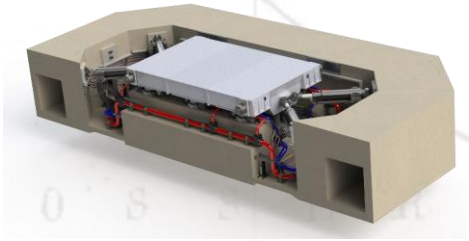
DESIGNSAFE-CI
A NATURAL HAZARDS ENGINEERING COMMUNITY

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

# Jupyter Notebooks for Data Workflow at NHERI@UCSD




Gilberto Mosqueda, Professor

*Department of Structural Engineering*
*University of California, San Diego*


DESIGNSAFE-CI A NATURAL HAZARDS ENGINEERING COMMUNITY
TEXAS The University of Texas at Austin
TACC RICE Florida Tech

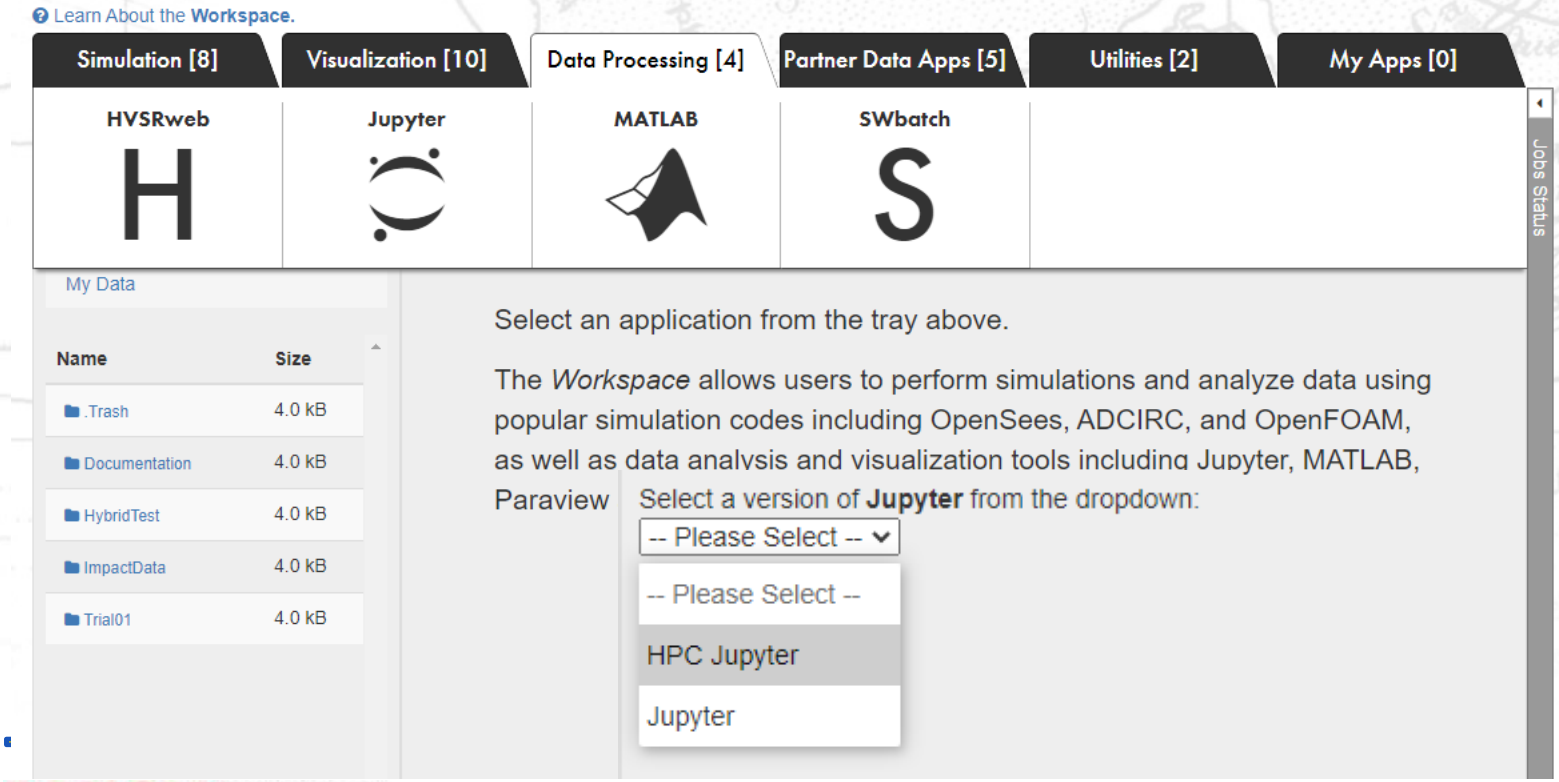
# Acknowledgements


- Students Contributing to Coding
  - Sydney Huynh, Former Graduate Student
  - Natalia Guerrero, Graduate Student
  - Zane Schemmer, REU Summer 2021
  - Enrique Simbort, Graduate Student
- Modular Testbed Building Project Presentation Tomorrow
  - Tara Hutchinson, Mike Morano, Louis Lin, UC San Diego
  - Chris Pantelides, Junwei Liu, University of Utah


DESIGNSAFE-CI A NATURAL HAZARDS ENGINEERING COMMUNITY | TEXAS The University of Texas at Austin | TACC | RICE | Florida Tech

# Discovery Workspace

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



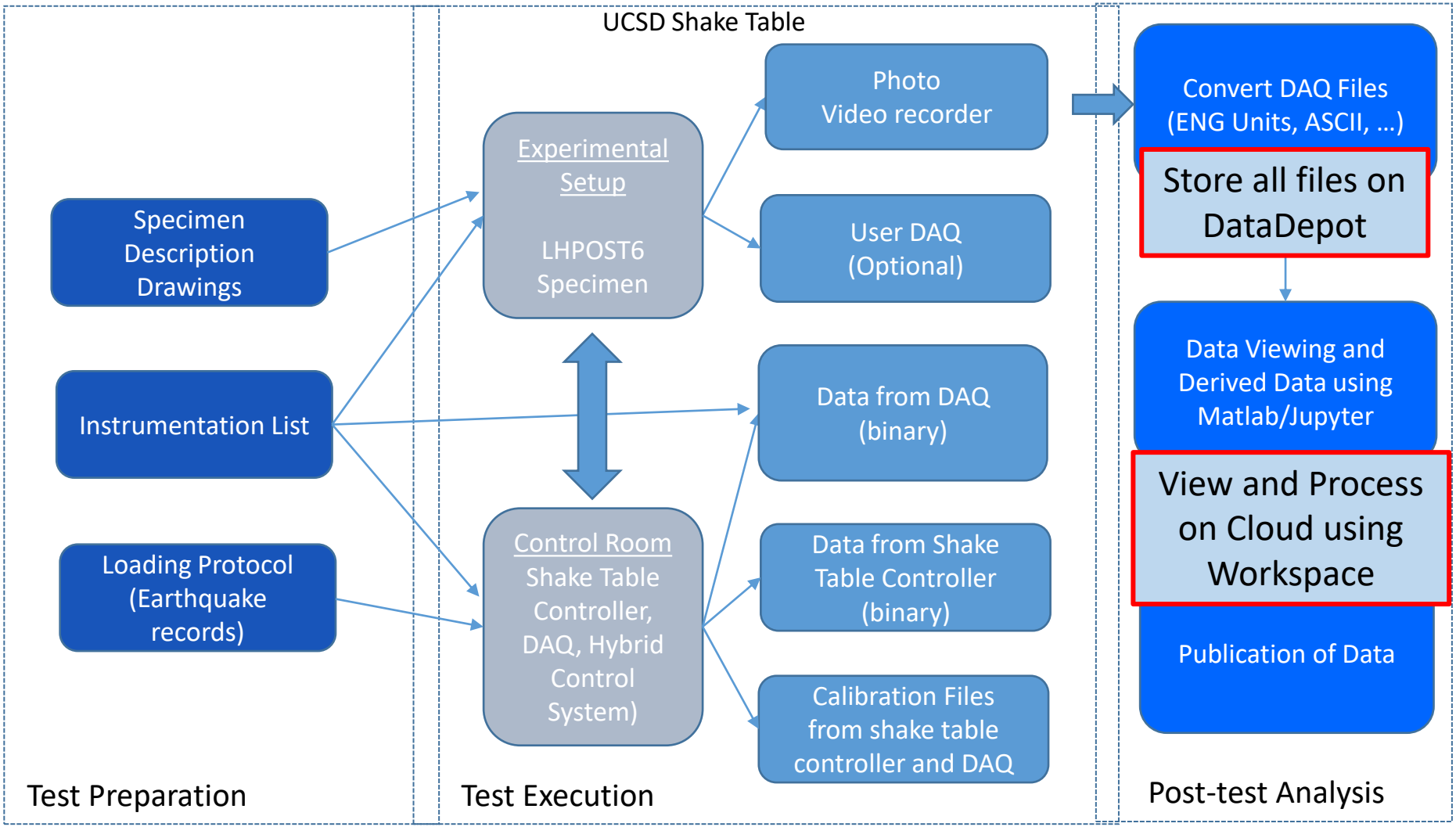
# DesignSafe with NHERI EF Workflow

- **Develop exemplary 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 workflow with Jupyter Notebooks accessing data on the cloud

DESIGNSAFE-CI A NATURAL HAZARDS ENGINEERING COMMUNITY | TEXAS The University of Texas at Austin | TACC | RICE | Florida Tech

# 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
- Same/Similar notebooks can be used for all steps
- Published data will be more easily accessible without having to download

# 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.

DESIGNSAFE-CI A NATURAL HAZARDS ENGINEERING COMMUNITY · TEXAS The University of Texas at Austin · TACC · RICE · Florida Tech

# Jupyter Notebook implemented for Hybrid Test on LHPOST

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

Run | 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)

Manuel A. Vega[1], Andreas H. Schellenberg[2], Humberto Caudana[1] and Gilberto Mosqueda[1]

[1]*Department of Structural Engineering, University of California, San Diego, CA, U.S.A.*

[2]*Department of Civil and Environmental Engineering, University of California, Berkeley, CA, USA*

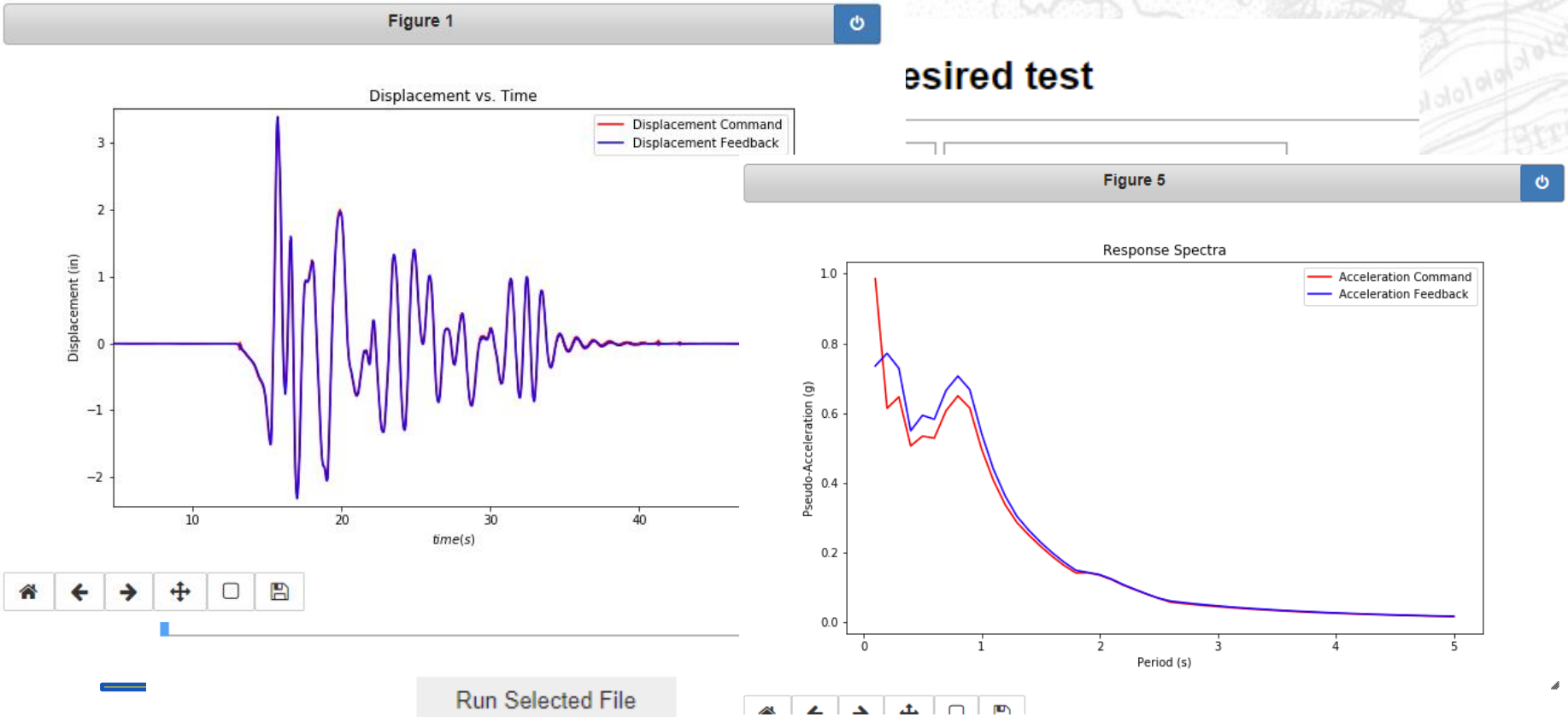
### SUMMARY

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

# Jupyter Notebook for LHPOST

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




DESIGNSAFE-CI A NATURAL HAZARDS ENGINEERING COMMUNITY

TEXAS The University of Texas at Austin

TACC RICE Florida Tech

# Jupyter Notebook Use Case

- Implement and fully integrate in workflow with upcoming Experiment: Modular Testbed Building (More Tomorrow)
  - Analysis of shake table performance
  - Analysis of structural models (System ID)
    - Explore Python libraries for System ID
    - Develop Faster Code (e.g., Cython)
    - Track performance of structure through test series
  - Simplify data upload to DesignSafe

- Work with DesignSafe team to have exemplary curated data easily explorable using Jupyter notebooks
  - Develop documentation within notebook using modular approach

# Jupyter Notebook for LHPOST

- Module: System Identification of Structural Model

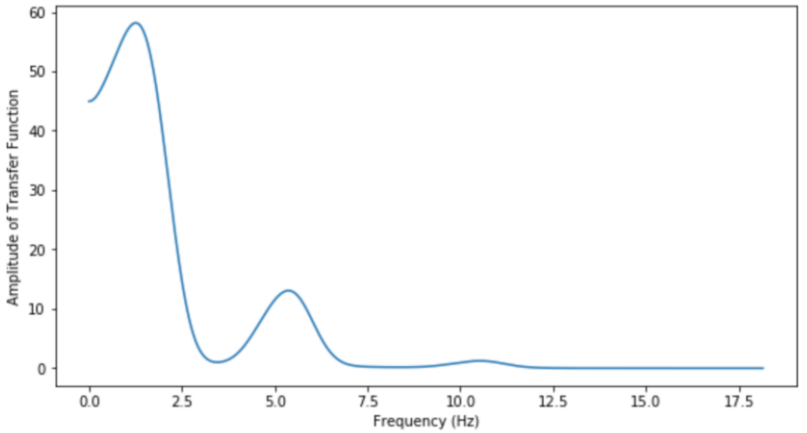



Fig. 13. Transfer function amplitude versus frequency for the third story of the trial building.

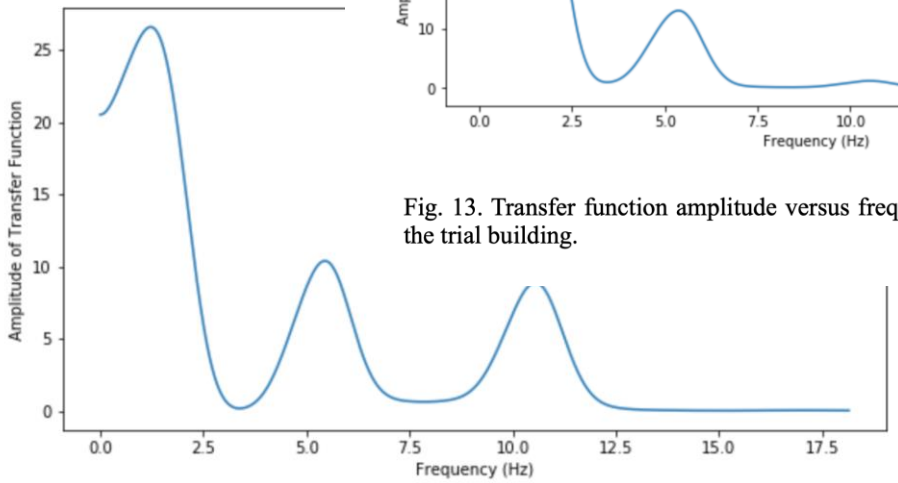



Fig. 14. Transfer function amplitude versus frequency for the second story of the trial building.

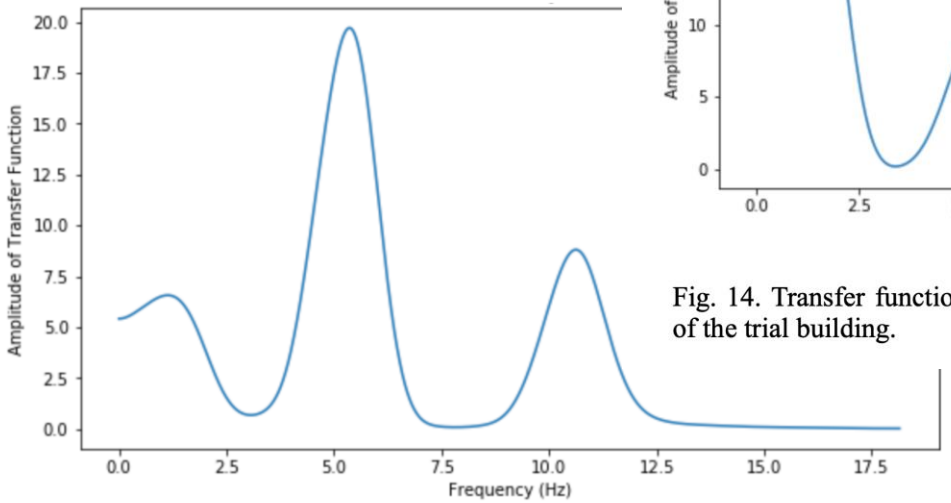
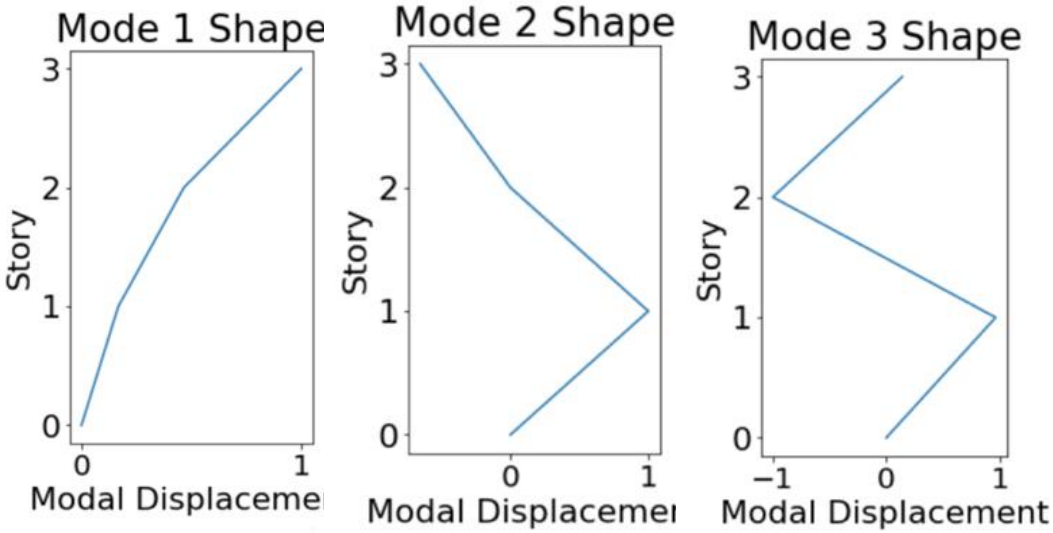


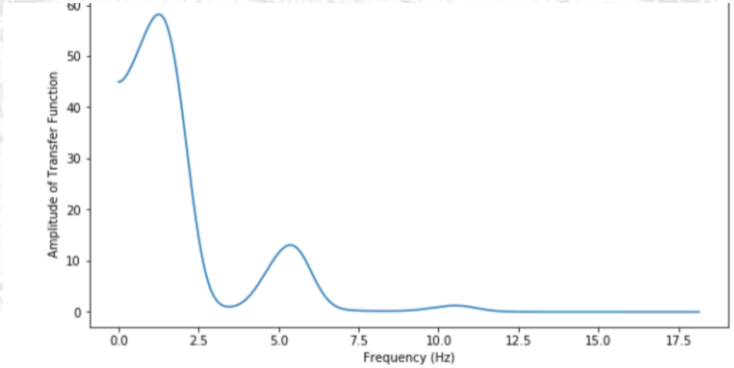

Fig. 15. Transfer function amplitude versus frequency for the first story of the trial building.

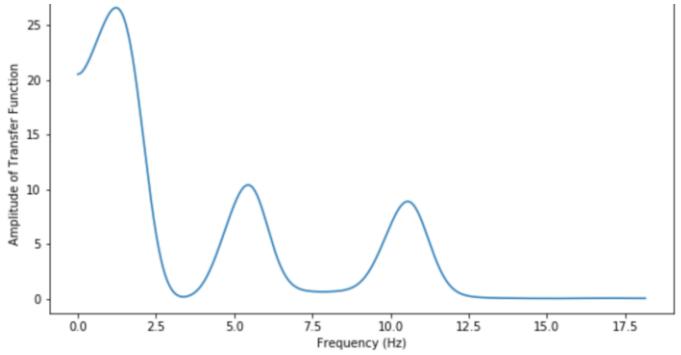
ACC RICE Florida Tech

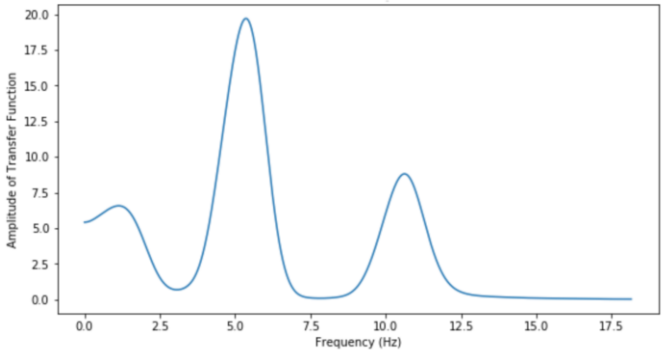
# Jupyter Notebook for LHPOST

- Module: System Identification of Structural Model




DESIGNSAFE-CI A NATURAL HAZARDS ENGINEERING COMMUNITY

TEXAS The University of Texas at Austin

TACC

RICE

Florida Tech

# Advantages of Jupyter Notebook

- Explore data on the cloud – no downloading
- Applications for cross test analysis
  - Utilize published data from past test to examine and compare performance of table across different payloads
  - Evaluate performance of structure as test progresses – automate damage detection
- Wide set of libraries available to explore
- Visualization tools and animations

# Thank you for your attention!