On a recent afternoon, two Jacobs School engineers equipped with 3D glasses stood in front of a towering 12’ digital reproduction of a six-story building, projected onto a curved wall of screens. They had tested the building a few weeks before, putting its light-weight steel frame through a series of increasingly powerful earthquake and fire tests on the world’s largest outdoor shake table at UC San Diego. Now researchers were zooming in and out of the building’s digital twin to assess damage.

This virtual inspection was made possible by data gathered by small drones, which flew around the building, first before the tests to help create a digital, 3D map of the structure, and then during the tests to capture the impact of the earthquake. Finally, after the tests, they took to the sky to look for damage. Researchers used powerful visualization algorithms to turn the data the drones collected into an immersive 3D environment. The combination of these unique technologies — a one-of-a-kind shake table and powerful data visualization methods — allows structural engineers at the Jacobs School to get an incredibly detailed digital model of the structures they test. This in turn allows them to make recommendations to improve design methods and building codes around the nation and the world.

“This series of tests is particularly important because, for the first time, we simulated on a shake table an aftershock and main shock occurring after a live fire,” said principal investigator and UC San Diego structural engineering professor Tara Hutchinson.

In the past 12 years, many projects have been put to the test on the shake table at the NSF-funded Englekirk Structural Engineering Center.

“Researchers at the University of California San Diego prepare for a series of shake table tests designed to test the structural integrity of buildings during earthquakes and fires.”
Texas demonstrates 3D levee imaging

The University of Texas is working to bring levee research into the future

UT is working to bring levee research into the future

Texas demonstrates 3D levee imaging

Allocations policy for high performance computing

When natural disasters happen, there is a small window to collect valuable data that could save future lives, and The University of Washington NHERI RAPID team is working to make sure this data gets collected.

Joe Wartman, H.R. Berg Associate Professor of Geotechnical Engineering at the University of Washington, is helping the RAPID team get off the ground. “We just got started in September (2016),” Wartman said. “Unlike the other experimental facility we are getting built from the ground up. Our timeline for year one is set around developing our science plan.”

The goal of the science plan is to help Wartman and the RAPID team gain a better idea of what kind of data they need to be collecting in the field. According to Wartman the science plan will help answer to key questions for the RAPID team moving forward. The first is what kind of data gathering needs and opportunities in wind and seismic disasters. The second is what kind of hardware and software instrumentation tools will be needed. A community input workshop to develop the science plan is currently in the planning stages.

“Science plan will help us see what we have accomplished.”

While still in year one, Wartman says the team is focusing on using the science plan to determine what kind of equipment they will need moving forward. Year two will be spent gathering and calibrating all the equipment, and year three will see the RAPID team fully operational.

Wartman and the RAPID team face a unique set of challenges compared to other NHERI facilities. Being a response-based team, the unit will have to be prepared to go whenever a disaster strikes in order to avoid the loss of valuable data. While the science plan will help the RAPID team quickly plan, Wartman says there are a lot of other factors to consider before they deploy that will be unique to each disaster.

“You have to stop and ask, ‘Hold on what’s happened?’ ” Wartman said. “What’s been affected? What reports are we seeing? Is it safe to go at this point in time? Are there live power lines down? Is it overseas?” We never want to get in the way of rescue and recovery units either. The data is perishable, though, so we will have to move quickly.

For Wartman, the fully operational stage of the RAPID team in 2018 can’t come fast enough.

“I’ve done work with the Network for Earthquake Engineering Simulation (NEES) and we learned a lot but nothing is ever as rich and complex as the real world, Wartman said. “When a disaster strikes you have full-scale living lab. It’s extraordinary to go in and learn how systems function. The recon findings are of great value in a limited amount of time and often on a smaller budget. You learn fundamental things that might inspire follow up work in the labs. We are the only facility in world that does this.”

For more information on the University of Washington RAPID team please visit https://rapid.designsafe-ci.org.

Jupyter Notebooks underscore initial webinars

DesignSafe hosted three webinars this Fall providing users with hands-on training for how to upload, manage, and analyze their research data using the scientific applications available in DesignSafe’s Data Depot and Discovery Workspace within the Research Workbench.

The initial webinars provide foundational training on general use of DesignSafe, the use of MATLAB, and the use of Jupyter Notebooks for both DesignSafe and third-party software.

Jupyter Notebook usage was encouraged and example Jupyter Notebooks were provided in the Data Depot that users can copy and customize for their research.

The webinar recordings are available online in our Training Archive. In the Spring we will continue the webinar series, starting with an introductory session for researchers that are new to DesignSafe along with some sessions on advanced topics to explore more in-depth use cases of DesignSafe for natural hazards engineering research.

Allocations policy for high performance computing

DesignSafe Allocations Policy for Access to High Performance Computing Resources

DesignSafe’s Discovery Workspace provides access to many scientific applications supporting natural hazards engineering research that use the high performance computing resources at the Texas Advanced Computing Center (TACC). A modest amount of computing time is allocated to each DesignSafe user for scientific codes such as ADCIRC, OpenSEES, OpenFOAM, and others. Users requiring additional computing time with access to a larger number of processing cores or more data storage may submit allocation requests per our Allocations Policy. The DesignSafe project team will work with researchers to determine the optimal approach to meeting your computing and storage needs while maintaining the data sharing, discoverability, and reuse advantages of the Data Depot.

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“A science plan can be used in different ways by different groups,” Wartman said. “Researchers can look at it and develop research plans to address the issues that we encounter. In five years, the science plan will help us see what we have accomplished.”

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Wall of Wind blows researchers away

Florida International University recently had a chance to blow perspective researchers away. FIU hosted its 2016 National Science Foundation NHERI Wall of Wind Experimental Facility User Workshop on Nov. 18. The goal of the workshop was to spread the word to people in the engineering community about the facilities capabilities and the work being done there.

Arindam Chowdhury, director of the laboratory for wind engineering at the FIU International Hurricane Research Center and associate professor in the civil and environmental departments at FIU, was thrilled to show off the wall of wind. “It was a great opportunity to show what our facilities are capable of,” Chowdhury said. I think they really got to learn a lot from the wall of wind doing hands on experiments. Seeing it in person is a totally different thing than seeing videos or pictures.”

The workshop kicked off with a tour of the Wall of Wind facility. Attendees were shown the facilities and introduced to some of the research that has been ongoing at the Wall of Wind. Chowdhury feels that many left with a good idea of the types of research people can do at the facility. “We got a good indication of who is interested in what proposals in the near future,” Chowdhury said. “We got interest from several potential users. If anyone wants to submit a proposal or setting up a conference,” Chowdhury said.

With much of NHERI focused on earthquake research the Wall of Wind hopes to expand and grow the wind hazard research community. Like other NHERI facilities the ability to collaborate is a huge asset for the Wall of Wind. By having multiple institutions being able to work together the research possibilities grow. Later in the afternoon the conference attendees were split up into three different groups to discuss the future of NHERI.

“We had three groups and moderators that spoke to the groups about how we can improve NHERI as well as future project ideas,” Chowdhury said. “This discussion included ideas for the non-wind facilities.”

Overall Chowdhury feels the conference went very well and will help to further the awareness of the Wall of Wind and the future of wind based research. “We had a forum and it indicated that there are people interested in submitting a proposal or setting up a conference,” Chowdhury said. “We got interest from several potential users. If anyone wants to diversify and do multi-hazard testing this is the place to come to.”

The state that comes to mind the most often when people think of earthquakes in the United States is California. In comparison to The Golden State, the Pacific Northwest region remains largely unprepared for “the big one” and at the University of Washington, engineers are working to develop solutions to potential problems caused by seismic events. By working to improve the resilience of buildings, bridges and other structures, researchers hope to find ways to minimize the damage in the event of an earthquake.

In this lecture by Jeffery Berman, associate professor of civil and environmental engineering at the University of Washington, you can learn about earthquake hazards in the Pacific Northwest and examine the structural engineering technologies that enable quicker and more efficient post-event repairs.

Education Corner

University of Washington looks at seismic events in the Pacific Northwest

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Know your ECO

With all the exciting work being done at NHERI sites across the country, somebody has to help spread the word. That’s where the NHERI Education and Community Outreach (ECO) committee comes into play.

The ECO has a representative at each NHERI site. ECO team members all combine their efforts into the planning and strategic actions that NHERI as a whole takes. They also help report the educational activities that are happening at their sites. One such ECO committee member is Karina Vielma-Cumpian, a research fellow and outreach specialist at The University of Texas at San Antonio. Vielma-Cumpian says the scope of the ECO covers all levels of education.

“It (ECO) encompasses all educational activities that connect the research to the practice,” Vielma-Cumpian said. “We have K-12 outreach and that’s important to keeping kids motivated to go into STEM fields,” Vielma-Cumpian said. “At the undergraduate level, we have competitions and the research experience for undergraduate students (RFU). Then we have the graduate students who act as mentors to the undergraduate students. We also have graduate students that will be participating in the summer institute.”

Vielma-Cumpian thinks that the connections being made will positively impact the field and future STEM students. “I think the engineering world has room for everyone to do something,” Vielma-Cumpian said. “It’s just a matter of making those connections to students.”
Continued from front

Engineering Center — everything from wind turbines, to parking garages, to one-story residential structures and six-story concrete buildings. Back in 2011, Hutchinson assembled a team of engineers to test the safety of a five-story building's nonstructural components — elevators, stairs and facades. Those tests resulted in new building design requirements and new construction methods — and will likely yield more insights in coming years.

More recently, researchers tested different ways to retrofit wood-frame soft-story structures, which feature large open spaces on the first floor. The series of tests was critical to an initiative to seismically retrofit about 6,000 of these buildings in California alone.

Earthquake engineering is very important for society because engineers help lessen the number of deaths in earthquakes and decrease disruptions on society, said Joel Coe, a professor of structural engineering and the principal investigator on the Jacobs School's shake table. The facility has made a significant impact on building design and codes, he said.

Hutchinson's latest $1.5 million project is a good example for the facility's mission. It is supported by a coalition of government agencies, foundations and industry partners including the U.S. Department of Housing and Urban Development, the California Seismic Safety Commission and partners from the steel industry and insurance companies. The researchers received approximately $1 million in in-kind donations from industry partners to build and outfit the structure.

The building's architectural layout was designed to replicate a multi-family residential condominium or apartment building at full scale. But in this case, engineers were pushing the limit of structural height, erecting the building 64 feet above the shake table. The largest building of this construction type tested before was a two-story residential structure. Testing a building at full scale is important because certain failure mechanism can't be reproduced when structures are scaled down, said Conte. In this recent experiment, engineers were trying to find out how a mid-rise building made of cold-formed steel framing would perform during an earthquake and a post-earthquake fire. The answer is that it did well after going through the seismic tests. "The building could have been easily repaired," Hutchinson said. "The occupants would have gotten out safely."

Hutchinson believes that it's likely because the structure is lighter than a concrete building of the same height and as a result has less mass to generate damaging forces.

The fire tests were less kind to the structure, which was equipped with few fireproof materials and fire- stop systems. Researchers led by Brian Meacham, a professor at the Worcester Polytechnic Institute, ignited pools of heptane, a liquid fuel, in eight rooms on the building's second and sixth floors to achieve temperatures as high as 1000 degrees Celsius (almost 1800 degrees Fahrenheit) within the seismically damaged rooms. Doors fell off their plastic hinges, which melted. Several of the researchers' video cameras, installed to record the fire's progression, suffered a similar fate. Finishing materials detached from ceilings and walls. The simulated earthquakes occurring after the fire tests further weakened some of the structures' floors, bringing them close to collapse.

The building's performance was captured by an extensive array of more than 250 analog sensors, as well as digital cameras, and of course, by drones. The drones, operated by the research group of professor Falko Kuester, took 4k video footage of the building during each of the tests as well as hundreds of high-resolution images, before and after.

"We used the drones to get the right sensor to the right location at the right time," Kuester said. And his team then compiled the data into high-resolution 3D models consisting of billions of data points, called point clouds. Hutchinson, Conte and colleagues navigated through the point clouds together using the tall, curved display environment called the WAVE (for Wide-Angle Virtual Environment). The WAVE is a Holodeck-like environment that allows the viewer to step into a virtual recreation of the research. An array of 35 monitors that ends in a crest above viewers' heads and a trough at their feet, the WAVE fills a person's field of view for 180 degrees at the vertical and 160 degrees at the horizontal. If you are wearing special 3D glasses, the display can also tell where you are looking and adjust the images it shows accordingly. Users can step back to study the entire structure and then zoom in to see the tiniest details, such as cracks and changes in shape and color.

"This is big VR for big data and big science," Kuester said.

The WAVE and its software allow researchers to travel through space and time to explore how structures have changed and how they have been damaged by natural disasters or earthquakes.

At the same time, the shake table allows researchers to gather baseline data before and right after an extreme event, an opportunity that they wouldn't have in real life.

"Well then have high definition data from before, during and after the test, which was very rare available before," Kuester said.

The next step for engineers is to look closely at this data and produce a series of technical reports and scientific papers — a process that could take a year or so.

UC San Diego's shake table is funded by a $5.2 million grant from the National Science Foundation. The facility is part of the NSF's Natural Hazards Engineering Research Infrastructure — a network of over 20 such research facilities and tools designed to better understand and prevent earthquakes as well as wind and water hazards.

### Recent NHERI grant awardees

All awards are funded by the National Science Foundation.

**Natural Hazards Engineering Research Infrastructure: Experimental Facility with Large-Scale, Multi-directional, Hybrid Simulation Testing Capabilities**

- **James Ricles** (Principal Investigator)
- **Richard Sause** (Co-Principal Investigator)
- **Lehigh University**

Award amount: $3,040,268.00
Start Date: January 1, 2016   End Date: December 31, 2020 (Estimated)

**Natural Hazards Engineering Research Infrastructure: Experimental Facility with Geotechnical Centrifuges**

- **Ross Boulanger** (Principal Investigator)
- **Bruce Kutter** (Co-Principal Investigator)
- **Daniel Wilson** (Co-Principal Investigator), UC Davis

Award amount: $2,934,099.00
Start Date: January 1, 2016   End Date: December 31, 2020 (Estimated)

**Natural Hazards Engineering Research Infrastructure: Experimental Facility with Large Wave Flume and Directional Wave Basin**

- **Daniel Cox** (Principal Investigator)
- **Christopher Higgins** (Co-Principal Investigator)
- **Pedro Lomosano** (Co-Principal Investigator), Oregon State University

Award amount: $1,451,079.00
Start Date: January 1, 2016   End Date: December 31, 2020 (Estimated)

**Natural Hazards Engineering Research Infrastructure: Experimental Facility with Large, Dynamic Shakers for Field Testing**

- **Kenneth Stokoe** (Principal Investigator)
- **Brady Cox** (Co-Principal Investigator)
- **Patricia Clayton** (Co-Principal Investigator), University of Texas at Austin

Award amount: $1,475,349.00
Start Date: January 1, 2016   End Date: December 31, 2020 (Estimated)

**Natural Hazards Engineering Research Infrastructure: Experimental Facility with Large-Scale, Multi-directional, Hybrid Simulation**

- **James Ricles** (Principal Investigator)
- **Ioannis Zisis** (Co-Principal Investigator), UC Davis

Award amount: $1,508,392.00
Start Date: January 1, 2016   End Date: December 31, 2020 (Estimated)

**Natural Hazards Engineering Research Infrastructure: Experimental Facility with Twelve-Fan Wall of Wind**

- **Antonio Bobet** (Co-Principal Investigator)
- **Julio Ramirez** (Co-Principal Investigator), Pennsylvania State University

Award amount: $4,190,000.00
Start Date: July 1, 2016   End Date: June 30, 2021 (Estimated)

**Natural Hazards Engineering Research Infrastructure: Post-Disaster, Rapid Response Research (RAPID) Facility**

- **Joseph Wartman** (Principal Investigator)
- **Michael Olsen** (Co-Principal Investigator)
- **Jennifer Irish** (Co-Principal Investigator)
- **Scott Miles** (Co-Principal Investigator)
- **Jeffrey Berman** (Co-Principal Investigator), University of Washington

Award amount: $797,098.00
Start Date: September 1, 2016   End Date: August 31, 2021 (Estimated)

**Natural Hazards Engineering Research Infrastructure: Cyberinfrastructure**

- **Ellen Rafiee** (Principal Investigator)
- **Jean-Paul Pinelli** (Co-Principal Investigator), University of California, Berkeley
- **Clinton Dawson** (Co-Principal Investigator), University of Washington
- **Ellen Rathje** (Principal Investigator), University of Washington

Award amount: $8,000,000.00
Start Date: July 1, 2015   End Date: June 30, 2020 (Estimated)

**Natural Hazards Engineering Research Infrastructure: Computational Modeling and Simulation Center**

- **Stephen Mahin** (Principal Investigator)
- **Ahban Kareem** (Co-Principal Investigator)
- **Gregory Dedeine** (Co-Principal Investigator)
- **Lauria Lowes** (Co-Principal Investigator)
- **Camille Crittenend** (Co-Principal Investigator), University of California-Berkeley

Award amount: $4,792,000.00
Start Date: October 1, 2016   End Date: September 30, 2021 (Estimated)
NHERI research in action

Student researchers work on a centrifuge at the Center for Geotechnical modeling at The University of California at Davis. Current experiments at UC Davis are focusing on soil structure and soil liquefaction.