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A NATURAL HAZARDS ENGINEERING COMMUNITY

University of California at San Diego
NHERI
Natural Hazards Engineering Research Infrastructure

Jupyter Notebooks for Data Workflow at NHERI@UCSD

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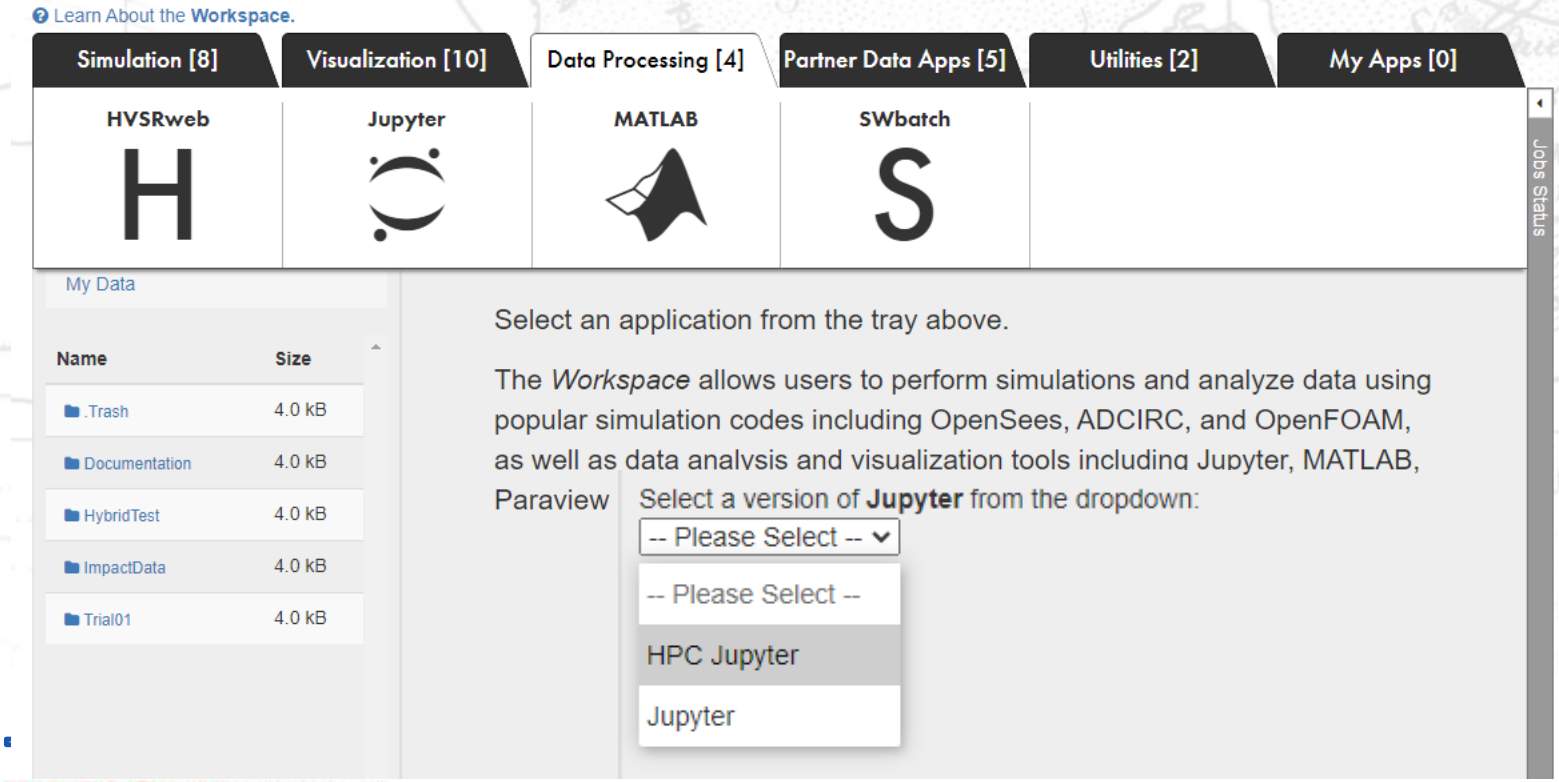
Discovery Workspace

- Cloud-based tools and HPC enabled codes
- Jupyter Notebooks with access to DataDepot



DesignSafe with NHERI EF Workflow

- **Project team collaborative workspace from planning to publication using DesignSafe**
- Specimen Preparation
  - Share design, construction, and instrumentation documents
- During Experiments
  - Rapid Visualization and cloud sharing of data and ana
- 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

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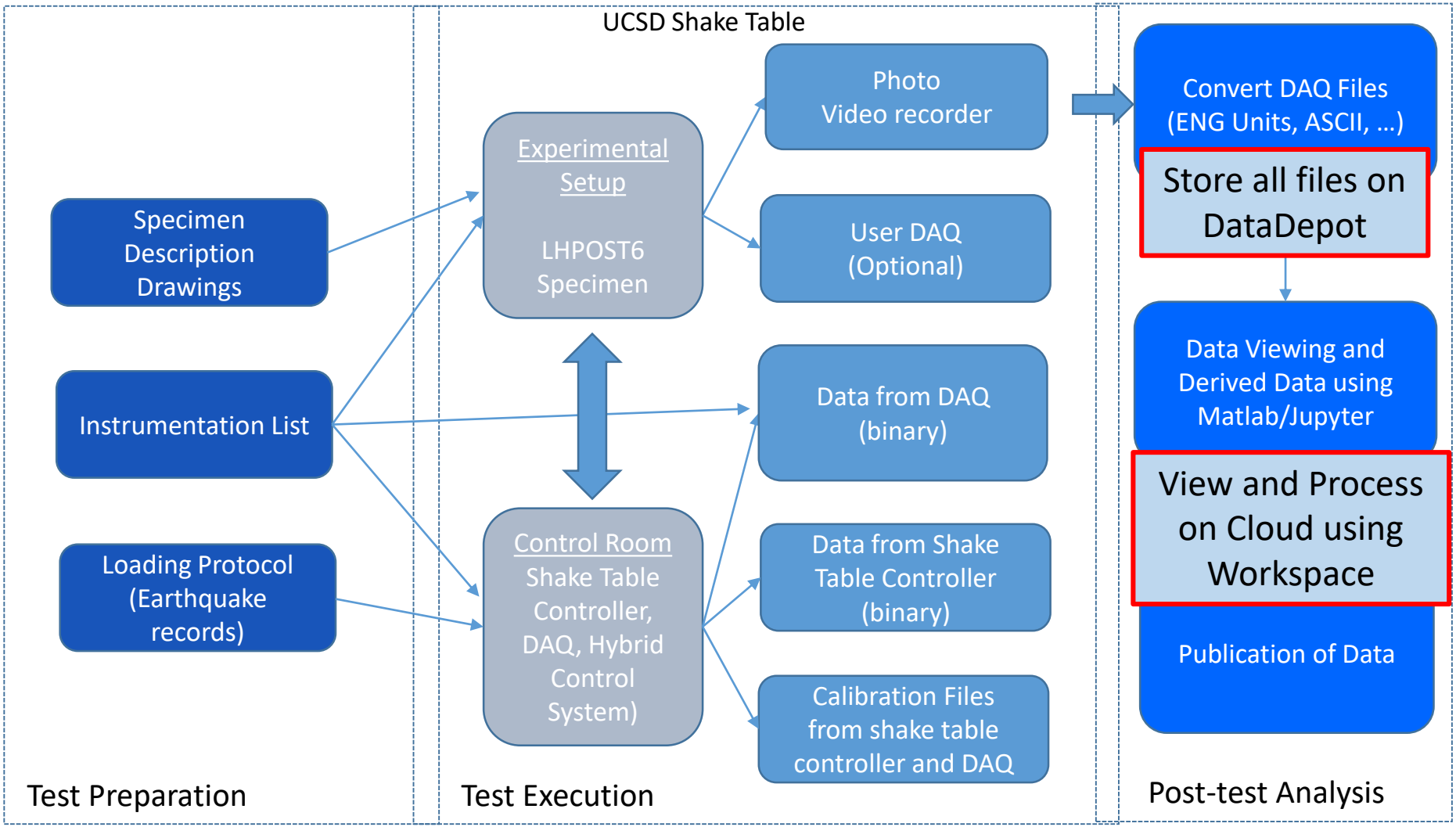
Data Workflow – Shake Table



NHERI@UCSD Jupyter Notebook Template

- Develop template notebooks to read, visualize and process data from experiments on LHPOST6
- Jupyter Notebooks in DesignSafe can be used to
  - View data following experiments
  - Share and view data on cloud with remote collaborators
  - Publish with data for accessible visualization tools
  - Data can be accessed in all these steps from DataDepot
- Similar notebooks can be used for all steps
- Published data will be more easily accessible

Past 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.

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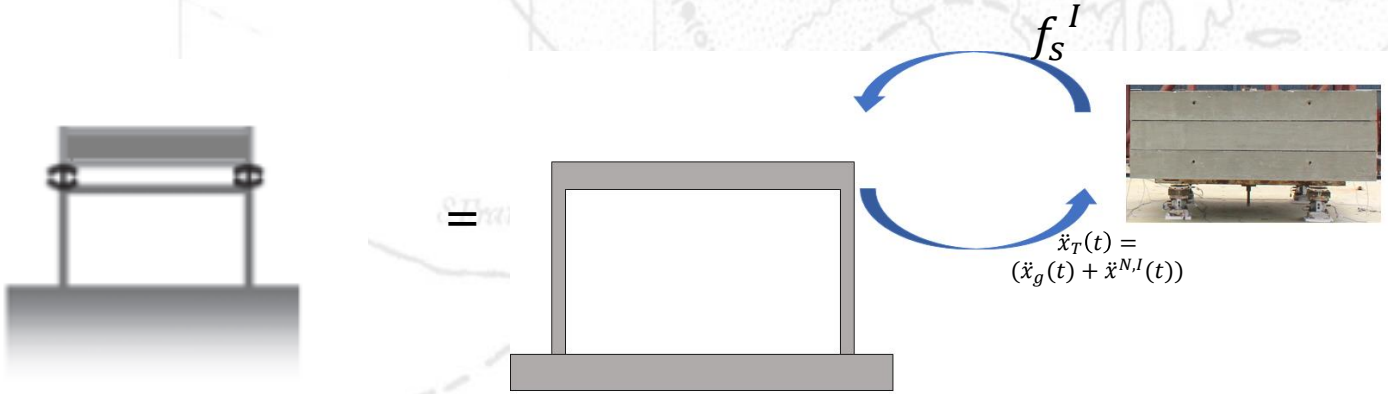
Past Experiment on LHPOST

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



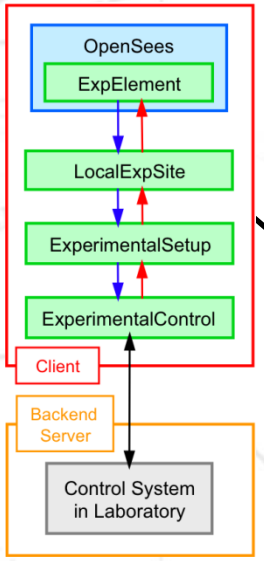
$$M^N\ddot{x}(t) + C^N C\dot{x}(t) + K^N x(t) = -M^N L\ddot{x}_g(t) + f_s^I$$

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

where f_s^I only affects the interface DOF

Assuming no mass in the interface of the experimental

Past Experiment on LHPOST



OpenSees Finite Element Model

OpenFresco Middleware

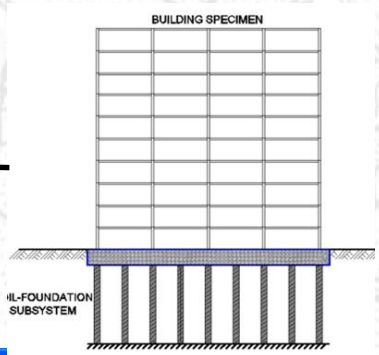
TCP/IP or SCRAMNet

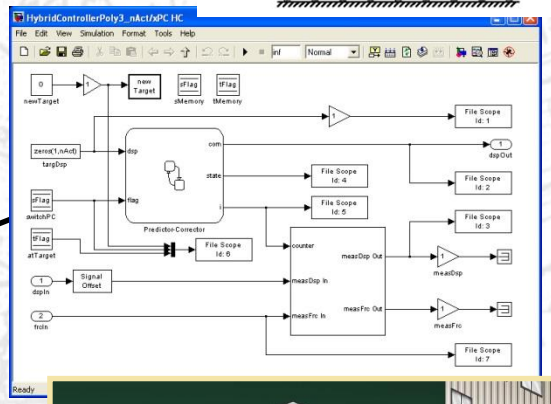
xPC-Target real-time Predictor-Corrector

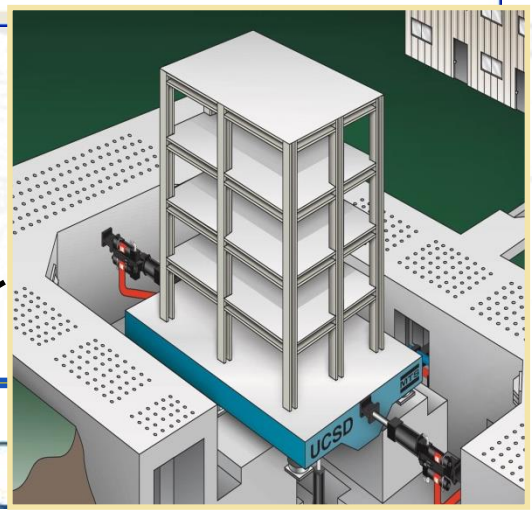
SCRAMNet

MTS 469D real-time Controller

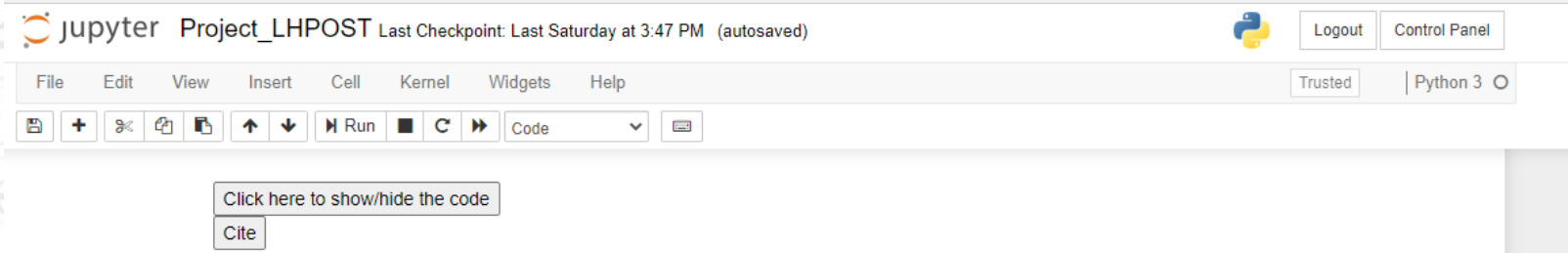
Physical Specimen on Shake Table







Jupyter Notebook for LHPOST



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

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SUMMARY

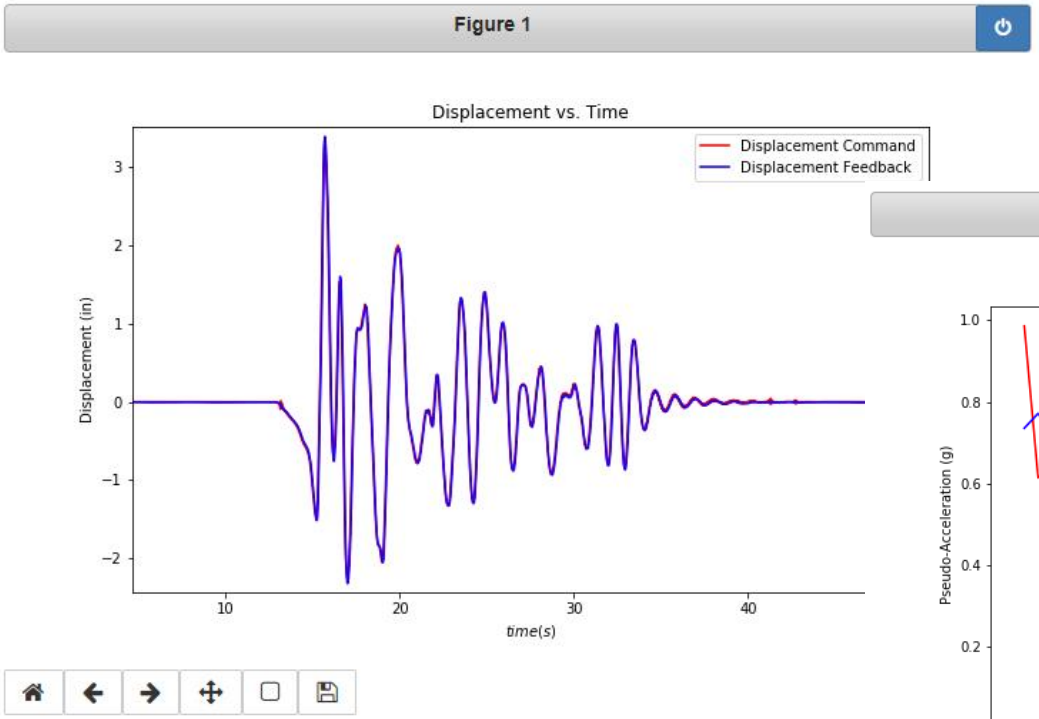
The use of large shake tables is needed to be able to conduct large- and full-scale testing to study structural seismic behavior issues that cannot readily be obtained from testing at smaller scale, or under pseudo-dynamic conditions. However, additional issues arise such as high costs of full scale 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

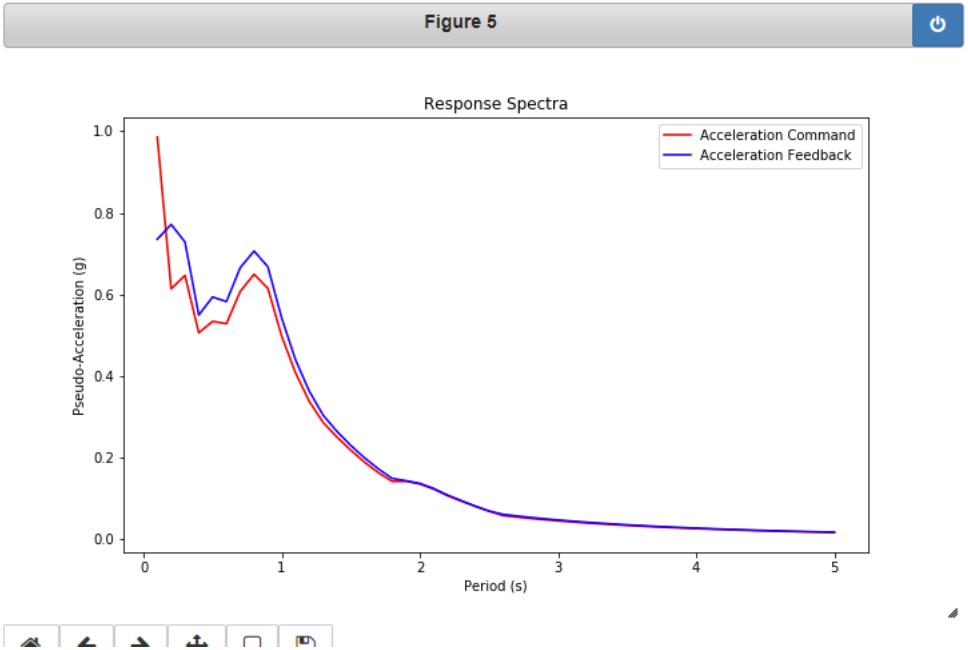
1. INTRODUCTION

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 ratedependent structures (i.e. base isolation bearings) as part of the

Jupyter Notebook for LHPOST

- View any channel or processed data
  - Performance of shake table





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NHERI@UCSD Jupyter Notebook Development

- Implement and fully integrate in workflow with upcoming experiments
  - Reconfigurable testbed structure
  - First experiment as part of shakedown for upgraded LHPOST6
- Capability to integrate Machine Learning and other tools that can be included in Jupyter notebook
- Published data will be more easily accessible

DesignSafe: Resources

Available to the Global Natural Hazards Research Community

- Get Started using Resources available in DesignSafe Learning Center
- Sample Jupyter notebooks available in Community Data
  - Published Notebooks available to view data from UC Davis Centrifuge EF (Scott Brandenberg, UCLA)
- All webinars archived at DesignSafe YouTube channel
  - "Leveraging Python, Jupyter Notebook, DesignSafe & SimCenter" Webinar Oct 29, 2020
  - "What's New in DesignSafe?" Webinar, Sept 12, 2020
  - "Publishing with the Hybrid Simulation Data Model", Aug 29, 2020

slack

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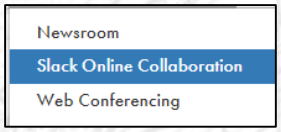
DesignSafe: We are here for you!

Available to the Global Natural Hazards Research Community

- Interact with us and the community using the DesignSafe Slack team
- Cite data using DOIs in your reference list!
- Cite DesignSafe marker paper (Rathje et al. 2017, *Natural Hazards Review*) if you use DesignSafe in your research



Ellen Rathje e.rathje@mail.utexas.edu

Please share your feedback, ideas, experiences!

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