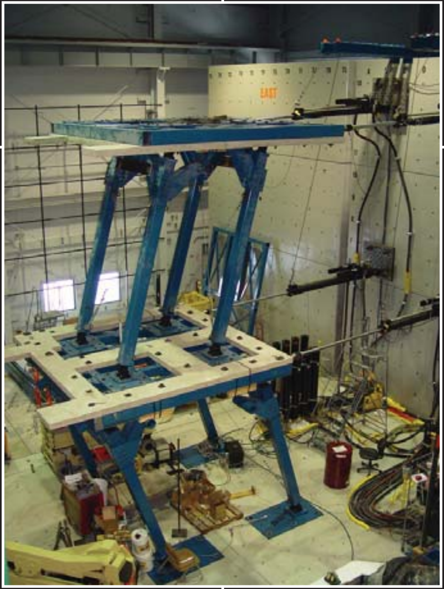
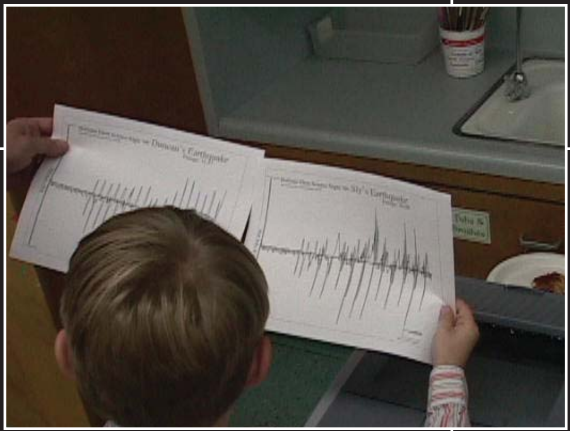
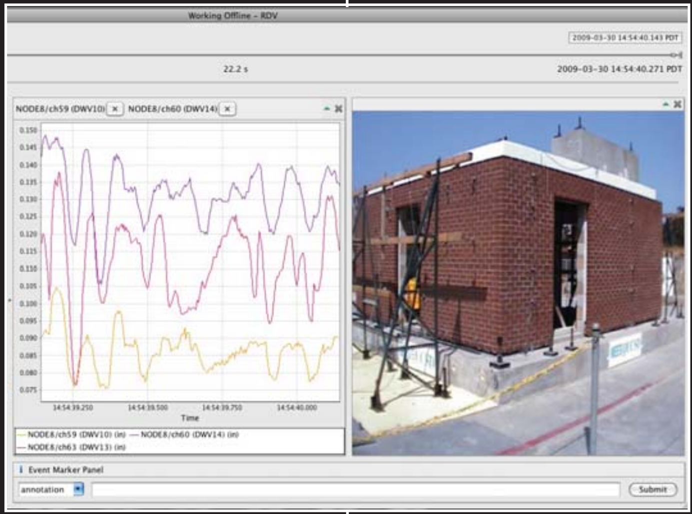




NEES

the George E. Brown, Jr.
Network for Earthquake Engineering Simulation



NSF

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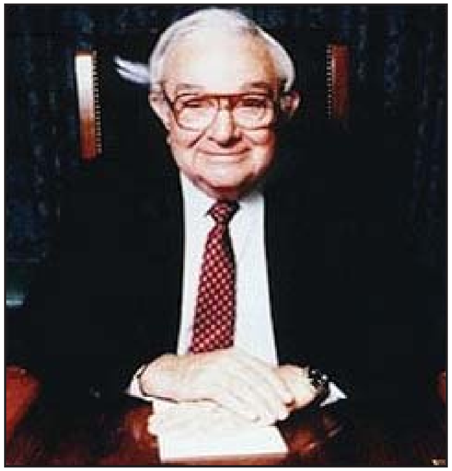
The Network for Earthquake Engineering Simulation

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) was funded by Congress and planned by the National Science Foundation (NSF) to elevate earthquake engineering to a new level in the 21st century. Research facilities have been established at over a dozen universities, along with advanced information technology infrastructure (cyberinfrastructure) to connect geographically distributed researchers, educators, and practitioners. Congress named the program after one of its most productive members in advancing national science and technology capabilities, George E. Brown, Jr. (1920-1999).



George E. Brown, Jr.

The goal of NEES is to play a flagship role in advancing engineering in general. Through the NEES program, the earthquake engineering field is taking the lead in modernizing the way the nation conducts civil engineering research and how it makes that research accessible to earthquake researchers and educators, practicing engineers, government agencies, and the general public.

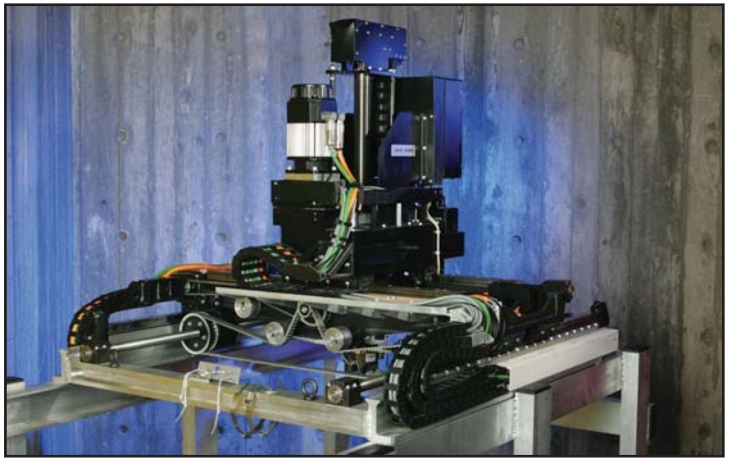
The earthquake engineering field has been known for its important innovations, and the NEES program is designed to stimulate many more. In research laboratories and in industry around the world and across a broad spectrum of engineering disciplines, no instrument is more widely used than the electric resistance strain gauge. It was co-invented by Arthur Ruge of MIT during his 1930s earthquake shake table experimentation on structural models. One of the most influential analytical techniques in engineering disciplines is the Finite Element Method, which was co-developed in the 1950s by U.C. Berkeley professor Ray Clough, a prominent earthquake engineer. The way NEES encourages collaborative research and supports more complex testing techniques promises to facilitate further innovation to aid practitioners and researchers.

The Elements of NEES

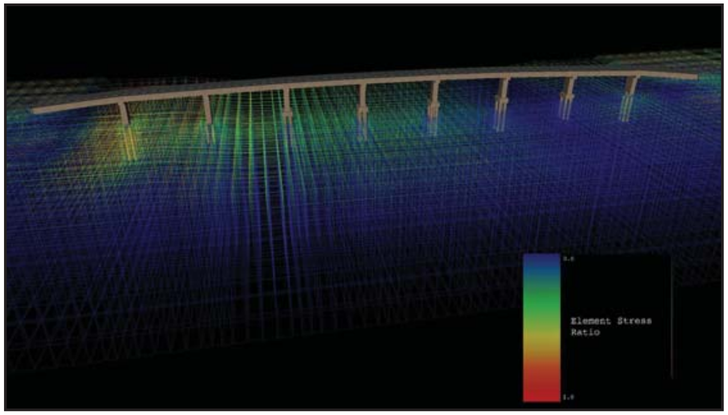
NEES research is conducted using the following elements.

- Laboratories (**research sites**) at over a dozen universities, constitute the single-most important upgrade to U.S. civil engineering research facilities that NSF has ever supported. Since the construction of the facilities were completed in 2004, they have been seeds of innovation in advancing different kinds of testing, and in exploring new ways to combine testing at multiple facilities. Each research site is a shared national resource for use by researchers across the U.S. as well as world-wide.

- **Cyberinfrastructure** enables the user to retrieve, store, and transmit information. A variety of IT (information technology) infrastructure (cyberinfrastructure) services are needed for communication and collaboration among researchers. Data from experiments are archived, as well as the information on how the information was acquired (the metadata). This information can be accessed through a central databank. The "Simulation" in the name of NEES includes both computer and laboratory simulation, working hand-in-hand rather than separately.



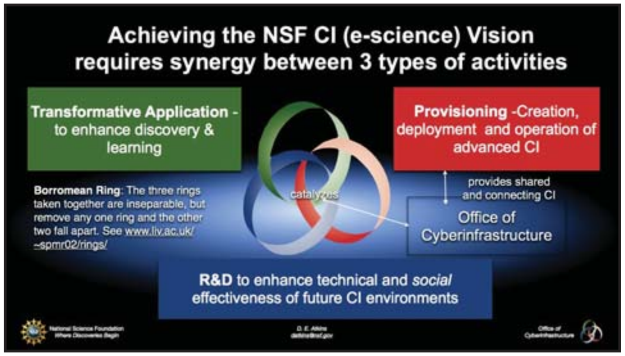
The in-flight robot at the RPI NEES site is designed to perform multiple tasks while the centrifuge is spinning.



Computer simulation of the response of the Humboldt Bay Bridge.

- An **Operations** organizational hub coordinates the complexities of the budgeting, monitoring, and scheduling of research site and cyberinfrastructure activities. Research projects that use the NEES research facilities and that are supported by the NSF NEES research program are selected through the competitive, peer-review process managed by NSF. Projects have also been supported by various federal, state, and local government agencies; non-profit organizations; and the private sector.

- **Education, Outreach, and Training** is another key element of NEES. Education and Outreach takes place at several levels, including involvement of undergraduates and graduate students. Motivating and informing students in the K-12 grades about science, technology, engineering and mathematics (STEM) is an NSF-wide priority and is a key element of NEES education and outreach. One of the most important types of outreach is to practicing engineers, the professionals who need to apply earthquake engineering in their daily work, whether on domestic or international projects. Many of the NSF-supported NEES research projects awarded include practicing engineers as part of the research team. Workshops and online training help potential users become familiar with the research sites and the cyberinfrastructure.



The NEES Operations organizational hub provides the integrative function to manage support for both the cyberinfrastucture and research facilities (shown above).

NEES and NEHRP: Research To Reduce Earthquake Losses

George E. Brown, Jr., the namesake of the NEES program, was the member of the House of Representatives who was central in the passage of the Earthquake Hazard Reduction Act of 1977, which has been reauthorized eleven times, most recently via PL 108-360 in 2004. The Act set up the National Earthquake Hazards Reduction Program (NEHRP), with the mission "to reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program." [i] NEHRP includes NEES within its scope. Through NEHRP, earthquake risk reduction efforts are carried out by four agencies:

- Federal Emergency Management Agency
- National Institute of Standards and Technology (lead agency)
- National Science Foundation (which supports NEES)
- U.S. Geological Survey

In the 1994 Northridge Earthquake in the Los Angeles area, a moderate-sized (magnitude 6.7) earthquake located on the fringe of a metropolitan area rather than a "direct hit," caused over $70 billion in damage.[ii]

A recent loss study of the effect of a magnitude 7.9 earthquake in the San Francisco Bay Area estimated up to 3,400 deaths and $120 billion in damage, not counting damage to transportation and utility infrastructure and long-term economic effects.[iii]

Federally supported studies of U.S. urban regions at risk to earthquakes have calculated estimated losses in the billions of dollars and at least hundreds of casualties for not only West Coast cities such as Los Angeles, San Francisco, Portland, and Seattle, but also for Salt Lake City, Memphis, Charleston, Boston, New York, and Honolulu.

A staggering loss of property and life that will impact a region for years can result from an earthquake that lasts only a few seconds.

Engineering Laboratories: The NEES Research Sites

A variety of testing facilities are needed that are capable of simulating earthquake effects on structures and soils. Three fundamental problems confront the earthquake engineering experimentalist:

- Ground shaking is by nature a dynamic phenomenon, changing from one split-second to another, and also greatly varies from one earthquake to the next. Dynamic response - the forces and deformations in a structure as it is shaken in an earthquake, or a specimen subjected to a simulated earthquake in the lab - has as much to do with the structure's dynamic properties as those of the shaking ground. Earthquakes also introduce the hazards of liquefaction, landslides, and surface rupture of the ground, and the generation of tsunamis in the sea.

- Economical design usually requires allowance for significant inelastic behavior, with the steel, concrete, masonry, and/or timber being stressed well into the region of permanent deformation. This in turn affects dynamic response.

- The uncertainties in the ground motion and in the properties of construction and soils combine to make it one of the most challenging probabilistic problems.

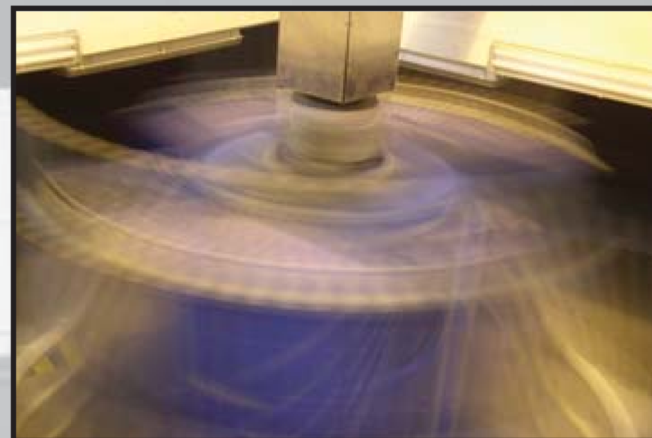
The NEES laboratories across the U.S. were extensively renovated and expanded from existing facilities or custom built to provide a range of testing options never before seen in the research community. They have achieved world-class levels of accuracy in the way in which they simulate earthquakes, including the dynamic, inelastic, and probabilistic issues listed above. The range of types of facilities includes:

- Geotechnical centrifuges
- Field and mobile apparatus
- Large-scale testing
- Shake tables
- Tsunami wave basin

Each is suitable for a specialized type of research. All are designed to be usable in the same research project with one or more other facilities, sometimes simultaneously with real-time interactive use of data from one to the other.

■ GEOTECHNICAL CENTRIFUGE LABORATORIES

The soil underneath and around a structure exists in a state of pressure created by the weight of the soil above it. Because of the equivalence of gravitational and inertial mass, imposing a high constant acceleration on a soil sample makes it “feel” the same as if it were under a large gravitationally imposed stress.



Soil experiences pressure from the weight of soil above it, which is simulated by the spinning of a centrifuge, which provides inertial forces on soil samples that are equivalent to the gravitational effect of soil pressure.

The spinning centrifuge, creating a steady outward centrifugal force, can simulate those at-depth soil conditions. The container with the soil sample and any scale models of structures and their foundations tilts horizontally as it revolves, creating a sideways analog for the vertical orientation in the field.

Centrifuges were adapted for use in geotechnical engineering research relatively recently as compared to many other kinds of testing, and even more recently was technology developed to simultaneously simulate an earthquake with a device to play back the scaled recording of an actual earthquake at the tip of the revolving arm.

The two NEES geotechnical earthquake engineering centrifuge facilities are among the most advanced in the world.

Background image: Geotechnical Centrifuge at NEES@UC Davis research facility.

NEES @ RENSSELAER

The NEES geotechnical centrifuge installed at Rensselaer Polytechnic Institute has a radius of 3 m (9.8 ft). The platform is capable of handling multiple types of soil containers and accessories. Earthquake motions are simulated using 1- or 2-dimensional shaking platforms.

The geotechnical centrifuge at RPI; at left the counterweight, at right the hinged container for the soil to be modeled (which swings into a horizontal position during operation).

An experiment is only as useful as the data it produces. How do the deformations of the soil, accelerations, and other data collected in the container at the tip get communicated and stored in the laboratory, when a hard-wired connection through the hub is not possible? Optical and electrical slip rings are used at the hub to seamlessly convey signals to and from the container.

Studies at the RPI NEES facility have been conducted on topics such as earthquake-induced landslides and the performance of deep piling foundation systems.

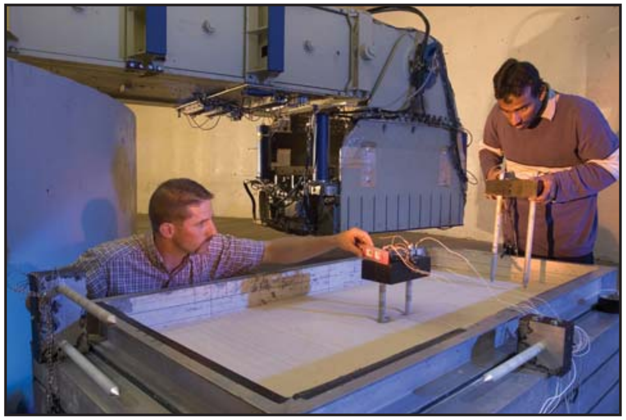
The RPI NEES equipment can carry a payload of 0.9 metric ton (1 ton) subjected to 150 g, and features an in-flight miniature robotic tool that can do construction-simulation tasks in the soil as the centrifuge is spinning.

nees.rpi.edu

NEES @ UCDAVIS

The centrifuge at the University of California, Davis, in terms of radius 9.1 m (30 ft), maximum payload mass 4500 kg (9,900 lb), and available bucket area 4.0 sq m (43 sq ft) is one of the largest geotechnical centrifuges in the world. The centrifuge is capable of producing 75 g of centrifugal acceleration, partly because of its size, because the longer the revolving arm, the greater the acceleration at the tip. With scaling, this means a soil model one meter deep simulates the in situ soil 75 meters deep. ("In situ:" Latin for "in the original place.")

The UC Davis centrifuge has been used to model a number of geotechnical earthquake engineering problems, including the stability of harbor facilities. A unique type of research conducted at the UC Davis facility is an experimental investigation, paired with analytical modeling, of the way the shaking of one building imparts vibrations into the soil that affect nearby buildings.



Structural models are carefully inserted into a soil sample inside the payload "bucket," which will be shaken with earthquake motions as it is spinning.

The NEES centrifuge at the University of California at Davis is one of the largest geotechnical engineering centrifuges in the world. Portions of it were originally used at a NASA facility to simulate g forces on astronauts.

nees.ucdavis.edu

FIELD AND MOBILE LABORATORIES

To conduct research where structures already exist - or to test the soil where existing or future construction may be sited, researchers need to conduct experiments outside of the traditional laboratory. The NEES program's three field and mobile laboratories make it possible to test on-site and relay the data directly from the field.

One type of field-deployed equipment mounts shakers inside or on a structure to subject it to low level vibrations, making it give up its secrets of how it will dynamically respond in an actual earthquake. Another resembles a massive piece of earth-moving equipment that is driven onto a site of interest. Through a vibrating metal plate in contact with the ground, the equipment imposes a localized earthquake on that soil. A third facility is located in an area of the U.S. where earthquakes happen frequently, with instrumented test structures and sensors in the ground to obtain data from real earthquakes.

A vehicle-mounted vibrating machine that can simulate earthquake motions is shown with its plate firmly in contact with the ground, ready to begin a geotechnical engineering test.

Background image: Garner Valley, the NEES@UCSB site for the study of Soil- Foundation-Structure Interaction (SFSI) and liquefaction.

NEES @ UCLA

The mobile field laboratory at the University of California at Los Angeles has enabled detailed, seismic performance characterization of full-scale structural and foundation systems. Through use of this equipment, it is possible to develop an inventory of field test results that provide significant new insights into the nonlinear response of full-scale structural systems, as well as soil-structure-interaction effects.

Inertial forces, similar to those experienced by the structure and soil in an earthquake, are generated by eccentric-mass shakers. These shakers rotate weights horizontally, and just as a wheel out of balance in a car causes vibration, so an intentionally out-of-balance distribution of rotating mass in the shaker causes vibration. The arrangement of the weights causes a motion along a particular axis of interest, and changing the frequency is like tuning the dial on a radio to find “stations,” or modes of vibration inherent in the structure. The largest of the shakers can exert forces up to 445 kN (100,000 pounds).

The UCLA mobile lab can deploy forced vibration equipment to sites or structures of interest.

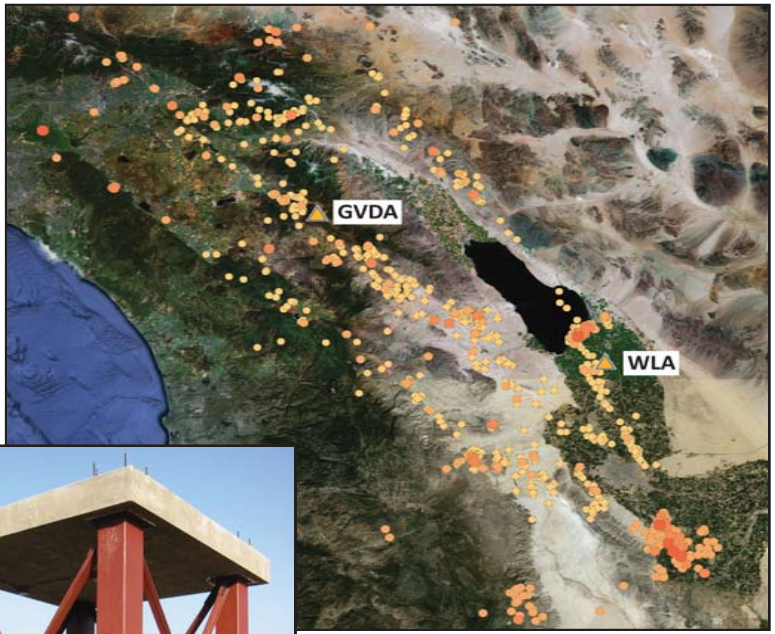
The UCLA shakers are used in research to excite bridges, buildings, and the ground itself.

nees.ucla.edu

NEES @ UCSB

The University of California at Santa Barbara in partnership with the University of Southern California has established a permanent field-testing site in the seismically active area of Garner Valley. Garner Valley is located in southern California and contains an ancestral lake bed with soft alluvium in approximately the upper 20m (65 ft), overlaying weathered and competent granite, a site selected for both its geotechnical and geologic characteristics as well as its unusually high seismic activity.

The Garner Valley Array is a thoroughly characterized strong motion monitoring site with surface accelerometers, borehole pore pressure transducers and accelerometers, and an extensively instrumented Soil-Foundation-Structure Interaction (SFSI) test facility.



The NEES@UCSB permanently instrumented field sites are located in one of the most seismically active areas in the country. They have been outfitted with instrumentation and experimental apparatus to allow for a variety of experiments. The two locations currently instrumented are the Garner Valley Digital Array (GVDA) and the Wildlife Liquefaction Array (WLA).

The Garner Valley NEES research site records at least micro-earthquakes on a daily basis – a natural laboratory for earthquake experimentation.

NEES @ UTEXAS

The University of Texas at Austin NEES facility is a mobile one that specializes in dynamic field testing using large vehicle-mounted shakers. In addition to the brute force needed to actually generate localized earthquakes, sophisticated equipment is needed to produce ground motions of a realistic nature and to accurately record data in the field. The field equipment, affectionally named T-Rex, Liquidator, and Thumper, can be used in a variety of applications, including shear wave velocity characterization, liquefaction testing, geophysical testing, and dynamic testing of structures. During experiments, the instrumentation van can wirelessly connect to the NEES IT infrastructure, allowing offsite access to both live video and data.

The UT-Austin mobile equipment has been used in testing in a number of states across the country.

T-Rex (Tri-Axial shaking) is one of only a few large types of vibroseis apparatus capable of propagating energy signals into the earth over an extended period of time, which provide axis transformation between vertical, inline, and cross-line at the push of a button. Liquidator (Low Frequency) is the only large vibroseis designed to provide useful force below 1 Hz, which enables low frequency liquefaction studies. Thumper (High Frequency) is intended as both a high frequency source with useful force up to 500 Hz and as a falling weight impact generator to “thump” the ground and elicit its properties.

The NEES mobile lab operated by the University of Texas at Austin is the home of three earth shakers, nicknamed T-Rex (tri-axial), Liquidator (low frequency), and Thumper (high frequency).

nees.utexas.edu

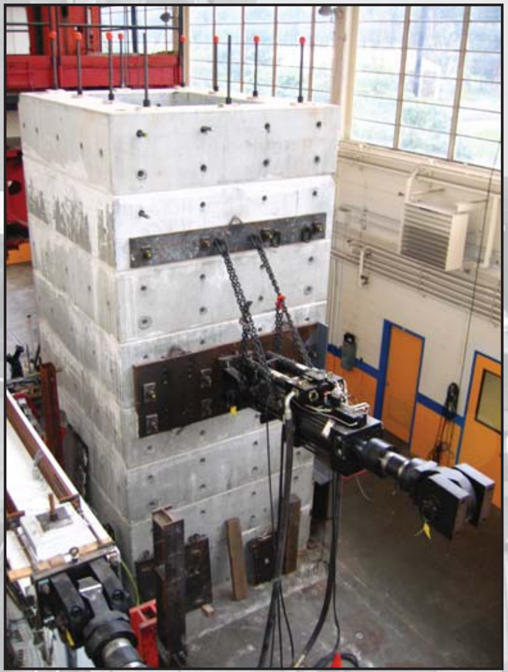
LARGE-SCALE TESTING FACILITIES

Any object that is structurally tested as a scale model behaves differently than the life-size version. Galileo first explained the scale effect whereby an ant could carry a twig much larger than itself but a horse cannot carry an entire tree trunk on its back.

In structural testing, the ratio of weight to vertical load resistance must be kept realistic. In earthquake testing, the horizontal stiffness and strength of the structural specimen are also critical, and when subjected to sideways displacements by hydraulically-powered actuators (pistons), the realistic vertical gravity load must also be maintained.

Materials are also most accurately tested at full-scale. For example, full-scale reinforced concrete test specimens can have actual reinforcing bars (rebar) with the same deformations (knobs) on them that bond with the concrete as in a real structure, and the aggregate (gravel) and other ingredients of the concrete mix need not be scaled down in complex, nonlinear ways to try to recreate the behavior of the full-size material ingredients.

In the NEES suite of large-scale testing facilities, "large" can be very large indeed. Structures a few stories in height can be built in the lab. By anchoring actuators to essentially rigid supports ("strong floors," "strong walls"), the apparatus can impose any amount of vertical or horizontal loading desired, in a precise sequence, to make the structure deform as it would during an earthquake.



The reconfigurable wall at the UC Berkeley facility is shown at left, with an actuator in position ready to be connected to a structural specimen and impose lateral motions.

Background image: The NEES@Minnesota's Multi-Axial Subassemblage Testing (MAST) apparatus for large structures.

NEES @ CORNELL

Utility and transportation systems are essential to the daily functioning of our modern world. This infrastructure includes communication, electric power, liquid fuel, natural gas, transportation (airports, highways, ports, rail and transit), water, and wastewater systems. An outage of any of these services, for even a few minutes, is a significant disruption. If badly damaged in an earthquake, these systems can take months to be restored to service.

Cornell University operates the Cornell Large-Scale Lifelines Testing Facility. Pipelines can be embedded in soil and then subjected to large displacements of about a meter. Experiments have been conducted to test the behavior of pipelines crossing a fault that suddenly ruptures and the affect of liquefaction-induced lateral spreading. Aboveground utility and transportation construction subjected to permanent ground deformation caused by faulting, liquefaction, subsidence, or landslides, can also be tested.



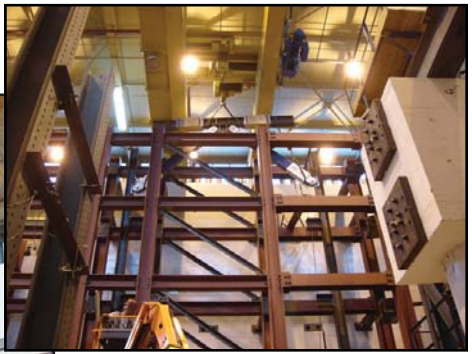

After placement of soil and the pipeline were complete, this test sheared the container along a joint to simulate fault rupture.

The NEES research facility at Cornell University is a unique, world-class site for testing underground pipeline response to large ground deformations.

nees.cornell.edu

NEES @ LEHIGH

The NEES large-scale testing facility at Lehigh University has strong walls that extend 15 m (50 ft) high. A full-scale structure can be built and tested in this apparatus, where realistic seismic simulations can be conducted that in real-time cause the specimen to displace multi-directionally.



Full-scale buildings several stories high are subjected to seismic simulations in the research site at Lehigh University.

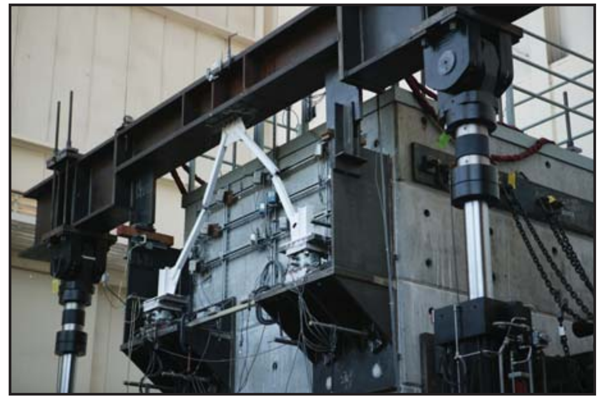
Large-scale tests that best simulate an earthquake are dynamic, that is, the actuators that impose displacements on the test specimen do so as fast as the earthquake would, causing a rapid succession of different movements in the structure. Especially challenging for seismic simulations are the large strokes required of actuators, as much as half a meter or more, which are required to emulate the large displacements that can occur during earthquakes. Large strokes and velocities require massive “back room” facilities to pump hydraulic fluid to the required pressure and maintain that reserve in accumulators. Along with computer control and data acquisition systems, the entire massive installation must function as a single smart piece of equipment.

The NEES testing facility at Lehigh University contains a unique system enabling real-time hybrid simulation to investigate the multi-directional seismic response of large-scale structural components and systems.

www.nees.lehigh.edu

NEES @ BERKELEY

NEES supported the creation and operation of the Reconfigurable Reaction Wall-Based Earthquake Simulator Facility operated by the University of California, Berkeley. "Reconfigurable" means that it is possible to rearrange the geometry of the strong walls to provide supports at various locations for horizontally- or vertically-oriented actuators. The innovative solution designed at Berkeley is to stack large square "hollow concrete blocks" at various locations in the laboratory and anchor them to the strong floor. A crane lifts each block into place, then removes it from the stack and rearranges it in a different location for another test, somewhat like rearranging blocks.



A test in the UC Berkeley NEES facility of a portion of a braced frame.

A ground story column of a building will experience its usual very large gravity loads at the same time as it moves sideways in an earthquake. The laboratory's huge universal testing machine is adjacent to simulate the weight of those upper stories, exerting vertical forces up to 18,000 kN (4,000,000 pounds) on a specimen at the same time it is pushed and pulled laterally to simulate the earthquake. The forte of the Berkeley NEES facility is hybrid testing, testing that is a combination of both physical testing and computer simulation. A portion of a structure, say its ground story, can be built full-scale and subjected to earthquake motions in the lab. Simultaneously a computer calculates from that data how the upper portion of the structure would respond and how those forces from above in turn affect the ground story. This almost instantaneous feedback is especially challenging – and challenging new research is the mission of NEES.

The NEES Reconfigurable Reaction Wall located at the University of California, Berkeley can perform hybrid tests that simultaneously combine physical testing of a sub-structure and computer simulation of the rest of the structure.

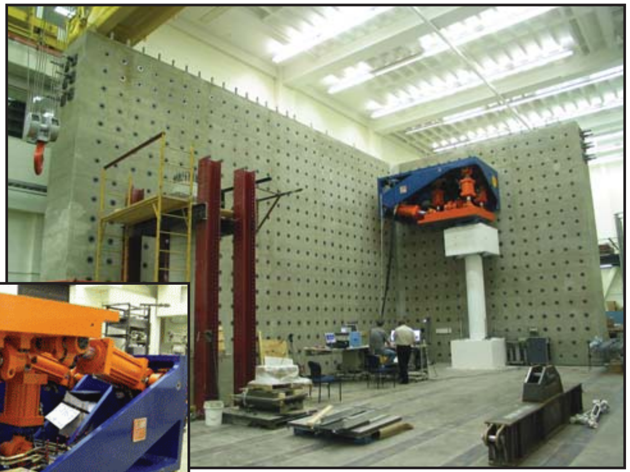
nees.berkeley.edu

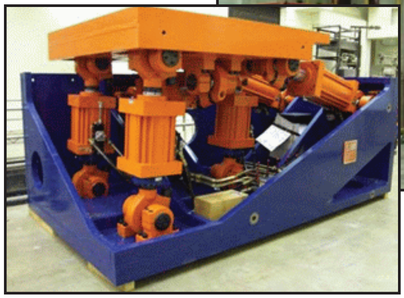
NEES @ UIUC

The Multi-axial Full-scale Substructure Testing and Simulation facility at the University of Illinois at Urbana-Champaign has unique features, which allow full-scale structures or structural subassemblages to be subjected to complex loading and deformation states at multiple connection points on the structural specimen, including the connection between the structure and its foundation. This is a new concept in “strong floor” or “strong wall” testing.

The facility is also equipped with a 1/5 scale version of the large laboratory to provide advance simulations of the operation of the full-scale laboratory apparatus.

The small-scale laboratory is essential to the efficient operation of the complex large-scale facility in that it allows users to understand the capabilities and limitations of the laboratory and the control systems prior to conducting expensive experiments using the large facility. It has also proven to be a valuable learning experience for students to give them hands-on experience in earthquake engineering experimental research.





An actuator pod mounted to strong walls is ready to exert simulated earthquake effects at the tops of reinforced concrete columns.

The NEES research facility at the University of Illinois features “pods” of actuators that can be floor- or wall-mounted in various positions to exert multi-axial displacements on test specimens.

nees.uiuc.edu

NEES @ MINNESOTA

The University of Minnesota's Multi-Axial Subassemblage Testing Laboratory provides a powerful and unique tool for investigating the effects of earthquakes, hurricanes, and other extreme events on large structural components, such as bridge or building columns up to 8.7 m (29 ft) tall.

The centerpiece of the massive apparatus is an overhead rigid cruciform, which is connected to actuators that in turn are provided with their necessary reactions by strong walls. Making that overhead platform translate vertically or horizontally, or rotate, makes the specimen beneath twist, compress, stretch, and shear as during an earthquake.

The amount of vertical and horizontal force applied 5,780 kN (1.3 million pounds) and 4,000 kN (900,000 pounds) respectively, makes it capable of testing very strong structures. The types of structures it can test include portions of beam-column frame systems, walls, tanks, and bridge piers.

The steel box column mounted in the center of the apparatus at the University of Minnesota is experiencing a simulation of the earthquake motion of the structure above it.

The University of Minnesota's Multi-Axial Subassemblage Testing Laboratory is the largest of its kind in the world.

nees.umn.edu

SHAKE TABLE FACILITIES

A shake table is designed to simulate the movement of the ground and thus is the most direct way to represent an earthquake in the laboratory. The accumulation of strong motion records over the last 75 years, especially in recent decades, provides a valuable library of data for shake table testing. Just as a sound recorder can record music and then play that music back with high fidelity, so a sophisticated shake table has the ability to precisely recreate strong motions that have been recorded.

One of the NEES facilities at the University at Buffalo has two tables that can be used independently or with a framework spanning between them to provide a larger “footprint.”

The size of the simulator is significant. Larger, full-scale structural specimens provide more realistic data than small models, though dynamic similitude relations can be used for slightly scaled-down specimens. The weight of the specimen that can be shaken to a particular degree is another performance specification. The maximum acceleration is relevant, because strong earthquakes have been recorded to have peak ground accelerations over 1 *g*. A large amount of displacement in the operation of the table is valuable, as is a high and sustained velocity. The more degrees of freedom – X, Y, Z, and rotations – the better as well. The NEES facilities have been designed to operate at among the highest performance levels in the world. More than one NEES research site is devoted to this type of testing to provide enough capacity for the research projects, and in addition each has slightly different advantages.

Background image: NEES@UC San Diego conducted a test of a million-pound precast concrete structure with the largest footprint of any structure ever tested on a shake table in the U.S.

NEES @ BUFFALO

The University at Buffalo Structural Engineering and Earthquake Simulation Laboratory actually includes two kinds of facilities in addition to a shake table simulator. One of those is designed to simulate the sideways out-of-plumb motion of a building that varies from story to story (interstory drift), which is a major cause of nonstructural damage. Full-scale partitions, ceilings, piping, and heating-ventilating-air conditioning components that extend up through a building, and other nonstructural fittings can be installed and tested. Another kind of apparatus allows large-scale testing, of the type previously described. The description here emphasizes the shake table – or rather two adjacent shake tables.

A full-size townhouse, shown here almost completed, was built on a “chassis” spanning between the two tables and tested to simulate an earthquake.

Both tables measure 3.6 m by 3.6 m (11.8 ft x 11.8 ft) and have six degrees-of-freedom: back-and forth on one horizontal axis, say the north-south axis, constitutes one of those displacement patterns; translation on the east-west axis another; and up and down a third degree of freedom. Rotation degrees of freedom make up the other three (pitch, roll, and yaw). The equipment can be moved within the laboratory building, up to 30 m (100 ft) apart, center-to-center, and operated separately or in unison, functioning as a much larger shaker, with a frame or chassis spanning between them. This allows the table to carry a structural specimen like a full-size building up to 37 m (120 ft) long.

The NEES research site at the University at Buffalo includes shake tables, strong wall/floor for large-scale testing, and a nonstructural component simulator.

nees.buffalo.edu

NEES @ UC SAN DIEGO

The University of California at San Diego operates a NEES shake table at the Englekirk Structural Engineering Center about 8 miles from the main university campus. The site affords ample space for the largest shake table in the country, and the only major outdoor shake table in the world. At 7.6 m by 12.2 m (25 by 40 ft), it is able to test structures weighing up to 2,000 metric tons (2,200 tons) and as tall as 30 m (100 ft). Its hydraulic actuators are capable of very large velocities, allowing it to create simulations of extremely devastating earthquakes.

Because it is outdoors, it facilitates construction of realistic structures and moving them onto the table, thereby avoiding the space limitations of working inside a laboratory building. The site also affords ample room for a blast testing facility and large excavated areas that can be filled with custom-specified soil for soils-related testing such as soil-structure-interaction studies. The facility has been used to test full-scale portions of multi-story reinforced concrete building models.

An actual wind turbine, 21 m (70 ft) tall, has been tested on the outdoor UC San Diego shake table.

The University of California, San Diego is home to the largest shake table in the U.S. and the world's first outdoor shake table.

nees.ucsd.edu

NEES @ RENO

The NEES research site at the University of Nevada, Reno includes three biaxial shake tables that can be repositioned for maximum flexibility. An experiment can be set up on one table while another table is running. Alternatively, the three can be electronically controlled to act as one, with one structural specimen of long length on them. Yet another possibility is slightly varying the motion of each table to account for slight differences that could occur at multiple points of support of a bridge during an earthquake.

The three biaxial shake tables at the University of Nevada, Reno laboratory.

Each table is 4.25 m by 4.25 m (14 ft by 14 ft), can carry a maximum specimen mass of 68,000 kg (150,000 pounds), and can generate 1 g accelerations. Tests of nonstructural components as well as structures have been conducted in the facility.

The ability to use the tables together for a large specimen is illustrated by the testing of a four-span, 110-ft large model of a concrete bridge, the largest such experiment performed in the United States.

nees.unr.edu

TSUNAMI WAVE BASIN

The NEES facility at Oregon State University is devoted to the study of tsunamis.

Tsunamis are seismic sea waves that are generated by earthquakes that displace the ocean floor. Raising the seafloor raises a relatively incompressible column of water above, creating a bulge that speads over a huge area. Gravity quickly sets that raised plateau of water in motion, and the tsunami waves travel with great efficiency across entire oceans.

To simulate tsunami waves at smaller scale, a wave basin is needed in which waves at one end can be generated with precise characteristics. The waves travel the length of the basin and then arrive at carefully instrumented model structures or shorelines where their effects are measured.

The tsunami wave basin is about the size of a 50-meter swimming pool. In that basin, earth moving equipment can enter the lab prior to a test and place a desired type and profile of sand. Related to the tsunami wave basin are testing capabilities for a variety of other ocean and coastal engineering research. As shown here, the facility is extensively used for education and outreach as well as research.

Tsunami simulation with scale-model structures in the Oregon State University tsunami wave basin.

Background image: Tsunami damage from the 1964 Alaska Earthquake.

NEES @ OREGONSTATE

The NEES facility at Oregon State University is part of the O.H. Hinsdale Wave Research Laboratory. It is one of the world's largest and most sophisticated laboratories for education, research, and testing on coastal, ocean and related topics. It includes a tusnami wave basin and a large wave flume. The facilities are capable of tsunami research, sediment suspension and transport, nearshore hydrodynamics, wave-structure interaction, and environmental fluid mechanics.

The tsunami wave basin has piston-powered hinged paddles that generate precise shapes and sizes of waves.

The Tsunami Research Facility offers a unique facility for the study of earthquake-generated tsunami waves and their impact on nearshore and coastal environments. Besides tsunami-structure-interaction, it can examine such processes as tsunami inundation and overland flow, debris flow and scour, harbor resonance, and landslide generated tsunami. Tests have been done to measure pressures and effects on structures as tsunami waves strike them.

The NEES tsunami experimentation facility at Oregon State University is the world's largest.

nees.oregonstate.edu

NEES CYBERINFRASTRUCTURE

The information technology infrastructure, or cyberinfrastructure, of the Network for Earthquake Engineering Simulation, is based on computer networks and application-specific software, tools, and data repositories that support NEES research and use of research results.

One of the inefficiencies in most civil engineering research over the years has been the lack of standardization in the way data was collected, organized, and maintained. Improving the data and metadata procedures in the earthquake engineering field via the leadership of NEES is expected to bring widespread benefits. While atmospheric scientists, for example, can easily access large quantities of data contributed from numerous sources and not be hindered by the different hardware, software, and instrumentation used over the years, civil engineers have yet to benefit from that type of collaborative library of information that is easily accessed. A goal of NEES is to make it easier for researchers to reuse data for future discoveries and innovations and for practicing civil engineers to obtain useful testing and analytical results to aid in their design work.

The extensive visualization of experiments and data at the University of California at Davis geotechnical centrifuge relies on real-time computer operations.

The cyberinfrastructure of NEES has been designed and developed over the past several years by the University of California at San Diego Supercomputer Center and the University of Illinois Urbana-Champaign National Center for Supercomputing Applications. Its services are required to tie together the geographically distributed testing laboratories, enable real-time hybrid simulations, allow individuals to remotely participate in or observe experiments, organize and share data, and in general to make the entire set of NEES resources operate in a unified way.

- **OpenSees**
  OpenSees, the Open System for Earthquake Engineering Simulation, is a software framework for developing applications to simulate the performance of structural and geotechnical systems subjected to earthquakes. Developed at the University of California at Berkeley, OpenSees is fully supported by the IT functions within the NEES cyberinfrastructure to improve the modeling and computational simulation in earthquake engineering through open-source development.

- **NEESforge**
  NEESforge is the community code repository for the Network for Earthquake Engineering Simulation community. NEESforge enables all members of the NEES community to make their software publicly available, view software developed by other sites, and to find developers to collaborate on their software projects.

- **NEEScentral**
  NEEScentral is the web portal designed to provide a simple way for researchers to share their project data with each other and to archive their data for access by the general public.

The Founding Vision of NEES

We believe that this utilization of advanced IT will enable the earthquake engineering research field to move from a reliance on physical testing to model-based simulation….Despite their geographic dispersion, the various components of NEES will be interconnected with a computer network, allowing for remote access, the sharing of information, and collaborative research.[iv]

Dr. Eugene Wong, Assistant Director for Engineering, NSF, 1999

Design Methodology for Precast Floor Diaphragms • NEES Experimental Project for Verifying Full-Scale Semiactive Control of Nonlinear Structures • NEES Consortium Operation: FY 2005 - FY 2014 • Multi-Site Soil-Structure-Foundation Interaction Test (MISST) • Workshop for Outreach to Future NEES Proposers • Seismic Performance of Bridge Systems with Conventional and Innovative Materials • Self-Centering Damage-Free Seismic-Resistant Steel Frame Systems • Physical modeling of 3D Tsunami Evolution Using a Landslide Tsunami Generator • Evaluation of Ground Rupture Effects on Critical Lifelines • Highly Damage Tolerant and Intelligent Slab-Column Frame Systems Through Combination of Advanced Materials and Embedded Wireless Sensing • In Situ Determination of Soil Modulus and Damping as a Function of Level of Strain • Dynamic Passive Pressure on Full-Scale Pile Caps • Large-scale testing and micromechanical simulation of ultra-low-cycle fatigue cracking in steel structures • Sidesway Collapse of Deteriorating Structural Systems • Seismic Behavior, Analysis and Design of Complex Wall Systems • Planning Meeting for NEES/E-DEFENSE Collaboration in Earthquake Engineering • Collaborative Research: Field demonstration of utility of NEES Vibrator to meet EarthScope science objectives for earthquake-hazard and crustal-structure studies • Col- laborataive Research: Field demonstration of utilit of NEES vibrator to work with IRIS equipment pool to meet Earthscope science objectives for crustal-struc- ture and earthquake • Indian Ocean Tsunamis - Environmental and Socio- Economic Impacts on the Malay-Thai Peninsula • Physical and Social Infra- structure Impacts and Interdependen- cies in the December 2004 Tsunami in Southern Thailand • Factors affecting behavioral response to natural warning signs of tsunami: the case study of the December 26, 2004 earthquake.• Cross- Cultural Analysis of Responses to Mass Fatalities Following the Indian Ocean Tsunami of Decem- ber 26, 2004 • The Role of Coastal Eco- system Degradation in Tsunami Damage • Social Vulnerabil- ity Mapping and GIS in Tsunami Impact Analysis • Structural Health Monitoring of Bridges Subjected to Seismic Loads Using Distributed Fiber Optic Sensors at the University of Nevada NEES Shaking Table Testing Facility • Researchand Education Experiences for Students to Examine Earthquake Hazard Mitigation Utilizing the Network for Earthquake Engineering Simulation • NEESR Payload - Large-Scale Validation of Innovative SMA Recentering Devices for Multi-Span Bridges • NEESWood: Development of a Performance-Based Seismic Design Philosophy for Mid-Rise Woodframe Construction • Experimental and Micromechanical Computational Study of Pile Foundations Subjected to Liquefaction-Induced Lateral Spreading • Study of Surface Wave Methods for Deep Shear Wave Velocity Profiling Applied to the Deep Sediments of the Mississippi Embayment • Mechanisms and Implications of Time-Dependent Changes in the State and Properties of Recently Liquefied Sands • Innovative Applications of Damage Tolerant Fiber-Reinforced Cementitious Materials for New Earthquake-Resistant Structural Systems and Retrofit of Existing Structures • Seismic Risk Mitigation for Port Systems • Inelastic Web Crushing Performance Limits of High-Strength-Concrete Structural Walls • Seismic Performance Assessment and Retrofit of Non-Ductile RC Frames with Infill Walls • Towards Developing an Engineering Procedure for Evaluating Building Performance on Softened Ground • Seismic Simulation and Design of Bridge Columns under Combined Actions, and Implications on System Response • Controlled Rocking of Steel-Framed Buildings with Replaceable Energy Dissipating Fuses • Development of Performance Based Tsunami Engineering, PBTE • HACU National Internship Program • NEESR Payload Project for NSF Award 0420347 - Control of Plastic Hinging Behavior of RC Bridge Systems • A Phase 1 Prediction of Dynamic Response of Spread Footings on Sand • US/New Zealand/Australia Conference and Workshop on the Future Security of Infrastructure • Second Annual Cybersecurity Summit for Large Federally Sponsored Facilities; Arlington, Virginia; November or December, 2005 • REU Site: The Network for Earthquake Engineering Simulation Research Experiences for Undergraduates (NEESreu) • NEES Experimental Project for Verifying Full-Scale Semiactive Control of Nonlinear Structures • Researchand Education Experiences for Students to Examine Earthquake Hazard Mitigation Utilizing the Network for Earthquake Engineering Simulation • Deployment and Integration of Instructional Shake Tables Using the NEES Cyberinfrastructure • Mitigation of Collapse Risk in Vulnerable Concrete Buildings • System Behavior Factors For Composite And Mixed Structural Systems • High-fidelity site characterization by experimentation, field observation, and inversion-based modeling • TSUNAMOS: A Validated, Multi-Scale Tsunami Model for Hybrid Numerical-Experimental Simulation • Performance-Based Design of New Masonry Structures • Experimental Determination of Performance of Drift-Sensitive Nonstructural Systems under Seismic Loading • International Hybrid Simulation of Tomorrow's Braced Frame Systems • National Earthquake Hazards Reduction Program • Leveraging Tsunami Research - Wave Loading on Residential Structures with Earthquake and Hurricane Applications • Workshop to Identify and Establish Priorities for NEES Research on the Seismic Vulnerability of Existing Build... Spring 2007 • Earthquake Hazard Reduction for Critical Facilities • 5th NRCEN Workshop: Creating Positive Influence: Innovative Approaches to Research-based Education and Outrea... National Earthquake Hazards Reduction Program (NEHRP) • Simulation of the Seismic Performance of Nonstructural Systems • Soil Improvement Strategies to Mitigate Impact of Seismic Ground Failures via Novel Integration of Experiment and Simulation • Damage Detection and Health Monitoring of Buried Pipelines after Earthquake-Induced Ground Movement • Measurement of the Strength of Liquefied Soil in Physical Models • Behavior and Design of Cast-in-Place Anchors under Simulated Seismic Loading • Framework for Development of Hybrid Simulation in an Earthquake

RESEARCH PROJECTS

The purpose of the NEES research sites is to enable the research that NSF separately supports. Over 100 projects have been completed to date. Those projects range from individual investigators to small groups to large collaborative projects involving over a dozen investigators and using more than one NEES research site. The process by which research grants are solicited and awarded is managed by NSF in its usual competitive process, with peer reviews.

Control room at the RPI geotechnical centrifuge facility.

LARGE SCALE COLLABORATIVE PROJECTS

The concept of NEES is perhaps most fully realized in the large-scale, multi-research-site projects that allow investigators across the country to interact and conduct testing and analysis at facilities that their own institutions could not provide.

Examples of such projects supported by the NSF NEES research program, called grand challenges, include the following:

Collapse Risk of Vulnerable Concrete Buildings

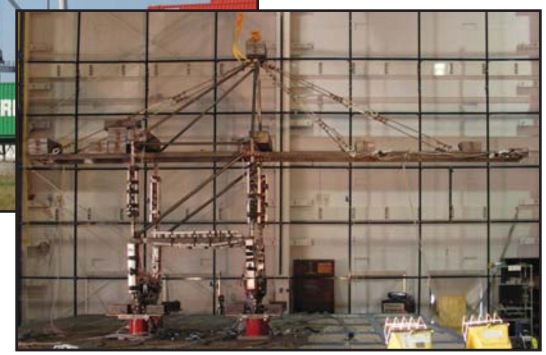
The Pacific Earthquake Engineering Research Center (PEER) at the University of California at Berkeley was awarded a five-year, $3.6 million NEES Grand Challenge grant from NSF to study the collapse potential of older nonductile concrete buildings during earthquakes. These buildings are pervasive throughout the U.S. and other countries.

The PEER project team includes these institutions: University of California at Berkeley; UC Irvine; UC Los Angeles; San Jose State University; University of Puerto Rico at Mayaguez; University of Kansas at Lawrence; University of Washington; Purdue University; University of Southern California, the Earthquake Engineering Research Institute, and the Concrete Coalition.


Complete collapse of a five-level parking structure at a medical facility in the 1994 Northridge Earthquake.

Seismic Risk Mitigation for Port Systems

Georgia Institute of Technology was awarded $3.3 million for NSF-supported NEES research on the seismic vulnerabilities of ports. Earthquakes pose a significant threat to many U.S. seaports, which serve as critical gateways for domestic and international trade. Ports often face more than their share of earthquake vulnerabilities. Their coastal sites are usually underlain with soft alluvium subject to both ground motion amplification and permanent ground deformation due to liquefaction or subsidence. The types of structures they require, such as large cranes, also pose challenges.



Ports handle the bulk of international cargo as well as extensive domestic shipments. Large cranes and the material under them that provides support have been vulnerable in past earthquakes.

Four NEES research sites are being used in a coordinated manner, the coordination spanning across the disciplines of geotechnical and structural engineering. Two innovative soil improvement techniques are being evaluated using the UT Austin mobile shaker and the UC Davis centrifuge. The strength and ductility of piles and their connections to the overlying deck play a vital role in the seismic performance of pile-supported wharves. Improved pile configurations and pile-deck connections will be developed using full-scale tests at the UIUC facility. Tests will be performed at the Buffalo research site to investigate innovative bracing systems to mitigate damage to cranes from large ground displacements due to liquefaction. These tests exploit the full potential of the NEES program by using hybrid numerical and experimental simulation.

Simulation of the Seismic Performance of Nonstructural Systems

NSF awarded to the University of Nevada, Reno a $3.6 million grant to study the seismic performance of ceiling-piping-partition nonstructural systems. Nonstructural systems represent 75% of the value of buildings in the US exposed to earthquakes and have been estimated by the Federal Emergency Management Agency (FEMA) to account for even slightly more than that in estimated future earthquake losses of the nation. This project is integrating multidisciplinary system-level studies that will develop, for the first time, a simulation capability and implementation process for enhancing the seismic performance of the ceiling-piping-partition system.

Complete collapse of the suspended ceiling over a swimming pool facility.

The University at Buffalo and University of Nevada at Reno research sites are being used, and other participating institutions are: UC San Diego, Georgia Institute of Technology, Rutherford & Chekene, Consortium of Universities for Research in Earthquake Engineering, Cornell University, North Carolina State University, and North Carolina A & T State University. The project is guided by extensive interaction with design professionals and industry representatives.

OTHER NEES RESEARCH PROJECT EXAMPLES

One of the many other NEES research projects that illustrates the unique capabilities of the multi-site NEES portfolio of research sites is testing a long span bridge. To improve the seismic performance of bridges, the total system behavior of the structure and soil has to be understood.

Past testing studies have been limited to segments of bridges due to a lack of large-scale testing facilities. A project that used the shake table systems at NEES sites at the University of Nevada at Reno and the University of California at San Diego developed a detailed understanding of bridge seismic performance, including the abutments at the ends of the bridge as well as the bridge structure itself. Four-span bridge models, some with supports of a single column and some with two-legged bents, were tested at UNR and an abutment wall system was tested at UCSD. Comprehensive computer models at the University of California, Berkeley integrated the results.

The piers of this reinforced concrete model of a highway bridge are mounted on shake tables in the University of Nevada at Reno laboratory at the locations where they would connect to foundations in the ground.

NSF also supports within the NEES program research by individual investigators, using perhaps only a single research site. Such projects are well-suited for some topics, and they also provide early career faculty with opportunities for entry into the field of earthquake engineering research.

INTERNATIONAL COLLABORATION

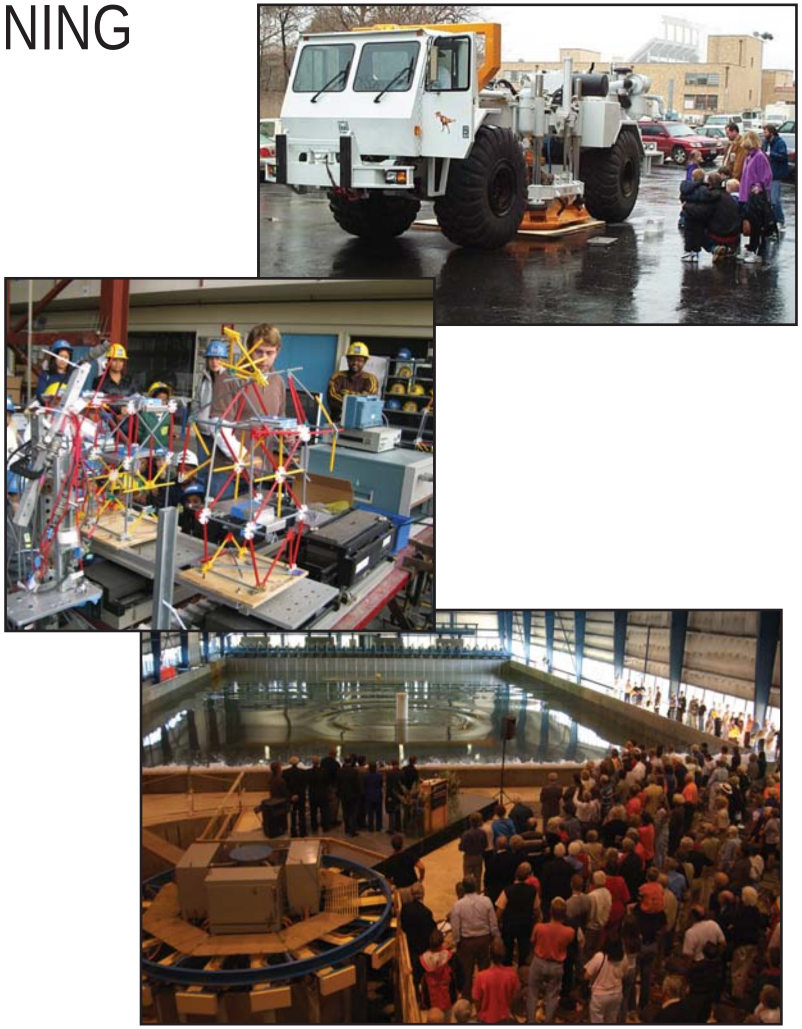
Earthquakes are a worldwide occurrence, and while the U.S. is a leader in the field, there are other nations with facilities and researchers with advanced capabilities. In an effort to expand research possibilities beyond the borders of the United States, Memoranda of Understanding (MOUs) have been established by NEES and NSF.

The E-Defense shake table facility.

Researchers from the Tokyo Institute of Technology completed two major experiments using the NEES facility at UC Davis. This work was made possible by the MOU between NEES and NIED, the Japanese government's National Research Institute for Earth Science and Disaster Prevention, and the MOU between the National Science Foundation and the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT). Under these agreements, NEES researchers are able to access the world's largest shake table, known as "E-Defense," located in Miki City, outside Kobe, Japan, and Japanese researchers are able to access the NEES research sites in the U.S.

Other collaborations involving the E-Defense facility include a collaborative NEES project called Development of a Performance-Based Seismic Design Philosophy for Mid-Rise Woodframe Construction. This project seeks to take on the challenge of developing a seismic design philosophy that will provide the necessary mechanisms to safely increase the height of woodframe structures. This is expected to have significant construction industry benefits. This will be accomplished through the development of a new seismic design philosophy that will make mid-rise woodframe construction a reality in regions of moderate to high seismicity. Researchers from Colorado State University, the University of Delaware, University at Buffalo-SUNY, Texas A&M, and Rensselaer Polytechnic Institute have come together to conduct testing of their design at the E-Defense shake table in Miki City, Japan.

EDUCATION, OUTREACH, AND TRAINING



This function of NEES can be described in terms of the audiences that are served. Almost all NEES projects, even small ones, involve some aspect of education and outreach, and NEES resources are available to provide specialized training on use of experimental or IT services. A few can be highlighted here.

- **Undergraduates**

  Each year, about a third of the NEES research sites host Research Experiences for Undergraduates (REU), an NSF-funded program that places undergraduates in the laboratories or out in the field where actual science and engineering research is being performed. The 10-week REU program gives students the opportunity to conduct state-of-the-art earthquake research under the supervision of a faculty advisor, and to network with students and graduate advisors from other universities. Because the learning capitalizes on an already funded research project, this mode of education provides a cost-effective as well as realistic experience.

- **High School**

To promote interest in science, technology, engineering, and mathematics (the STEM subjects, as NSF terms them), the NEES research project centered at Georgia Tech on Seismic Risk Management for Port Systems is supporting collaborative educational efforts with Georgia Tech's Center for Education Integrating Science, Mathematics, and Computing (CEISMC) and Atlanta's Westlake High School, a 99% African-American science and mathematics magnet school.

Specific initiatives include: (a) hosting teachers from Westlake High School as part of CEISMC's Georgia Intern-Fellowships for Teachers (GIFT) program for seven-week summer internships to expose them to scientific research, data analysis, curriculum development and real-world inquiry and problem solving; (b) hosting a team of three high school students to conduct a summer research project; (c) developing seismic risk reduction term projects for Westlake's pre-engineering courses for juniors and seniors that utilize the tele-presence capabilities of NEES to more directly engage students in collecting data for their projects; and (d) encouraging graduate research assistants to participate in CEISMC's Student and Teacher Enhancement Partnership (STEP) program, an NSF-sponsored K-12 program that places graduate students in area high schools.

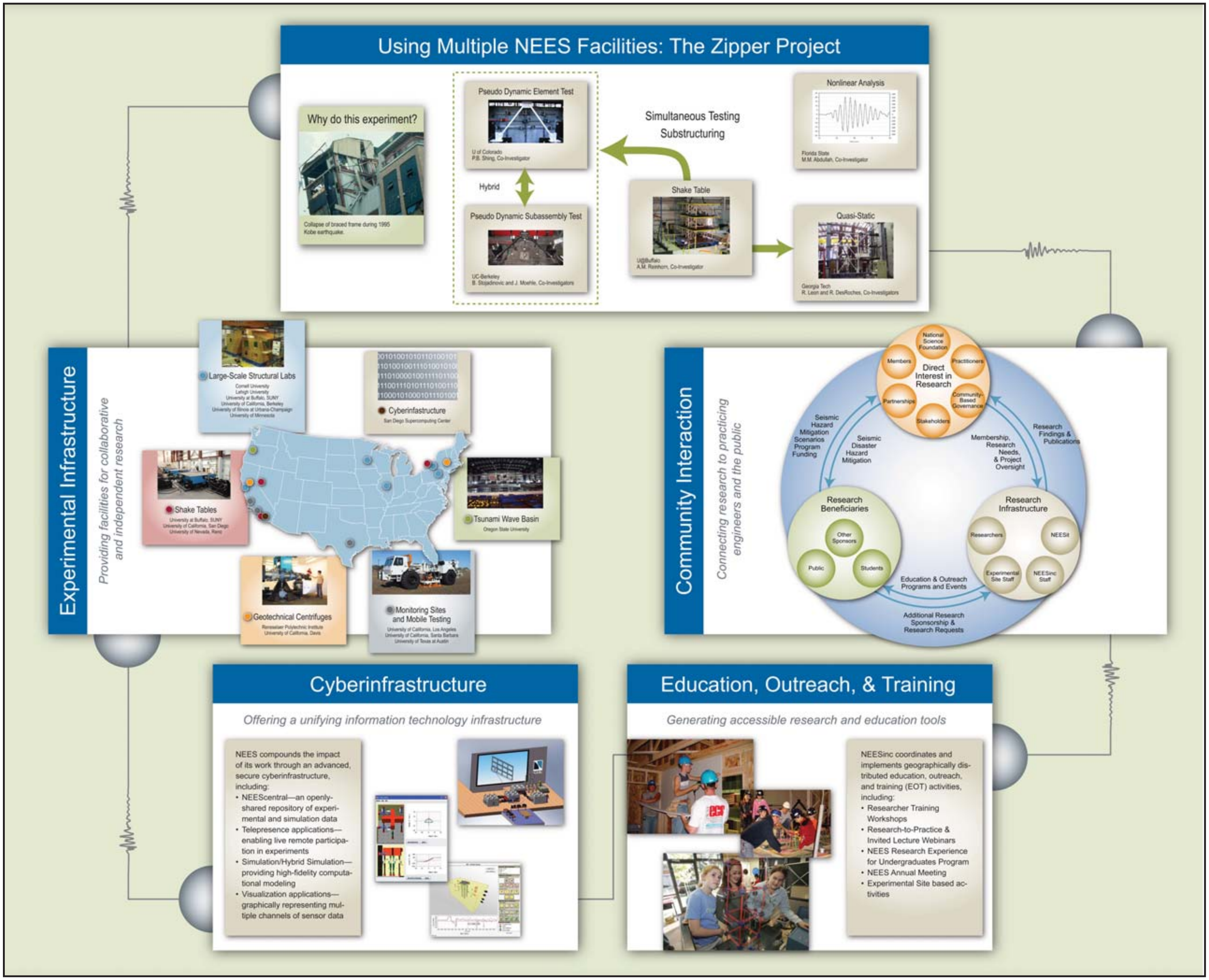
Atlanta high school students in the Georgia Tech structures laboratory getting a first-hand look at experimentation in the NEES research project on port facilities.

- **Middle School**
  At the University of Nevada at Reno, middle school minority and female students have explored earthquakes as they relate to structures in one-week summer day camps. In association with the Raggio Science, Technology, Engineering, Mathematics Center at the University, students are encouraged to have the confidence to pursue careers in these field.

- **Elementary School**
  The State of Oregon 5th Grade Earth Science Standards state that students should be able to “identify causes of Earth surface changes and identify effects of wind and water on Earth materials using appropriate models.” Fitting into that curricular standard and responding to teacher requests, the NEES Tsunami Research Facility at Oregon State University developed a hands-on, inquiry-based beach erosion activity to integrate with existing classroom curricula such as the FOSS2 “Landforms” kit.

- **General Public**
  On November 13 2008, five million people throughout Southern California participated in the Great Southern California ShakeOut (www.shakeout.org), the largest earthquake preparedness activity in U.S. history.

  As part of the ShakeOut Drill, the NEES experimental facility at University of California, Los Angeles was invited to conduct a laboratory demonstration to illustrate improvements made to design requirements for reinforced concrete structures in the past few decades.


Using Multiple NEES Facilities: The Zipper Project
Why do this experiment?
Collapse of braced frame during 1995 Kobe earthquake.
Pseudo Dynamic Element Test
U of Colorado
P.B. Shing, Co-Investigator
Hybrid
Pseudo Dynamic Subassembly Test
UC-Berkeley
B. Stojadinovic and J. Moehle, Co-Investigators
Simultaneous Testing
Substructuring
Shake Table
U@Buffalo
A.M. Reinhorn, Co-Investigator
Nonlinear Analysis
Florida State
M.M. Abdullah, Co-Investigator
Quasi-Static
Georgia Tech
R. Leon and R. DesRoches, Co-Investigators
Experimental Infrastructure
Providing facilities for collaborative and independent research
Large-Scale Structural Labs
Cyberinfrastructure
San Diego Supercomputing Center
Shake Tables
Tsunami Wave Basin
Oregon State University
Geotechnical Centrifuges
Monitoring Sites and Mobile Testing
Community Interaction
Connecting research to practicing engineers and the public
Direct Interest in Research
Research Beneficiaries
Research Infrastructure
Education & Outreach Programs and Events
Additional Research Sponsorship & Research Requests
Research Findings & Publications
Membership, Research Needs, & Project Oversight
Cyberinfrastructure
Offering a unifying information technology infrastructure
NEES compounds the impact of its work through an advanced, secure cyberinfrastructure, including:
• NEEScentral—an openly-shared repository of experimental and simulation data
• Telepresence applications—enabling live remote participation in experiments
• Simulation/Hybrid Simulation—providing high-fidelity computational modeling
• Visualization applications—graphically representing multiple channels of sensor data
Education, Outreach, & Training
Generating accessible research and education tools
NEESinc coordinates and implements geographically distributed education, outreach, and training (EOT) activities, including:
• Researcher Training Workshops
• Research-to-Practice & Invited Lecture Webinars
• NEES Research Experience for Undergraduates Program
• NEES Annual Meeting
• Experimental Site based activities

NEES OPERATIONS

Over the years, NSF has established several large research facilities for the shared use of researchers, which are called Major Research Equipment and Facilities Construction projects. Besides NEES, examples of these large facilities include the Gemini Observatories (major telescopes in the Northern and Southern Hemispheres), the Large Hadron Collider (the world's highest-energy nuclear particle accelerator), North and South polar research facilities, the Ocean Observatories Initiative (deep-sea and seafloor instruments around the world and coastal observatories), and EarthScope, a program that consists of a multi-purpose array of instruments and observatories that greatly expands the observational capabilities of the Earth Sciences. The central operational and coordination functions of operating these facilities are provided in various ways. In the NEES program, the organizational hub carrying out the NEES operations functions is the NEES Consortium.

NEES Consortium, Inc. was established during the same 2000-2004 developmental period when the formation of NEES research sites and cyberinfrastructure services were formed. The NEES Consortium was structured to respond to the NSF requirement to "organize and run activities to engage the earthquake engineering community to gain community-generated input and broad consensus for the organizational structure and governance of a single community-based and community-led NEES Consortium." NEES Consortium, Inc. was incorporated as a non-profit corporation in January 2003, being incubated under an award to the Consortium of Universities for Research in Earthquake Engineering. This new organization ran elections for members of the Board of Directors in May, 2003 and submitted the proposal to NSF that budgeted for the ten-year operation of NEES in October of that year. Approval of the Consortium-submitted proposal by NSF led to the operational phase of NEES, with the first research proposals to NSF for use of the research sites due in January of 2005.

Support for approximately half the operating cost of the NEES research sites is provided by NSF to the Consortium, which manages the subawards of those funds to the research site universities. The remainder of the laboratory operating costs is the responsibility of the universities, giving them an incentive to obtain research projects and support from non-NSF sources. The NEES Consortium budget also includes the funds for the subaward for cyberinfrastructure services, plus the budget for the Consortium central office costs. NSF provides research project budgets directly to researchers in the traditional NSF peer-review competitive proposal process.

In addition to financial functions and providing a single point-of-contact with the numerous NEES subawardees and research sites, the NEES Consortium provides a central source of information through its website and has the task of coordinating program-wide education, outreach, and training activities. Research projects, especially the larger ones, as well as each research site, also have education and training activities pertinent to their own scopes of work.

The NEES Consortium operates committees on the topics of Site Operations; Education, Outreach, and Training; Finance; and Nominations. Additional Task Groups are established as needed.

The NEES Consortium has provided NEES Operations services for the first five years of NEES, since the fall of 2004. As of the fall of 2009, the National Science Foundation expects to have a new entity selected to provide those services for the next five years, as the outcome of a competitive process underway as of this writing (May 2009).

NEES Consortium, Inc.
email: info@nees.org
web: www.nees.org

Photo Credits

Photos are credited to the universities operating NEES facilities unless otherwise noted.

Cover, (upper left): The Nonstructural Component Simulator, University at Buffalo, State University of New York; (lower left): bridge collapse, 1999 Chi-Chi Earthquake, Taiwan, Chia-Ming Uang; (upper right): Students from the Riverside area inside the University of California at Los Angeles mobile, satellite linked, seismic laboratory; (lower right): The Real-time Data Viewer (RDV) provides an interface for viewing and analyzing live or archived time-synchronized data either locally or streamed across a network.

page 2: (lower image) Humboldt Bay Bridge computer simulation, Pacific Earthquake Engineering Research Center

page 23: (background image) Karl Steinbrugge Collection, EERC-NISEE Library

page 28: Robert Reitherman, photo collection of Pacific Earthquake Engineering Research Center Library

page 30: Shojiro Motoyui, Tokyo Institute of Technology

Notes

i. The 1994 figure of $50 billion has been adjusted for inflation; "Overview of the Northridge Earthquake," R. Reitherman, *Proceedings of the NEHRP Conference and Workshop on Research on the Northridge, California Earthquake of January 17, 1994*, funded by the National Science Foundation, U.S. Geological Survey, Federal Emergency Management Agency, and National Institute of Standards and Technology; Consortium of Universities for Research in Earthquake Engineering, Richmond, CA, vol. I, p. I-33.

ii. http://www.nehrp.gov/pdf/PL108-360.pdf

iii. Kircher, Charles et al. (2006). "When the Big One Strikes Again – Estimated Losses due to a Repeat of the 1906 San Francisco Earthquake," *Earthquake Spectra 22* (SII), April, 1906, 297-339.

iv. Wong, Eugene (1999). "Testimony of Dr. Eugene Wong," Subcommittee on Science, Technology, and Space, Senate Commerce, Science and Transportation Committee, US Senate, October 15, 2004.

This document was produced by the NEES Consortium, Inc. as part of its cooperative agreement with the National Science Foundation, Dr. Joy M. Pauschke Program Director. Any opinions, findings and conclusions or recommendations expressed in this material are those of the awardee and do not necessarily reflect the views of the National Science Foundation.

Brochure Design and Production: Darryl Wong (design), Reed Helgens and Robert Reitherman (editorial), Consortium of Universities for Research in Earthquake Engineering (CUREE)

For more information and listings of contact information for NEES and NSF staff members, see www.nees.org.

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