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Updated July 20, 2023

Congressional Research Service
https://crsreports.congress.gov
R43141

CRS REPORT
Prepared for Members and
Committees of Congress

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SUMMARY

R43141

July 20, 2023

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The National Earthquake Hazards Reduction Program (NEHRP): Overview and Issues for Congress

The National Earthquake Hazards Reduction Program (NEHRP) aims to understand earthquake hazards and reduce earthquake risks in the United States. Portions of all 50 states, as well as U.S. territories and the District of Columbia, are vulnerable to earthquake hazards and their associated risks, to varying degrees. Each region's risk is shaped by the frequency and scale of the hazard as well as by the population, infrastructure, and economic activity vulnerable to the hazard. Alaska is the most earthquake-prone state; it has experienced a magnitude 7.0 earthquake almost every year and a magnitude 8.0 earthquake every 13 years, on average, since 1900. Alaskan earthquakes can trigger damaging tsunamis, which can be particularly threatening for Alaska, Washington, Oregon, California, and Hawaii. California has the greatest earthquake risk, because the state has frequent earthquakes that affect a dense built environment and a large population. The 1994 magnitude 6.7 Northridge earthquake in Los Angeles, Ventura, Orange and San Bernardino counties is the third-costliest disaster in the United States.

Congress created NEHRP as a coordinated program through the Earthquake Hazards Reduction Act of 1977 (P.L. 95-124) and most recently reauthorized the program in 2018 (P.L. 115-307). Four federal agencies have responsibilities related to earthquake hazards and risk reduction—the U.S. Geological Survey (USGS), the National Science Foundation (NSF), the Federal Emergency Management Agency (FEMA), and the National Institute of Standards and Technology (NIST). Congress assigned NIST as the lead agency for NEHRP in 1990. These agencies perform the four major NEHRP activities:

1. Develop effective measures for earthquake hazards reduction
2. Promote the adoption of earthquake hazards reduction measures
3. Improve understanding of earthquakes and their effects
4. Continue the development of the Advanced National Seismic System, a nationwide network of seismic stations operated by the USGS

The 2018 NEHRP reauthorization did not change the program's overall structure but did establish new priorities. For example, the legislation emphasized advancing earthquake early warning systems and promoting community resilience to earthquakes. An earthquake early warning system is to detect the start of an earthquake and immediately send an alert that intense and potentially damaging ground shaking will reach a nearby location within seconds to minutes of the alert's receipt. Various actions can enhance community resilience, such as building earthquake-resistant structures based on a location's seismic hazard and designing structures for *functional recovery*, meaning the structures can be reoccupied and can function after an earthquake.

Since the 2018 reauthorization, NEHRP has made progress on warning, resilience, and research, among other activities. An earthquake early warning system called *ShakeAlert* operates in California, Oregon, and Washington, providing actionable alerts to protect people and property from earthquake damage. NIST and FEMA have supplied information and tools to build and retrofit structures for greater earthquake resistance and for functional recovery. NSF and the USGS have continued to support research and have initiated new research opportunities that are coordinated across NSF directorates or across agencies.

Issues for Congress regarding NEHRP include the program's effectiveness (i.e., how much and how well NEHRP reduces risks), the effectiveness of federal and nonfederal partnerships (i.e., how well the four agencies work together and with other partners), and the effectiveness of program management (i.e., how well the agencies plan, manage, and implement program objectives). The FY2022-FY2029 strategic plan for NEHRP and a Government Accountability Office report on the effectiveness of the program may inform congressional deliberations related to NEHRP and consideration of extending the program's authorization of appropriations beyond FY2023.

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The United States is vulnerable to earthquake hazards and their associated risks,[1] although hazards and risks vary greatly across the nation and its territories. Earthquake hazards are greatest in the western United States, particularly in California, Washington, Oregon, Alaska, and Hawaii. Alaska is the most earthquake-prone state; it has experienced a magnitude (M) 7.0 earthquake almost every year and a M8.0 earthquake every 13 years, on average, since 1900.[2] Despite being the most earthquake-prone state, because of Alaska's small population and low infrastructure density, most of the state has a relatively low risk for large economic losses from an earthquake. In contrast, a larger portion of California has greater earthquake risk than Alaska, because of California's frequent seismic activity, large population, and extensive infrastructure.[3] The most damaging earthquake and the third-costliest natural hazard event in the United States was the 1994 M6.7 Northridge earthquake in the Los Angeles metropolitan region, which caused 60 fatalities, more than 7,000 injuries, 22,000 displaced people, more than 40,000 damaged buildings, and an estimated economic loss of $20 billion.[4]

Since 1977, the federal government has supported efforts to assess and monitor earthquake hazards and to reduce related risks in the United States through the National Earthquake Hazards Reduction Program (NEHRP). The four major NEHRP activities are (1) develop effective measures for earthquake hazards reduction; (2) promote the adoption of earthquake hazards reduction measures; (3) improve understanding of earthquakes and their effects; and (4) continue the development of the Advanced National Seismic System (ANSS), a nationwide network of seismic stations. Today, four federal agencies responsible for earthquake risk reduction coordinate their activities under NEHRP: the U.S. Geological Survey (USGS), National Science Foundation (NSF), Federal Emergency Management Agency (FEMA), and National Institute of Standards and Technology (NIST). For an overview of each agency's responsibilities, see **Table 1**.

[1] Hazard is not the same as risk. Hazard is a source of danger, whereas risk is the possibility of loss or injury. Earthquake *hazard* is related to an earthquake causing intense ground shaking and other damaging effects. The degree of earthquake hazard is related to the probability of certain damaging effects caused by an earthquake occurring within a certain period. The degree of earthquake *risk* is the combination of the degree of earthquake hazard and the extent of the affected population (which includes the infrastructure supporting that population). Large population centers would therefore be at a higher risk than small population centers for the same degree of earthquake hazard, in general. In U.S. Congress, House Committee on Science and Technology, *Earthquake Hazards Reduction Act of 1977*, report to accompany H.R. 6683, 95th Cong., 1st sess. H.Rept. 95-286, part 1, May 11, 1977, p. 3, Congress defined *earthquake hazard reduction* as "reducing by any available methods the harm done by earthquakes," so the intent of Congress is to reduce risks of earthquake hazards.

[2] State of Alaska, Alaska Seismic Hazards Safety Commission, "Earthquake Risk in Alaska," at http://seismic.alaska.gov/earthquake_risk.html.

[3] For estimates of earthquake hazards and risks displayed on maps divided into states—and the significant hazards and risks in California, in particular—see the 2018 update of the USGS's National Seismic Hazard Map. The USGS, Earthquake Hazards, "Seismic Hazard Maps and Site-Specific Data," at " https://www.usgs.gov/natural-hazards/earthquake-hazards/seismic-hazard-maps-and-site-specific-data; and Federal Emergency Management Agency (FEMA), *Hazus Estimated Annualized Earthquake Losses for the United States*, FEMA P-366, April 2017, Figure E-1.

[4] The USGS, "Impact Summary," at https://earthquake.usgs.gov/earthquakes/eventpage/ci3144585/impact and California Earthquake Authority, "Northridge earthquake remembered as one of the costliest natural disasters in U.S. history," at https://www.earthquakeauthority.com/Press-Room/Press-Releases/2019/Northridge-earthquake-remembered.

Table 1. National Earthquake Hazards Reduction Program (NEHRP) Agencies: Roles and Activities

Agency	Roles and Activities
NIST	• Is the lead agency for NEHRP and coordinates NEHRP activities • Conducts applied earthquake engineering research to provide the technical basis for building codes, standards, and building practices • Is responsible for research and development to close the gap between research and implementation of earthquake risk mitigation technologies
FEMA	• Assists other agencies and private-sector groups to prepare and disseminate building codes and practices for structures and lifeline infrastructure • Aids development of performance-based codes for buildings and other structures • Supports communication of earthquake early warning alerts via the Integrated Public Alert and Warning System and Wireless Emergency Alerts[a]
USGS	• Provides earthquake monitoring and notification, earthquake hazards assessments, earthquake hazards maps, and earthquake research • Operates the Advanced National Seismic System (ANSS), regional geodetic networks, and the National Earthquake Information Center (NEIC) to provide earthquake understanding, information, warning, and response[b]
NSF	• Supports basic research in the earth sciences, engineering, and social sciences to understand earthquakes, their hazards, and their risk reduction • Supports additional engineering research through the Natural Hazards Engineering Research Infrastructure (NHERI),[c] additional earth science research through the Seismological Facilities for the Advancement of Geoscience (SAGE) and the Geodetic Facilities for the Advancement of Geoscience (GAGE),[d] and additional social science research through the Natural Hazards Center (NHC)[f]
USGS and NSF	• Together, support the Global Seismographic Network (GSN),[g] regional networks, the Southern California Earthquake Center,[h] earthquake research, earthquake early warning,[i] post-earthquake assessments, and education and outreach

Source: Activities summarized from NEHRP's website under, "About Us," at https://www.nehrp.gov/about/agencies.htm.

Notes: FEMA = Federal Emergency Management Agency; NIST = National Institute of Standards and Technology; NSF = National Science Foundation; USGS = U.S. Geological Survey.

a. See FEMA, "Integrated Public Alert & Warning System," at https://www.fema.gov/emergency-managers/practitioners/integrated-public-alert-warning-system; and FEMA, "Wireless Emergency Alerts," at https://www.fema.gov/emergency-managers/practitioners/integrated-public-alert-warning-system/public/wireless-emergency-alerts.

b. For more information about ANSS, NEIC, GSN, and other USGS earthquake monitoring efforts see the USGS, Earthquake Hazards, "Monitoring," at https://www.usgs.gov/natural-hazards/earthquake-hazards/monitoring.

c. See NSF's NEHRI description at NSF, "Natural Hazards Engineering Research Infrastructure (NHERI)," at https://beta.nsf.gov/funding/opportunities/natural-hazards-engineering-research-infrastructure-nheri.

d. See NSF's award descriptions: NSF, "Award Abstract # 1724794

Enabling Discoveries in Multiscale Earth System Dynamics: Geodetic Facility for the Advancement of Geoscience (GAGE)," at https://www.nsf.gov/awardsearch/showAward?AWD_ID=1724794 and NSF, "Award Abstract # 1851048

e. Enabling Discoveries in Multiscale Earth System Dynamics: Seismological Facility for the Advancement of Geoscience (SAGE) - EAR Scope" at https://www.nsf.gov/awardsearch/showAward?AWD_ID=1851048.

f. See NSF's NHC description at Natural Hazards Center at https://hazards.colorado.edu/.

g. See the USGS's GSN description at the USGS, "GSN—Global Seismographic Network" https://www.usgs.gov/natural-hazards/earthquake-hazards/gsn-global-seismographic-network.

h. For more information about the Southern California Earthquake Center, see https://www.scec.org.

i. For more information about the earthquake early warning system operating in California, Oregon, and Washington, see the ShakeAlert website at https://www.shakealert.org.

Major Changes to NEHRP Since 1977

In 1977, Congress passed the Earthquake Hazards Reduction Act (P.L. 95-124), establishing NEHRP as a *coordinated* earthquake hazards reduction program for the United States.[5] The legislation directed the President to establish a program to advance the following objectives:

- Development of earthquake-resistant construction
- Earthquake prediction and identification and assessment of seismic hazards
- Development and promotion of model codes for land use and building
- Development of earthquake preparedness, warning, response, and recovery
- Development of research to increase earthquake hazards and risks knowledge to reduce risks, deal with prediction consequences, assure insurance availability, and control seismic events

The law authorized appropriations for the USGS and NSF to carry out these objectives. Beyond these specific authorizations, Congress did not specify a lead agency or specific activities for other agencies. FEMA was created in 1979 and in 1980, Congress amended the Earthquake Hazards Reduction Act in P.L. 96-472 to make FEMA the lead agency. Since 1980, NEHRP has been a coordinated program of four agencies: the USGS, NSF, FEMA and NIST (formerly National Bureau of Standards). In 2004, Congress designated NIST the lead agency for NEHRP in the National Earthquake Hazards Reduction Program Reauthorization Act of 2004 (P.L. 108-360).

The USGS and NSF roles in NEHRP initially focused on research to understand and predict earthquakes. However, earthquake prediction proved insoluble,[6] and NEHRP shifted its focus beginning in 1990 to understanding, monitoring, assessing, issuing early warnings,[7] and

[5] Congress emphasized a *coordinated* program in the Earthquake Hazards Reduction Act (P.L. 95-124). It also requested management, budget, and implementation plans to explain how the program would carry out its objectives and to define the roles and responsibilities of federal agencies involved in the program. P.L. 95-124 directed the President to establish the program to include the USGS, the National Science Foundation (NSF), Department of Defense, Department of Housing and Urban Development, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, National Bureau of Standards, Energy Research and Development Administration, Nuclear Regulatory Commission, and National Fire Prevention and Control Administration. Congress also called for coordination and cooperation with state and local governments in P.L. 95-124; this directive remains part of the statute.

[6] See, for example, the USGS, "Can You Predict Earthquakes?" at https://www.usgs.gov/faqs/can-you-predict-earthquakes?qt-news_science_products=0#qt-news_science_products.

[7] The National Earthquake Hazards Reduction Program (NEHRP) shifted its focus from predicting earthquakes to issuing a warning after an earthquake is detected in the 1990s. Congress's initial, prediction-focused definition of *earthquake warning* in P.L. 95-124 arose because China had predicted and evacuated over a million people about five hours before a damaging earthquake struck on February 4, 1975 (see the USGS, Earthquake Hazards Program, "Repeating Earthquakes," at https://earthquake.usgs.gov/learn/parkfield/eq_predict.php) and because research suggested prediction and imminent warning for earthquakes might be feasible. H.Rept. 95-286 Part 1, stated, "As defined in the act, an earthquake prediction is a prediction, in definite or probabilistic terms, of the time, place, and magnitude of an earthquake, whereas an earthquake warning means a recommendation that normal life routines should be changed for a time because an earthquake is believed imminent." However, to date, there is no feasible way to provide an earthquake prediction or a warning that an earthquake is imminent. Today, the terms *earthquake warning* and *earthquake early warning* typically are defined as a warning that damaging ground shaking may reach a warned location within seconds to minutes after an earthquake has been detected as starting.

responding to earthquakes. Congress removed language related to earthquake prediction in the National Earthquake Hazards Reduction Program Reauthorization Act of 2018 (P.L. 115-307). Congress reauthorized NEHRP in 1990, 1997, 2000, and 2004 and changed the program's emphasis and oversight in various ways, as detailed below.

- In 1990, the National Earthquake Hazards Reduction Program Reauthorization Act (P.L. 101-614) directed the USGS to study faults and earthquakes to determine earthquake frequency, provide a seismic hazards assessment, and conduct research and development for earthquake-resistant structures. The amendments directed the USGS to establish a Center for International Exchange of Earthquake Information, operate a National Seismic Network, continue work on earthquake prediction, and conduct post-earthquake investigations with NSF. The law directed NIST to develop seismic standards for buildings and *lifelines* (i.e., essential utility and transportation systems).[8] It established a NEHRP Advisory Committee until September 30, 1993, to report on NEHRP activities and advise the program.[9] The act directed the Office of Science and Technology Policy (OSTP) to study and report on interagency collaboration.
- In 1997, P.L. 105-47 amended NEHRP to (1) direct the USGS to develop a prototype real-time seismic warning system,[10] (2) allow NSF to use competitive grants to develop earth science education materials for kindergarten through 12th grade, and (3) request FEMA to study and assess national earthquake emergency training capabilities.
- In 2000, P.L. 106-503 amended NEHRP to (1) direct the USGS to establish an Advanced National Seismic Research and Monitoring program and a Scientific Earthquake Studies Advisory Committee and (2) direct NSF to establish the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) program to research earthquakes' effects on structures and to develop improved designs for earthquake-resistant structures.[11]
- In 2004, P.L. 108-360 established an Interagency Coordinating Committee (ICC) and an Advisory Committee on Earthquake Hazards Reduction (ACEHR).[12] The

[8] Within the earthquake community, the term *lifelines* generally has been replaced by the term *lifeline infrastructure*. See Earthquake Engineering Research Institute, "Improve Reliability of Lifeline Infrastructure Systems," white paper, April 5, 2016, at https://www.eeri.org/wp-content/uploads/eeri-policy-lifelines.pdf.

[9] The NEHRP Advisory Committee was composed of experts outside of the NEHRP agencies. Congress intended the committee to review NEHRP and present its findings to Congress, while advising NEHRP about its review. Congress established a new Advisory Committee on Earthquake Hazards Reduction (ACEHR) in 2004. ACEHR is distinct from the previous committee, but the two share some aspects of committee structure and some objectives.

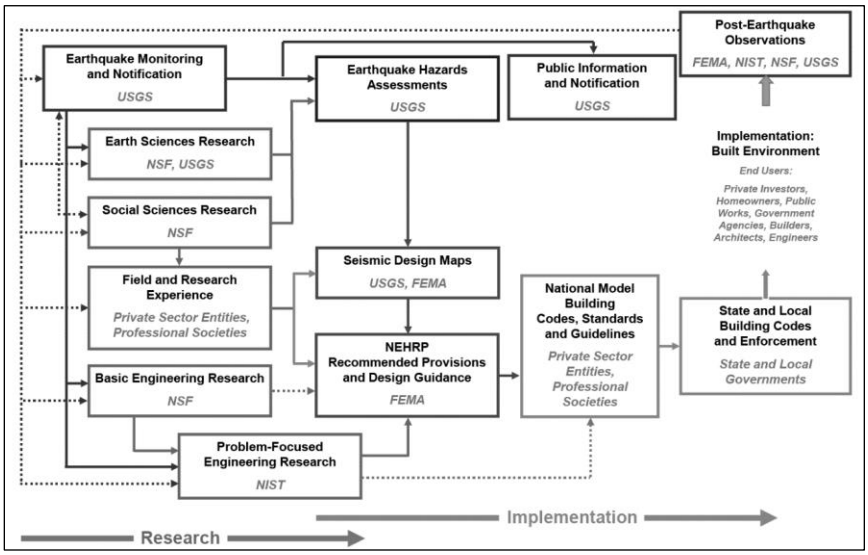
[10] This warning system refers to providing an automated alert to high-risk activities (e.g., stopping trains when an earthquake is detected) about damaging ground shaking after an earthquake starts. See footnote 7 for an explanation of the changing definition of warning over NEHRP's legislative history.

[11] From FY2004 through FY2014, the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) program activities consisted of 15 experimental facilities and an information-technology infrastructure with a goal of mitigating earthquake damage by the using improved materials, designs, construction techniques, and monitoring tools. NSF ended NEES in FY2014 and started the Natural Hazards Engineering Research Infrastructure (NEHRI) program in FY2015. NEHRI is a distributed, multiuser, national facility that provides research infrastructure for the natural hazards research community, including earthquake and wind engineering experimental facilities, cyber infrastructure, computational modeling and simulation tools, and research data. A description of NEHRI facilities and opportunities is available at NSF, "Natural Hazards Engineering Research Infrastructure (NEHRI)," at https://beta.nsf.gov/funding/opportunities/natural-hazards-engineering-research-infrastructure-nheri.

[12] ACEHR is composed of 11 outside experts on earthquake hazard risk reduction from science, engineering, and (continued...)

ICC consisted of the USGS, NSF, FEMA, NIST, OSTP, and the Office of Management and Budget.

Figure 1. NEHRP Agency Responsibilities and End Users of NEHRP Products



Source: National Earthquake Hazards Reduction Program (NEHRP) program office at http://www.nehrp.gov/pdf/ppt_sdr.pdf (modified by CRS).

Notes: FEMA = Federal Emergency Management Agency; NIST = National Institute of Standards and Technology; NSF = National Science Foundation; USGS = U.S. Geological Survey.

NEHRP Reauthorization Act of 2018 (P.L. 115-307)

The 2018 NEHRP reauthorization act (P.L. 115-307) kept the four-agency program intact. The act called for additional oversight, management planning, and strategic planning to enhance coordination, cooperation, and efficient progress on objectives (See **Figure 1** for agency coordination and cooperation from research through implementation). The act expanded emphasis on earthquake early warning systems and earthquake-resistant construction and requested support for resilience, such as earthquake-resistant structures that continue to function after an event and communities that are prepared to respond effectively to and recover efficiently from a seismic event.

Changes to Findings, Purposes and Definitions (Section 2)

Starting in the 1990s, NEHRP activities shifted from earthquake prediction to earthquake warning after an earthquake is detected. The 2018 NEHRP reauthorization act codified that shift by removing references to earthquake prediction throughout the act. For example, Section 2 of the 2018 act modified the congressional findings section (42 U.S.C. 7701) by omitting the linkage between seismological research and earthquake prediction, substituting the finding that "a well-

industry standards organizations; financial organizations; and state and local governments. ACEHR is to provide the following assessments in biennial reports to Congress: (1) trends and developments in the science and engineering of earthquake hazards reduction; (2) effectiveness of NEHRP; (3) the need to revise NEHRP; and (4) NEHRP's management, coordination, implementation, and activities. ACEHR is distinct from the congressionally established 1990 NEHRP Advisory Committee, which ended its service in 1993.

funded seismological research program could provide the scientific understanding needed to fully implement an effective earthquake early warning system."[13]

Section 2 of the 2018 act introduced the concept of *resilience* to earthquake hazards.[14] For example, Section 2 cited a National Research Council study with objectives for achieving national earthquake resilience.[15] Section 2 amended the congressional statement-of-purpose section (42 U.S.C. 7702) to add the purpose of increasing communities' resilience to future earthquakes to the existing purpose of reducing risks to life and property. The definitions section of the 2018 act defined *community resilience* as "the ability of a community to prepare and plan for, absorb, recover from, and more successfully adapt to seismic events" (42 U.S.C. 7703). Section 2 of P.L. 115-307 called for resilience to include building design and construction, so that structures are built to potentially continue functioning or be reoccupied despite earthquake damage. Section 2 introduced the language of "re-occupancy, recovery, reconstruction."

In addition, P.L. 115-307 added the states of Oregon and Tennessee, together with the Commonwealth of Puerto Rico, to the 15 states the law named as facing significant earthquake risk. The 2018 law identified 39 states facing major or moderate seismic risk (42 U.S.C. 7701).[16]

Changes to Program Activities and Agency Responsibilities (Section 3)

Section 3 of the 2018 NEHRP reauthorization act added new duties for the ICC. P.L. 115-307 required the ICC to develop a strategic plan for NEHRP, a management plan to implement the strategic plan, and a coordinated interagency budget on a biennial basis. The ICC completed a strategic plan for FY2022-FY2029 and noted eight focus areas:

1. Advance earthquake science for subduction zone regions[17]
2. Develop enhanced performance-based seismic design procedures and metrics for functional recovery of buildings and infrastructure
3. Advance performance-based seismic design and assessment methods to implement multisystem coordination
4. Further expand earthquake early warning capabilities
5. Develop consistent performance guidance for lifeline infrastructure

[13] For a discussion of prediction and warning and the changes in the meaning of a warning system see footnote 7.

[14] The term *resilience* in discussions regarding reducing earthquake risk and resilience typically refers to better preparations, better situational awareness, and more earthquake-resistant structures that lead to less damage and faster recovery from an earthquake. *Earthquake-resistant structures* are structures that are capable of withstanding, with less damage, an earthquake that could harm people and property and that are capable of reoccupation and function right after an earthquake.

[15] National Research Council, *National Earthquake Resilience, Research, Implementation, and Outreach*, 2011, at http://www.nehrp.gov/pdf/nrc2011.pdf.

[16] The act identifies these states—Alaska, California, Hawaii, Illinois, Massachusetts, Missouri, Montana, Nevada, Oregon, New Jersey, New York, South Carolina, Tennessee, Utah, and Washington—and the Commonwealth of Puerto Rico as facing significant earthquake risks.

[17] *Subduction zone regions* are areas where tectonic plates converge and one plate slides beneath the other plate (called subduction by geoscientists). In general, these regions have earthquakes and volcanic activity. Earthquakes and volcanic activity may trigger other hazards, such as tsunamis and landslides. USGS, "Introduction to Subduction Zones: Amazing Events in Subduction Zones," at https://www.usgs.gov/special-topics/subduction-zone-science/science/introduction-subduction-zones-amazing-events.

6. Enhance guidance to ensure information and tools effectively support the needs of those who implement mitigation, preparedness, and recovery measures
7. Advance the science of earthquake sequence characterization[18]
8. Enhance risk reduction strategies for federal agencies[19]

In addition, P.L. 115-307 required the ICC to develop memoranda of understanding with any relevant federal agencies (such as the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration) on data sharing and resource commitments in the event of an earthquake disaster.

Further, the ICC shall coordinate with the Secretaries of Agriculture and the Interior on the use of federal lands for monitoring, research, and data collection. The ICC is required to coordinate with the Secretaries of Transportation and Housing and Urban Development on earthquakes' effects on transportation and building stocks (including the lifeline infrastructure). The 2018 act required the NEHRP ICC to coordinate with its counterpart committee on the National Windstorm Impact Reduction Program,[20]—as well as with other natural hazards coordination committees, as determined appropriate—to share data and best practices.

Section 3 of P.L. 115-307 modified FEMA's duties and required FEMA to enter into cooperative agreements or contracts to establish demonstration projects on earthquake hazards modification, link research and mitigation efforts with emergency management programs, and prepare educational materials for national distribution (substituting the word "shall" in the enacted language for the word "may" in existing law).

Section 3 of P.L. 115-307 removed statutory language requiring the USGS to develop procedures for making earthquake predictions and replaced it with language for developing procedures to issue earthquake alerts and early warnings. The 2018 act inserted language to "continue the development of the ... [ANSS], including earthquake early warning capabilities," as part of 42 U.S.C. 7704(a)(2)(D).[21] Further, P.L. 115-307 required the USGS, in the event of an earthquake, to issue an alert and a warning, when necessary and feasible, to FEMA, NIST, and state and local officials. The act required the USGS to publish maps of active faults and folds, plus maps of areas that are susceptible to specific earthquake hazards (e.g., liquefaction or landslides).[22]

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[18] Earthquake sequence characterization refers to understanding how earthquakes are related to each other in space and time. In general, the largest magnitude earthquake in a sequence is called the mainshock while smaller magnitude earthquakes that occur before the mainshock are called foreshocks and after the mainshock are called aftershocks. Personal communication between USGS and CRS, July, 2023.

[19] The eight focus areas are not in order of priority. Laurie Locascio et al., *Strategic Plan for the National Earthquake Hazards Reduction Program*, Fiscal Years 2022 to 2029, April 2023, https://www.nehrp.gov/pdf/FY2022-29%20NEHRP%20Strategic%20Plan%20-%20Post%20Version.pdf.

[20] See National Institute of Standards and Technology (NIST), Engineering Laboratory/Materials and Structural Systems Division, "National Windstorm Impact Reduction Program Office," at https://www.nist.gov/el/materials-and-structural-systems-division-73100/national-windstorm-impact-reduction-program-nwirp.

[21] In Section 8 (Technical Corrections) of P.L. 115-307, the act deleted references in the *U.S. Code* to the Advanced National Seismic System (ANSS) predecessor—the Advanced National Seismic Research and Monitoring System. For more on ANSS, see the "Management of Advanced National Seismic System (Section 6)" section of this product. Also note that *earthquake early warning* means providing an alert after the start of an earthquake is detected, which is the modern definition and usage of the term (as opposed to the meaning of warning in the 1977 act, see footnote 7).

[22] Earthquakes cause intense ground shaking, ground displacement and liquefaction. Liquefaction occurs when loose, weak, or water-saturated soils or rocky materials lose their strength because of earthquake-induced ground shaking. When liquefaction happens around structural elements, such as buildings or bridges, these structures can be damaged or collapse. For more information about liquefaction, see USGS' *What is liquefaction* at https://www.usgs.gov/faqs/what-liquefaction. Earthquakes can trigger other natural hazards such as tsunamis, landslides, fires, floods, or volcanic eruption.

The 2018 NEHRP reauthorization act removed language in existing law that required NSF to support earthquake-related research using NEES. Instead, P.L. 115-307 referred to using "experimental and computational facilities."[23] Section 3 of P.L. 115-307 added a new subsection to existing law requiring NSF to identify and track NEHRP grant funding.

Review of NEHRP (Section 4)

Section 4 of P.L. 115-307 required the Government Accountability Office (GAO) to complete a review of federal earthquake hazards risk reduction efforts and report its findings within three years of enactment.[24] In 2022, GAO completed its review and recommended seven actions:

1. Conduct a national risk assessment to identify progress and remaining gaps in earthquake resilience in communities
2. Increase awareness among tribes about earthquake risk reduction initiatives
3. Assess the need for state, local, territorial, and tribal input about research priorities to meet community needs
4. Develop strategies to better communicate program priorities to research entities
5. Develop performance measures and monitor research to achieve research priorities
6. Leverage program resources to achieve research priority outcomes
7. Implement a plan to make state, local, territorial, and tribal stakeholders aware of practices for disseminating research[25]

According to GAO, NEHRP is working on these recommended actions and aims to address these actions.[26]

Seismic Standards (Section 5)

Section 5 of P.L. 115-307 replaced language in current law (42 U.S.C. 7705b) that called for the adoption of seismic safety standards for buildings constructed or leased by the federal government. The 2018 NEHRP reauthorization act required, instead, an assessment and recommendations for improving the built environment and critical infrastructure, specifically "to reflect performance goals stated in terms of post-earthquake reoccupancy and functional recovery time." This language highlighted one of the changes in NEHRP emphasis to enhance resilience.

The NIST Director and the FEMA Administrator appointed a committee of experts, representing federal agencies, nongovernmental organizations, the private sector, disaster management associations, engineering associations, and construction and homebuilding industry associations, to prepare such a report for Congress.[27] NIST and FEMA jointly published the committee of

[23] See footnote 11.

[24] P.L. 115-307 required GAO to submit the report to the Senate Committees on Commerce, Science, and Transportation; Energy and Natural Resources; and Homeland Security and Governmental Affairs, and to the House Committees on Science, Space, and Technology; Natural Resources; and Homeland Security.

[25] U.S. Government Accountability Office, *Earthquakes: Opportunities Exist to Further Assess Risk, Build Resilience, and Communicate Research*, GAO-22-105016, May 4, 2022, https://www.gao.gov/products/gao-22-105016.

[26] See the section on "Recommendations" for the seven recommendations and the status of the program response at GAO, "Earthquakes," at https://www.gao.gov/products/gao-22-105016.

[27] P.L. 115-307 required the expert committee to submit a report to Congress with recommended options no later than June 30, 2020. The committee submitted the report to the Senate Committees on Commerce, Science, and (continued...)

experts' report in January 2021.[28] The report recommended seven actions for communities to enhance resiliency:

1. Develop a framework for post-earthquake reoccupancy and functional recovery objectives
2. Design new buildings to meet recovery-based objectives
3. Retrofit existing buildings to meet recovery-based objectives
4. Design, upgrade, and maintain lifeline infrastructure systems to meet recovery-based objectives
5. Develop and implement pre-disaster recovery planning focused on recovery-based objectives
6. Provide education and outreach to enhance awareness and understanding of earthquake risk and recovery-based objectives
7. Facilitate access to financial resources needed to achieve recovery-based objectives

Management of Advanced National Seismic System (Section 6)

ANSS is a nationwide network of seismic stations operated by the USGS. It consists of a "backbone" network of about 100 seismic stations throughout the United States, the National Earthquake Information Center, the National Strong Motion Project, and 15 regional seismic networks operated by the USGS and partner institutions.[29] The 2018 NEHRP reauthorization act required a new five-year management plan for ANSS. The USGS submitted a five-year management plan for ANSS to Congress in November 2021.[30] The plan prioritized core ANSS activities including monitoring, 24/7 reporting, rapid assessment, and earthquake early warning.

Authorization of Appropriations (Section 7)

Section 7 of P.L. 115-307 authorized appropriations for NEHRP activities over a five-year period, FY2019-FY2023. The act apportioned the same authorized amount per agency each year. The total authorization broken down by agency was as follows:

- USGS: $83.4 million per year, $417.0 million total[31]
- NSF: $54.0 million per year, $270.0 million total
- FEMA: $8.76 million per year, $43.8 million total
- NIST: $5.9 million per year, $29.5 million total

Transportation; Energy and Natural Resources; and Homeland Security and Governmental Affairs, and to the House Committees on Science, Space, and Technology; Natural Resources; and Homeland Security.

[28] NIST and FEMA, *Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time*, NIST-FEMA Special Publication FEMA P-2090/NIST SP-1254, January 2021, at https://doi.org/10.6028/NIST.SP.1254.

[29] For more information, see the USGS, Earthquake Hazards Program, "ANSS—Advanced National Seismic System," at https://www.usgs.gov/natural-hazards/earthquake-hazards/anss-advanced-national-seismic-system.

[30] The USGS, Earthquake Hazards Program, *Advanced National Seismic System 5-Year Management Plan*, November 2021.

[31] P.L. 115-307 required $30 million of the annual authorized amount for the USGS be made available for completion of ANSS.

The total five-year NEHRP authorization of appropriations was $760.3 million for FY2019-FY2023, or about $152.1 million annually. The findings section (Section 2) of P.L. 115-307 noted that the National Research Council in 2011 recommended funding of approximately $300 million annually for 20 years (in 2009 dollars);[32] that amount is about twice the average annual amount authorized for appropriations in P.L. 115-307. **Table 2** shows the enacted funding for NEHRP agencies from FY2005 through FY2023 and the budget request for FY2024.[33]

Table 2. Enacted Funding for NEHRP, FY2005-FY2023, and FY2024 Budget Request

(in millions of current dollars)

Fiscal Year	USGS	NSF	FEMA	NIST	Total
FY2005	58.3	53.1	14.7	0.9	**127.0**
FY2006	54.5	53.8	9.5	0.9	**118.7**
FY2007	55.4	54.8	9.1	1.7	**121.0**
FY2008	58.1	55.6	6.1	1.7	**121.5**
FY2009	61.2	55.3	9.1	4.1	**129.7**
FY2010	62.8	55.3	9.0	4.1	**131.2**
FY2011	61.4	53.3	7.8	4.1	**126.6**
FY2012	60.4	53.2	7.8	4.1	**125.5**
FY2013	55.6	52.2	7.8	3.9	**119.5**
FY2014	58.7	51.0	7.8	3.9	**121.4**
FY2015	64.4	52.2	7.4	3.9	**127.9**
FY2016	67.0	54.2	8.5	5.2	**134.9**
FY2017	71.0	54.2	8.5	5.2	**138.9**
FY2018	90.1	65.7	8.5	5.2	**169.5**
FY2019	90.1	60.5	8.7	5.2	**164.5**
FY2020	92.1	53.4	8.9	4.8	**159.2**
FY2021	92.6	52.2	8.9	4.8	**158.5**
FY2022	97.2	54.0	8.5	4.8	**164.5**
FY2023	99.9	52.0	8.5	4.8	**165.2**
FY2024 Requested	109.7	54.0	8.5	4.8	**177.0**

Sources: Enacted funding FY2005 to FY2022 from NEHRP, "2005-2022 NEHRP Agency Budgets," at https://www.nehrp.gov/pdf/FY%202023%20NEHRP%20Agency%20Requested%20Funding_FEMA-

[32] National Research Council, *National Earthquake Resilience, Research, Implementation, and Outreach*, 2011, p. 4, at http://www.nehrp.gov/pdf/nrc2011.pdf.

[33] Enacted appropriations for FY2005-FY2009 totaled $617.9 million, or 68% of the total amount of $902.4 million authorized in P.L. 108-360 over the five-year span. P.L. 115-307 authorized a total of $760.3 million for NEHRP activities summed over the five-year span FY2019-FY2023, approximately $142 million less than the total amount authorized by P.L. 108-360 (not adjusted for inflation). In constant 2018 dollars, the difference between total authorized amounts over the five-year periods in P.L. 108-360 and P.L. 115-307 would be at least $330 million (using the U.S. Department of Labor, Bureau of Labor Statistics, CPI Inflation Calculator, at https://www.bls.gov/data/inflation_calculator.htm).

USGS_NSF%20apprvd.pdf and enacted FY2023 and requested FY2024 from personal correspondence between NIST and CRS, June 2023.

Notes: According to the NEHRP office, the FEMA and NIST budgets are those agencies' allocations for NEHRP activities from the total agency appropriations through FY2022. The NSF budget is the foundation's estimated expenditure for NEHRP activities from total agency appropriations through FY2022. Beginning in FY2018, the USGS budgets included congressional "one-time" funding additions for ShakeAlert but excluded the $8.0 million supplemental funding for seismic network restoration following Hurricane Maria. Amounts are reported to the nearest $0.1 million.

NEHRP Progress Since Reauthorization in 2018

Since NEHRP's reauthorization in 2018, the program has focused on earthquake early warning systems, improved building codes and building standards, functional recovery methods for structures, pathways to community resilience, and continued basic research to understand earthquake hazards and risks. ACEHR reviews NEHRP progress and recommends actions to make NEHRP more effective in biennial reports to Congress, as mandated by P.L. 108-360. [34] The 2021 ACEHR report identified the following three NEHRP activities as noteworthy and continued priorities:

1. ShakeAlert, the earthquake early warning system operating on the West Coast
2. The joint NIST-FEMA report on reoccupancy and functional recovery, which made seven recommendations and detailed four options for Congress to carry out these recommendations
3. The significance and status of basic research on earthquakes and earthquake-resistant structures through traditional grants and cooperative agreements, plus the addition of three new coordinated research opportunities

Earthquake Early Warning: ShakeAlert

The first *operational* earthquake early warning system in the United States,[35] called ShakeAlert, provides alerts to users in California, Oregon, and Washington.[36] Several studies show that earthquake early warning systems are cost-effective—that is, the cost savings in terms of risk reduction is greater than the actual cost of the system.[37] One study estimated that early warnings

[34] The ACEHR, established by Congress (P.L. 108-360), provides comprehensive biennial reports on NEHRP progress. Two reports, covering FY2018-FY2019 and FY2020-FY2021, respectively, provide more details on recent NEHRP activities: NEHRP, *ACEHR Report on NEHPR Effectiveness FY18-FY19: A Report from the Advisory Committee on Earthquake Hazards Reduction*, September 27, 2019, at https://www.nehrp.gov/pdf/September_2019_ReporttotheNISTDirector.pdf; and NEHRP, *ACEHR Report*, 2021.

[35] *Operational* means the system sends warnings to technical users who have agreements with ShakeAlert (and, in some cases, hardened communications that allow for the most rapid and secure alerting) and to individuals who signed up for ShakeAlert messaging through their state emergency management agencies. In some areas and in some cases, the system is not fully operational, because there are not enough sensors to monitor for earthquakes or because the communications of alerts are not established to provide adequate warning before the shaking arrives.

[36] Users include government and nongovernmental organizations that partner with ShakeAlert to receive warnings so they can take specific actions to reduce risks. Some of these actions are automated, such as the Bay Area Rapid Transit System (BART) automatically slowing or stopping trains because of an earthquake alert. Other users include individuals who sign up to receive the alerts through the California, Oregon, or Washington emergency management agencies. Alerts to individuals suggest protective actions based on the severity of the shaking. Action standards were developed by the Southern California Earthquake Center and other authorities.

[37] NEHRP, *ACEHR Report*, 2021, p. 13; and J. A. Strauss and R. M. Allen, "Benefits and Costs of Earthquake Early Warning," *Seismological Research Letters*, vol. 87, no. 3 (May-June 2016), pp. 765 -772 (hereinafter cited as Strauss and Allen, "Benefits and Costs").

reduce injuries from earthquakes by more than 50%.[38] Today, after an earthquake starts, ShakeAlert is to warn users in California, Oregon, and Washington that intense ground shaking will reach their location in seconds to minutes. This warning allows users to take actions to protect people and property before shaking occurs and thereby reduce the risk of damage to structures, lifelines, transportation, construction, medical procedures, business operations, educational services, and other activities. Several organizational users, such as train systems and large buildings, have programmed their infrastructure to take certain automated actions upon receipt of a warning.[39] Nonautomated responses by individuals include executing the drop, cover, and hold on maneuver and stopping school activities, vehicles, and hazardous activities.[40]

Reoccupancy Recommendations and Building Codes

NEHRP generates improved design guidance products, model building codes, national consensus building standards, and construction guidelines to reduce earthquake risks. A 2019 study by the National Institute of Building Sciences estimated that the development and adoption of seismic provisions in building codes since the advent of modern seismic design provisions have produced a national average benefit-cost ratio of 12 to 1 (i.e., $12 saved in avoided losses for every $1 invested in earthquake requirements for buildings).[41] The study estimated that retrofitting older buildings to earthquake-resistant standards provides a national average benefit-cost ratio of 13 to 1.

The 2021 ACEHR report encouraged NEHRP to follow through on the recommendations in the 2020 joint NIST-FEMA report on reoccupancy and functional recovery. The 2021 ACEHR report suggested four options for Congress to help NEHRP follow through on the recommendations:

1. Support technical development of recovery-based regulations and retrofitting of buildings and lifeline infrastructure systems
2. Incentivize action (e.g., through FEMA's Building Resilient Infrastructure and Communities grants)[42] by encouraging state and local jurisdictions to adopt recovery-based codes, standards, and practices
3. Encourage the executive branch to develop recovery-based seismic design and retrofit requirements for federally owned and leased buildings
4. Lead the development and implementation of a federal education campaign around earthquake risk and recovery-based objectives

[38] Strauss and Allen, "Benefits and Costs."

[39] See footnote 36 for an example of an automated alert.

[40] For a list of actions to take before, during, and after an earthquake, including a description of drop, cover, and hold on, see Ready.gov, "Earthquakes," at https://www.ready.gov/earthquakes.

[41] National Institute of Building Sciences, *Natural Hazard Mitigation Saves*, 2019, see https://nibs.org/projects/natural-hazard-mitigation-saves-2019-report.

[42] FEMA introduced a new program in FY2020, the Building Resilient Infrastructure and Communities (BRIC). The priorities for BRIC in FY2021 are to incentivize natural hazard risk reduction activities that mitigate risk to public infrastructure and disadvantaged communities; projects that mitigate risk to one or more community lifelines; projects that incorporate nature-based solutions; projects that enhance climate resilience; and adoption and enforcement of the latest published editions of building codes. More information is available at the FEMA BRIC website, https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities.

Basic Research

The 2021 ACEHR report considered basic research the foundation for making progress on earthquake early warning systems and improving earthquake-resistant building codes, standards, and construction practices. Together, research, warning, and standards enhance resilience, and resilience is a congressional objective emphasized in the NEHRP law. Much of the basic research occurs through grants and cooperative agreements awarded in three of the NSF's directorates: Geosciences; Engineering; and Social, Behavioral, and Economic Sciences. The 2021 ACEHR report highlighted three new research initiatives involving these NSF directorates and other agencies. One of these initiatives, a new cross-directorate opportunity known as Coastlines and People Competition, funds a research hub to examine Cascadia Subduction Zone hazards and mitigation, among other projects.[43] The other new initiatives, NSF-NIST Disaster Resilience Research Grants and the NSF-Department of Homeland Security Civic Innovation Challenge, are interagency competitions that aim to strengthen earthquake resilience by improving fundamental knowledge of earthquakes and their effects.[44]

Issues for Congress

Congress established NEHRP in 1977 to understand earthquake hazards and reduce their risks. NEHRP has made progress on congressional objectives for earthquake warning, risk reduction, and resilience. Congress may consider several issues regarding NEHRP, including the following:

- **Program Efficacy.** How much and how well does NEHRP reduce risks?
- **Federal and Nonfederal Partnerships**: How well do the four agencies work together and with other partners?
- **Program Management**: How well do the agencies plan, manage, and implement program objectives?

Congress may consider the ICC's FY2022-FY2029 strategic plan for NEHRP and GAO's report on the effectiveness of earthquake hazards risk reduction as part of its deliberations on and oversight of NEHRP. In addition, in its deliberations on NEHRP funding and the authorization of appropriations timeframe (which currently expires at the end of FY2023), Congress may use information in these and earlier reports, such as the 2011 National Research Council report that recommended $300 million annually for NEHRP.

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[43] The Cascadia Subduction Zone is a major tectonic plate boundary that lies just offshore of southwestern British Columbia, the Pacific Northwest and northern California. At the plate boundary, the Juan de Fuca oceanic plate subducts beneath the North American crustal plate causing earthquakes and volcanic activity, among other hazards. See NSF Award Description: Large-Scale CoPe: The Cascadia Coastlines and People Hazards Research Hub https://www.nsf.gov/awardsearch/showAward?AWD_ID=2103713&HistoricalAwards=false.

[44] NEHRP, *ACEHR Report*, 2021, pp. 8-9 and 14-15.

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