



NHERI@UCSD: Tools for Shake Table Users

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December 13, 2018



Outline

- **Shake table simulation and input motion** generation tools
- **Instrumentation**
 - Sensor Inventory and DAQ System
- **Tele-presence and Video Recording System**
 - Camera Inventory
 - Site Drones
- **Live Video Streaming Capabilities**
 - WireCast System
 - DaCast service for zero latency live video streaming
- **IT Infrastructure**
 - Visible and invisible IT networks
- **Our Websites and Social Media Presence**
 - Resources for Researchers

Shake Table Simulation and Input Motion Generation Tools

- **Two different types of tools can be provided**
 - 1) **Shake Table Simulation Tools**
 - ✓ For **pre-test evaluations** and **checks**
 - 2) **Input Motion Generation Tools**
 - ✓ For **performing actual dynamic tests** on the shake table using the **motions generated** by these tools

(1) Shake Table Simulation Tools

a. Forward Simulation Tool

- **Pre-test studies** using **the real controller** and **a validated model** of the shake table
 - ✓ The forward model is **like the real system** (i.e., when servo-valves are commanded, table motion results)

b. Inverse Simulation Tool

- **Checking** the **suitability** of **ground motions** to be **reproduced** on the table in term of the **table's physical limits** (e.g., disp., force etc.)
 - ✓ In the inverse model, **cause** and **effect** are **reversed** (i.e., the system motion is input to the model, servo-valve openings result)

Shake Table Forward Simulation Tool

► PC Simulation Mode

469 Uniaxial Seismic Controller: Settings.set

File Calibration 469D Digital Seismic Table Controller: Settings.set

File Configuration Operation Display Service

Hydraulics **Main On**

Control Variable **Acceleration**

Program Source **Function Generator**

Master gain 100 %

Parking setpoint 0.0 %

Desired span 100.0 %

Current span 0.0 %

Adaptive Control

Feedback...

AFC Disabled

APC Disabled

AHC Disabled

AIC Disabled

OLI Disabled

Stop Preview Run

X Y Z Rx Ry Rz

function() out

Simulation Model of LHPOST

- The forward simulation tool
- Enable the controller
- Offline tuning of the controller

Shake Table Forward Simulation Tool

499 Uniaxial Seismic Controller: Settingsset

File Calibration Configuration Operation Display Service

Hydraulics

HPS On HSM Lo HSM Hi

Interlocks Disabled Reset

Control Variable: Acceleration

Table: Internal

Simulation: Internal

Program: Random

Master gain: 100.0 %

auto-reduce gain on limit

Setpoint: 0.0 mm

Desired span: 100.0 %

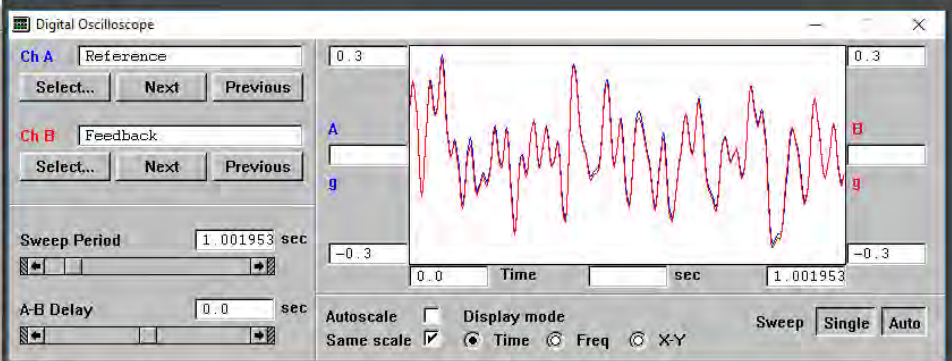
Current span: 100.0 %

Stop Preview Run

Adaptive Control

Feedback...

AFC Disabled APC Disabled AHC Disabled AIC Disabled OLI Disabled



Function Gen...

Program: Random

Shape: Flat

RMS Amplitude: 0.1 g

Minimum freq: 0.25 Hz

Maximum freq: 35.0 Hz

Limit Detectors

Displacement fbk

Action: Indicate

Active

Upper: 10.0 mm

Lower: -10.0 mm

Persistence: 0.0 sec

Reset

Spectrum Analyzer

Input: Reference

Output: Feedback

Enable

Remove mean Differentiate input Differentiate output

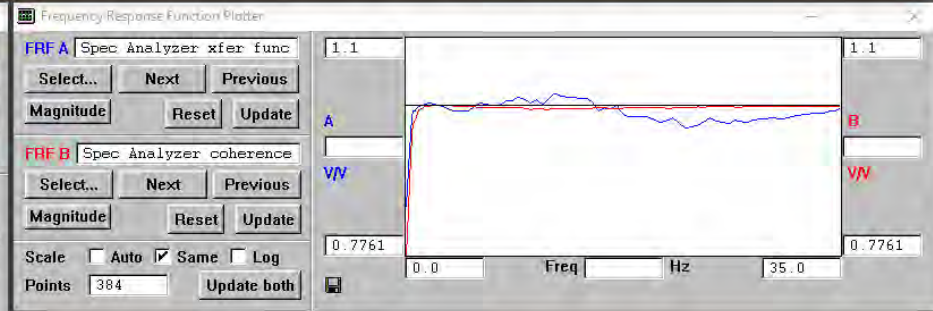
Sample rate: 256 Hz

FFT size: 512

Decay time const: 100 avgs

Averages taken: 1167 avgs

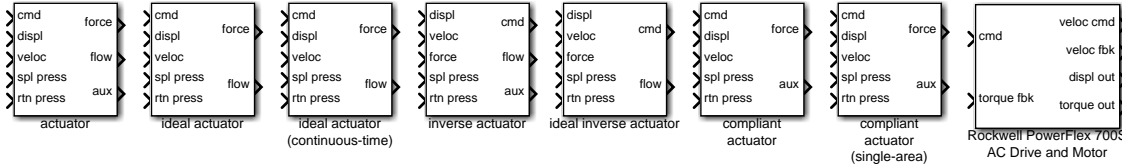
Reset



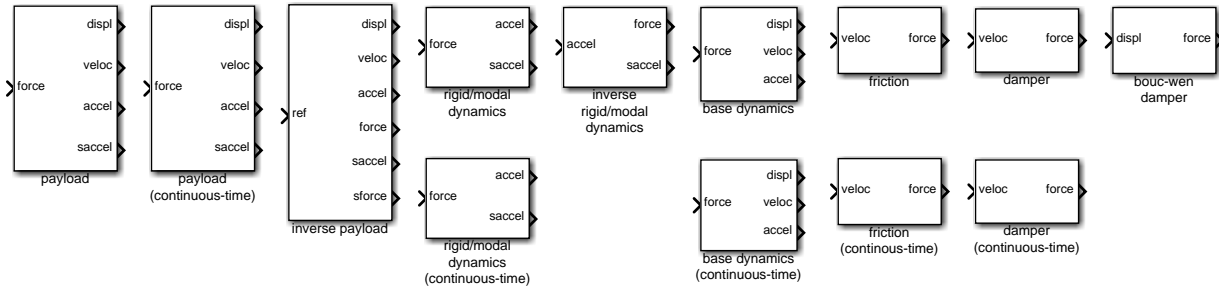
Shake Table Forward Simulation Tool

➤ Forward Model can be enhanced by using **an extensive dynamic library**

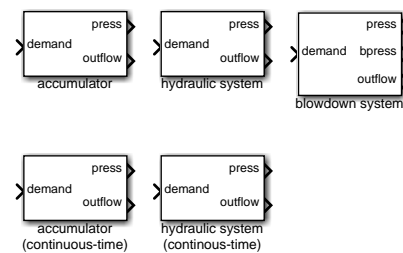
PRIME MOVERS



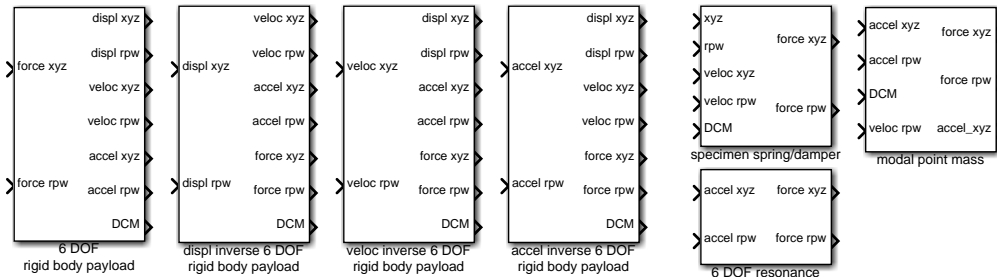
1-DOF PAYLOADS



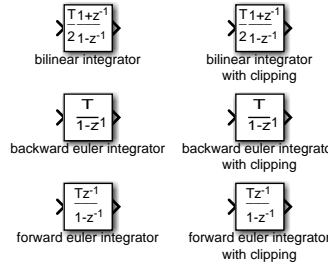
HYDRAULICS



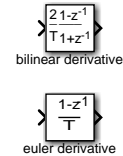
6-DOF PAYLOADS



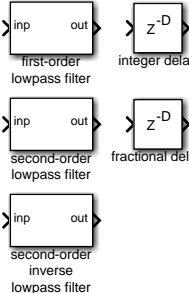
INTEGRATORS



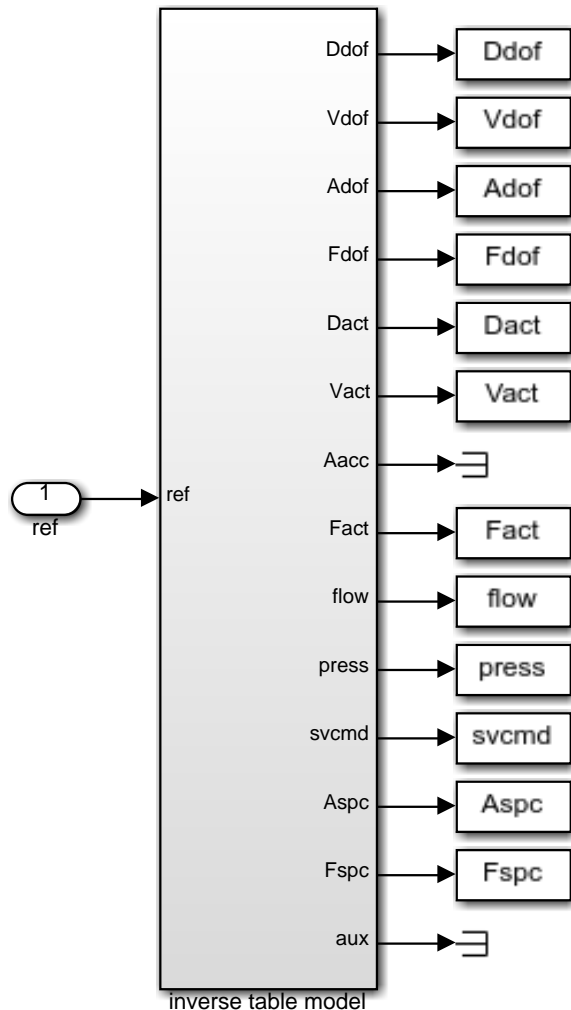
DIFFERENTIATORS



MISC



Shake Table Inverse Simulation Tool



- Allows the user to take a **desired motion profile** (uni- or tri-axial) and
 - Verify that the system can **meet the demands** in terms of **displacement**, **velocity**, **acceleration**, **force**, **oil flow** and **pressure**.

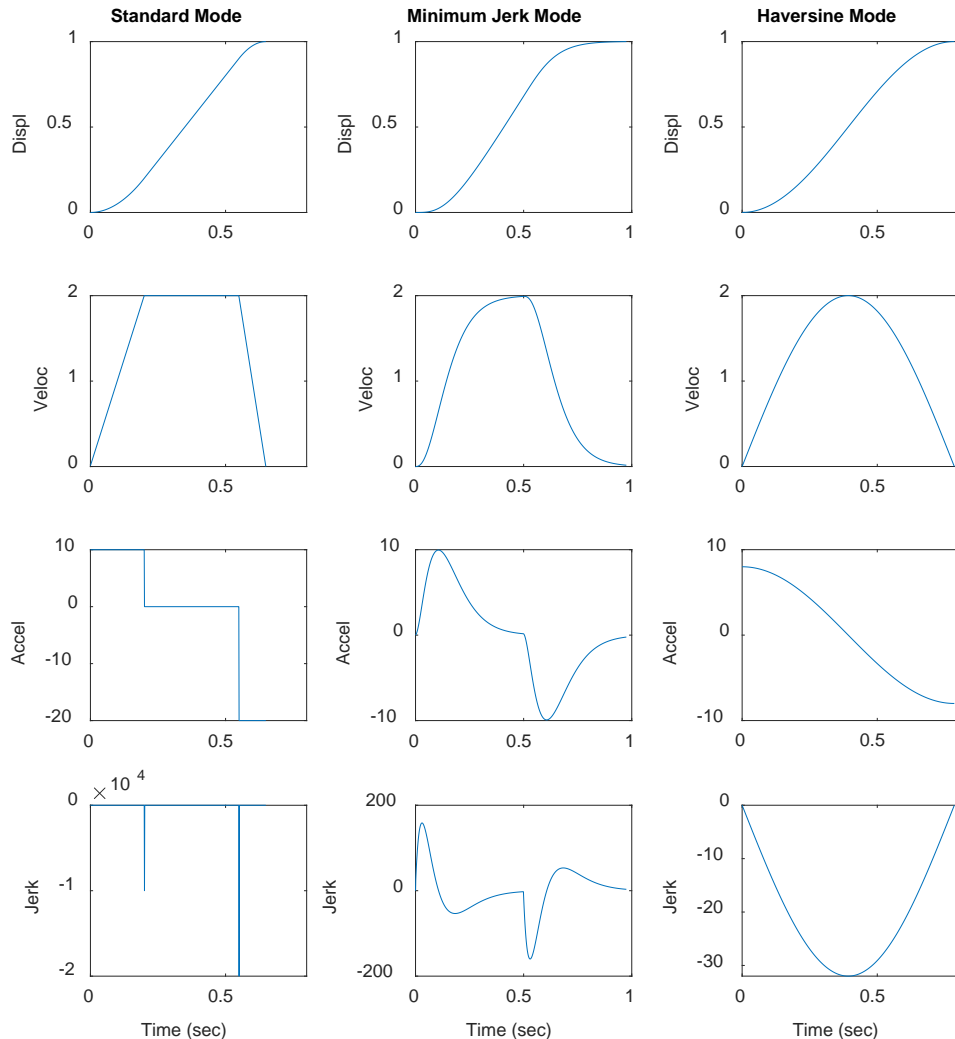
(2) Input Motion Generation Tools

➤ These tools are needed for

- **Input ground motion** preparations for shake table testing
 - Ramp function, sine-sweep, sine-beat, random time histories
 - Pseudo-random THs
 - Response spectrum compatible THs
 - Base-line correction of THs

Input Motion Generation Tools

Ramp Time Histories

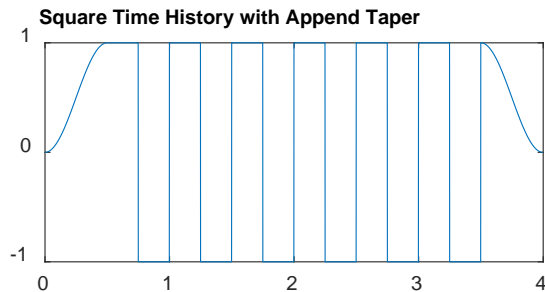
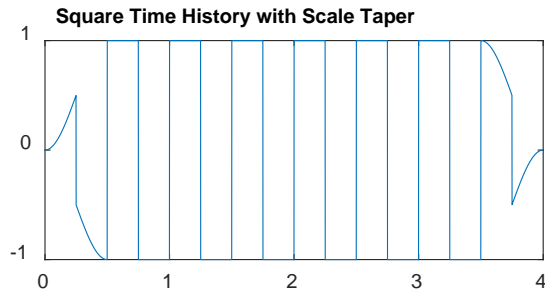


- We want to make sure that a smooth displacement ramp waveform is generated which has smooth and predictable maximum velocity, acceleration, and jerk (3rd time derivative of displacement).

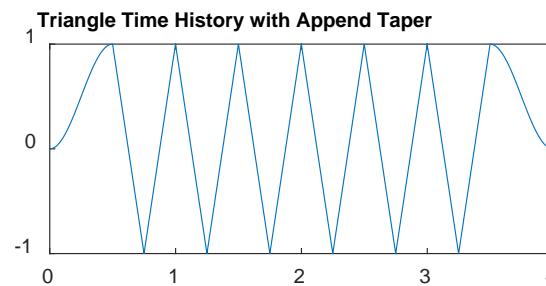
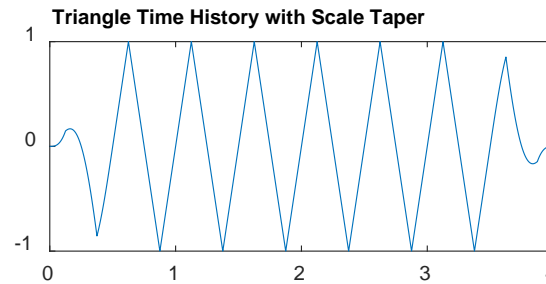
Input Motion Generation Tools

Square/Triangle/Sine THs

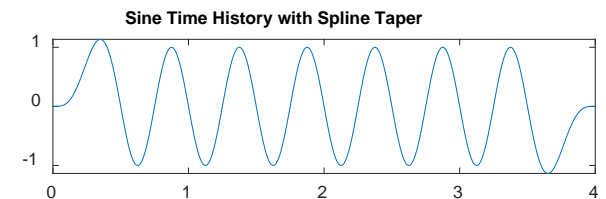
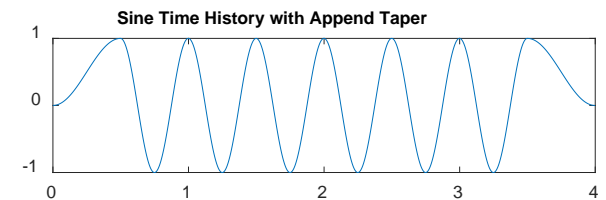
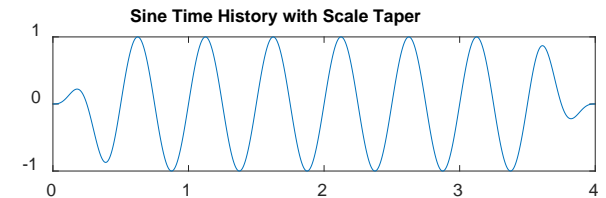
- When we want to generate a periodic function,
 - Make sure that **beginnings** and **ends** must be **tapered**



Time (sec)



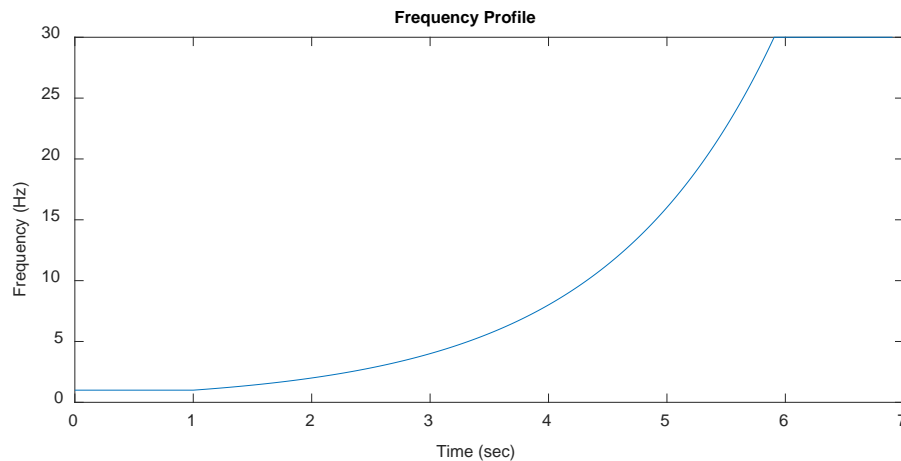
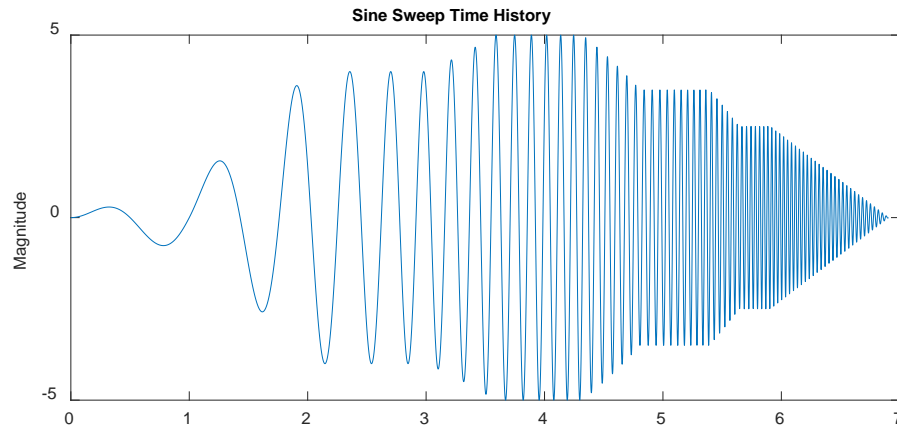
Time (sec)



Time (sec)

Input Motion Generation Tools

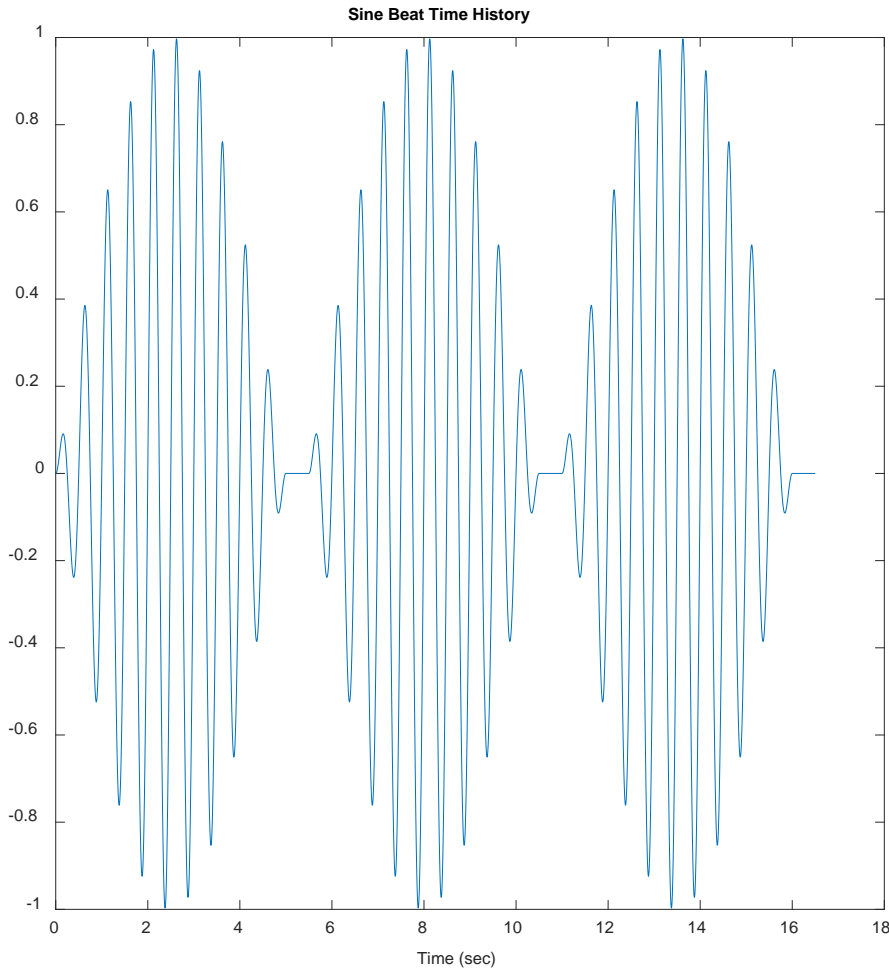
Sine Sweep THs



- Sweep can be **linear** or **logarithmic**
- **Taper up** and **taper down** can be specified
- Taper shape can be **linear**, **haversine** or **spline**

Input Motion Generation Tools

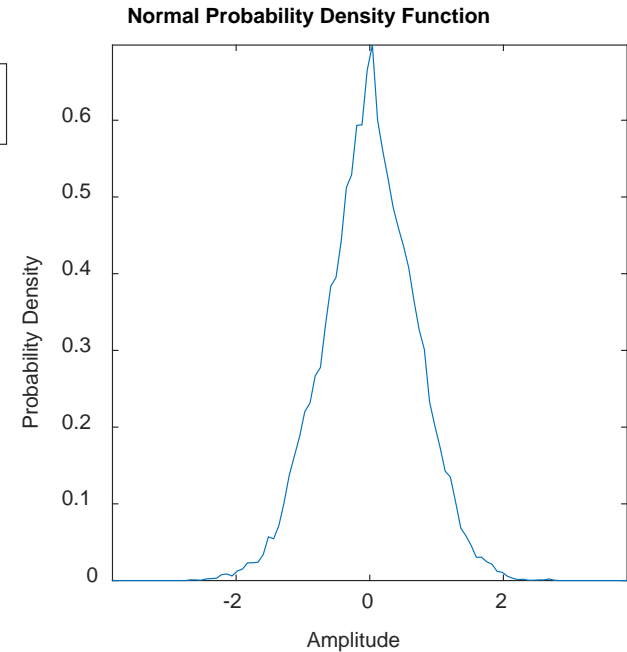
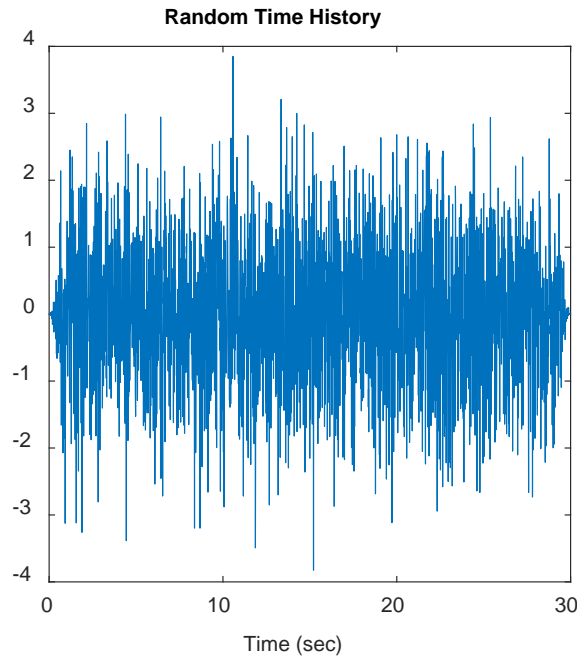
Sine Beat THs



- Number of **beats**
- Number of **cycles** per beat
- **Pause** between beats in sec can be specified

Input Motion Generation Tools

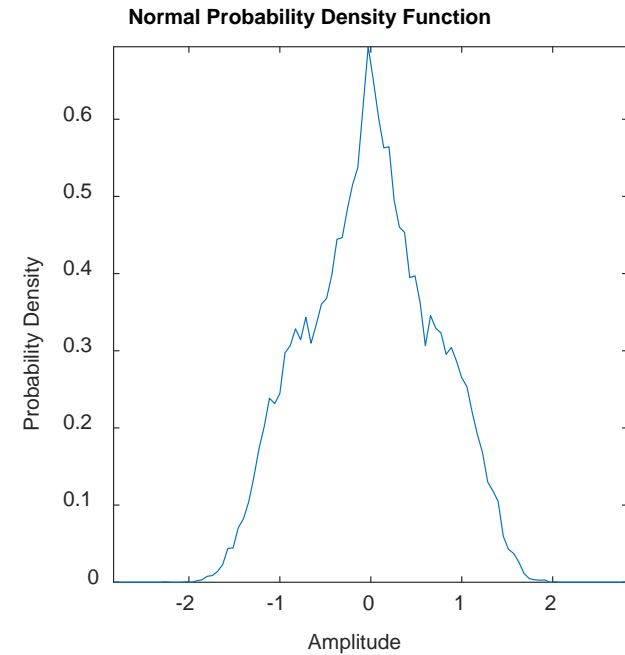
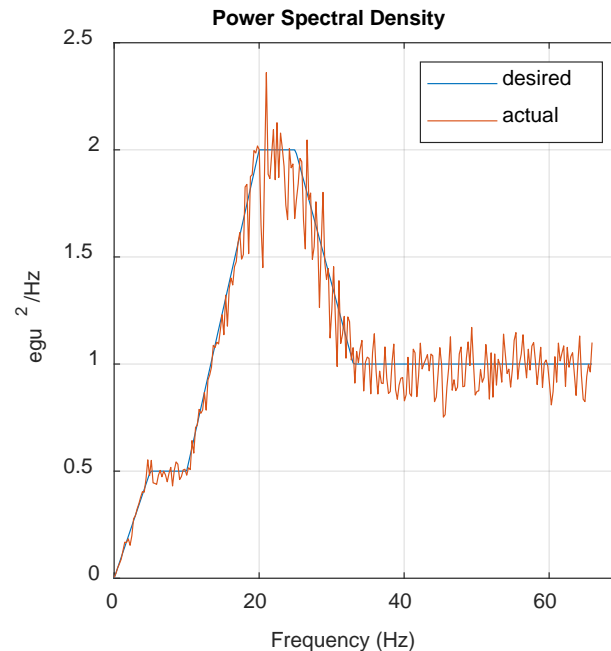
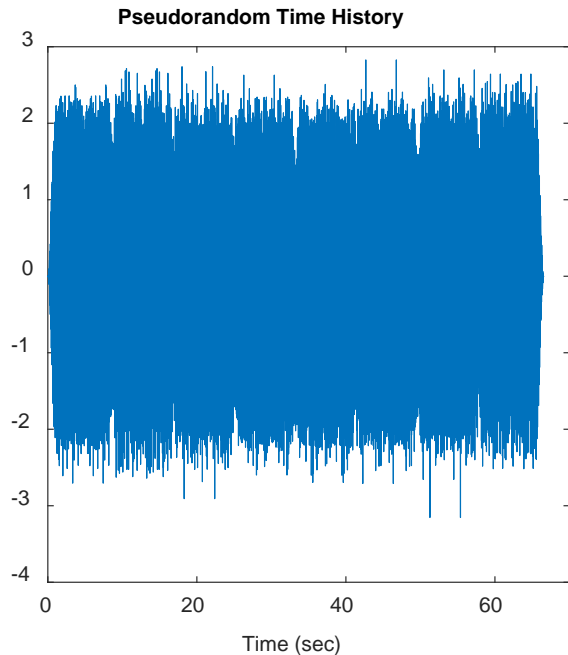
Random THs



- Creating a non-repeating random TH by passing uniform WN through a filter with desired spectral shape and bandwidth

Input Motion Generation Tools

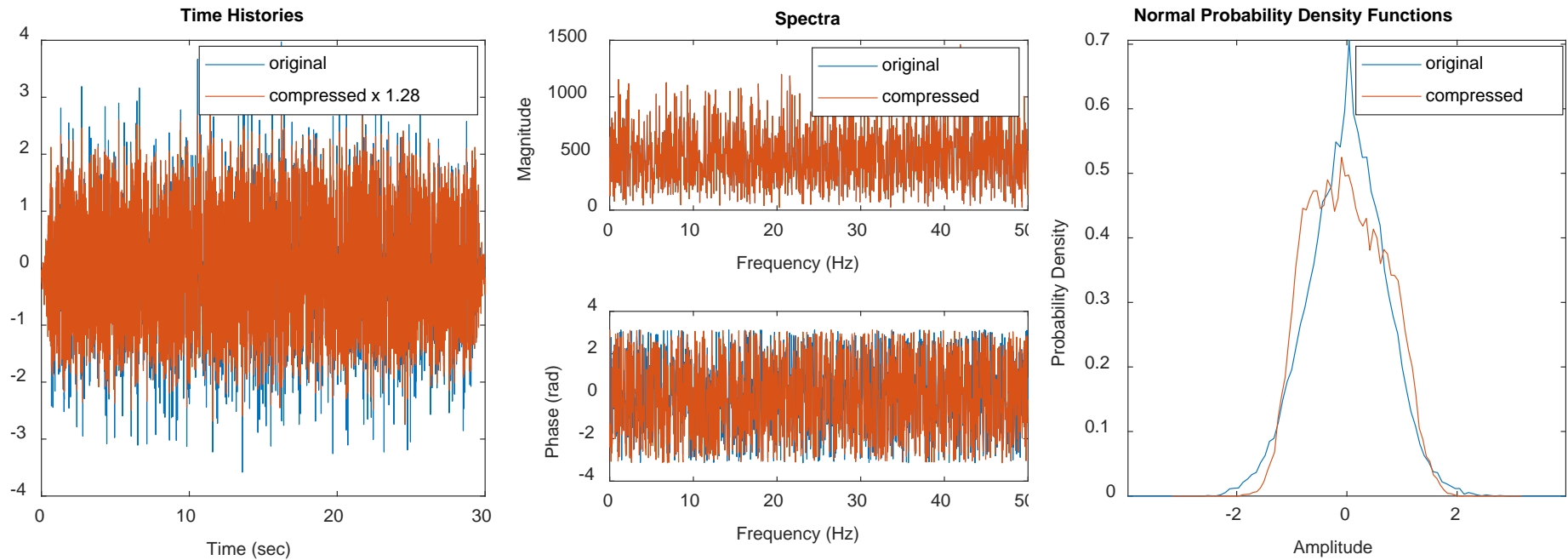
Pseudo-random THs with Desired Spectral Density



- A different version of this tool can also be used for generating response spectrum compatible acceleration THs.

Input Motion Generation Tools

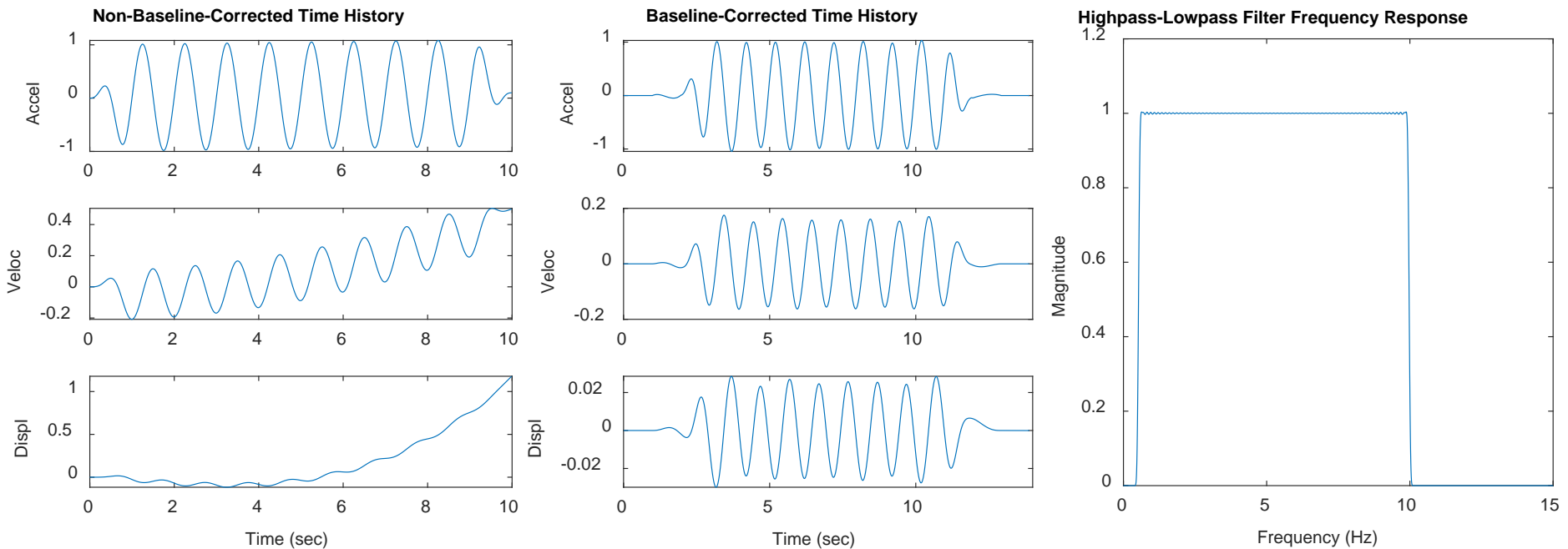
Compressing Dynamic Range of THs



- The **compressed signal** still has the **desired RMS amplitude** and **flat** magnitude response spectrum.

Input Motion Generation Tools

Baseline Correction



- Modifies acceleration records so that it **begins** and **ends** at **zero displacement, velocity, and acceleration** by series of operations
 - High-pass/low-pass filtering, detrending, padding the beginning and end with zeros

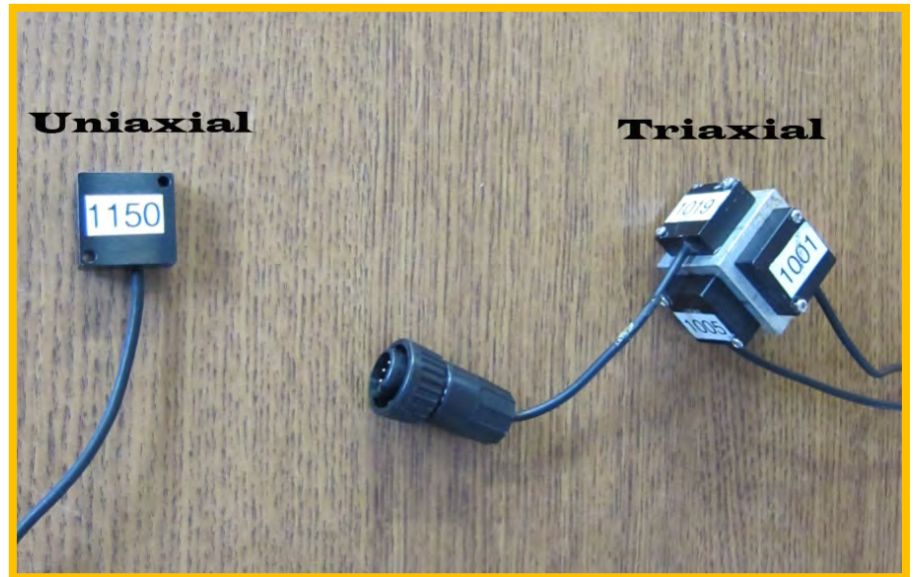
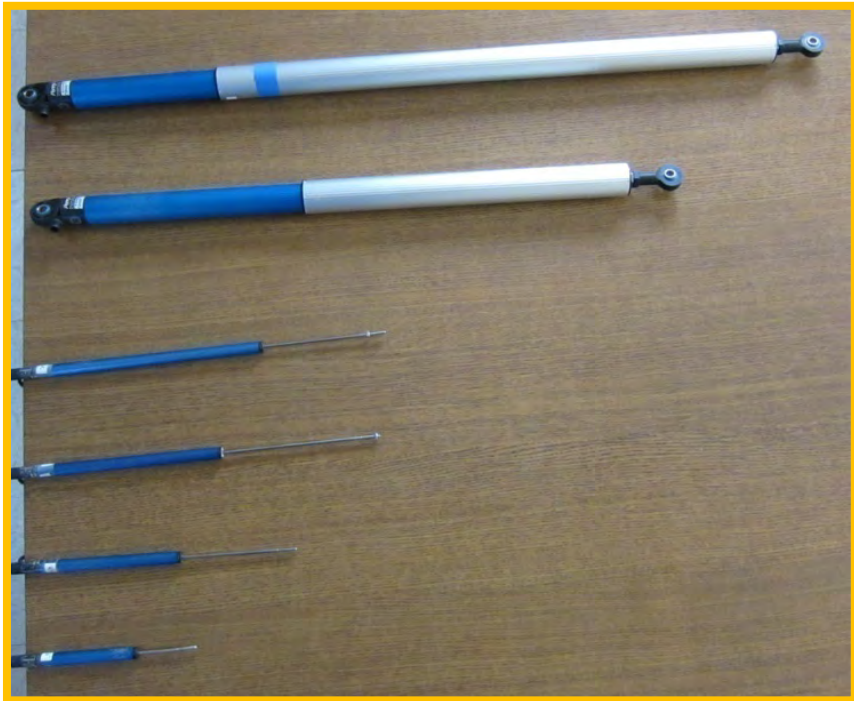
Instrumentation

➤ The instrumentation inventory consists of

- **200** MEMS type accelerometers
 - ✓ +/- 5g – DC to 200 Hz – Sensitivity 200mV/g
- **180** linear potentiometers (ranging 2 in to 20 in)
- **135** string potentiometers (ranging 2 in to 60 in)
- **10** spring potentiometers (range 1 in)
- **24** load cells (up to 20,000 lbs)
- **32** soil pressure transducers
- Load jacks (various)
- **1** GPS system with a network of antennae (two mobile and one reference), provides dynamic displacement monitoring in three coordinates, operates at 50 Hz

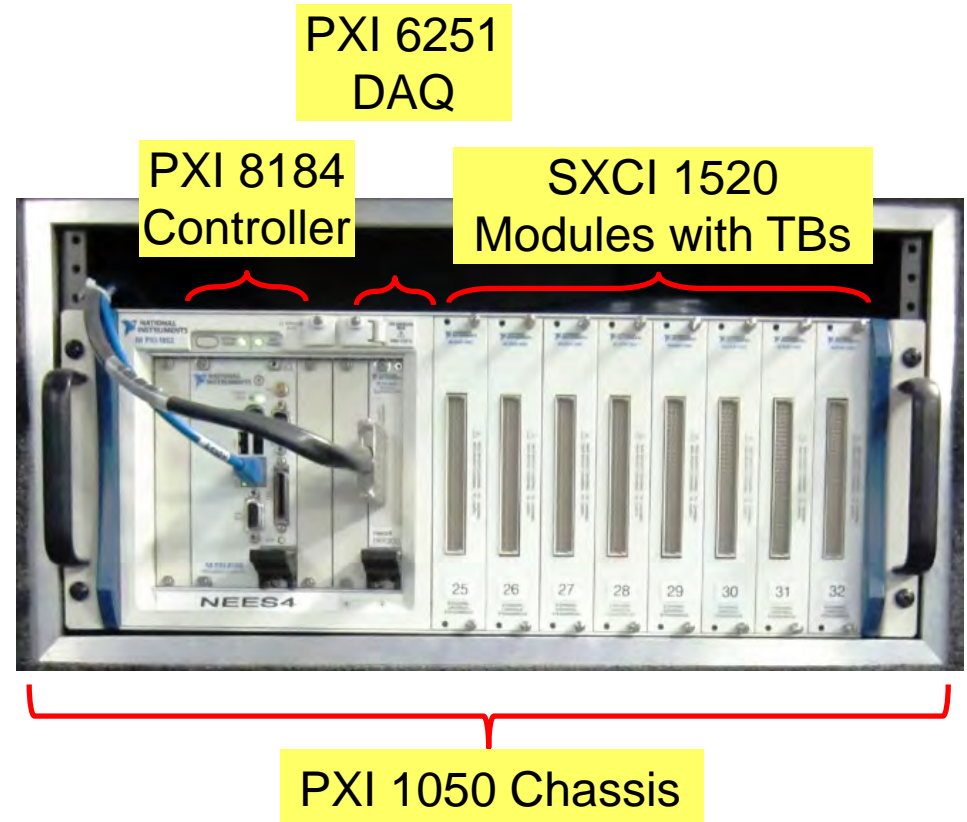
➤ All sensors are calibrated (**accredited in-house calibration is available!**)

Instrumentation



Data Acquisition System

- **12** Data acquisition nodes (a distributed system) with **64 channels** and **16-bit** resolution each (total of **768 channels**)
- **7** are in active use now (total of **448 channels**)
- Each channel can be **configured** to accept **any type of sensor** (strain gauges, displacement transducers, accelerometers, pressure cells, load cells, etc.)



Telepresence/Video Recording System

- **Axis P1365 (3 Cameras)**
 - Provide delay-time viewing via web site
 - Provide **time-lapse** for projects
- **IDVR-Pro H.264 HD CCTV DVR (32 Coax)**
 - **Trigger-based recording** for synchronization with data
 - **16 channels** of digital video recording with immediate playback capabilities (**synchronized with data**)
- **NUUO Hybrid Video Recorder/IP NVR**
 - **Trigger-based recording** for synchronization with data
 - **16 channels** of digital video recording with immediate playback capabilities (**synchronized with data**)



Coax Cams 1080p HD

- 32 Coax Cameras



GoPro Cameras

- We have **15 GoPro cameras** available (GoPro2, GoPro3+, and Hero4) – True HD
- Recently, they are equipped with **external battery packs** for longer recording time (approx. **24 hours** with single charge, it used to be **1 hour**)
- Also, for **synchronization** purpose they are fitted with a **central start/stop feature**



Site Drones



Wirecast System for Live Video Streaming

Wirecast Workflow



Wirecast Gear
Live streaming production system

- **4 cameras** can be hooked
- Has its own **live streaming software**
- **Live production** such as switching between multiple cameras while dynamically mixing with remote live guests, movies, images, audio etc.
- Streaming over **popular social media platforms** (YouTube, Facebook, Twitter etc.)

Control Center

- Houses host computer for shake table control
- Camera control system
- Data acquisition system
- Data and safety video streaming system
- FlexTest GT System
- Real-time hybrid testing system
 - Host and real-time target computers



Meeting/Conference Room




NHERI@UCSD Site IT Infrastructure

- 1-GB Campus Wide Area Network
 - Internet2 participant
- 802.11g Campus Wireless Network
 - WPA-2 Enterprise security
- Provide guest wireless account for visitors/researchers
- Site dedicated 1GB LAN
- Video/Data backup systems

Data/Video Backup System

- **On-site** data backup system (daily)
 - 16 TB
- **Off-site** data backup system (daily)
 - 16 TB
- Publish **curated data/metadata** in DesignSafe Data Depot
 - **Web interface** of DesignSafe
 - For large files use **Globus** bulk data transfer



The screenshot shows the DesignSafe-CI website interface. At the top, the logo 'DESIGNSAFE-CI' is displayed alongside a stylized 'W' logo. Below the logo, the text reads 'NHERI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE'. In the top right corner, there are 'Log in' and 'Register' buttons. A navigation menu includes 'Research Workbench', 'Learning Center', 'NHERI Facilities', 'NHERI Community', 'About', and 'Help'. A search bar is located on the right side of the navigation menu. The main content area features the heading 'DATA TRANSFER GUIDE' in large blue letters, followed by the sub-heading 'TRANSFERRING FILES TO DESIGNSAFE'S DATA DEPOT'. The text below explains that DesignSafe supports multiple ways of moving data in and out of the Data Depot, and that while the web interface is easy for small files, Globus, Cyberduck, or Command Line tools are recommended for large volumes of data. A bulleted list of methods is provided at the bottom of the page.

DESIGNSAFE-CI 

NHERI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE

Log in Register

Research Workbench Learning Center NHERI Facilities NHERI Community About Help

Search DesignSafe Q

DATA TRANSFER GUIDE

TRANSFERRING FILES TO DESIGNSAFE'S DATA DEPOT

DesignSafe supports multiple ways of moving data in and out of the Data Depot – which one is best depends on how you will use DesignSafe. While the web interface in the DesignSafe portal is easy for moving small numbers of modest size files, if you need to move **large volumes of data, large numbers of files (> 50) or move folders**, the Globus, Cyberduck or Command Line tools are the **recommended** way of moving data in and out of DesignSafe.

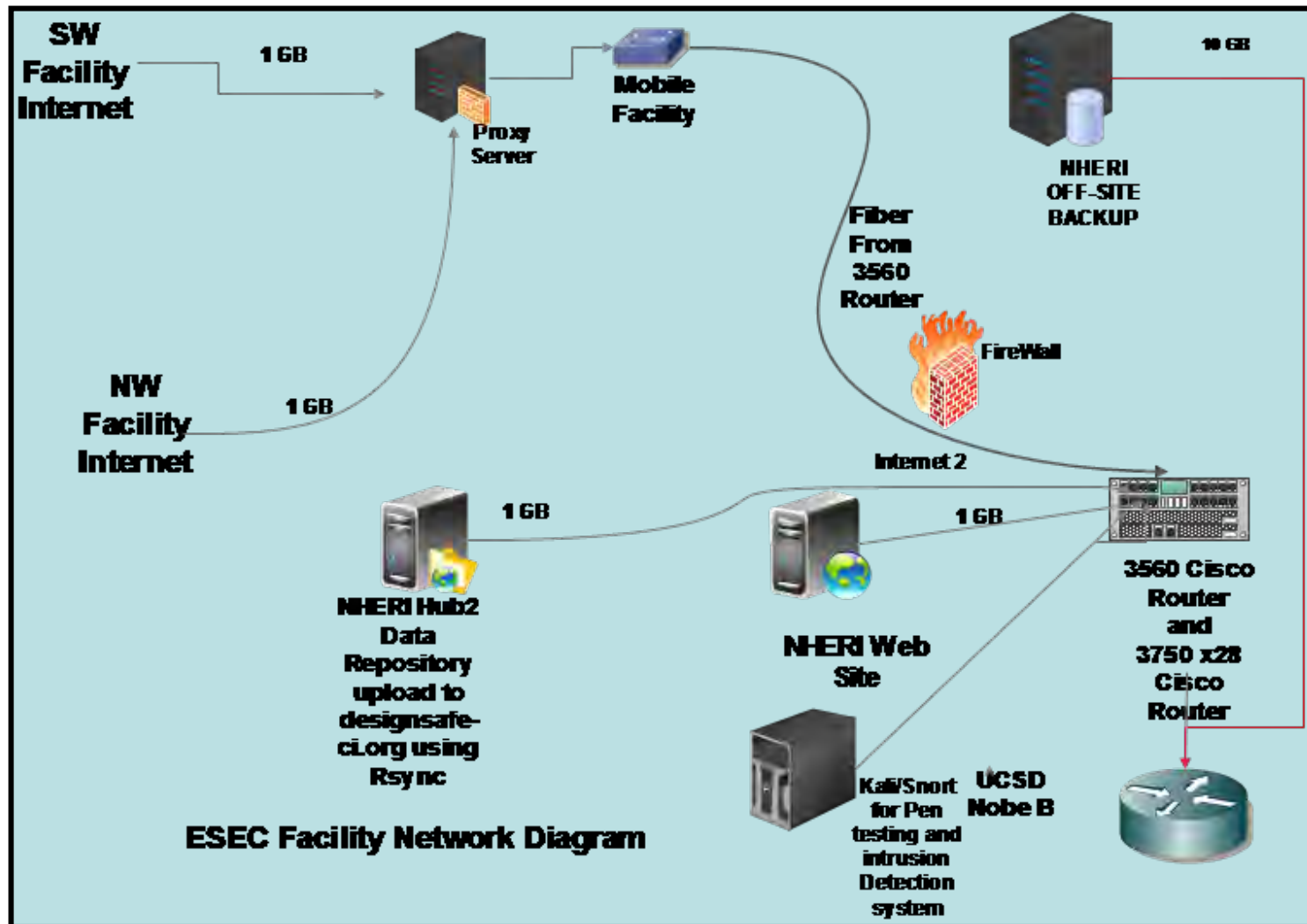
This document details the various methods you can use to import and export your data from DesignSafe.

- Globus bulk data transfer
- Cyberduck
- DRAG AND DROP/ file select from the browser
- Integrating BOX.com
- Integrating DROPBOX.com
- Command-line Utilities

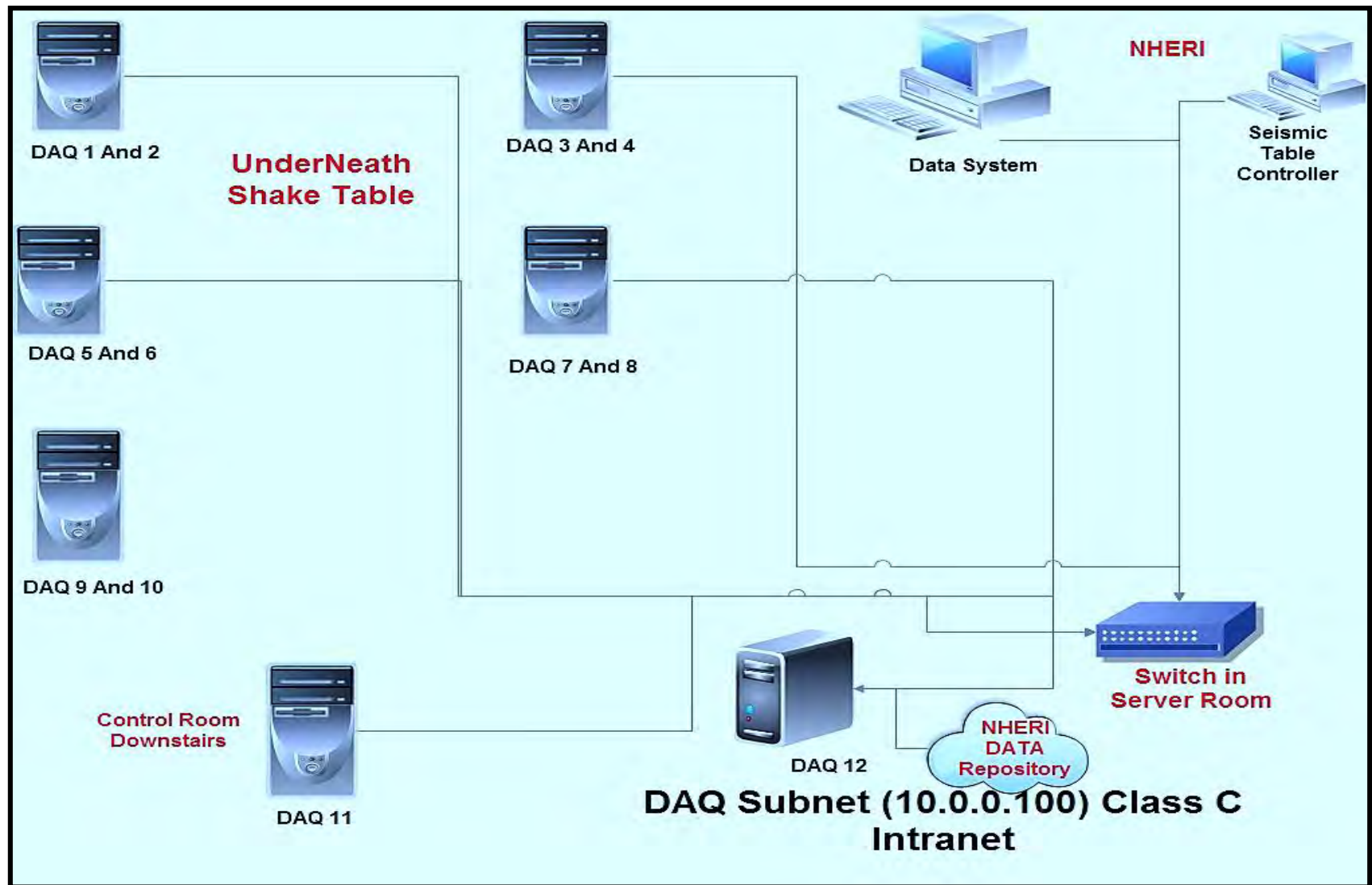
IT Infrastructure

- **The site has two different network systems:**
 - The general site network **visible** to the **outside world**
 - The DAQ and Video intranet **invisible** to **outside world**

General Site IT Network (visible)



DAQ and VIDEO Intranet (**invisible**)



NHERI@UCSD Websites

UC SAN DIEGO
EXPERIMENTAL FACILITY

<http://ucsd.designsafe-ci.org>

DESIGNSAFE-CI
A NATURAL HAZARDS
ENGINEERING COMMUNITY

🏠 Facility Overview Equipment Portfolio Experimental Protocol **Payload Projects** Workshops ▾ **Resources** Contact

FACILITY OVERVIEW

The National Science Foundation sponsored Natural Hazards Engineering Research Infrastructure (NHERI) Experimental Facility at the University of California, San Diego will provide a large, high performance, outdoor shake table (LHPOST) to support research in structural and geotechnical earthquake engineering. Earthquakes have had considerable destructive effects on society in terms of human casualties, property and infrastructure damage, and economic losses. Building a multi-hazard, disaster-resilient, and sustainable environment requires the understanding and ability to predict more reliably the system-level response of buildings, critical facilities, lifelines, and other civil infrastructure systems to these extreme events. This facility will enable research, with extensively instrumented large- or full-scale structural, geotechnical, and soil-foundation-structural systems tested under extreme earthquake loads, to produce the experimental data essential to advancing predictive seismic performance tools. Research experiments performed using LHPOST will provide life-size investigation that will transform the practice of earthquake engineering and educate graduate, undergraduate, and K-12 students, as well as 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.

The LHPOST, with a steel platen that is 12.2 meters long by 7.6 meters wide, has performance characteristics that allow the accurate reproduction of near- and far-field earthquake ground motions. The facility will support seismic testing, under near real-world conditions, of large structural, nonstructural, geotechnical, and geotechnical systems, as well as soil-foundation-structural systems, up to a weight of 20 MN. Two large soil boxes can be used in conjunction with the shake table to investigate the seismic response of soil-foundation-structural systems. Software and hardware are available to support hybrid testing with substructures on the shake table. Systems tested at the facility can utilize extensive data acquisition and instrumentation capabilities, including a broad array of state-of-the-art sensors and high-definition video cameras, to support detailed monitoring, through hundreds of data channels, of the system response. The landmark system-level tests performed using this facility will provide fundamental knowledge and data to support the development, calibration, and validation of high-fidelity, physics-based computational models of structural, geotechnical, and 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. These simulation tools will



NHERI@UCSD Websites

The screenshot shows the NHERI @ UCSD website homepage. At the top, there is a navigation bar with the NHERI logo, the text "NHERI @ UC San Diego", the URL "http://nheri.ucsd.edu" (highlighted in yellow), and a "Site Map" link. Below the navigation bar is a menu with links for "ABOUT US", "FACILITIES", "PROJECTS", "EOT", "RESOURCES" (highlighted in yellow), "LIVE VIDEO", "FOR MEDIA", and "WORKSHOPS" (highlighted in yellow). The main content area features a large image of a multi-story building under construction on a shake table. To the right of this image is a section titled "NHERI @ UC San Diego Large High Performance Outdoor Shake Table" with a sub-headline "The world's first outdoor shake table is also the largest in the U.S." and a "learn more" link. Below this are several menu items: "Live Video", "News & Announcements", "Projects", "Contact Us", and "Site Safety Manual". A red-bordered box contains the text "User material to help plan future test programs" and "See previous training workshop materials at: December 2015, December 2016 and December 2017." Below this is a "Current Project" section with a 3D model of a building and a photograph of the shake table. The 3D model is titled "Collaborative Research: Seismic Resiliency of Repetitively Framed Mid-Rise Cold-Formed Steel Buildings, Phase I: In-line Wall Component Tests" and includes a "Full Size" link. The photograph is titled "Southeast Camera" and includes a "Live Video" link. The text below the photograph describes the need for low-cost, multi-hazard resilient buildings and the benefits of CFS-framed structures.

NHERI @ UC San Diego <http://nheri.ucsd.edu> Site Map

ABOUT US FACILITIES PROJECTS EOT **RESOURCES** LIVE VIDEO FOR MEDIA **WORKSHOPS**

NHERI @ UC San Diego Large High Performance Outdoor Shake Table

The world's first outdoor shake table is also the largest in the U.S. [learn more](#)

- Live Video
- News & Announcements
- Projects
- Contact Us
- Site Safety Manual

Large-Scale Validation of Seismic Performance of Bridge Columns

User material to help plan future test programs

See previous training workshop materials at: [December 2015](#), [December 2016](#) and [December 2017](#).

Current Project

Collaborative Research: Seismic Resiliency of Repetitively Framed Mid-Rise Cold-Formed Steel Buildings, Phase I: In-line Wall Component Tests [Take a Virtual Tour of the Shake Table!](#)

[Full Size](#)

[Live Video](#)

[Southeast Camera](#)

The need for low cost, multi-hazard resilient buildings constructed of sustainable, low-carbon footprint materials is urgent. Mid-rise buildings framed from thin-walled, cold-formed steel (CFS) have the ability to support this urgent need. The potential benefits of CFS-framed structures include low installation and maintenance costs, high durability and ductility, lightweight framing, and use of a non-combustible material. By using framing schemes with closely-spaced vertical members repetitively placed in the walls, CFS buildings develop lateral resistance through sheet, or

NHERI@UCSD

Social Media Presence (Youtube, Twitter, Facebook)

The image is a screenshot of a Twitter post. At the top, the Twitter interface is visible, including the navigation bar with 'Home', 'Moments', 'Notifications', and 'Messages', a search bar, and a 'Tweet' button. The tweet content shows a video player with a grey header containing 'Done', navigation arrows, the URL 'iframe.dacast.com', and icons for refresh, share, and search. The video itself features a blue and yellow NSF logo in the top left corner and a view count of '10' in the top right. The video shows two views of a building under construction, with a blue arc highlighting a specific area. In the bottom right corner of the video frame, the NHERI logo is displayed with the text 'NHERI Natural Hazards Engineering Research Infrastructure'. Below the video, the Twitter engagement bar shows 8 retweets and 22 likes.



Questions?

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Dynamic Test Protocol

NHERI@UCSD vs. Nevada Reno Table

UCSD

1. Tune the bare table with TVC (bare table),
2. Train AIC to get an estimate of the inverse model of the plant (bare table)
3. Apply iteration with OLI at 1.0x (bare table),
4. Use the converged drive file from OLI iterations to perform the actual test (loaded table).

Nevada Reno

1. Tune the bare table with TVC (bare table),
2. Put the specimen on the table,
3. No tuning of 469D with the specimen on the table (loaded table),
4. Measure a model with AIC (loaded table),
5. In OLI, run 0.25x (that's a single motion on the specimen),
6. In OLI, run 0.5x (that's a single motion on the specimen),
7. In OLI, run 0.75x (that's a single motion on the specimen),
8. ... (up until the verge of collapse)