Update: National Science Foundation
NEHRP ACEHR Meeting, November 7, 2018

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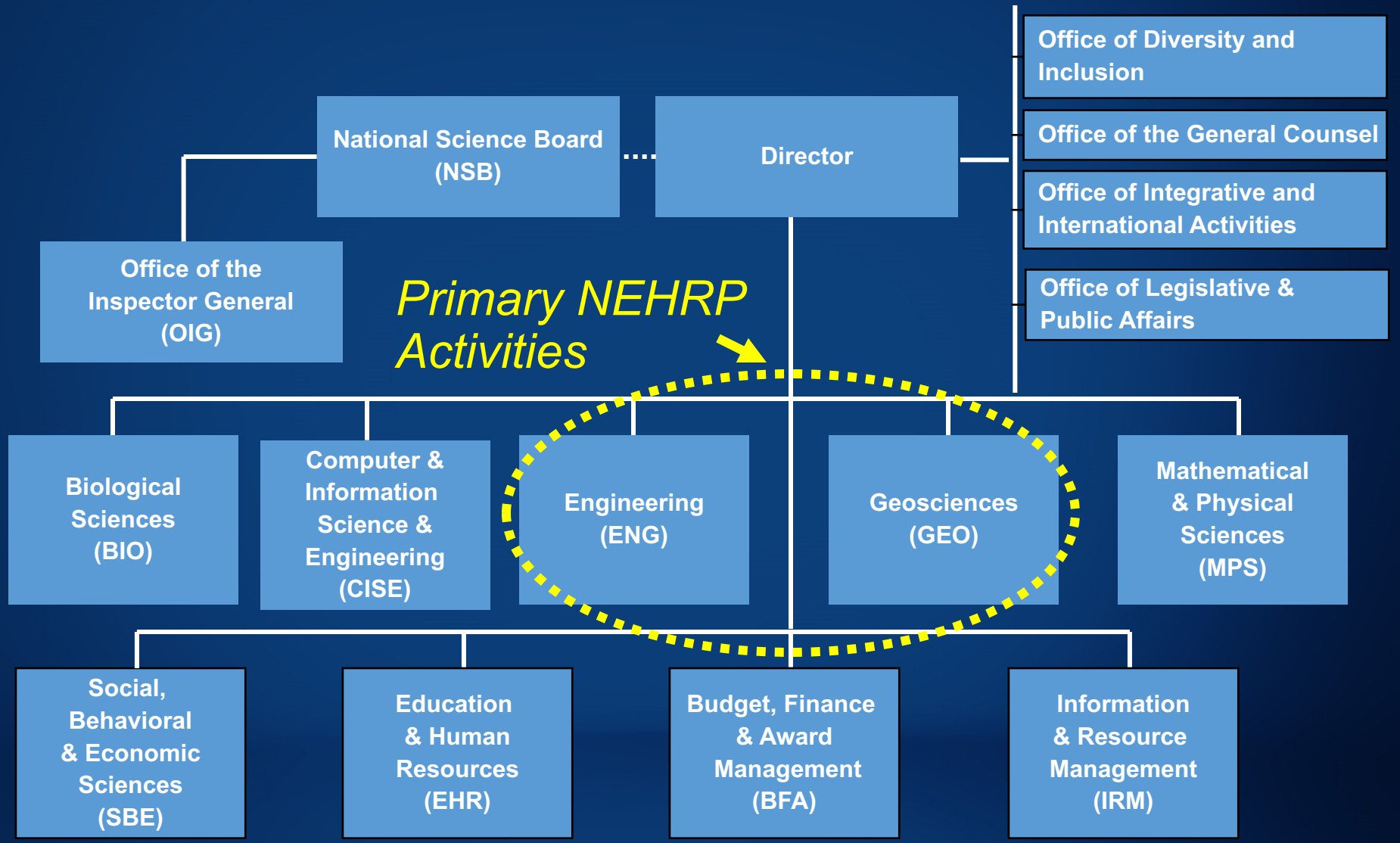
National Science Foundation



NSF Role in NEHRP

- Supports fundamental earthquake research - earth sciences, earthquake engineering, and social, behavioral and economic sciences through programs that support solicited and unsolicited proposals
- Includes support for
  - Fundamental research in earth sciences, earthquake engineering, and earthquake mitigation, preparedness, response and recovery
  - Research and data centers
  - Research infrastructure/facilities
  - Integration of research with education (e.g., CAREER, graduate and REU students)
  - Rapid response research (RAPID) (perishable data collection)
- Enables disciplinary and multidisciplinary research, from areas such as
  - Computer and information science and engineering
  - Earth sciences
  - Architecture/architectural engineering
  - Engineering (e.g., civil: structural, geotechnical, coastal; mechanical)
  - Social, behavioral, and economic sciences
  - Urban planning and geography

NSF Programs and Awards Supporting NEHRP Strategic Plan Goal A: Improve Understanding of Earthquake Processes and Impacts

ENG Programs Supporting NEHRP in the Division of Civil, Mechanical and Manufacturing Innovation (CMMI)

(As of August 15, 2018, ENG Core Unsolicited Programs no longer have deadlines)

- *Engineering for Civil Infrastructure (ECI) – core unsolicited program*
  - Supports research on the impact/mitigation of earthquakes and windstorms on civil infrastructure
  - https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505488
  - Supports research awards, including RAPID awards
  - Dear Colleague Letter: Discoveries to Revolutionize Engineering and Architectural Materials for Buildings (DREAM-B)

- *Humans, Disasters, and the Built Environment (HDBE), formerly IMEE – core unsolicited program*
  - Supports multidisciplinary research on the interactions between humans and the built environment within and among communities exposed to natural, technological and other types of hazards and disasters
  - https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13353
  - Supports research awards, including RAPID awards
  - Support for Natural Hazards Center at University of Colorado, Boulder

- *Natural Hazards Engineering Research Infrastructure (NHERI)* (NSF 14-605 and NSF 15-598)
  - Provides research and education tools for understanding the impacts of earthquake and windstorms on civil infrastructure
  - Network Coordination Office
  - Cyberinfrastructure
  - Computational Modeling and Simulation Center
  - Eight Experimental Facilities, including a RAPID facility

Examples of Recent ECI Awards (Geotechnical)

- Collaborative Research: Soil-Structure-Water Interaction Effects in Buried Reservoirs - Centrifuge and Numerical Modeling (NSF Awards 1763129 and 1762749)
- Experimental Investigation of Wave, Surge, and Tsunami Transformation over Natural Shorelines (NSF Award 1825080)
- Collaborative Research: Seismic Isolation of Embedded Foundations Using Periodic Meta-material Barriers to Create Resilient Structures (NSF Awards 1761659 and 1761597)
- Collaborative Research: Bridging the In-situ and Elemental Cyclic Response of Transitional Soils (NSF Awards 1663654 and 1663531)
- RAPID/Collaborative Research: Dynamic Site Characterization Following Mw 7.1 Puebla Earthquake for Development of a Refined 3D Shallow Crust Velocity Model of the Mexico City Basin (NSF Awards 1822484, 1822488, and 1822482)
- RAPID/Collaborative Research: Investigating Unanticipated Geotechnical Phenomena in Kumamoto, Japan, Observed from the April 2016 Earthquake Sequence (NSF Awards 1727593 and 1727594)

Examples of Recent ECI Awards (Liquefaction)

- Collaborative Research: Validation of Constitutive and Numerical Modeling Techniques for Soil Liquefaction Analysis (NSF Awards 1635307, 1635524, and 1635040)
- Field Application of Induced Partial Saturation (IPS) for Liquefaction Mitigation (NSF Award 1633970)
- Pile Foundations Under Inertia and Liquefaction-Induced Lateral Spreading (NSF Award 1761712)
- CAREER: Decoding the Enigmas of U.S. Seismic Hazard Via Multi-Scale, Multi-Physics Approaches to Paleoliquefaction Analysis (NSF Award 1751216)
- Evaluation of Liquefaction Potential of Saturated Granular Soils under Partial Drainage Conditions (NSF Award 1728612)
- Collaborative Research: Novel Measurement of Shear Strength Evolution in Liquefied Soil and Calibration of a Fluid Dynamics-based Constitutive Model for Flow Liquefaction (NSF Awards 1728172 and 1728199)
- Evaluating Liquefaction Potential of Challenging Soil Sites: Linking Geomorphological Controls and Novel Approaches for Site Characterization (NSF Award 1825189)
- United States-New Zealand-Japan International Workshop on Liquefaction-Induced Ground Movements Effects; Berkeley, California; November 2-3, 2016 (NSF Award 1640922)

Examples of Recent ECI Awards (Structures)

Structural Reinforced Concrete and Masonry Systems

- RUI/Collaborative Research: Framework for Earthquake-Resilient Design of Tall Buildings (NSF Awards 1563577 and 1563428)
- Collaborative Research: Resilient Seismic Retrofit by Integrating Selective Weakening and Self-Centering (NSF Awards 1663063 and 1662963)
- RAPID/Collaborative Research: Investigation of Reinforced Concrete Buildings Damaged in the Magnitude 6.4 Southern Taiwan Earthquake of February 2016 (NSF Awards 1637169 and 1637163)
- Collaborative Research: Self-Centering Pendulum Shear Walls in Buildings via Nonlinear Elastic Kinematics (NSF Awards 1762119 and 1762170)
- RAPID/Collaborative Research: The Effects of the 2017 Central Mexico Earthquake on Reinforced Concrete Buildings (NSF Awards 1810870, 1810907, 1810876, 1811084, and 1810899)
- Collapse Simulation of Shear-Dominated Reinforced Masonry Wall Systems (NSF Award 1728685)

Examples of Recent ECI and PFI Awards (Structures)

Structural Wood Systems

- Enabling Next Generation Hybridized Wood Buildings for Resilient and Sustainable Construction (NSF Award 1537788)
- Achieving Sustainable Urban Buildings with Seismically Resilient Mass Timber Core Wall and Floor System (NSF Award 1563612)
- Collaborative Research: A Resilience-based Seismic Design Methodology for Tall Wood Buildings (NSF Awards 1636164, 1635227, 1635156, 1634628, 1634204, and 1635363)
- RAPID/Collaborative Research: Japan-U.S. Collaboration on the Seismic Resilience of Wood-frame Building Systems (NSF Awards 1829433 and 1829412)

Advancing Mass Timber Building Systems and Modeling

- Collaborative Research: Innovation in Sustainable Mass Timber Building Systems (NSF Awards 1762526 and 1762757)
- PFI-RP: Manufacture of Durable and Stable Cross-Laminated Strand-Veneer Lumber for Mass Timber Construction (NSF Award 1827434)

Examples of Recent ECI Awards (Structures)

Structural Steel Systems

- Collaborative Research: Transforming Building Structural Resilience through Innovation in Steel Diaphragms (NSF Awards 1562821, 1562669, and 1562490)
- Collaborative Research: Simulating Crack Propagation in Steel Structures Under Ultra-Low Cycle Fatigue and Low-Triaxiality Loading from Earthquakes and Other Hazards (NSF Awards 1635043 and 1634291)
- Advancing Knowledge on the Performance of Seismic Collectors in Steel Building Structures (NSF Award 1662816)
- Collaborative Research: Seismic Resiliency of Repetitively Framed Mid-Rise Cold-Formed Steel Buildings (NSF Awards 1663569 and 1663348)
- CAREER: A Micromechanics-Based Approach to Ductile Fracture Simulation in Additively Manufactured Steels for Seismic Structural Fuse Design (NSF Award 1751699)
- System Level Seismic Performance of Steel Gravity Framing (NSF Award 1825691)

Examples of Recent ECI Awards (Structures)

- EAGER: A New Perspective on Seismic Intensity Measures and Fragility Analysis (NSF Award 1639669 co-funded w/IMEE)
- CAREER: Using Metamodeling to Enable High-Fidelity Modeling in Risk-based Multi-hazard Structural Design (NSF Award 1750339)
- Vertical Evacuation Structures Subjected to Sequential Earthquake and Tsunami Loadings (NSF Award 1726326)
- RCN: Research Network in Hybrid Simulation for Multi-Hazard Engineering (NSF Award 1661621)

NSF Engineering/ECI Program Highlight
Engineering Earthquake Resilience in Downtown Skyscrapers
(NSF Award 1538866)

https://www.nsf.gov/news/special_reports/science_nation/resilienttallbuildings.jsp?WT.mc_id=USNSF_51

“Structural engineers at the University of California, Los Angeles, (UCLA) are using downtown Los Angeles as a testbed to broaden the design of earthquake-resistant buildings to earthquake-resilient communities. In this case, resilience means that in the event of a major earthquake, or even "the big one," tall buildings would better withstand the initial impact, and clusters of skyscrapers would be able to recover more quickly from any disruptions, such as water and power outages. The key is in the data and computer modeling.

With support from the National Science Foundation (NSF), the UCLA team is creating new models that incorporate performance data not only from shake-table tests, but from sensor networks in actual buildings. The models and new systems the team engineers are meant to guide safety inspections following earthquakes, helping engineers get to hotspots more quickly.”

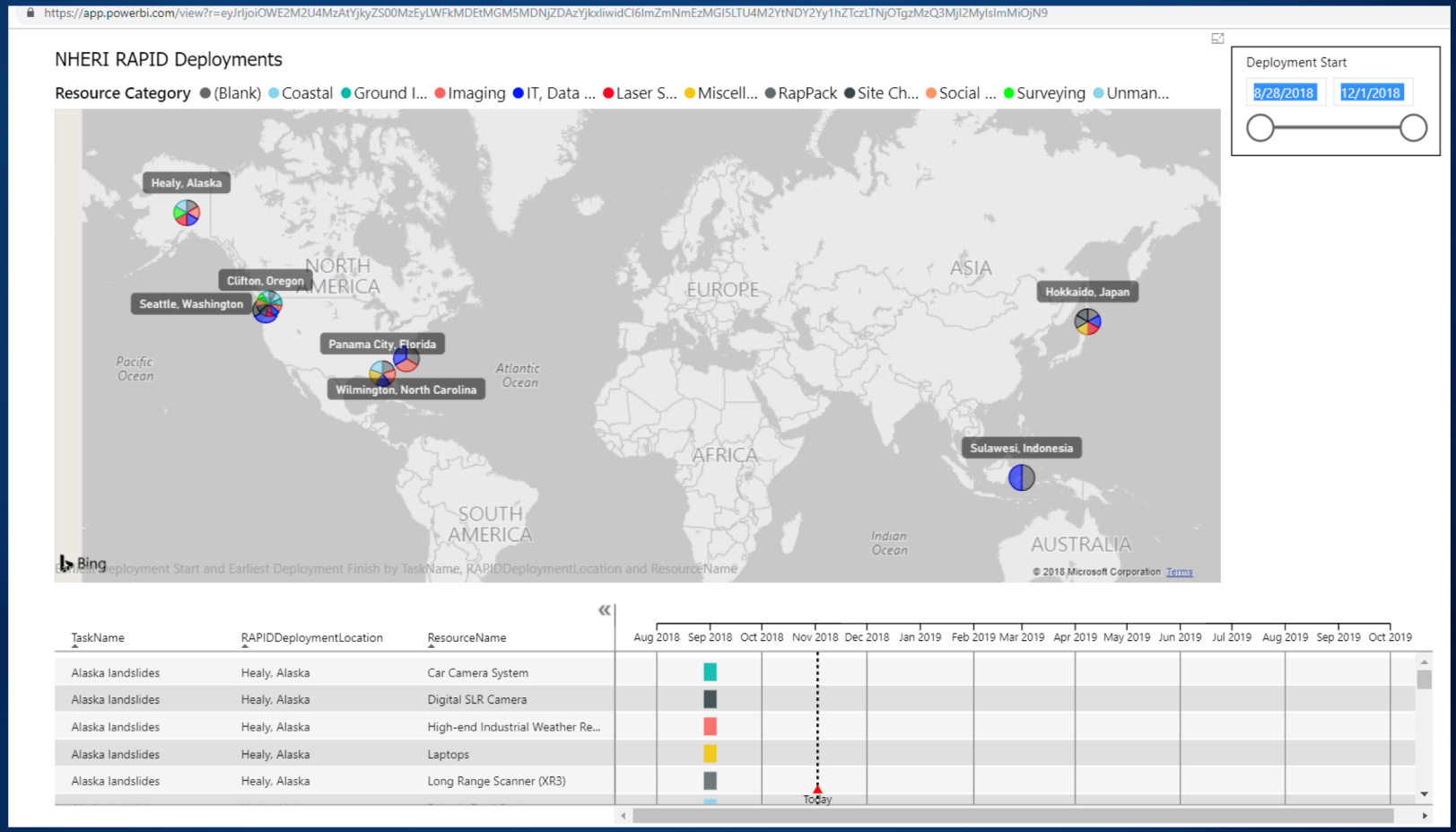
Natural Hazards Engineering Research Infrastructure (NHERI)
https://www.designsafe-ci.org/

Component	Institution	NSF Award
Network Coordination Office	Purdue University	1612144
Cyberinfrastructure	University of Texas at Austin	1520817
Computational Modeling and Simulation Center	University of California, Berkeley	1612843
Twelve-Fan Wall of Wind	Florida International University	1520853
Large-Scale, Multi-Directional, Hybrid Simulation Testing Capabilities	Lehigh University	1520765
Large Wave Flume and Directional Wave Basin	Oregon State University	1519679
Geotechnical Centrifuges	University of California, Davis	1520581
Large, High-Performance Outdoor Shake Table	University of California, San Diego	1520904
Boundary Layer Wind Tunnel, Wind Load and Dynamic Flow Simulators, and Pressure Loading Actuators	University of Florida	1520843
Large, Mobile Dynamic Shakers for Field Testing	University of Texas at Austin	1520808
Post-Disaster, Rapid Response Research (RAPID) Facility (operational on September 1, 2018)	**University of Washington**	**1611820**

NHERI RAPID Facility
University of Washington

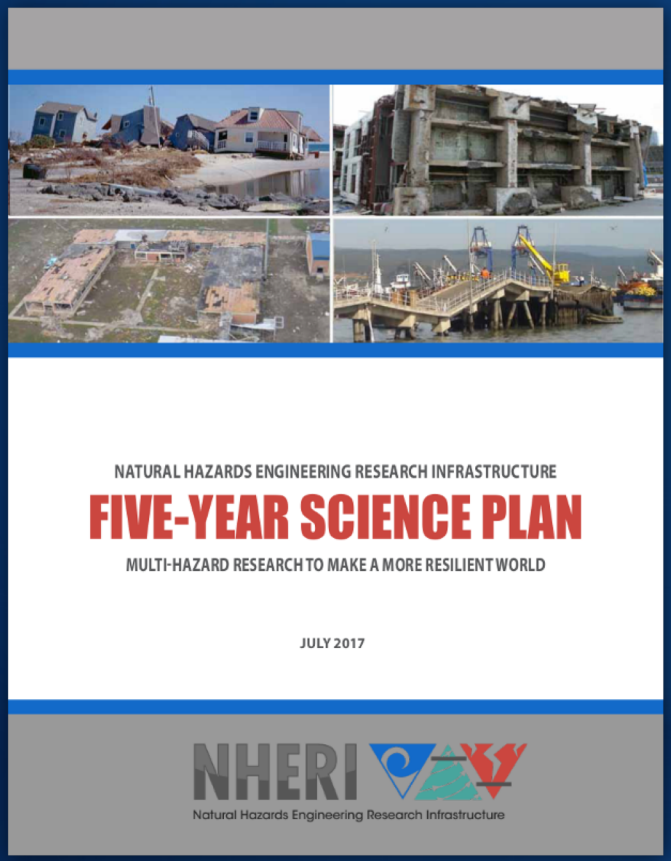
https://rapid.designsafe-ci.org/

Recent Deployments



Natural Hazards Engineering Research Infrastructure

NHERI Science Plan
https://www.designsafe-ci.org/facilities/nco/science-plan/



July 2017 release; to be updated 2019

"Three Grand Challenge subject areas are:

1. Identify and quantify the characteristics of earthquake, windstorm, and associated hazards — including tsunamis, storm surge, and waves — that are damaging to civil infrastructure and disruptive to communities.
2. Evaluate the physical vulnerability of civil infrastructure and the social vulnerability of populations in communities exposed to earthquakes, windstorms, and associated hazards.
3. Create the technologies and engineering tools to design, construct, retrofit, and operate a multi-hazard resilient and sustainable infrastructure for the nation."

NHERI Computational Modeling and Simulation Center (SimCenter) University of California, Berkeley

Research Tools Released

https://simcenter.designsafe-ci.org/research-tools/overview/

- uqFEM Application
- CWE-UQ Application
- EE-UQ Application
- PBE Application
- Regional Hazards Workflow

Learning Tools Released

https://simcenter.designsafe-ci.org/learning-tools/overview/

- MDOF
- Pile Group Tool
- Earthquake vs. Wind
- Braced Frame Modeling

NSF Mid-Scale Research Infrastructure

- Natural Hazards Engineering Research Infrastructure: Upgrade of the Large High Performance Outdoor Shake Table to Six Degrees of Freedom (NSF Award 1840870)
  - Award to University of California, San Diego
  - $16.3 M over three years

- Dear Colleague Letter: Mid-Scale Research Infrastructure (Mid-scale RI) Opportunities (NSF 19-013): transform scientific and engineering research fields by making available new capabilities, while simultaneously training researchers in the acquisition, implementation, development, design, and/or construction of cutting-edge infrastructure.
  - FY 2019 Solicitation for $6M - ~$20M
  - FY 2019 Solicitation for $20M - $70M

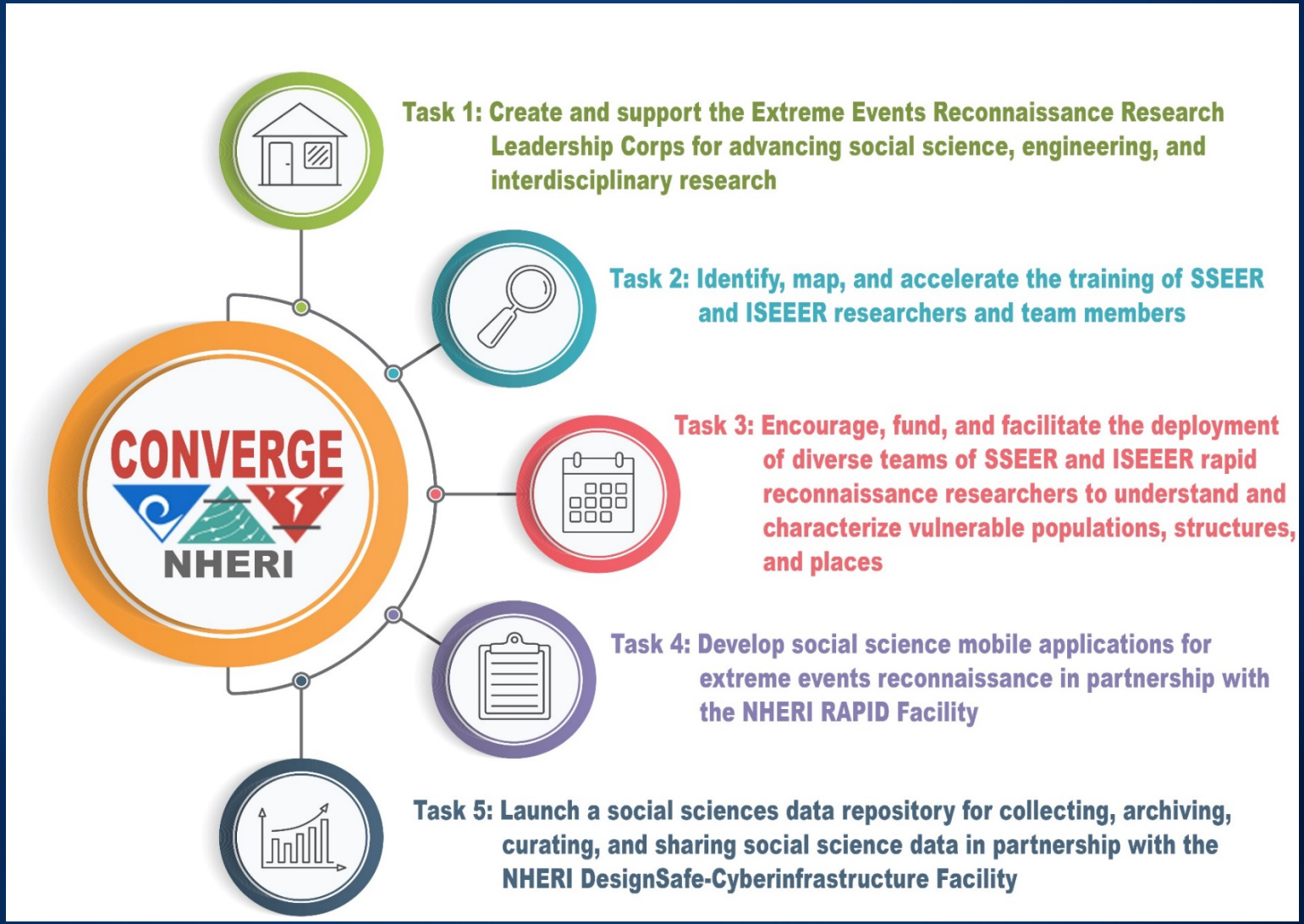
Examples of Recent ENG Awards Post-Disaster Science

- CONVERGE: Coordinated Social Science, Engineering, and Interdisciplinary Extreme Events Reconnaissance Research (NSF Award 1841338)
- Collaborative Research: GEER Post Disaster Reconnaissance (NSF Awards 1826118, 1825351, 1825249, and 1826458)
- EAGER: Operationalization of the Structural Extreme Events Reconnaissance (StEER) Network (NSF Award 1841667)
- EAGER: Interdisciplinary and Social Science Extreme Events Reconnaissance (ISSEER) (NSF Award 1745611)
- Workshop: Hazards and Disaster Researchers Meeting: Improving Post-Disaster Rapid Reconnaissance Research; Broomfield, Colorado; July 11-12, 2018 (NSF Award 1833298)

Examples of Recent ENG Awards
CONVERGE (NSF Award 1841338)

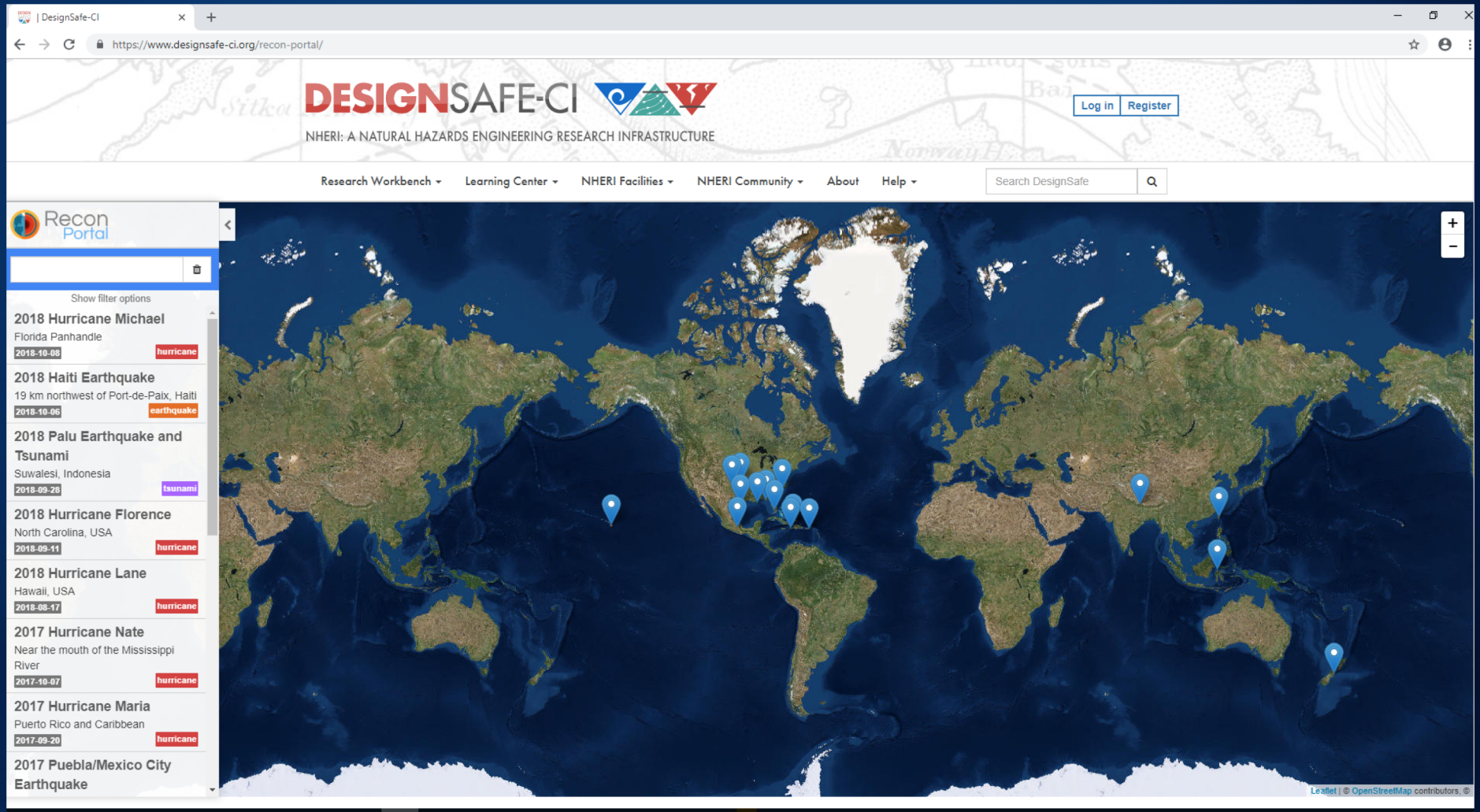
Graphics Courtesy of Dr. Lori Peek, University of Colorado, Boulder

CONVERGE (NSF Award 1841338)



Graphics Courtesy of Dr. Lori Peek, University of Colorado, Boulder

NHERI Reconnaissance Portal
https://www.designsafe-ci.org/recon-portal/



Examples of Recent ENG/HDBE Awards

- Decision Entropy: A New Theory for Representing Uncertainty in Managing Natural Hazard Risks (NSF Award 1636217)
- A Clearinghouse on Natural Hazards Applications (NSF Award 1635593)
- Assessing the Influence of Cultural Variables, Perceptions, and Earthquake Hazard Information on Household Emergency Preparedness (NSF Award 1663642)
- EAGER: A Dynamic, Reliability-Weighted, Multi-Pass Probabilistic Framework to Reduce Uncertainty in Crowd-Sourced Post-Disaster Damage Assessments (NSF Award 1645335)
- RAPID: Building Community Resilience: Understanding Homeowner Response to Extreme Events (NSF Award 1715197)
- RAPID/Collaborative Research: Households Immediate Response During a Night Time Earthquake (NSF Awards 1833084 and 1833076)
- Household Risk Perceptions and Hazard Adjustments to Earthquakes in Oklahoma (NSF Award 1827851)
- Collaborative Research: Understanding Evacuation Behavior for Rapid Onset Disasters such as Flash Floods and Tsunamis in the Cascadia Subduction Zone (NSF Awards 1826407 and 1826455)

Examples of Recent Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) Awards

The goals of the CRISP solicitation are to:

(1) foster an interdisciplinary research community of engineers, computer and computational scientists and social and behavioral scientists, that creates new approaches and engineering solutions for the design and operation of infrastructures as processes and services;

(2) enhance the understanding and design of interdependent critical infrastructure systems (ICIs) and processes that provide essential goods and services despite disruptions and failures from any cause, natural, technological, or malicious;

(3) create the knowledge for innovation in ICIs so that they safely, securely, and effectively expand the range of goods and services they enable; and

(4) improve the effectiveness and efficiency with which they deliver existing goods and services.

RECENT AWARDS

- CRISP Type 2: Interdependencies in Community Resilience (ICoR): A Simulation Framework (NSF Award 1638186)
- CRISP Type 2/Collaborative Research: Defining and Optimizing Societal Objectives for the Earthquake Risk Management of Critical Infrastructure (NSF Awards 1735499, 1735407, 1735483, and 1735539)
- CRISP 2.0 Type 1: Collaborative Research: Distributed Edge Computing to Improve Resilience of Interdependent Systems (NSF Awards 1832711, 1832688, and 1832683)

Examples of Recent ENG/Innovation Awards

NSF I-Corps program prepares scientists and engineers to extend their focus beyond the university laboratory and accelerates the economic and societal benefits of NSF-funded, basic-research projects that are ready to move toward commercialization.

- I-Corps: Crowdsource sensing of earthquakes (NSF Award 1744819)
- I-Corps: Autonomous Seismic-Controlling System (NSF Award 1758196)
- I-Corps: Dual adaptive self-centering system for mitigating earthquake-induced damage and wind induced vibrations of structures (NSF Award 1836746)

NSF Small Business Innovation Research program supports startups and small businesses to transform their ideas into marketable products and services

- SBIR Phase I: Achieving a scalable Earthquake Early Warning System (EEWS) with a sub-second response (NSF Award 1746187)
- SBIR Phase I: MetaMaterial for Seismic Energy Absorption (NSF Award 1721975)

Examples of Recent NSF-supported Earthquake and Earthquake-related Workshop Awards

- A Career Development Workshop for Early Career Geotechnical Engineering Faculty; Cleveland, Ohio; Fall 2017 (NSF Award 1748944)
- The Second Cargese School on Earthquakes - Participant Support (NSF Award 1743284)
- Workshop/Collaborative Research: Interdisciplinary Methods for Disaster Research (NSF Awards 1744225 and 1649879)
- Workshop on Additive Manufacturing (3D Printing) for Civil Infrastructure Design and Construction; Arlington, Virginia; July 13-14, 2017 (NSF Award 1713983)
- Workshop: Hazards and Disaster Researchers Meeting: Improving Post-Disaster Rapid Reconnaissance Research; Broomfield, Colorado; July 11-12, 2018 (NSF Award 1833298)
- Resilience of Interdependent Infrastructure Systems: A CRISP/RIPS Grantees Workshop - September 25-26, 2018 - Fairfax/Arlington, VA (NSF Award 1807998)
- Scoping Workshops for Coastlines and People (NSF Award 1844215)
- Workshop on modeling earthquake source processes: from tectonics to dynamic rupture; October 8-10, 2018, Pasadena, CA (NSF Award 1836288)
- Workshop: Coastal Engineering Research Framework, Arlington, Virginia, November 12-13, 2018 (NSF Award 1835563)
- Workshop to Update the NHERI Science Plan, March 2019, Washington, DC area (NSF Award 1612144)

Seismological Facility for the Advancement of Geoscience (SAGE)

- Enabling Discoveries in Multiscale Earth System Dynamics: Seismological Facility for the Advancement of Geoscience (SAGE) - EAR Scope (NSF Award 1851048)

- Enabling Discoveries in Multiscale Earth System Dynamics: Seismological Facility for the Advancement of Geoscience (SAGE) - EAR Scope (NSF Award 1851971)

- Enabling Discoveries in Multiscale Earth System Dynamics: Seismological Facility for the Advancement of Geoscience (SAGE) - OPP Scope (NSF Award 1851037)

Geodetic Facility for the Advancement of Geoscience (GAGE)

- Enabling Discoveries in Multiscale Earth System Dynamics: Geodetic Facility for the Advancement of Geoscience (GAGE) - EAR Scope (NSF Award 1851159)

- Enabling Discoveries in Multiscale Earth System Dynamics: Geodetic Facility for the Advancement of Geoscience (GAGE) - OPP Scope (NSF Award 1851163)

- Enabling Discoveries in Multiscale Earth System Dynamics: Geodetic Facility for the Advancement of Geoscience (GAGE)-NASA Scope (NSF Award 1851169)

Examples of Recent EAR Awards

- Collaborative Research: Mining Seismic Wavefields (NSF 1818579, 1818582, 1818589 and 1818611) funded by the Geo-Informatics Program

- Phase I IUCRC at California Institute of Technology – Center for Geomechanics and Mitigation of Geohazards (GMG) (NSF 1822214) – jointly funded by GEO/ENG

- Funded by the Geophysics Program in EAR:
  - CAREER: Dynamics of surface rupturing thurst earthquakes (NSF 1749556)
  - CAREER: Along-strike Variation: A Comparative Study of Subduction Zones at Multiple Scales Using Joint Receiver Function and Tomographic Inversion (NSF 1751974)
  - CAREER: Multiscale Mechanics of Fluid Infiltrated Fault Zones – An Integrated Research and Education Plan. (NSF 1753249)
  - Architecture of the Subduction to Strike-Slip Transition in New Zealand (NSF 1756075)
  - NSF/EAR-BSF: Resolving slow slip transients before and after the 2011 Tohoku-oki earthquake with geodesy and seismicity (NSF 1801720)
  - A New Adjoint-state Full-waveform Tsunami Source Imaging Method (NSF 1833532)
  - Use of Artificial Intelligence toward Automation of Analog Seismogram Digitization (NSF 1822136)

NSF Support for NEHRP Strategic Plan Goal C, Objective 14:

"Develop the Nation's human resource base in earthquake safety fields"

NSF Support for NEHRP Strategic Plan Goal C, Objective 14 "Develop the Nation's human resource base in earthquake safety fields"

NSF Research Awards

- Typically support "xx" graduate students/year, where "xx" is number of students and dependent on award size
  - Typically one graduate student/faculty investigator
  - REU supplement to support 1-2 (typically) undergraduate students/year

NSF CAREER Awards (see previous slides)

Southern California Earthquake Center

- REU Site: Undergraduate Studies in Earthquake Information Technology (SCEC/UseIT) (NSF Award 1659880)

NHERI Network Coordination Office (NSF Award 1612144)

- NHERI-wide REU Site beginning in summer 2017
- NHERI Summer Institute (July 2017, June 2018, June 2019)

Enabling the Next Generation of Hazards and Disasters Researchers (NSF Award 1424075)

Examples of Recent NSF East Asia and Pacific Summer Institutes for U.S. Graduate Students (EAPSI) Awards

Supports graduate students for a research experience at a summer research institute in East Asia and Pacific locations and to develop professional relationships to enable future collaboration with foreign counterparts

- EAPSI: The Role of Silica-redistribution in Healing Subduction-related Fault Rocks (NSF Award 1713908)
- EAPSI: Investigation of Cryptic Dextral Faulting and Implications for Seismic Hazard (NSF Award 1713981)
- EAPSI: Numerical and Experimental Investigations of Supplemental Distributed Damping for Seismic Energy Dissipation (NSF Award 1713850)
- EAPSI: Earthquake Probability Assessment Using Slow Slip Events (NSF Award 1713928)

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