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on
"From Risk to Resilience: Reauthorizing the Earthquake and Windstorm Hazards Reduction Programs"

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Introduction

Chairman Collins, Ranking Member Stevens, and Members of the Subcommittee, it is a privilege to appear before you today to discuss the important roles the U.S. National Science Foundation (NSF) plays in understanding, mitigating, and building community resilience to natural disasters and extreme weather events.

Established by the National Science Foundation Act of 1950 (P.L. 81-507), NSF is an independent federal agency charged with the mission "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF is unique in carrying out its mission by supporting research across all fields of science, technology, engineering, and mathematics (STEM), and at all levels and settings of STEM education. NSF investments contribute significantly to the economic and national security interests of the Nation, and the development of a future-focused science and engineering workforce that draws on the talents of all Americans.

For more than seven decades, NSF has invested in research, researchers, innovations and innovators, and world-class scientific research infrastructure that has garnered incredible benefits to the nation. The internet, 3D printing, the economic theory underpinning spectrum auctioning and kidney exchanges are all examples of the outcomes and benefits of NSF investments. Many of the technologies and industries that are the focus of national conversations around competitiveness today — artificial intelligence (AI), quantum information science, advanced manufacturing, advanced wireless and biotechnology, to name a few — are rooted in sustained NSF support, in many cases over many decades, for research at the frontiers of science and engineering.

NSF's ability to leverage expertise across disciplines allows the agency to bring diverse groups of scientists and engineers together with private industry, communities, philanthropic organizations and others to identify problems and use science, engineering, and technology to develop solutions. In doing so, the agency tackles problems from the national level to the local level, with the goal of ensuring that citizens from every geographic and demographic background benefit from NSF investments and breakthroughs.

For decades, NSF has been investing in fundamental research and innovation to improve community and infrastructure resilience to natural hazards including wildland fires, flooding, drought, landslides, earthquakes, and windstorms. NSF-funded researchers seek to advance our fundamental understanding of these hazards to improve prediction, risk assessment, and warnings. They examine the behavior of buildings, infrastructure, and the natural environment in the face of these events to enable better designs and mitigation options. And they examine community consequences and human responses to support improved planning and policy, emergency response options, better risk communication, and decision support for resilience of households throughout the nation in rural and urban communities, Tribes, cities, and states.

Forecasting, mitigating, and adapting to a changing climate — which often makes extreme events, such as wildfires, hurricanes, and drought, more severe and frequent — at global to local scales requires scientific, engineering, and technological advances. Improving our understanding of natural hazards, community resilience, and the associated social and behavior dimensions is critical to developing solutions to the interconnected challenges of resilience. NSF will continue to take action to advance knowledge, empower and engage communities, grow a capable and diverse scientific workforce, and generate innovative technological solutions to tackle these challenges.

NSF's Role in the National Earthquake Hazards Reduction Program

The mission of the National Earthquake Hazards Reduction Program (NEHRP) 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." Established by Congress in 1977, NEHRP is a coordinating program whose goals are carried out through earthquake monitoring, research, implementation, education, and outreach activities developed and conducted by several lead NEHRP agencies — NSF, the National Institute of Standards and Technology (NIST), the Federal Emergency Management Agency (FEMA), and the United States Geological Survey (USGS) — which work in close coordination to improve the nation's understanding of earthquake hazards and to mitigate their effects. The NEHRP Strategic Plan FY2022-2029[1] includes four goals: 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

[1] https://www.nehrp.gov/pdf/FY2022-29%20NEHRP%20Strategic%20Plan%20-%20Post%20Version.pdf

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.

Pursuant to these four NEHRP goals, NSF supports critical research to advance our understanding of the causes and consequences of earthquakes across the country; to learn from post-earthquake investigations; and to mitigate the impacts of earthquakes on infrastructure and the built environment. As the only NEHRP agency with a mission to promote fundamental research, this is an area where NSF's contributions are most numerous and, often, most impactful. The following examples demonstrate how NSF-funded science is both critical to and synergistic with NEHRP's mission to improve the Nation's earthquake resilience.

Understanding the causes and consequences of earthquakes

Subduction zones, where one tectonic plate slides beneath another, produce some of the most devastating earthquakes on the planet. Understanding subduction zone earthquakes and the serious risks they present is a focus area in the NEHRP Strategic Plan. Related to this goal, the U.S. geosciences community has recently been especially active advancing capabilities for ocean floor geodesy, which is crucial for subduction zone monitoring and research. NSF has made infrastructure, workshop, and research awards over the last several years to advance the design and development of ocean floor measurements relevant to seismic activity. This sort of investment in next-generation instrumentation is an example of the fundamental contributions NSF makes in support of NEHRP research needs.

Of special note, in terms of NSF contributions to understanding the causes and consequences of great subduction zone earthquakes, are two recently funded Centers dedicated to understanding the mechanisms and ramifications of seismic hazards along the Cascadia Subduction Zone: Cascadia Region Earthquake Science Center (CRESCENT) and the Cascadia CoPes (Coastlines and Peoples) Research Hub. CRESCENT takes a system-wide approach to investigating the Cascadia Subduction Zone across the shoreline, focusing on using research toward practical applications as well as involving students across all levels. The Cascadia CoPes Hub explores multiple hazards relevant to both earthquakes and climate forces and is driven by the resilience needs of local populations in the Cascadia subduction zone hazard region. The Cascadia CoPes Hub has established collaboratories dedicated to, among other topics, earthquakes, tsunamis, landslides, and land-level change; climate-driven fluvial and coastal flooding and how these change coastal morphology and risks; and risk mitigation and adaptation strategies, including adaptation and risk reduction approaches that incorporate Traditional and Local Ecological Knowledge. Importantly, CRESCENT and the Cascadia CoPes Hub have some overlapping personnel and are mindfully sharing plans and findings for maximum impact across the two Centers.

NSF has recently made several awards to improve seismic hazard estimates in different regions. NSF-funded research includes developing methodologies to help increase time resolution of paleo seismicity as well as projects to better understand the physics of earthquakes and the earthquake cycle through fault mechanics studies.

The San Andreas Fault System accounts for 65% of the nation's annualized earthquake losses. In 2023, NSF made a new award to the Statewide California Earthquake Center (SCEC), which investigates the full length of this tectonic environment. SCEC combines field observations, laboratory experiments, theoretical studies and numerical simulations to create system-level physics-based models to understand seismic hazards. They maintain strong community relations in order to convey findings to promote community resilience. Importantly for NEHRP, they are responsible for coordinating the Great Shakeout earthquake drills, where millions of people across the United States and many other countries practice earthquake safety annually.

Learning from post-earthquake investigations

As natural disasters unfold, it is vital to record and preserve information that would otherwise be lost and is impossible to replicate. One of NSF's mechanisms for ensuring that researchers can get into the field quickly when disasters happen is the Rapid Response Research (RAPID) award, which enables researchers to gather important data that might degrade or disappear quickly. NSF typically receives and funds multiple RAPID project proposals when significant domestic earthquakes occur. The December 2019-January 2020 earthquake sequence in Puerto Rico, following on the heels of Hurricane Maria, presented an unusual opportunity to learn about the effects of multiple disasters affecting a single area. This is an area of interest to the disaster science community as compound disasters are growing more common. NSF's RAPID award mechanism was leveraged to support a collaborative project between researchers at Rice University and the University of Connecticut to investigate interactions between hurricane and earthquake effects on critical infrastructure in Puerto Rico. The researchers had access to fast-response documentation of Hurricane Maria damage when the earthquake occurred. Their RAPID investigation allowed them to document in specific terms the ways in which the earthquake damage was more severe and followed different failure patterns than would have been expected due to the previous hurricane impacts.

The NSF-funded Geotechnical Extreme Events Reconnaissance (GEER) Association – one of eight Extreme Event Reconnaissance (EER) Networks, described in more detail below – has conducted earthquake reconnaissance activities since the 1990s and reconnaissance for additional hazards, including landslides and windstorms, since the 2010s. Most recently, GEER conducted significant reconnaissance for last year's Kahramanaras, Turkey, earthquake sequence, coordinating with Turkish researchers as well as with the NEHRP agencies. Their work focused on tectonics, surface rupture, ground motions, liquefaction, and performance of buildings and lifelines, because there was much to learn from the Turkey experience that can help us improve earthquake assessments and resilience here in the United States.

Mitigating the impacts of earthquakes on infrastructure

NSF investments are developing ways to make our homes, schools, and lifelines, such as drinking water, electric power, and ground transportation, more resilient to earthquakes and other disasters. They are also building fundamental knowledge about how human reasoning and decision-making, governance, and social and cultural processes enable the building and maintenance of effective, resilient infrastructure.

NSF's Strengthening American Infrastructure program incorporates scientific insights about human behavior and social dynamics to better design, develop, rehabilitate, and maintain strong and effective infrastructure. A 2022 award to Purdue University through this program is using several approaches to better capture the feedback between human interaction with the built environment and infrastructure vulnerability, with the goal of producing a decision support system that policy makers can use to design retrofit and funding strategies that closely align with community preferences.

NSF's Role in the National Windstorm Impact Reduction Program

The National Windstorm Impact Reduction Program (NWIRP) is a science- and engineering-based federal program with the mission of achieving major measurable reductions in losses of life and property from windstorms, through a coordinated federal effort in cooperation with other levels of government, academia, and the private sector. The four designated NWIRP agencies are NSF, NIST, the National Oceanic and Atmospheric Administration (NOAA), and FEMA. The Federal Highway Administration (FHWA) has also participated in NWIRP from its inception. NSF is an active participant in NWIRP coordinative discussions, planning activities, and briefings. This level of coordination enables agency officials to share ideas, best practices, and lessons learned that are used to improve the effectiveness of each agency's activities related to windstorms and their effects.

NSF's specified responsibilities within NWIRP are to invest in engineering and the atmospheric sciences to improve the understanding of the behavior of windstorms and their impact on buildings, structures, and lifelines; and research in the economic and social factors influencing windstorm risk reduction measures. This mandate capitalizes on the agency's ability to support a range of short-, mid- and long-term science and engineering research and infrastructure across disciplines that helps us better understand, prepare for, and respond to extreme weather events.

NSF plays important roles in mobilizing the nation's science and engineering research communities to advance each of the NWIRP's three strategic goals: improve the understanding of windstorm process and hazards; improve the understanding of windstorm impacts on communities; and improve the windstorm resilience of communities nationwide.

Understanding windstorm processes and hazards

Recent atmospheric science and Earth systems research that has contributed to this goal include studies of the physical processes that determine hurricane intensity, tornado genesis, and tornadic vortex structure. Unsolicited windstorm-related research projects have addressed challenges presented by hurricanes, tropical cyclones, storm surge, tornadoes, derechos, and chinooks. Projects were funded across the country, including the east, west, southern and Great Lake coasts, the heartland and great plains states, Hawaii, and the major island territories. Topics included storm dynamics; disruptions to energy systems; effects on natural environments, built environments, infrastructure, plants, aquaculture, ocean ecologies, and communities; improved methods for risk communication, evacuation, response, and recovery; and more.

NSF has also funded studies that will potentially aid NOAA for better forecasting tornadic storms, provide NIST the needed science for establishing building codes, and help FEMA improve emergency management. For example, NSF funded a major field campaign, the Targeted Observation by Radars and UAS of Supercells (TORUS), which is led by the University of Nebraska-Lincoln and involves scientists from multiple universities and NOAA. This campaign is designed to increase understanding of storm structures that may be attributed to tornado genesis. Recently, NSF also funded the Boundary-layer Evolution and Structure of Tornadoes (BEST) campaign, led by the University of Illinois at Urbana-Champaign. The study is trying to resolve tornado structure, evolution, the intensity of winds and their potential damages by deploying mobile radars, Tornado Pods, and SwarmSonde balloons in and near tornadoes.

Other multi-year projects funded by NSF seek to improve understanding of supercell storms through data science; a study of hurricane-generated tornadoes; a wind-wave tank study of air-sea interaction in hurricanes; and an examination of how planetary boundary layer heterogeneities impact tornadic storms during storms intensification and tornadogenesis.

In addition, the NSF-supported federally funded research and development center NCAR (National Center for Atmospheric Research) not only supports the nation's academic community's research capability, but also collaborates with other federal agencies, such as NOAA, the National Aeronautics and Space Administration (NASA), the U.S. Department of Energy, and the U.S. Department of Defense to develop world-class weather and climate forecast models for operational needs.

Understanding windstorm impacts on communities

NSF's ability to fund both rapid response research and longer-term investigations allows the agency to play important roles in advancing understanding of disaster impacts and consequences, ensuring that impacts are documented and measured quickly before they degrade or are repaired.

NSF's Structural Extreme Events Reconnaissance (StEER) research network, another of the EERs, has developed quick-response datasets and reconnaissance reports for 59 extreme hazard events since 2018, including windstorm events, such as hurricanes, tornadoes and cyclones, and earthquakes. The network's regional nodes reside at the institutions of the five founding universities: University of Notre Dame, University of Florida, Auburn University, University of California, Berkeley and University of Hawai'i at Manoa. In the days following Hurricane Ian, on September 28, 2022, StEER deployed a team of local researchers, including equipment from the NSF Natural Hazards Engineering Research Infrastructure (NHERI) Natural Hazards Reconnaissance Facility – to collect observations and data from the impact of Hurricane Ian on structures and communities. The team prepared a report on damage to buildings and infrastructure, with a recommended research response strategy, and shared their data on NHERI's website[2], where it is available to the research community, government agencies, and other stakeholders.

Improving windstorm resilience nationwide

NSF is a significant source of funding for U.S. researchers who conduct research in economic and social factors influencing windstorm risk reduction measures, including understanding of impacts and vulnerabilities, risk communication approaches, and incentives to mitigate against risk. NSF is also committed to "convergent" research approaches that engage scientists closely with affected communities so that the problems addressed are relevant and the approaches to research are appropriate and likely to succeed.

[2] https://www.designsafe-ci.org/data/browser/public/designsafe.storage.published/PRJ-3268/#details-56471329073917460-242ac114-0001-012

A number of multi-year projects funded by NSF seek to improve understanding of how social, behavioral, and economic factors influence decisions relevant to community resilience, including: factors that affect decisions to relocate from flood-prone locations; how certain traits of visualizations and media messages affect decisions about hazard mitigation and response; and, how people make decisions when confronting multiple hazards simultaneously, as when they face both a pandemic and impending hurricanes.

Resilience Investments across NSF

As a critical partner within NEHRP and NWIRP, NSF leverages an array of funding mechanisms and infrastructure in support of these national priorities.

Standing programs across NSF receive and fund innovative unsolicited proposals relevant to natural hazards, including earthquakes and windstorms, and will continue to do so. Some of the key programs for disaster-relevant research proposals include the Engineering for Civil Infrastructure; Humans, Disasters and the Built Environment; Physical and Dynamic Meteorology; and Decision, Risk and Management Sciences programs. At the same time, programs across the agency fund projects relevant to natural hazards. For example, NSF computing investments in partnership with other research domains provide significant support for disaster-resilience research through programs such as Smart and Connected Communities and CIVIC innovation Challenge. Further, the STEM Education Directorate funded an important research projects undertaken in response to the Lahaina, Maui, fire, which examines the effects of trauma on education and the potential for educational environments to facilitate healing.

The vast majority of NSF research grants awarded, across the country and across all fields, include support for one or more undergraduate or graduate students. These projects provide students with hands-on, team science and engineering experiences working at the cutting edge of knowledge on real-world projects. Many students are motivated to continue their professional journey after graduation, and join the future workforce as colleagues.

NSF Research Infrastructure

NSF's Geosciences programs that fund work on geomorphology, geophysics, tectonics, and geodynamics processes at transform or rifting plate boundaries as well as at subducting margins have, over time, supported work that led to significant improvements in our understanding of how earthquakes originate, behave, and produce damage. None of this is possible without advanced scientific instrumentation and computational infrastructure.

NSF invests in the development of submarine geodetic and seismic instruments as well as their deployment and maintenance as a system of research infrastructure across the globe. The Global Seismographic Network (GSN), jointly funded by NSF and the USGS, consists of 150 globally distributed observing stations that provide high-quality seismic data rapidly for global earthquake alerts and situational awareness products, tsunami warnings, national security (through nuclear test treaty monitoring and research), seismic hazard assessments and earthquake loss reduction. GSN data is also invaluable for research on earthquake sources and the structure and dynamics of the Earth interior. The GSN provides critical data for rapid and accurate characterization of large earthquakes worldwide, ensuring the USGS National Earthquake Information Center is able to provide timely information on potentially damaging earthquakes. Recordings from GSN stations are also used for NSF funded research studies that may help provide input to USGS earthquake hazard maps and earthquake early warnings developed by the USGS.

Geoscience research infrastructure includes the NSF Geodetic Facility for Advancement of Geoscience (GAGE) and the NSF Seismological Facility for the Advancement of Geoscience (SAGE), which are mostly funded by NSF Geoscience with ancillary support by the USGS and NASA.

GAGE supports cutting-edge geoscience discoveries, applications, and education with geodesy for broad societal benefit. GAGE provides the foundation and infrastructure to support research on every continent across a broad spectrum of geosciences, facilitated by data, engineering, education, and community services. The GAGE Facility is committed to supporting and growing a diverse community of scientists and students toward advancing science for a resilient society.

SAGE is a distributed, multi-user national facility operated by the EarthScope Consortium providing state of-the-art seismic and related geophysical instrumentation and services to support research and education in the geosciences. This integrated set of facility capabilities enables advances in our understanding of Earth structure and dynamics, earthquakes and volcanic eruptions, and interactions between the solid Earth, hydrosphere, and atmosphere through the management and operation of:

- Global seismic networks that collect data continuously
- Portable seismic and magnetotelluric instrumentation for use in PI-driven and community experiments
- Data management systems that collect, provide quality assurance, curate, and distribute open access to raw geophysical data and data products
- Education, workforce development, and public outreach programs that engage a wide variety of audiences, including groups historically underrepresented in the geosciences

NHERI, a component of which was briefly mentioned above, is another prime example of facilities and tools that advance NEHRP and NWIRP program goals. NHERI is a distributed, multi-user network that allows researchers to investigate the effects of earthquake, wind and coastal hazards, and test ground-breaking concepts to protect individuals, communities and critical infrastructure. NHERI includes experimental facilities; a facility for field equipment and support for post-disaster, rapid-response research; high-performance computational modeling and simulation tools; and cyberinfrastructure. The NHERI cyberinfrastructure operated by the University of Texas at Austin provides information about all of NHERI's capabilities and includes a certified publicly accessible repository for researchers to archive and share data generated from their NSF-supported disaster-related research projects. The network also provides significant training, educational and public engagement opportunities. National leadership and coordination of these activities is the responsibility of NHERI's Network Coordination Office, based at Purdue University.

The NHERI Large High Performance Outdoor Shake Table at the University of California, San Diego, is an experimental facility that supports research in structural and geotechnical earthquake engineering. With an NSF-supported upgrade completed in 2022, the facility dramatically improved its ability to create realistic earthquake motions. The table previously could move with one degree of freedom; after the upgrade, it can move with six degrees of freedom. The NHERI shake table is now the largest shake table facility in the U.S. and possesses the biggest payload capacity globally. One of the first projects tested using the upgraded facility was the NHERI TallWood project, led by the Colorado School of Mines, which tested a 10-story mass timber building against previously recorded earthquake motions ranging from magnitude 4 to magnitude 8. The TallWood project team is part of a collaborative effort led by the University of Oregon seeking to advance mass timber technologies in the Pacific Northwest—a project that was among the first cohort of Development Awards made through NSF's Regional Innovation Engines program.

NHERI's windstorm-related facilities include the Boundary Layer Wind Tunnel for Scaled Wind Hazard Research at the University of Florida, one of the largest and most diverse suites of wind hazard experimental research facilities in the world, and the Wall of Wind (WOW) at Florida International University (FIU), which enables scientists and engineers to perform hurricane mitigation research to better understand how wind speeds impact civil infrastructure systems and how to prevent wind hazards from becoming community disasters.

The research enabled by NHERI facilities often has applications across multiple natural hazard types. For example, the NHERI geotechnical centrifuge facility at the University of California at Davis provides users with access to geotechnical modeling resources that include 9-meter and 1-meter radius centrifuges, both with shake tables. Experiments on the centrifuges, with detailed, reduced-scale models, outfitted with large numbers of sensors, enables major scientific and engineering advances for a broad range of soil and soil-structure systems, such as building foundations, bridge foundations, near-shore and off-shore energy infrastructure foundations, underground structures, pipelines, ground improvement technologies, wharves, embankment dams, and levee systems affected by earthquake, wave, wind, and storm surge loadings.

NHERI's multi-institutional Computational Modeling and Simulation Center (SimCenter), led by the University of California, Berkeley, is developing models and techniques for regional hazard simulations. These simulations aim to integrate diverse data sets into comprehensive regional-scale simulations of natural hazard effects, simultaneously advancing computational science and natural hazard science and building multidisciplinary networks of collaborators. Of particular interest for NWIRP, the SimCenter has developed loss models for major hurricanes in Atlantic City, New Jersey, and Lake Charles, Louisiana. Relevant to NEHRP priorities, the SimCenter is building two testbeds to assess building performance at a regional level, one focused on Anchorage, Alaska and the other on the San Francisco Bay area.

In the foregoing review of research infrastructure, we mention many times the importance of data and computing across Natural Hazards research – for modeling and simulation, analysis, open science sharing, and increasingly multi-disciplinary, multi-hazard collaboration and integration. These new computing- and data-intensive modes of science and engineering research – driven by NSF's experimental research infrastructure – would be impossible without the concomitant NSF investments in large-scale computing, data, networking, and software cyberinfrastructure, as well as the investments in training and workforce development for research technologists to design and build that infrastructure and hazards researchers to use it. Moreover, the rapidly growing centrality of artificial intelligence in facilitating analysis of complex multi-modal hazards data and improving prediction capabilities again highlights the importance of NSF's investments in computational and data capabilities and in foundational computer science research that are helping to keep the nation on the cutting edge of AI research and research use of AI.

Fast Response Research Capabilities

As natural disasters unfold, it is vital to record and preserve information that would otherwise be lost and is impossible to replicate. NSF has the capability to make awards for this sort of work quite quickly — in a matter of weeks or even days — through its previously mentioned RAPID funding mechanism. Any NSF program can fund a RAPID award if there is danger that an important scientific opportunity will otherwise be lost because the relevant data, facilities, or specialized equipment will only be available for a short time. Through RAPID projects, NSF invested in research in the immediate aftermath of several earthquakes and major windstorms, including: the 2020 magnitude 6.4 earthquake sequence in Puerto Rico; 2021 magnitude 8.2 earthquake offshore of the Alaskan Peninsula; wind-rainfall interaction in Hurricanes Florence and Michael in 2018; the Easter Sunday 2020 tornadoes; the U.S. Midwest 2020 derecho; and Hurricane Ian in 2022.

The agency also funds eight standing fast-response research networks, called Extreme Event Reconnaissance (EER) Networks, that are ready to deploy as disasters unfold. These community led EERs collect crucial, ephemeral data that will help answer research questions about U.S. infrastructure and community resilience. These networks coordinate with each other through the NHERI CONVERGE hub at the University of Colorado, Boulder. CONVERGE houses two EERs of its own focused on human and community impacts of disasters, the Social Science Extreme Events Research and the Interdisciplinary Science and Engineering Extreme Events Research networks. Importantly, it also coordinates the leadership teams of all the NSF-funded EERs, as well as a Public Health Extreme Events Reconnaissance Network recently established through a partnership with the Centers for Disease Control and Prevention, to ensure continuous improvement of EER operations. CONVERGE offers training and tools that convey best practices for safe, ethical, and rigorous extreme events research. Their training modules are certified by the International Association of Emergency Managers for continuing education credit. To date, more than 10,000 modules have been completed by more than 9,000 registrants.

Importantly, during disaster responses, it has become common for EERs to connect in real time with each other, with other university researchers, and with Federal researchers, to share who is gathering what sort of data and where, as well as imagery, forecasts, and warnings that can help them operate safely and effectively during dangerous times. During Hurricane Ida (2021), for example, NOAA, NIST, and the Army Corps of Engineers were among the agencies coordinating with others through the Slack channel created by StEER and hosted on NHERI's DesignSafe cyberinfrastructure facility.

Also, in support of rapid-response research, NHERI includes a Natural Hazards Reconnaissance Facility (referred to as the "RAPID Facility"), which is a collaboration among the University of Washington, Oregon State University, Virginia Tech, and the University of Florida. This facility equips natural hazards and disaster researchers with equipment and capabilities – such as portable seismic, laser, and radar instruments; drones; and a wide range of specialized cameras -- to conduct advanced rapid response investigations into building and civil infrastructure performance and community responses to natural hazards. The data are used to evaluate the effectiveness of design methodologies, calibrate simulation models, and develop solutions for resilient communities. Since opening its doors in 2018, this facility has supported 139 post-disaster reconnaissance missions.

NSF Partnerships

The Disaster Resilience Research Grants (DRRG) program, run in partnership with NIST, also advances the goals of both NEHRP and NWIRP. DRRG advances fundamental understanding of disaster resilience in support of improved, science-based planning, policy, decisions, design, codes, and standards. One DRRG project led by the University of California, Los Angeles, aims to transform the way that physical damage to infrastructure is estimated in the aftermath of a major disaster event. The UCLA team is using AI to develop near real-time infrastructure damage prediction models that can process and utilize different types of data and information for greater situational awareness, thereby enhancing the emergency response and recovery planning phases that follow. Another example, from San Jose State University, has developed new instruments to better track fire behavior in wildlands.

NSF also collaborates with other agencies to coordinate for enhanced disaster resilience as a member of the congressionally-established Interagency Coordinating Committee on Landslide Hazards. In addition, NSF is an active participant on the Subcommittee for Resilience Science and Technology and the Working Group on the Science for Disaster Reduction established by the Executive Office of the President. NSF makes special contributions to all these bodies by supporting fundamental research across science and engineering fields; as a provider of major, shared natural hazards research infrastructure; and as a steward for STEM education and training of the nation's future science and technology workforce.

Looking Forward

Looking forward, NSF will continue to leverage research across all fields of science, technology, engineering, and mathematics, and all levels of STEM education, encouraging the conduct of convergent approaches to research. The facilities, fundamental research, and researchers supported by NSF are — and will continue to be — key to achieving our shared goal of preventing natural hazards, including earthquakes and windstorms, from becoming societal disasters.

We see some emerging areas where NSF can make significant impacts through coordination and partnerships with the other NEHRP and NWIRP agencies. These include:

- expanding opportunities for a diverse, world-class next generation of researchers in the U.S. who can advance knowledge and solutions related to natural hazards;
- increasing the effective integration of Federal and university-based researchers and sharing of data and resources for post-disaster reconnaissance; and
- growing connections between resilience- and climate-related research and education to enable the best possible models and forecasts.

NSF will continue to bring its collaborative and agile approach to supporting research and innovation to bring the science and engineering research communities to bear on pressing societal challenges such as natural hazards. This work has long been a part of NSF's critical mission and was further emphasized with the enactment of the CHIPS and Science Act of 2022. The legislation included "natural and anthropogenic disaster prevention or mitigation" as one of the initial 10 key technology areas for NSF's Directorate for Technology, Innovation and Partnerships (TIP), alongside topics such as AI and biotechnology, as well as societal, national, and geostrategic challenges such as climate change and environmental sustainability — all of which are examples relevant to today's hearing.

In 2021, NSF created the Civic Innovation Challenge (CIVIC), a research and action competition that accelerates the transition to practice of foundational research and emerging technologies into communities through civic-engaged research. CIVIC is laying the foundation for a broader and more fluid exchange of research and technology capabilities and civic priorities through joint partnerships involving civic stakeholders and the research community. The program has had a major focus on how research can enable community resilience to natural disasters and other hazards. Examples include projects that seek to create a Flood Resilience Framework for comprehensive disaster response and long-term community recovery in West Virginia and creating rural resiliency hubs in central Florida.

The recently announced Responsible Design, Development, and Deployment of Technologies (ReDDDoT) program, which constitutes a collaboration led by NSF's TIP directorate, other directorates, and five philanthropic partners, will fund research that will examine the implementation and impacts associated with responsible deployment of these key technologies. The key goal of the program is to ensure that ethical, legal, and societal considerations and community values are embedded into the lifecycle of technology's creation and use, promote the public's wellbeing, and mitigate harm. AI, biotechnology, and natural and anthropogenic disaster prevention and mitigation are the initial areas for focus for the FY 2024 version of the program.

The NSF Regional Innovation Engines (NSF Engines) program — a transformational investment for the NSF, Federal Government, and nation called for by the CHIPS and Science Act of 2022 — seeks to catalyze place-based research, innovation, and workforce development all across the U.S. The program is investing in regions and communities, particularly those that have not benefited from the technology and innovation booms of the last several decades, transforming them into national and global leaders of technology development, translation, and adoption in key topic areas. NSF Engines will catalyze new technologies, train diverse talent, and grow regional economies and create new jobs. The NSF Engines program announced 44 planning grants in May 2023, investing $1 million per project for up to two years to support coalition building toward regional innovation ecosystems for future NSF Engines proposals. That portfolio includes multiple projects focused on sustainability and climate resiliency. One such project, a Development Award led by the University of Puerto Rico, is focused on advancing coastal resiliency in the Caribbean. Ultimately, the NSF Engines program has the potential to be a key contributor in realizing long-term U.S. competitiveness and security across the 10 key technology focus areas identified in the CHIPS and Science act of 2022, including in natural and anthropogenic disaster prevention or mitigation.

In addition to ReDDDoT, NSF Engines, and other exciting new initiatives, NSF is continuing to invest in programs such as the National Artificial Intelligence Research Institutes (AI Institutes). Among the AI Institutes portfolio is the Artificial Intelligence for Environmental Sciences (AI2ES) Institute led by the University of Oklahoma. AI2ES is a convergent, multi-sector institute that brings together researchers in AI, atmospheric science, ocean science, and risk communication to develop user-driven trustworthy AI that addresses the diverse data and research needs of pressing environmental concerns. By directly engaging environmental scientists and risk managers, AI2ES will improve the Nation's understanding of severe weather and ocean phenomena, will save lives and property, and will increase societal resilience to climate change.

Natural hazards of various kinds threaten almost every corner of our country, from the coasts to the plains, from small towns to big cities. Through partnerships and collaborative research, NSF is developing ways to engage vulnerable communities in resilience research. NSF's commitment to equity is also important for the future of resilience research. We are growing opportunities to bring diverse groups of people into the U.S. science and engineering workforce, to reach the missing millions and add their unique and valuable knowledge and perspectives to science and solutions. NSF invests about $1 billion each year in its Broadening Participation programs and projects at institutions across the country, including Historically Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCU), and other Minority Serving Institutions as well as those with individuals in historically underrepresented and underserved groups. The NSF Historically Black Colleges and Universities-Undergraduate Program (HBCU-UP) provides awards to strengthen STEM undergraduate education and research at HBCUs. One example of a natural hazards-related project is an HBCU-UP Research Initiation Award (RIA) at the University of the District of Columbia in which researchers are seeking to improve the management of earthen levees against multiple hazards, such as floods and earthquakes.

By bringing all fields of science and engineering to bear on resilience, by partnering with other agencies and organizations, and by including people from all geographic and demographic backgrounds, NSF can strive to deliver the benefits of our investments to everyone in the U.S.

NSF appreciates the longstanding support of Congress that has enabled the agency to support research, education, and advanced infrastructure in many priority areas. With the continued support of this Committee and the Congress, NSF will continue investments that lead to greater understanding of all natural hazards, including earthquakes and windstorms, their impacts on communities, and the resilience of communities across the country — an example of how NSF-funded research and researchers positively impact the nation and help secure our future.

Thank you for the opportunity to testify before you today.