### **National Science Foundation (NSF)**

### **NSF Earthquake Program Update**

National Earthquake Hazards Reduction Program (NEHRP)
Advisory Committee on Earthquake Hazards Reduction (ACEHR)
August 18, 2014
Golden, CO

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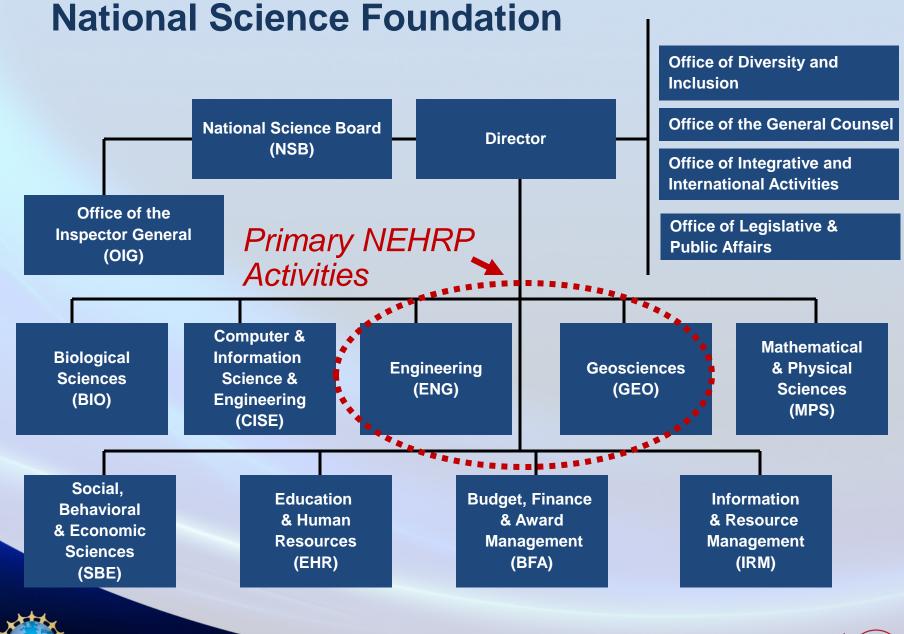


# Agenda

- About NSF
- NSF Directorate for Engineering in NEHRP
  - Response to 2013 ACEHR Recommendation
- NSF Directorate for Geosciences in NEHRP
  - Response to 2013 ACEHR Recommendation
- Examples of NSF Interdisciplinary Programs









## **NEHRP Success Stories - Seismic Waves** NSF-supported Research (examples)

http://www.nehrp.gov/library/success.htm



### Strengthening Pipeline Survivability to Avoid Post-Quake Devastation

hen earthquakes impact urban areas, the realismos of underground utilities can have a teamentous effect on what happens other the shaking steps. Recken water place led to the spreading firms that consumed more than three-quarters of Son Francisco in

more than 500 fine ignited, and with responders hampered by the lack of water and traffic daruptions, at least 12 confin-grations developed and burned for 24 to 48 hours.

A toam of measurchers from Cornell University and Beasolater Polynchnic Institute (BPI) are responding to said enter by conducting a systematic and comprehensive assessment of ground reptore effects on critical under-ground bildine. Their objective is to improve the skingle-ground bildine. Their objective is to improve the skingle-or of their conduction of berind pipinion and conduct used for votes mixed ago, lived life, objectivity and delocumentational to-tument ago, lived life, objectivity and delocumentational.

National Assembly Canagerian (Not ) onesis that recent agreement perfolipsing in NE-HBE Therepict was made possible by the unique experimental facilities available through the George E. Brown, E. Netsoch for Earthquake Engineering Simulation (NOEES) under NST award CMMIO-000400. These facilities,

This project is being cerried out by the University of Nevada, leno (UNR) in cooperation with several other universities in the United States and abroad. It is enabling researchers

Queen from Selly Kabis and Melion Hoghes, repenselly ABC News on August 1, 2007, in "things Collapse Survivers Tell Their Takes" Reviewed & condense indexes against the Collapse Survivers Tell Their Takes" Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes" Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes" Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes" Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes" Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes" Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes" Their Takes "Reviewed & condense indexes against the Collapse Survivers Tell Their Takes "Reviewed & condense indexes against the Col

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Improved pipelines are mediad to keep fishers earthquakes from homesting the two-stage disasters own in San Francisco and Koho, where damage from the large in followed by pleasage from first date are jurisd, finded or allowed to grow by respecting more that are jurisd, finded or allowed to grow by respecting good water lines. This seasonth is producing findings that one last to better, more quale-resistant spellines as the findings.

Seismic Waves MAN

### Ensuring That When the Ground Starts Shaking, Bridges Can Bend Without Breaking at each end of the bridge). These interactions determine the performance of the entire bridge system, which is the primary from of the UNR project.



**SeismicWaves** New Findings to Keep Flat-Plate Frames from Flattening

In the result of the state of the grants in traceing more retrieval to the city. In the trace it is week to come present the state of t



He valurably insurpensive to construct and because of the reduced story heights and open floor plans that are ploy rolle with such framing. However, their values always to punching shear folies has caused invocated segments to restaink the design of sibh-reducen connections in new flast-plans frames constructed in reass of high neutronic flavorable frames constructed in mean of high neutronic flavorable may have been found to make these connections.



SeismicWaves.

### Bringing Down the House

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### Getting in GEER for New Zealand





**SeismicWaves** 

### Keeping the Containers Moving Through U.S. Ports

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U.S. Department of Transportation, <u>America's Committee Ports</u>. Linking Mechan at Horse and Abrand B Borons, <u>Container Flores in World Tanks</u>, U.S. Waterderen Commerce and Mrd Majments in North Assessic Congression of Budget Office, The Engerman Contain of Ministryins in Container Signatures, Mar sp. 2005.



The most of security near You!

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was planned as a one-time event to motivate
millions of people to practice "Desp. Corre,
and Hold On' and to get prepared at work, whood, and
home for the percental of a major earthquake. With the
involvement of many partner organizations, the
ShaleCost program has more capanized to include a shaleCost program has more capanized to include a
More than 19,3 million people participated in zouz.



**SeismicWaves** 

### **Bridging Boundaries to Reduce Risk**

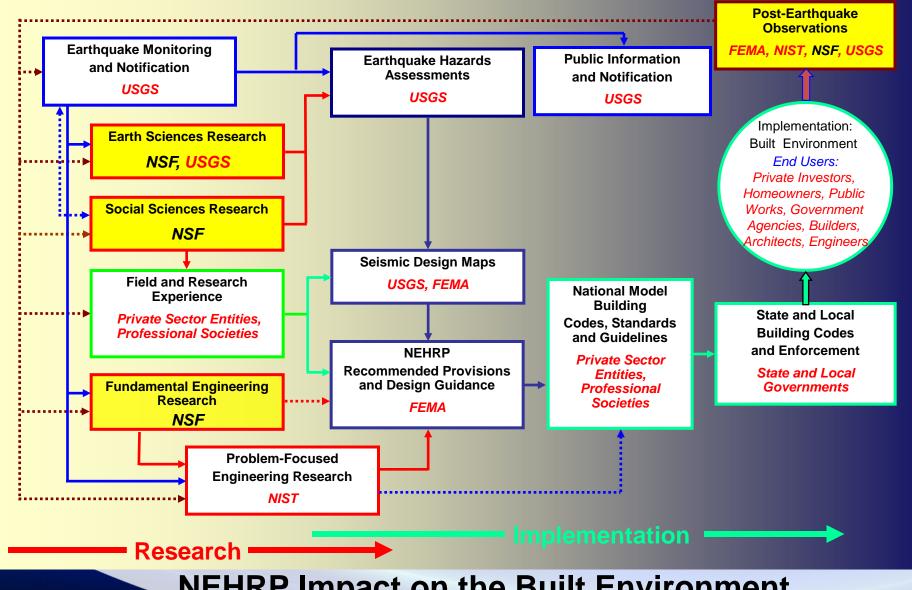
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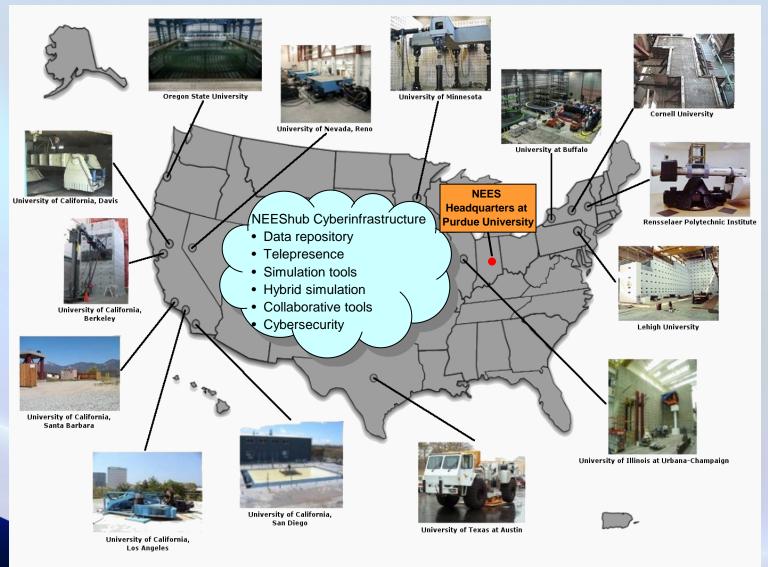
# NEHRP - NSF Directorate for Engineering Division of Civil, Mechanical and Manufacturing Innovation

- George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)
  - Operations (Purdue University)
  - Fundamental Research
- Fundamental Research Programs (Unsolicited Proposals)
  - Hazard Mitigation and Structural Engineering (HMSE)
  - Geotechnical Engineering (GTE)
  - Infrastructure Management and Extreme Events (IMEE)
    - Natural Hazards Center (University of Colorado, Boulder)





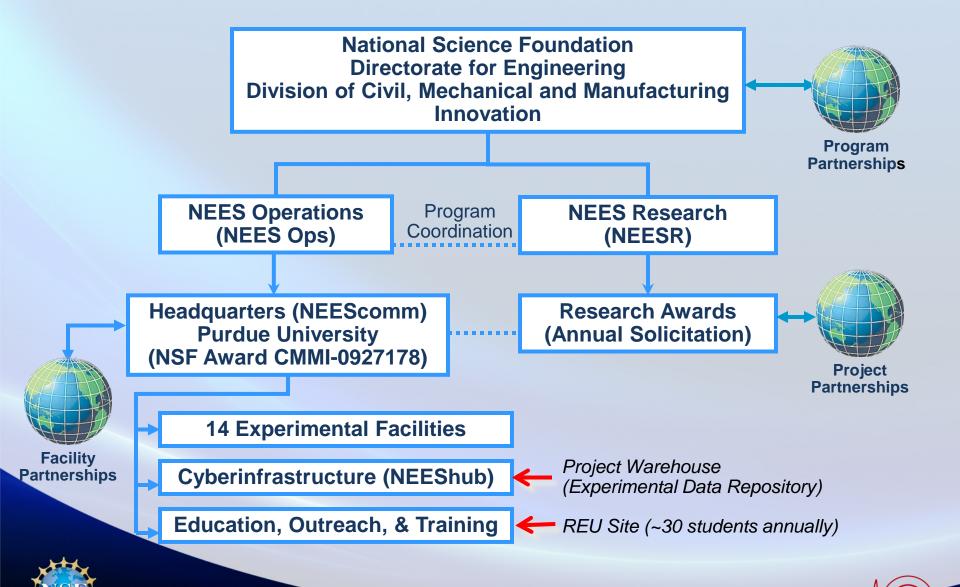
# George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)







# **NSF NEES Program FY 2010-FY 2014**



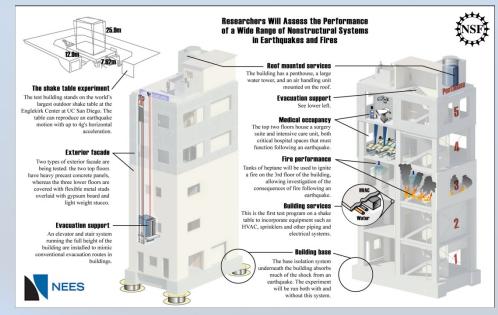
# Full-scale Test on Building Nonstructural Components and Systems (NSF award CMMI-0936505)



Photo credit: UCSD and Tara Hutchinson

- Tests completed in 2012
- Performance of nonstructural components and systems at full-scale using the NSFsupported NEES UCSD large outdoor shake table

40 industry partners



Credit: Detail illustrations and layout Zina Deretsky, National Science Foundation; Building illustrations UC San Diego Department of Structural Engineering.

Illustration depicting several of the components contained in a massive shake-table experiment being conducted by researchers at University of California, San Diego (UCSD), Worcester Polytechnic Institute (WPI), Howard University, & San Diego State University.





# Base Isolation Tests at Japan's E-Defense Shake Table Facility in 2011



Five-story test on base isolation and nonstructural systems at Japan's E-Defense shake table facility during August 2011

(NSF Awards CMMI-1113275, Keri Ryan, PI and CMMI-0721399, Emmanuel Maragakis, PI)

Credit: Joy Pauschke





# NSF Support for Post-earthquake, Rapid Response Research (RAPIDs)

- NSF supports post-earthquake, rapid response research (RAPIDs) through
  - Unsolicited proposals to core programs, primarily through the RAPID proposal mechanism
  - Supplements to existing NSF research awards
  - Core program research awards, e.g., Geo-Engineering Extreme Events Reconnaissance (GEER) (CMMI-1266418, CMMI-1265761, CMMI-1300744)
  - Event-based Dear Colleague Letter, as warranted (e.g., 2010 Haiti earthquake and 2010/2011 New Zealand earthquakes and 2011 Japan earthquake/tsunami)
- NSF supports dissemination of rapid response research findings via grantee workshops, e.g.,
  - 2010 Haiti earthquake workshop and report
     http://www.eqclearinghouse.org/20100112-haiti/wp-content/uploads/2010/10/Haiti-Workshop-Report\_FINAL1.pdf
  - 2010 Chile earthquake workshop and report
     http://www.eqclearinghouse.org/20100227-chile/wp-content/uploads/2010/11/Chile-Workshop-Report\_FINAL.pdf
  - 2010/2011 New Zealand earthquakes and 2011 Japan earthquake/tsunami workshop and report https://www.eeri.org/wp-content/uploads/JAPAN\_NZ\_RAPID\_Workshop\_Final.pdf

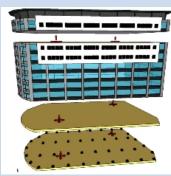




### **NSF Awards following New Zealand Earthquakes**



Photo from nees.utexas.edu



Credit: Robin Farrell



Credit: Henri Gavin

### **Liquefaction Mitigation**

- RAPID: Field Investigation of Shallow Ground Improvement Methods for Inhibiting Liquefaction Triggering, Christchurch, New Zealand
  - Award CMMI-1343524, Professors Kenneth Stokoe and Brady Cox, University of Texas at Austin
- RAPID: Deep Shear Wave Velocity Profiling for Seismic Characterization of Christchurch, NZ Reliably Merging Large
  Active-Source and Passive-Wavefield Surface Wave Methods
  Award CMMI-1303595, Professor Brady Cox, University of Texas at Austin
- RAPID: Pile Downdrag Behavior Based on Blast Liquefaction Testing
   Award CMMI-1408892, Professor Kyle Rollins, Brigham Young University

### Seismic Isolation Systems

- RAPID: Performance of the Base-Isolated Christchurch Women's Hospital during the Sequence of Strong Earthquakes and Aftershocks in New Zealand from September 2010 through 2011 and
- EAGER: Instrumentation and Modeling of Seismic Isolation in Aftershocks

  Wards CMMI-1138714 and CMMI-1258466, Professor Henri Gavin, Duke University





# IMEE Programmatic Action Enabling the Next Generation of Hazard Researchers NSF Awards CMMI-9531297, 0218413, 0758484 & 1424075

- First three awards have recruited and mentored 44 young faculty working in areas of hazards, disasters, and risk research
- Researchers from the areas of political science, public policy, urban and regional planning, geography, civil engineering, decision sciences, economics, operations research, and sociology
- Has led to research on topics such as homeland security, enhanced emergency response, emergency medical services, protecting power and other lifelines, community resilience, and frameworks to reduce losses and speed recovery in vulnerable areas





## NSF Response to 2013 ACEHR Recommendations

### **ACEHR RECOMMENDATION: ENDORSE THE CONTINUATION OF NEES**

The committee recommends continued support of the NEES infrastructure and collaboratory and of the associated research that uses these facilities, at current or increased levels.

NSF Response: NSF has issued the NSF 14-054 Dear Colleague Letter (DCL) "Support for Natural Hazards Engineering Research Infrastructure and Research during FY 2015-FY 2019" <a href="http://www.nsf.gov/pubs/2014/nsf14054/nsf14054.jsp?WT.mc">http://www.nsf.gov/pubs/2014/nsf14054/nsf14054.jsp?WT.mc</a> id=USNSF 25&WT.mc ev=click , which includes a discussion of planned support for earthquake engineering research infrastructure and research during 2015 - 2019.





## **NEES History**

	·
Date	Activity
Pre-1998	Planning for NEES
1998	National Science Board approves NEES for construction
2000-2004	Major Research Equipment and Facilities Construction (MREFC)
2005-2014	10-year Support for NEES Operations and Research
2011-2012	Planning for Earthquake Engineering Research and Research Infrastructure beyond FY 2014
2013	Recompeted a Reduced NEES2 Infrastructure (NSF 13-537); no award
2014	NSF 14-054 Dear Colleague Letter: Natural Hazards Engineering Research Infrastructure (NHERI) — up to 10 awards
2015	Five-year awards made for NHERI
~2017	Completion of Community Decadal Science Plan for Natural Hazards Engineering Research, Education, and Research Infrastructure for 2020 - 2029
~2018	NSF Decision on Program beyond 2019





### **Recent Studies**

National Research Council, *National Earthquake Resilience: Research, Implementation, and Outreach*. Washington, DC: The National Academies Press, 2011, <a href="http://www.nap.edu/catalog.php?record\_id=13092">http://www.nap.edu/catalog.php?record\_id=13092</a>.

National Research Council, *Grand Challenges in Earthquake Engineering Research: A Community Workshop Report*. Washington, DC: The National Academies Press, 2011, <a href="http://books.nap.edu/catalog.php?record">http://books.nap.edu/catalog.php?record</a> id=13167.

NIST GCR 14-973-13, Measurement Science R&D Roadmap for Windstorm and Coastal Inundation Impact Reduction. (This roadmap developmental effort was supported in part by NSF, through award CMMI-1235689, to obtain community input on related long-term fundamental research challenges in windstorm and coastal inundation impact reduction), <a href="https://www.nist.gov/customcf/get\_pdf.cfm?pub\_id=915541">http://www.nist.gov/customcf/get\_pdf.cfm?pub\_id=915541</a>.





## NSF 14-054 Dear Colleague Letter Support for Natural Hazards Engineering Research Infrastructure and Research during FY 2015 - FY 2019

Operations of Research Infrastructure (solicitation pending)

- Network Coordination Office (one award)
- Cyberinfrastructure (one award)
- Computational Modeling and Simulation Center (one award)
- Experimental Facilities for Earthquake and Wind Engineering Research, including a RAPID Facility (up to seven awards)

### Research

- Focus on Multi-hazard Resilient and Sustainable Civil Infrastructure
- Initiated with NSF 14-557 Decision Frameworks for Multi-hazard Resilient and Sustainable Buildings

### Cyberinfrastructure continuity

 Purdue University will operate the cyberinfrastructure until transition to new awardee in 2015





# Directorate for Geosciences





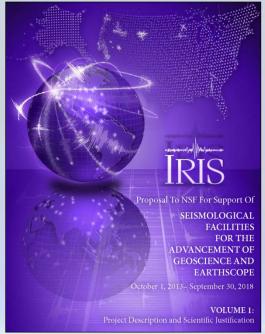
SAGE Seismic Facility

 SAGE: Seismological Facilities for the Advancement of Geoscience and EarthScope

 Integration of prior seismic facilities & EarthScope/USArray

- Operations:
  - Year 1 nearly complete
  - Annual budget ~\$25M
  - Planned through 2018
- Primary NEHRP link: Global Seismographic Network (GSN)
  - GSN review in FY 2015
- Also via Transportable Array & Central and Eastern US Seismic Network (CEUSN)

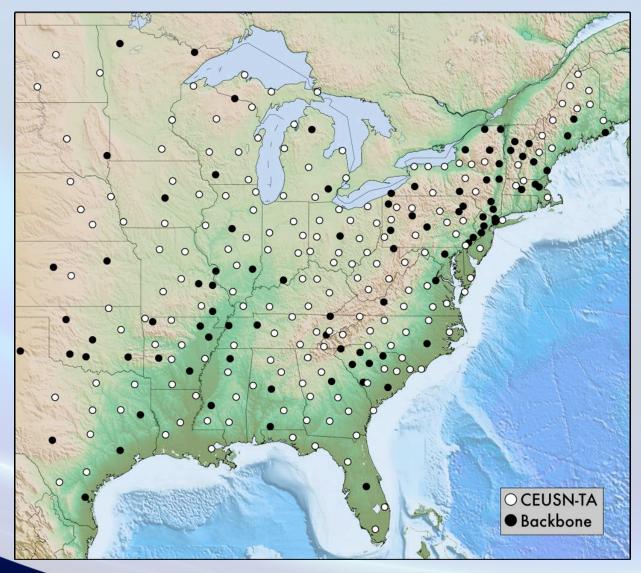








# Central & Eastern US Seismic Network: CEUSN







## **CEUSN**

### Goal

- Convert to long-term ops up to ~160 EarthScope
   Transportable Array seismic stations
- Enhance research and monitoring in central and eastern United States, including monitoring of critical facilities

### Costs

- 5-yr conversion: \$12M
- Annual O&M: \$1.6M

### Status

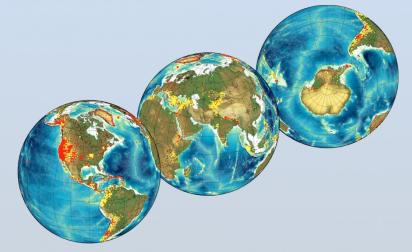
- NSF/USGS Interagency Agreement for joint funding
- To date: \$6.2M from NSF, \$200k from USGS
- All target stations currently collecting data
   All are publicly available





## **GAGE:** Geodetic Facilities

- GAGE: Geodesy Advancing Geosciences and EarthScope
- Integration of prior geodetic facilities & EarthScope/PBO
- Operations:
  - Year 1 nearly complete
  - Annual budget ~\$12.5M (NSF/NASA)
  - Planned through 2018
- 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









## NSF Response to 2013 ACEHR Recommendations

ACEHR RECOMMENDATION: PROVIDE INCREASED MONITORING TO ASSESS THE IMPACT OF INDUCED SEISMICITY

NSF should begin sponsoring the conversion of EarthScope Transportable Array stations to permanent seismic stations maintained and operated by the USGS as soon as possible.

NSF Response: NSF has begun sponsoring these conversions and anticipates supporting further conversions and operations of the Central and Eastern US Seismic Network stations through FY 2017, subject to the availability of future funding. In FY 2013, NSF provided \$2.5M, and in FY 2014, NSF anticipates providing approximately \$3.5M to IRIS, our awardee responsible for the Transportable Array. We are in close coordination with USGS Earthquake Hazards Program staff, which have indicated their intention to provide at least \$200,000 for operations in FY 2014, ramping upward to at least \$800,000 in FY 2017 and beyond, again pending availability of future funding. NSF intends to end its support for these stations in FY 2017. Currently, all 158 stations that are planned for conversion are collecting data, which are available both directly to agency partners and to the community via the IRIS Data Management Center.





## Additional GEO Activities

 Continued joint support (w/USGS) for Southern California Earthquake Center at ~\$2.7M/year http://www.scec.org

 Support for wide range of fundamental research via Geophysics, Tectonics, EarthScope, GeoPRISMS, Geomorphology & Land-Use Dynamics, and other EAR programs





### **Examples of NSF Interdisciplinary Research Programs**

NSF ENG/CMMI

Infrastructure Management and Extreme Events

"...focuses on the impact of large-scale hazards on civil infrastructure and society and on related issues of preparedness, response, mitigation, and recovery. The program supports research to integrate multiple issues from engineering, social, behavioral, political, and economic sciences. It supports fundamental research on the interdependence of civil infrastructure and society, development of sustainable infrastructures, and civil infrastructure vulnerability and risk reduction.

NSF GEO, CISE, ENG, MPS, and SBE Directorates and OIIA

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

NSF 14-524, Resilient Interdependent Infrastructure Processes and Systems (RIPS)

"The goals of the...RIPS solicitation are (1) to foster an interdisciplinary research community that discovers new knowledge for the design and operation of infrastructures as processes and services (2) to 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, and (3) to create the knowledge for innovation in ICIs to advance society with new goods and services."





# National Science Foundation www.nsf.gov

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Find NSF Funding Opportunities <a href="http://www.nsf.gov/awardsearch/">http://www.nsf.gov/awardsearch/</a>

NSF, Directorate for Engineering, Division of Civil, Mechanical and Manufacturing Innovation, Resilient and Sustainable Infrastructures Cluster Programs <a href="http://www.nsf.gov/funding/pgm\_summ.jsp?pims\_id=13545&org=CMMI&from=home">http://www.nsf.gov/funding/pgm\_summ.jsp?pims\_id=13545&org=CMMI&from=home</a>

NSF, Directorate for Geosciences, Division of Earth Sciences <a href="http://www.nsf.gov/div/index.jsp?div=ear">http://www.nsf.gov/div/index.jsp?div=ear</a>



