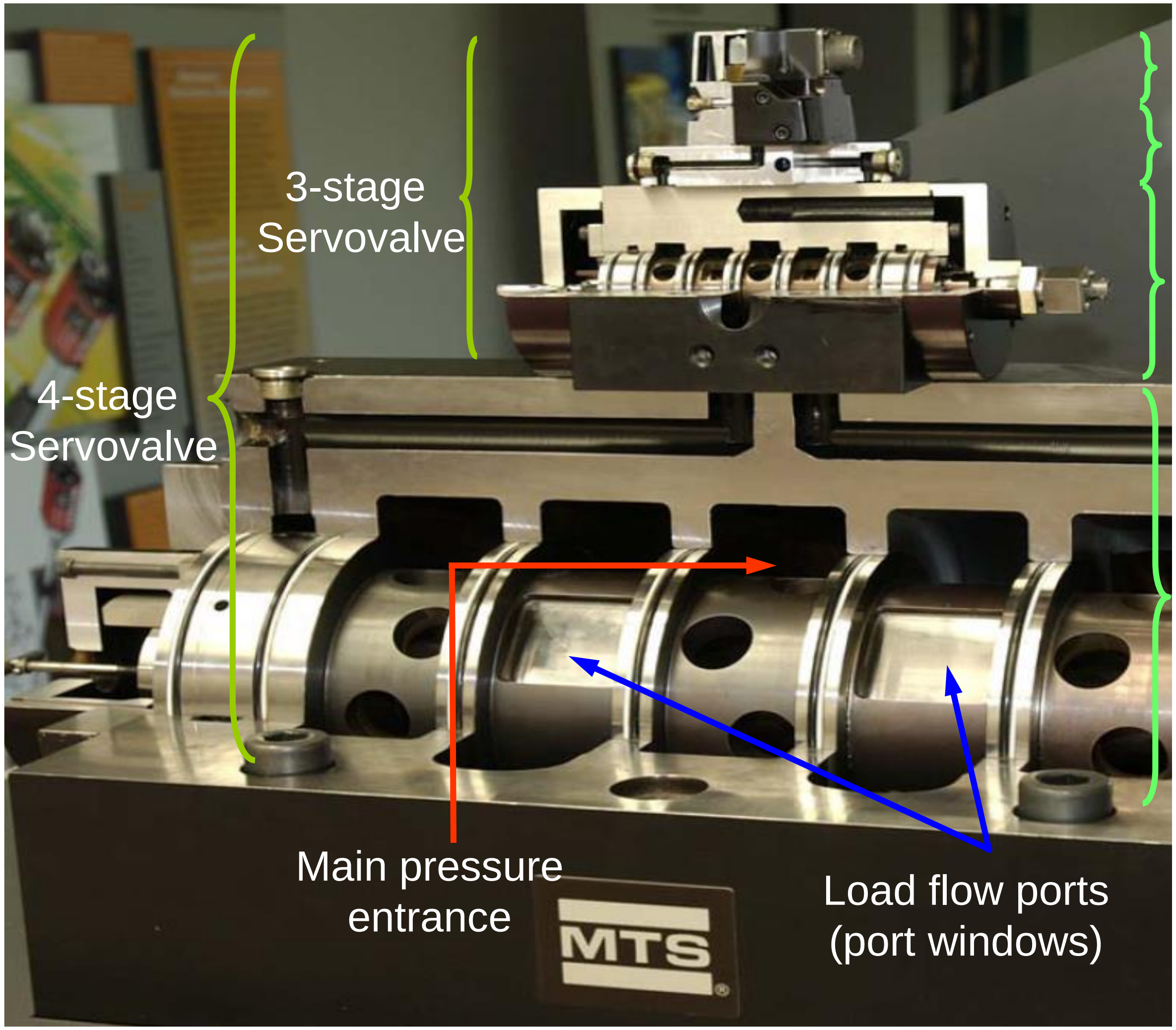


Due to various peaks and valleys in the shaking table system transfer function, the signal reproduced by the table differs from the commanded signal.

Sources of Signal Distortion

- Many potential sources of signal distortion and many of them are highly interdependent:
  - Hydraulic sources:
    - Servovalves (inherently nonlinear devices)
    - Oil Column resonance
    - Changes/fluctuations in the pressure supply
    - Flow limits
    - Force limits
    - Leakage flows in the servovalves and actuators
  - Mechanical sources:
    - Dissipative (viscous, frictional) forces
    - Mechanical resonances
    - Linear/Nonlinear specimen - table interaction
    - Backlash (bolted connections within the load train, actuator swivels)

High-Flow High-Performance Servovalves



1st stage (Pilot stage)

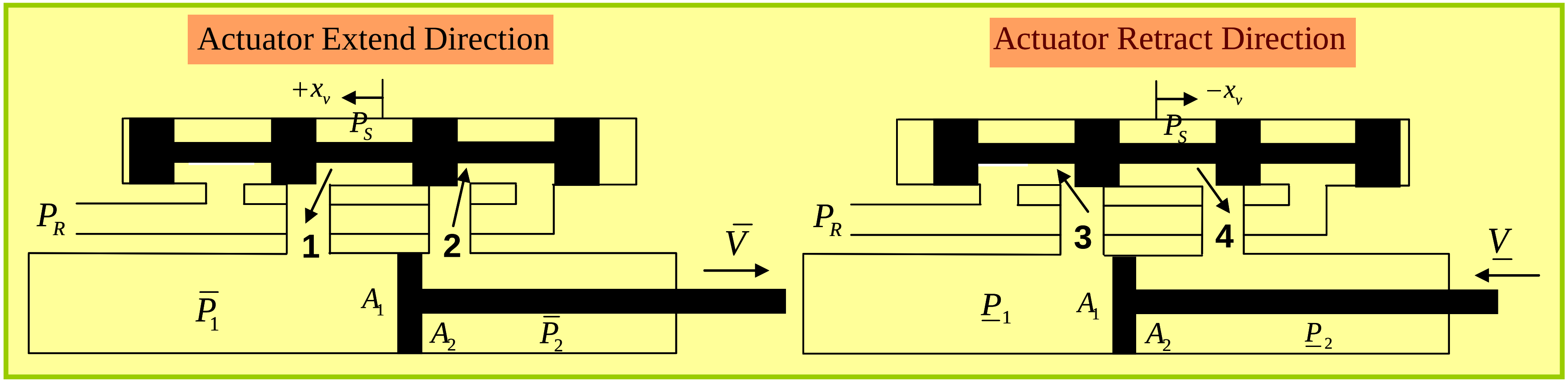
2nd stage

3rd Stage

4th Stage (Main stage)

Courtesy of MTS Systems Inc.

Hydraulics - Servovalves



$$q_1 = A_1 \cdot \bar{V} = K_v w_1 x_v \sqrt{P_S - \bar{P}_1}$$

$$q_2 = A_2 \cdot \bar{V} = K_v w_2 x_v \sqrt{\bar{P}_2 - P_R}$$

$$q_4 = A_2 \cdot \underline{V} = K_v w_4 x_v \sqrt{P_S - \underline{P}_2}$$

$$q_3 = A_1 \cdot \underline{V} = K_v w_3 x_v \sqrt{\underline{P}_1 - P_R}$$

K_v	: Flow gain (linearized flow coefficient)
w_i	: Valve port window widths
A_1, A_2	: Compression and tension piston areas
x_v	: 4th stage valve spool displacement
P_s , P_R	: Supply and return system pressures
$\bar{P}_1$ and $\bar{P}_2$	: Actuator chamber pressures during extend direction
$\underline{P}_1$ and $\underline{P}_2$	: Actuator chamber pressures during retract direction

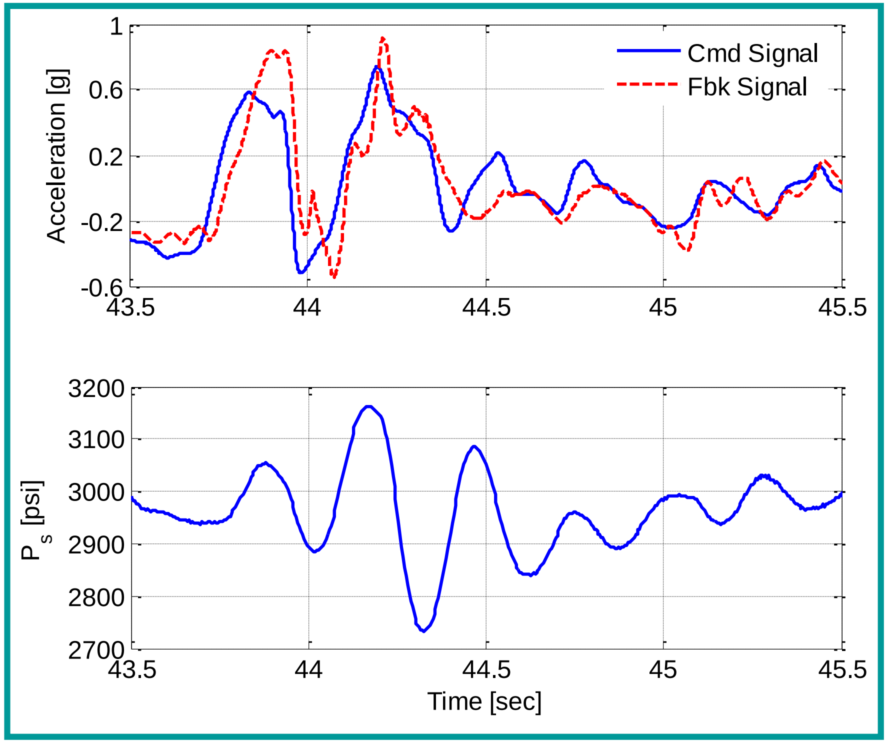
- Servo-valve flows present two independent sources of nonlinearity:
  - Load pressure nonlinearity or pressure drop - flow nonlinearity (explicitly represented by the square root term)
  - Flow gain nonlinearity (K_v changes as a function of orifice size)

Flow Gain Nonlinearity – Hydraulic Pressure Effects

- Hydraulic supply pressure fluctuates especially as the hydraulic demand is high. Inertial pressure spikes can cause noise and result in increased signal distortion.

$$K_v = \left(C_d w \sqrt{1/\rho}\right)\sqrt{P_S}$$

where C_d = discharge coefficient

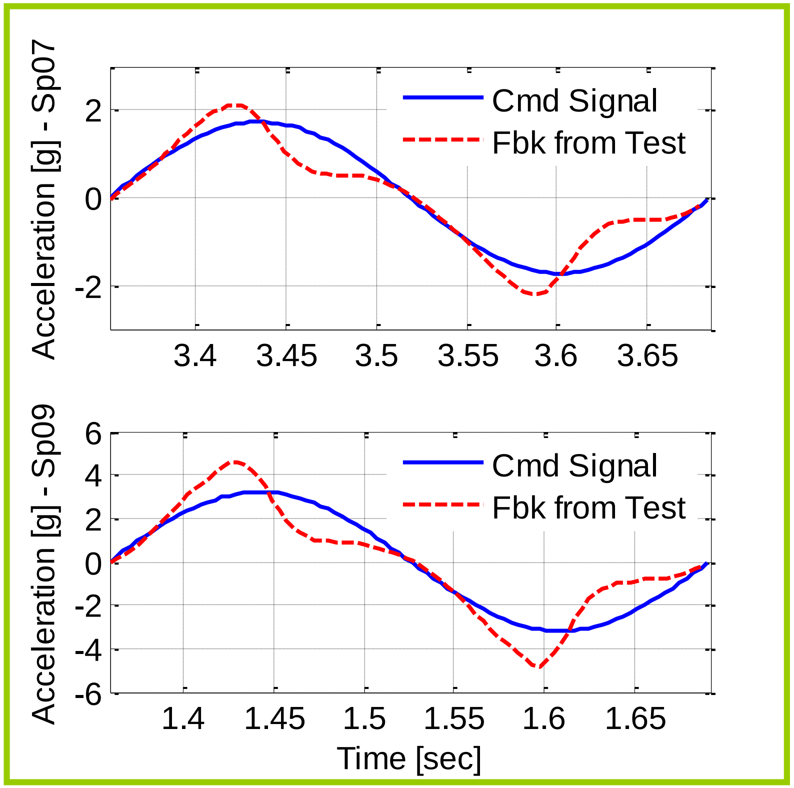


1994 Northridge Earthquake recorded at Sylmar Station (Seven-story R/C building specimen mounted on the table)

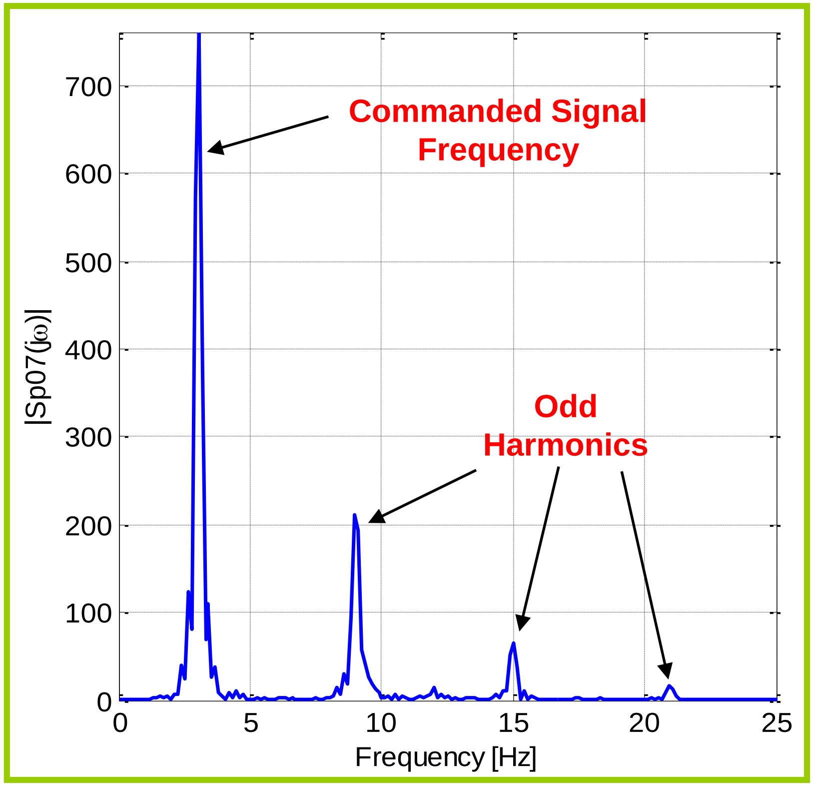
Change in supply pressure P_S at West actuator during test

Effect of Load Pressure Nonlinearity on Fidelity in Signal Reproduction

Sine Tests @ 3 Hz (Bare Table)



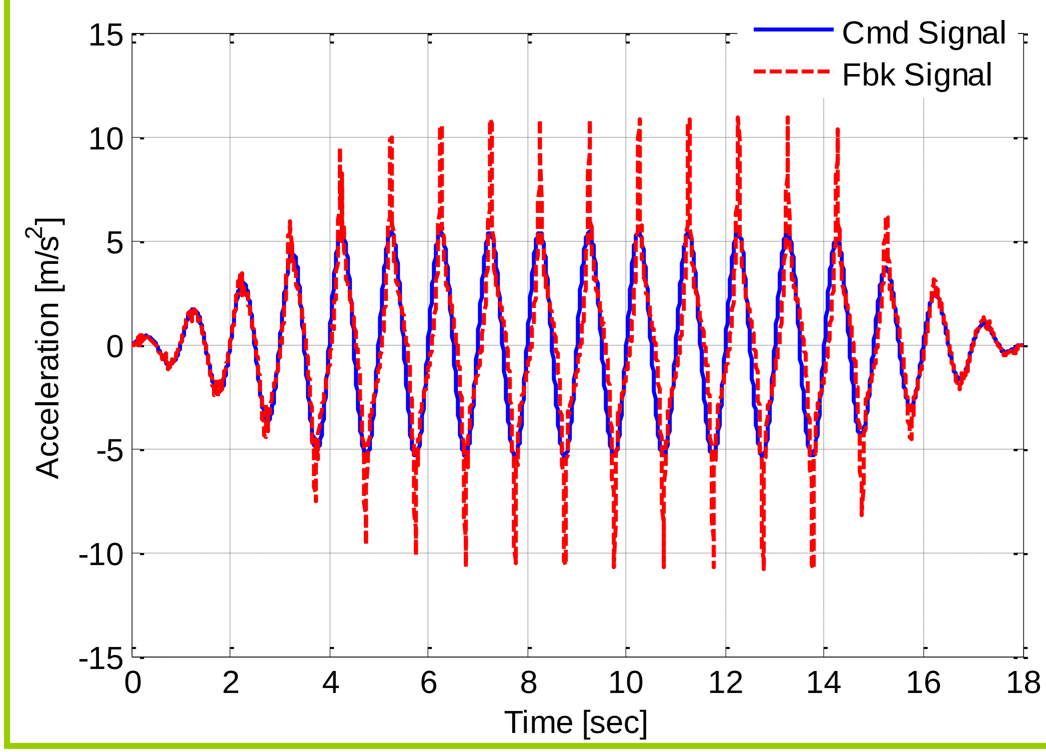
FFT of the Sp07 Test Fbk Signal

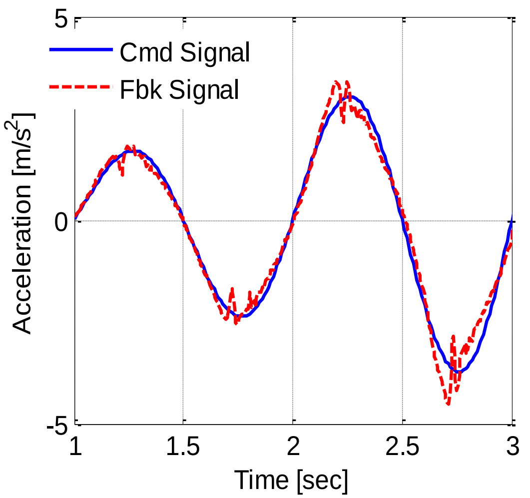


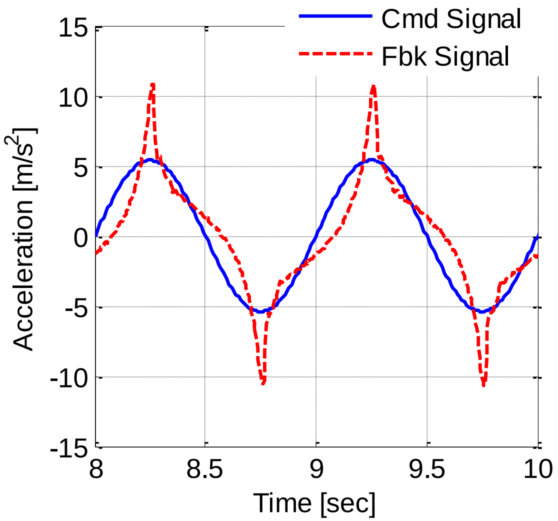
High acceleration signals suffer from load pressure non-linearity.

Example of Signal Distortion from UNAM Shake Table – Time Histories

Sine Test @ 1 Hz

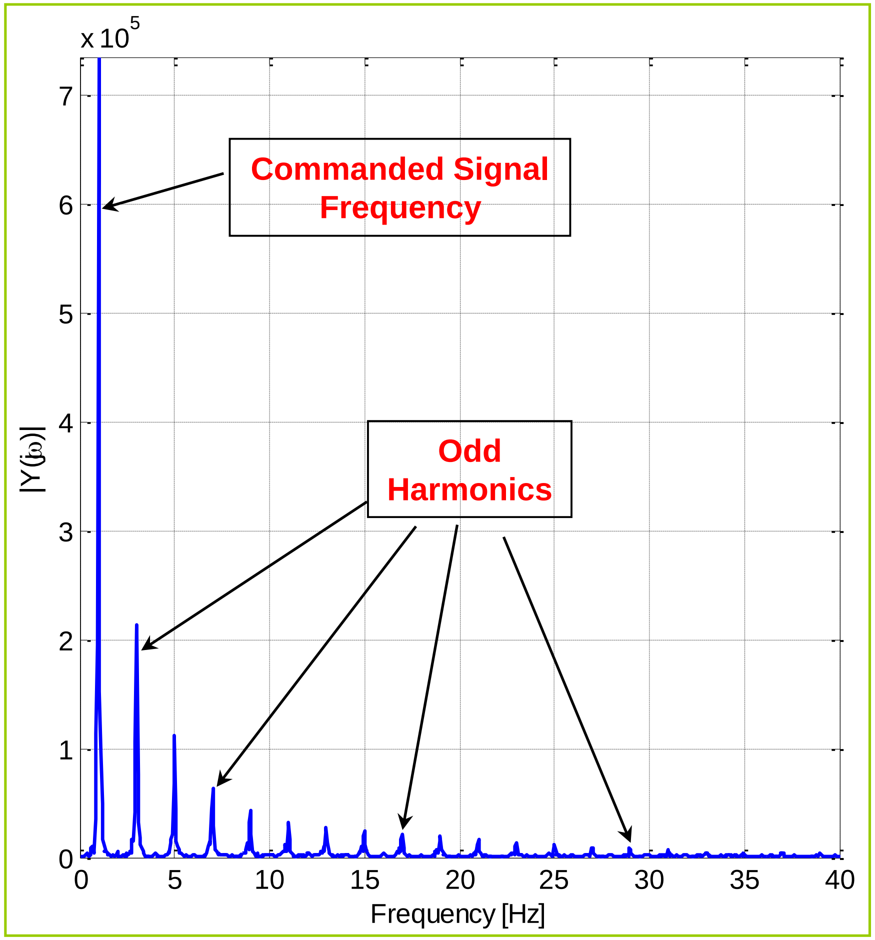






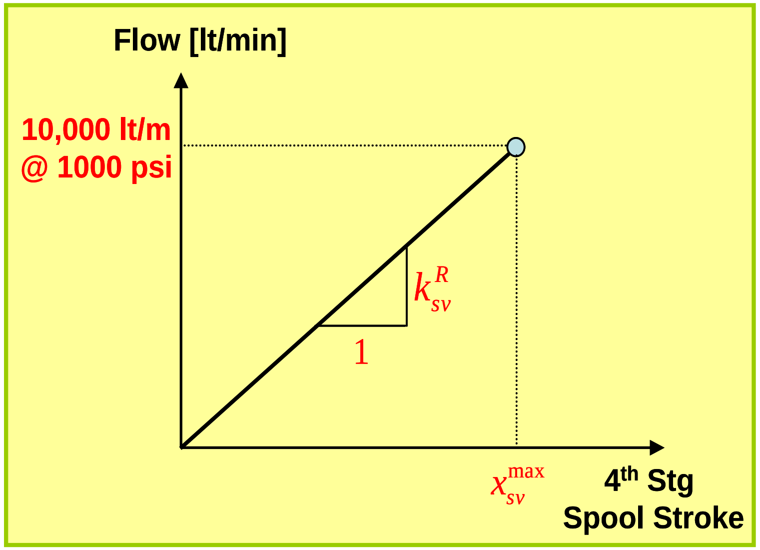
Example of Signal Distortion from UNAM Shake Table – Fourier Spectra

Sine Test @ 1 Hz



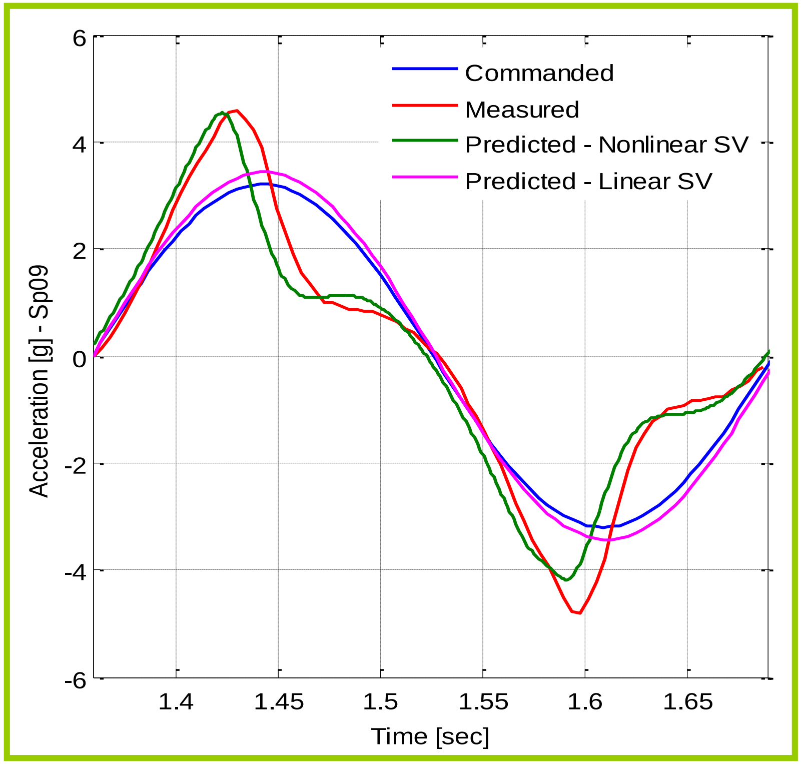
Simulation of Signal Reproduction with "Linearized" and Nonlinear Servovalve Models

Servo-valve Rated Flow Gain
Linearization of the Flow Equation
(Bernoulli's Equation)



Servo-valve Flow Gain
@ 3000psi - Linear

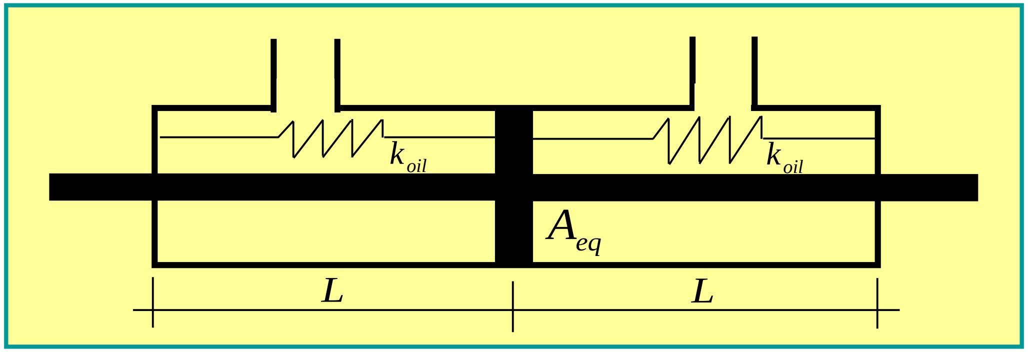
$$k_{sv} = k_{sv}^{R} \times \sqrt{3}$$



Oil Column Resonance

- The effective table mass of the system and the oil columns within the actuators define a mass-spring system with a natural frequency referred to as the oil column frequency.

Sketch of Double Ended Actuator



$$f_{oil} = \frac{1}{2\pi}\sqrt{\frac{2\left(\beta A_{eq}/L\right)}{m_{eff}}}$$

β : Effective bulk modulus of oil

m_{eff} : Effective mass of the table

A_{eq} : Piston area

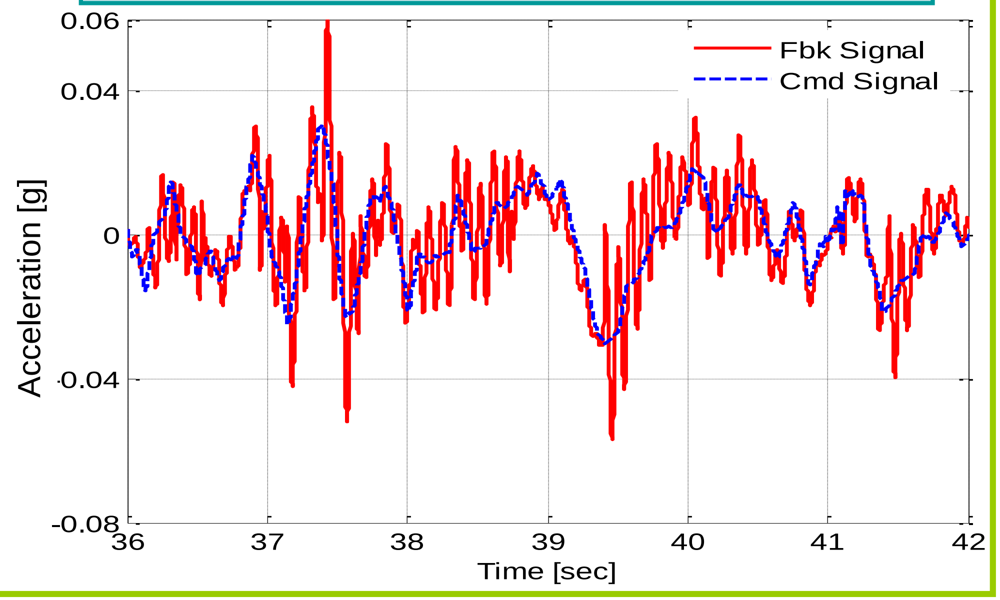
L : Oil column length

- Note that the oil column frequency depends on the effective mass of the "table + specimen".
- Oil column frequency of LHPOST under bare table condition has been identified at 10.4 Hz.

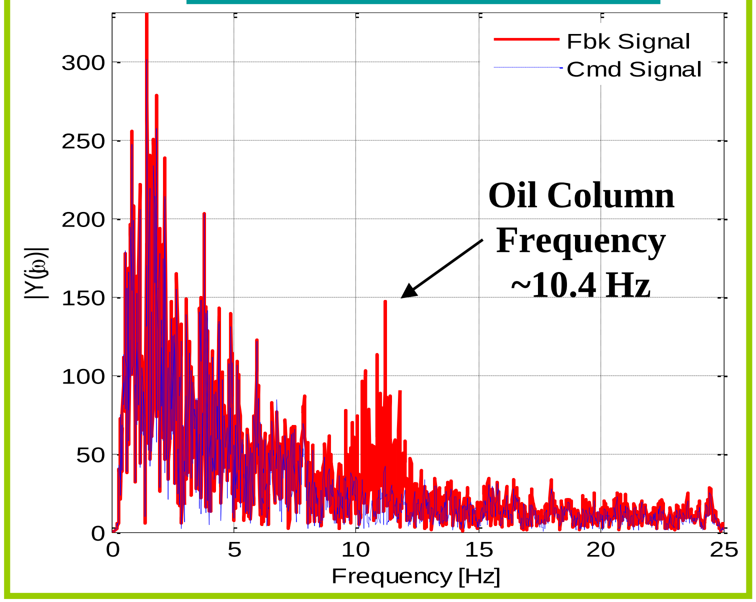
Effects of Oil Column on Fidelity in Signal Reproduction

- Oil column resonance distorts the commanded signal at and around the oil column frequency.
- On most shaking tables, the oil column frequency falls within the operating frequency range of the system.
- Operation of a shake table at or around the oil column frequency may result in high gain problems.
- Shake table operation at frequencies around 1/3 of oil column frequency will result, due to servovalve load pressure nonlinearity (odd harmonics are excited), in frequency components around the oil column frequency that may cause significant signal distortion.

1940 El Centro Record - Part of the Time History (Bare Table)

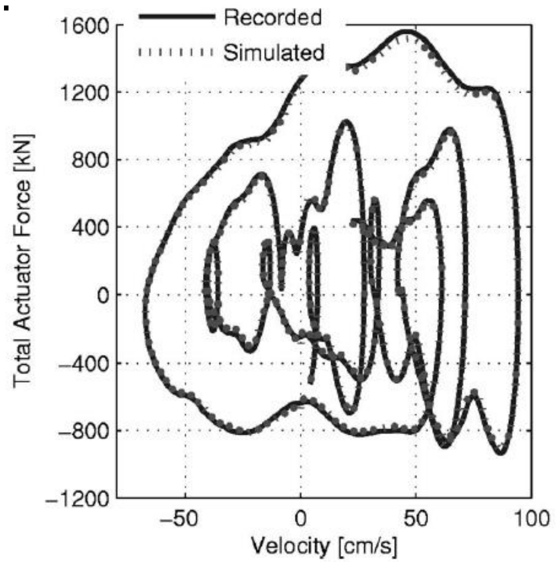


FFT of the Cmd and Fbk Signals



Mechanical Sources – Dissipative (friction, viscous) Forces

- Friction arises from a number of sources within the system, e.g., slide bearings, mechanical linkages, etc. Specific sources of friction depend on the design and layout of the shake table system.
- Frictional forces are typically not large, especially in the case of hydrostatic bearings.
- Signal distortion (high frequency) occurs during motion reversals.
- The magnitude of friction-induced signal distortions is approximately constant. Therefore such distortions are more significant for lower amplitude signals.



Identified Dissipative Force Model for LHPOST (Bare Table)

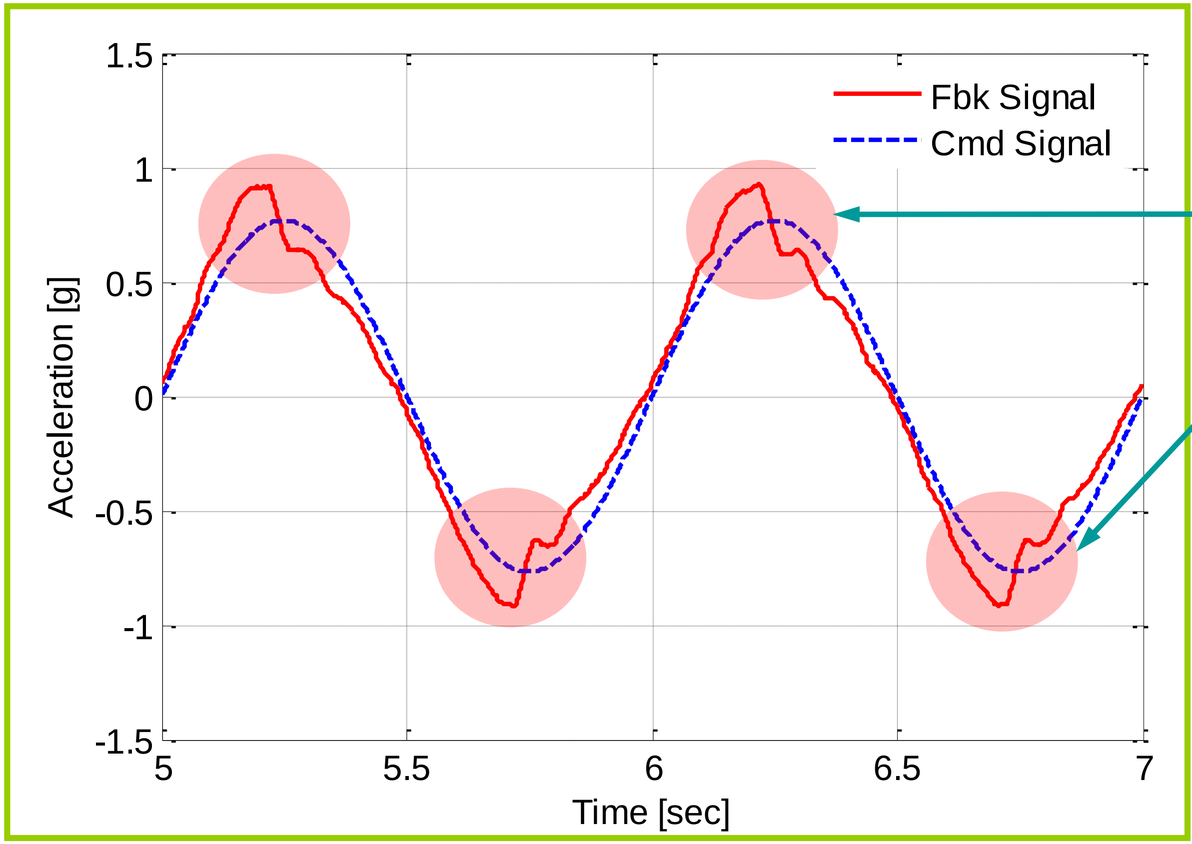
$$F_{viscous}(t) + F_{Coulomb}(t) = C_e \left|\dot{u}_x\right|^{0.5} sign(\dot{u}_x) + F_{\mu_e} sign(\dot{u}_x)$$

Viscous Force (C_e = 44.6 kN(s/m)$^{0.5}$)

Friction Force - Constant (~ 26.0 kN ⇒ friction coeff. of 0.45%)

Effects of Friction on Fidelity in Signal Reproduction

SR-11 Sinusoidal Test
f_{test}= 1 Hz and Amplitude = 0.769 g
(Bare Table)



High-frequency waveform distortions at motion reversals due to frictional forces. These waveform distortions may be large.

MTS Three-Variable Controller (TVC)

- **MTS Controller Model 469D** used on all large shake tables manufactured by MTS worldwide.

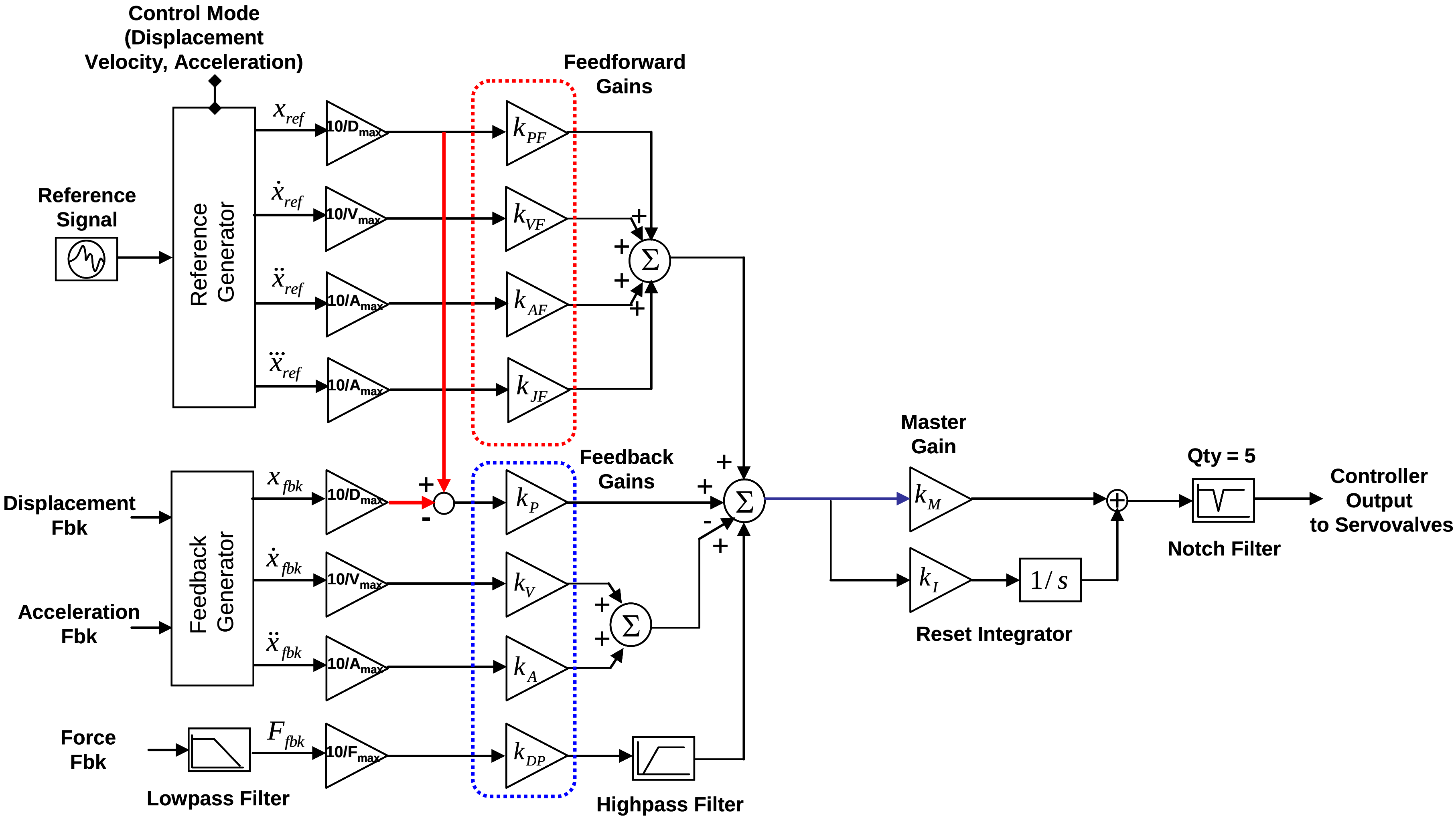
- TVC is a linear **state variable controller**. The three **state variables controlled by TVC** are:
  - Displacement
  - Velocity
  - Acceleration

  TVC can be set to run under displacement, velocity or acceleration mode.

- TVC has **additional special features to compensate for linear/nonlinear sources of signal distortions** within the system for both harmonic and broadband command signals:
  - Amplitude/phase control
  - Adaptive harmonic cancellation
  - Adaptive inverse control (AIC)
  - On-line iteration (OLI): Iterative signal matching technique
  - Notch filters

- Depending on the control mode, only one state variable becomes the **primary control variable** with the others serving only as compensation signals to improve the damping and stability of the system.

MTS Three-Variable Controller (TVC)

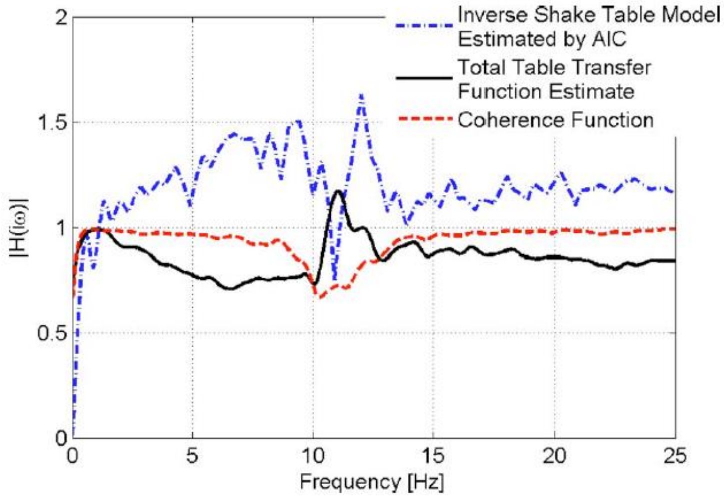


Courtesy of MTS Systems Corporation

Tuning of LHPOST Controller (MTS 469D)

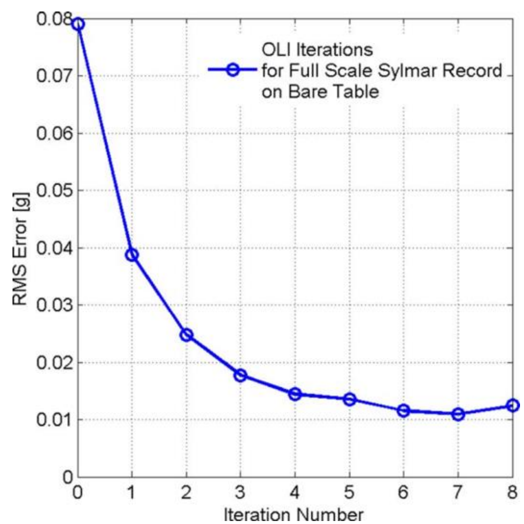
Tuning: Process of adjusting multiple control parameters (e.g., feedback and feedforward gains) and of preconditioning the input motion (through OLI) to optimize signal reproduction (tracking) capability of the shake table system.

Step 1: Iterative process in which the control parameters of the controller are manually adjusted iteratively in small increments while the (bare or loaded) table is in motion, until the total table transfer function (estimated recursively) is deemed satisfactory.

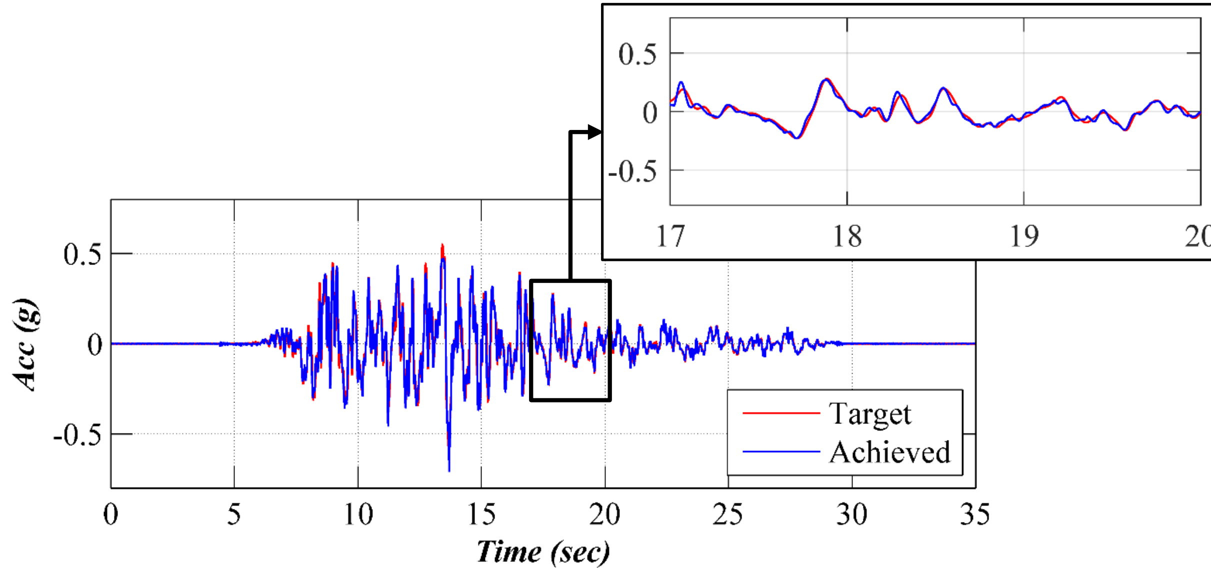


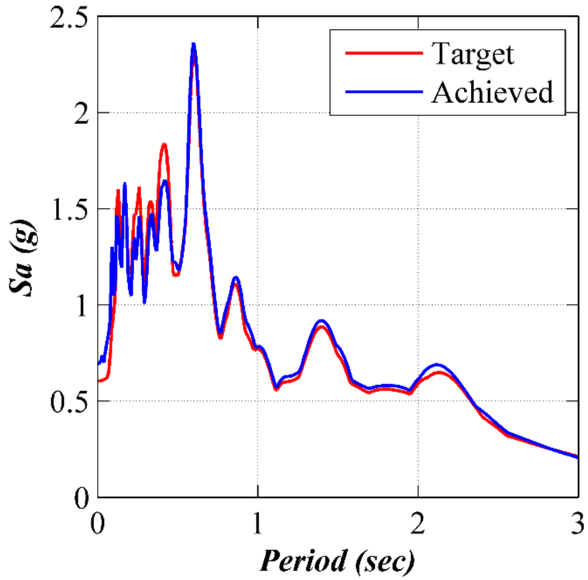
Step 2: Estimation of the inverse model of the plant using the adaptive inverse controller (AIC) technique.

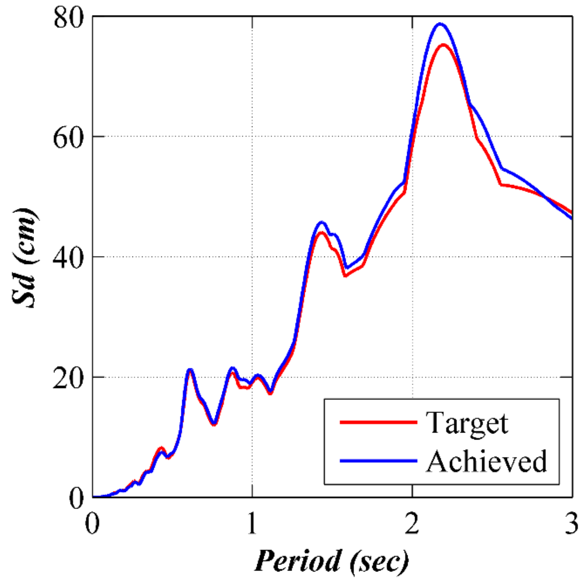
Step 3: Application of iterative time history matching technique called online iteration (OLI). The command input to the shake table controller (drive file) is repeatedly modified to optimize the match between the actual table motion and the desired/target motion.



Tracking Performance of NHERI@UCSD Shake Table







1994 Northridge Earthquake
Canoga Park (comp. 196)
Amplitude scaling: 1.55

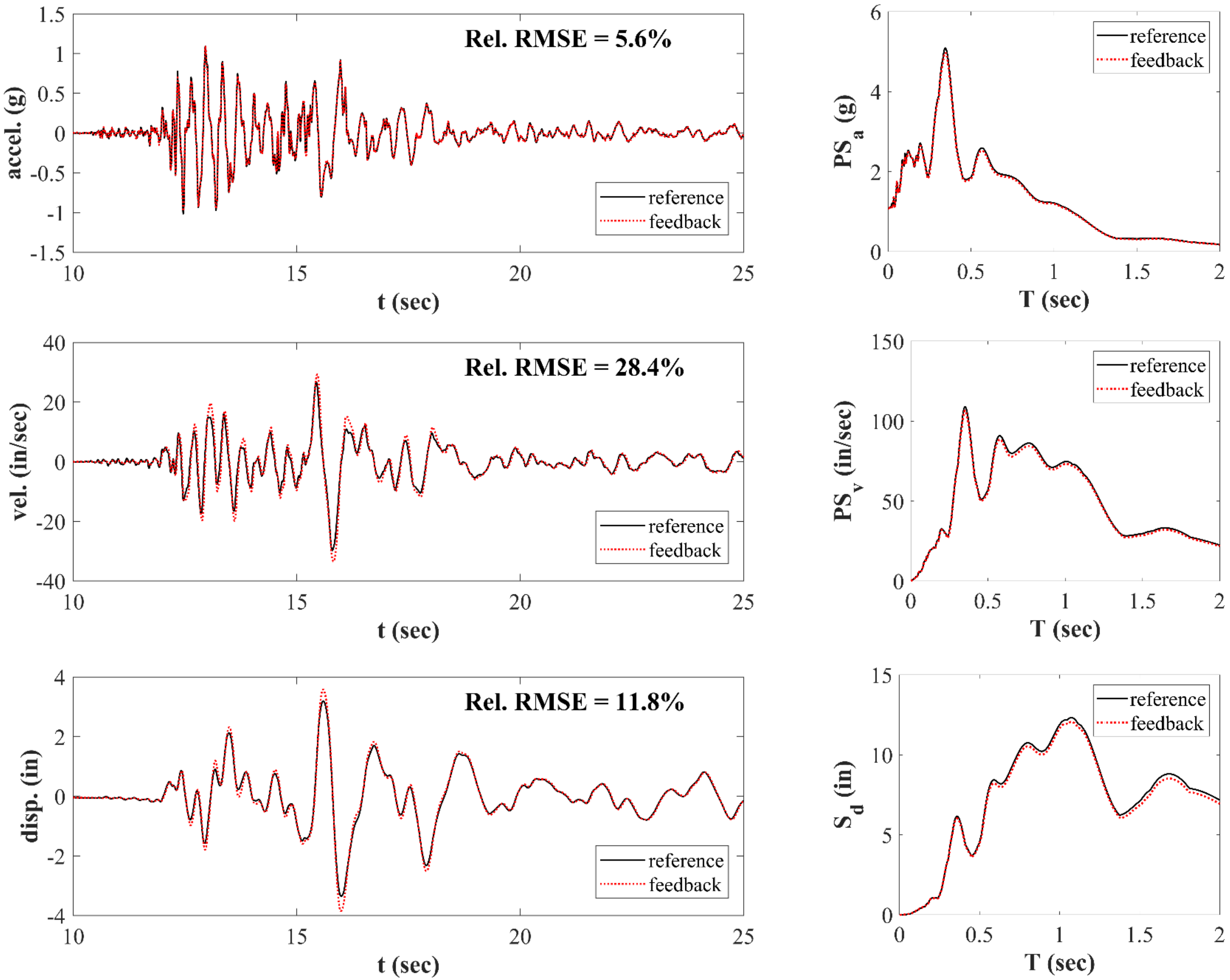
Tracking Performance of NHERI@UCSD Shake Table

- Specimen and safety pedestals as constructed on the shake table platen:

- Total weight on the table: 142 kips

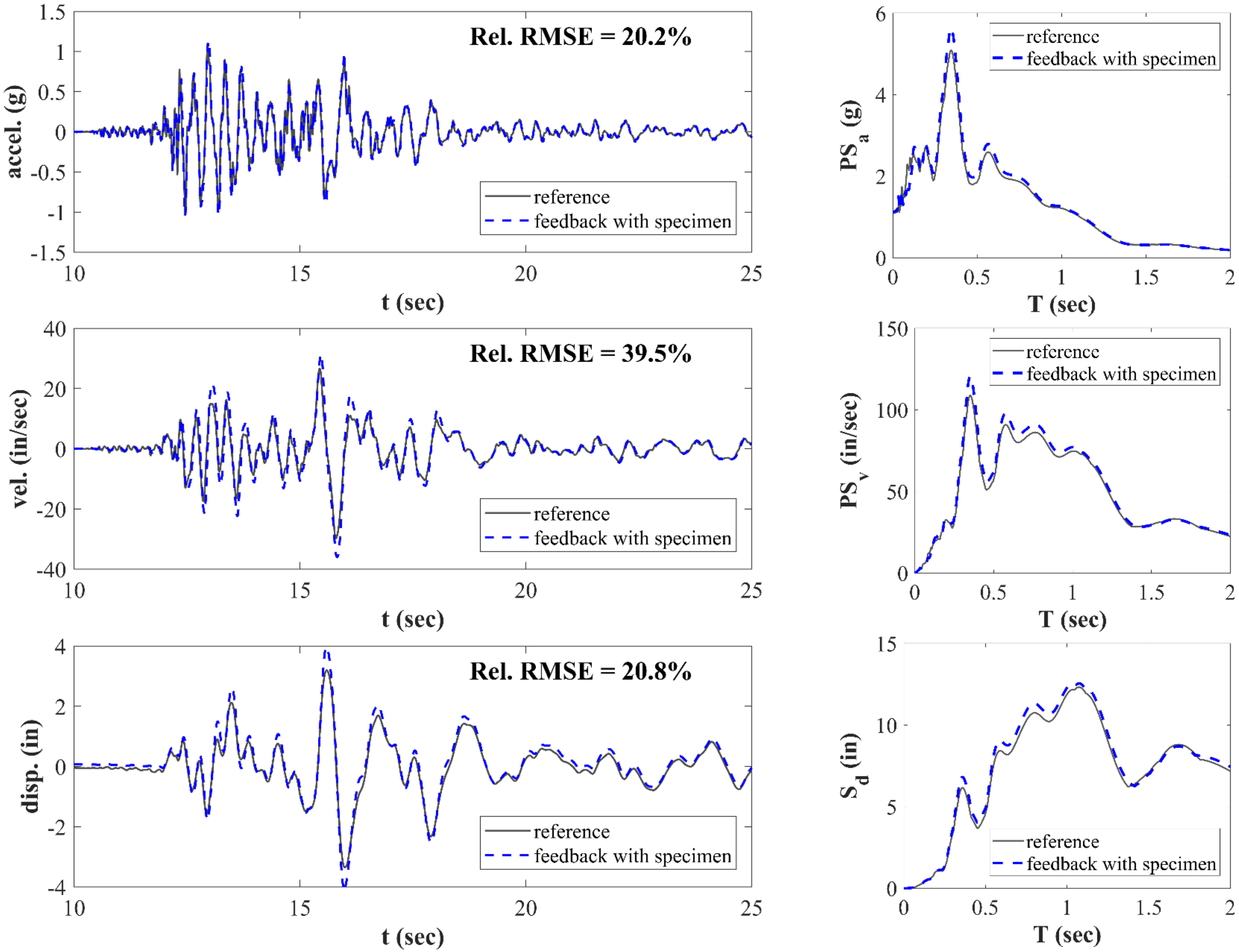
Tracking Performance of NHERI@UCSD Shake Table

1994 Northridge, Mulholland-279 at 90% (iteration 6)
(Bare table condition)



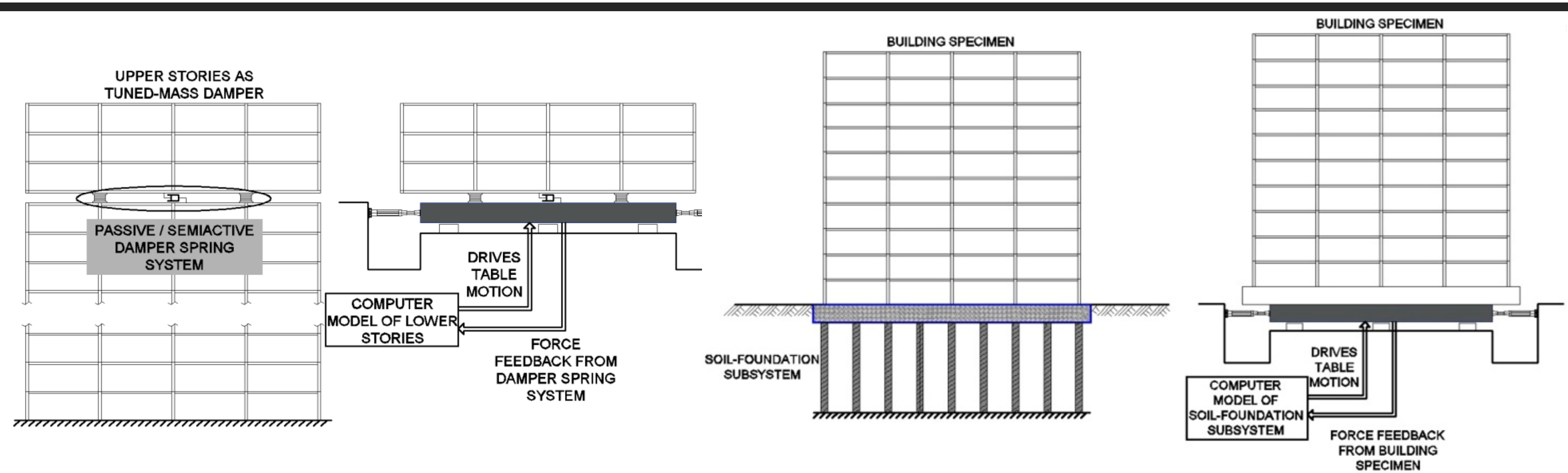
Tracking Performance of NHERI@UCSD Shake Table

1994 Northridge, Mulholland-279 at 90% (iteration 6)
(Loaded table)

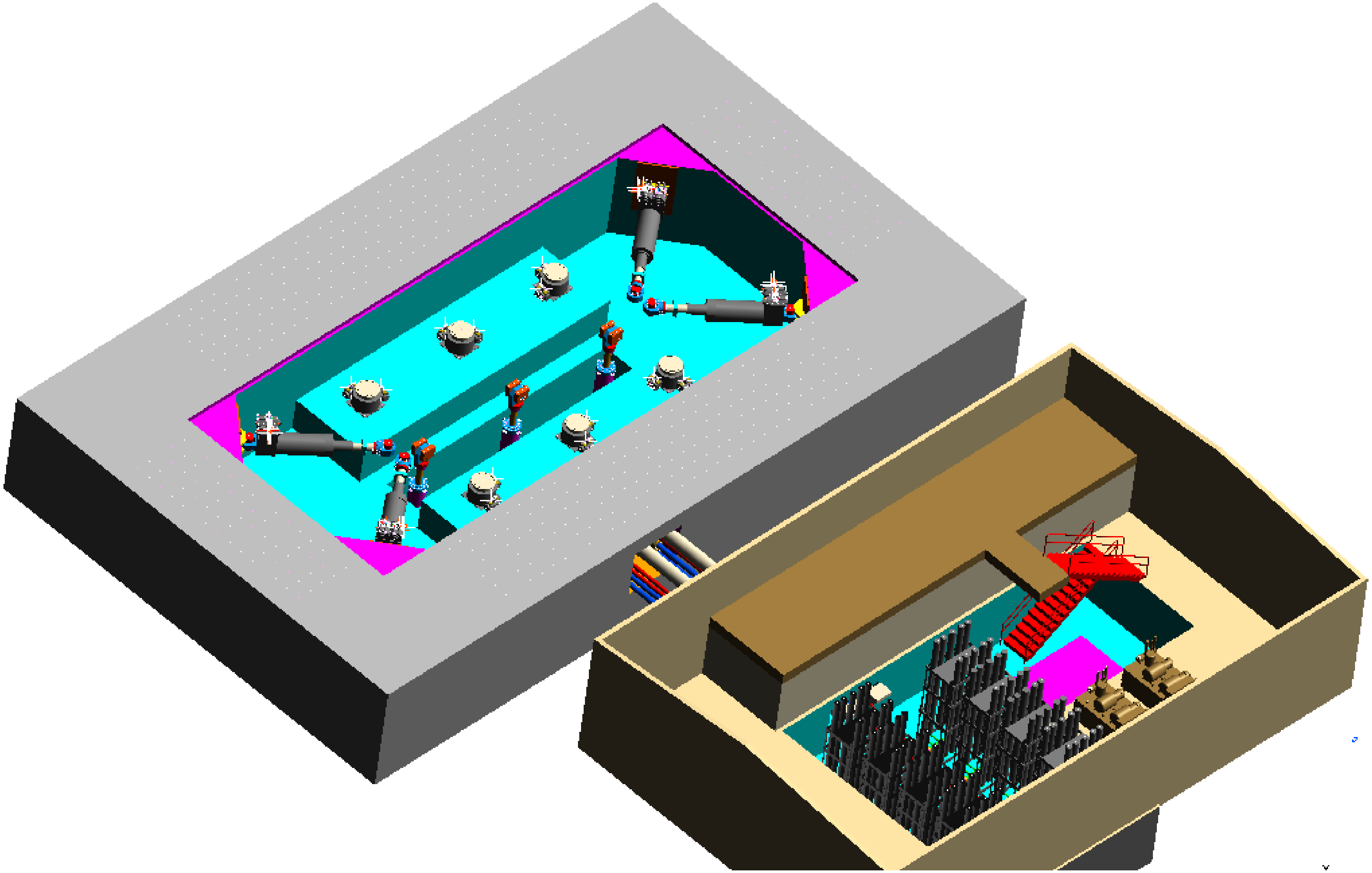


Hybrid Shake Table Testing

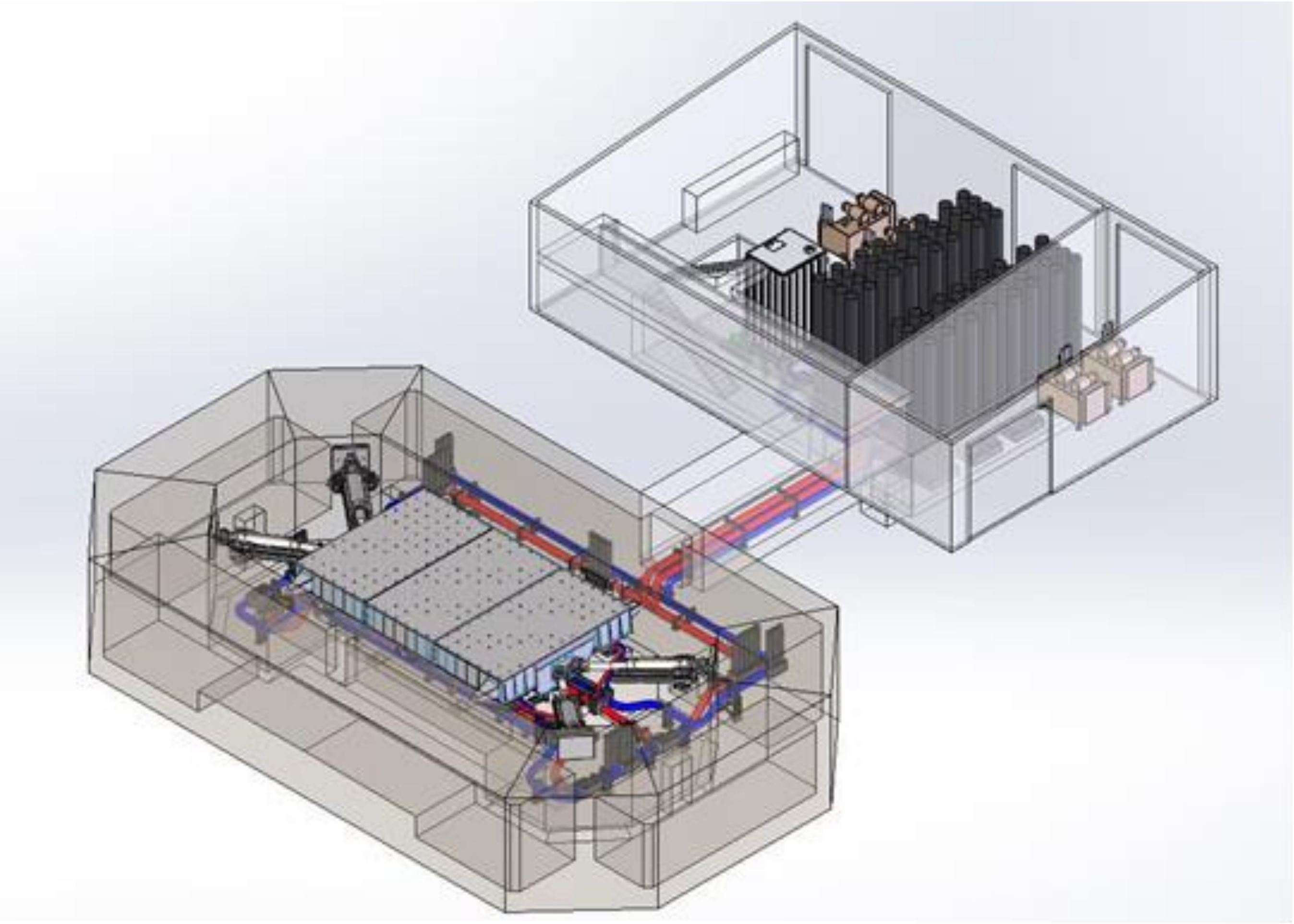
- **Basic hardware and software in place for real-time hybrid shake-table testing:**
    - Multi-channel MTS FlexTest controller
    - SCRAMNet ring for real-time communication and synchronization of data flow between shake-table controller, FlexTest controller, and real-time target PC running the Matlab/SIMULINK Real-time Workshop and xPC Target software
    - Easy integration of OpenSees/OpenFresco open-source software framework
    - 50-ton dynamic actuator
    - Portable hydraulic power system



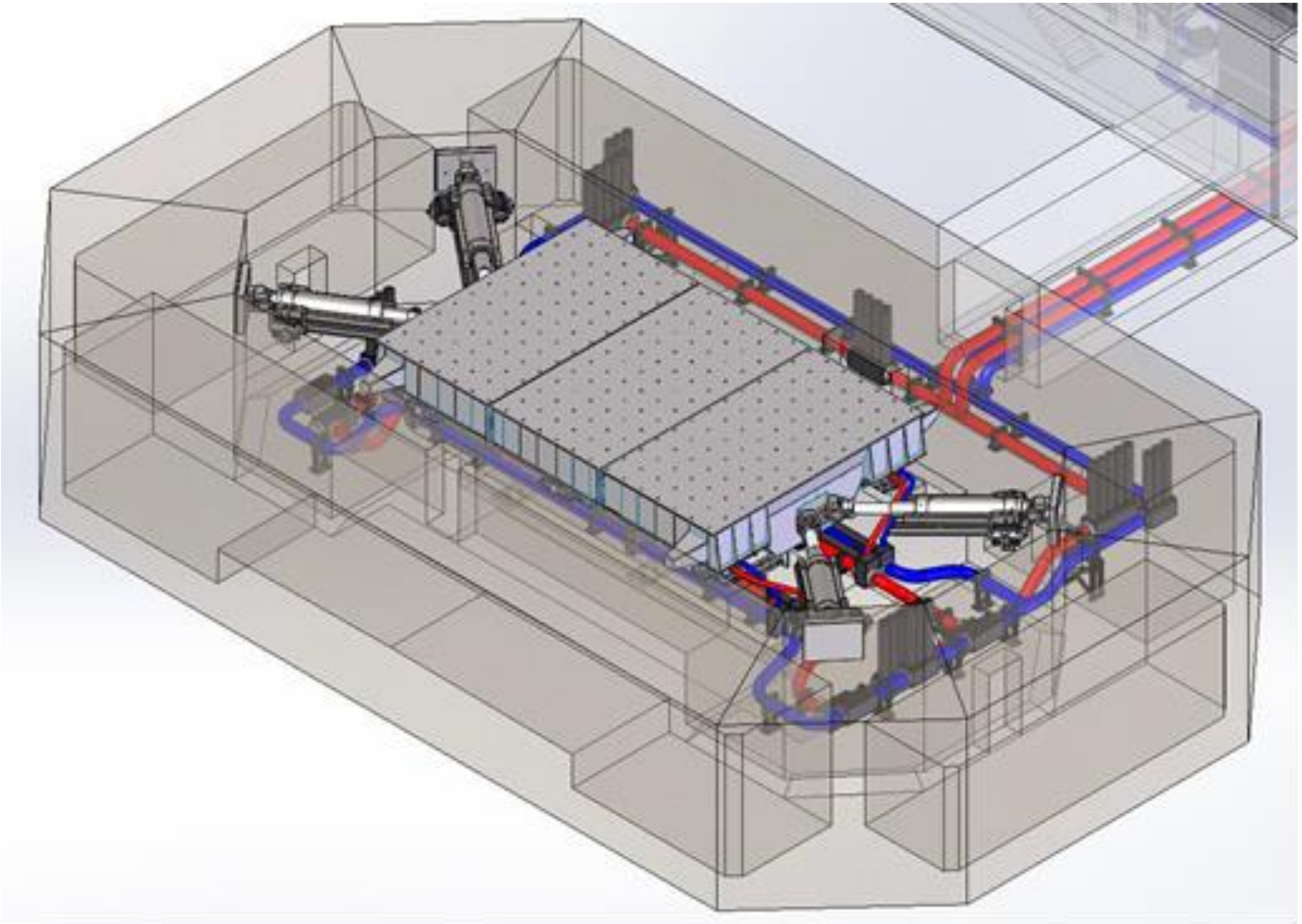
Current Upgrade to 6 DOF - Configuration



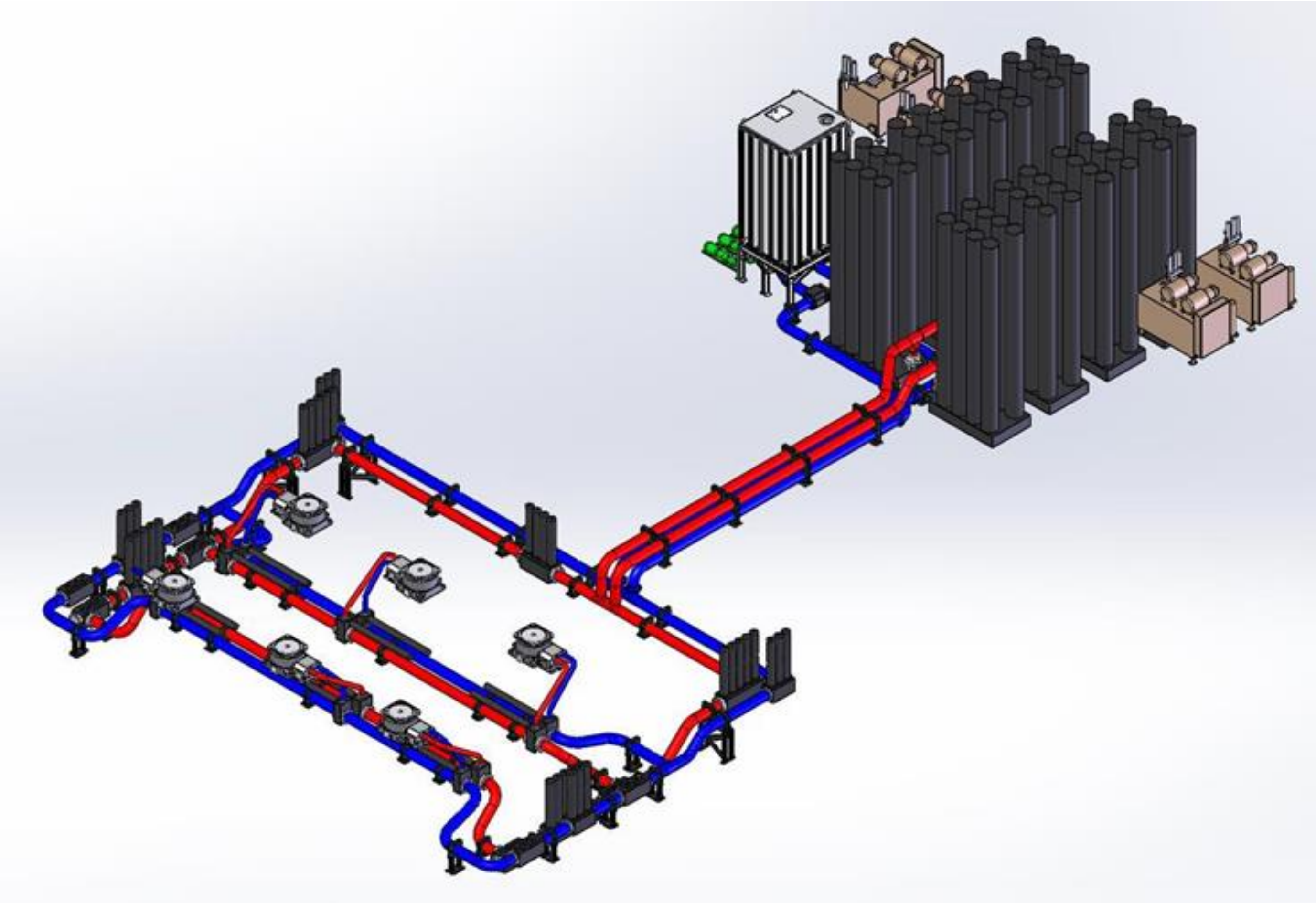
Upgrade to 6 DOF - Configuration



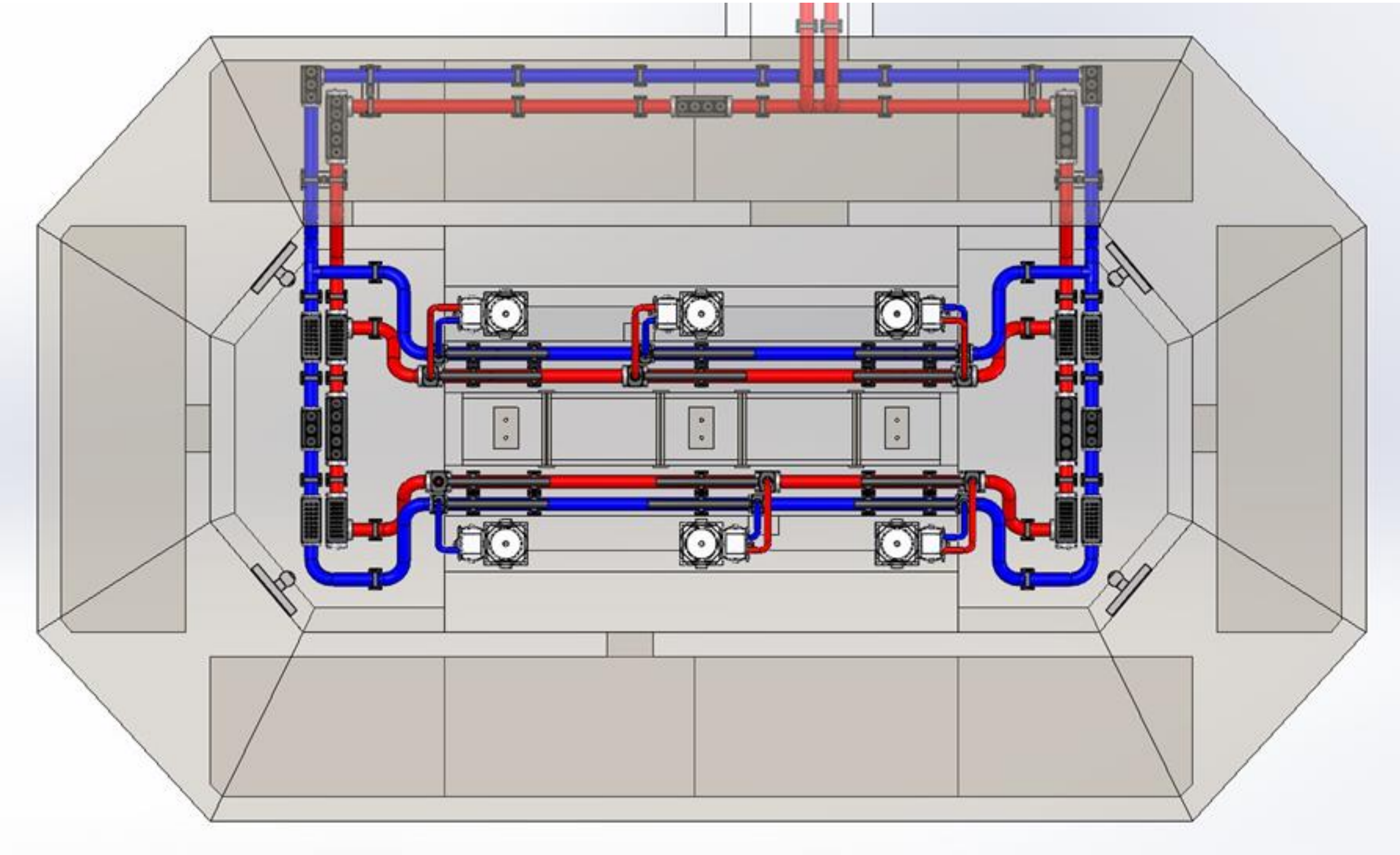
Upgrade to 6 DOF - Configuration



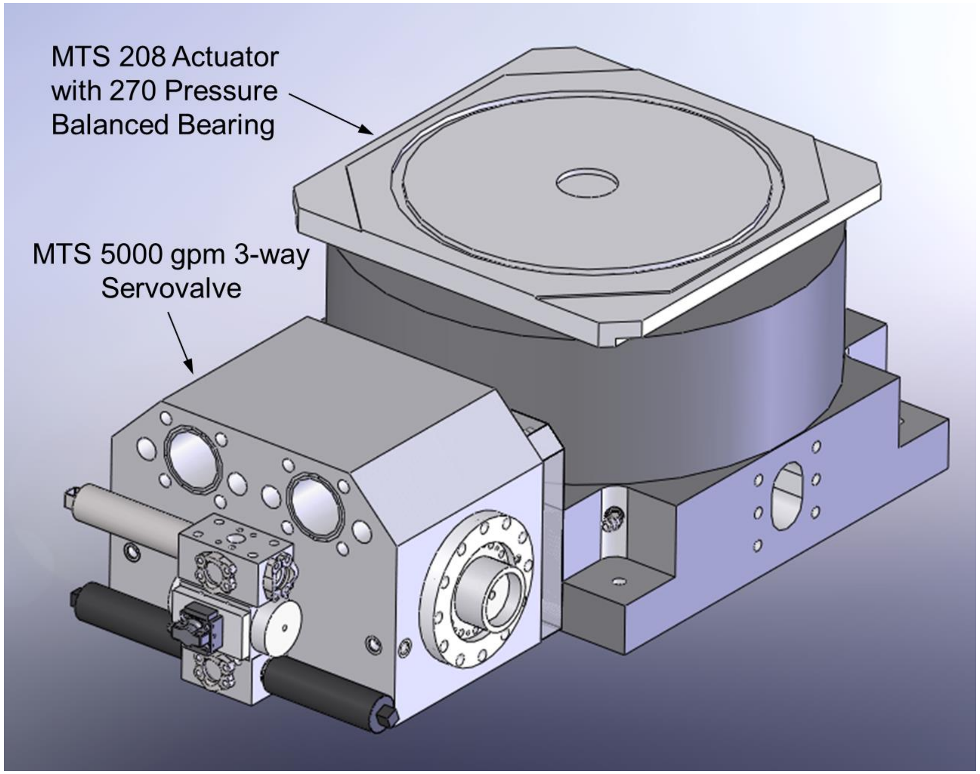
Upgrade to 6 DOF - Configuration

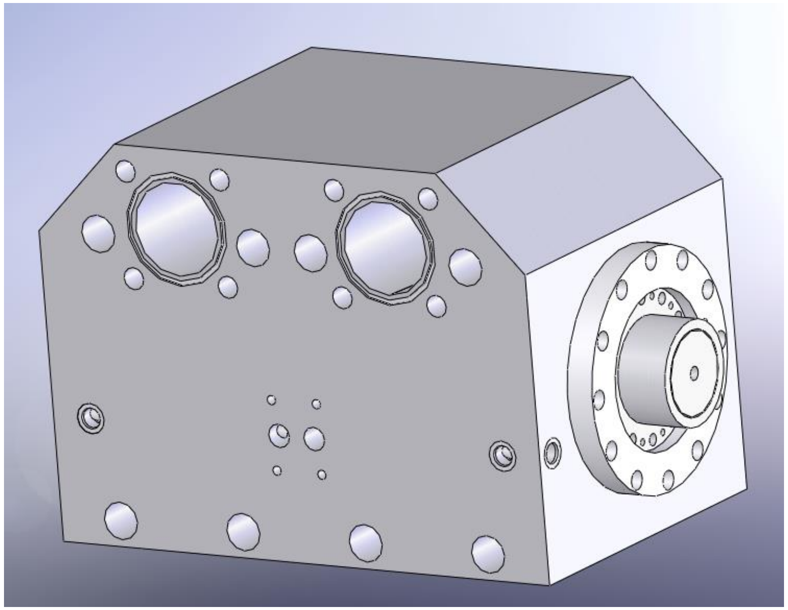


Upgrade to 6 DOF - Configuration



High-Flow Servovalves for Vertical Actuators





Design Uni-axial Performance Characteristics of 6-DOF LHPOST

Platen size	12.2 m × 7.6 m (40 ft × 25 ft)		
Frequency Bandwidth	0 – 33 Hz		
Vertical Payload Capacity	20 MN (4,500 kip)		
	Horizontal X	Horizontal Y	Vertical Z
Peak Translational Displacement	±0.89 m (±35 in)	±0.43 m (±17 in)	±0.127 m (±5 in)
Peak Translational Velocity	2.5 m/sec (100 in/sec)	2.0 m/sec (80 in/sec)	0.6 m/sec (25 in/sec)
Peak Translational Force*	10.6 MN (2,380 kip)	8.38 MN (1,890 kip)	54.8 MN** (12,300 kip)
Peak Rotation*	2.5 deg	1.5 deg	9.9 deg
Peak Rotational Velocity*	21.0 deg/sec	12.4 deg/sec	40.5 deg/sec
Peak Moment*	37.2 MN-m (27,400 kip-ft)	49.0 MN-m (36,200 kip-ft)	47.0 MN-m (34,600 kip-ft)
Overturning Moment Capacity	45.1 MN-m (33,200 kip-ft)	50.0 MN-m (36,900 kip-ft)	

* peak demand obtained during sinusoidal motions

** peak compressive force in the compression-only vertical actuators

Table loaded with rigid payload of 1,100 kips (5 MN)

Selected Set of Specimens tested on the LHPOST









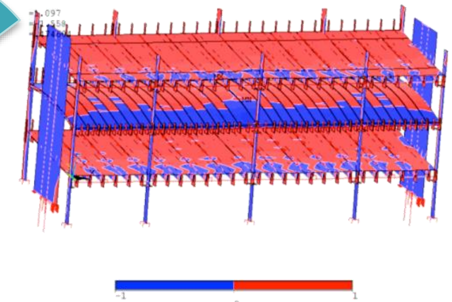




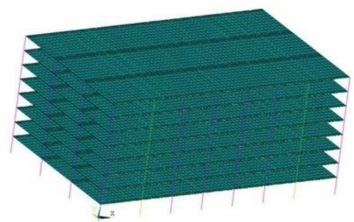
Integrated Experimental-Analytical Approach

Experimental Research
- Materials
- Structural components
- Structural systems

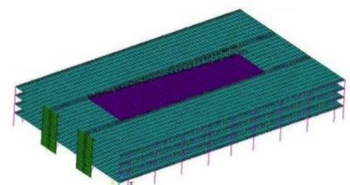
Computational Simulation
- Model development
- Model calibration
- Model validation



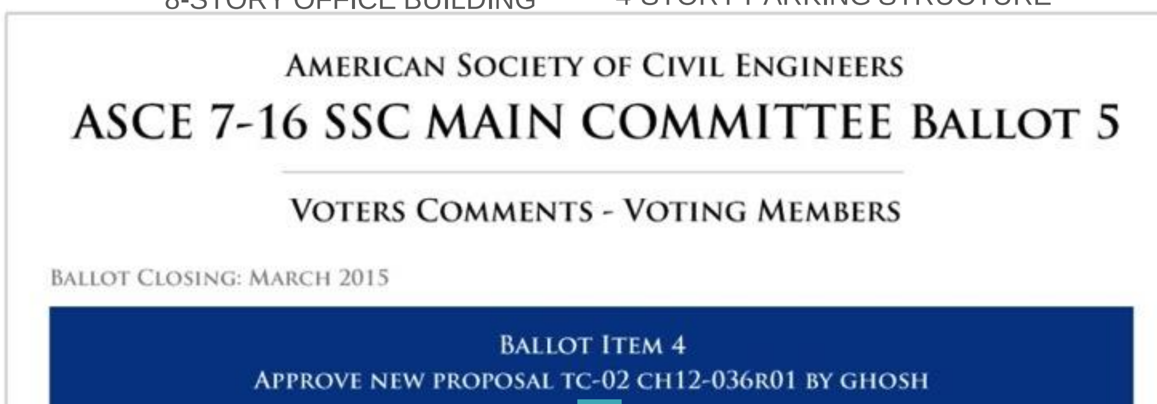
Design Provisions and Assessment Methods
- Development
- Verification through numerical simulation



8-STORY OFFICE BUILDING



4-STORY PARKING STRUCTURE



AMERICAN SOCIETY OF CIVIL ENGINEERS

ASCE 7-16 SSC MAIN COMMITTEE BALLOT 5

VOTERS COMMENTS - VOTING MEMBERS

BALLOT CLOSING: MARCH 2015

BALLOT ITEM 4

APPROVE NEW PROPOSAL TC-02 CH12-036R01 BY GHOSH

EARTHQUAKE RESILIENT INFRASTRUCTURE

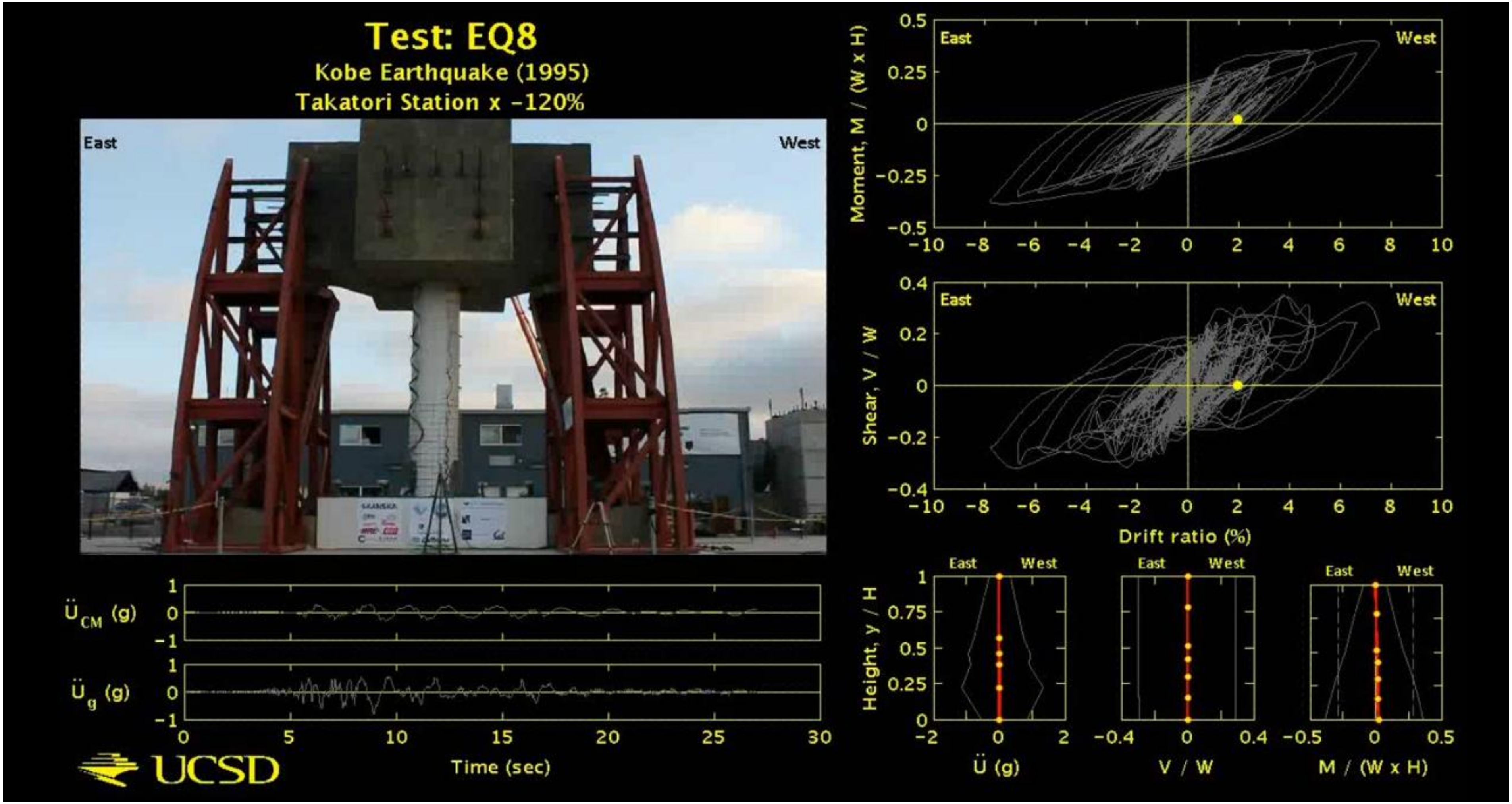
Development of a Seismic Design Methodology for Precast Building Diaphragms.

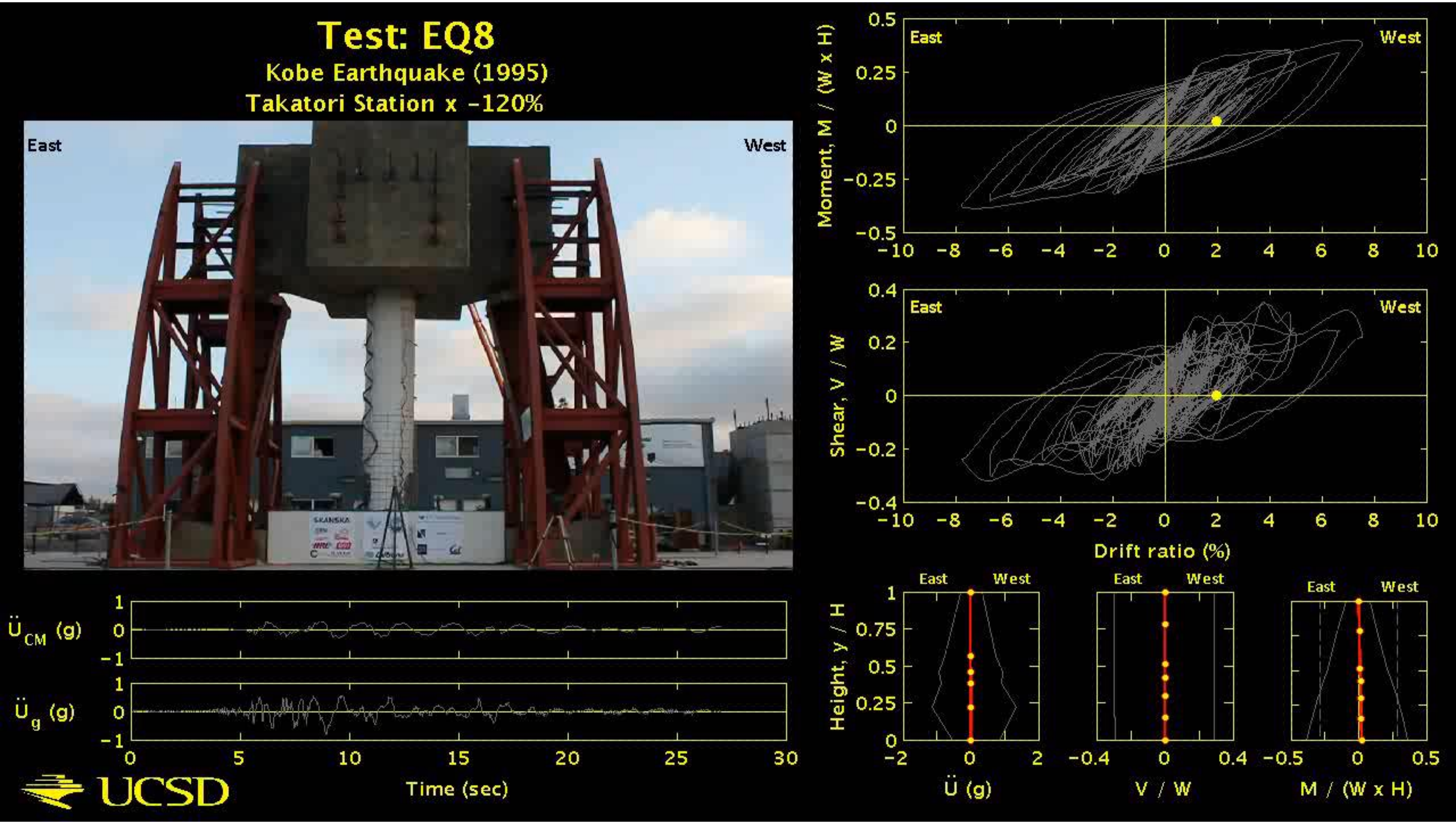
PI – Prof. Robert B. Fleischman University of Arizona

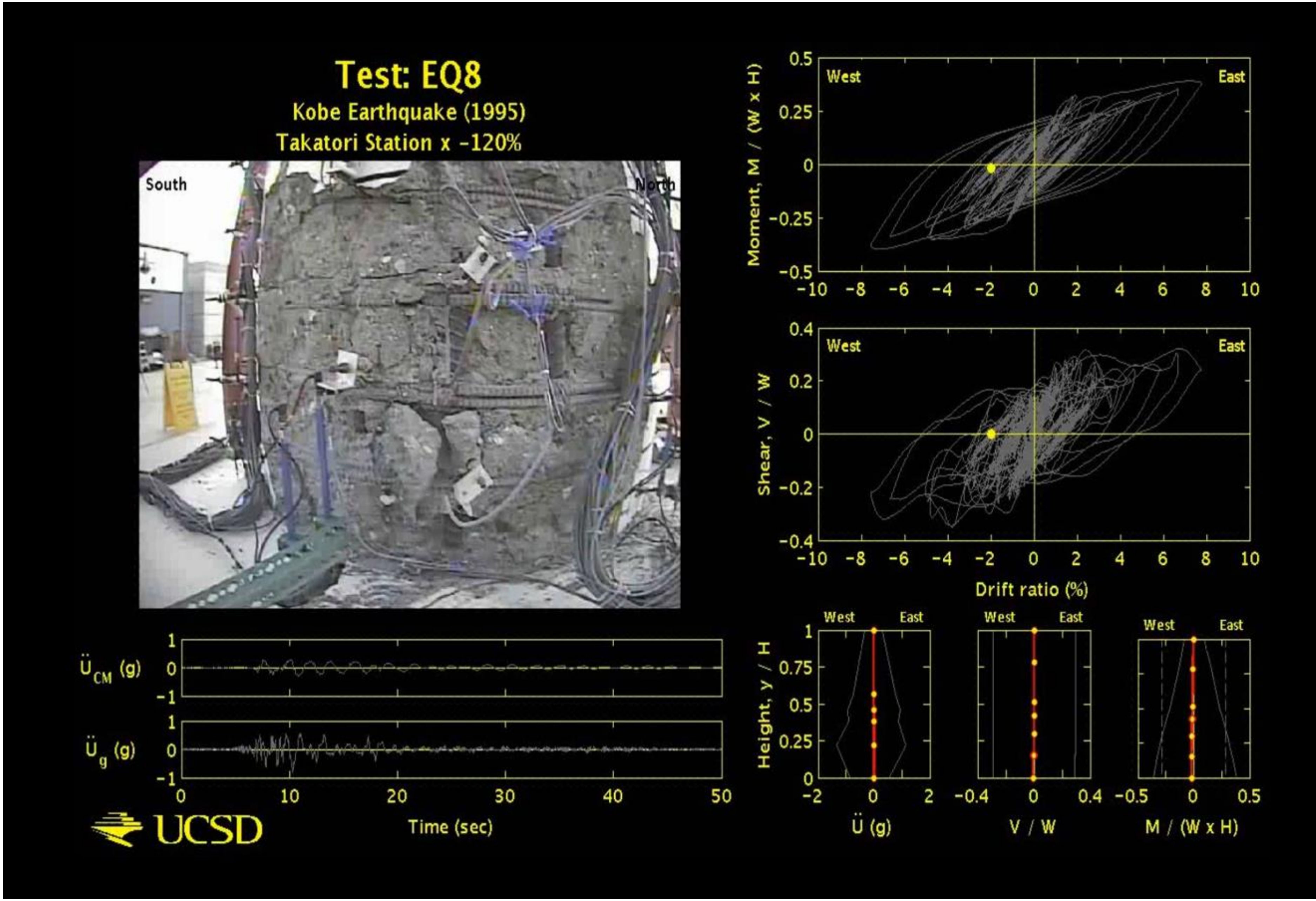

NEES

Large Scale Validation of Seismic Performance of Bridge Columns

PI: Prof. Jose Restrepo, UC San Diego



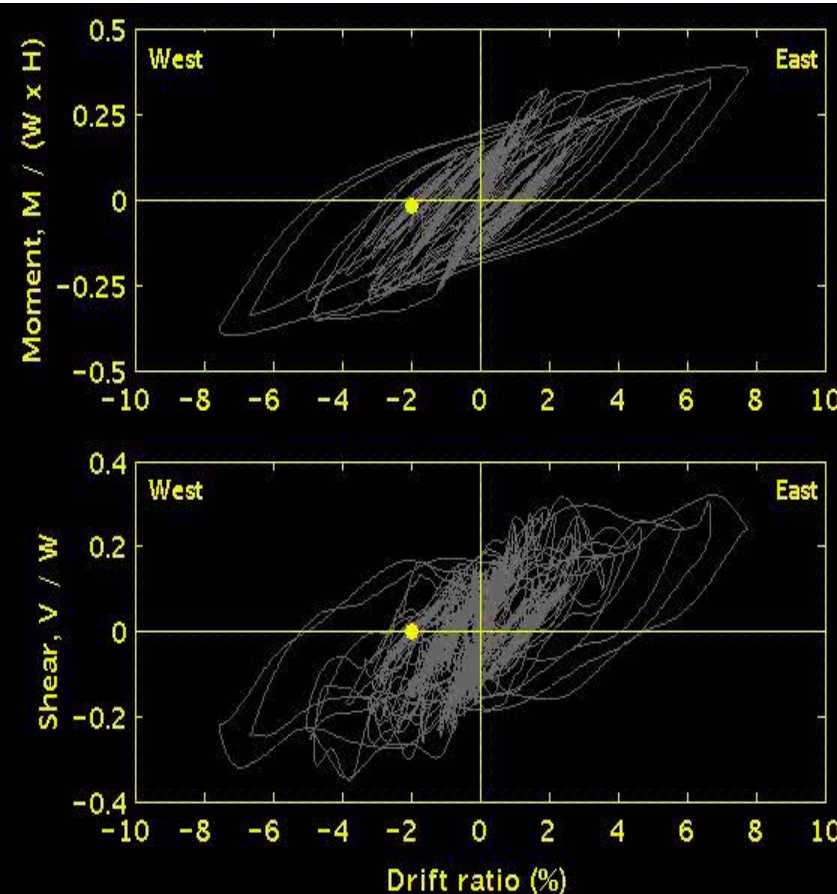

Test: EQ8
Kobe Earthquake (1995)
Takatori Station x -120%
East
West
Moment, M / (W x H)
0.5
0.25
0
-0.25
-0.5
-10 -8 -6 -4 -2 0 2 4 6 8 10
Shear, V / W
0.4
0.2
0
-0.2
-0.4
Drift ratio (%)
Ü_CM (g)
Ü_g (g)
1
0
-1
0 5 10 15 20 25 30
Time (sec)
Height, y / H
1
0.75
0.5
0.25
0
-2 0 2
Ü (g)
-0.4 0 0.4
V / W
-0.5 0 0.5
M / (W x H)
UCSD

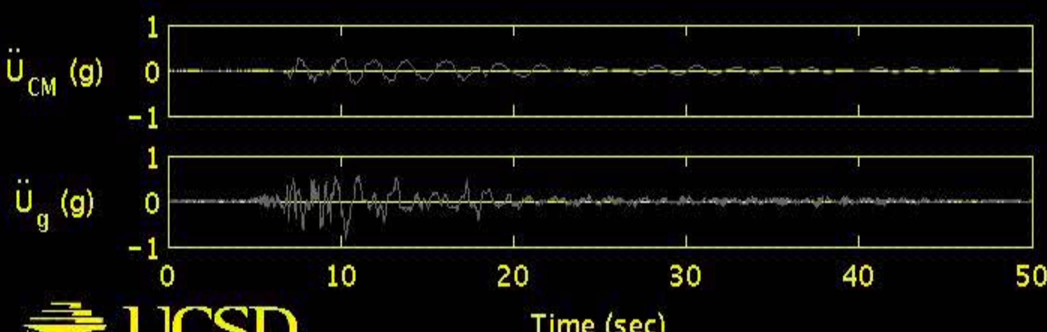

Test: EQ8
Kobe Earthquake (1995)
Takatori Station x -120%
South
North
West
East
Moment, M / (W x H)
0.5
0.25
0
-0.25
-0.5
-10 -8 -6 -4 -2 0 2 4 6 8 10
Shear, V / W
0.4
0.2
0
-0.2
-0.4
Drift ratio (%)
Height, y / H
1
0.75
0.5
0.25
0
-2 0 2
Ü (g)
-0.4 0 0.4
V / W
-0.5 0 0.5
M / (W x H)
Ü_CM (g)
Ü_g (g)
1
0
-1
0 10 20 30 40 50
Time (sec)
UCSD

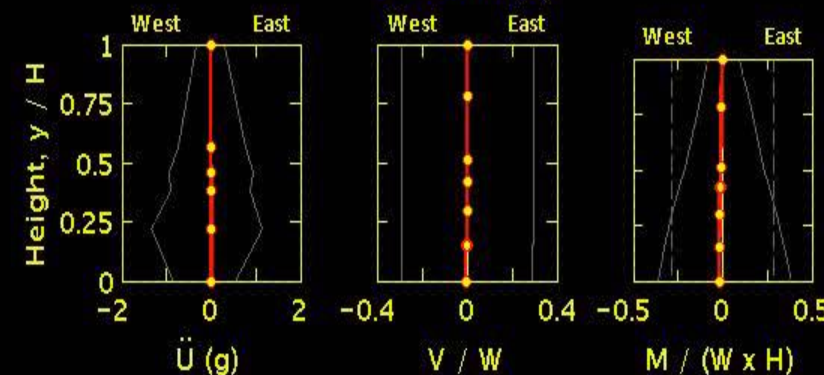
Test: EQ8

Kobe Earthquake (1995)

Takatori Station x -120%







Collapse Vulnerability and Seismic Design of Metal Buildings

PI - Prof. Chia-Ming Uang, UC San Diego

Full-Scale Structural and Non-Structural Building System Performance During Earthquakes

PI - Prof. Tara Hutchinson, UC San Diego

[redacted]

Full-Scale Structural and Non-Structural Building System Performance During Earthquakes

PI - Prof. Tara Hutchinson, UC San Diego

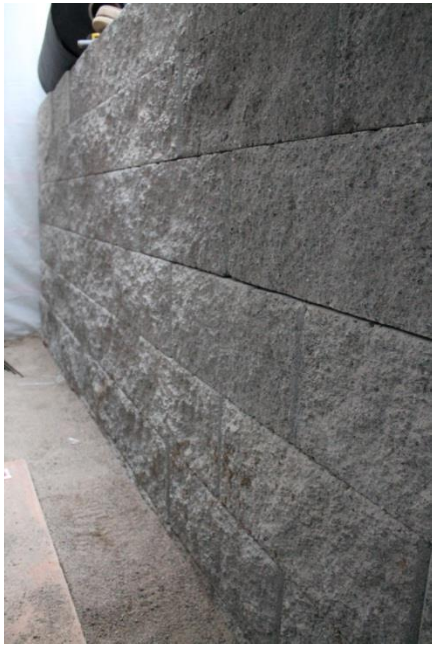
Full-Scale Structural and Non-Structural Building System Performance During Earthquakes

PI - Prof. Tara Hutchinson, UC San Diego

Seismic Performance Tests of Full-Scale Retaining Wall

PI – Prof. Patrick Fox, UCSD

22 ft. Above Table Elevation

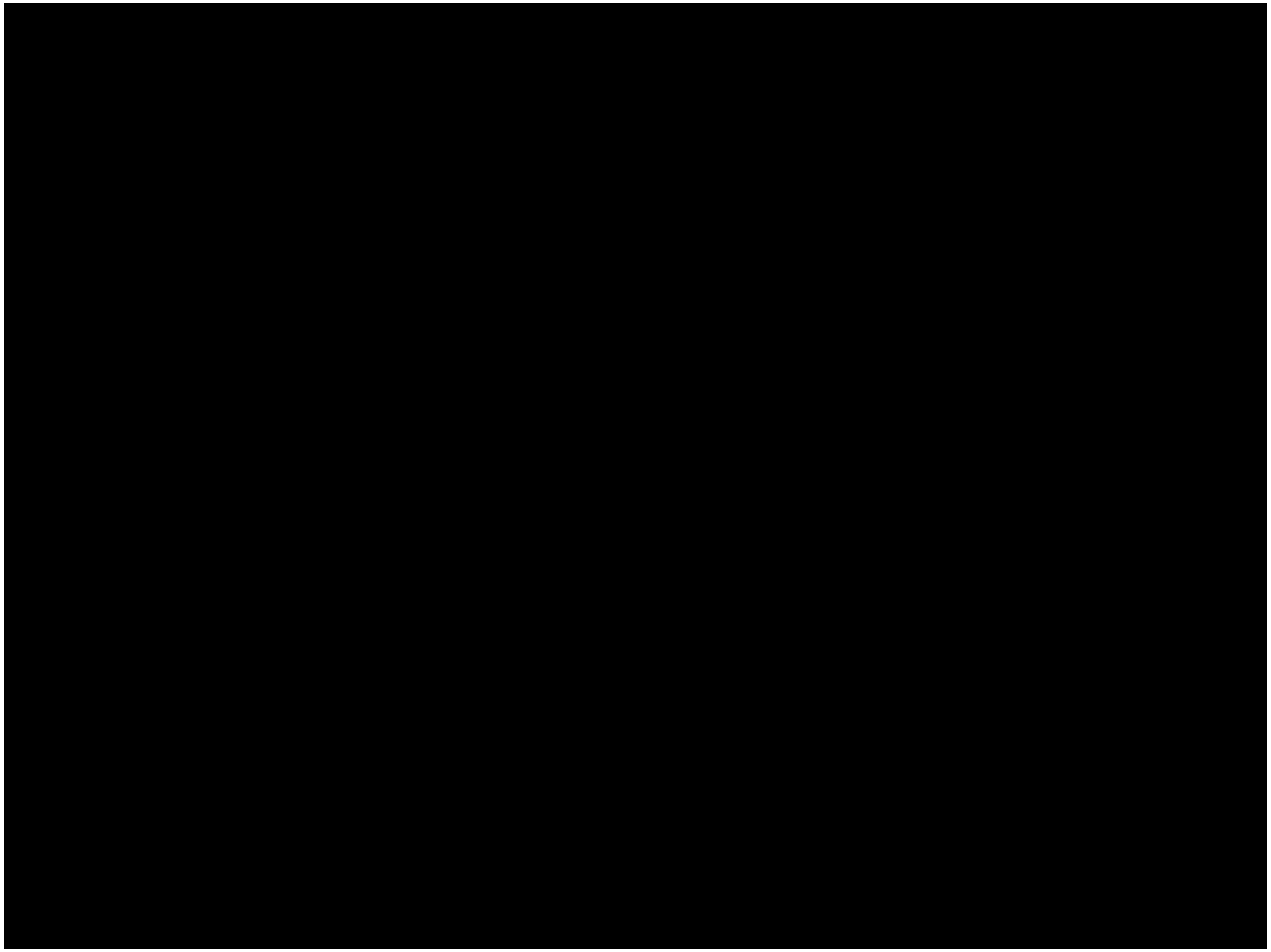


Earthquake Performance of Full-Scale Reinforced Soil Wall

PI: Prof. Patrick Fox, UC San Diego

Earthquake Performance of Full-Scale Reinforced Soil Wall

PI: Prof. Patrick Fox, UC San Diego



Seismic Risk Reduction for Soft-Story Woodframe Buildings

PI - Prof. John W. van de Lindt, Colorado State University

Seismic Risk Reduction for Soft-Story Woodframe Buildings

PI - Prof. John W. van de Lindt, Colorado State University

Soil-Foundation-Structure Interaction Test

PI – Prof. Marios Panagiotou, UC Berkeley

Broad Public Dissemination

- Jacobs School of Engineering Communications and Media Relations
- International, National, Regional, and Local Exposure


La estructura incluirá aisladores sísmicos chilenos

Recrearán en EE.UU. el terremoto del 27-F en un edificio experimental de cinco pisos

La actividad forma parte de un ciclo de simulación de sismos que tendrá lugar la próxima semana en la Universidad de California, en San Diego.

Así es la mesa vibradora que replica sismos

Crece desarrollo de aisladores

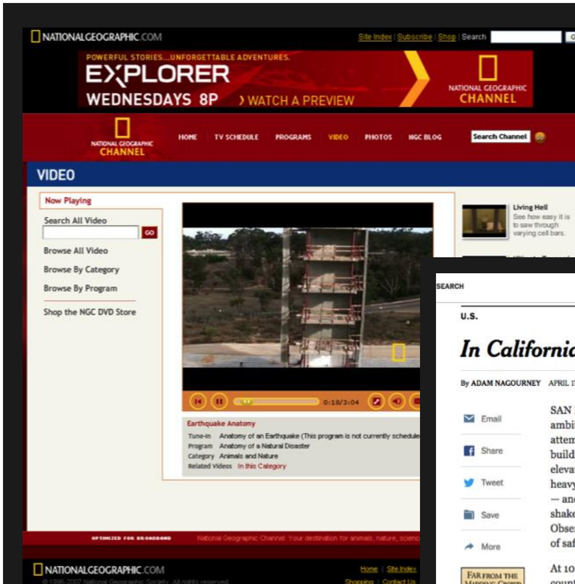
Tres desafíos

Para teléfonos inteligentes:

Dos aplicaciones nacionales sacan provecho al GPS

Canal 13C Documental sobre chilenos en Silicon Valley

Éxito de la cirugía: Edad del donante vivo no incide en un trasplante

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The New York Times

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In California Quake Research, Boring Is the Hoped-for Result

By ADAM NAGOURNEY APRIL 17, 2012

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SAN DIEGO — It was billed as one of the most ambitious earthquake simulations ever attempted. Engineers constructed a five-story building — complete with an operating room, an elevator, a kitchen loaded with glassware and a heavy air-conditioning unit perched on the roof — and placed it atop a platform known as a shake table on the outskirts of San Diego. Observers were issued hard hats and a strict set of safety instructions.

At 10:30 a.m. Tuesday, after an ominous countdown and as red warning lights whirled, the shake table unleashed the mechanical equivalent of a one-minute earthquake that replicated the 6.7-magnitude Northridge temblor that rolled through Los Angeles in 1994. It was the first of two earthquake re-enactments

Researchers conducted two earthquake simulations in San Diego on Tuesday.
Sam Hodgson for The New York Times

THANK YOU !

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