NHERI Lehigh EF Overview

Richard Sause

NHERI Lehigh EF Associate Director

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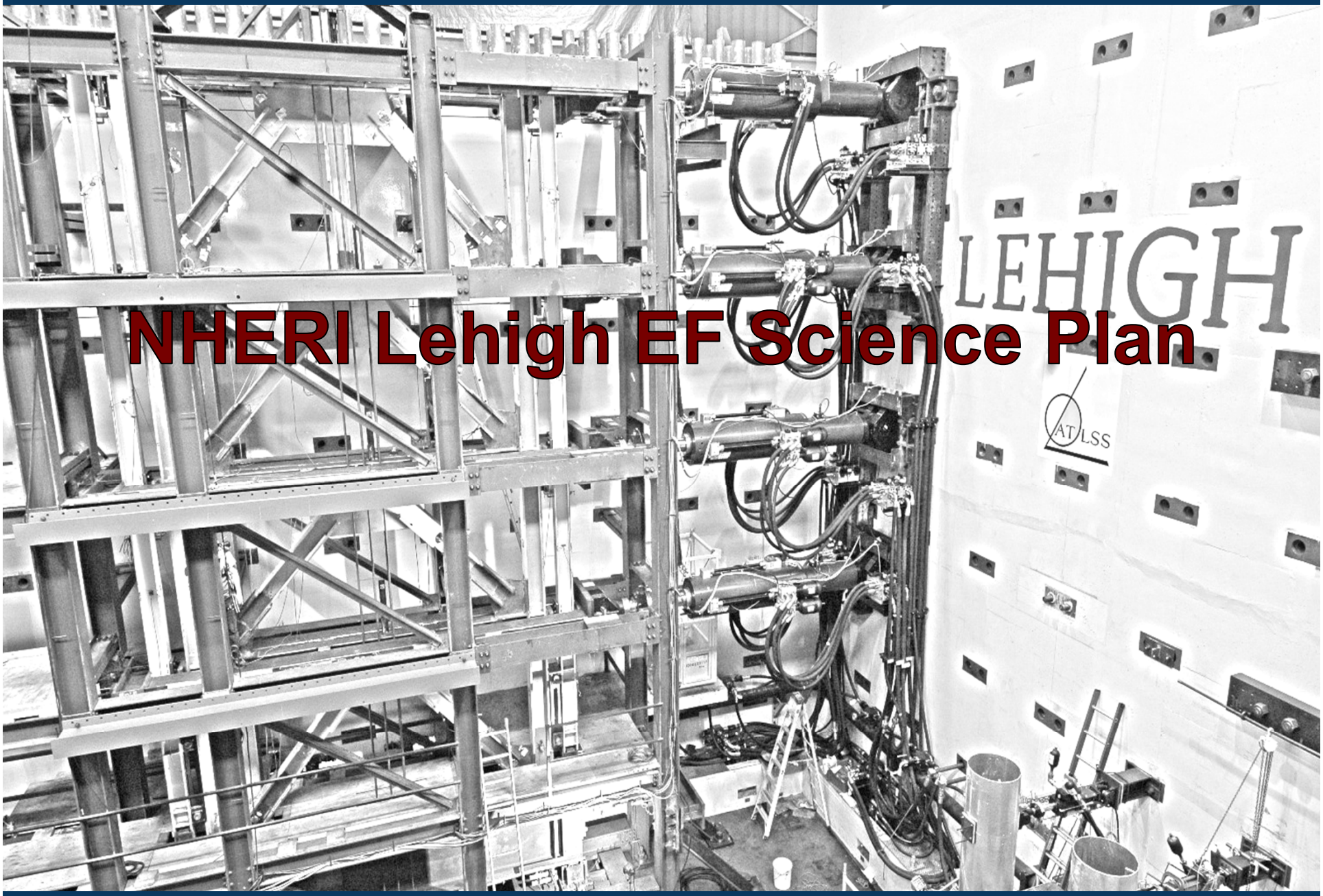
NHERI Lehigh EF Science Plan



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NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE
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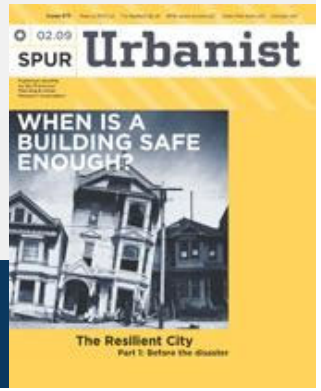
NHERI Lehigh EF Science Plan

Provide a next generation multi-user facility to perform transformative research by closely integrating numerical simulations and experiments to advance natural hazards engineering research and education, enabling the challenge of community resilience to natural hazards to be met:

- Improved concepts for renewal and retrofit of the built environment
- Exploitation of new emerging materials
- Development of innovative, resilient structural concepts
- Economical design approaches toward natural hazard mitigation
- Development and validation of more accurate physics-based computational simulation models



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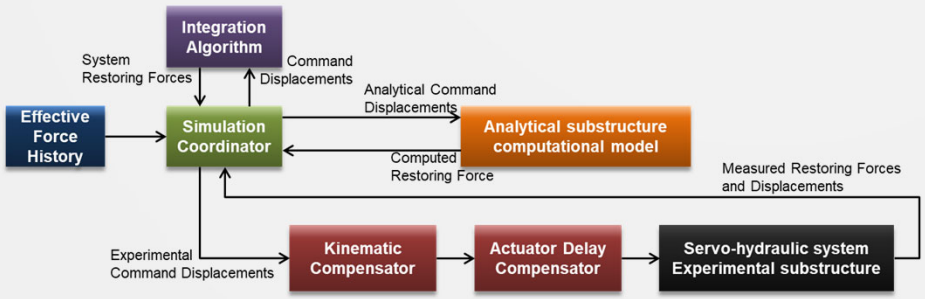
NHERI Lehigh EF Science Plan

- The NEHRI Lehigh EF focus is on large-scale, multi-direction, real-time hybrid simulations that combine physical experiments with computer-based simulations for evaluating performance of large-scale components and systems.
- The NEHRI Lehigh EF provides user-friendly tools that enables researchers to readily utilize the advanced testing technology and algorithms to perform complex experiments.



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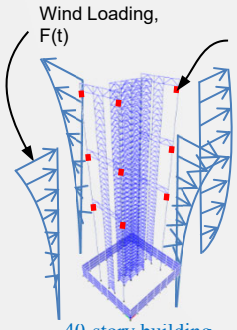
NHERI Lehigh EF

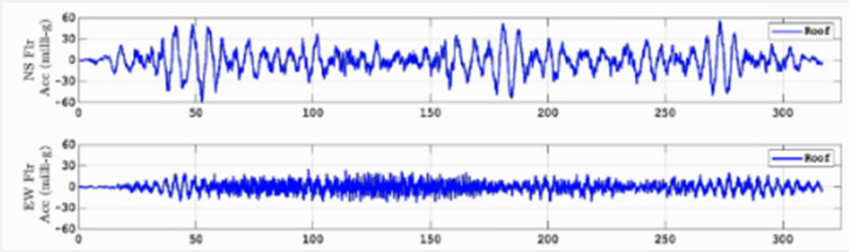
- Facility Enables Researchers to Readily Perform:
  - 3-D RTHS of large, complex nonlinear systems subjected to multi-natural hazards, (e.g., wind and earthquake) using analytical substructures created with robust computational models;
  - 3-D multi-natural hazard RTHS of systems with numerous response modification devices, where models of numerically modeled devices are updated in real-time using data from physically modeled devices;
  - Accurate large-scale 3-D multi-directional experiments (e.g., quasi-static, HS, RTHS) that involve nonlinear kinematics of actuator and specimen motions;
  - Accurate 3-D experiments of systems with precise hydraulic actuator control.



40-story building


FIU wind tunnel testing


Analytical substructure



Windward and crosswind roof acceleration response

RTHS Wind Simulation Results, 40-story Building With Supplemental Damper Outriggers

NHERI Lehigh EF Broader Impacts

- Key questions in natural hazards mitigation can be addressed through research performed at NHERI Lehigh EF that will lead to:
  - Development and implementation into practice new natural hazard mitigation strategies and innovative resilient structural systems
  - Enhanced understanding of response to multi-natural hazards by accounting for SSI and FSI effects
  - Comprehension of system-level effects on structural and non-structural components through large-scale 3-D system experiments.
- Acquire high quality experimental data, leading to improved computational models for predicting community infrastructure system response to natural hazards.
- Training the next-generation workforce in natural-hazards engineering through research and ECO activities.

NHERI Lehigh EF Science Plan

- Examples of Potential Research Projects at NHERI Lehigh EF:
  - *Autonomous Semi-active Control Devices for Achieving Resilient Performance of Structural Systems Subject to Multi-hazards* (approach: real-time hybrid simulation)
  - *Advanced Bracing Systems with Shape Memory Alloys for Achieving Multi-hazard Resiliency of Buildings* (approach: quasi-static; hybrid simulation)
  - *Multi-agent Replicator Control Methodologies for Sustainable Vibration Control of Smart Building Structures* (approach: real-time hybrid simulation)
  - *Advancing Computational Modeling of Structural Damage in Reinforced Concrete Subject to Complex Loading Histories* (approach: quasi-static; multi-directional mixed mode control hybrid simulation)
  - *Quantifying Seismic Resilience of Multi-functional Floor Isolation Systems Through Cyber-physical Testing* (approach: real-time hybrid simulation)
  - *Performance of Nonstructural Components of Systems and Minimizing Multi-Hazard Losses* (approach: hybrid simulation, real-time hybrid simulation)
  - *Effects of Soil-Foundation-Structure Interaction on Multi-hazard Performance of Tall Buildings With Supplemental Damper Outrigger Systems* (approach: hybrid simulation, real-time hybrid simulation)
  - *Semi-Active Controlled Cladding Panels for Multi-Hazard Resilient Buildings* (approach: hybrid simulation, real-time hybrid simulation)

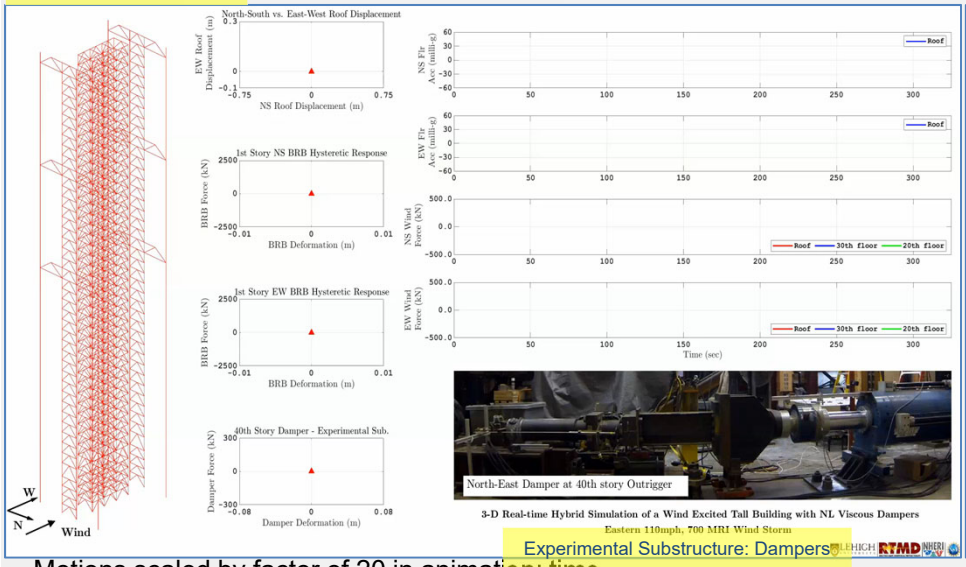
Example of Research Vision at NHERI Lehigh

Real-time Hybrid Simulations (RTHS) to Improve Resilience of Tall Buildings to Multi-Natural Hazards

Rate Dependent Nonlinear Viscous Damper

3D RTHS of 40-story Building with Supplemental Nonlinear Viscous Dampers in Outriggers

Analytical Substructure: Building



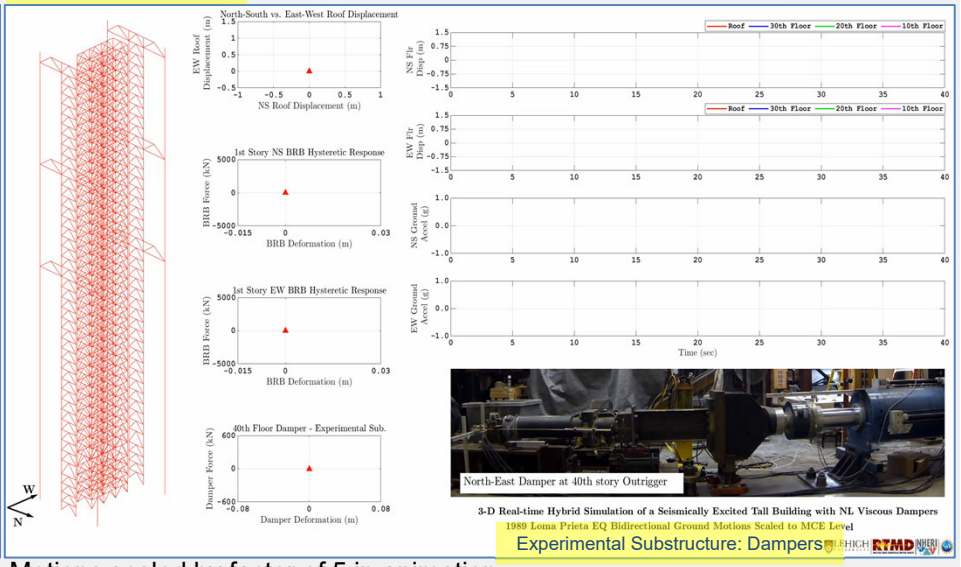
Experimental Substructure: Dampers

Motions scaled by factor of 20 in animation; time-lapse

RTHS: 700 year MRI (110 mph Wind Speed)

Wind

Analytical Substructure: Building

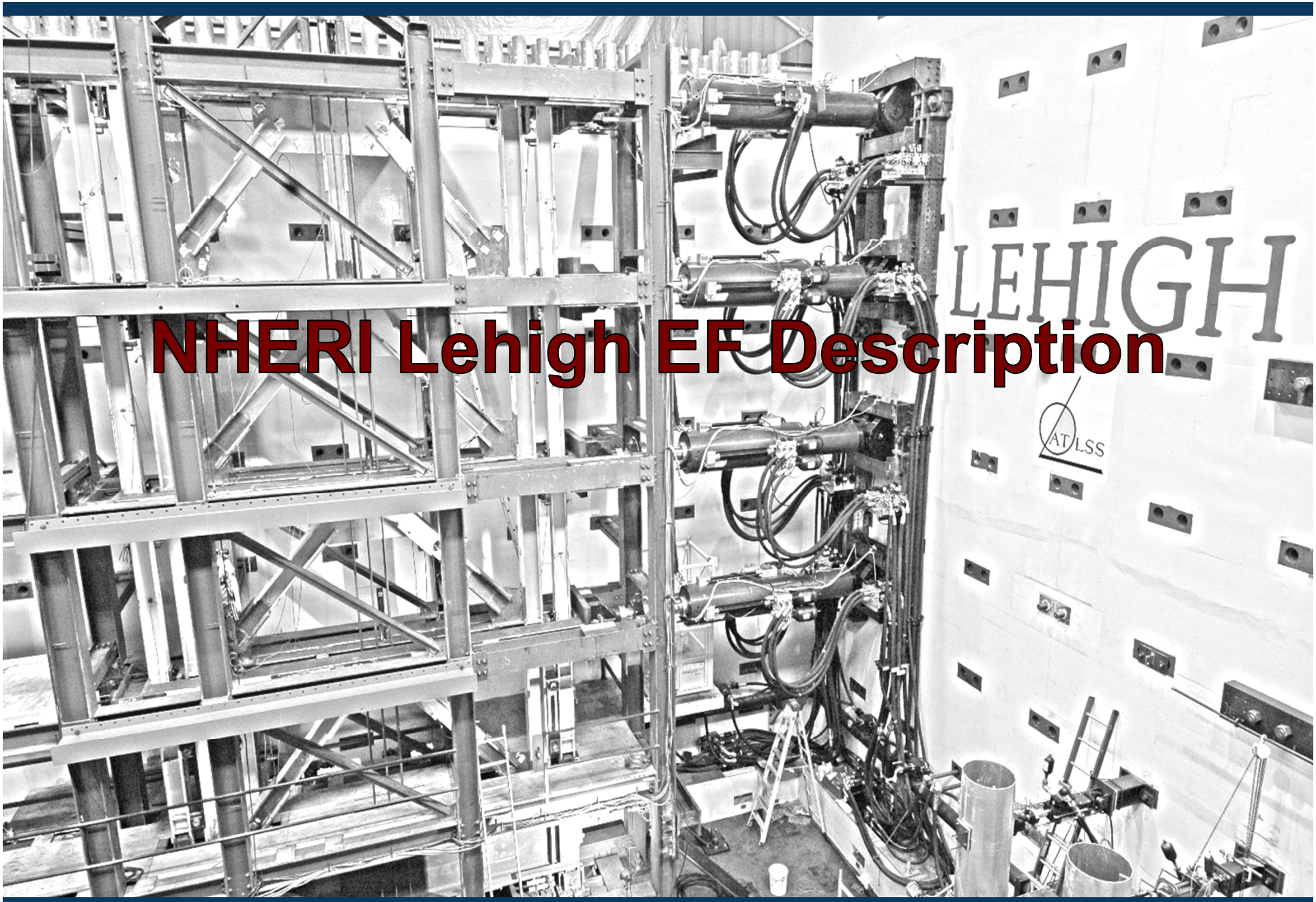


Experimental Substructure: Dampers

Motions scaled by factor of 5 in animation

RTHS: 2474 year EQ (MCE)

Earthquake



NHERI Lehigh EF Description

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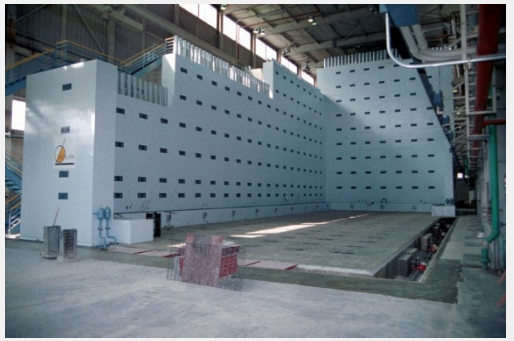
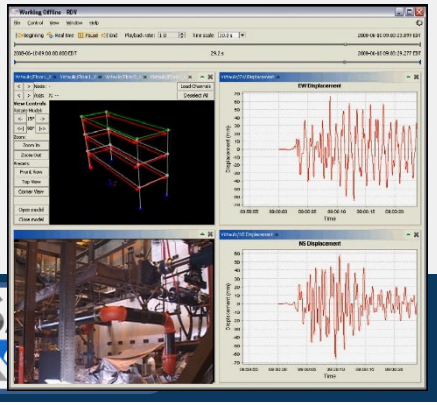
What is the NHERI Lehigh EF?

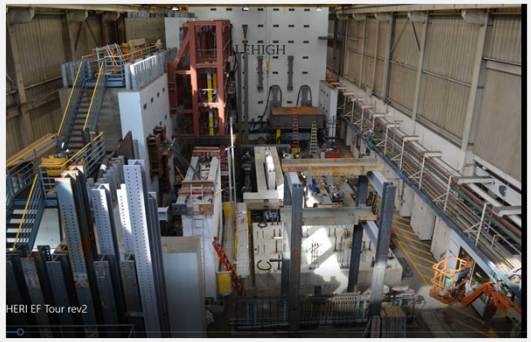
- Former NEES Site: Real-time Multi-directional (RTMD) Earthquake Simulation Facility
- Unique facility
  - Portfolio of equipment, instrumentation, infrastructure, testbeds, and experimental simulation control protocols for large-scale multi-directional testing

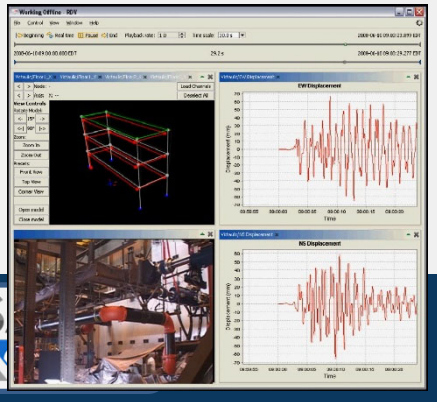




What is the NHERI Lehigh EF?

- Former NEES Site: Real-time Multi-directional (RTMD) Earthquake Simulation Facility
- Unique facility
  - Portfolio of equipment, instrumentation, infrastructure, testbeds, and experimental simulation control protocols for large-scale multi-directional testing
  - Concurrent multiple large-scale experiments
  - Operated by experienced staff
- Facility exists within ATLSS Center to provide access to additional resources and ATLSS infrastructure





ATLSS Center

NHERI Lehigh EF Strengths - Facility

- Large-scale, multi-directional testing
- Real-time loading
  - Actuators, hydraulic equipment and power
  - Actuator control with adaptive compensation
- Hybrid simulation
  - Integration algorithms
  - Analytical modeling
  - Multi-grid real-time simulations
  - Actuator multidirectional kinematic compensation
  - Real-time actuator control
  - Real-time on-line model updating
  - Data model for large-scale test data
- Instrumentation, DAQ, advanced instrumentation (Digital Image Correlation, laser transducers)
- Large inventory of ATLSS testing and ancillary equipment

NHERI Lehigh EF Strengths - People

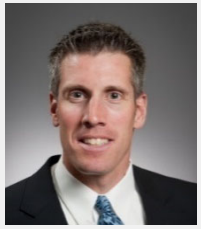
Lehigh Team includes

- Expertise in
  - Structural Engineering
  - EQ Engineering
  - Geotechnical Engineering
  - Aeroelasticity and Wind Engineering
  - Hydrodynamics and fluid-structure interaction
  - Probabilistic-based modeling
  - Structural monitoring and damage assessment
- Pioneers in real-time hybrid simulation (RTHS)
- Know-how in large-scale experimentation, RTHS
- Relationship with industry, practicing engineers, familiarity with codes and standards
- Experienced laboratory staff

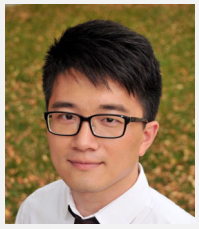
NHERI Lehigh EF Team

James Ricles, PI

Richard Sause, Co-PI



Chad Kusko
Operations Mgr



Liang Cao
Research Eng

Thomas Marullo
IT Systems Mgr

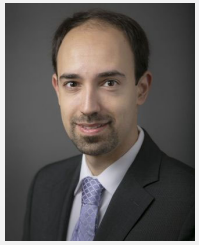
Darrick Fritchman
ATLSS Lab Mgr

Doris Oravec
ATLSS Finance Mgr

Capacity Building Partners

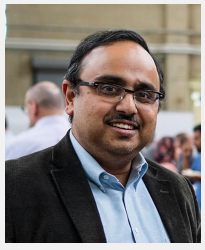
Justin Jaworski
Aeroelasticity and
Fluid-Structure Interaction

Muhannad Suleiman
Soil-Structure Interaction



Paolo Bocchini
Probabilistic Modeling and
Infrastructure Resilience

Shamim Pakzad
Adv. Sensors,
Structural Monitoring



Arindam Banerjee
Hydrodynamics and
Fluid-Structure Interaction

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Advisory Council

- ***Advisory Council:*** *provide advice on marketing to broaden user base and ECO; advise on recent developments in natural-hazards engineering*
  - ***Expertise****: Community Resilience, Geotechnical Engineering, Performance-Based Engineering, Isolation Systems, Structural Control, Structural Surveillance and Health Monitoring, Advanced Damping and Structural Response Modification Devices.*

Elaina Sutley
Univ Kansas

Brady Cox
Utah State

Dawn Lehman
Univ Washington

John van de Lindt
Colorado State

Scott Harvey
Univ Oklahoma

Patricia Clayton
Wake Forest Univ

Claudia Marin
Howard Univ

Erik Johnson
Univ Southern Cal

Thank you