

National Science Foundation (NSF)

Update of NSF's Role in the National Earthquake Hazards Reduction Program (NEHRP) Advisory Committee on Earthquake Hazards Reduction (ACEHR) April 9, 2015 NIST Headquarters, Gaithersburg, MD

Joy M. Pauschke, Ph.D., P.E.

Program Director

Engineering for Natural Hazards Program (PD 15-7396)

Natural Hazards Engineering Research Infrastructure (NSF 14-605)

Division of Civil, Mechanical and Manufacturing Innovation

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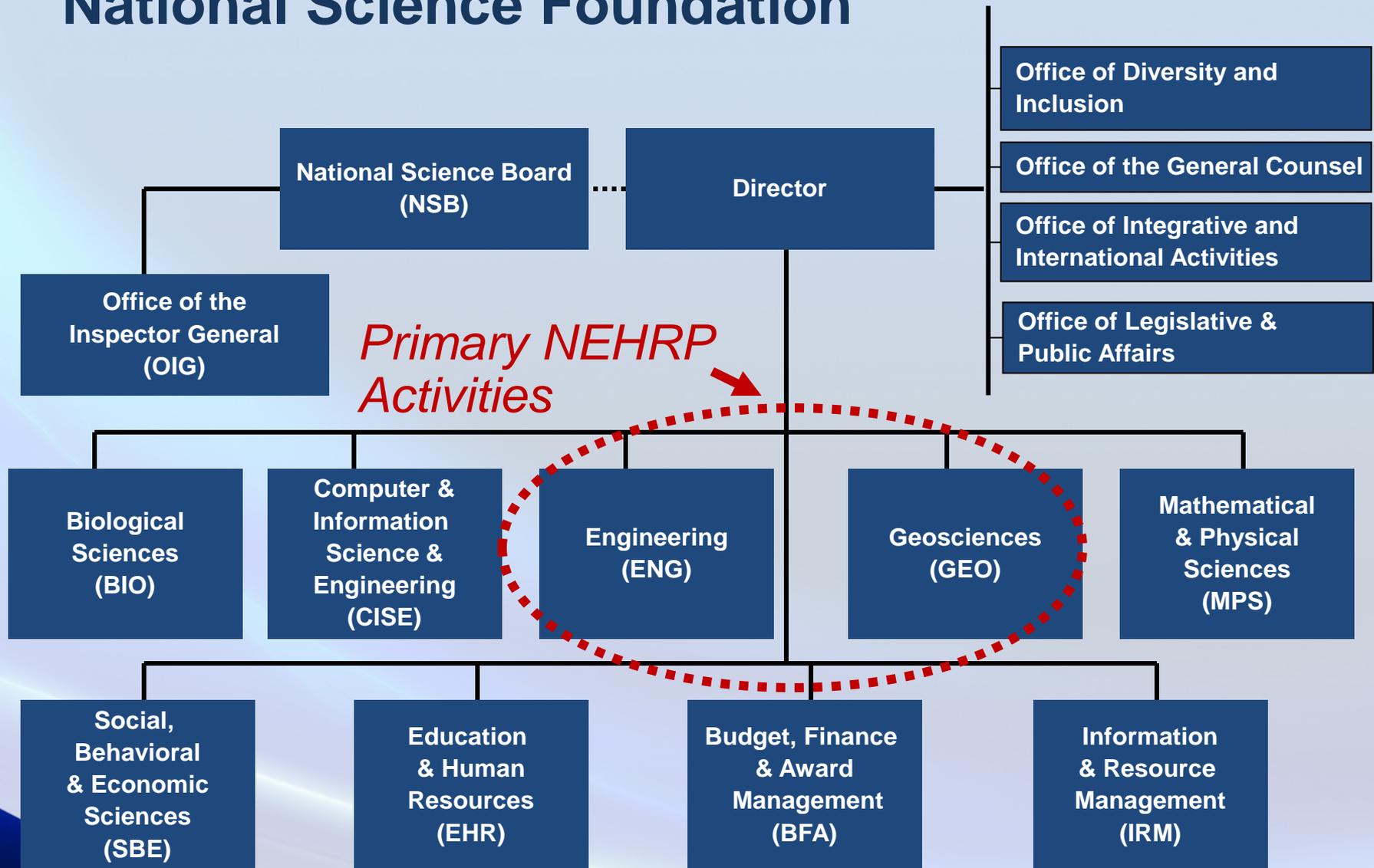


Outline

- About NSF
- NSF Directorate for Engineering (ENG) in NEHRP
- NSF Directorate for Geosciences (GEO) in NEHRP
- Examples of NSF Multidisciplinary Programs addressing hazards



National Science Foundation



National Science Foundation FY 2016 Budget Request

<http://www.nsf.gov/about/budget/fy2016/pdf/fy2016budget.pdf>

FY 2016 BUDGET REQUEST

NSF Budget by Appropriation (dollars in millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	Change Over FY 2015 Estimate	
				Amount	Percent
Research and Related Activities	\$5,775.32	\$5,933.65	\$6,186.30	\$252.66	4.3%
Education and Human Resources	\$832.02	\$866.00	\$962.57	\$96.57	11.2%
Major Research Equipment and Facilities Construction	\$200.00	\$200.76	\$200.31	-\$0.45	-0.2%
Agency Operations and Award Management	\$305.95	\$325.00	\$354.84	\$29.84	9.2%
National Science Board	\$4.25	\$4.37	\$4.37	-	-
Office of Inspector General	\$13.84	\$14.43	\$15.16	\$0.73	5.1%
TOTAL	\$7,131.39	\$7,344.21	\$7,723.55	\$379.34	5.2%

Totals may not add due to rounding.

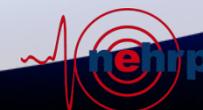
FY 2016 Cross-Foundation Investments includes “Risk and Resilience”
Risk and Resilience will include PREEVENTS and CRISP (see later slides)



NSF NEHRP Expenditures

Directorate	(Dollars in Millions)		
	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request
ENG	\$30.00	\$40.20	\$42.20
GEO	\$12.00	\$12.00	\$12.00
Total	\$42.00*	\$52.20	\$54.20

*Does not include for FY 2014 per the NSF FY 2016 Budget Request: Carryover from FY 2014 into FY 2015 – approximately \$8.47 million for awards to be made in FY 2015 under program solicitation NSF 14-557, Decision Frameworks for Multi-Hazard Resilient and Sustainable Buildings (RSB). NEHRP expenditures for FY 2015 will be reflected in the FY 2015 Actuals.



NSF Role in NEHRP

- Supports basic earthquake research - earth sciences, earthquake engineering, and social, behavioral and economic sciences - through programs that support solicited and unsolicited proposals
- Includes support for
 - Basic research in earth sciences, earthquake engineering, and earthquake mitigation, preparedness, response and recovery
 - Research and information centers
 - Research infrastructure/facilities
 - Integration of research with education (e.g., REU students)
- Involves 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



NEHRP Stories - Seismic Waves

NSF-supported Research Examples)

<http://www.nehrp.gov/library/success.nfm>

Seismic Waves
New National Earthquake Hazards Reduction Program is Advancing Earthquake Safety

May 2007

Strengthening Pipeline Survivability to Avoid Post-Quake Devastation

When an earthquake strikes, the ground beneath the pipeline shifts. This movement can cause the pipeline to pull away from its supports, or to buckle under the weight of the soil above it. In some cases, the pipeline can be pulled out of the ground, or it can be crushed by the weight of the soil above it. This can result in a major leak, or even a rupture that causes a fire or explosion. To prevent this from happening, the pipeline must be designed to withstand the forces of an earthquake. This is done by strengthening the pipeline and its supports, and by using materials that are resistant to seismic forces.



The idea is to simulate earthquake fault motions and to see how the pipeline reacts. The pipeline is supported by a series of supports, and the ground beneath it is moved back and forth to simulate the motion of an earthquake. The pipeline is then observed to see how it reacts to the motion. This is done by using sensors to measure the displacement of the pipeline and its supports. The results of the simulation are used to design a pipeline that is able to withstand the forces of an earthquake.

A similar study was conducted in Japan in 1984, when a powerful earthquake struck. A city of 1.3 million, including the plant, was destroyed. The plant was destroyed because the pipeline was not designed to withstand the forces of an earthquake. This was a major disaster, and it led to the development of new standards for pipeline design. These standards require that pipelines be designed to withstand the forces of an earthquake, and that they be able to withstand the forces of an earthquake without leaking or rupturing.

The pipeline is being applied to conventional steel pipelines as well as to new, high-strength polyethylene (HDPE) pipes. The idea is to see how the pipeline reacts to the motion of an earthquake. This is done by using sensors to measure the displacement of the pipeline and its supports. The results of the simulation are used to design a pipeline that is able to withstand the forces of an earthquake.

A team of researchers from Cornell University and the National Institute of Standards and Technology (NIST) is working to improve the design of pipelines to withstand the forces of an earthquake. They are doing this by using sensors to measure the displacement of the pipeline and its supports, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the pipeline and its supports, and by using materials that are resistant to seismic forces.

The research, led by Cornell Professor Thomas Healey, is being funded by the National Science Foundation (NSF) and the Department of Energy. The project will result in a new design for pipelines that is able to withstand the forces of an earthquake. This is done by using sensors to measure the displacement of the pipeline and its supports, and by using materials that are resistant to seismic forces.

At Cornell, Healey and his colleagues have been studying pipelines in a laboratory. They are doing this by using sensors to measure the displacement of the pipeline and its supports, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the pipeline and its supports, and by using materials that are resistant to seismic forces.

Seismic Waves
New National Earthquake Hazards Reduction Program is Advancing Earthquake Safety

January 2007

New Findings to Keep Flat-Plate Frames from Flattening

Understanding the behavior of flat-plate frames is important because these structures are common in multi-story buildings. They are made of concrete and steel, and they are used to support the floors of a building. During an earthquake, these frames can be subjected to large forces, and they can be damaged. This can result in a major disaster, and it can lead to the loss of lives and property. To prevent this from happening, it is important to understand the behavior of these frames, and to design them to withstand the forces of an earthquake.



A team of researchers from the University of California, San Diego (UCSD) is working to improve the design of flat-plate frames. They are doing this by using sensors to measure the displacement of the frame and its supports, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the frame and its supports, and by using materials that are resistant to seismic forces.

The research, led by UCSD Professor David Borzi, is being funded by the National Science Foundation (NSF) and the Department of Energy. The project will result in a new design for flat-plate frames that is able to withstand the forces of an earthquake. This is done by using sensors to measure the displacement of the frame and its supports, and by using materials that are resistant to seismic forces.

At UCSD, Borzi and his colleagues have been studying flat-plate frames in a laboratory. They are doing this by using sensors to measure the displacement of the frame and its supports, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the frame and its supports, and by using materials that are resistant to seismic forces.

Seismic Waves
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March 2003

Getting in GEER for New Zealand

Joint Reconnaissance of the Great Christchurch Earthquake

On the early morning of 22 Feb. 2011, New Zealand's South Island was struck by a major earthquake. The earthquake caused significant damage to the city of Christchurch, and it resulted in the loss of lives and property. To understand the causes of the earthquake, and to prevent similar earthquakes from happening in the future, it is important to conduct a joint reconnaissance of the earthquake. This is done by using sensors to measure the displacement of the ground and the buildings, and by using materials that are resistant to seismic forces.



A team of researchers from the United States and New Zealand is working to improve the design of buildings to withstand the forces of an earthquake. They are doing this by using sensors to measure the displacement of the ground and the buildings, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the ground and the buildings, and by using materials that are resistant to seismic forces.

The research, led by the United States Geological Survey (USGS) and the New Zealand Geological Service (NZGS), is being funded by the National Science Foundation (NSF) and the Department of Energy. The project will result in a new design for buildings that is able to withstand the forces of an earthquake. This is done by using sensors to measure the displacement of the ground and the buildings, and by using materials that are resistant to seismic forces.

At the USGS, the researchers have been studying the earthquake in a laboratory. They are doing this by using sensors to measure the displacement of the ground and the buildings, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the ground and the buildings, and by using materials that are resistant to seismic forces.

Seismic Waves
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September 2003

Great ShakeOut Earthquake Drills

ShakeOut Drilling

Beginning in 2003, more states, territories, and countries began to join the ShakeOut, with weather reports from the National Weather Service (NWS) and local agencies who recruit participants. Nevada and Georgia led the way, followed by Oregon and British Columbia in early 2004. As part of the New Madrid Corridor Seismological Consortium (NSC) project, the first ShakeOut drill was held in the St. Louis area in 2003. The NSC is a consortium of researchers from the United States and Canada who are working to improve the design of buildings to withstand the forces of an earthquake.



The research, led by the National Science Foundation (NSF) and the Department of Energy, is being funded by the National Science Foundation (NSF) and the Department of Energy. The project will result in a new design for buildings that is able to withstand the forces of an earthquake. This is done by using sensors to measure the displacement of the ground and the buildings, and by using materials that are resistant to seismic forces.

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Seismic Waves
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November 2007

Ensuring That When the Ground Starts Shaking, Bridges Can Bend Without Breaking

The bridge, built in 1964, was not designed to withstand the forces of an earthquake. This was a major disaster, and it led to the loss of lives and property. To prevent this from happening, it is important to understand the behavior of bridges, and to design them to withstand the forces of an earthquake.



A team of researchers from the University of California, San Diego (UCSD) is working to improve the design of bridges to withstand the forces of an earthquake. They are doing this by using sensors to measure the displacement of the bridge and its supports, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the bridge and its supports, and by using materials that are resistant to seismic forces.

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Seismic Waves
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May 2007

Bringing Down the House

NEESwood Project Shakes Up San Diego Wood Townhome in Narragansett Simulation

It has shattered and the walls, which is a very good representation of the behavior of a wood townhome during an earthquake. This is done by using sensors to measure the displacement of the townhome and its supports, and by using materials that are resistant to seismic forces.



A team of researchers from the University of California, San Diego (UCSD) is working to improve the design of wood townhomes to withstand the forces of an earthquake. They are doing this by using sensors to measure the displacement of the townhome and its supports, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the townhome and its supports, and by using materials that are resistant to seismic forces.

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July 2003

Keeping the Containers Moving Through U.S. Ports

As the United States container ports have become an important segment of the commercial industry, a critical element of the economy, and a key driver for export and import. However, the growing value of these facilities has generally not been accompanied by commensurate advances in their seismic risk management practices. This observation led to a major research effort initiated in 2001 by the Georgia Institute of Technology and partnering institutions. This work, supported by the National Science Foundation (NSF), a NEHRP agency, significantly advanced seismic risk assessment and risk mitigation knowledge applicable to container ports as an effort was funded by the National Institute of Standards and Technology (NIST) through work with NSF's NEHRP.



A team of researchers from the Georgia Institute of Technology (Georgia Tech) is working to improve the design of container ports to withstand the forces of an earthquake. They are doing this by using sensors to measure the displacement of the port and its supports, and by using materials that are resistant to seismic forces. This is done by using sensors to measure the displacement of the port and its supports, and by using materials that are resistant to seismic forces.

The research, led by Georgia Tech Professor George E. Brown, is being funded by the National Science Foundation (NSF) and the Department of Energy. The project will result in a new design for container ports that is able to withstand the forces of an earthquake. This is done by using sensors to measure the displacement of the port and its supports, and by using materials that are resistant to seismic forces.

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Seismic Waves
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June 2007

Bridging Boundaries to Reduce Risk

It's a global risk reduction effort, one that brings together public and private organizations to work together to reduce risk. This is done by using sensors to measure the displacement of the ground and the buildings, and by using materials that are resistant to seismic forces.



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NSF

The National Science Foundation (NSF) is a federal agency in the United States that is responsible for the support of the physical, biological, and behavioral sciences. It is one of the largest and most prestigious research funding agencies in the world. The NSF is funded by the U.S. Congress, and it has a budget of approximately \$7 billion per year. The NSF is responsible for the support of a wide range of research projects, from basic research to applied research. The NSF is also responsible for the support of a wide range of educational programs, from undergraduate education to graduate education. The NSF is a key player in the U.S. research and innovation system, and it plays a vital role in the advancement of science and technology.

NEHRP

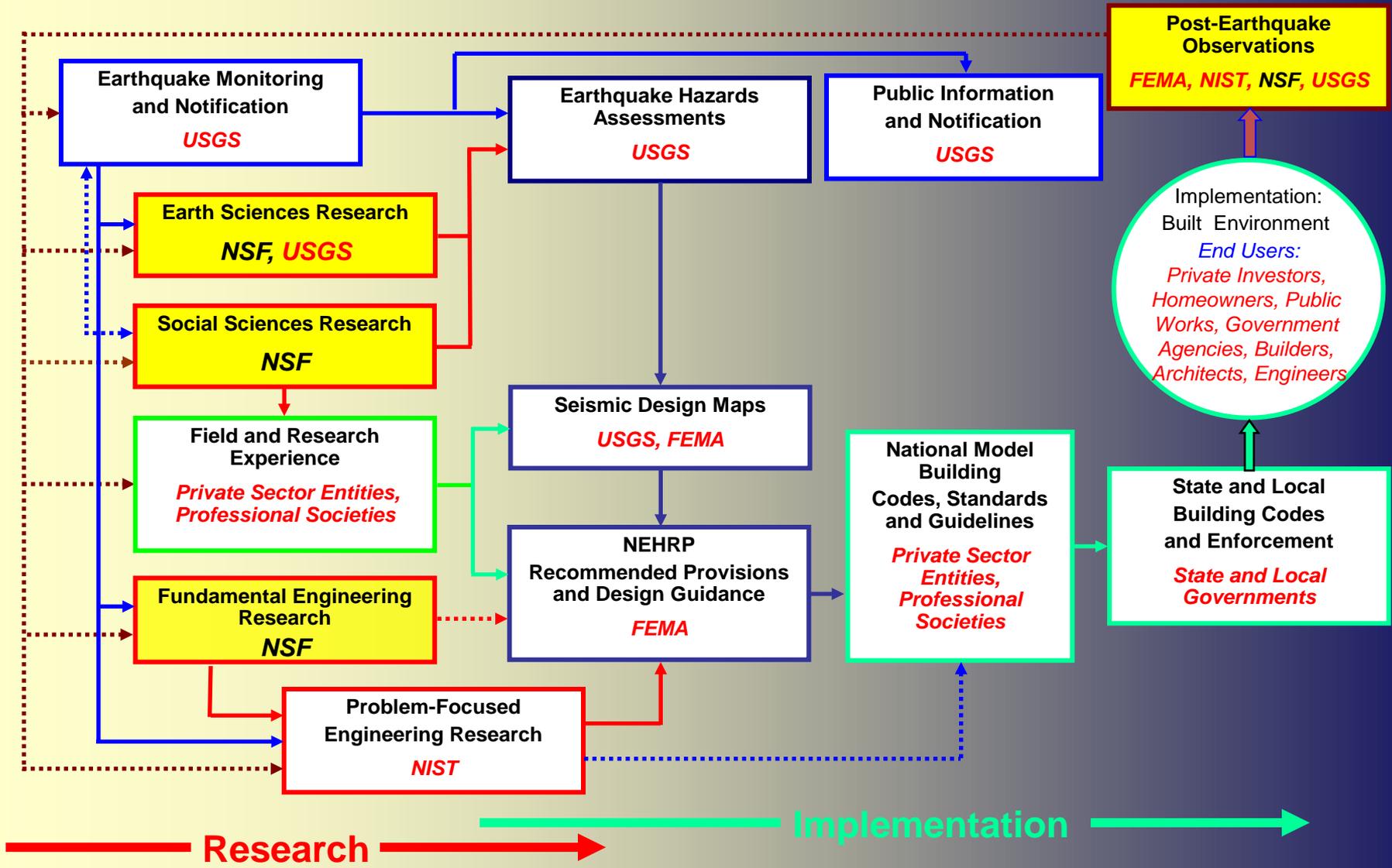
The National Earthquake Hazards Reduction Program (NEHRP) is a federal program in the United States that is responsible for the support of research and development in the field of earthquake engineering and seismology. It is one of the largest and most prestigious research funding agencies in the world. The NEHRP is funded by the U.S. Congress, and it has a budget of approximately \$1 billion per year. The NEHRP is responsible for the support of a wide range of research projects, from basic research to applied research. The NEHRP is also responsible for the support of a wide range of educational programs, from undergraduate education to graduate education. The NEHRP is a key player in the U.S. research and innovation system, and it plays a vital role in the advancement of earthquake engineering and seismology.

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NEHRP Impact on the Built Environment



Directorate for Engineering (ENG)

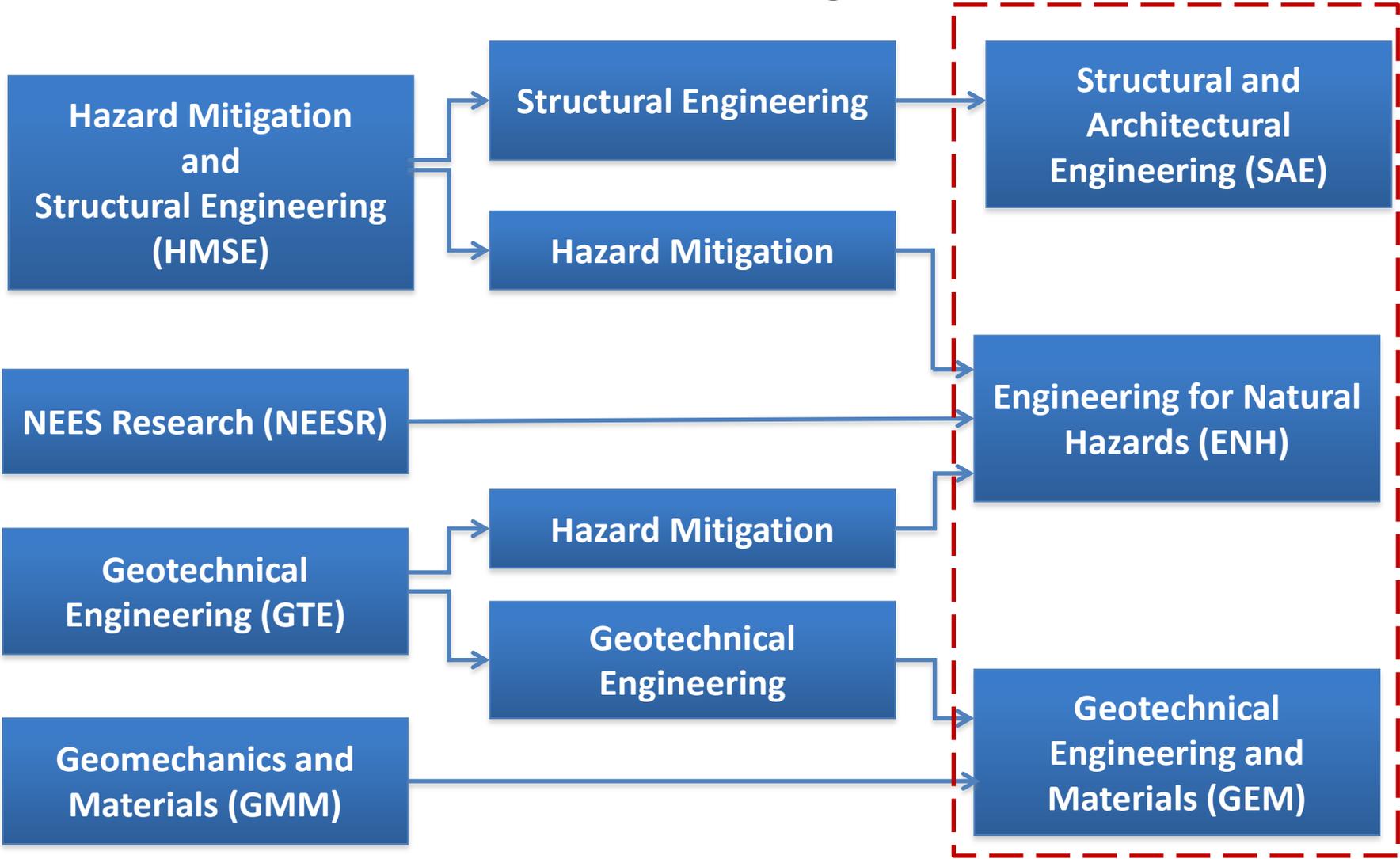


FY 2015 ENG Programs Supporting NEHRP in the Division of Civil, Mechanical and Manufacturing Innovation (CMMI)

- Engineering for Natural Hazards (ENH) – new for Spring 2015
 - Research awards, including RAPID awards
- Infrastructure Management and Extreme Events (IMEE)
 - Research awards, including RAPID awards
 - Support for Natural Hazards Center at University of Colorado, Boulder
- Natural Hazards Engineering Research Infrastructure (NHERI) – new in FY 2015 (NSF 14-605)
 - \$62 million over five years, support starting in FY 2015
 - Earthquake and wind engineering research, education, and community outreach resources
 - Four components
 - Network Coordination Office
 - Cyberinfrastructure
 - Computational Modeling and Simulation Center
 - Experimental Facilities, including a RAPID facility – up to 7



New CMMI Research Programs in FY 2015



**Former CMMI Programs
through September 2014
submission window**

**New CMMI Programs
as of February 2015
submission window¹¹**

Engineering for Natural Hazards Program

PD 15-7396 (ENG/CMMI)

http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505177&org=NSF

GOALS

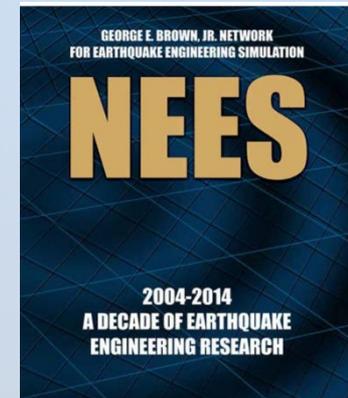
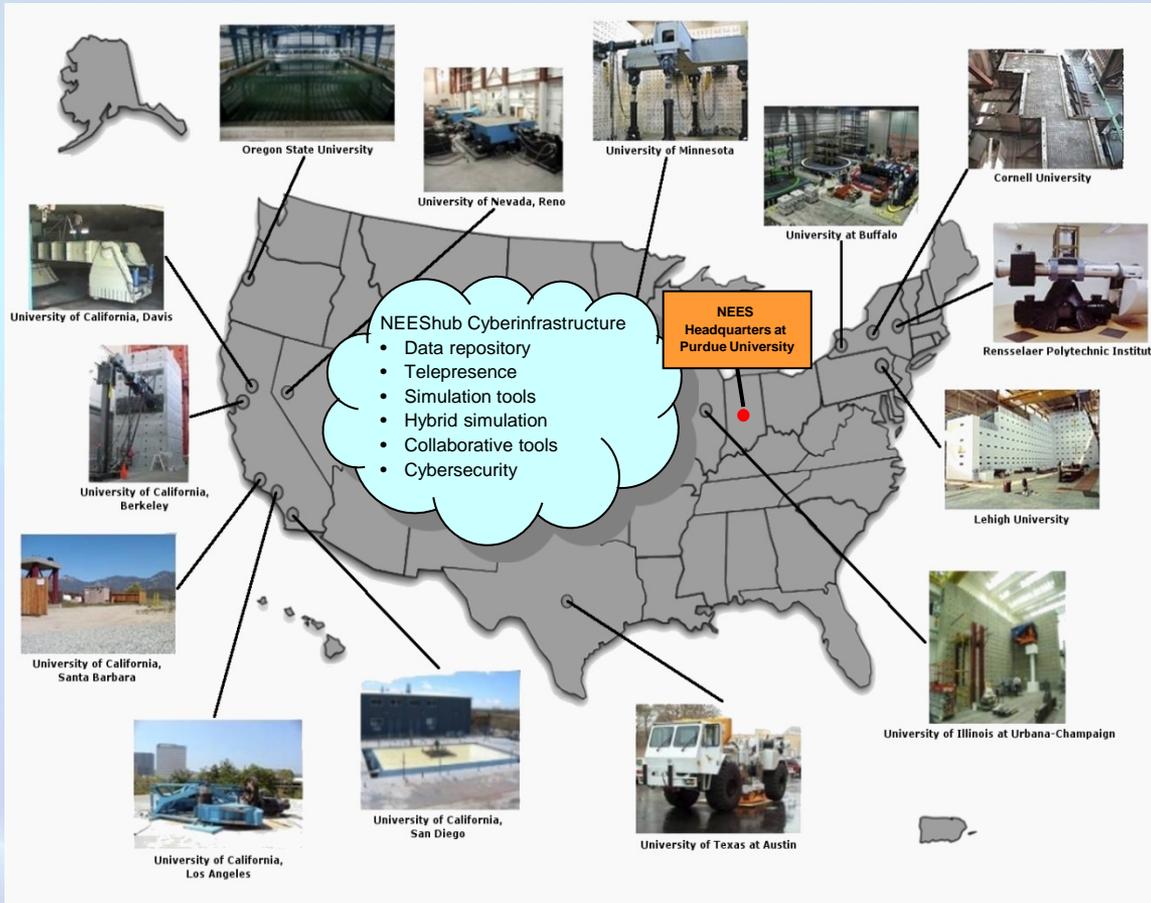
- Prevent natural hazards (e.g., earthquakes, windstorms, tsunamis, landslides) from becoming disasters, and
- Broaden consideration of natural hazards independently to the consideration of the multi-hazard environment within which the constructed civil infrastructure exists.

RESEARCH AREAS

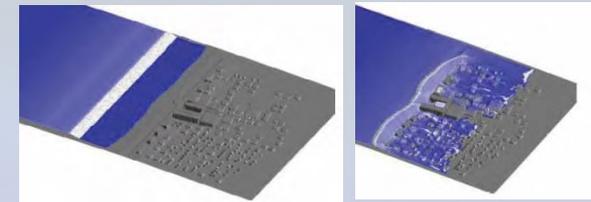
- Advances in system-level design concepts for new and existing sustainable civil infrastructure to achieve desired lifetime system-level performance under single or multi-hazard loadings;
- Advances in geotechnical engineering for design and construction of natural hazard-resistant foundations and geostructures, liquefaction mitigation, soil-foundation-structure interaction, levee and earth dam stability, and landslide, mudflow and debris flow analysis and mitigation, with a focus on field or system performance;
- Applications of decision theory for design concepts for civil infrastructure to achieve desired lifetime system-level performance for both multi-hazard resilience and sustainability; and
- Advances in computational modeling and simulation that integrate theory, computation, experimentation, and data, as appropriate, to advance natural hazard mitigation for civil infrastructure.

*The **ENH program encourages knowledge dissemination & technology transfer activities that lead to broader societal benefit & implementation for natural hazard mitigation for civil infrastructure***





<http://nees.org/retrospective>

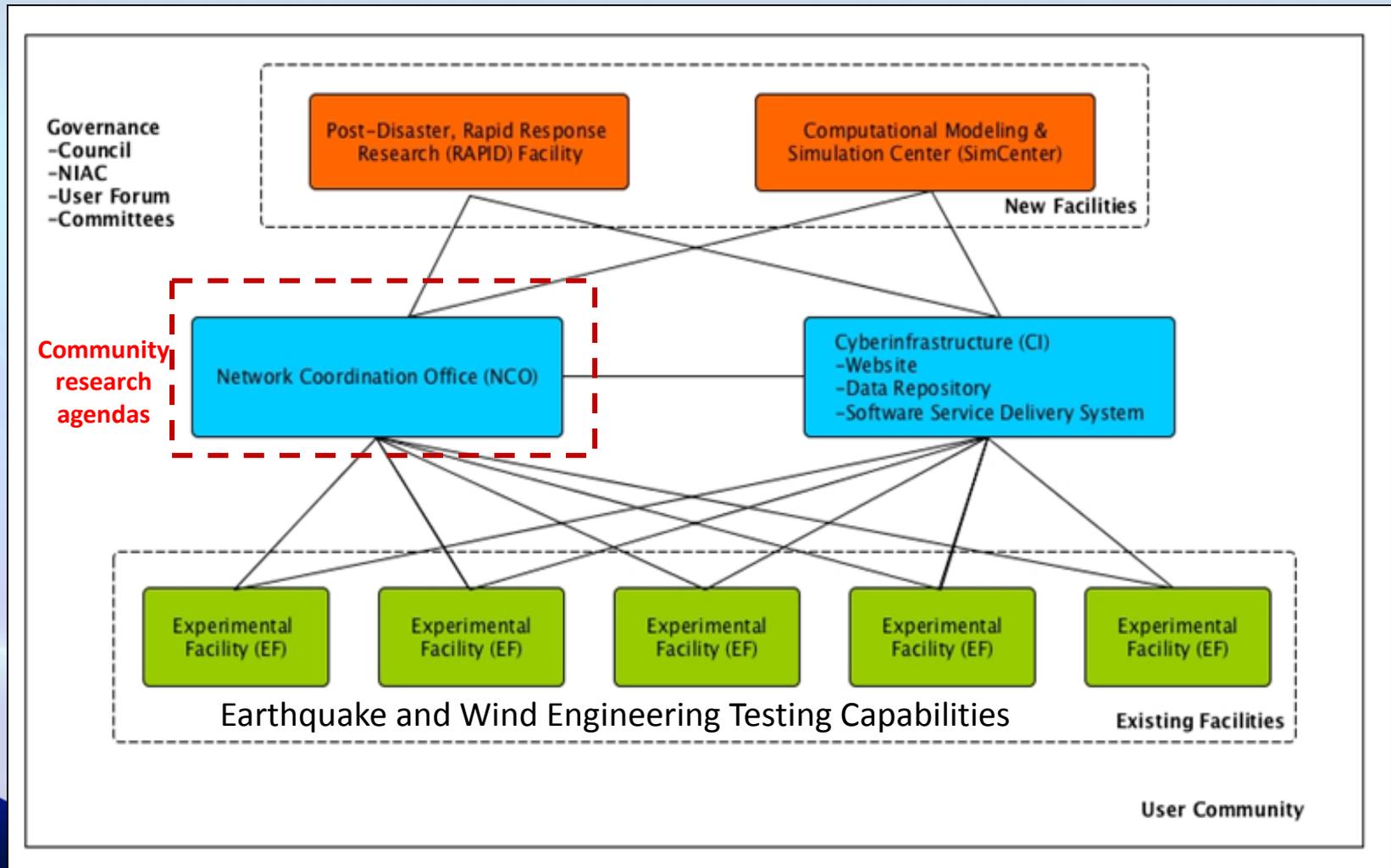


NEES 2005 - 2014

Snapshots from a numerical model of a tsunami flooding a coastal town. The top plot shows the approaching tsunami, where the white face of the wave indicates breaking. The lower plot shows the wave inundating the town, and interacting with the infrastructure. NSF Awards 0619083 and 1215454 (Reference: <http://nees.org/site/images/pdf/NEES2004-2014.pdf>)



Natural Hazards Engineering Research Infrastructure Notional Diagram per NSF 14-605



Vision for NHERI (NSF 14-605)

- Understand, model, and predict the lifecycle performance of civil infrastructure, from component to holistic system levels, under different natural hazard events (earthquakes and windstorms);
- Reduce the reliance on physical testing for modeling the performance of civil infrastructure under natural hazard events through advanced computational modeling and simulation capabilities;
- Build the basic science knowledge and computational modeling and simulation capabilities to evaluate multi-hazard resilient and sustainable civil infrastructure and communities;
- Translate research into innovative mitigation strategies and technologies to reduce the impact of natural hazards on existing and new sustainable civil infrastructure and communities; and
- Integrate research, education, and outreach to train a broad and inclusive STEM workforce to conduct and translate research into an innovation ecosystem for multi-hazard resilient and sustainable civil infrastructure and communities.

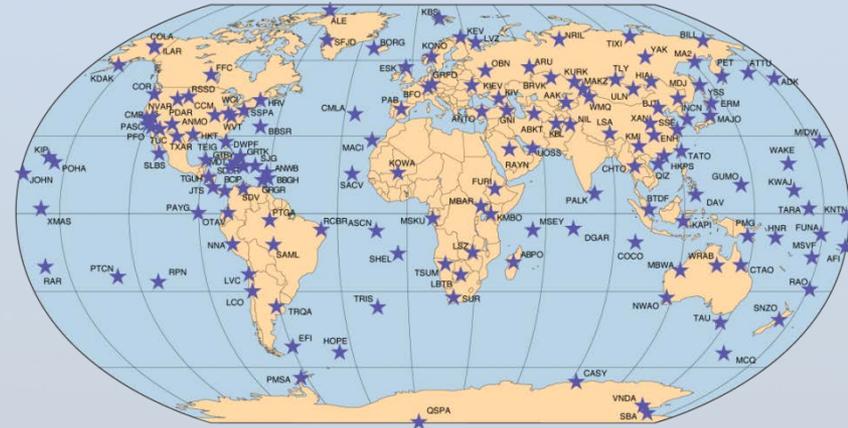


Directorate for Geosciences (GEO)

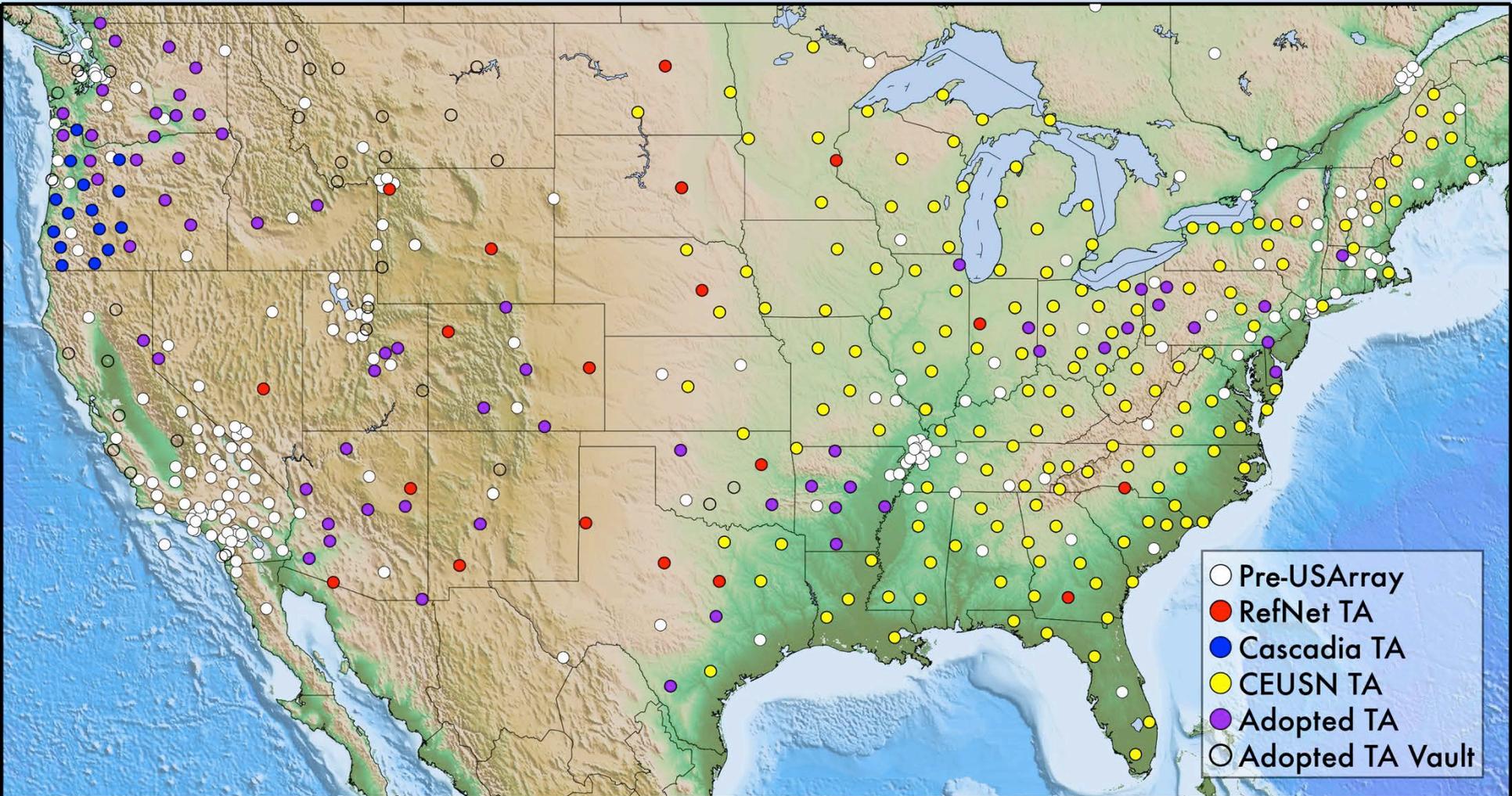


SAGE Seismic Facility

- SAGE: Seismological Facilities for the Advancement of Geoscience and EarthScope
- Operations planned FY14-18
 - Annual budget ~\$25M
- NEHRP links
 - Primary: Global Seismographic Network (GSN)
 - External review underway, report due within a month
 - Contributing: Transportable Array
 - Data key in understanding seismicity related to fracking
 - Conversion of selected stations to long-term operations
 - Contributing: Data management
 - ACEHR notes this is key resource for community



Long-term legacy from Transportable Array



~221 long-term broadband stations prior to TA

260 TA stations added to the long-term network

Courtesy IRIS

18



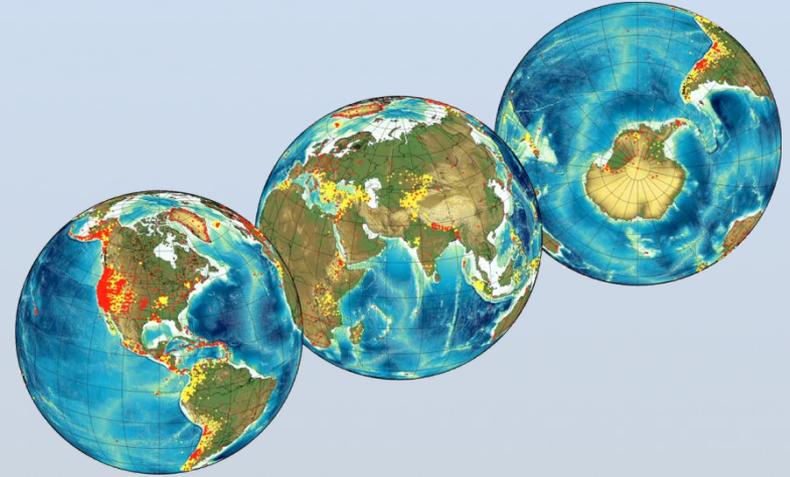
CEUSN: Central & Eastern US Seismic Network

- Joint effort of NSF, USGS, other partners
- Goal
 - Convert to long-term ~160 TA seismic stations
 - Enhance research and monitoring in central & eastern United States, including monitoring of critical facilities
- Estimated costs
 - 5-yr conversion: \$12M
 - Annual O&M: \$1.6M
- Status
 - All stations collecting data, all data publicly available
 - Cumulative funding: \$8.2M NSF, \$200k USGS
 - Plan through FY15: \$9.3M NSF, \$600k USGS



GAGE: Geodetic Facilities

- GAGE: Geodesy Advancing Geosciences and EarthScope
- Integration of prior geodetic facilities & EarthScope/PBO
- Operations planned FY14-18
 - Annual budget ~\$12.5M (NSF/NASA)
- Primary NEHRP link:
 - GAGE-provided GPS data now incorporated into USGS National Seismic Hazard Maps
- Real-time, high-rate GPS being assessed for use in Earthquake Early Warning systems



Additional GEO Activities

- Continued joint support (w/USGS) for Southern California Earthquake Center (SCEC)
(~\$2.7-3.0M NSF/year) www.scec.org
- Fundamental research via Geophysics, Tectonics, EarthScope, GeoPRISMS, Geomorphology & Land-Use Dynamics, and other core EAR programs
- Planned FY16 new start: PREEVENTS
 - Prediction of and Resilience against Extreme Events



PREEVENTS

- Program w/multidisciplinary portfolio to improve
 - Fundamental understanding of processes underlying geohazards & extreme events
 - Models of geohazards, extreme events, and their impacts
 - Enhance societal preparedness & resilience
- Focused on natural hazards
- GEO-centered, with potential for links
- \$23.5M in FY16 request
- Part of NSF's Risk & Resilience activity



PREEVENTS: Timeline

Year	Major items
FY15	Dear Colleague Letter to announce program and plans
FY16	Accepting first proposals under DCL
FY17	First solicitation for full program, including Nucleus
FY19	Second solicitation for full program
FY20	Program evaluation



Science Across Virtual Institutes (SAVI)

An NSF International Collaboration Funding Mechanism

- SAVI/Collaborative Research: Pacific Rim Earthquake Engineering Mitigation Protective Technologies International Virtual Environment (NSF awards CMMI-1446424 and CMMI-1446353) – links researchers in Chile, Japan, New Zealand and U.S. to accelerate research on seismic protective systems
- SAVI: Virtual International Institute for Seismic Performance Assessment of Structural Wall Systems (NSF award CMMI-1446423) – links researchers in Chile, Japan, New Zealand and U.S. for seismic performance assessment of structural wall systems
- Virtual Institute for the Study of Earthquake Systems (FY 2012 supplement to NSF award EAR-1033462, Southern California Earthquake Center) – links SCEC researchers with researchers in Japan at the Earthquake Research Institute, Tokyo University, and the Disaster Prevention Research Institute, Kyoto University, <http://www.scec.org/vises/>



Examples of NSF Multidisciplinary Research Programs Addressing Hazards

- NSF ENG/CMMI

- **Infrastructure Management and Extreme Events (PD 15-1638)**

- “...supports fundamental, multidisciplinary research on the impact of hazards and extreme events upon civil infrastructure and society. The program is focused upon research on the mitigation of, preparedness for, response to, and recovery from multi-hazard disasters. Community and societal resilience and sustainability are important topics within the research portfolio of IMEE. The program is deeply multidisciplinary and attempts to integrate multiple issues from civil, mechanical, transportation, and system engineering, sociology, psychology, economics, geography, political science, urban planning, epidemiology, natural and physical science, and computer science.

- NSF GEO, CISE, ENG, MPS, and SBE Directorates and OIIA (anticipated \$20 million)

- **NSF 14-581, Interdisciplinary Research in Hazards and Disasters (Hazards SEES)**

- Hazards SEES...seeks to: (1) advance understanding of the fundamental processes associated with specific natural hazards and technological hazards linked to natural phenomena, and their interactions; (2) better understand the causes, interdependences, impacts, and cumulative effects of these hazards on individuals, the natural and built environment, and society as a whole; and (3) improve capabilities for forecasting or predicting hazards, mitigating their effects, and enhancing the capacity to respond to and recover from resultant disasters. The overarching goal of Hazards SEES is to catalyze well-integrated interdisciplinary research efforts in hazards-related science and engineering in order to reduce the impact of hazards, enhance the safety of society, and contribute to sustainability.

- NSF CISE, ENG, and SBE Directorates (anticipated \$20 million)

- **NSF 15-531 Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP)**

- 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.



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