



UC San Diego
JACOBS SCHOOL OF ENGINEERING
Structural Engineering

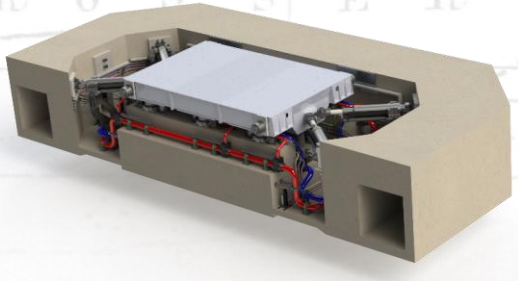
Jupyter Notebooks for Data Workflow using NHERI EF

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DESIGNSAFE-CI
NHERI: NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE



UCLA TACC

RICE

Florida Tech

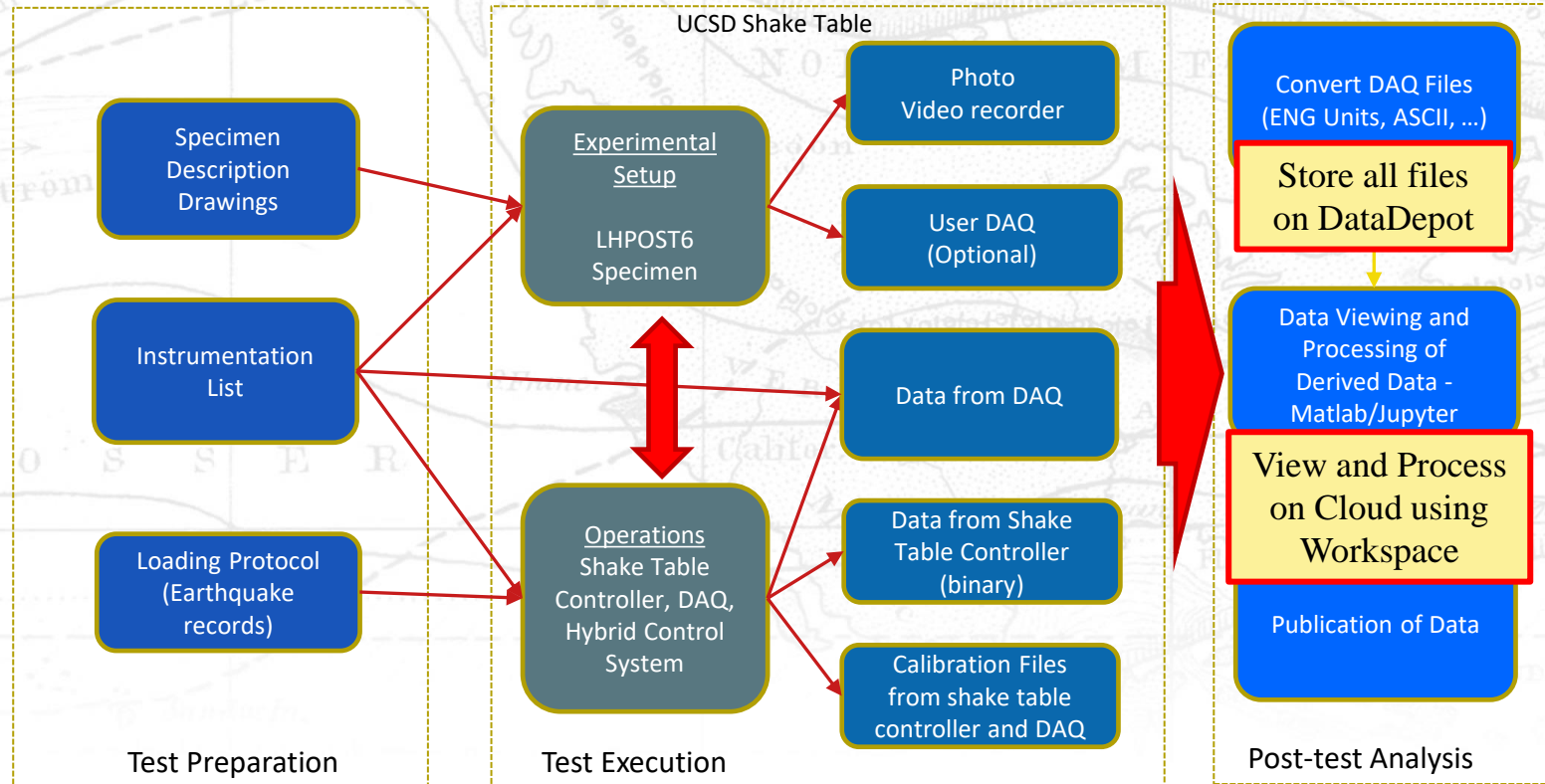
DesignSafe in Experimental Workflow

- Collaborative workspace for project team from planning to publication
- Specimen Preparation
 - Share design, construction, and instrumentation documents
- During Experiments
 - Rapid Visualization and cloud sharing of data and analysis tools
- Post - Experiments
 - Analyze Data on the cloud using HPC
 - Curate and Publish Data with data viewers for easier accessibility
- Published data with DOI for citation tracking

Streamline and enhance these steps with Jupyter Notebooks accessing data on the cloud



Data Workflow – Shake Table



Workspace Tools & Applications

- Cloud-based tools with access to HPC
- Jupyter Notebooks using DataDepot

TOOLS & APPLICATIONS

[Learn About Tools & Applications.](#)



The screenshot shows a web interface with a top navigation bar containing tabs for Simulation, SimCenter Tools, Visualization, Analysis, Hazard Apps, Utilities, and My Apps. Below this, there are three main application cards: HVSrweb (with a large 'H' icon), Jupyter (with the Jupyter logo icon), and MATLAB (with the MATLAB logo icon). The Jupyter card is highlighted in blue. To the left of the Jupyter card is a 'My Data' section with a table listing folders and their sizes.

Name	Size
Trash	4.0 kB
Documentation	4.0 kB
HybridTest	4.0 kB
ImpactData	4.0 kB
Trial01	4.0 kB

The Jupyter card contains the following text:

The Jupyter Notebook is a web application that allows you to create and share documents that contain live code, equations, visualizations and explanatory text. Uses include: data cleaning and transformation, numerical simulation, statistical modeling, machine learning and [much more](#).

Please visit our [help documentation](#) for more information.

[Launch](#)   **jupyterhub**

NOTE: This Jupyter instance will terminate after being idle for 3 days.



NHERI@UCSD Jupyter Notebook Template

- Developed template notebooks to read, visualize and process data from experiments on LHPOST6
- Jupyter Notebooks in DesignSafe can be used to
 - View data following experiments
 - Document experiments with interactive plots
 - Share and view/analyze data on cloud with collaborators
 - Publish notebook with data for accessible visualization tools
- Similar notebooks can be used for all steps
- Published data will be more easily accessible



Jupyter Notebook for LHPOST

- Three Use Case Notebooks
 1. Shake Table Performance using published data from LHPOST
 2. Structural Response and System Identification using published data from NEES
 3. Experiment conducted on LHPOST6 (pending publication of data)
- Code Provided with Step-by-Step Instructions for Use and Adaptation



Published Experiment on LHPOST

- Data used for development

PRJ-1811: NHERI UCSD Hybrid Simulation Commissioning

[Download Dataset](#)

PI	Mosqueda, Gilberto	View Team Members	DOI	doi:10.17603/DS25M42	Citation
Date of Publication	Dec/6/2018		Award	NSF 1520904	
Project Type	Hybrid_simulation		Keywords	hybrid simulation, shake table substructure, seismic isolation	

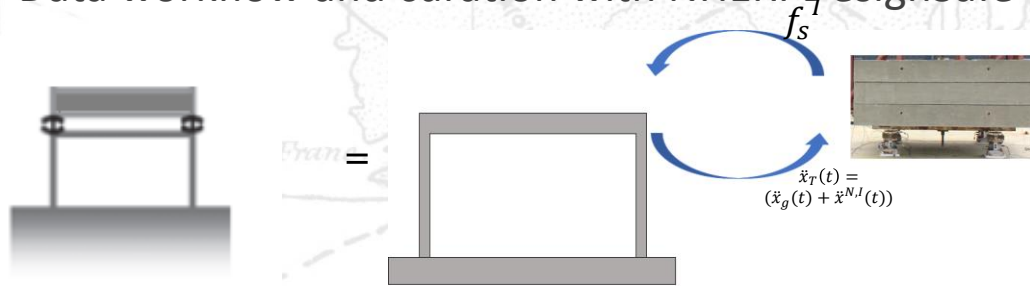
Description

The use of large shake tables can provide extended capabilities to conduct large- and full-scale tests examining the seismic behavior of structural systems that cannot be readily obtained from reduced scale testing, or under pseudo-dynamic conditions. When considering large or complex structural systems, however, additional challenges arise such as high costs of full scale specimens or capacity limitations of currently available shake table. Some of these limitations can be overcome by real-time hybrid shake-table substructure test method that requires only key parts to be evaluated experimentally on the shake table while the remainder of the structure is modeled numerically. As a demonstration of the applicability of this method using a large shake tables, a series of hybrid shake table tests were conducted on the UCSD Large High Performance Outdoor Shake Table (LHPOST) with capabilities to test full scale structural models. A physical specimen was built on the LHPOST, and coupled with a numerical model using hybrid simulation techniques. Comparison of different methods to interface the numerical model with the control systems were evaluated. The physical specimen consisted on a rigid mass resting on four triple friction pendulum bearings that represented the upper story of a shear building model having the effect of a tune mass damper. Numerical models of shear buildings with different periods and multiple degree of freedom were considered to evaluate the performance of the table and stability and accuracy of the simulation results. The teste results demonstrate the effectiveness of tune mass dampers in reducing structural response and the benefit of using a hybrid shake table test method towards expanded system level dynamic testing. The performance of the shake table is evaluated and methods to compensate delay and other sources of error are discussed.



Published Experiment on LHPOST

- Hybrid Simulation Commissioning Tests using LHPOST
 - Collaborative development effort with NHERI SimCenter
 - Data workflow and curation with NHERI DesignSafe



$$M^N \ddot{x}(t) + C^N \dot{x}(t) + K^N x(t) = -M^N L \ddot{x}_g(t) + f_s^I$$

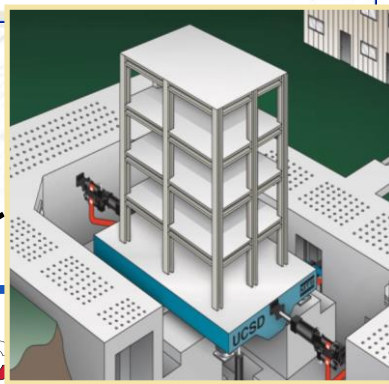
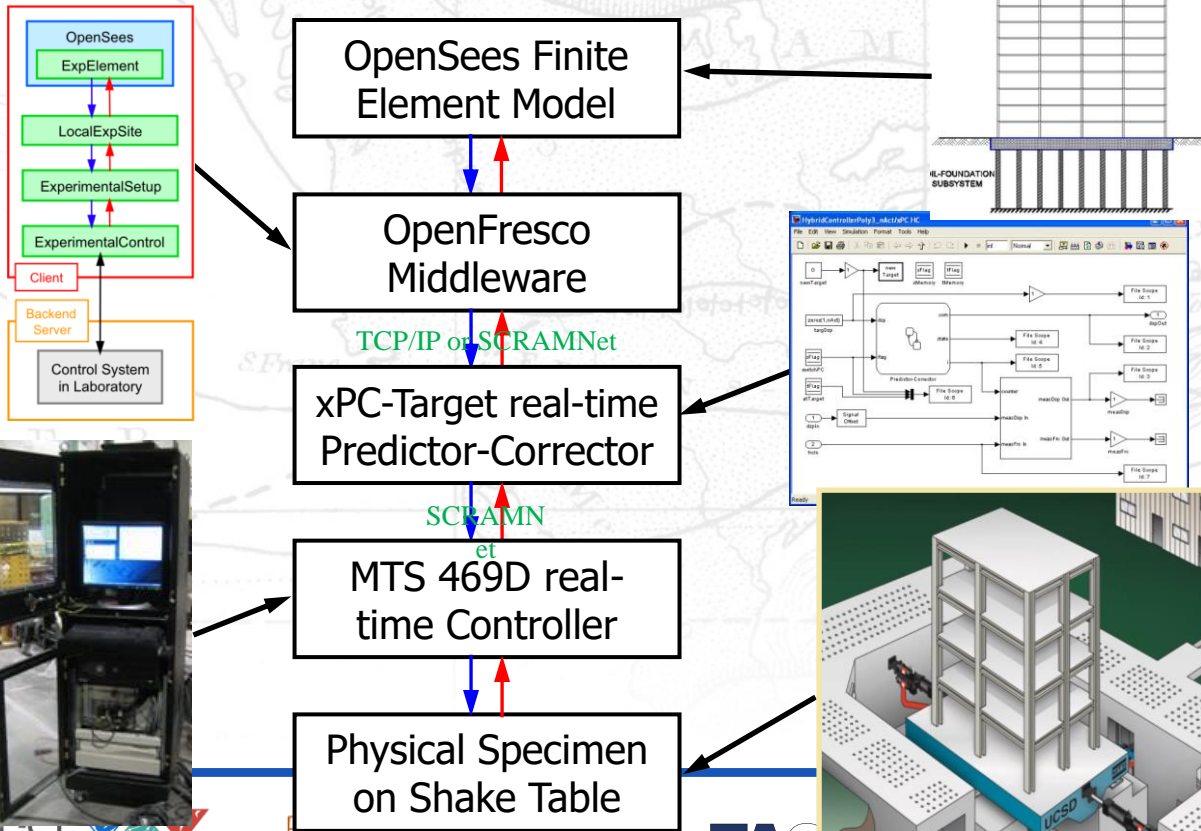
$$M^E \ddot{x}(t) + C^E \dot{x}(t) + K^E x(t) = -M^E L \ddot{x}_T = -M^E L (\ddot{x}_g(t) + \ddot{x}^{N,I}(t))$$

where f_s^I only affects the interface DOF


Assuming no mass in the interface of the experimental
















Published Experiment on LHPOST



Jupyter Notebook Example

Jupyter Project_LHPOST Last Checkpoint: Last Saturday at 3:47 PM (autosaved)  Logout Control Panel

File Edit View Insert Cell Kernel Widgets Help Trusted Python 3

            Code 

[Click here to show/hide the code](#)

[Cite](#)

Implementation of real-time hybrid shake table testing method in the UCSD large high performance outdoor shake table (LHPOST)

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SUMMARY

The use of large shake tables is needed to be able to conduct large- and full-scale testing to study structural seismic behavior issues that cannot readily be obtained from testing at smaller scale, or under pseudo-dynamic conditions. However, additional issues arise such as high costs of full scale specimens or capacity limitations of a shake table. These limitations can be alternatively overcome by a real-time hybrid shake table test method. As a demonstration of the applicability of this method in large shake tables, a hybrid shake table test was conducted. A physical specimen was built in LHPOST, and coupled with a numerical model using hybrid simulation techniques. Comparison of different methods to interface the numerical model with the control systems is discussed. The physical specimen consisted on a concentrated mass resting on four triple friction pendulum bearings. This physical substructure behaved as a tune mass damper when coupled with a shear building model. Shear buildings with different periods in some cases are used to represent the building below the tune mass damper. A multiple degree of freedom numerical model was also implemented to see how this hybrid shake table method performs under higher modes. Successful results confirm the effectiveness of tune mass dampers and the benefit of using a hybrid shake table test method. This test also shows the advantages of using midlevel isolation to retrofit existing

1. INTRODUCTION

Real-time hybrid simulation (RTHS) is an attractive alternative method to evaluate the response of structures under earthquake loads. A hybrid model consists on numerical and experimental substructures. Generally, the experimental substructure should represent the part in the domain of the structure that is difficult to model analytically. Real-time simulations allow to test rate-dependent structures (i.e. base isolation bearings) as part of the experimental substructure of the hybrid model. Lately, this method has also been applied to extend the use of traditional shake table testing. In-raschi



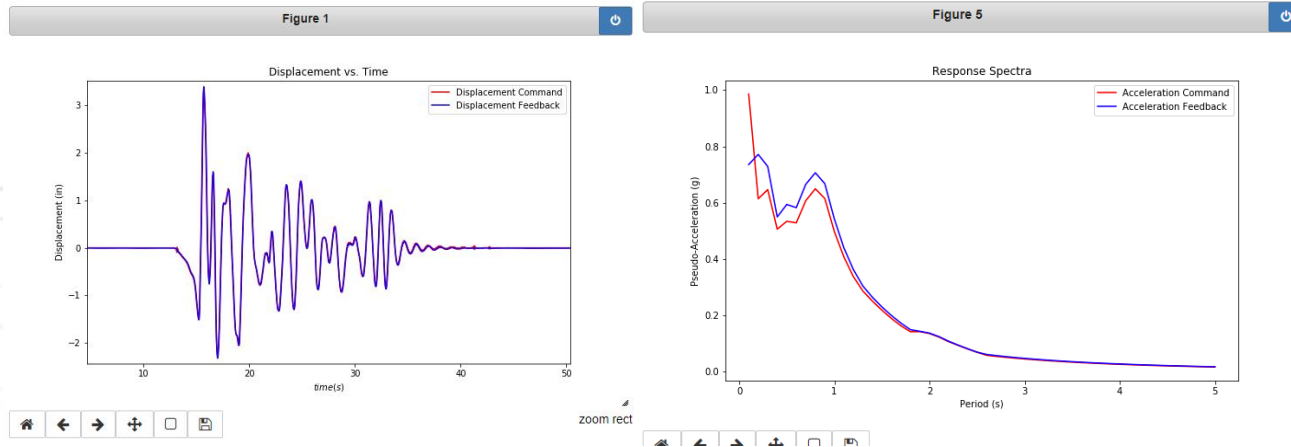
DESIGN
NHRI: NATURAL HAZARDS

orida Tech

Jupyter Notebook Example

Use Case 1: Shake Table Response

- View any channel or processed data
 - Time history, response spectra, frequency content
- View shake table signal performance



Jupyter Notebook Example

Use Case 2: System ID



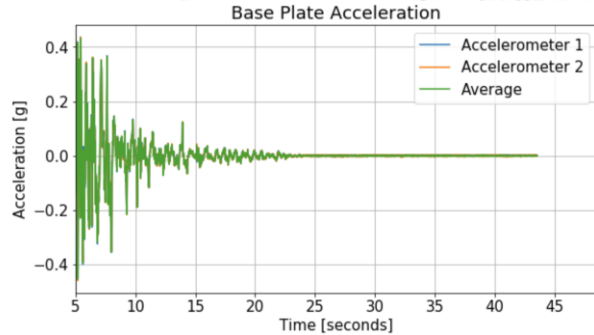
(Masroor and Mosqueda 2013)

- NEES Project
- Plot structural response
 - Floor accelerations and displacements
- Analyze data including system identification
 - Approximate system modal properties (period, mode shapes, damping ratio)
 - Toggle through progressive tests to see how nonlinear deformation changes system properties

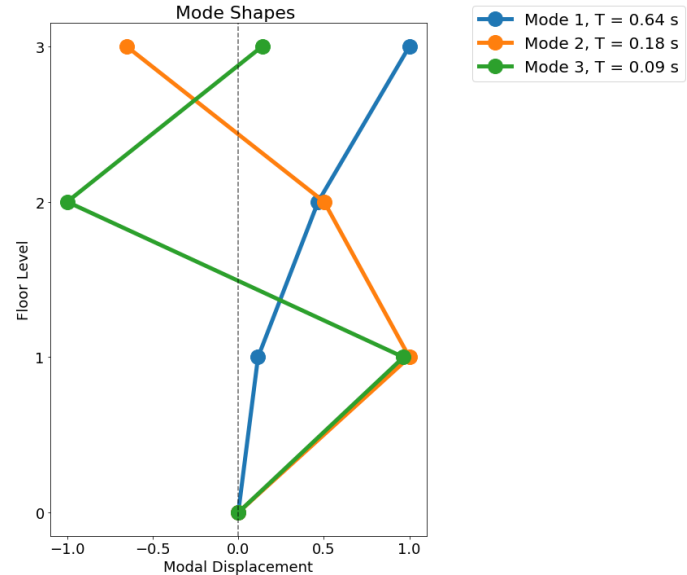


Jupyter Notebook Example

Use Case 2: System ID



Mode #	Damping Ratio [%]
1	5.233
2	1.849
3	1.369



Jupyter Notebook Example

Use Case 3: Test on LHPOST6

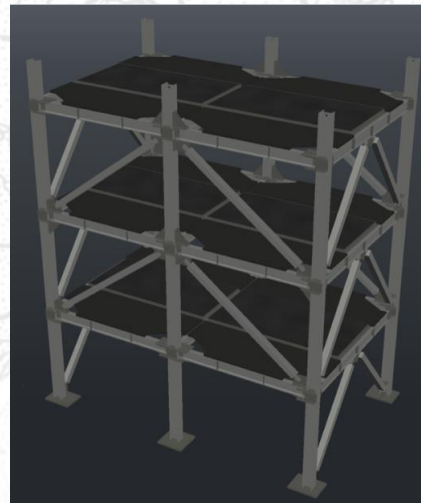
- Shared-use Modular Test Bed Building MTB²



SMF



BRB-1



BRB-2

Nheri@UC San Diego



Jupyter Notebook Use Case 3

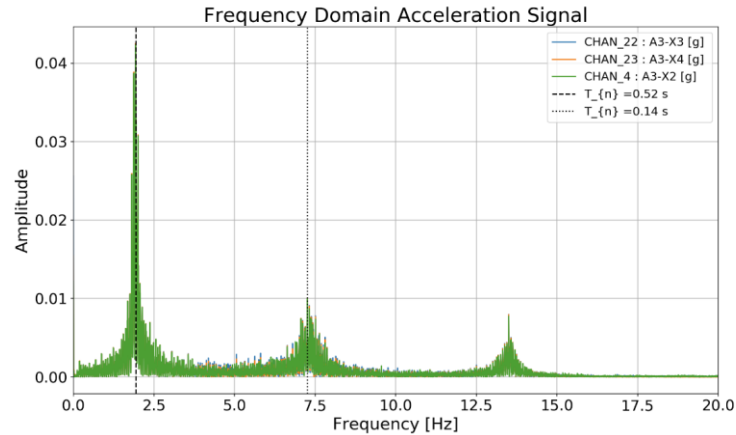
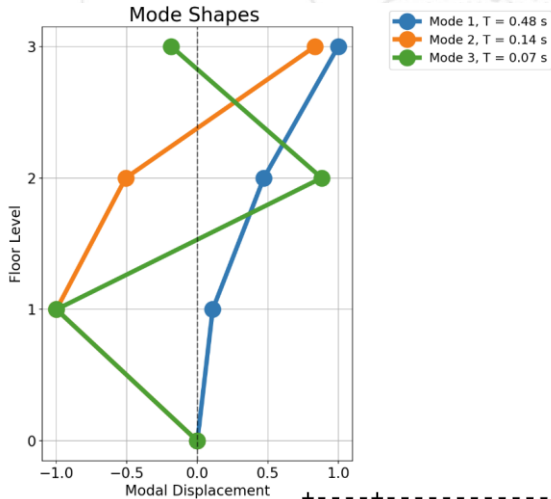
Test on LHPOST6

- Application of System ID with LHPOST6 with building subjected to 3D shaking
- View structural response
 - Floor accelerations and displacements
- Data analysis including system identification
 - Approximate system modal properties (period, mode shapes, damping ratio)
 - Comparison for damage assessment or different configurations
 -



Jupyter Notebook Use Case 3

Test on LHPOST6

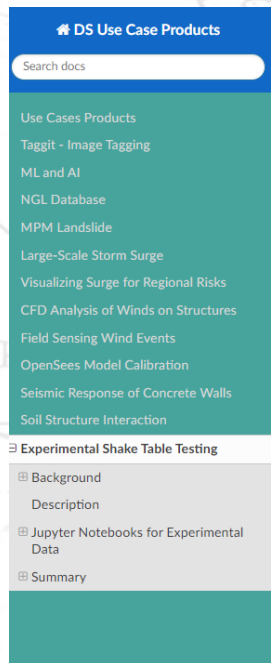


	Theoretical [s]	Experimental [s]	Difference [%]
T1	0.458	0.482	5.2
T2	0.195	0.1399	28.2
T3	0.098	0.0746	23.8



Jupyter Notebook Use Case Examples

- More information and links available at
 - DesignSafe->Worksspace->Use Case Products



DS Use Case Products

Search docs

- Use Cases Products
- Taggit - Image Tagging
- ML and AI
- NGL Database
- MPM Landslide
- Large-Scale Storm Surge
- Visualizing Surge for Regional Risks
- CFD Analysis of Winds on Structures
- Field Sensing Wind Events
- OpenSees Model Calibration
- Seismic Response of Concrete Walls
- Soil Structure Interaction

Experimental Shake Table Testing

- Background
- Description
- Jupyter Notebooks for Experimental Data
- Summary

Docs » Experimental Shake Table Testing

INTEGRATED WORKFLOW OF EXPERIMENTS USING JUPYTER NOTEBOOKS: FROM EXPERIMENTAL DESIGN TO PUBLICATION

Enrique Simbort and Gilberto Mosqueda - University of California, San Diego

Jupyter Notebooks can provide fully integrated workflows of experiments from documentation of experimental design through analysis and publishing of data using the DesignSafe cyberinfrastructure. A series of Notebooks are being developed to demonstrate their use in the experimental workflow including notebooks showing how to view and analyzed past published data and data from testing of a reconfigurable, modular test bed building planned to be tested on the NHERI@UC San Diego Experimental Facility. The Python-based code is implemented in a modular fashion so that components can be used as desired in other experiments and are transferable to other experimental facilities. In the examples provided, the Notebook can be used to evaluate shake table performance as well as dynamic properties of the structure. A key functionality is to increase the integration and collaboration between researchers at local or remote sites to view and analyze the experimental data during and after testing including after the data is published. As Notebooks are developed to view experimental data by the research team, they can also be published with the data allowing other researchers to quickly view the data for promoting data reuse. Examples are providing for viewing data from past shake table experiments including NEES and more current NHERI data repositories. The example makes use of the following DesignSafe resources:



Jupyter Notebook Use Case Examples

- Available resources accessing published data

DATA DEPOT

+ Add

My Data

My Projects

Shared with Me

Box.com

Dropbox.com

Google Drive

Published

Published (NEES)

Community Data

Help ▾

Find in Community Data



Rename

Move

Copy

Preview

Preview Images

Download

Move to Trash

Community Data / Use Case Products / Shake Table Experimental Data

<input checked="" type="checkbox"/> Name	Size	Last modified
<input type="checkbox"/> Case 1. Shake table performance.ipynb	60.1 kB	5/22/22 12:28 PM
<input type="checkbox"/> Case 2. Module for Structural Response and System Identification.ipynb	527.2 kB	5/22/22 12:28 PM

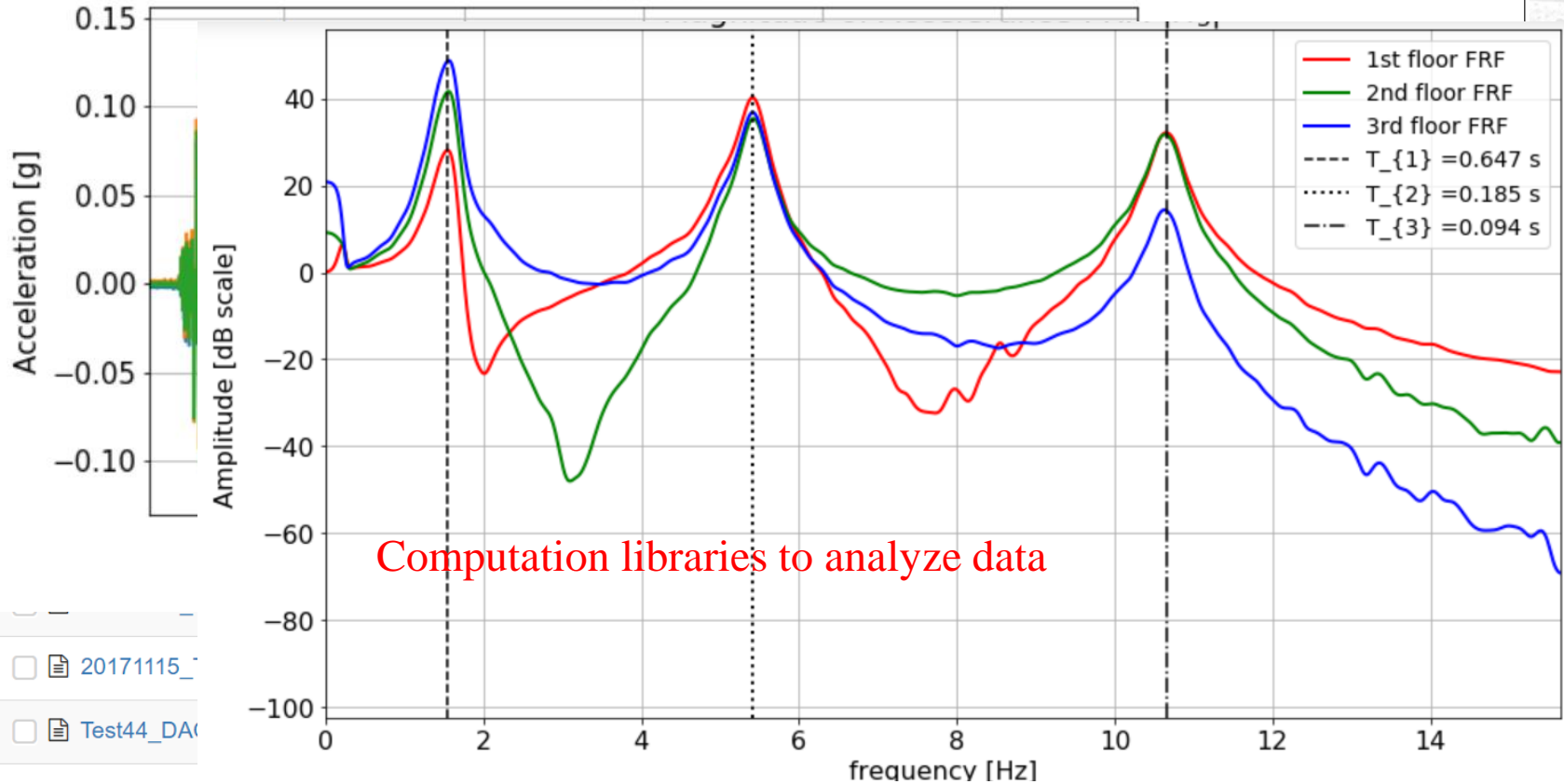
CASE 3 under development – publishing of data



In short.... Jupyter Notebooks can make data readily accessible

Interact with and plot data...

Level 3



Computation libraries to analyze data

20171115_

Test44_DA

Future Work

- Publish Use Case 3 on MTB² with data set
- Applications for cross test analysis
 - Examine and compare two different tests
 - Track changes in dynamic properties
- New Notebooks for Application of AI algorithms
 - Step-by-step process of regression analysis using multiple machine learning algorithms using shake table data



DesignSafe: We are here for you!

Available to the Global Natural Hazards Research Community

- Interact with us and the community using the DesignSafe Slack team
- Attend Curation Office Hours
- Cite data using DOIs in your reference list
- Cite DesignSafe marker paper if you use DesignSafe in your research



Please share your feedback, ideas, experiences!

Ellen Rathje e.rathje@mail.utexas.edu

Gilberto Mosqueda gmosqueda@ucsd.edu



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