# User Experience

## *NHERI Lehigh Researcher Workshop*

June 6, 2025

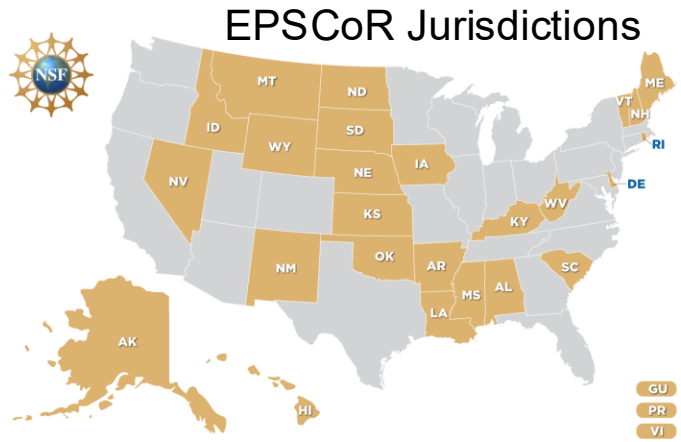
P. Scott HARVEY Jr., Ph.D., P.E., S.E.(OK)

*Associate Professor, University of Oklahoma*

GALLOGLY COLLEGE OF ENGINEERING
SCHOOL OF CIVIL ENGINEERING AND ENVIRONMENTAL SCIENCE
*The* UNIVERSITY *of* OKLAHOMA

# PROPOSAL WRITING & PLANNING

# Proposal Timeline




**Nov. 2015**
Met Dr. Ricles at NSF-sponsored workshop in Japan

**Dec. 5-6, 2016**
Attended NHERI Lehigh Research Workshop

**Jan. 2018**
Submitted internal proposal; *selected!*

**Dec. 2019**
Project Funded!

2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021

**Award Period 12/2019 – 11/2022***

**Nov. 2016**
Internal (OU) competition for NSF EPSCoR Track-4 program announced; contacted Dr. Ricles

**March 2018**
Submitted proposal to NSF w/ input from Drs. Ricles and Kusko; proposal not funded

**March 2019**
Re-competed internally, selected, and submitted revised proposal with feedback

**Dec. 2016**
Submitted internal proposal; not selected

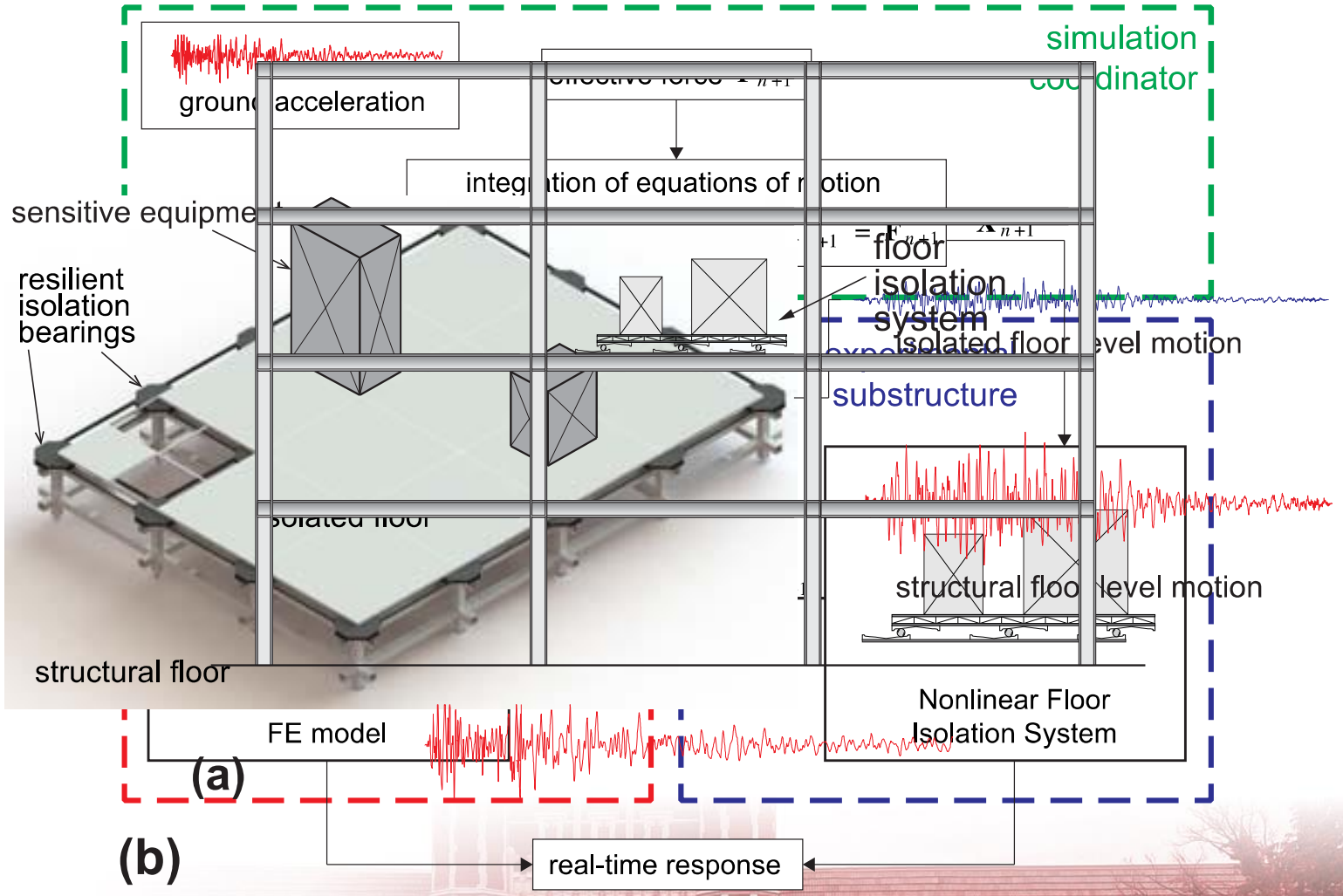
# *RII Track-4: Quantifying Seismic Resilience of Multi-Functional Floor Isolation Systems through Cyber-Physical Testing* [OIA-1929151]

## Overview

- Investigate the *multi-directional* nonlinear dynamics of floor isolation systems (FISs) used to reduce seismic force demand and protect vital building contents.
- Rigorously evaluate a design methodology for multi-functional FISs incorporating building-FIS interactions.

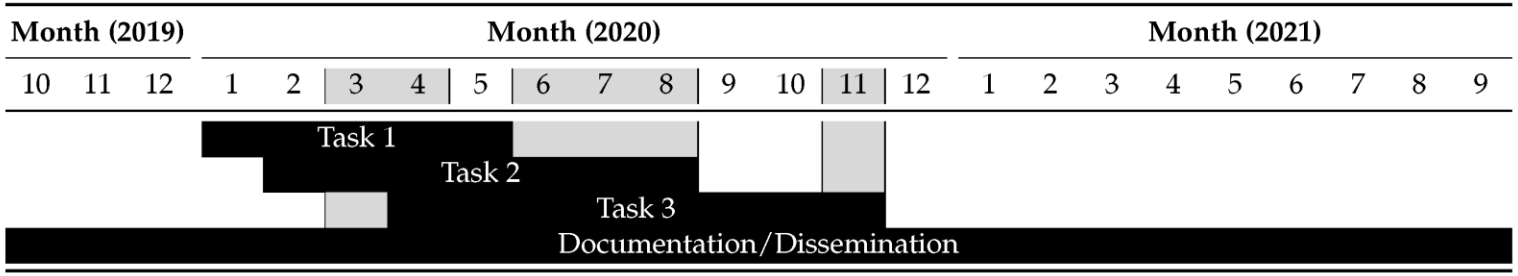
## Scope

- Perform large-scale FIS characterization tests to experimentally validate physics-based mathematical models.
- Perform large-scale real-time hybrid simulations to quantify the performance of FISs which incorporate multi-scale building-FIS interactions.
- Use of the Real-time Cyber-Physical Structural Systems Laboratory (CPSSL)



# *RII Track-4: Quantifying Seismic Resilience of Multi-Functional Floor Isolation Systems through Cyber-Physical Testing* [OIA-1929151]

**Table 1:** Overview of project timeline. Host site visits are indicated by gray shading.




**Covid-19 lockdown!**

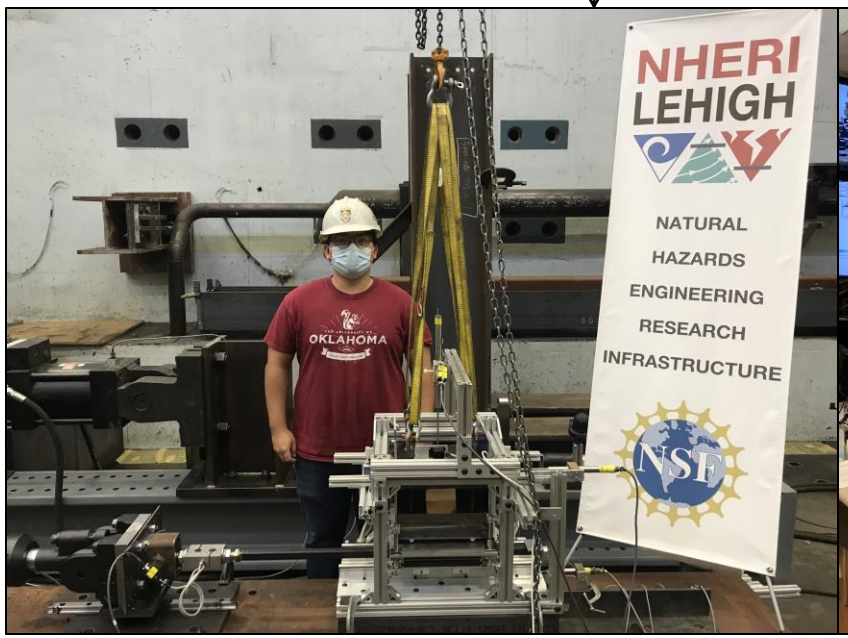
**Table 2:** Project timeline. Host site visits are indicated by gray shading.

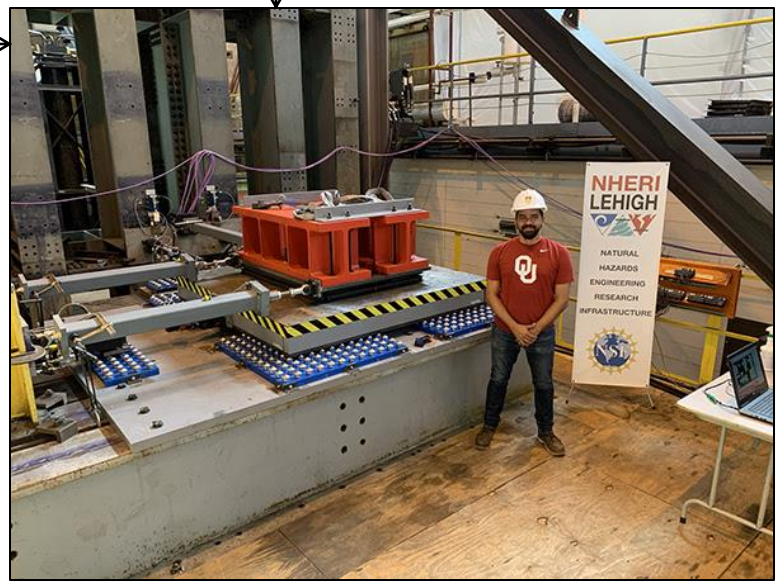
| Activity | Month (2020) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| RTHS Primer | 1(a) | | | | | | | | | | | |
| RTHS Hands-on Training | | | 1(b) | | | 1(b) | | | | | | |
| FIS Testbed Design/Fabrication | | 2(a) | | | 2(a) | | | | | | | |
| Assembly and Characterization Testing | | | 2(b) | | | | | | | | | |
| RTHS FIS Experimental Trials | | | | | | 2(c) | | | | | | |
| Data Processing / Manuscript Preparation | | | | 3(a) | | | | | 3(a) | | | |
| Debriefing and Proposal Planning | | | | | | | | | | | 3(b) | |

https://beta.nsf.gov/funding/opportunities/epscor-research-infrastructure-improvement-track-4-epscor-research-fellows

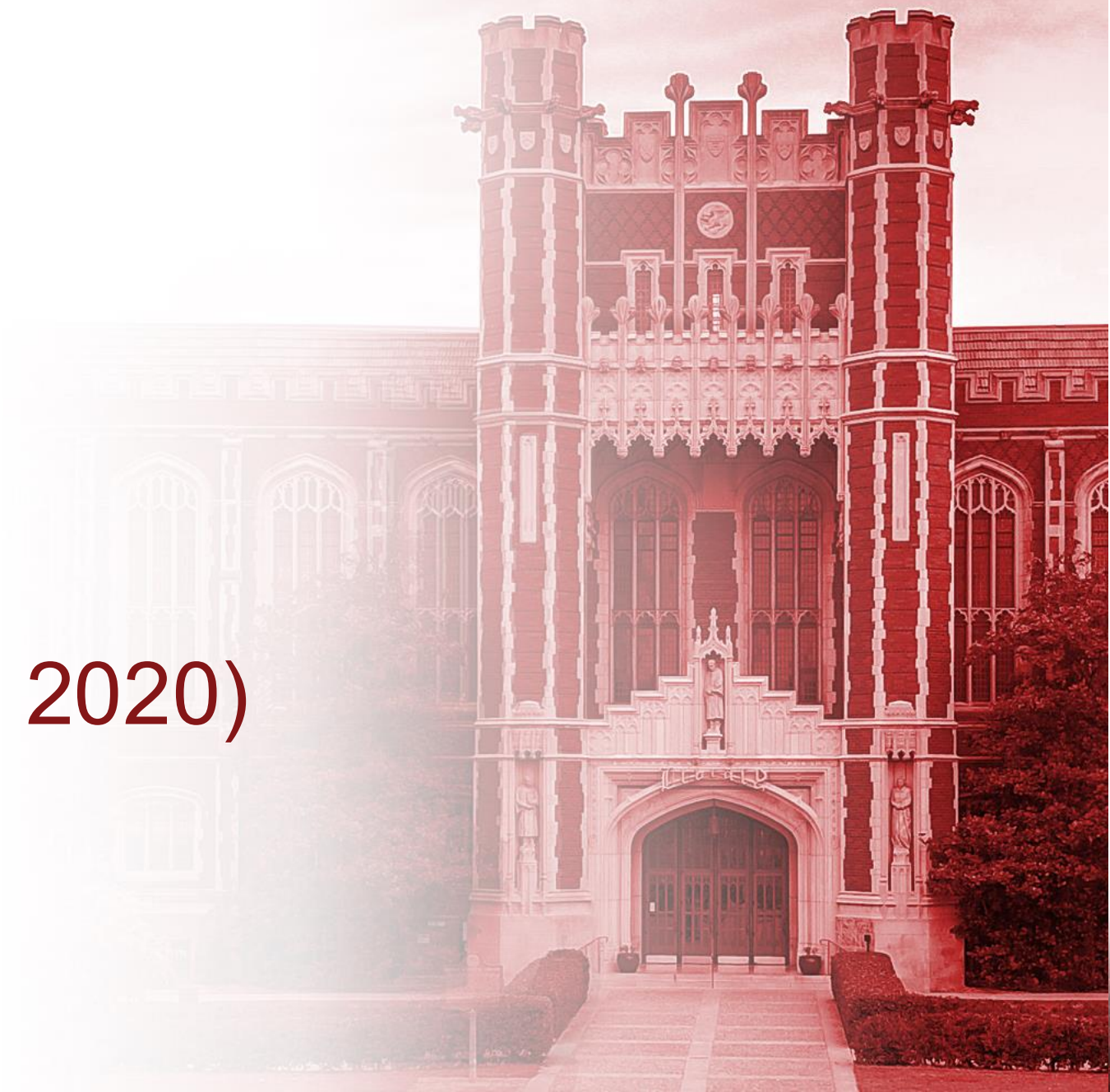
# *RII Track-4: Quantifying Seismic Resilience of Multi-Functional Floor Isolation Systems through Cyber-Physical Testing* [OIA-1929151]

| Month (2020) | | | | | | | | | | | | Month (2021) | | | | | | | | | | | | Month (2022) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | | | | | | Phase 1 | | | | | | | | | | Phase 2(a) | | | | | | | 2(b) | | | | | | 2(c) | | | | | | | |

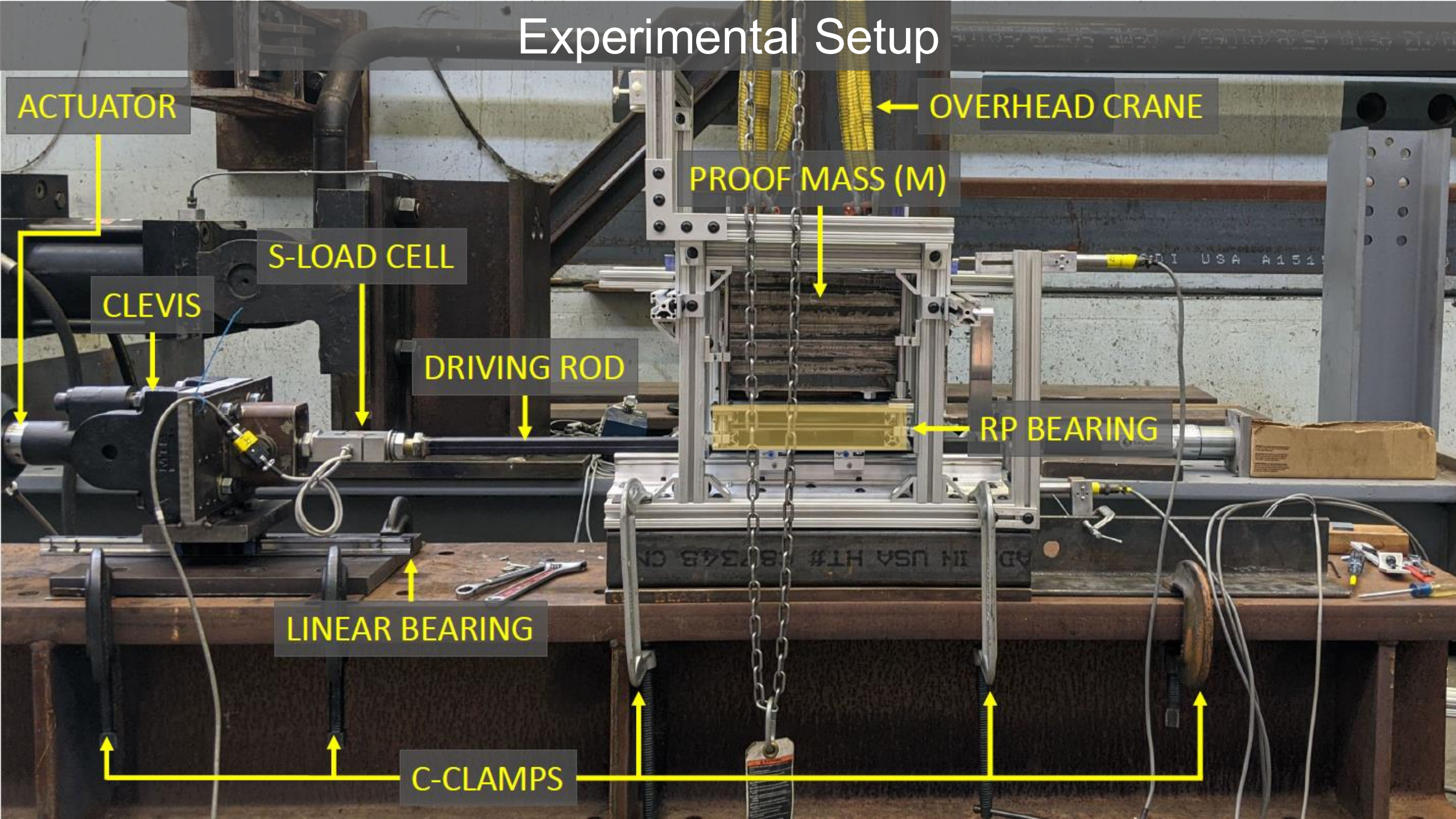


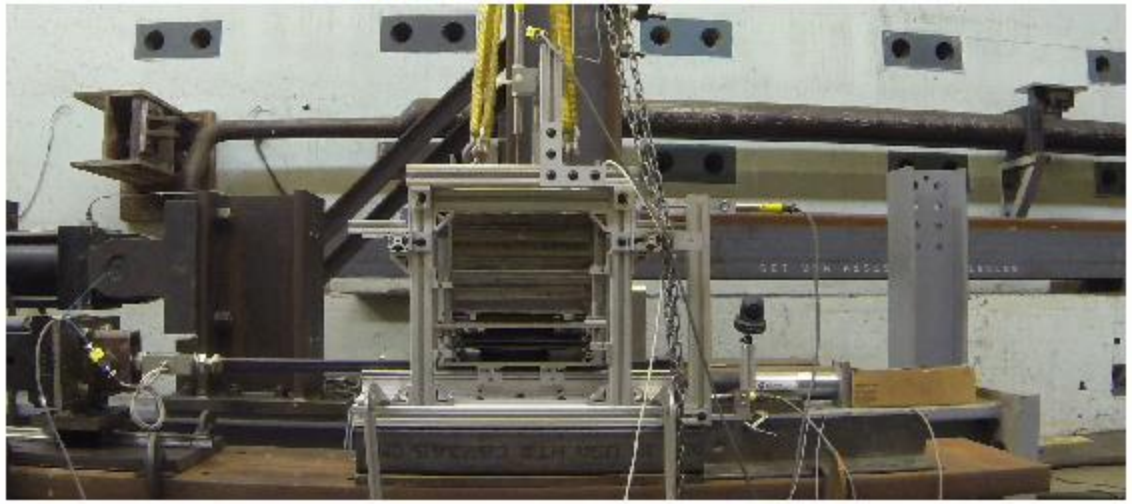
# PHASE 1 (SUMMER 2020)

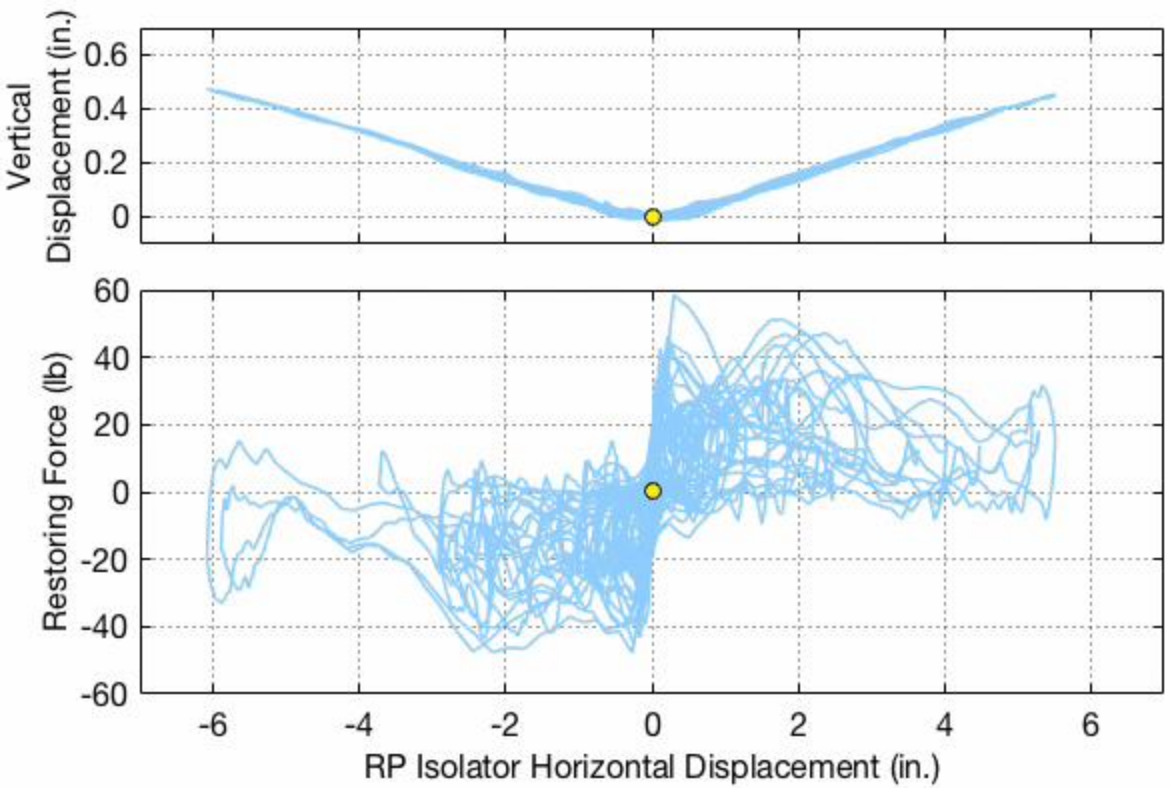


# Experimental Setup

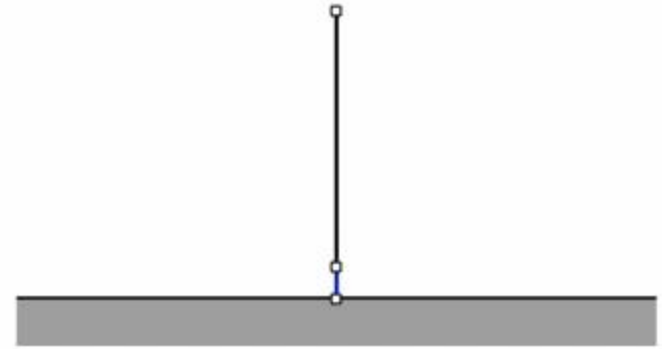


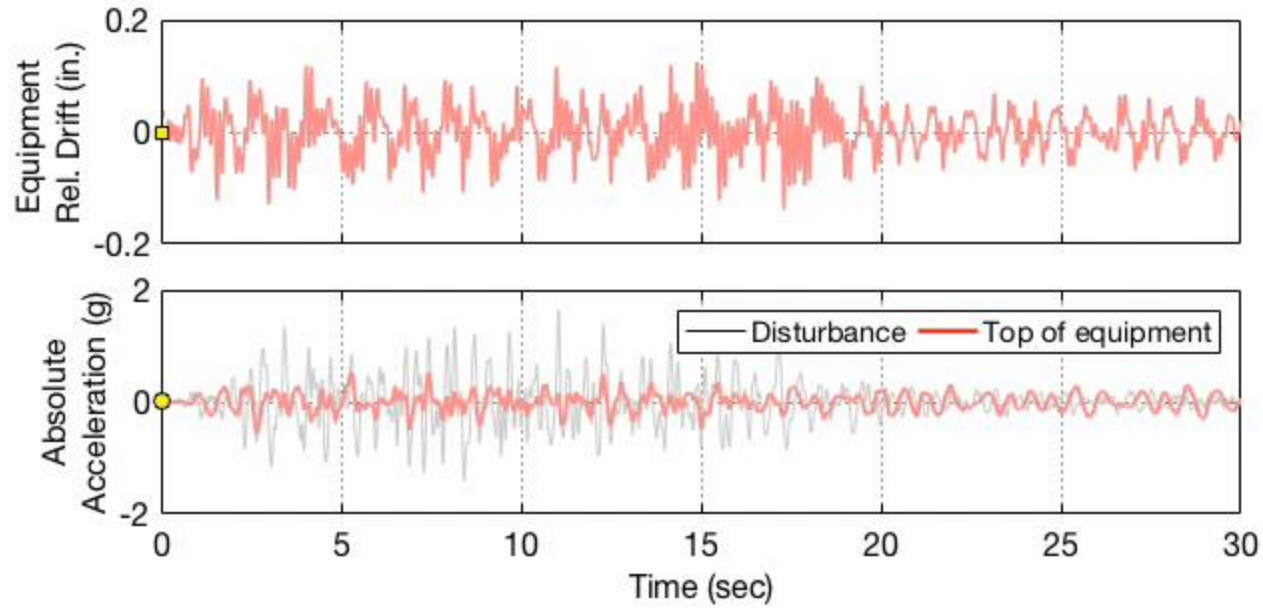
## Experimental Substructure






## Numerical Substructure (5x Deformation Scale)





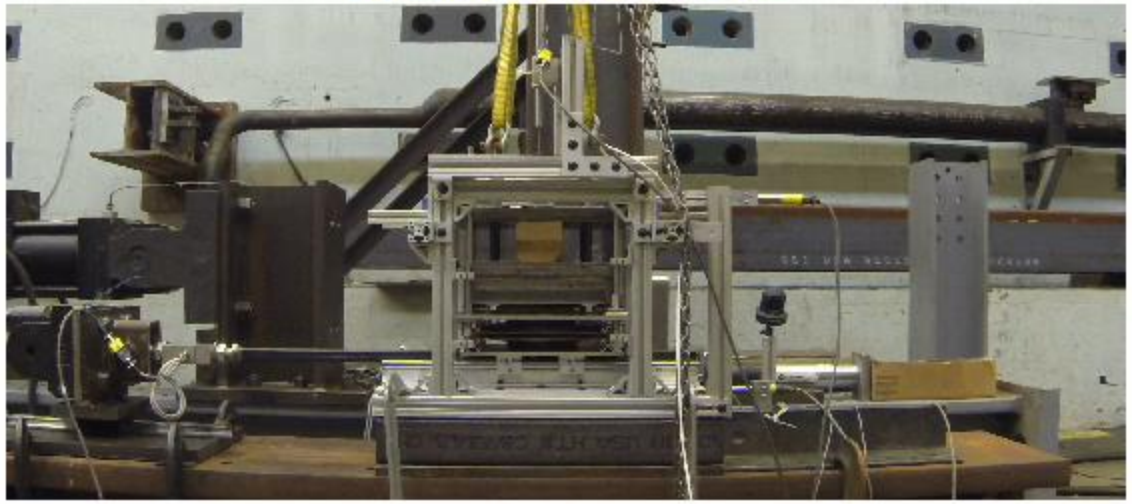

**Real-Time Hybrid Simulation of Flexible Equipment Isolated via a Rolling Pendulum (RP)-based Isolation System**

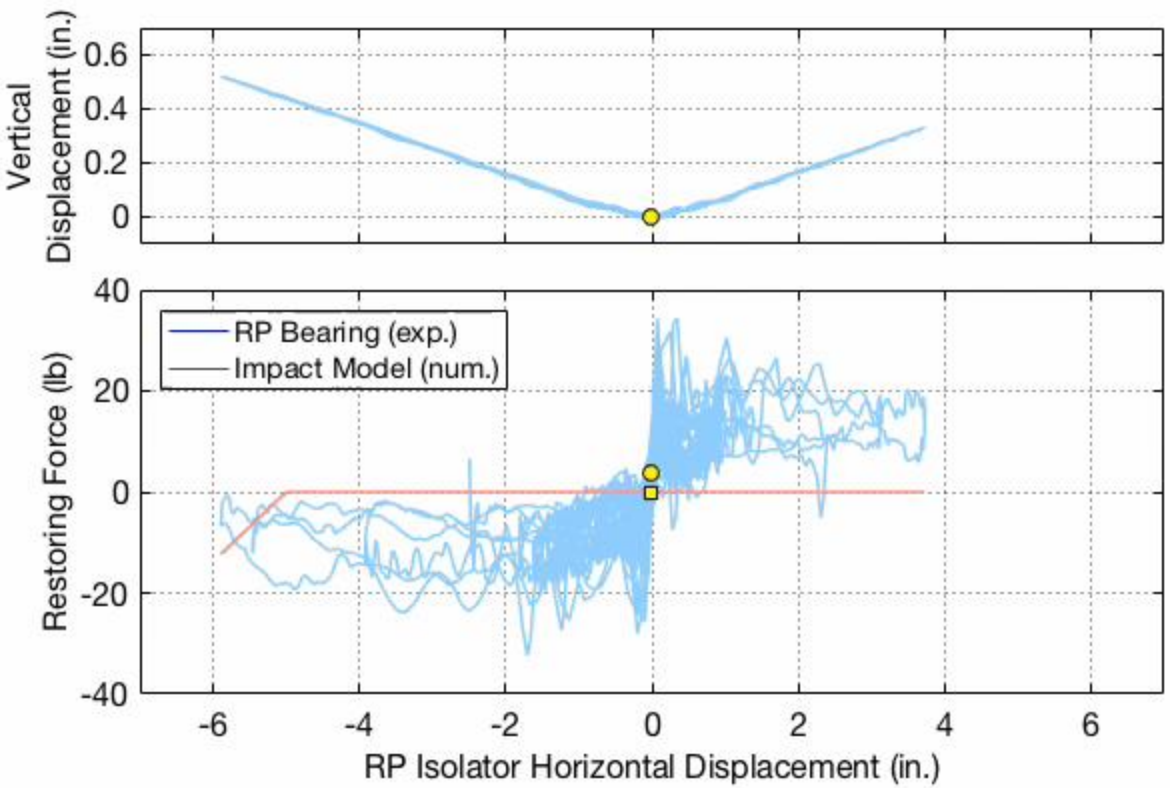
Nominal QuakeCoat Treatement w/ 240-lb proof mass
78.7-in.-Tall Flexible Equipment (5 Hz, 2% damped)
0.75x VERTEQII per GR-63-CORE

*Supported by NSF Award No. OIA-1929151*

LEHIGH NHERI
Real-Time Multi-Directional Testing Facility

## Experimental Substructure



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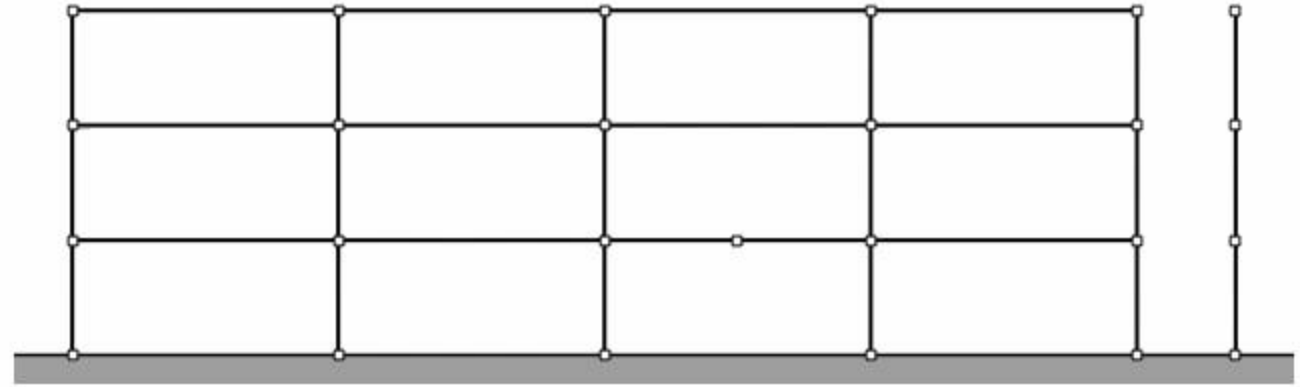

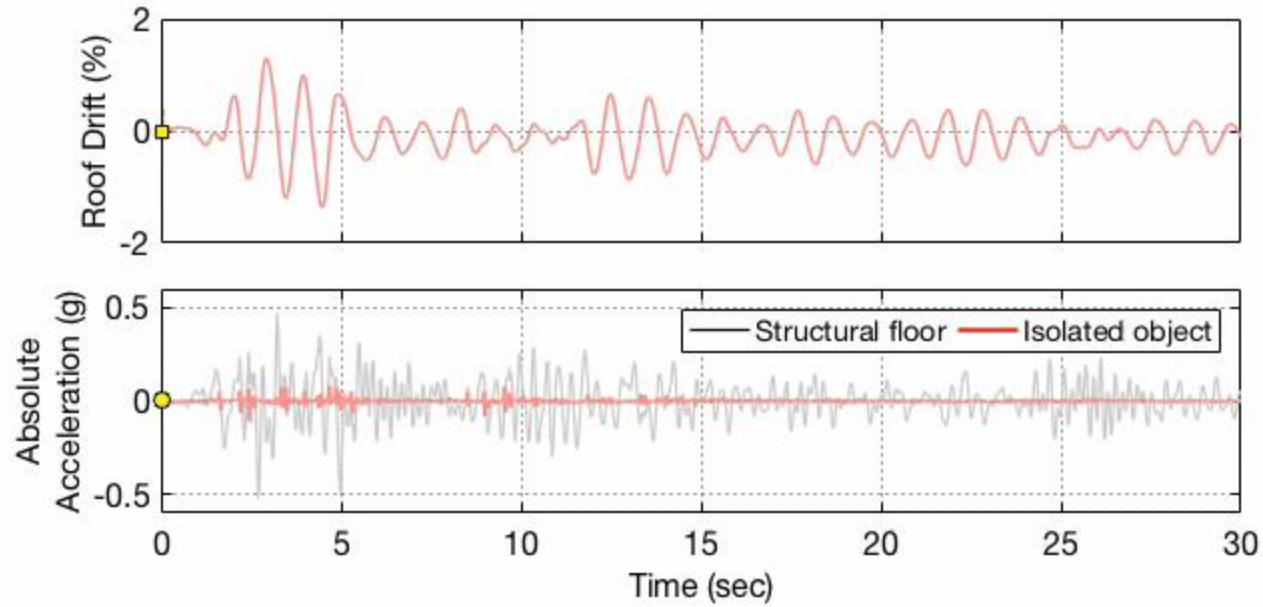


**Real-Time Hybrid Simulation of a 3-Story Steel MRF Building with a Rolling Pendulum (RP)-based 50-kip Floor Isolation System (FIS) on the First Floor**

2-Layer QuakeCoat Treatement w/ 143-lb proof mass

Impact Model w/ 5-in. gap (13.75 lb/in.)

1x El Centro, Imperial Valley Irrigation District substation, 1940

*Supported by NSF Award No. OIA-1929151*

LEHIGH NHERI

Real-Time Multi-Directional Testing Facility

# Research Products

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DOI: 10.1002/eqe.3694

RESEARCH ARTICLE

WILEY

## Characterization and real-time hybrid simulation testing of rolling pendulum isolation bearings with different surface treatments

**Braulio A. Covarrubias Vargas**[1] | **P. Scott Harvey Jr.**[1] | **Liang Cao**[2] | **James M. Ricles**[2] | **Safwan Al-Subaihawi**[2] | **Esteban Villalobos Vega**[1]

[1]School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, Oklahoma, USA

[2]ATLSS Engineering Research Center, Department of Civil and Environmental Engineering, Lehigh University, Bethlehem, Pennsylvania, USA

**Correspondence**
Philip Scott Harvey Jr., School of Civil Engineering and Environmental Science, University of Oklahoma, 202 W. Boyd St., Norman, OK 73019, USA.
Email: harvey@ou.edu

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National Science Foundation, Grant/Award Numbers: CMMI-1663376, OIA-1929151, CMMI-1943917, CMMI-1520765

**Abstract**

Damage caused by earthquakes to buildings and their contents (e.g., sensitive equipment) can impact life safety and disrupt business operations following an event. Floor isolation systems (FISs) are a promising retrofit strategy for protecting vital building contents. In this study, real-time hybrid simulation (RTHS) is utilized to experimentally incorporate multi-scale (building–FIS–equipment) interactions. For this, an experimental setup representing one bearing of a rolling pendulum (RP) based FIS is studied—first through characterization tests and then through RTHS. A series of tests was conducted at the Natural Hazards Engineering Research Infrastructure (NHERI) Experimental Facility at Lehigh University. Multiple excitations were used to study the experimental setup under uni-axial loading. Details of the experimental testbed and test protocols for the characterization and RTHS tests are presented, along with results from these tests, which focused on the effect of different rolling surface treatments for supplemental damping, the FIS–equipment and building–FIS interactions, and rigorous evaluation of different RP isolation bearing designs through RTHS.

**KEYWORDS**
floor isolation, hybrid testing, rolling resistance, vibration mitigation

### 1 | INTRODUCTION

Earthquakes can damage civil structures causing great economic and, in the worst cases, human losses. Several design strategies have been developed to minimize and mitigate the impact of the seismic actions imposed on structures. For instance, base isolation systems mitigate the inertial loads caused by an earthquake excitation on the whole structure and, ultimately, reduce structural drifts.[1,2] On the other hand, floor isolation systems (FISs) are gaining popularity as they have shown to be a valuable retrofitting approach for protecting specific nonstructural equipment and vital building contents, as well as for the rapid post-event functionality of the structure.[3] FISs are designed under the premise that an object (e.g., telecommunications equipment) can be decoupled (isolated) from the rest of a structure and its respective disturbances (see Figure 1). Thus, these systems decrease the transmitted vibrations and ultimately protect the sensitive objects from damaging effects.[4]

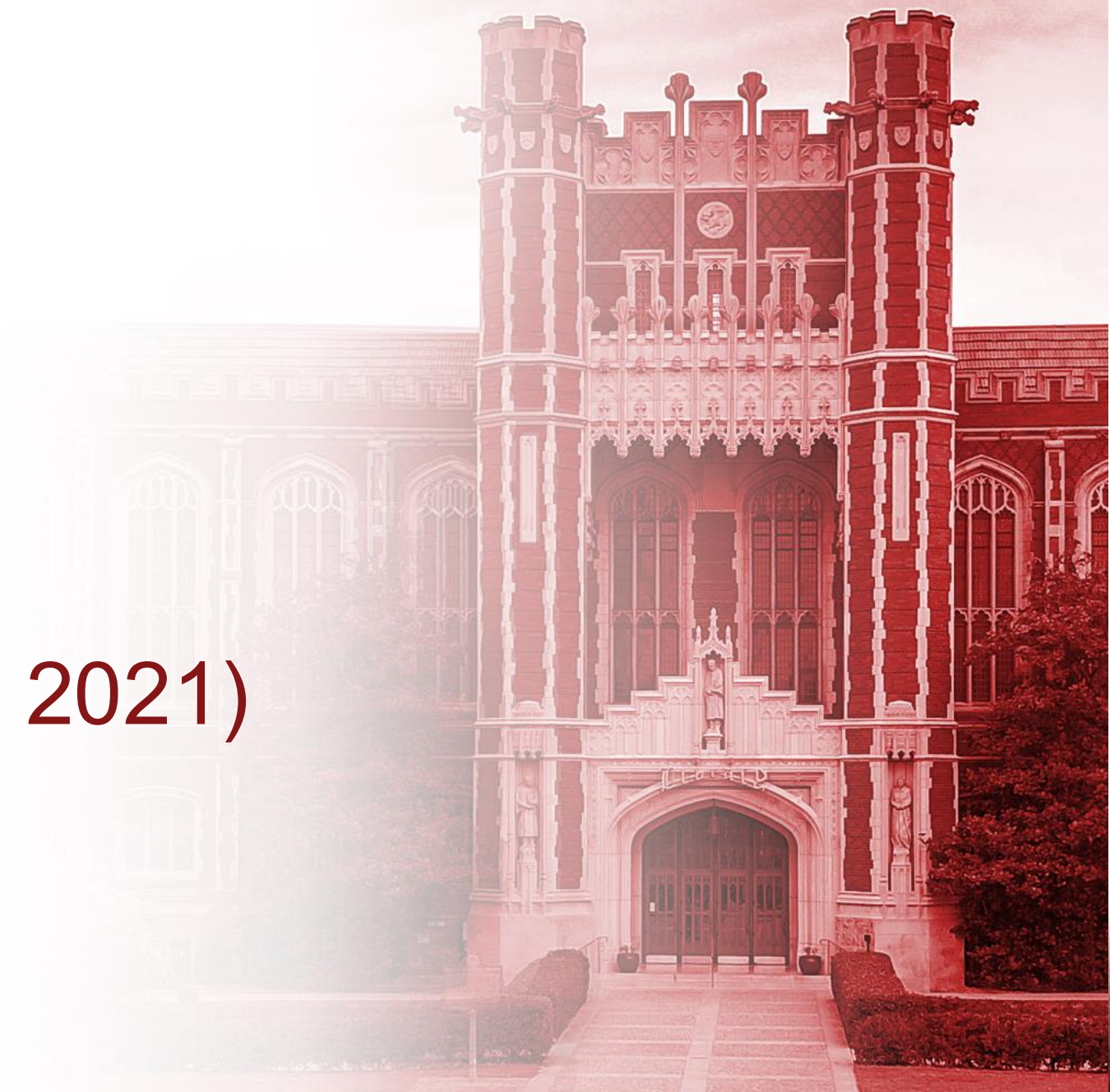
Experiment | **Characterization Tests of Rolling Pendulum Isolation Bearings with Different Surface Treatments**

| | |
|---|---|
| Experiment Type | **Characterization** |
| Author(s) | Harvey, Philip; Covarrubias Vargas, Braulio Andres; Cao, Liang; Ricles, James |
| Experimental Facility | **Advanced Technology for Large Structural Systems (ATLSS) Engineering Research Center, Lehigh University** |
| Equipment Type | **Small-Scale, Real-Time/Hybrid Capable Servo-Hydraulic Actuator System** |
| Date of Experiment | **08-26-2020 — 09-03-2020** |
| Date of Publication | **11-11-2022** |
| DOI Citation | **10.17603/ds2-5je0-5f35** |
| License(s) | **Open Data Commons Attribution** |
| Data Reuse | View Experiment Metrics |

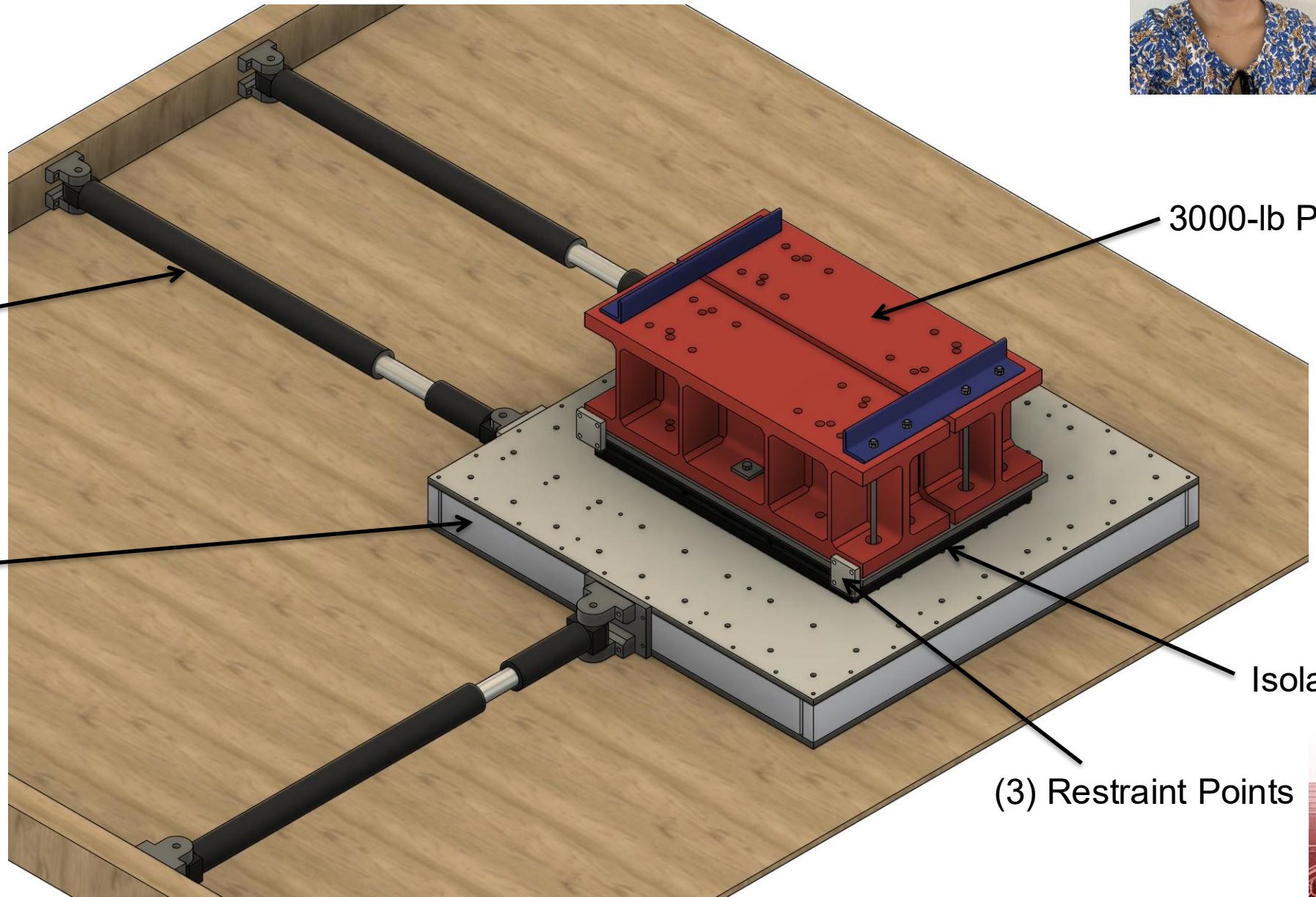
Rolling-pendulum (RP) isolation bearings with different surface treatments were tested under quasi-static, harmonic, and simulated earthquake-induced motions. These tests were used to characterize the behavior of the RP bearings, including the gravitational restoring force and the rolling resistance associated with the elastomeric coatings of different thicknesses. The experimental data from analog sensors and cameras is archived here, as documented in the data report.

- Report | **Data Report**
- Model Configuration | **Experimental Setup**
  - Sensor Information | **Analog Sensors, GoPro Camera, and Web Cameras**
    - Event | **01_C0-240**
    - Event | **02_CN-240**
    - Event | **03_C1-240**
    - Event | **04_C2-240**

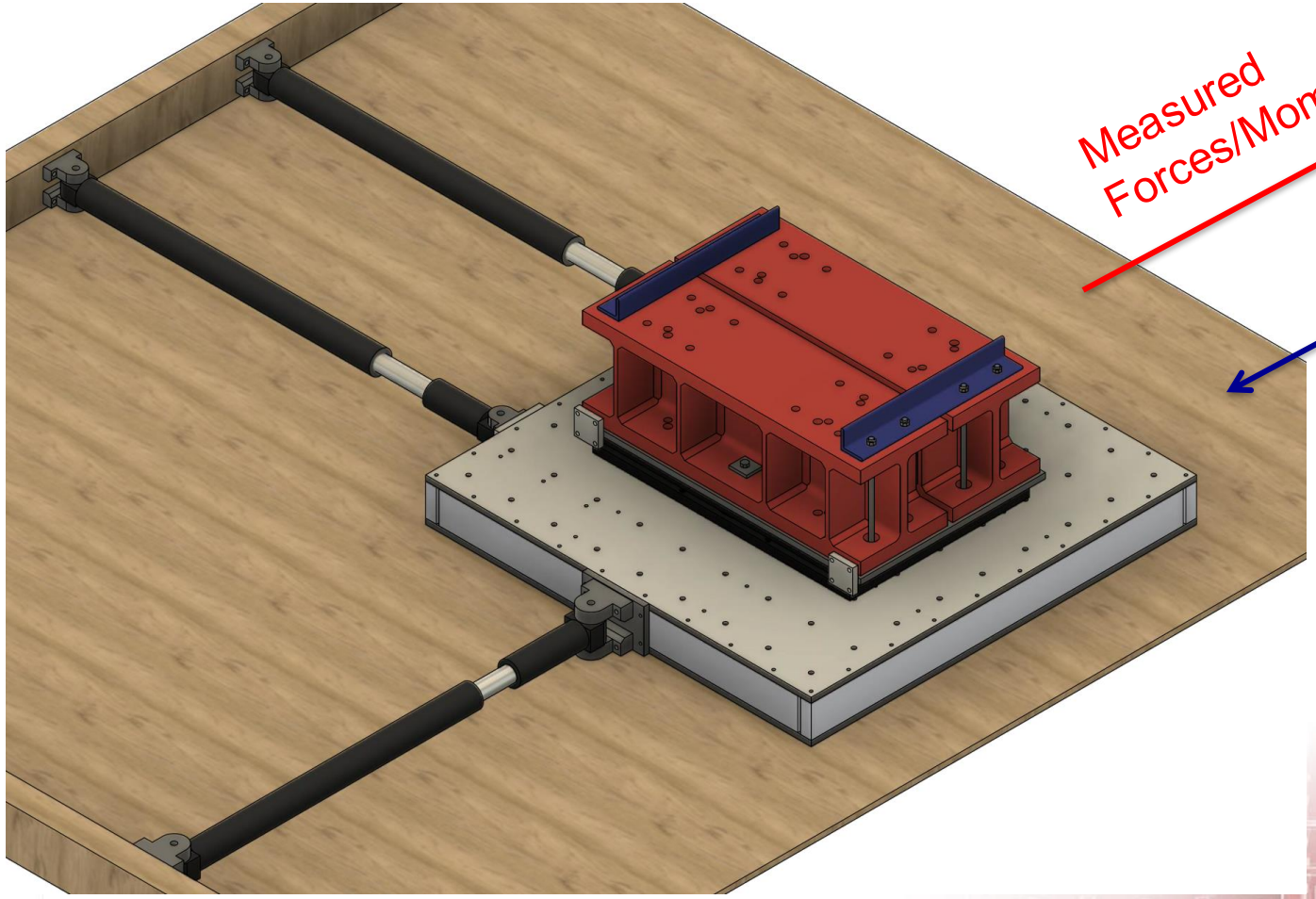
# PHASE 2 (SUMMER 2021)



# Multi-Directional RTHS Testing

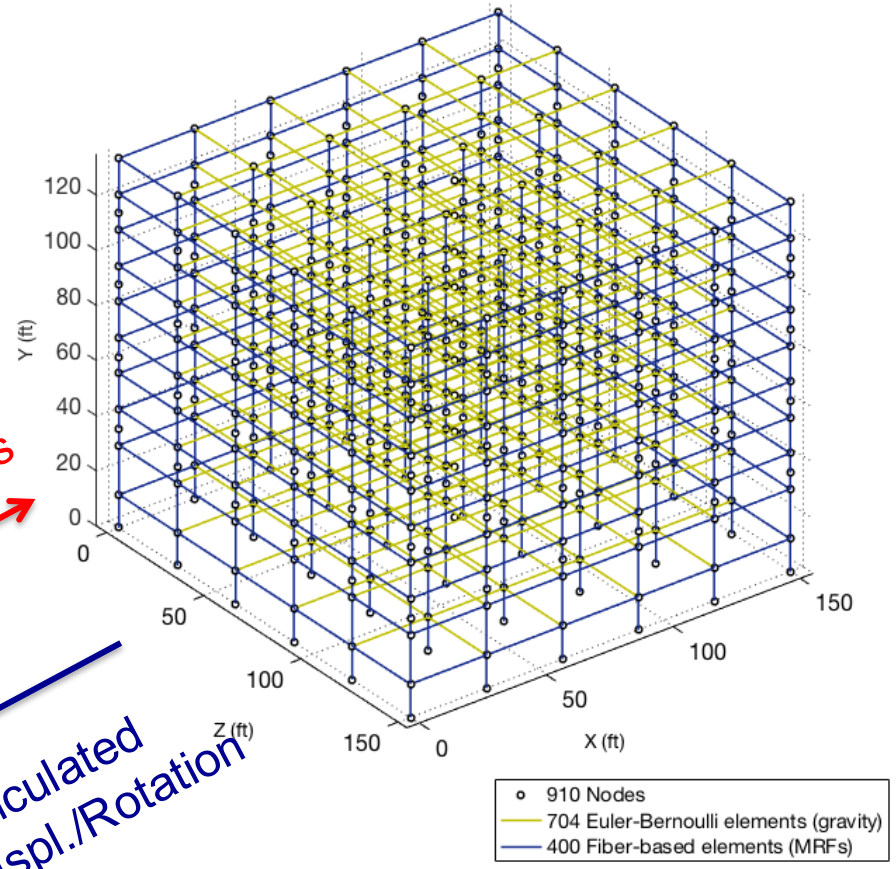



# Multi-Directional RTHS Testing

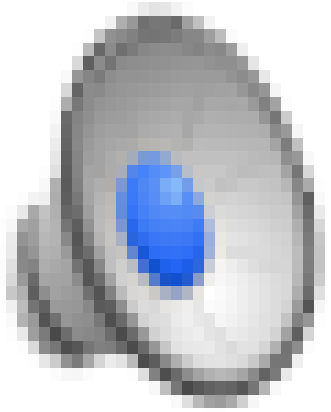


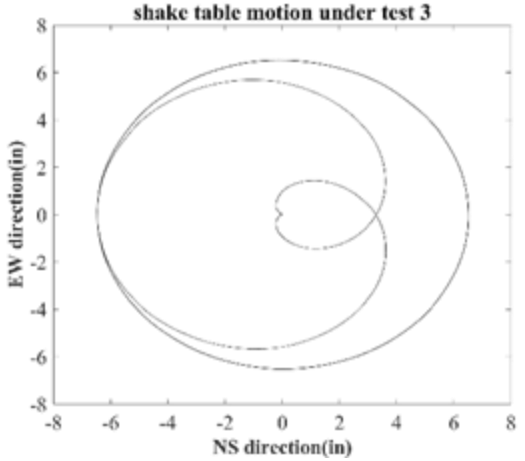
Measured Forces/Moments

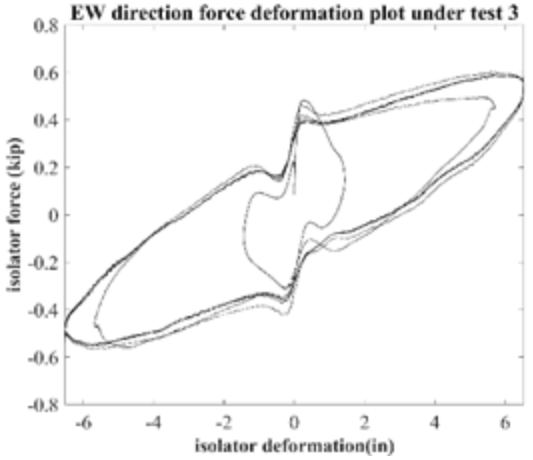
Calculated Displ./Rotation

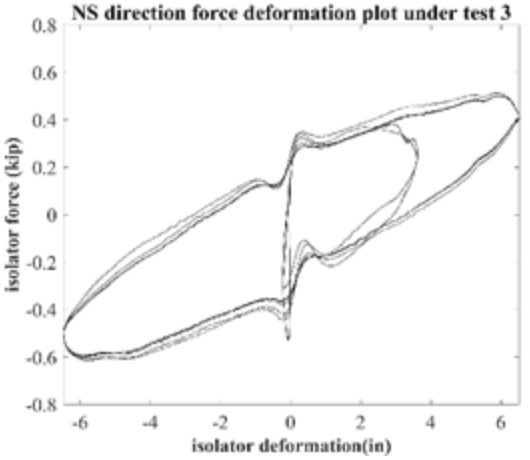



# Multi-Directional RTHS Testing





# Acknowledgements


- This material is based upon work supported by the **National Science Foundation** under Award Nos. CMMI-1663376, OIA-1929151, and CMMI-1943917. This support is greatly appreciated.
- Thanks to **WorkSafe Technologies** for providing the isolation systems used for this research.
- Thanks to **NHERI Lehigh EF** for the use of their laboratories and technical expertise.


# Thank You! Questions?

**P. Scott HARVEY Jr.**

E// harvey@ou.edu

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