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Report to Congressional Committees

May 2022

EARTHQUAKES

Opportunities Exist to Further Assess Risk, Build Resilience, and Communicate Research

GAO-22-105016

GAO Highlights

Highlights of GAO-22-105016, a report to congressional committees.

May 2022

EARTHQUAKES

Opportunities Exist to Further Assess Risk, Build Resilience, and Communicate Research

Why GAO Did This Study

Established in 1977, NEHRP aims to help reduce the risks to life and property from earthquakes. NEHRP's initiatives include strengthening community resilience through improved design and construction methods, conducting research to better understand the impacts from earthquakes, and providing outreach and education. NEHRP is comprised of four federal agencies (FEMA, NIST, NSF, and the U.S. Geological Survey) that promote and support NEHRP's initiatives for strengthening earthquake resilience.

The National Earthquake Hazards Reduction Program Reauthorization Act of 2018 includes a provision for GAO to assess the program's efforts. This report examines, among other things, NEHRP's progress in identifying gaps and strengthening resilience to earthquakes, and its activities to identify and communicate about research priorities. GAO reviewed NEHRP's strategic plans, agency guidance, and external communications; compared procedures to leading practices for interagency collaboration; and interviewed federal and state officials, among others.

What GAO Recommends

GAO is making seven recommendations, including that NEHRP agencies conduct a national assessment to identify progress and remaining gaps in earthquake resilience; develop strategies to better communicate research priorities; and follow leading practices to identify and leverage resources. NIST, NSF, and FEMA concurred with our recommendations.

View GAO-22-105016. For more information, contact Chris Currie at (404) 679-1875 curriec@gao.gov

What GAO Found

The National Earthquake Hazards Reduction Program (NEHRP) has goals outlined in its most recent Strategic Plan for fiscal years (FY) 2009-2013 for the improvement of earthquake resilience in communities nationwide. However, officials from the National Institute of Science and Technology (NIST) said that a national risk assessment has not been done to identify improvements and remaining gaps in resilience. The Federal Emergency Management Agency (FEMA) initiated some efforts to identify improvements by collecting data on the adoption of building codes. The NEHRP agencies are currently working to update the Strategic Plan FY 2022-2029. By conducting a national risk assessment, NEHRP would gain greater awareness of earthquake resilience improvements and be better positioned in planning long-term goals and objectives toward closing remaining gaps.

Damage to Anchorage, Alaska Following a Magnitude 7.1 Earthquake in 2018

Source: United States Geological Survey. | GAO-22-105016

Accomplishing NEHRP's strategic objectives requires developing and applying research in the geological, engineering, and social sciences areas. NEHRP identifies research priorities, and many of the NEHRP agencies award grants to entities such as universities or state and local agencies, to conduct research. While the communication mechanisms used by the National Science Foundation (NSF) include program solicitations, program descriptions, and letters issued to research entities, they do not communicate NEHRP's strategic research priorities. By developing strategies to better communicate its research priorities, NEHRP can help ensure that they are met.

NEHRP's Program Coordination Working Group is responsible for coordinating the implementation of NEHRP's strategic research priorities and has followed leading practices for leadership and outcomes. However, the working group did not follow two leading practices for accountability and resources. For example, the working group did not track and monitor progress, and did not identify and leverage resources needed to achieve outcomes for research priorities. Identifying resources would enable the interagency group to leverage all relevant resources across the NEHRP agencies, and better align them with research priorities. Further, the identification of resources would provide an opportunity for the working group to build programmatic partnerships aimed at strengthening earthquake resilience.

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Abbreviations

FEMA	Federal Emergency Management Agency
FY	Fiscal Year
IBC	International Building Code
ICC	Interagency Coordinating Committee
NEHRP	National Earthquake Hazards Reduction Program
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
USGS	U.S. Geological Survey

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Congressional Committees

Almost half of the U.S. population—150 million people—reside in areas that are at risk of experiencing a damaging earthquake within the next 50 years. In 2017, the Federal Emergency Management Agency (FEMA) estimated that the total average annual loss from earthquakes in the U.S. is $6.1 billion, with California, Oregon, and Washington accounting for 73 percent of such losses ($4.5 billion).[1] Large earthquakes are not just a risk on the west coast. For example, according to a FEMA and Mid-American Earthquake Center scenario, a magnitude 7.7 earthquake in the New Madrid Seismic Zone would be expected to produce severe ground shaking in Kentucky, Tennessee, Missouri, and Arkansas, causing widespread impacts to the population and economic losses approaching $300 billion.[2] According to the U.S. Geological Survey (USGS), 16 states are at very high risk of a seismic event, and their metropolitan regions could face unprecedented life loss and catastrophic damage to buildings, and lifelines (e.g. electrical power lines, water, and sanitary sewer system).

Established in 1977, the National Earthquake Hazards Reduction Program (NEHRP) includes four federal agencies: (1) the National Institute of Standards and Technology (NIST); (2) FEMA; (3) the National Science Foundation (NSF); and (4) USGS.[3] Further, the National Earthquake Hazards Reduction Program Reauthorization Act of 2004 (NEHRP Reauthorization Act of 2004) established the Interagency

[1]See Federal Emergency Management Agency, Hazus® Estimated Annualized Earthquake Losses for the United States, FEMA P-366, (Washington, D.C: April, 2017).

[2]DHS, Homeland Security Enterprise Geospatial Concept of Operations, *The New Madrid Earthquake Scenario*. According to this study, the New Madrid Seismic Zone has a 10 percent probability of a catastrophic earthquake in the next fifty years. The four states that would incur severe ground shaking include western Kentucky, Tennessee, southeast Missouri, and northeast Arkansas. The impacts from the earthquake scenario include 3 million people needing shelter, 82,000 injuries, 3,500 deaths, and about 715,000 buildings damaged.

[3]See 42 U.S.C. § 7704.

Coordinating Committee (ICC) to oversee planning, management, and coordination of the program.[4]

Under the program, the federal government supports efforts to assess and monitor seismic activity in the U.S., and reduce the risks to life and property from future earthquakes. In particular, NEHRP promotes the adoption of earthquake risk reduction measures through the development of standards, guidelines, and seismic building codes aimed at reducing the damaging effects of earthquakes. NEHRP also promotes improved design and construction methods, coordinated emergency preparedness plans, and public education and involvement programs.

The National Earthquake Hazards Reduction Program Reauthorization Act of 2018 (NEHRP Reauthorization Act of 2018) placed further emphasis on earthquake early warning systems, earthquake-resistant design and construction practices, and community resilience.[5] The law defined community resilience as the ability of a community to prepare and plan for, absorb, recover from, and more successfully adapt to adverse seismic events.[6] The NEHRP Reauthorization Act of 2018 also included a provision that we review the program, including assessing the progress of NEHRP agencies in advancing the plans and goals of the program, to include its strategic planning efforts, collaboration to meet strategic priorities, and efforts to strengthen resilience.[7]

Also in response to this provision, we reported in March 2021 that USGS, through its Earthquake Hazards Program, made several efforts to identify the dangers from earthquakes, such as ground shaking, tsunamis, and landslides, to inform the public and help decision-makers ensure public safety and mitigate losses.[8] For example, USGS updated the national

[4]§ 7704(a)(3). The Interagency Coordinating Committee oversees the planning, management, and coordination of the NEHRP program and is comprised of the principals of the four NEHRP agencies, plus the Director of the Office of Management and Budget and the Director of the Office of Science and Technology Policy. One major action of the committee is to approve the NEHRP Strategic Plan FY 2022 - 2029.

[5]Pub. L. No. 115-307, § 3, 132 Stat. 4408, 4409 (codified as amended at 42 U.S.C. § 7704).

[6]42 U.S.C. § 7703(10).

[7]Pub. L. No. 115-307, § 4, 132 Stat. at 4414.

[8]GAO, *EARTHQUAKES: Progress Made to Implement Early Warning System, but Actions Needed to Improve Program Management,* GAO-21-129 (Washington, D.C.: March 25, 2021).

seismic hazard maps used to strengthen building codes throughout the nation, and made progress implementing (ShakeAlert), the earthquake early warning system. USGS implemented cost-cutting actions to meet the program's mission, but not all actions were consistent with leading practices for strategic planning, performance measurement, and human capital planning. In addition, USGS had not followed best practices in establishing schedules, milestones, and timeframes for its ShakeAlert implementation, and has not completed its plan for coordinating outreach with stakeholders.

We made nine recommendations (seven to the Director of USGS, and one each to the Secretaries of Commerce and the Interior). As of April 2022, the Director of USGS and Secretaries of Commerce and the Interior have not implemented the recommendations, though they generally concurred and are taking steps to implement them.

This report addresses:

1. The extent to which NIST and the ICC updated the NEHRP strategic plan and developed a management plan.
2. The extent to which NEHRP assessed earthquake resilience nationwide since 2015, and informed tribal governments about how to strengthen earthquake resilience.
3. The extent to which NEHRP collaborated with stakeholders to prioritize earthquake research and communicate these priorities to research entities.
4. The extent to which NEHRP disseminates earthquake research findings to federal, state, local, and tribal governments.

To address our first objective, we interviewed officials from NIST, FEMA, NSF, and USGS to determine progress being made updating NEHRP's Strategic Plan for fiscal years for fiscal years 2022 – 2029 (Strategic Plan FY 2022 – 2029) and developing a management plan. We discussed the long-term goals and timelines for releasing NEHRP's Strategic Plan FY 2022 – 2029, and what steps, if any, they took to develop the management plan. We also interviewed the Advisory Committee for Earthquake Hazards Reduction (Advisory Committee) to discuss recommendations that the ICC and NIST establish strategic plans and

identify resources towards achieving the strategic plan's goals and objectives.[9]

To address our second objective, we reviewed NEHRP's Strategic Plan for FY 2009 – 2013, reports, assessments, and planning documents relevant to NEHRP's efforts to plan and assess improvements in earthquake resilience in communities nationwide, since 2015.[10] We also reviewed the Advisory Committee's 2015 and 2017 biennial reports to identify recommendations made to NIST, the ICC, and to the member agencies addressing progress in strengthening resilience in communities nationwide, and identifying gaps with respect to seismic vulnerability of buildings, critical infrastructure, and lifeline systems.[11] We met with the Advisory Committee to discuss their recommendations and to determine whether the NEHRP agencies took steps to address them. Further, we interviewed NIST, FEMA, NSF, and USGS officials to determine whether they conducted any plans or assessments to assess improvements in earthquake resilience in communities since 2015. We also selected and interviewed officials from 19 stakeholder groups to discuss their perspectives on earthquake resilience in communities, and any

[9]The NEHRP Reauthorization Act of 2004 established the Advisory Committee for Earthquake Hazards Reduction and charged it with assessing NEHRP's effectiveness and recommending improvements. 42 U.S.C. § 7704(a)(5).

[10]NEHRP, *Strategic Plan for National Earthquake Hazards Reduction Program, Fiscal Years 2009 – 2013*, October 2008. National Research Council, *National Earthquake Resilience: Research, Implementation, and Outreach,* 2011, FEMA, *Community Resilience Indicator Analysis: County Level Analysis of Commonly Used Indicators from Peer Reviewed Research,* 2020, and FEMA's Building Code Adoption Tracking (BCAT) tool, which evaluates aspects of a community's natural hazard risks and building code adoption.

[11]Advisory Committee on Earthquake Hazards Reduction, *Effectiveness of the National Earthquake Hazards Reduction Program,* September 2015, and Advisory Committee on Earthquake Hazards Reduction, *Effectiveness of the National Earthquake Hazards Reduction Program,* September 2017.

assessments to identify improvements in resilience in communities nationwide, since 2015.[12]

To identify FEMA's efforts toward identifying progress in earthquake risk reduction, we reviewed NEHRP's annual and biennial reports provided to Congress from fiscal years 2015 to 2019, as well as other reports and documents.[13] We also reviewed FEMA's NEHRP State Assistance Grant Program guidance and related documents to identify how FEMA uses performance measurement data submitted by states to assess progress made on activities intended to improve seismic safety and earthquake risk reduction. Further, we interviewed FEMA officials to obtain information on their initiatives used to identify progress in earthquake risk reduction, such as tracking the status of building code adoption by jurisdictions.

To determine the extent to which FEMA conducts outreach and education to inform tribal governments about earthquake risk reduction, we reviewed FEMA's tribal policy, which addresses collaboration with tribal governments to further develop education and training opportunities in areas related to disaster preparedness. Although FEMA's National Tribal Strategy was not released as of February 2022, we interviewed FEMA to determine whether any plans were being developed on the approaches for conducting outreach and training with tribes. We also asked FEMA officials what actions, if any, have been taken to help tribes understand earthquake risk reduction. Further, we interviewed representatives from nine tribes and one tribal association to obtain their perspectives on the

[12]Selected stakeholders included representatives from one U.S. territory and three state emergency management agencies, one state geological survey agency, two regional earthquake consortiums, one national civil engineering association, one national building code and standards council, nine tribes, and one tribal association. See Appendix I for more details concerning our stakeholder selection methodology. While the information gathered during interviews with these selected stakeholders cannot be generalized to all states or other stakeholders, it provides a range of perspectives on a variety of topics relevant to earthquake hazards reduction. We selected 2015 as the timeframe for determining the extent NEHRP made progress in identifying gaps and strengthening resilience to earthquakes because that is when implementation of the NEHRP's Strategic Plan FY 2009 – 2013 can be identified and monitored.

[13]NEHRP, *Annual Report of the National Earthquake Hazards Reduction Program for Fiscal Year 2015, March 2018;* NEHRP, *Annual Report of the National Earthquake Hazards Reduction Program for Fiscal Year 2016,* May 2019; NEHRP*, Annual Report of the National Earthquake Hazards Reduction Program for Fiscal Year 2017, December 2019;* and NEHRP, *Biennial Report of the National Earthquake Hazards Reduction Program for Fiscal Years 2018 and 2019,* August 2021.

extent to which FEMA conducted outreach and training with them on earthquake risk reduction.[14]

To address our third objective, we reviewed NEHRP's Strategic Plan for fiscal years 2009 – 2013 (Strategic Plan FY 2009 – 2013) and related documents to identify strategic research priorities, and the extent stakeholders were involved in the development of the NEHRP's Strategic Plan FY 2022 - 2029.[15] Further, we interviewed officials from NIST, FEMA, NSF and USGS to discuss their perspectives on the extent to which stakeholders were included in the process of identifying strategic research priorities. We also interviewed officials from 19 selected stakeholder groups to discuss their perspectives on the strategic research priorities, and whether they were included in the process of identifying the priorities.[16]

To determine the extent to which NSF and NIST communicated the strategic research priorities to research entities, we reviewed NSF's mechanisms to communicate research opportunities, such as program solicitations, program descriptions, and Dear Colleague Letters.[17] We also assessed NSF's Dear Colleague Letters provided to research entities from 2016 to 2021 to determine whether the letters identified NEHRP's research priorities. Further, we interviewed officials from NIST and NSF to discuss how, if at all, NEHRP's strategic research priorities are identified in the mechanisms used to communicate with research entities. Also, to help provide an understanding about the number of research entities conducting research on topics related to NEHRP, we reviewed research grants awarded in NSF's award database.

To determine the extent to which NEHRP's Program Coordination Working Group followed leading practices for interagency collaboration in implementing NEHRP's strategic research priorities, we compared the working group's collaboration practices against four leading practices

[14]See appendix I for more details concerning our selection methodology.

[15]NEHRP, *Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009-2013,* October 2008.

[16]Appendix I provides more details concerning our stakeholder selection methodology.

[17]The NEHRP Strategic Plan FY 2009 – 2013 identified nine strategic priorities, three of which were research priorities. Those research priorities are to 1) improve techniques for evaluating and rehabilitating existing buildings; 2) further develop performance-based seismic design; and 3) develop earthquake-resilient lifeline components and systems.

identified in our past work.[18] We determined that four leading practices in our report on interagency collaboration were most relevant to this engagement and include practices related to (1) defining shared outcomes and goals, (2) ensuring accountability by developing performance measures and tracking progress, (3) establishing leadership, and (4) identifying resources, such as funding, staffing, and technology. We assessed the extent to which NEHRP's working group followed these leading collaboration practices by assessing them as (1) generally followed, (2) partially followed, or (3) not followed.[19]

To address our fourth objective, we reviewed NEHRP's Strategic Plan FY 2009 – 2013 to determine how, if at all, goals and objectives identified linkage to the dissemination of materials and research. We also reviewed NIST and NSF policies and supporting documents addressing how NIST and NSF are to disseminate research findings related to NEHRP. In addition, we interviewed NIST and NSF officials to discuss the mechanisms and practices used to disseminate research findings related to NEHRP. Further, we selected and interviewed officials from 19 stakeholder groups to discuss their awareness and perspectives concerning how NIST and NSF disseminate research findings related to NEHRP. Lastly, we reviewed the Advisory Committee's biennial reports in 2015 and 2017 to identify any challenges reported on NEHRP's practices in disseminating research findings.[20] For more details on our stakeholder selection methodology, see appendix I.

We conducted this performance audit from February 2021 to May 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain

[18]GAO, *Managing for Results: Implementation Approaches Used to Enhance Collaboration in Interagency Groups*, GAO-14-220 (Washington, D.C.: Feb. 14, 2014).

[19]In assessing whether the working group followed leading collaboration practices, we reviewed NEHRP's Strategic Plan and other planning documents, along with testimonial evidence from NIST and NSF that showed their collaboration practices. For each leading collaboration practice, one analyst reviewed the NEHRP's planning documents and testimonial evidence to determine the extent the working group followed each of the leading practices. The results of the assessment were recorded in a spreadsheet. In addition, a second analyst reviewed the evidence and the first analyst's assessment and verified the result indicating agreement.

[20]Advisory Committee on Earthquake Hazards Reduction, *Effectiveness of the National Earthquake Hazards Reduction Program,* September 2015, and Advisory Committee on Earthquake Hazards Reduction, *Effectiveness of the National Earthquake Hazards Reduction Program,* September 2017.

sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The National Earthquake Hazards Reduction Program

NEHRP agencies' roles and responsibilities

- **NIST** is the lead agency with primary responsibility for program planning and coordination. NIST is also responsible for conducting earthquake engineering research for building codes, standards, and practices. NIST Engineering Laboratory Materials and Structures Division conducts NEHRP's applied research activities.
- **FEMA** is responsible for promoting better building code practices and providing assistance to enable states to improve earthquake preparedness. FEMA's NEHRP state assistance team coordinates with FEMA regions, states, territories, nonprofits, institutions of higher education, and other public and private partners.
- **NSF** supports a broad range of research in geosciences; engineering; computational; and social, behavioral, and economic sciences relevant to the understanding of the causes and impacts of earthquakes. It also supports research to improve safety and performance of buildings, structures, and lifelines.
- **USGS** is responsible for providing earthquake monitoring and notification, delivering seismic hazard assessments, conducting applied scientific research to improve these functions, and coordinating post-earthquake investigations. USGS also maintains a grants program to support NEHRP external research activities.

Source: GAO. I GAO-21-129

NEHRP was established in 1977 to help reduce the risks to life and property from earthquakes in the U.S.[21] The federal law that established the program states that loss, destruction, and disruption from future earthquakes can be substantially reduced through the development and implementation of earthquake risk reduction measures. These measures include a) improved design and construction methods and practices guided by seismic hazard assessments, b) land-use controls and redevelopment, c) early-warning systems and rapid estimates of earthquake impact, d) coordinated emergency preparedness plans, and e) public education and involvement programs.[22]

The NEHRP Reauthorization Act of 2018 expands the types of information that NEHRP is to maintain in a repository to include technical data on community resilience to earthquake-related seismic events. This act also requires NEHRP to publish information on the susceptibility for seismically-induced hazards across the U.S.[23] The act charges NEHRP with continuing the development of the Advanced National Seismic System, which has improved the development of materials and dissemination of information on earthquake safety, training, education, and other activities.[24] The act requires NIST and FEMA to jointly convene a committee of experts to assess and recommend options for improving

[21]See 42 U.S.C. § 7704.

[22]Pub. L. No. 95–124, § 2(2), 91 Stat 9108 (1977).

[23]Pub. L. No. 115-307, § 3, 132 Stat. 4408, 4409 (codified as amended at 42 U.S.C. § 7704(a)(2)(B).

[24]§ 7704(a)(2)(D). The Advanced National Seismic System is the USGS initiative to improve the monitoring and reporting of earthquakes in the United States. Specifically, it provides earthquake alerts describing a magnitude, location, and significant suite of earthquake situational awareness products such as PAGER and ShakeMaps within a few minutes after an earthquake.

the built environment and critical infrastructure to reflect functional recovery performance goals.[25]

Additionally, the act outlines key FEMA responsibilities, such as supporting implementation of comprehensive earthquake risk education and public awareness programs. FEMA is also responsible for working with NIST and others to use research results to support the preparation, maintenance, and wide dissemination of seismic-resistant design guidance and related information on building codes, standards, and practices.[26] Broadly, these agencies are to advance knowledge of earthquake causes and effects and develop and share measures to reduce their impacts.

Further, the National Research Council, the operating and principal programmatic arm of the National Academies of Sciences, Engineering, and Medicine, helped to support NEHRP's mission by providing a comprehensive understanding of how to move the nation toward earthquake resilience. The Council defines a disaster-resilient nation as one in which its communities, through mitigation and pre-disaster preparation, develop the adaptive capacity to maintain important community functions and recover quickly when major disasters occur. According to the Council, NEHRP has improved earthquake safety for existing buildings and the design and construction of new buildings.[27]

The Interagency Coordinating Committee

The NEHRP Reauthorization Act of 2004 established the ICC to oversee planning, management, and coordination of the program.[28] The NIST Director chairs the ICC and members include the Administrator of FEMA and the directors of NSF, USGS, the White House Office of Science and Technology Policy, and the Office of Management and Budget. ICC issues biennial reports to Congress on the budgets and activities of NEHRP, including progress NEHRP agency programs are making toward

[25]§ 7705b.

[26]§ 7704(b)(2)(A). The law directs that NEHRP activities be designed to develop effective earthquake risk (hazard) reduction measures and to promote the adoption of those measures by Federal, State, and local governments, national standards and model code organizations, architects and engineers, building owners, and others with a role in planning and constructing buildings, structures, and lifeline infrastructure. § 7704(a)(2)(B).

[27]National Research Council. 2011. *National Earthquake Resilience: Research, Implementation, and Outreach*, Washington, D.C. The National Academies Press.

[28]§ 7704(a)(3).

achieving earthquake risk reduction.[29] In August 2021, the ICC released the biennial report on NEHRP for fiscal years 2018 and 2019.[30]

The act charged the ICC to develop and periodically update a strategic plan and a management plan to implement the strategic plan.[31] The act also charged the ICC to develop a coordinated interagency budget for the program that will ensure appropriate balance among the program's activities.[32]

The Advisory Committee

The NEHRP Reauthorization Act of 2004 also established an Advisory Committee to assess the effectiveness of the NEHRP program and making recommendations for improvement.[33] The Advisory Committee is to be comprised of at least 11 members appointed by the Director of NIST who have an established record of distinguished service in their professional community and are knowledgeable of NEHRP-related issues. The Advisory Committee provides a biennial report to the NIST Director that assesses the effectiveness of NEHRP performing its statutory activities, management of NEHRP, and trends in the science and engineering of earthquake hazards reduction.[34]

NEHRP National Strategy and Planning Framework

In 2008, NIST and ICC issued NEHRP's National Strategic Plan FY 2009 – 2013, which identified the mission, long-term goals, and strategic

[29]§ 7704(a)(4).

[30]*Biennial Report of the National Earthquake Hazards Reduction Program, FY 2018 – 2019*, August 2021.

[31]§ 7704(a)(3)(D)(ii)(I).

[32]§ 7704(a)(3)(D)(ii)(II).

[33]§ 7704(a)(5).

[34]The Advisory Committee's 2021 biennial assessment of NEHRP presented observations and recommendations for NEHRP to consider. The Advisory Committee provided six recommendations related to NEHRP resources, structure of its meetings; functional recovery and community resilience; research support in earth science, engineering, and social science to further develop earthquake early warning capabilities; jointly-funded activities; and the organization of workshops for the earthquake science and engineering community.

priorities for the program.[35] In 2008, NIST contracted with the National Research Council to conduct a study in three phases, building on the national strategy, to identify activities and costs needed to achieve earthquake hazard and risk reduction.[36] The National Research Council considers the results of the study a roadmap for how NEHRP will achieve its long-term goals and strategic priorities. For example, the study recommends that NEHRP conduct additional research to advance the understanding of earthquake phenomena and earthquake generation processes and to improve the predictive capabilities of earthquake science. In addition, the study recommends complete deployment of the Advanced National Seismic System and the National Seismic Hazard Model.[37]

NEHRP's Program Coordination Working Group is a mid-level interagency coordinating group responsible for coordinating the implementation of ICC directives, policies, and strategies. The working group, led by the NEHRP Director, is comprised of representatives from the four NEHRP agencies. According to NIST, the working group meets monthly and collaborates on activities and agency programs towards achieving the program's strategic goals. On occasion, there are smaller working groups/sub-working groups focused on specific issues that involve one or two agencies. For example, NIST and NSF issued a joint Disaster Resilience Research Grants competition to solicit research proposals to improve policies, practices, and decisions for natural disaster resilience. In another example, NIST stated that since 2006 USGS has

[35]According to the NEHRP Strategic Plan 2009-2013, NEHRP's mission is to develop, disseminate, and promote knowledge, tools, and practices for earthquake risk reduction—through coordinated, multidisciplinary, interagency partnerships among the NEHRP agencies and their stakeholders—that improve the Nation's earthquake resilience in public safety, economic strength, and national security.

[36]The National Research Council study, completed in 2011, consisted of three phases: Phase 1 (September 29, 2008 - June 28, 2009); Phase 2 (June 29, 2009 – March 28, 2010); and Phase 3 (March 29, 2010 – July 28, 2010).

[37]The National Research Council states that full deployment of the Advanced National Seismic System would allow the capability of recording all earthquakes down to moment magnitude-3 and up to the largest anticipated magnitude. The National Seismic Hazard Maps produced by USGS are the authoritative reference for earthquake ground motion hazard in the United States. According to the National Research Council, these maps are the basis of the probabilistic portion of the NEHRP Recommended Provisions, are a resource for the model building codes, and are used in seismic retrofit guidelines, earthquake insurance, land-use planning, and the design of highway bridges, dams, and landfills. They are also used in nationwide earthquake risk and loss assessment and development of credible earthquake scenarios for planning and emergency preparedness.

been the lead agency in earthquake early warning and worked with a number of partner organizations. Additionally, USGS and NSF collaborated on instrumentation issues and reported out at the working group meetings.

NEHRP Strategic Research Priorities

NEHRP's National Strategic Plan FY 2009 – 2013 identified nine strategic priorities; three of which are research priorities.[38] The strategic research priorities are to 1) improve techniques for evaluating and retrofitting existing buildings; 2) further develop performance-based seismic design; and 3) develop guidelines for earthquake-resilient lifelines (e.g. electrical power lines, water, and sanitary sewer system).[39] NEHRP's strategy states that accomplishing NEHRP's mission and strategic priorities requires developing and applying research in the geological, engineering, and social sciences areas. Three NEHRP agencies—NIST, NSF, and USGS—award grants to universities, state and local agencies, and research organizations to help achieve the research priorities and goals identified in the strategy.[40]

NIST and FEMA award grants to improve earthquake hazard and risk reduction through advancing building codes and standards, and construction practices for structures and lifelines. FEMA officials stated that NIST and FEMA also award grants and contracts to conduct

[38]NEHRP's long term goals are to 1) Improve understanding of earthquake processes and impacts; 2) develop cost effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large and 3) improve the earthquake resilience of communities nationwide.

[39]NEHRP's Strategic Plan FY 2009- 2013 identified nine strategic priorities, however we are focusing on the three strategic priorities related to research. The other six strategic priorities are 1) Fully implement the Advanced National Seismic System; 2) increase consideration of socioeconomic issues related to hazard mitigation implementation; 3) develop a national post-earthquake information management system; 4) develop advanced earthquake risk mitigation technologies and practices; 5) develop and conduct earthquake scenarios for effective earthquake risk reduction and response and recovery planning; and 6) facilitate improved earthquake mitigation at State and local levels.

[40]NSF supports research to improve the understanding of earthquake engineering and socioeconomic information on the issues that affect decision making for mitigation and response efforts. NIST is responsible for earthquake engineering applied research to improve building codes and standards for new and existing buildings and infrastructure lifelines; advance seismic resistant construction practices; develop measurement and prediction tools supporting performance based standards; and evaluate advanced technologies. USGS awards grants and cooperative agreements for work that contributes to research on earthquake causes and effects, assessment and characterization of earthquake hazards and risks, and monitoring and reporting of earthquake activity and crustal deformation.

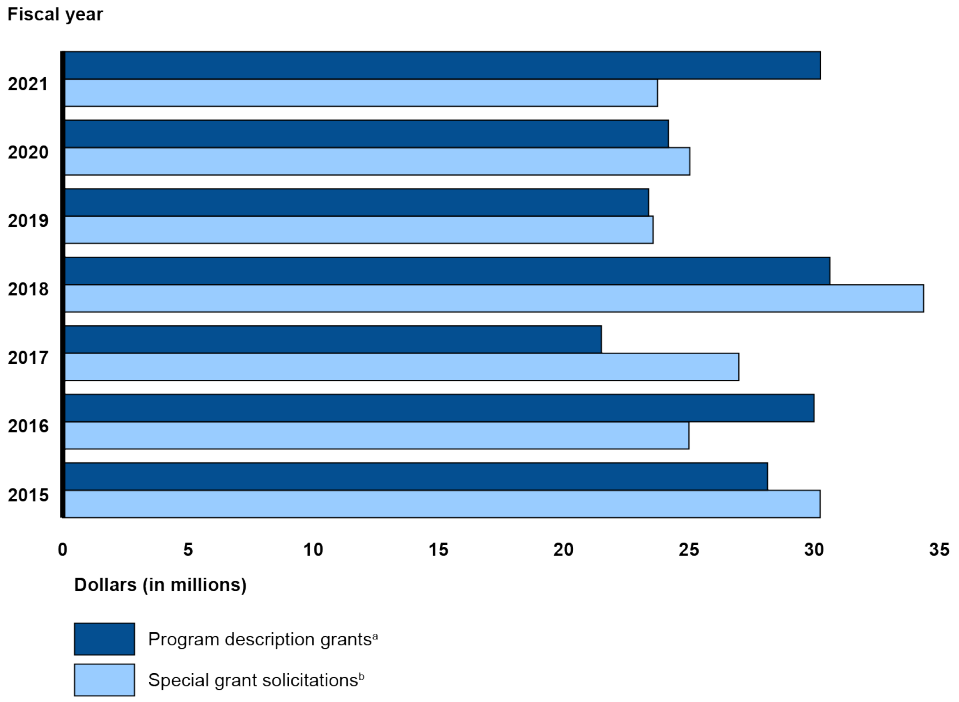
research to evaluate and test earthquake-resistant design and construction practices for implementation into building codes and engineering practices.

- In fiscal years (FY) 2018 and 2019, NIST awarded more than $6.6 million for research on improving building resiliency against earthquakes, wind, and fire hazards. In 2020, NIST and NSF established a joint Disaster Resilience Research Grant solicitation with the intent to fund $3.1 million in research projects relevant to improved natural disaster resilience.
- FEMA officials stated that in FY 2018 and 2019, they awarded $3.9 million through two contracts for the development, publication, and promotion of seismic design guidance to improve the performance of buildings and the codes and standards that are used in their design and construction, according to FEMA officials.

NSF supports research in earth science, engineering, computational, social, behavioral, and economic sciences that is relevant to improving the understanding of the causes and impacts of earthquakes and to developing effective measures to reduce their effects.[41] According to NSF, research proposals are submitted either to special solicitations issued by the agency or to standing programs that accept “unsolicited” proposals on topics. The research is conducted through grants awarded to individual universities, institutions, businesses, and other organizations. Figure 1 shows that from FY 2015 to 2021, NSF awarded approximately $377 million in solicited and unsolicited grants for research related to NEHRP.

[41]NSF received $8.49 billion in appropriations for fiscal year 2021. Of this amount, 81.4 percent supported research and related activities, 11.4 percent supported education and human resources, and 2.8 percent supported major research equipment and facilities construction, with the remainder supporting administrative and related activities. Pub. L. No. 116-260, 134 Stat. 1182, 1271 (2020). See also Congressional Research Service, *The National Science Foundation: An Overview.* Washington, D.C. (April 9, 2021)

Figure 1: National Science Foundation (NSF) Program Solicitation and Program Description Grants Awarded for Research Related to National Earthquake Hazards Reduction Program, from Fiscal Years 2015 to 2021



Source: GAO presentation of National Science Foundation data. | GAO-22-105016

[a]Unsolicited grants support research on topics defined by researchers and relevant to some NSF programs.

[b]Solicited grants support research on topics defined in special solicitations.

NIST and ICC Plan to Release the Update to the NEHRP Strategic Plan in 2022

Since 2009, NEHRP has been operating under its Strategic Plan FY 2009 - 2013. In October 2004, the NEHRP Reauthorization Act of 2004 mandated that the ICC develop and periodically update a NEHRP Strategic Plan and management plan.[42] According to NIST officials, the NEHRP Strategic Plan FY 2022 – 2029 is scheduled to be released for public comment in the spring of 2022.

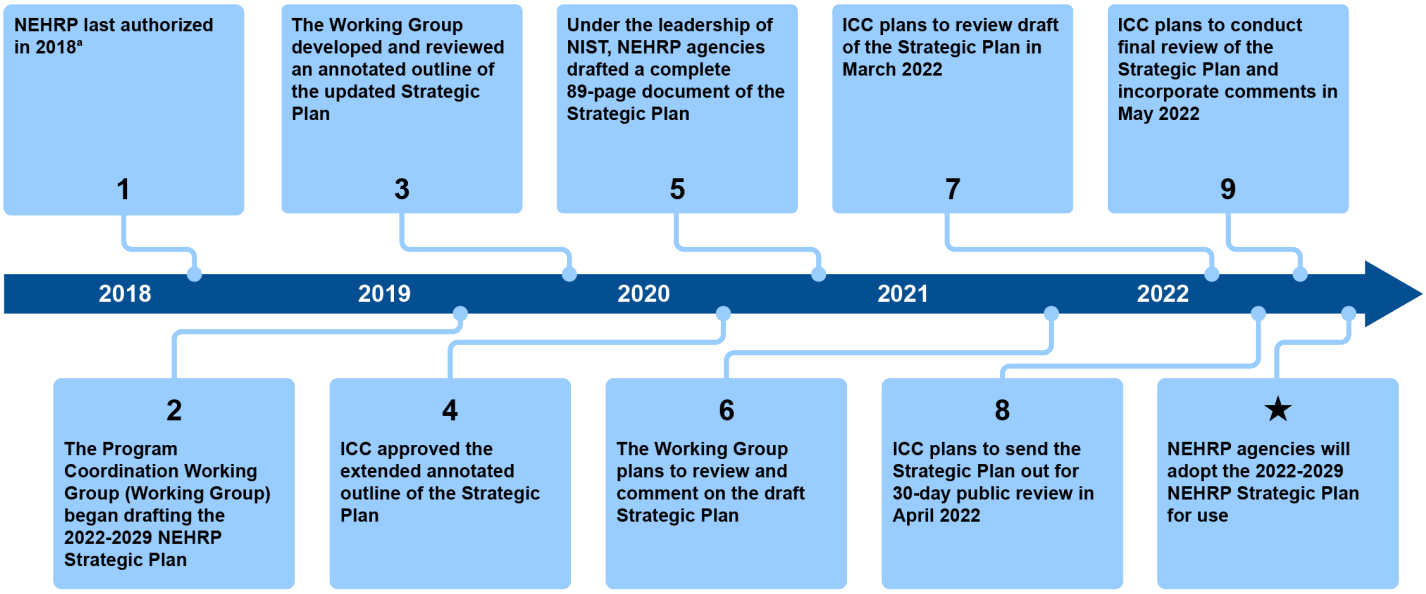
[42]§ 7704(a)(3)(D)(ii). The management plan is to be a detailed plan that implements the strategic plan. Key elements in an implementation plan include (a) identification of actions needed to achieve goals, (b) identification of lead agencies responsible for executing these actions, (c) development of project milestones to guide the execution of actions, and (d) description of skills and technologies, and resources needed to execute the actions.

According to NIST officials, the NEHRP Strategic Plan FY 2022 – 2029 will have four long-term goals, supported by 18 objectives. During the Advisory Committee's November 2020 meeting, the Acting NEHRP Deputy Director reported that the four long-term goals will include the following:

1. Advance the understanding of earthquake processes and their consequences;
2. Enhance existing and develop new information, tools, and practices for protecting the nation from earthquake consequences;
3. Promote the dissemination of knowledge and implementation of tools, practices, and policies that enhance strategies to withstand, respond to and recover from earthquakes; and
4. Learn from post-earthquake investigations to enhance the effectiveness of available information, tools, practices, and policies to improve earthquake resilience.

NIST officials told us the working group began updating the Strategic Plan in 2019, and proposed updated goals and new areas of research priorities. In addition, the working group developed and reviewed an annotated outline of the updated Strategic Plan, which included significant changes to the Plan, such as an additional program goal. NIST officials told us that they will begin developing the Management Plan in 2022, after the updated Strategic Plan is released. Figure 2 shows the timeline of steps taken by the ICC and NIST to develop the NEHRP Strategic Plan FY 2022 - 2029.

Figure 2: Timeline of National Institute of Science and Technology and Interagency Coordination Committee's Efforts to Update the National Earthquake Hazards Reduction Program's (NEHRP) Strategic Plan



Source: GAO presentation of National Institute of Standards and Technology information. | GAO-22-105016

NEHRP Has Not Fully Assessed Earthquake Resilience and Informed Tribal Governments

NEHRP's Strategic Plan Has Goals for Community Resilience, but Progress Has Not Been Fully Assessed

NEHRP's Strategic Plan FY 2009 – 2013 provides for the improvement of earthquake resilience in communities nationwide. More specifically, the plan's objectives call for the development of seismic standards and building codes and adoption and promotion of earthquake-resilient measures in professional practice and in private and public policies.[43] However, according to NIST officials, NEHRP has not completed a comprehensive assessment identifying progress communities have made

[43]Other objectives call for the improvement, accuracy, timeliness, and content of earthquake information products and development of earthquake risk scenarios and risk assessments.

Damage in Anchorage, Alaska Following a Magnitude 7.1 Earthquake

According to the Geotechnical Extreme Events Reconnaissance Association, on November 30, 2018 a magnitude 7.1 earthquake occurred near Anchorage. The earthquake caused widespread power outages, structural and non-structural damage to buildings, damage to roadways and railways, and closure to schools and businesses The picture below illustrates an engineered embankment that failed during earthquake shaking caused by loss of bearing strength in underlying deposits. This failure caused damage to about 90 meters of Vine Road in Anchorage. The 2018 earthquake is one of the largest magnitude earthquakes to strike near a major U.S. city since the 1994 Northridge earthquake in California.

Source: U. S. Geological Survey. | GAO-22-105016

nationwide to strengthen earthquake resilience and identify remaining gaps.

In 2015 and 2017, the Advisory Committee recommended that NIST conduct a national risk assessment to identify the extent to which the federal government, states, localities, tribes, and the private sector are taking actions to strengthen earthquake resilience, such as addressing the seismic vulnerability of buildings, critical infrastructure and lifeline systems. The Advisory Committee's 2015 biennial report stated there are inconsistencies in adopting and enforcing building codes with seismic provisions across states and localities, even in areas with high seismic hazards. The report also states there are relatively few states and localities in areas with moderate to high earthquake hazards that have programs that address seismically vulnerable construction such as unreinforced masonry, pre-1980 non-ductile concrete buildings, and other vulnerable building types—many of which are used as hospitals, schools, offices, and apartments. In response to the recommendation, NIST stated the NEHRP agencies are not presently resourced to undertake a comprehensive assessment, without redirecting funds that are currently applied to specific hazard assessment and risk reduction efforts.

In fiscal year 2018, NIST solicited applicants for the 2018 Disaster Resilience Research Grants Program to conduct research in one of four areas defined under NEHRP.[44] One of the four areas was a comprehensive evaluation of the nation's progress made towards strengthening earthquake resilience since NEHRP was established in 1977. According to NIST, there were no funds awarded for the evaluation research. NIST officials added that the subsequent Disaster Resilience Research Grant in fiscal year 2020 did not specifically solicit applicants to conduct an evaluation of the nation's progress with earthquake risk reduction.

[44]NIST 2018 Disaster Resilience Research Grants Program solicited research on NEHRP in four areas: 1) developing improved simulation capabilities and potential cost-effective solutions to mitigate earthquake vulnerabilities in older non-ductile masonry, and structural steel or reinforced concrete buildings or building elements; 2) developing improved techniques, tools, and guidelines to assess the resilience of civil lifelines at both the individual component and system scales prior to an earthquake; 3) developing approaches and frameworks within the social sciences to improve engagement in mitigation of seismic risk at the state, region, and local community levels; and 4) conducting a comprehensive evaluation of the nation's earthquake risk reduction progress over the years since the Earthquake Hazards Reduction Act of 1977 was enacted to the present.

In our discussions, officials from two state emergency management agencies in Alaska and California told us that communities within their state differ in their adoption of earthquake risk reduction measures to strengthen resilience. For example, officials from the California Governor's Office of Emergency Services said large municipalities like San Francisco and Los Angeles adopted seismic retrofit programs and are moving forward with other seismic mitigation efforts (e.g., concrete mitigation efforts). However, California officials said smaller municipalities in high earthquake hazards areas are not doing as much with seismic mitigation efforts because they do not have a large tax base to use as a funding source. Additionally, officials from the International Code Council told us seismic code adoption varies widely across the nation because some states and localities regularly update their codes, while others do not. They noted that some states allow local jurisdictions to decide whether to adopt the codes. FEMA has reported that although most states and local jurisdictions adopt the codes, some have amendments or exclusions relating to the seismic provisions.[45]

In our 2019 disaster resilience framework, we reported the importance of monitoring progress towards achieving disaster resilience goals where resilience investments are needed.[46] The framework also calls for developing a quantitative means of assessing community resilience to identify the priority needs and to monitor how resilience had improved. Additionally, in June 2016, the Mitigation Framework Leadership Group, led by FEMA and the National Oceanic and Atmospheric Administration reported most actions to improve community resilience occur at the local level, and that federal programs provide the resources that support community capacity building nationwide. The Mitigation Framework Leadership Group also reported that it is important to understand how such actions improve local resilience capacity, and that federal agencies

[45]FEMA, *Building Codes Save: A Nationwide Study, Losses Avoided as a Result of Adopting Hazard Resistant Building Codes*, November 2020. Building codes are sets of regulations governing the design, construction, alteration, and maintenance of structures. They specify the minimum requirements to adequately safeguard the health, safety, and welfare of building occupants.

[46]GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, GAO-20-100SP (Washington, D.C.: Oct. 2019).

must gauge how their efforts individually and collectively impact community resilience capacity nationwide.[47]

In 2009, NIST requested the National Research Council to conduct a study identifying activities and resources needed to achieve the plan's long-term strategic goals and provide a basis for a more earthquake resilient nation.[48] The report identified 18 tasks essential for achieving resilience over a 20-year period. According to NIST officials, the Council's report helped define some of the progress toward earthquake risk reduction, and constitutes the "roadmap" for furthering NEHRP goals and implementing the NEHRP Strategic Plan FY 2022 - 2029. However, NIST officials said a more comprehensive and up-to-date evaluation is needed to identify where progress is being made, and where gaps remain.

While NIST officials said that a national risk assessment would be valuable to them because it can inform strategic planning efforts, no such assessment has been completed because of other priorities, such as updating the NEHRP Strategic Plan. By conducting a national risk assessment, NEHRP could gain greater awareness of earthquake resilience improvements and be better positioned to strategically plan long-term goals and objectives and identify capabilities and vulnerabilities across different jurisdictions. In addition, a national risk assessment can help inform FEMA's ongoing work on the National Threat and Hazard Identification and Risk Assessment.[49]

[47]Mitigation Framework Leadership Group, *Draft Interagency Concept for Community Resilience Indicators and National Level Measures,* June 2016.

[48]National Research Council. 2011. *National Earthquake Resilience: Research, Implementation, and Outreach*, Washington, D.C. The National Academies Press.

[49]FEMA's Threat and Hazard Identification and Risk Assessment is a three-step risk assessment process that helps communities understand their risks and what they need to do to address those risks. FEMA's process represents an initial effort to identify the greatest threats and hazards to the nation, the potential impacts of those threats and hazards to life and property, and the capabilities needed to address those impacts. The intended audience is emergency management officials engaged in risk assessment at the community level.

FEMA Has Initiated Efforts to Identify Progress States and Localities Made Strengthening Earthquake Resilience

FEMA has initiated efforts to identify progress states and localities made strengthening earthquake risk reduction nationwide by tracking the status of building code adoption; developing the use of logic models to better understand the public's awareness of earthquake risk reduction; and assessing communities' resilience to natural disasters.

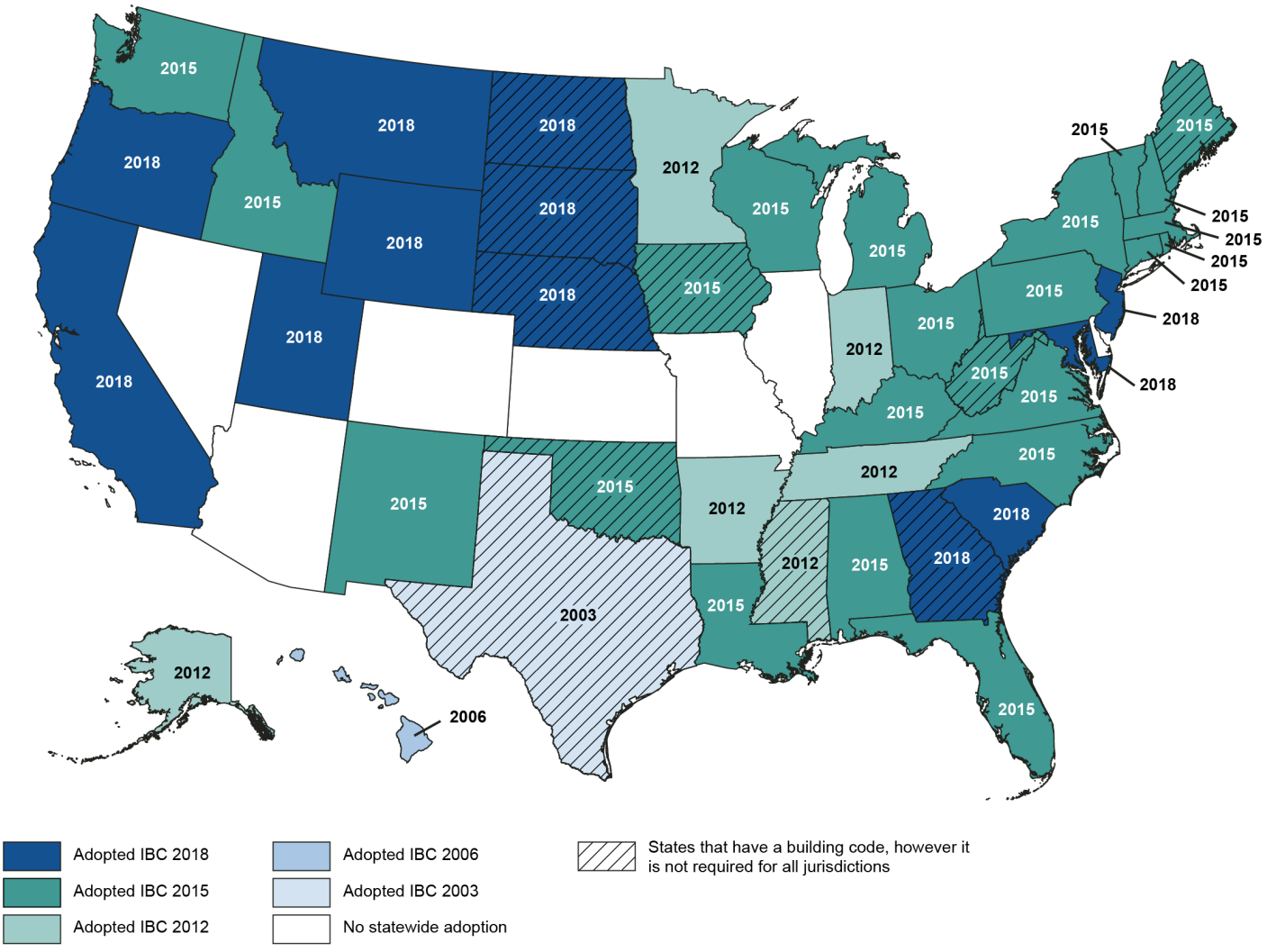
In 2007, FEMA began tracking building code adoption status for state, local, tribal and territorial governments across the nation, totaling about 22,000 jurisdictions.[50] This effort referred to as the Building Code Adoption Tracking evaluates several aspects of a community's natural hazard risks and building code adoption, including 1) state or territory requirements for mandatory building code adoption and 2) building code adoption status for jurisdictions, including residential and commercial construction requirements.[51]

In 2020, FEMA reported the status of states in adopting the International Building Code (IBC). As shown in figure 3, there are differences among states adopting the IBC. For example, as of April 2020, California had adopted the most recent IBC code (2018) at the time of the study, while other states such as Nevada and Arizona had not adopted any version of the IBC. According to FEMA, while tracking building code adoption provides valuable information, some states and jurisdictions include amendments or exclusions relating to seismic provisions.

[50]FEMA uses building code adoption tracking data to produce fact sheets for FEMA's Annual Building Code Adoption Tracking and FEMA's Annual Mutual Aid for Building Departments.

[51]International Building Code applies to almost all types of new buildings; International Residential Code applies to new one- and two-family dwellings and townhouses of not more than three stories in height; and the International Existing Building Code applies to the alteration, repair, addition, or change in occupancy of existing structures.

Figure 3: States Adoption of the International Building Code, As of April 2020



Source: GAO presentation of Federal Emergency Management Agency data. | GAO-22-105016

In 2020, FEMA tasked Argonne National Laboratory to analyze and assess community resilience to natural disasters.[52] The results of the analysis identified counties across the nation in high risk areas that may

[52]FEMA, *Community Resilience Indicator Analysis: County Level Analysis of Commonly Used Indicators from Peer Reviewed Research*, 2020 Update.

face challenges investing in resilient initiatives needed to mitigate earthquake risks, including seismic hazards.[53] The report further states that understanding how factors such as education, income, homeownership, and unemployment rate relate to resilience has important implications because they highlight areas where emergency managers and community leaders should consider outreach strategies and emergency operations plans.

In 2009, FEMA developed the NEHRP State Assistance Grant Program to increase and enhance the effective implementation of earthquake risk reduction at the state and local level.[54] The program provides funding opportunities through the Individual State Earthquake Assistance grant to eligible states and territories and through the Multi-State and National Earthquake Assistance grant to nonprofit organizations and institutions of higher education. In August 2021, NEHRP reported that the 2018 State Assistance Program enabled eligible states, territories and local communities to fund the development of seismic mitigation plans; conduct seismic safety inspections of critical structures and lifelines; update building codes and ordinances; and increase earthquake awareness and education.[55]

FEMA also developed the National Earthquake Technical Assistance Program as a mechanism for delivering direct assistance to the public through state, territory, and local government entities. This assistance funded a series of in-person trainings and webinars to help increase the public's knowledge and ability to analyze their risk, make a plan, and take actions aimed at reducing their risk from earthquakes, and supporting overall community resilience. NEHRP reported that FEMA conducted 55

[53]According to the analysis, some of the locations that may face challenges include the western coast of Alaska, Puerto Rico, central Appalachian counties in Kentucky and West Virginia, and Alaska's western coast and its interior.

[54]The NEHRP State Assistance Grant Program is one part of FEMA's activities conducted in response to the NEHRP Reauthorization Act of 2004.

[55]*Biennial Report of the National Earthquake Hazards Reduction Program, FY 2018 – 2019*, August 2021. The fiscal year 2019 State Assistance Program funded $3.6 million to states and local communities to increase and enhance the effective implementation of earthquake risk reduction.

in-person trainings with 2,123 participants, and held three national webinars with 2,413 attendees in fiscal year 2019.[56]

In 2017, FEMA began to require nonprofit organizations and institutes of higher education that received Multi-State and National Earthquake Assistance grants to submit a logic model in addition to their quarterly performance progress report.[57] The information in the logic model provides performance measures and describes progress made on activities intended to improve seismic safety and earthquake risk reduction. According to FEMA, the information provided in the logic models can be documented and substantiated in different ways, such as through after action reports and participant surveys. FEMA officials added that in 2021, FEMA began to require participating states and territories that receive the Individual State Earthquake Assistance funding to submit logic models with their quarterly performance progress reports.

FEMA Does Not Inform All Tribal Governments about How to Strengthen Earthquake Resilience

The NEHRP statute as amended by the NEHRP Reauthorization Act of 2018 outlines key FEMA responsibilities that include 1) using research results to support the preparation, maintenance, and dissemination of seismic design guidance and related information on building codes, standards, and practices; 2) operating a program of grants and assistance to the states to support seismic risk mitigation efforts; and 3) supporting implementation of comprehensive earthquake risk education and public awareness programs.[58] According to NIST officials, FEMA continues to be the NEHRP agency responsible for conducting outreach

[56]*Biennial Report of the National Earthquake Hazards Reduction Program, FY 2018 – 2019*, August 2021.

[57]FEMA's Notice of Funding for 2021 Multi-State and National Earthquake Assistance grant for (Nonprofits and Institutions of Higher Education) listed available funding up to $1.64 million in awards for 4 to 6 recipients. According to FEMA, only those recipients that have been awarded more than $400,000 in grant funds are required to submit the logic model with their performance progress report.

[58]42 U.S.C. § 4407(b)(2). The law directs that NEHRP activities be designed to develop effective earthquake risk (hazard) reduction measures and to promote the adoption of those measures by Federal, State, and local governments, national standards and model code organizations, architects and engineers, building owners, and others with a role in planning and constructing buildings, structures, and lifeline infrastructure. § 4407(a)(2)(B).

to states and localities promoting implementation of research results and better building practices.[59]

In December 2020, FEMA issued a tribal policy that calls for collaboration with tribal governments to further develop education and training opportunities in areas related to disaster mitigation, response, and recovery. For example, the policy states that FEMA, in consultation with tribal governments, is to provide tribal governments with information to participate in educational and technical assistance programs. Among other things, these programs should enhance tribal expertise to build, sustain, and improve the capacity to mitigate, respond to, and recover from all hazards. Further, in October 2021, FEMA stated in its response to recommendations from the National Advisory Council that it is developing a National Tribal Strategy that will include activities to better understand the tribal nation's resilience and capacity to mitigate and respond to natural disasters.[60]

While FEMA is developing a National Tribal Strategy, a representative from one tribal association and eight of nine tribal officials in northern California told us that there is little outreach from FEMA informing them about how to strengthen earthquake resilience. For example, tribal officials said they were not informed about guidance and provisions for improving resilience for new and existing buildings and lifelines. Tribal officials added that when they need information on guidance or other earthquake risk reduction measures, they sometimes rely on information obtained from internet searches. In addition, the representative from the tribal association told us that since there was no outreach by FEMA, they contacted FEMA's regional office in September 2021 to inquire about the

[59]According to NIST officials, the other NEHRP agencies generally do not conduct outreach to the states and localities, but all the agencies post guidance such as published articles and technical journals on their websites as a way to inform the public and stakeholders about earthquake hazards reduction initiatives. For example, NEHRP guidance on construction practices for new buildings and lifelines is posted on the website.

[60]In November 2020, the National Advisory Council recommended FEMA understand emergency capacity in Tribal Nations. According to FEMA, one of the tasks identified in FEMA's National Tribal Strategy is to complete an assessment of tribal capacity to better align FEMA and tribal resources, and to identify areas in need of improved planning and training.

NEHRP program and whether tribal governments were eligible for the NEHRP Earthquake Assistance grant.[61]

According to FEMA, one of its regions conducted outreach with tribes in 2021 to help them understand their earthquake risks, along with the other major hazards, and measures they can take to mitigate the risks. For example, through the hazard mitigation planning process and community meetings, FEMA Regional staff met with a Pacific Northwest tribe to help them understand their earthquake and tsunami risks and vulnerability.[62] As a result of this outreach, the tribe received a Pre-Disaster Mitigation grant in the amount of $2.8 million to build an evacuation tower.

In addition, according to FEMA, their Hazard Mitigation Administration officials conducted outreach with tribes on earthquake risk reduction in 2020. The outreach consisted of a national webinar presentation held in July 2020 that informed tribes about a provision in the Disaster Recovery Reform Act of 2018 that allows grant recipients to enhance the earthquake early warning system by using it on seismic instrumentation and other components necessary to monitor and transmit seismic activity to the system.[63] Further, FEMA officials said that FEMA's NEHRP staff played a role in the outreach by helping to organize and participate in the July 2020 webinar. FEMA officials added that the presentation provided

[61]States and territories determined to be at high or very high risk of earthquakes are eligible for a NEHRP Individual State Earthquake Assistance grant to be used to develop and implement local earthquake awareness and education activities that assist the public in preparing for, mitigating against, responding to and recovering from earthquakes. However, because the law provides that the grants are for states and territories, tribal governments determined to be in areas of high risk of earthquakes are not eligible for the NEHRP Individual State Earthquake Assistance grant. See §§ 7703, 7704(b)(2)(i).

[62]The Pacific Northwest tribe sits along the Cascadia Subduction Zone in the state of Washington. According to a state emergency management office, the Cascadia Subduction Zone is a 600-mile fault that runs from northern California up to British Columbia and is about 70-100 miles off the Pacific coast shoreline. There have been 41 earthquakes in the last 10,000 years within this fault. The last Cascadia earthquake happened in 1700 impacting tribes living along the Pacific Coast.

[63]The Disaster Recovery Reform Act of 2018 added earthquake early warning system as eligible expenses for two FEMA hazard mitigation programs. 42 U.S.C. § 5170(g).

tribal leaders points of contact to help with any questions about the earthquake early warning system.[64]

Although FEMA intends to issue its National Tribal Strategy in 2022 and has recently taken steps to begin outreach with tribes informing them about earthquake risk reduction, there are no plans describing how outreach to tribal governments will be achieved. According to FEMA officials, there are no plans developed for conducting outreach to tribal governments because their focus is to complete the National Tribal Strategy and to begin consulting with tribal governments to identify disaster preparedness capabilities.

However, as mentioned earlier, FEMA is required to support the implementation of an earthquake risk education and public awareness programs. In addition, we previously reported the importance of developing approaches or plans describing how to achieve strategic goals and objectives. Such plans should include a) the identification of actions needed to achieve goals, b) identification of regions responsible for executing these actions, c) development of project milestones to guide the execution of actions, and d) description of skills and technologies, and resources needed to execute the actions.[65]

Developing a plan to detail and document how outreach to tribal governments will be achieved can help ensure that tribal governments are made aware of earthquake resilience initiatives (e.g. building codes, standards, and practices). Such knowledge may help reduce the risk of tribes incurring significant damage to buildings and lifelines in the event of a large earthquake.

[64]According to FEMA officials, conferences and webinars are the mechanisms used to reach tribes and tribal organizations because they can provide information to a broad audience.

[65]GAO, *Managing For Results, Critical Issues for Improving Federal Agencies' Strategic Plans*, September 1997, GGD-97-180 (Washington, D.C.: Sept. 16, 1997).

NEHRP Updated Its Research Priorities, but Coordination with Stakeholders Was Limited

NEHRP Agencies Collaborated to Identify Research Priorities, but Some Stakeholders Were Not Included in the Process

According to NIST officials, during the process of updating the NEHRP Strategic Plan's research priorities in 2020 and 2021, NEHRP relied on expertise from the working group, workshops and conferences, and ongoing discussions with the Advisory Committee. However, officials from 19 selected stakeholder groups told us they were not included in the process of identifying updates to the strategic plan's research priorities.

The NEHRP Strategic Plan FY 2009 – 2013 identified nine strategic priorities, three of which were research priorities. Those research priorities are to (1) improve techniques for evaluating and rehabilitating existing buildings; (2) further develop performance-based seismic design; and (3) develop earthquake-resilient lifeline components and systems. Further, according to NIST officials, NEHRP has been updating the research priorities in 2020 and 2021, as part of the overall effort to update the NEHRP Strategic Plan FY 2022 – 2029. NEHRP generally relied on the expertise from the working group to identify updates to research priority areas.[66]

According to NIST officials, NEHRP's working group collaborates among its participants to update NEHRP's strategic research priorities. The expertise shared among the working group participants comes from workshops, conferences, and lessons learned held with the stakeholder community. For example, according to NSF, lessons learned on social science behavior from FEMA's annual Great Shakeout earthquake drill

[66]NIST stated that there are about 10 individuals staffed on the Program Coordination Working Group from the NEHRP agencies, representing their respective agency priorities, guided by their commitment to program objectives.

are shared among the working group members.[67] In addition, NIST officials said stakeholders have the opportunity to comment on updates to NEHRP's Strategic Plan FY 2022 - 2029, including research priorities during two annual meetings held by the Advisory Committee and when the update to the strategic plan is available for public comment.

However, 19 selected stakeholders told us they were not involved in the process of identifying updates to the strategic plan's research priorities.[68] Additionally, some stakeholders told us it would be beneficial to see research priority given to social sciences to better support their mission areas. For example, officials from a state emergency office told us they would like to see social science research prioritized so that more information becomes available for educating populations in high seismic areas about ways to prepare for disaster events so that they are not fearful about what will inevitably happen. Another stakeholder from a state geological survey agency told us it would be beneficial to see more research on unmapped faults to help them understand the extent of the locations of where faults or fractures are happening in the state. Thirteen of the 19 stakeholders (three state emergency management agencies, one U.S. territorial emergency management agency, and nine tribal governments) are located in areas identified as high risk to earthquakes.

We have reported in the past that organizations that are successful in strategic planning understand that stakeholders will play a key role in determining whether their programs succeed or fail. Thus, involving stakeholders in strategic planning helps ensure that their mission, goals, and strategies are targeted at the highest priorities.[69] We also reported in

[67]FEMA supports the annual Great ShakeOut earthquake drills, an earthquake preparedness event, conducted in collaboration with regional and local entities across the nation. The information shared for this event is social science based and used for continued improvement efforts. In 2021, over 15 million people in the U.S. participated in this preparedness event. FEMA's Great ShakeOut Earthquake Drills are open to the public, and participants include individuals, schools, businesses, local and state government agencies, and other groups.

[68]The 19 selected stakeholders we interviewed included representatives from one territory and three state emergency management agencies, one state geological survey agency, two regional earthquake consortiums, one national civil engineering association, one national building code and standards council, nine tribes, and one tribal association. See Appendix I for more details concerning our stakeholder selection methodology.

[69]GAO, *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms*, GAO-12-1022 (Washington, D.C.: Sept. 27, 2012) and *Managing For Results, Critical Issues for Improving Federal Agencies' Strategic Plans*, GGD-97-180, (Washington, D.C.: Sept. 16, 1997).

the past that organizations that assess strategic plans and program evaluations can provide input to the agency on how well a program's activities contributed to achieving strategic goals.

By assessing strategic plans and research priorities, the NEHRP agencies can determine if additional actions are needed to obtain input from state, local, territorial, and tribal governments and stakeholders on research priorities that align with community and stakeholder needs.

NEHRP's Strategic Plan Identified Research Priorities, but NSF and NIST Do Not Fully Communicate Priorities to Research Entities

NEHRP's Strategic Plan FY 2009 – 2013 identifies three strategic research priorities: (1) to improve techniques for evaluating and rehabilitating existing buildings; (2) develop performance- based seismic design; and (3) develop earthquake-resilient lifeline components and systems. Although the 2009-2013 Strategic Plan identifies a broad range of research needed to achieve the plan's goals and objectives, the ICC identified and endorsed the three strategic research priorities as efforts that deserve increased emphasis by the NEHRP agencies, beyond their ongoing activities.[70] However, NSF and NIST do not fully communicate NEHRP's research priorities to research entities.[71]

According to NSF officials, the mechanisms (program descriptions, program solicitations, and Dear Colleague Letters) used to communicate opportunities for research related to NEHRP generally do not identify NEHRP's three strategic research priorities. However, in some instances, program solicitations emphasize research in broad areas related to earthquake science to help improve the understanding of earthquake processes and effects on the built environment. For example, as shown in table 1, in 2017, NSF's Directorate for Geosciences solicited proposals under NSF-17-554 for applicants to conduct research in areas of

[70]NEHRP's Strategic Plan FY 2009 - 2013 identifies a broad range of research needed to achieve the plan's long-term goals and objectives. For example, some of the broad areas include research to better understand the effects of earthquakes on the built environment and research to better understand the social, behavioral, and economic factors linked to implementing risk reduction in the public and private sectors. The plan's three strategic research priorities were identified through a working level analysis of the gaps in NEHRP.

[71]Research entities include person(s), institutions, businesses, universities, or centers that conduct research.

seismicity, seismic wave propagation, and the nature and occurrence of geophysical hazards.[72]

In other instances, program solicitations emphasize broad research topics related to improving disaster resilience for all hazards (windstorms, water events, wildfires, and earthquakes). NSF officials provided examples of special program solicitations that identified research areas related to NEHRP.

[72]According to NSF, the majority of grants supporting NEHRP are generated and funded through the Directorates for Engineering and for Geosciences, however additional research related to NEHRP is conducted in other directorates, in part, because of the agency's broader impacts criterion. From 2015 to 2021, NSF awarded $377 million in program description grants and special grant solicitations.

Table 1: Examples of NSF Program Solicitations and Program Descriptions for Research Related to the National Earthquake Hazards Reduction Program (NEHRP)

Program Solicitation NSF-20-581[a]	Some areas of research emphasized in the grant program include topics to improve disaster resilience for NEHRP and the National Windstorm Impact Reduction Program. For example, topics emphasized research on science based measures or mechanisms for improved resilience, such as improved planning, policy, decisions, design, codes, and standards or other relevant mechanisms.
Program Solicitation NSF-17-554	Some areas of research emphasized in the grant program include topics to improve the understanding of earthquake processes. For example, topics emphasized (1) seismicity, seismic wave propagation, and the nature and occurrence of geophysical hazards; (2) earth's magnetic, gravity, and electrical fields; and (3) earth's thermal structure and (4) geodynamics.
Program Solicitation NSF-15-598	Some areas of research emphasized in the grant program include topics to improve the understanding earthquake effects on other natural systems, and on the built environment. For example, research under the National Hazards Engineering Research Infrastructure is to contribute knowledge and innovation for the nation's civil infrastructure and communities to prevent natural hazard events from becoming societal disasters.
Program Description NSF-19-073Y	Some areas of research emphasized in the grant include topics to improve the understanding of how the physical civil infrastructure responds to extreme single or multi natural hazards. For example, topics emphasized research on how the civil infrastructures respond to environmental conditions, such as construction; normal service loading conditions; and severe environmental conditions such as earthquakes, windstorms, tsunamis, storm surges, sinkholes, and landslides.

Source: GAO presentation of information identified in National Science Foundation grants. I GAO-22-105016

[a]In 2020, NIST and NSF issued a joint Disaster Resilience Research Grant in fiscal year 2020 totaling $3.1 million in available funding, of which $1.65 million was pledged by NIST and $1.5 million by NSF.

NSF officials said the grant programs discussed above point researchers to the importance of earthquake risk reduction, and encourage them to bring their best ideas forward to support progress towards that societal goal. NSF officials also said program solicitations are generally crafted to be as open as reasonable to encourage researchers to propose their best ideas. Additionally, NSF officials said the majority of NSF research funding is awarded through a competitive, merit-based assessment process that includes a peer review process—in which external reviewers assess the merits of each grant proposal and evaluate the proposal under intellectual merit and broader impacts criteria.[73]

In addition to NSF's program solicitations and program descriptions, NSF officials said Dear Colleague Letters are used to communicate opportunities for research related to NEHRP. However, officials said from 2016 to 2021, the Dear Colleague Letters communicated opportunities for research related to NEHRP, but did not identify NEHRP's three strategic

[73]Intellectual Merit criterion encompasses the potential to advance knowledge; and the Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific desired societal outcomes.

research priorities.[74] Of the 99 Dear Colleague Letters from 2016 to 2021 we identified on NSF's website, none mentioned NEHRP's three research priorities.

NIST officials told us the NIST Notice of Funding Opportunity for fiscal year 2016 and fiscal year 2018, and the joint NIST and NSF Disaster Research Resilience Grant in fiscal year 2020 communicate opportunities for research in areas related to NEHRP, but do not specifically identify NEHRP's strategic research priorities. For example, NSF's FY 2020 Notice of Funding Opportunity for the Disaster Resilience Research Grant program solicitation (NSF-20-581 cited above in table 1) does not identify NEHRP's research priorities.[75] Although NIST Disaster Resilience Research Grant does not identify NEHRP research priorities, the NIST 2018 Notice of Funding Opportunity specifically identifies research topics aligned with the National Windstorm Impact Reduction Program Strategic Plan's strategic research priority.[76]

Our past work on achieving results showed that creating an effective, ongoing communication strategy is essential to implementing transformation.[77] Communication with customers and stakeholders should be a top priority and is central to forming the partnerships that are needed to develop and implement the organization's strategies. Additionally, the communication strategy gives customers and stakeholders a greater understanding of how the transformation will affect them so they can quickly correct any misperceptions and address concerns. By developing strategies that directly communicate NEHRP's three strategic research priorities to the research entities (e.g. person(s), institutions, businesses,

[74]Dear Colleague Letters are used by NSF to provide information, clarify an existing document or policy, and inform the community of special competitions or topical areas of interest within regular ongoing programs or funding mechanisms.

[75]According to NIST officials, a memorandum of understanding was established in June 2020 between NIST and NSF to jointly solicit grants for research related to NEHRP. In 2020, NIST and NSF issued a Notice of Funding Opportunity for the 2020 Disaster Resilience Research Grant totaling $3.1 million in available funding of which $1.65 million was pledged by NIST, $1.5 million by NSF.

[76]The National Wind Impact Reduction Program's Strategic Research Priority #2 is to obtain measurements of surface winds and storm surge current and waves in severe storms and objective #6 is to develop computational tools for use in wind and flood modeling on buildings and infrastructure.

[77]GAO, *Results-Oriented Cultures: Implementation Steps to Assist Mergers and Organizational Transformations*, GAO-03-669, (Washington, D.C. July 2, 2003).

universities, or centers that conduct research), NEHRP can better ensure the research priorities are being met.

NEHRP's Working Group Did Not Follow Some Leading Collaboration Practices

NEHRP's working group responsible for implementing its strategic research priorities followed two of four leading practices for interagency collaboration. The working group followed leading practices for defining outcomes for short and long-term goals, and establishing leadership. However, the working group did not follow leading practices for developing accountability measures, such as tracking and monitoring progress, and identifying and leveraging resources needed to achieve outcomes for research priorities.

In our prior work, we have identified leading practices for interagency collaboration, which should be followed to effectively implement interagency collaborative groups.[78] These include practices related to (1) defining shared outcomes and goals, (2) ensuring accountability by developing performance measures and tracking progress, (3) establishing leadership, and (4) identifying resources, such as funding, staffing, and technology. As shown in table 2, we assessed the extent to which NEHRP's working group followed these four leading collaboration practices by assessing them as having (1) generally followed, (2) partially followed, or (3) not followed.

[78]GAO, *Managing for Results: Implementation Approaches Used to Enhance Collaboration in Interagency Groups*, GAO-14-220 (Washington, D.C.: Feb.14, 2014).

Table 2: Assessment of the Extent to Which the National Earthquake Hazards Reduction Program (NEHRP) Coordination Working Group Followed Leading Collaboration Practices

Leading Practices for Interagency Collaboration	Extent Followed[a]	Summary of Findings
Outcomes Defining shared outcomes and goals	Generally followed	In 2021, the working group defined research priorities and shared outcomes as part of their efforts to develop the NEHRP Strategic Plan FY 2022 – 2029. The strategic priorities reflect the collective opinion of the working group, and are based on knowledge of earthquake issues; and knowledge of respective stakeholders, communities, and the NEHRP statute. NEHRP's Strategic Plan FY 2009 – 2013 also identifies research related outcomes. For example, one outcome provides for improved engineering practices and design strategies for mitigating ground failure and improving seismic performance of structural and nonstructural systems. The strategic plan is the primary document used by the working group to guide its efforts towards implementing the research priorities.
Accountability Developing performance measures and tracking progress	Not followed	The working group has not developed performance measures to facilitate implementation of NEHRP Strategic Plan FY 2009 – 2013 goals and strategic research priorities. FEMA developed performance measures for some of its programs supporting NEHRP, however the programs are not related to efforts to implement research priorities. In addition, the working group does not have a method to track and monitor progress towards the plan's goals and research priorities. The working group provides updates on NEHRP's program activities, including agency accomplishments during meetings with the Advisory Committee and Interagency Coordinating Committee (ICC). The working group and the ICC also provide updates to Congress on the progress with NEHRP through NEHRP's biennial report, however the report does not address the three strategic goals.
Leadership Identifying leadership and clarifying shared leadership roles and responsibilities	Generally followed	NEHRP Director and the NEHRP Office develop agendas, coordinate activities and agency commitments, and guide discussions within the working group. High-level leaders from all the NEHRP agencies are regularly made aware of progress and issues that need to be addressed, and attend the working group meetings as the need arises. For example, high-level leaders from the National Institute of Standards and Technology (NIST) Engineering Laboratory have participated in meetings and regularly review documents. However, protocols for leading the working group are informal, and as of February 2022, there are no formal documents outlining protocols for leading meetings and sharing leadership responsibility.
Resources Identifying funding, staffing and shared technology	Not followed	NEHRP Strategic Plan FY 2009 – 2013 identifies agency programs that support NEHRP's goals and research priorities, however, the working group does not collectively identify and leverage the program's resources needed to achieve research priority outcomes.[b] For example, the working group has not considered creating an inventory of resources needed to achieve the interagency research priorities and outcomes defined in the Strategic Plan. NIST and NSF have taken steps to jointly leverage resources to broadly address disaster resilience (e.g. windstorms and earthquakes) through the FY 2020 Disaster Resilience Research Grant.[c] Staffing members for the working group are provided by the four NEHRP agencies, and are considered experts in the field of earthquake loss reduction.

Source: GAO presentation of NIST and National Science Foundation information. I GAO-22-10516

[a]Generally followed – the working group followed a practice without significant gaps in their coverage of actions associated with this subcategory. Partially followed – the working group followed a practice with some significant gaps in their coverage of actions associated with this subcategory. Not followed – the working group did not follow this practice or demonstrate coverage of associated actions with this subcategory.

[b]Resources in the form of competitive grants or contracts are used by the NEHRP agencies to conduct research related to NEHRP.

[c]In 2020, NIST and NSF issued a joint Disaster Resilience Research Grant in fiscal year 2020 totaling $3.1 million in available funding, of which $1.65 million was pledged by NIST and $1.5 million by NSF.

As shown in table 2 above, the working group generally followed leading practices for developing outcomes and establishing leadership in implementing NEHRP's strategic research priorities. For example, the working group identified research related outcomes in NEHRP's Strategic Plan FY 2009 – 2013 for improved engineering practices and design strategies for mitigating ground failure. Additionally, the working group NEHRP Director and Acting Deputy Director developed agendas and delegated responsibilities to agency representatives within the working group.

We are providing more details below with respect to the working group's actions taken to follow leading practices for accountability and resources.

- **Accountability (Developing performance measures and tracking progress)** As of December 2021, NIST officials acknowledged that the working group had not yet developed a method to track and monitor progress of research priorities and objectives identified in the Strategic Plan FY 2022 - 2029. Further, the working group has not developed performance measures tied to research priorities identified in the Strategic Plan. According to NIST, the development of cross-program performance measures and tracking and monitoring progress may be developed once the NEHRP Strategic Plan FY 2022 – 2029 is released.

  As we reported in 2012 and 2014, interagency groups should follow leading practices for accountability by developing performance measures linked to short term and long-term outcomes. Additionally, interagency groups should follow leading practices for developing methods to track and monitor progress towards achieving outcomes. Without a means to monitor, evaluate, and report the results and progress of research priorities and objectives, NEHRP may not be able to determine the extent research conducted by NSF and NIST meets research priorities. In addition, NEHRP may not be able to effectively report progress to Congress and stakeholders, which can result in a knowledge gap in efforts toward earthquake resilience.

- **Resources (Identifying funding, staffing, and shared technology)** According to NIST and NSF officials, the working group does not collectively identify and leverage the program's resources needed to achieve research priority outcomes defined in the 2022 -2029

Strategic Plan. For example, the working group has not considered collectively creating an inventory of resources (e.g. research organizations, think tanks, testing labs or other resources) that could be used to address the research priorities. NIST officials said that the NEHRP agencies are responsible individually for determining proper resources (e.g. funding and staffing) needed to achieve research priorities. Additionally, NIST stated that NEHRP agencies fund research through competitive grants or contracts, and an inventory collectively identifying federal programs and resources is not useful to them.[79]

We understand NEHRP agencies fund research through competitive grants or contracts and that NIST officials do not view collectively identifying federal programs and resources as being useful. Our past work on interagency collaboration shows that interagency groups should follow leading practices for resources by taking action to identify all the relevant resources to understand the full range of federal programs and resources devoted to NEHRP's research priorities. Specifically, identifying resources enables the interagency group to leverage all relevant resources across the individual agencies, and better align them with the research priorities. It also helps avoid duplicative efforts by being better informed about how resources are being used to address research priorities. Further, the identification of resources provides an opportunity for the working group to build programmatic partnerships aimed at strengthening earthquake resilience. For more information about the research entities conducting research related to NEHRP, see appendix II.[80]

[79]NIST stated that the working group did not create an inventory of research organizations, think tanks, testing labs or other resources. Researchers participate in competitive grant processes. NIST solicits and reviews research proposals and awards funding to the best proposals. NIST stated that they are not allowed to "steer" awards to entities who might be on a research organization list, rather competition is the mechanism to assure that the most competitive proposals are awarded.

[80]Appendix II shows identification of research entities conducting research on NEHRP topics obtained from NSF's awards database. We identified grants with a research start date between January 2021 and June 2022.

NSF and NIST Disseminate Research Findings, but Lack of Awareness Remains

NSF and NIST have policies and practices for disseminating research findings related to NEHRP; however, officials from 17 of the 19 selected stakeholder groups we interviewed were generally not aware of the research findings, including the mechanisms and methods being used to disseminate the findings.

According to NIST officials, NIST policies and practices for disseminating research findings provide for grantees to publish research findings in technical journals and to present the results of findings at conferences and during participation in technical societies. Officials added that NIST sponsors a research symposium each year to initiate its latest grant solicitation and to discuss recent research findings including those related to NEHRP, as well as needs for future research proposals. For example, according to NIST officials, during annual engineering conferences and meetings, NIST and FEMA rent exhibit booths and pass out earthquake publications to participants, as well as obtain participants' contact information for future NEHRP mailings.[81]

According to NSF's policy, grant awardees are expected to prepare and submit for publication all significant findings from work conducted under NSF grants.[82] Further, the policy states that grantees are to ensure all articles in peer-reviewed scholarly journals and papers in juried conference proceedings are deposited in a public access compliant repository and will be available for download, reading and analysis within 12 months of publication.[83] NSF officials told us they developed a central repository in 2016, and now requires grantees to submit their peer-reviewed research findings to that system. The repository provides search

[81]According to NIST officials, they are aware these practices are not reaching all key stakeholders because many are not attending the annual conferences and meetings.

[82]NSF, *Proposal and Award Policies and Procedures Guide*, October 4, 2021.

[83]After receiving funding, a researcher performs research as specified in the contract or financial assistance agreement. Based on the research conducted, federally funded intramural (agency personnel or scientists) or extramural researchers (scientists or research personnel working at external research institutions) may develop results, including draft papers summarizing their findings, datasets, or other types of results. Researchers may then submit draft papers to publishing companies or academic societies for peer review of the scientific findings and the work conducted. If favorably reviewed during the peer review process, these papers may then be published in journals produced by the publishing companies or societies.

mechanisms to help the public find peer-reviewed scholarly journals using keywords or phrases.[84]

We were told by officials from 17 of the 19 selected stakeholder groups we interviewed (four emergency management agencies representing three states and one U.S. territory, two regional earthquake consortiums, one national association representing building codes, nine tribes, and one tribal association) that they are generally not aware of research findings related to NEHRP, conducted under NSF's and NIST's research grants.[85] In some instances, stakeholders have to rely on other ways to obtain information on research findings related to NEHRP. For example, one state emergency management agency official told us they rely heavily on their staff attending conferences, such as state earthquake conferences and natural hazards workshops to obtain or learn about research findings. However, the official added that there are some challenges relying on staff attending conferences and workshops because in-person attendance is sometimes prohibited due to the COVID-19 pandemic or lack of funding for travel.

In addition, officials from three of 19 selected stakeholder groups we interviewed from two national associations representing civil engineering and building codes and one tribe from Southern California told us that they are aware of NSF's mechanism (central repository) used for disseminating research findings, however they had difficulty locating research findings on specific topics.[86] For example, officials from two national associations representing civil engineering and building codes said the search capabilities within the repository generally do not provide

[84]According to NSF officials, when grantees apply for a research grant, they are required to describe how they will share the research findings and data they collect in a data management plan, including who they plan to disseminate their research findings to after the research is completed. Upon deposit, the repository populates the relevant material into required NSF project reports for internal review by NSF program officers. For public use, this material is automatically displayed along with the relevant award abstract in the NSF's award search database.

[85]The other two selected stakeholders told us they had limited access to NIST and NSF research findings. For example, officials representing a civil engineering association told us that researchers or students may introduce the research findings at meetings.

[86]Thirteen of the 19 selected stakeholders told us they were not aware of NSF's mechanism (central repository) used for disseminating research findings, and therefore were not able to use the repository to locate research findings on specific topics. The other three stakeholders did not provide a response about their awareness of the central repository.

all available research findings on specific topics related to NEHRP. All of the selected stakeholders told us that research findings related to NEHRP would be helpful to achieving their missions with earthquake hazards mitigation and emergency management planning.

In September 2015, the Advisory Committee reported that it was challenging for the other NEHRP agencies and those in the broader research community to know the range and specific details of the various NSF-funded projects, and more should be done to document, disseminate and publicize past and current research activities. Additionally, in September 2017, the committee recommended that NEHRP agencies develop a uniform policy regarding the dissemination of information on NEHRP research and implementation efforts that helps to ensure that the information is readily available to a broad audience.[87]

NIST officials acknowledged that reliance on traditional means of dissemination outreach to the community has to change, and plan to take steps to improve overall awareness of NEHRP and related research findings. For example, NIST is planning to update the NEHRP website to make it easier to locate guidance and information on earthquake risk reduction. Additionally, there are ongoing discussions within the working group to determine how they can collectively reach more stakeholders since there is a greater reliance on social media platforms. However, these efforts are in preliminary phases, and it is unclear how NIST will implement the initiatives to improve overall awareness of NEHRP's research findings.

NEHRP's Strategic Plan FY 2009 – 2013 has an objective that calls for an increase in public awareness of earthquake hazards and risks, including the development and dissemination of materials to all appropriate audiences. We previously reported the importance of developing approaches or plans describing how to achieve strategic goals and objectives. To help ensure stakeholders are aware of the mechanisms and practices used by NSF and NIST a comprehensive plan should include a) the identification of actions needed to achieve goals, b) identification of agencies or working groups responsible for executing

[87]NIST response to the recommendation was that policies concerning dissemination of research results are based on federal government and individual agency policies regarding publication and dissemination of results. The NEHRP agencies will consider where improvements can be made to dissemination policies to improve the effectiveness of outreach to the earthquake community.

these actions, c) development of project milestones to guide the execution of actions, and d) description of skills and technologies, and resources needed to execute the actions.[88]

While NIST and NSF have policies and practices for disseminating research findings, there is not a comprehensive plan ensuring all stakeholders are informed of the mechanisms and practices used by NSF and NIST for disseminating research findings. Developing and documenting a plan can help ensure stakeholders are informed about valuable research findings that can help strengthen earthquake resilience and improve their response to earthquake events.

Conclusions

NEHRP has helped communities strengthen earthquake resilience by identifying dangers from earthquakes and taking measures to reduce their damaging effects. For example, FEMA has initiated efforts to identify progress states and localities have made strengthening earthquake risk reduction nationwide by tracking the status of building code adoption. However, opportunities exist to improve stakeholder involvement and better share information to help entities understand risk and how best to undertake resilience initiatives. Specifically, conducting a national risk assessment could help NEHRP gain greater awareness of earthquake resilience improvements and identify remaining gaps. Additionally, a national risk assessment could help NEHRP be in a better position to strategically plan long-term goals and objectives towards reducing remaining gaps and prioritize future research to address known vulnerabilities.

Determining if additional actions are needed to obtain input from stakeholders may help align research priorities with community and stakeholder needs. Also, developing approaches to communicate NEHRP's research priorities to research entities (e.g. person(s), institutions, businesses, universities, or institutions) can ensure research priorities are being met. Lastly, developing a documented plan will ensure all stakeholders are informed about the mechanisms and practices used to disseminate research findings.

[88]GAO, *Managing For Results, Critical Issues for Improving Federal Agencies' Strategic Plans*, GGD-97-180 (Washington, D.C.: Sept. 16,1997) and *Managing for Results: Agencies Should More Fully Develop Priority Goals under the GPRA Modernization Act*, GAO-13-174 (Washington, D.C.: April 19, 2013).

Recommendations for Executive Action

We are making a total of seven recommendations, including three recommendations to NIST, one to NSF, one to FEMA, and two to NEHRP. Specifically:

The Director of NIST should, in collaboration with FEMA, NSF, and USGS and in coordination with federal, state, local, territorial, and tribal governments and stakeholders, conduct a national risk assessment to identify the progress made by communities to strengthen earthquake resilience since 2015, and the gaps in resilience that remain. (Recommendation 1)

The Administrator of FEMA should develop and implement a plan to increase awareness among tribes about earthquake risk reduction initiatives. (Recommendation 2)

The Director of NIST should, in collaboration with FEMA, NSF, and USGS, assess and determine if additional actions are needed to obtain input from state, local, territorial, and tribal governments and stakeholders on research priorities that align with community and stakeholder needs. (Recommendation 3)

The Director of NSF should, in collaboration with NIST, develop strategies to better communicate NEHRP's priorities to research entities. (Recommendation 4)

The Director of NEHRP should, in collaboration with FEMA, NIST, NSF, and USGS, follow leading practices to develop performance measures linked to priority research outcomes, and to track and monitor research to ensure research priorities are being met. (Recommendation 5)

The Director of NEHRP should, in collaboration with FEMA, NIST, NSF, and USGS, follow leading practices to identify and leverage the program's resources needed to achieve research priority outcomes. (Recommendation 6)

The Director of NIST should, in collaboration with NSF, document and implement a comprehensive plan to better ensure that all state, local, territorial and tribal governments and stakeholders are aware of the mechanisms and practices used by NSF and NIST for disseminating research. (Recommendation 7)

Agency Comments

We provided a draft of this report to the Department of Commerce (Commerce), Department of Interior (DOI), Department of Homeland Security (DHS), and the National Science Foundation (NSF). Commerce, DHS, and NSF provided written comments, which are reproduced in appendix III, IV, and V. In its comments, all three departments generally concurred with our recommendations. Additionally, DOI, DHS, and NSF provided technical comments, which we incorporated as appropriate.

With regard to our first recommendation, Commerce concurred that the Director of NIST should in collaboration with stakeholders, conduct a national risk assessment to identify the progress made by communities to strengthen earthquake resilience since 2015, and the gaps in resilience that remain. Commerce stated that if resources are provided, NIST will lead a collaboration effort to conduct assessments to identify the progress made by communities to strengthen earthquake resilience and the gaps in resilience that remain. In addition, Commerce stated that the updated NEHRP Strategic Plan will prioritize future activities that can help communities strengthen their earthquake resilience.

With regard to our second recommendation, DHS concurred that the Administrator of FEMA should develop and implement a plan to increase awareness among tribes about earthquake risk reduction initiatives. According to DHS, the Director of FEMA's Federal Insurance and Mitigation Administration (FIMA) Planning and Safety Division, as well as FIMA's Earthquake and Wind Programs Branch, will collaborate with FEMA's National Tribal Affairs Advisor to develop culturally sensitive and relevant products to communicate earthquake risk effectively. DHS stated that once complete, a strategic communications plan will also support the distribution of these products.

With regard to our third recommendation, Commerce concurred that the Director of NIST should, in collaboration with FEMA, NSF, and USGS, assess and determine if additional actions are needed to obtain input from state, local, territorial, and tribal governments and stakeholders on research priorities that align with community and stakeholder needs. Commerce stated that NSIT has many mechanisms include grant programs, hosted workshops, program reviews by leading research councils, experience of the NIST workforce, strategic planning studies, collaboration with other NEHRP agencies and the Advisory Committee, and proactive participation with building code and standards development organizations. We reviewed the efforts by NIST to obtain input from external entities, however, our work shows that 19 selected stakeholders we interviewed were not involved in the process of identifying updates to

the strategic plan's research priorities. Commerce added that the NEHRP agencies will collectively evaluate additional outreach opportunities to obtain input from stakeholders and will continue to review the Advisory Committee membership to ensure a diverse representation of stakeholders.

With regard to our fourth recommendation, NSF concurred that the Director of NSF should, in collaboration with NIST, develop strategies to better communicate NEHRP's priorities to research entities. According to NSF, the agency has already begun conversations within the Foundation about this aim. NSF added that existing mechanisms will be enhanced, and new mechanisms may be created to improve research communities' awareness.

With regard to our fifth recommendation, Commerce concurred that the Director of NEHRP should, in collaboration with FEMA, NIST, NSF, and USGS, follow leading practices to develop performance measures linked to priority research outcomes, and to track and monitor research to ensure research priorities are being met. According to Commerce, NEHRP submits a biennial report to Congress that highlights milestones achieved from programmatic efforts during the reporting period that supports the NEHRP mission. The reports are written to align with the goals and priorities identified in the NEHRP Strategic Plan. We reviewed NEHRP's biennial report to Congress, however our work shows NEHRP's working group has not tracked and monitored progress with research priorities. Commerce stated that the NEHRP agencies will collectively evaluate other practices for tracking and monitoring progress.

With regard to our sixth recommendation, Commerce concurred that the Director of NEHRP should, in collaboration with FEMA, NIST, NSF, and USGS, follow leading practices to identify and leverage the program's resources needed to achieve research priority outcomes. Commerce stated that the NEHRP agencies collaborate at the programmatic level to ensure individual agency activities are unique and mutually supportive to a shared outcome established in the NEHRP Strategic Plan. Commerce also stated that although the NEHRP agencies do not share funding responsibilities for an external, multi-agency collaborative subject, the agencies do coordinate topical responsibilities, based on agency mission. We reviewed NEHRP's efforts to collaborate at the programmatic level, however our work shows that NEHRP's working group does not collectively identify and leverage the program's resources needed to achieve research priority outcomes defined in the strategic plan. Commerce added that the program will collectively explore what other

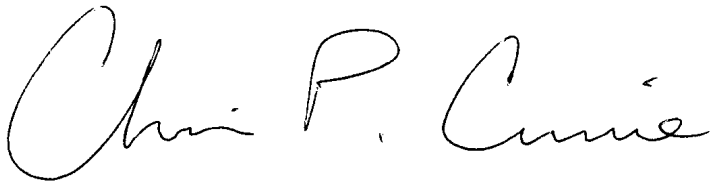
best practices can further maximize the collective efforts of the NEHRP agencies toward supporting a research priority.

With regard to our seventh recommendation, Commerce concurred that the Director of NIST should, in collaboration with NSF, document and implement a comprehensive plan to better ensure that all state, local, territorial, and tribal governments and stakeholders are aware of the mechanisms and practices used by NSF and NIST for disseminating research. According to Commerce, open access to research results is a fundamental mission of NIST. For example, NIST uses presentations and information booths at earthquake-focused conferences, active participation on, and collaboration with building code and design standards development committees, publications in peer-reviewed journals, and relevant postings on NIST supported website for disseminating research results that support NEHRP. However, our work shows that 17 of the 19 selected stakeholder groups we interviewed were generally not aware of research findings related to NEHRP. Commerce stated that NIST will continue to seek other opportunities to increase accessibility of research results to stakeholders. Commerce added that NEHRP will work to promote diverse representation on the Advisory Committee to enhance two-way communication with key state, local, territorial, and tribal governments and stakeholders.

We believe the actions discussed above, if implemented effectively, should address the intent of the recommendations. Additionally, once the agencies implement our recommendations, they will be better positioned to improve stakeholder involvement and better share information to help communities understand risk and how best to undertake resilience initiatives.

We are sending copies of this report to the appropriate congressional committees, the Secretaries of Homeland Security and the Interior, the Directors of the National Science Foundation and National Institute of Standards and Technology, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (404) 679-1875 or curriec@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix III.



Chris P. Currie
Director, Homeland Security and Justice

List of Congressional Committees

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Chair
The Honorable Roger Wicker
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Joe Manchin III
Chairman
The Honorable John Barrasso
Ranking Member
Committee on Energy and Natural Resources
United States Senate

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United States Senate

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Committee on Homeland Security
House of Representatives

The Honorable Raúl M. Grijalva
Chairman
The Honorable Bruce Westerman
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Committee on Natural Resources
House of Representatives

List of Congressional Committees Continued

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Chairwoman
The Honorable Frank Lucas
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House of Representatives

The Honorable Peter DeFazio
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Ranking Member
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House of Representatives

Appendix I: Additional Information on Stakeholder Selection

We selected 19 stakeholder groups from three states, one territory, one national tribal association, two regional tribal associations in California along with nine tribes, two regional earthquake consortiums, and two national associations representing civil engineering and building codes to discuss their perspectives on the strategic research priorities, and whether they were included in the process of identifying the priorities. Table 3 shows the agencies, organizations, and associations we interviewed.

Table 3: List of Selected Stakeholder Groups

Type of stakeholder	Organization
Federal agencies	• National Institute of Science and Technology • Federal Emergency Management Agency • National Science Foundation • U.S. Geological Survey
State Emergency Management Agencies	• Alaska Division of Homeland Security & Emergency Management • California Governor's Office of Emergency Services • Kentucky Emergency Management
State Geological Survey Agency[a]	• Kentucky Geological Survey
U.S. Territorial Emergency Management Agency	• Puerto Rico Emergency Management Bureau
Tribal Organizations	• National Tribal Emergency Management Council and nine tribes
National associations/organizations representing civil engineering and building codes and standards	• American Society of Civil Engineers • International Code Council
Regional earthquake consortiums/councils	• Central U.S. Earthquake Consortium • Western States Seismic Policy Council

Source: GAO. | GAO-22-105016

[a]We contacted Alaska Geological Survey and California Geological Survey agencies for their views on NEHRP related research but they did not respond.

We selected a non-generalizable sample of three states and one U.S. territory based on a number of different criteria:

1. States/territories determined by USGS to have high earthquake hazard;
2. States/territories that have fault lines (source of earthquake hazard);
3. States/territories where a major earthquake occurred from 2015 to 2020[1]; and

[1]We define a major earthquake as an earthquake of magnitude 5 or higher.

4. States/territories where no major earthquake occurred from 2015 to 2020.

Table 4 shows the breakdown of the three selected states and one U.S. territory earthquake hazard risk.

Table 4: Earthquake Hazard Risk for Alaska, California, Kentucky, and Puerto Rico

States and territory selected in NEHRP review	Example of earthquake hazard	Hazard risk from earthquakes	Example of damaging earthquakes from 2015 to 2020 (Magnitude and location)
California	San Andreas Fault[a]	High	Mag. 6.6 Ferndale, CA Mag. 7.1 Ridgecrest, CA Mag. 5.8 Lone Pine, CA
Alaska	Alaska-Aleutian Subduction Zone and Denali Fault	High	Mag. 7.9 Kodiak, AK Mag. 7.8 Perryville, AK Mag. 7.6 Sand Point, AK
Kentucky	New Madrid Fault and Wabash Valley Fault	High	No damaging earthquakes during this period
Puerto Rico	Bunce Fault and Punta Montalva Fault	High	Mag. 6.4 Indios, PR

Source: GAO presentation of U.S. Geological Survey data. I GAO-22-105016

[a]California earthquakes also occur on faults other than the San Andreas Fault.

We also relied on the selection of these three states in our prior work that reported that USGS, through its Earthquake Hazards Program, made several efforts to identify the dangers from earthquakes, such as tsunamis and landslides, to inform the public and help decision-makers ensure public safety and mitigate losses.[2] That report noted that two of the states in the sample (Alaska and California) experienced frequent damaging earthquakes. For example, in 2019 California had two damaging earthquakes in Ridgecrest, California within days of each other. The report further noted that, according to USGS, one earthquake was a magnitude 6.4 (July 4, 2019) and the other earthquake was a magnitude 7.1 (July 6, 2019). In addition, according to the Earthquake Engineering Research Institute, this was the largest earthquake in California in 20 years. Kentucky has experienced infrequent damaging earthquakes but

[2]GAO, *EARTHQUAKES: Progress Made to Implement Early Warning System, but Actions Needed to Improve Program Management,* GAO-21-129 (Washington, D.C.: March 25, 2021).

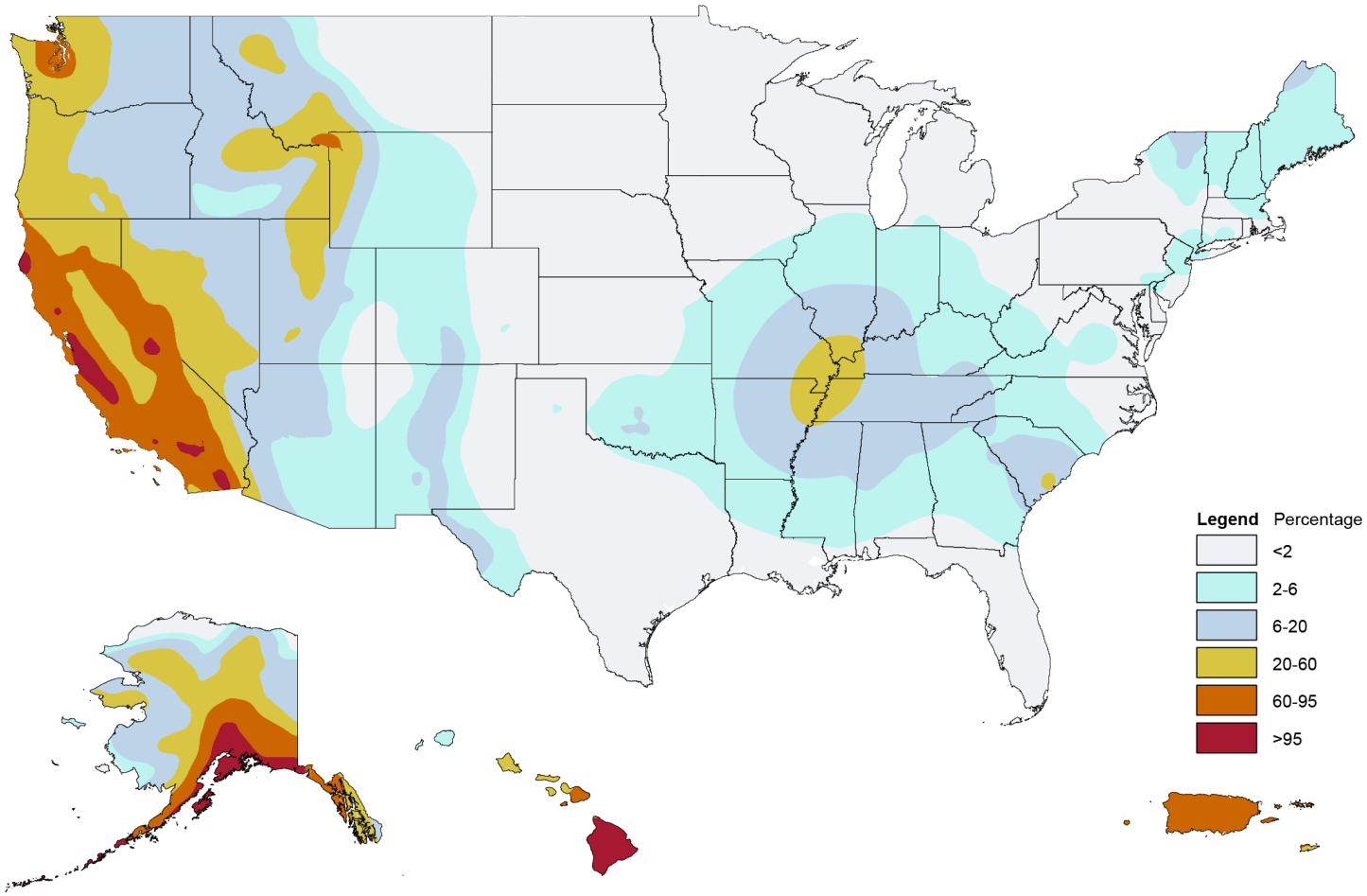
the state is still consider high risk for earthquakes because it sits on or along two faults, New Madrid and Wabash Valley Faults.

We selected one of the five U.S. territories (Puerto Rico) because in January 2020, Puerto Rico experienced its largest earthquake, a magnitude 6.4 earthquake. Puerto Rico also sits along two faults, Bunce Fault and Punta Montalva Fault, in addition to other significant sources of earthquake hazards on and around the island. As of February 2021, the southwestern part of the island experienced 15 magnitude 5.0 or greater earthquakes causing an estimated $1 billion in damages.[3] Within each of our selected states and the one U.S. territory, we interviewed officials from state and territorial emergency management agencies and a state geological survey agency.

We selected the tribes because many of these selected tribal communities are in a high earthquake seismic zone, as shown in figure 4. In addition, we selected these tribal governments to obtain perspectives about tribal involvement in achieving earthquake hazard and risk reduction through coordination with the four NEHRP agencies. Generally, tribes provide a unique perspective about tribal interaction with federal government agencies.

[3]According to USGS, the mainshock occurred on January 7, 2020, and was a magnitude 6.4 earthquake. As of February 2021, the latest earthquake of magnitude of 5.0 or higher occurred on July 3, 2020.

Figure 4: Example of a U.S. Geological Survey National Seismic Hazard Map for the Probability of a Modified Mercalli Intensity 6 Earthquake in 100 Years, Expressed as a Percentage



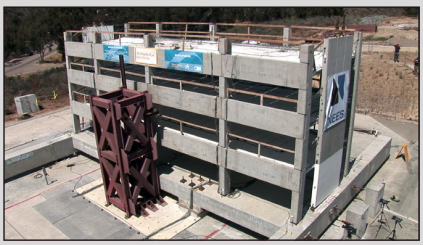
Source: GAO presentation of U.S. Geological Survey data. | GAO-22-105016

We conducted this performance audit from February 2021 to May 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Examples of Research Entities Conducting National Earthquake Hazards Reduction Program-Related Research (2021 – 2022)

University of California, San Diego Jacobs School of Engineering Shake Table

The large, high-performance, outdoor shake table experimental facility at the University of California, San Diego, is the largest facility of its kind in the United States for conducting earthquake engineering research on civil infrastructure. This facility can accommodate the tallest structures ever tested on any shake table.



Source: U. S. Geological Survey. | GAO-22-105016

We used NSF's award database to identify research entities (colleges, universities and think tanks) that have contributed to National Earthquake Hazards Reduction Program (NEHRP) progress through research grants from NSF. This review serves as an example for how NEHRP agencies can make their database more accessible for users interested in earthquake-related research. Because this review identifies which research entities contribute to NEHRP progress and categorizes their research, this type of review would allow NEHRP to leverage existing resources and avoid duplication of efforts.

We identified 926 research grants related to NEHRP from 218 research entities including colleges, universities, and think tanks. We further identified that 222 grants related to NEHRP had start dates between January 2021 and June 2022.[1] In Table 5, NSF Grants Related to NEHRP-Research, we list the grants with a start date between fiscal years 2021 - 2022. Based on the abstracts of the research grants, we assessed how each of these grants relate to the strategic goals listed in NEHRP's Strategic Plan FY 2009 - 2013. NEHRP's strategic goals include Goal A) Improve understanding of earthquake processes and impacts; Goal B) Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large; and Goal C) Improve the earthquake resilience of communities nationwide. Of these 222 grants, 141 address strategic goal A, 126 address strategic goal B, and 99 address strategic goal C.[2]

[1]We obtained data from the NSF database in November 2021.

[2]The sum of these values do not equal 222 because 123 grants addressed multiple goals.

Table 5: NSF Grants Related to NEHRP-Research for Fiscal Years 2021 to 2022

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
Chow, Bryant	2052839	EAR-PF: Active Tectonics and Crustal Structure of Northern Alaska	A
University of Alaska Fairbanks Campus	2104052	Collaborative Research: Frameworks: Seismic Computational Platform for Empowering Discovery (SCOPED)	B, C
	2052569	Collaborative Research: The M7.8 Simeonof earthquake: Untangling Slip from Seconds to Years across the edge of the Shumagin Seismic Gap	A, B, C
	1916575	An integrated geophysics cruise to map the northern edge in the Chukchi Borderland and the adjacent Canada Basin - constraints on basin history and crustal structure	A,B
	2022438	NNA Track 2: Collaborative Research: Planning for Infrastructure Resiliency and Adaptation amid Increasing Mass-Movement Risks across the Cryosphere	A, B, C
	2114015	RAPID: Characterizing the Trigger and Evolution of the December 2020 Haines, Alaska Landslide	A, B
	2040240	Collaborative Research: Developing high-resolution records of storminess from the southern Bering Sea	A, B, C
Arizona State University	2054926	CSEDI Collaborative Proposal: a multi-disciplinary investigation of slab deformation and resulting seismic anisotropy from the transition zone to the base of the mantle	A, C
	2051254	Acquisition and Upgrade of Instrumentation for Noble Gas Geochronology and Thermochronology	A
Northern Arizona University	2103514	Impact of horst and graben subduction on sediment flux and shallow décollement geometry in the Japan Trench	A, B, C
	2116018*	Collaborative Research: Characterizing Quaternary Fault Behavior and Surface Processes of an Active Rift: The Lake Malawi (Nyasa) Rift, East Africa	A, C
University of Arizona	2131889	RAPID: Response to the 2021 Earthquake Swarm and Volcanic Eruption in Reykjanes, Iceland	A, B
California Institute of Technology	2105358	Collaborative Research: A New 3-D Velocity and Structural Model of the Northern Basins in the Los Angeles Region for Improved Ground Motion Estimates	A, B
	2105740	Collaborative research: A better understanding of seismic hazard in Tehuantepec, Mexico, using amphibious MT studies	A
	2139331	NSFGEO-NERC: Earthquake nucleation versus episodic slow slip: what controls the mode of fault slip?	A, B
	2045285	Seismic and aseismic slip in faults with rock gouge using a 3D laboratory earthquake setup: the effect of fluid injection rate	A, B
	2049086	Integrating Marine Seismic and Ocean Drilling Results with three-dimensional dynamic models of Subduction Initiation	A, B
	2048237	CAREER: Co-Optimized Sensing and Reconstruction for Next-Generation Computational Cameras	A

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
	2034167	Microswarms: a lens into fault structure and aseismic processes deep in Southern California's crust	A
	2109831	General-Domain, Scalable, Accelerated Spectral Partial Differential Equation Solvers and Applications in Simulation and Design	B
California State L A University Auxiliary Services Inc.	2117908	MRI: Acquisition of a Confined Bi-Directional Cyclic Shear Apparatus for Research and Education on Earthquake-Resilient Infrastructure	B
Chapman University	2120238	Bringing Land, Ocean, Atmosphere and Ionosphere Data to the Community for Hazards Alerts	C
Lambert Valere R	2052594	EAR-PF The scale-dependent interplay between fault material strength, roughness and friction	A, C
Mendoza, Manuel Matthew	2053085*	ER-PF: Using Distributed Acoustic Sensing for Tremor Detection and Site Characterization in Cascadia to Evaluate Earthquake Hazard	A, B
Shaddox, Heather R	2053997	EAR-PF: The spatiotemporal scales of transient slow slip on the San Andreas fault near San Juan Bautista, central California, and the implications for seismic hazard	A
Occidental College	2116744	MRI: Acquisition of a Malvern Particle Size Analyzer for Interdisciplinary Research and Undergraduate Education and Research Training	A
Stanford University	2040425	Insights into Episodic Caldera Collapse and Magmatic Systems from the 2018 Eruption of Kilauea Volcano	A
	2049620	Geophysics of Iron in the Earth's Core	A, C
	2053414	Collaborative Research: Fusing Massive Disparate Data and Fast Surrogate Models for Probabilistic Quantification of Uncertain Hazards	B
	2119008	Collaborative Research: GP-IN: Connected to Earth: Cross-Cultural Knowledge Exchange for Advancing Earth Science Learning	C
	2053014	Assessing Urban Post-Earthquake Community Recovery to Inform Pre-Disaster Planning	B, C
University of California-Berkeley	2051759	Towards the Understanding of Deep Crustal Faulting and Fluid Movement through the Analysis of Long Period Earthquakes at Clearlake, CA	A
	2131111	Natural Hazards Engineering Research Infrastructure: Computational Modeling and Simulation Center 2021-2025	B, C
	2054964	CSEDI Collaborative Research: The Origins and Implications of Inner Core Seismic Anisotropy	A
	2054951	CSEDI Collaborative Proposal: a multi-disciplinary investigation of slab deformation and resulting seismic anisotropy from the transition zone to the base of the mantle	A, C
	2050011	Imaging deep mantle structure beneath Alaska using full waveform tomography	A

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
	2028554	Collaborative Research: Geodetic imaging of the interplay between creep, locking, earthquakes and land subsidence along the Chaman plate boundary	A, B
University of California-Davis	2053836	Collaborative Research: Development of Realistic Seismic Input Motions for Improving the Resilience of Infrastructure to Earthquakes	B
	2037883	Natural Hazards Engineering Research Infrastructure: Experimental Facility with Geotechnical Centrifuges 2021-2025	B, C
	2121800	Testing the Thermal Shear Instability Hypothesis for Deep Slab Seismicity	A
	2050623	Collaborative Research: From subduction to suture: testing collisional stage and lithospheric strength as controls on orogenic structure in the Caucasus	A
	2043357	SCC-CIVIC-PG Track B: Rehearsing Natural Disasters through Games and Simulations	C
	2047838	CAREER: Soil Liquefaction Evaluations at Multiple Scales: Reshaping Research, Training, and Education Through Physics-Guided Data Science	C
University of California-Irvine	2109199	Mathematics of Revealing Inaccessible Objects Using Linear and Nonlinear Waves	A
University of California-Los Angeles	2025310	Belmont Forum Collaborative Research: Resilient societies through smart-city technology; Assessing earthquake risk in ultra-high resolution	B,C
	2124650	Experimental investigation of deep fluids of the lower crust and subduction zones	A
University of California-Riverside	2103976	III: Medium: Collaborative Research: Scaling Time Series Analytics to Massive Seismology Datasets	B, C
University of California-San Diego Scripps Institute of Oceanography	2136301	EAGER: Prototyping three-dimensional printing of sand columns for granular physics experiments	B
	2150704	RAPID: Sentinel-1 and ALOS-2 InSAR interferograms to support community modeling, mapping, and estimation of hazards from strike-slip and thrust fault interactions in Haiti	A, B
	2105776	Collaborative research: A better understanding of seismic hazard in Tehuantepec, Mexico, using amphibious MT studies	A
	2116151	Scripps Institution of Oceanography - Oceanographic Equipment	C
	1750746*	CAREER: Experimental Investigation of the Transport Properties of Sulfide Melts at Upper Mantle Conditions	A, C
	2126298	Collaborative Research: EarthCube Capabilities: Repurposing FAIR-Compliant Earth Science Data Repositories	A
	2121568	Collaborative Research: Toward an integrated modeling framework for physics-based estimates of megathrust rupture potential	A, B, C

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
	2126396	Collaborative Research: Constraints on Interseismic Locking near the Trench on the Oregon Segment of the Cascadia Subduction Zone Using Seafloor Geodesy (GNSS-A)	A
	2104240	III: Medium: Collaborative Research: Scaling Time Series Analytics to Massive Seismology Datasets	A, B, C
	2123529	Seismological Investigations of Earthquakes and Deep Earth Structure	A
University of California-Santa Barbara	2109116	Bridging the Mathematical Analysis and Reconstruction Algorithms for Transmission and Reflection Seismic Tomography	A, B
	2046278	CAREER: Active forearc uplift, topographic growth, and permanent deformation above highly coupled subduction interfaces	A, C
	2053423	Collaborative Research: Fusing Massive Disparate Data and Fast Surrogate Models for Probabilistic Quantification of Uncertain Hazards	B
University of California-Santa Cruz	2102069	Volcanic eruptions in high resolution	A, B
	2031457	Dynamic Triggering Seen Clearly: Utilizing Continuous Waveforms and High-Resolution Catalogs to Measure the Importance and Mechanisms of Dynamic Triggering	A, B
	2050705*	REU Site: Collaborative Research: Research Opportunities in Rock Deformation	None
University of Southern California	2122168	Collaborative Research: Generation of Rock Damage and Localization of Seismicity Before Large Earthquakes	A, B
	2041892	Structure and motion of the inner core from dense arrays	A
	2124634	NSF Convergence Accelerator Workshop: Integrated research on societal infrastructure resilience to stressing events through interdisciplinary and transdisciplinary convergence	C
Colorado School of Mines	2103621	Collaborative Research: Frameworks: Seismic Computational Platform for Empowering Discovery (SCOPED)	B, C
Colorado State University	2120692	Collaborative Research: Converging Design Methodology: Multi-objective Optimization of Resilient Structural Spines	B, C
	2041910	CAREER: Data-Driven Inversion of Subduction Zone Topography using Tectonic Geomorphology	A, C
University of Colorado at Boulder	2100702	BSF-NSF: Collaborative Research: Deciphering the role of extreme rainstorms and hydroclimatic regime on arid escarpment retreat and sub-cliff slope evolution	A, B
	2127439*	NNA Research: The Greenland Hazards Project	B, C
	2028557	Collaborative Research: Geodetic imaging of the interplay between creep, locking, earthquakes and land subsidence along the Chaman plate boundary	A, B
Delaware State University	2100985	Excellence in Research: Effect of Hydration on the Thermo-elastic Properties of Mantle Minerals and the Geophysical Implications.	A
University of Delaware	2050854*	Collaborative Research: Hybrid Flow-Sediment-Structure Interaction Analysis of Extreme Scour due to Coastal Flooding	A, B, C

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
Florida International University	2037899	Natural Hazards Engineering Research Infrastructure: Experimental Facility with Twelve-Fan Wall of Wind 2021-2025	None
	2032974	Collaborative Research: Stakeholder Interdependencies in Post-Disaster Relocation under High Uncertainty	B, C
University of Florida	2037725	Natural Hazards Engineering Research Infrastructure: Experimental Facility with Boundary Layer Wind Tunnel 2021-2025	B, C
University of Miami	2119842	Collaborative Research: Probing feedbacks between thermal structure, petrologic transformation, and rheologic evolution within dynamically evolving subduction zones	A, C
Georgia State University Research Foundation, Inc.	2106712	IRES Track I: Mapping and Assessing the Seismic Hazard of the Guanacaste Tectonic Sliver, Costa Rica	B
University of Hawaii	2127807	Structure and thermal elastic properties of calcium silicate perovskite	A, C
	2119982	Collaborative Research: GP-IN: Connected to Earth: Cross-Cultural Knowledge Exchange for Advancing Earth Science Learning	C
Boise State University	2122188	Development of a User-Friendly, Low-Cost, Low-Power, Low-Noise, Lightweight, Self-Contained Infrasound Logging System	B
Board of Trustees of Illinois State University	2113158	Collaborative Research: Moving mountains: timing and emplacement of the Marysvale gravity slide complex	A, C
Northwestern University	2120374	Effect of Pore Pressure Rate on Rate and State Frictional Slip In Experiments	A, B
University of Illinois at Urbana-Champaign	2047692	CAREER: Programming Multi-functional Responses into Civil Structures via Topology Optimization	B, C
Indiana University	2045291	Collaborative Research: Vertical signatures of lithospheric deformation in the western US	A, B
	2121631	Collaborative Research: Toward an integrated modeling framework for physics-based estimates of megathrust rupture potential	A, B, C
	2123412*	Collaborative Research: GEMT: Bridging Multiple Time Scales of Erosion and Rock Uplift in Taiwan	A
Purdue University	2129782	Natural Hazards Engineering Research Infrastructure: Network Coordination Office 2021-2025	B, C
	2140139	NSF Workshop on State-of-the-Art and Challenges in Resilience	C
University of Notre Dame	2103550	Structural Extreme Events Reconnaissance (StEER): Data to Knowledge Framework for Coordinated Reconnaissance following Natural Hazard Events	B
University of Kansas Center for Research Inc	2127938	Collaborative Research: Deployment of Seafloor Optical Fiber Strainmeters for the Detection of Slow Slip Events	A, B

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
Louisiana State University	2105320	Collaborative Research: A New 3-D Velocity and Structural Model of the Northern Basins in the Los Angeles Region for Improved Ground Motion Estimates	A, B
Tulane University	2039963	Collaborative Research: Unraveling distributed deformation during early-stage rifting in the Western and Southwestern African Rifts	A, B
Amherst College	2119843	Collaborative Research: Probing feedbacks between thermal structure, petrologic transformation, and rheologic evolution within dynamically evolving subduction zones	A, C
Massachusetts Institute of Technology	2123254	Collaborative Research: The role of subducting seamounts in fault stability and slip behavior throughout the seismic cycle	A, B
Northeastern University	2053741	Scalable Assessment of Urban Earthquake Resilience: A Novel Model-informed Deep Learning Paradigm	B, C
Shinevar, William J	1952642	EAR-PF:Quantifying Scale of Lower Crust and Mantle Heterogeneities Beneath the Continental United States: Bridging Seismology, Mineral Physics, Petrology, and Magnetotellurics	A, B, C
Trustees of Boston University	2043281	Collaborative Research: Roles of rupture complexity, geological structure and stress interaction on earthquake sequences	A, B
University of Massachusetts Amherst	2040570	The role of strike-slip fault interaction on long-term slip rates	A, B, C
University of Massachusetts, Dartmouth	2047832	CAREER: An Integrated Framework for Resilience Analytics: From Physics-based Modeling of Building Components to Dynamics of Community Level Recovery	B
Hoover, William Floyd	2053033	EAR-PF: What is the role of metasomatic alteration in subduction zone episodic tremor and slip?	A, C
Morgan State University	2101080	Excellence in Research: A Data-Driven Computational Framework for Seismic Detection, Modeling and Prediction	B
University of Maryland, College Park	2112828	Collaborative Research: Resource-Constrained Optimal Learning Framework for Post-Seismic Regional Building Damage Inference	B
	2122512	Collaborative Research: Developing crystal clocks in metamorphic rocks: Using lithium in subduction zone garnets to decipher fluid release timescales	A
	2047966	CAREER: Transcending Barriers between Natural Hazard Researchers, Educators, and Practitioners - An Integrative Approach to Multi-Hazard Probabilistic Assessment	B
	2123696*	Collaborative Research: An integrated evaluation of lower crustal rheology and localization processes in plagioclase-rich rocks	A
Central Michigan University	2053694	Collaborative Research: Development of Realistic Seismic Input Motions for Improving the Resilience of Infrastructure to Earthquakes	B
Michigan State University	2137618	Geodetic Characterization of the Easternmost Alaska Subduction Zone	A, B, C

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
	2137370	Collaborative Research: RAPID Geodetic Field Response to the 2018 Magnitude 7 Anchorage Earthquake	A, B
	2147422	Collaborative Research: RAPID: Response to the 29 July 2021 Chignik M8.2 Earthquake	A, B, C
	2039961	Collaborative Research: Unraveling distributed deformation during early-stage rifting in the Western and Southwestern African Rifts	A, B
	2042553	CAREER: Investigating composition and rheology of circum-Pacific mantle wedges with body-wave attenuation	A, C
	2052558	Collaborative Research: The M7.8 Simeonof earthquake: Untangling Slip from Seconds to Years across the edge of the Shumagin Seismic Gap	A, C
Regents of the University of Michigan - Ann Arbor	2050618	Collaborative Research: From subduction to suture: testing collisional stage and lithospheric strength as controls on orogenic structure in the Caucasus	A
University of Minnesota-Twin Cities	2127476	MCA: Multi-scale considerations of climatic signatures on debris flows and alluvial fans	A, B, C
	2050893*	REU Site: Collaborative Research: Research Opportunities in Rock Deformation	A
Missouri University of Science and Technology	2038179	CAREER: Paleoseismicity along the North American-Caribbean Plate Boundary: Research, Education and Outreach	A, B, C
	2044013	SCC-CIVIC-PG Track B: Community Resilience Micro-Bonds to Balance Cost and Social Equity among Stakeholders	C
Saint Louis University	2041631	Characterization of the Oceanic Lithosphere-Asthenosphere Boundary in the Colombian Subduction Zone through Receiver Function Analysis	A, B
Washington University	2050372*	REU Site: Collaborative Research: Research Opportunities in Rock Deformation	A
Duke University	2042325	CAREER: An Integrated Dissipative Modeling Framework for the Long-Term Assessment of Geohazards	B
North Carolina State University	2104986	Mechanics of Granular Materials: Rigidity, Nonlocality, and Activated Failure	A, B, C
University of North Carolina at Charlotte	2134366	GSA Penrose Conference: PRF2022 Progressive Failure of Brittle Rocks; Western North Carolina; June 2022	A
University of North Carolina at Wilmington	2040225	Collaborative Research: Developing high-resolution records of storminess from the southern Bering Sea	A
North Dakota State University Fargo	2045538	CAREER: Reduced-scale Additively Manufactured Models for Quantifying the Behavior of Large Structural Steel Castings	B, C
University of New Hampshire	2050808*	Collaborative Research: Hybrid Flow-Sediment-Structure Interaction Analysis of Extreme Scour due to Coastal Flooding	A, B, C

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
New Jersey Institute of Technology	2128679	EAGER: Compressibility of Nanopore-Confined Liquids Probed by Ultrasonic Experiments	A
New Mexico Institute of Mining and Technology	2034896	Collaborative Research: Quantifying the thermal effects of fluid circulation in oceanic crust entering the Cascadia subduction zone	A
University of New Mexico	2113315	Collaborative Research: High resolution passive seismic imaging beneath Valles Caldera	A, B
	2104537	III: Medium: Collaborative Research: Scaling Time Series Analytics to Massive Seismology Datasets	B, C
Board of Regents, NSHE, obo University of Nevada, Reno	2122191	Collaborative Research: Generation of Rock Damage and Localization of Seismicity Before Large Earthquakes	A, B
Columbia University	2103741	Collaborative Research: Frameworks: Seismic Computational Platform for Empowering Discovery (SCOPED)	B, C
	2031017	The Influence of Fault Geometry on Shallow Frictional Sliding in Subduction Zones	A, B
Cornell University	2147438	Collaborative Research: RAPID: Response to the 29 July 2021 Chignik M8.2 Earthquake	A, B
	2039962	Collaborative Research: Unraveling distributed deformation during early-stage rifting in the Western and Southwestern African Rifts	A, B
D'Youville College	2046316	CAREER: Bolstering Food System Resilience to Reduce the Human Impacts of Disasters	C
New York University	2133356	SCC-CIVIC-FA Track B UNUM: Unification for Underground Resilience Measures	B
Rensselaer Polytechnic Institute	2027496	Investigation of Anomalous Travel Times in the Central Andes: Possible Evidence for a Lithospheric Root Trapped Above a Flat Slab	A
Russell, Joshua B	1952702	EAR-PF Discerning the nature of the oceanic lithosphere-asthenosphere boundary through integration of seismological-scale and laboratory-scale observations	A, C
SUNY at Stony Brook	2050798*	Collaborative Research: Hybrid Flow-Sediment-Structure Interaction Analysis of Extreme Scour due to Coastal Flooding	A, B, C
Syracuse University	2116017*	Collaborative Research: Characterizing Quaternary Fault Behavior and Surface Processes of an Active Rift: The Lake Malawi (Nyasa) Rift, East Africa	A, C
University of Rochester	2102495	Developing a Seismic Model for Investigating Layering in Cratonic Lithosphere beneath Africa	A
Kent State University	2113157	Collaborative Research: Moving mountains: timing and emplacement of the Marysvale gravity slide complex	A, C
Ohio State University	2113155	Collaborative Research: Moving mountains: timing and emplacement of the Marysvale gravity slide complex	A, C

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
University of Oklahoma Norman Campus	2043064	Collaborative Research: Roles of rupture complexity, geological structure, stress interaction on earthquake sequences	A, B
	2033376	RII Track 4: Illuminating the Dark Subsurface using Fiber Optic Distributed Acoustic Sensing (DAS) Array	A, B, C
Oregon State University	2050047*	Collaborative Research: Parameterizing The Drivers and Timing of Post-Earthquake Landslides	A, B, C
	2120683	Collaborative Research: Converging Design Methodology: Multi-objective Optimization of Resilient Structural Spines	B, C
	2046001	CAREER: Innovative Technology for Mass Timber and Hybrid Modular Buildings	B
	2034872	Collaborative Research: Quantifying the thermal effects of fluid circulation in oceanic crust entering the Cascadia subduction zone	A
	2118594	RAPID: Nearshore Sound Propagation of and Species Response to Active-Source Seismic Surveys	None
	2037914	Natural Hazards Engineering Research Infrastructure: Experimental Facility with Large Wave Flume and Directional Wave Basin 2021-2025	B, C
	2103713	Large-Scale CoPe: The Cascadia Coastlines and People Hazards Research Hub	B, C
University of Oregon Eugene	2053372	Collaborative Research: Exploring System-Wide Events on Complex Fault Networks using Fully-Dynamic 3D Earthquake Cycle Simulations	A, B
Bolton, David Chas	2050006	EAR-PF: Towards a robust understanding of the spatio-temporal evolution of foreshock sequences from the laboratory to the field	A, B
Carnegie-Mellon University	2053856*	Disaster Recovery and Response Innovation through Fuel Cell Deployment	C
Lehigh University	2037771	Natural Hazards Engineering Research Infrastructure: Experimental Facility with Large-Scale, Multi-directional, Hybrid Simulation Testing Capabilities 2021-2025	B
Pennsylvania State Univ University Park	2120684	Collaborative Research: Converging Design Methodology: Multi-objective Optimization of Resilient Structural Spines	B, C
	2022444	NNA Track 2: Collaborative Research: Planning for Infrastructure Resiliency and Adaptation amid Increasing Mass-Movement Risks across the Cryosphere	A, B, C
	2053620	LEAP-HI: Optimal Design and Life-Long Adaptation of Civil Infrastructure in a Changing and Uncertain Environment for a Sustainable Future	B, C
	2046598	CAREER: Testing models of early Earth crust formation and tectonics	A
University of Pittsburgh	2123413*	Collaborative Research: GEMT: Bridging Multiple Time Scales of Erosion and Rock Uplift in Taiwan	A
Brown University	2039700	Collaborative Research: Identifying shallow slow slip using hematite textures and (U-Th)/He thermochronometry of exhumed and experimental faults	A, C

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
	2044136	Seismological studies of cratonic lithosphere: investigating lithospheric rheology, heat flow beneath ice sheets, and the origin of mid-lithospheric discontinuities	A
	2054522	Experimental constraints on the rheology of the mantle lithosphere at the base of the seismogenic zone	A
University of South Carolina at Columbia	2122513	Collaborative Research: Developing crystal clocks in metamorphic rocks: Using lithium in subduction zone garnets to decipher fluid release timescales	A
South Dakota School of Mines and Technology	2136809*	EAGER: Collaborative Proposal: Probabilistic Scenarios for Megathrust Earthquakes and Tsunami Genesis	B
University of Memphis	2104002	Elements: Developing an integrated modeling platform for tectonics, earthquake cycles and surface processes	A
Texas A&M Engineering Experiment Station	2052930	Focused CoPe: Fundamental research to inform holistic decision-making for historically underrepresented communities impacted by coastal hazards	C
Trinity University	2042114	RUI: Developing A Predictive Model Of Strain Accommodation For Segmented Normal Fault Evolution, Sevier Fault Zone, Southern Utah	B
University of Texas at Austin	2123255	Collaborative Research: The role of subducting seamounts in fault stability and slip behavior throughout the seismic cycle	A, B
	2103494	Collaborative Research: Frameworks: Seismic Computational Platform for Empowering Discovery (SCOPED)	B, C
	2045292	Collaborative Research: Vertical signatures of lithospheric deformation in the western US	A, B
	2041496	Impact of upper-plate splay faults on accreting-sediment stress state and on megathrust strength and fluid budgets	A, B
	2103937	Elements: Cognitasium - Enabling Data-Driven Discoveries in Natural Hazards Engineering	B
	2037900	Natural Hazards Engineering Research Infrastructure: Experimental Facility with Large, Mobile Dynamic Shakers for Field Testing 2021-2025	B
	2121666	Collaborative Research: Toward an integrated modeling framework for physics-based estimates of megathrust rupture potential	A, B, C
	2129801	RAPID: Implications of Utilities Decision-making and Communication Strategies in Urban Populations Response under Extreme Weather Events	B
University of Texas at Dallas	2042098	CAREER: Developing a Multi-Parameter Seismic Model of North America	A, C
University of Texas at El Paso	2054442	Insights into the complexities of a seismogenic subduction zone: Analysis of a high-quality aftershock data set from the 2017 Tehuantepec (M8.2) offshore Mexico earthquake	A, C
	2049603	EAGER: Development of Techniques for 3D mapping at Macroscopic Scales	A, B

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
William Marsh Rice University	2108175	Recovery of Material Parameters and Friction Laws Associated with Earthquakes, Interseismic Slip, and Tidal Deformation	A, B
	2114382*	Opening and reestablishment of Kilauea's lower east rift zone magma plumbing system during the 2018 eruption	B,C
University of Utah	2121169	MCA: Using Machine Learning to Predict Seismic Failure Limit States in Buildings	B, C
	2112758	Collaborative Research: Resource-Constrained Optimal Learning Framework for Post-Seismic Regional Building Damage Inference	B
	2107926	Structures, Composites, and Inhomogeneous Bodies	B
	2125196	SCC-PG: Online Role-Playing Games for Improving Multi-Stakeholder Collaboration in Concurrent Disaster Response Planning	C
	2032838	Collaborative Research: Stakeholder Interdependencies in Post-Disaster Relocation under High Uncertainty	B, C
Utah State University	2100753	BSF-NSF: Collaborative Research: Deciphering the role of extreme rainstorms and hydroclimatic regime on arid escarpment retreat and sub-cliff slope evolution	A, B
	2039727	Collaborative Research: Identifying shallow slow slip using hematite textures and (U-Th)/He thermochronometry of exhumed and experimental faults	A, C
Westminster College of Salt Lake City	2113156	Collaborative Research: Moving mountains: timing and emplacement of the Marysvale gravity slide complex	A, C
Virginia Polytechnic Institute and State University	2050030	Seismic Retrofit of Horizontal Lateral Force Resisting Systems in Buildings	B, C
	2046387	CAREER: Scalable Computational Seismology for All	A
University of Washington	2045058	CAREER: Mollusk and Arthropod-inspired Bio-Cemented Composites for Sustainable, Resilient, and Multifunctional Ground Improvement	B, C
	2141047	RAPID: A Community Test of Distributed Acoustic Sensing on the Ocean Observatories Initiative Regional Cabled Array	B
	2125337	Collaborative Research: Cross-Validation of Empirical and Physics-based ground motion predictions	A
	2040716	Trapped in travertine: Physical and chemical signature of paleoseismicity in hot spring deposits on active faults of the Central Nevada Seismic Belt	A, B
	2103701	Collaborative Research: Frameworks: Seismic COmputational Platform for Empowering Discovery (SCOPED)	B, C
	2050057*	Collaborative Research: Parameterizing The Drivers and Timing of Post-Earthquake Landslides	A, B, C
	2124722	CAREER: Dynamics of surface rupturing thrust earthquakes	A, B, C
	2130997	Natural Hazards Engineering Research Infrastructure: Natural Hazard and Disaster Reconnaissance (RAPID) Facility 2021-2025	B

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
	2127140	Collaborative Research: Constraints on Interseismic Locking near the Trench on the Oregon Segment of the Cascadia Subduction Zone Using Seafloor Geodesy (GNSS-A)	A
	2121616	EAGER: SAI: Collaborative Research: Conceptualizing Interorganizational Processes for Supporting Interdependent Lifeline Infrastructure Recovery	C
	2119844	Collaborative Research: Probing feedbacks between thermal structure, petrologic transformation, and rheologic evolution within dynamically evolving subduction zones	A, C
	2121616	EAGER: SAI: Collaborative Research: Conceptualizing Interorganizational Processes for Supporting Interdependent Lifeline Infrastructure Recovery	C
Western Washington University	2128783	Collaborative Research: Relationship between plate boundary obliquity, strain accommodation, and fault zone geometry at oceanic-continental transforms: The Queen Charlotte Fault	A, B, C
	2128785	Collaborative Research: Behavior and structure on and around the megathrust revealed by the Alaska Amphibious Seismic Community Experiment	A
	2128784	Collaborative Research: Capturing 4D Variations in Stress, Slip, and Fault-Zone Material Properties: The 2019-2021 Gofar Transform Fault Earthquake Prediction Experiment	A, C
University of Wisconsin-Madison	2045259	CAREER: Mechanics of Viscous Damage Zones Along Rough Faults and Community Tutorial/Forums for Experimental Rock Mechanists	A, B
	2042919	Applications of double-difference seismic attenuation tomography	A
	2051565	Do slickenfibers record episodic tremor and slow slip?	A
	2136772*	EAGER: Collaborative Proposal: Probabilistic Scenarios for Megathrust Earthquakes and Tsunami Genesis	B
	2119907	Collaborative Research: GP-IN: Connected to Earth: Cross-Cultural Knowledge Exchange for Advancing Earth Science Learning	C
	2123718*	Collaborative Research: An integrated evaluation of lower crustal rheology and localization processes in plagioclase-rich rocks	A
University of Wisconsin-Whitewater	2119978	Collaborative Research: GP-IN: Connected to Earth: Cross-Cultural Knowledge Exchange for Advancing Earth Science Learning	C
West Virginia University Research Corporation	2046059	CAREER: Mapping Anthropocene Geomorphology with Deep Learning, Big Data Spatial Analytics, and LiDAR	A, B, C
Alaska Conservation Foundation	2114573	NNA Track 2: Developing coordinated monitoring networks across Alaska and Northwest Canada to evaluate and address rapidly changing environments	C
Earth Images Foundation	2139041	Producing New Geo-media to Increase Outreach and Diversity	C

Research Entities	Award Number	Title of Research	Relevant Strategic Goal(s)
UNAVCO, Inc.	2148792	United States Geological Survey Supplemental Funding for the Geodetic Facility for the Advancement of Geoscience (GAGE)	A, B
American Geophysical Union	2139353	Defining research and educational priorities in Near-Surface Geophysics: a workshop and survey in light of the Vision for NSF 2020-2030 Earth in Time report	C
Woods Hole Oceanographic Institution	2131932	Mid-scale RI-1 (M1:DP): Design and Construction of a New Generation of Ocean-Bottom Seismographs for the U.S. Academic Community	B
	2114652	Accomplishment Based Renewal: The Architecture and Tectonics of the Ultraslow Spreading SW Indian and Gakkel Ridges	A

Legend: * Award numbers followed by an asterisk indicate a start date of 2022. All other research grants have a 2021 start date.

Source: GAO. I GAO-22-105016

Appendix III: Comments from the Department of Homeland Security

U.S. Department of Homeland Security
Washington, DC 20528

Homeland Security

April 12, 2022

Christopher Currie
Director, Homeland Security and Justice
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Re: Management Response to Draft Report GAO-22-105016, "EARTHQUAKES: Opportunities Exist to Further Assess Risk, Build Resilience, and Communicate Research"

Dear Mr. Currie:

Thank you for the opportunity to comment on this draft report. The U.S. Department of Homeland Security (DHS or the Department) appreciates the U.S. Government Accountability Office's (GAO) work in planning and conducting its review and issuing this report.

The Department is pleased to note GAO's recognition of: (1) the importance of the National Earthquake Hazards Reduction Program (NEHRP) in reducing earthquake-related risks to life and property, and (2) initiatives such as strengthening community resilience through improved design and construction methods and conducting research to better understand the impacts from earthquakes. NEHRP is a broad working partnership of four agencies, including the Federal Emergency Management Agency (FEMA), and provides leadership and technical resources to reduce the human, economic, and societal losses caused by earthquakes in the U.S. and its territories. Through enhanced standards, guidelines, and building codes, NEHRP has improved earthquake resilience in communities nationwide. FEMA remains committed to continuing its work with Tribal Nations on earthquake risk reduction initiatives through increased communication and education.

The draft report contained seven recommendations, including one for DHS, with which the Department concurs. Enclosed, please find our detailed response to this recommendation. DHS previously submitted technical comments addressing several accuracy, contextual, and other issues under a separate cover for GAO's consideration.

Again, thank you for the opportunity to review and comment on this draft report. Please feel free to contact me if you have any questions. We look forward to working with you again in the future.

Sincerely,

JIM H CRUMPACKER

Digitally signed by JIM H CRUMPACKER
Date: 2022.04.12 09:48:37 -04'00'

JIM H. CRUMPACKER, CIA, CFE
Director
Departmental GAO-OIG Liaison Office

Enclosure

2

Enclosure: Management Response to Recommendation Contained in GAO-22-105016

GAO recommended that the Administrator of FEMA:

Recommendation 2: Develop and implement a plan to increase awareness among tribes about earthquake risk reduction initiatives.

Response: Concur. The Director of FEMA's Federal Insurance and Mitigation Administration (FIMA) Planning and Safety Division, as well as FIMA's Earthquake and Wind Programs Branch, will collaborate with FEMA's National Tribal Affairs Advisor to develop culturally sensitive and relevant products to communicate earthquake risk effectively. Once complete, a strategic communications plan will also support the distribution of these products. Estimated Completion Date: December 30, 2022.

Appendix IV: Comments from the National Science Foundation

National Science Foundation
Office of the Director

April 20, 2022

Christopher P. Currie
Director
Homeland Security & Justice
U.S. Government Accountability Office
441 G Street, NW
Washington, D.C. 20548

Dear Mr. Currie:

Thank you for the opportunity to review and provide comments on the Government Accountability Office (GAO) draft report, *EARTHQUAKES: Opportunities Exists to Further Assess Risk, Build Resistance, and Communicate Research* (GAO-22-105016).

The National Science Foundation (NSF) values the GAO staff's professionalism and many constructive interactions during this GAO engagement. NSF further appreciates GAO's acknowledgement of agency efforts to promote and enable research relevant to enhanced earthquake resilience across the nation.

NSF concurs with GAO's Recommendation to develop strategies to better communicate the National Earthquake Hazards Reduction Program (NEHRP) priorities to research entities, in collaboration with NIST. NSF has already begun conversations within the Foundation about this aim. Existing mechanisms will be enhanced, and new mechanisms may be created to improve research communities' awareness.

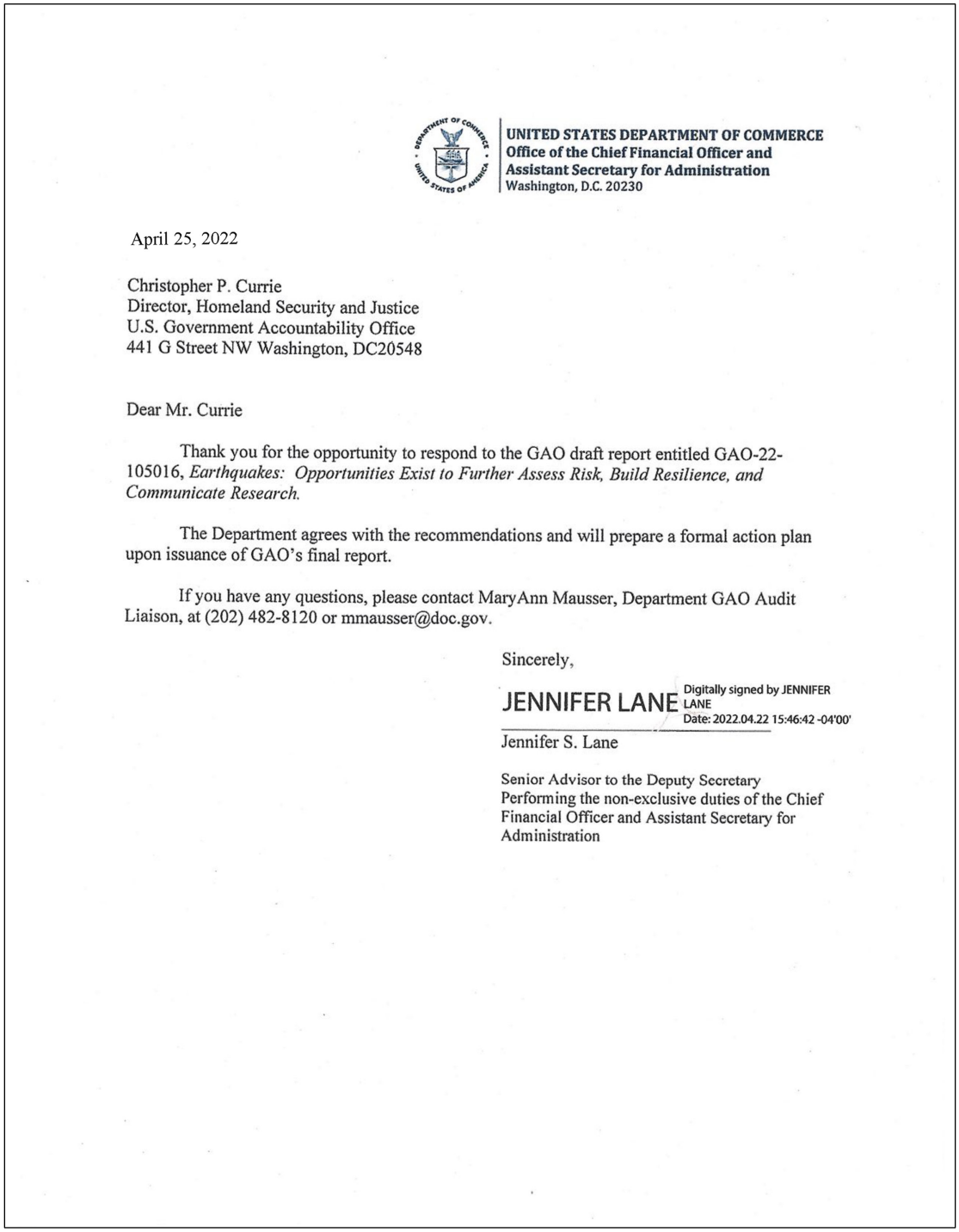
Again, thank you for the opportunity to review and comment on this draft report. Please feel free to contact Veronica Shelley at vshelley@nsf.gov or 703-292-4384 if you have any questions or require additional information. We look forward to working with you again in the future.

Sincerely,

Sethuraman Panchanathan
Director

2415 Eisenhower Avenue, Suite 19100 Alexandria, VA 22314

Appendix V: Comments from the United States Department of Commerce



UNITED STATES DEPARTMENT OF COMMERCE
Office of the Chief Financial Officer and
Assistant Secretary for Administration
Washington, D.C. 20230

April 25, 2022

Christopher P. Currie
Director, Homeland Security and Justice
U.S. Government Accountability Office
441 G Street NW Washington, DC20548

Dear Mr. Currie

Thank you for the opportunity to respond to the GAO draft report entitled GAO-22-105016, *Earthquakes: Opportunities Exist to Further Assess Risk, Build Resilience, and Communicate Research.*

The Department agrees with the recommendations and will prepare a formal action plan upon issuance of GAO's final report.

If you have any questions, please contact MaryAnn Mausser, Department GAO Audit Liaison, at (202) 482-8120 or mmausser@doc.gov.

Sincerely,

JENNIFER LANE Digitally signed by JENNIFER LANE Date: 2022.04.22 15:46:42 -04'00'

Jennifer S. Lane

Senior Advisor to the Deputy Secretary
Performing the non-exclusive duties of the Chief Financial Officer and Assistant Secretary for Administration

Department of Commerce's Comments on
GAO Draft Report entitled *Earthquakes: Opportunities Exist to Further Assess Risk, Build Resilience, and Communicate Research* (GAO-22-105016)

The Department of Commerce has reviewed the draft report and we offer the following comments for GAO's consideration.

General Comments

The Department of Commerce and the National Institute of Standards and Technology (NIST) wish to thank the Government Accountability Office (GAO) for their efforts in developing this report in accordance with the National Earthquake Hazards Reduction Program (NEHRP) Reauthorization Act of 2018 (Public Law 115-307). The recommendations provided in this report were well-researched and developed to assist the NEHRP agencies (Federal Emergency Management Agency, NIST, National Science Foundation, and U.S. Geological Survey) work to achieve a stronger interagency program. The responses provided here are focused solely on NIST's roles in NEHRP.

Comments on Recommendations

The Government Accountability Office (GAO) made five recommendations to the Department of Commerce in the report.

- **Recommendation 1:** The Director of NIST should, in collaboration with FEMA, NSF, and USGS and in coordination with federal, state, local, territorial, and tribal governments and stakeholders, conduct a national risk assessment to identify the progress made by communities to strengthen earthquake resilience since 2015, and the gaps in resilience that remain.

  Commerce Response: The Department of Commerce agrees with this recommendation.

  If resources are provided, NIST will lead a collaboration effort to conduct a national risk assessment to identify the progress made by communities to strengthen earthquake resilience and the gaps in resilience that remain. In addition, the updated NEHRP Strategic Plan will prioritize future NEHRP activities that help communities strengthen their earthquake resilience.

- **Recommendation 3:** The Director of NIST should, in collaboration with FEMA, NSF, and USGS assess and determine if additional actions are needed to obtain input from state, local, territorial, and tribal governments and stakeholders on research priorities that align with community and stakeholder needs.

  Commerce Response: The Department of Commerce agrees with this recommendation.

  NIST has many mechanisms routinely used to obtain relevant input from external entities to

support its mission. These mechanisms include grants programs, hosted workshops, program reviews by leading research councils, experience of the NIST work force, strategic planning studies, collaboration with other NEHRP agencies and the Advisory Committee for Earthquake Hazards Reduction (ACEHR), and proactive participation with building code and standards development organizations. Through these activities NIST develops state-of-the-art and state-of-the-practice research programs that support the needs of its stakeholders. Through a routine assessment process, these programs remain flexible to adapt to needed changes. Relevant needs regarding earthquake engineering are routinely communicated from NIST to the other NEHRP agencies. The NEHRP agencies will collectively evaluate additional outreach opportunities to obtain input from stakeholders and will continue to review ACEHR membership to ensure a diverse representation of stakeholders.

- **Recommendation 5:** The Director of NEHRP should, in collaboration with NIST, NSF, USGS, and FEMA, follow leading practices to develop performance measures linked to priority research outcomes, and to track and monitor research to ensure research priorities are being met.

  Commerce Response: The Department of Commerce agrees with this recommendation.

  NEHRP submits a biennial report to the Congress that highlights milestones achieved from programmatic efforts during the reporting period that supports the NEHRP mission. These reports are written to align with the goals and priorities identified in the NEHRP Strategic Plan. A guiding principle used in the development of the updated Plan was to organize it to facilitate development of the NEHRP biennial report so that the Program and its stakeholders can monitor progress towards research priorities more efficiently. The NEHRP agencies will collectively evaluate other practices for tracking and monitoring progress.

- **Recommendation 6:** The Director of NEHRP should, in collaboration with NIST, NSF, USGS, and FEMA, follow leading practices to identify and leverage the program's resources needed to achieve research priority outcomes.

  Commerce Response: The Department of Commerce agrees with this recommendation.

  The NEHRP agencies collaborate at the programmatic level to ensure that individual agency activities are unique and mutually supportive to a shared outcome established in the NEHRP Strategic Plan. While the NEHRP agencies do not share funding responsibilities for an external, multi-agency collaborative subject, the agencies do coordinate topical responsibilities, based on agency mission, so that each agency will then have responsibility for specific components. A guiding principle used in the development of the updated NEHRP Strategic Plan was to organize the Plan to demonstrate how efforts by each agency collaborate with efforts by other agencies to support the defined goals and priorities. This provides the Program a mechanism to identify the extent of efforts supporting an issue and whether other activities are needed elsewhere. NEHRP also oversees the Interagency Committee on Seismic Safety in Construction (ICSSC) which is composed of over thirty federal organizations with a shared mission that supports Executive Order 13717. This allows the Program to understand and share technical issues and resources needed by the ICSSC

agencies. Generally, information regarding NEHRP and ICSSC efforts are shared on the Program website (www.nehrp.gov). The Program will collectively explore what other best practices can further maximize the collective efforts of the Program agencies in progress toward supporting a research priority.

- **Recommendation 7:** The Director of NIST should, in collaboration with NSF, document and implement a comprehensive plan to better ensure that all state, local, territorial and tribal governments and stakeholders are aware of the mechanisms and practices used by NSF and NIST for disseminating research.

  Commerce Response: The Department of Commerce agrees with this recommendation.

  Open access to research results is a fundamental mission of NIST. For example, NIST uses presentations and information booths at earthquake-focused conferences, active participation on, and collaborations with, building code and design standards development committees, publications in peer-reviewed journals, and relevant postings on NIST-supported websites for disseminating research results that support NEHRP. Grants awarded by NIST generally require periodic presentations at NIST-hosted symposiums and a final research report to be submitted to NIST, which is made available to the public. NIST will continue to seek other opportunities to increase accessibility of research results to stakeholders. NEHRP will also work to promote diverse representation on ACEHR to enhance two-way communication with key state, local, territorial and tribal governments and stakeholders.

Appendix VI: GAO Contact and Staff Acknowledgement

GAO Contact

Chris P. Currie at (404) 679-1875 or curriec@gao.gov

Staff Acknowledgements

In addition to the contact named above, Aditi S. Archer (Assistant Director), James Lawson (Analyst-in-Charge), Sally Gilley, and Tangere Hoagland made key contributions to this report. Other key contributors were Tammy Conquest, Benjamin Crossley, Dominick Dale, Elizabeth Dretsch, David Hooper, Tracey King, Katrina Pekar-Carpenter, and Sarah Veale.

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