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Successful coordination of the distributed network, Natural Hazards Engineering Research Infrastructure

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A Network Coordination Office (NCO) is at the core of the Natural Hazards Engineering Research Infrastructure (NHERI), a national, 12-component, distributed research network, funded by the National Science Foundation (NSF). NHERI is focused on research that both mitigates damage and increases resilience from natural hazards such as hurricanes and other extreme windstorms, storm surge, tsunami waves, and earthquakes. NCO activities engage all facilities within NHERI, uniting the network's four diverse component types comprised of experimental facilities, a cyberinfrastructure for data and computing resources, a center for the creation of modeling and simulation tools, and a repository of equipment, software and support for rapid reconnaissance. Outcomes from NCO governance activities include two network-wide summits, five international partnerships, a central scheduling tool, and a means for external evaluation. The NCO's education and community outreach has established an extremely successful pipeline for engineering education from elementary and secondary educators to undergraduates, graduate students, and early career faculty. The NCO conducts centralized communication activities such as newsletter publication, e-mail announcements, podcasts, and social media engagements that unite the natural hazards research community and amplify NHERI's impact. Led by the NCO, the NHERI Science Plan presents a long-term vision for the natural hazards research community and serves as a roadmap for future high-impact, high-reward, hazards engineering and interdisciplinary research at NHERI facilities. The NCO also promotes technology transfer through education and one-on-one engagement with researchers. Overall, the NCO unifies and strengthens the research network through its variety of initiatives, amplifying the impact of this multifaceted NSF research network and provides a template for the management of large, distributed research networks.

KEYWORDS

NHERI, distributed research network, natural hazards network, research network governance, engineering education pipeline, education and community outreach, extreme events research, natural hazards engineering

Introduction

Since 2015, the NHERI has operated through NSF support as a Mid-Scale Research Infrastructure, where mid-scale is defined as a research infrastructure—including equipment, cyberinfrastructure, large-scale datasets and personnel—whose total project costs are under $20 million. NHERI is a US nationally distributed, 12-component (Figure 1), multi-user facility that provides the natural hazards engineering community with access to research infrastructure. NHERI facilities enable investigators to study damage mitigation from hurricanes and other extreme windstorms, storm surge, tsunami waves, and earthquakes. At the heart of the NHERI is the NCO, and functioning within the NCO are network governance, education and community outreach, centralized communication, science visioning, and research-to-practice initiatives. The governance structure consists of the Council of NHERI awardees, the Network Independent Advisory Committee (NIAC), and the User Forum (UF).

Two funded prototype expansion facilities, NEWRITE and NICHE (indicated by yellow dotted lines in Figure 1), do leverage resources of the NHERI network and most particularly those of the NCO. The NCO engages in promotional communication activities for these upcoming facilities and offers consultation in methods for incorporating technology transfer into their planning. Future research at NICHE is also included in the recent Science Plan (NEWRITE was awarded after the latest Science Plan).

There are, of course, many other natural hazards research institutes located both in the Americas and Europe. Some examples include the US Center for Wind Hazard and Infrastructure Performance (WHIP), funded in 2019 under the NSF Industry-University Cooperative Research Centers Program, focusing on a single hazard, wind; it is a collaborative effort between Texas Tech University and Florida International University with industry partners in insurance and construction. Another network centered at a single university is the University of South Florida's Natural Hazards Network which consists of 50 faculty, cross-cutting university disciplines and also working with industry and policymakers to address causes, mitigation, and response to natural hazards and disasters. In Europe, the Joint Research Centre's European Crisis Management Laboratory adopts a multi-hazard approach as a research, development, and test facility that focuses its efforts toward effective crisis management resulting from threats and natural and man-made hazards. The European Commission is quite supportive of the research infrastructure paradigm. Two examples are 1) ESS, the world's next-generation neutron science facility, a pan-European project with 13 European nations as members, and 2) ELIXIR, a distributed infrastructure for life science information, bringing together scientists from over 240 research institutes spread

FIGURE 1
The Natural Hazards Engineering Research Infrastructure (October 2024). Twelve distributed, university-based facilities (blue dotted lines) plus two funded prototype expansion facilities, NEWRITE and NICHE (yellow dotted lines).

over 21-member countries and three observer countries. One other research infrastructure is UKCRIC, a multidisciplinary 16-member network of United Kingdom universities connecting research with policy and practice in infrastructure and urban systems. The NHERI NCO has already initiated formal communications with UKCRIC, expecting that we can mutually benefit from our shared experiences in management of a distributed research network, education and outreach, and in the conversion of research into practice. Though there are clearly other networks of research infrastructures, the coordination of these networks is not widely publicized. This work aims to reveal the details of an effective coordination office, the NCO, for a distributed research infrastructure, NHERI.

The leadership and guidance of the NCO has had a profound influence on the success of the network, which is further illustrated by NSF's renewal of the NCO component, announced in August 2024. As the administrative core for the network, the NCO appears at the top of the NHERI wheel in Figure 1. The NCO's role is to lead the organization of network-wide activities such as governance, educational programs, communications, scientific planning, and technology transfer. Indeed, the NCO functions as the network's hub; NCO activities engage all other facilities, uniting the network's diverse components. As "coordination" implies, the NCO team unifies and strengthens the network by guiding, educating, communicating, organizing—and overall amplifying the impact of this multifaceted NSF research network.

The NCO itself is comprised of 15 members, 9 of whom are subject matter experts in various engineering fields that encompass the natural hazards engineering focus of the network. Engineering fields covered include geotechnical, earthquake, tsunami, wind, and coastal as well as the social sciences. These nine experts include a Director of the NCO with the remaining eight persons functioning as the NCO Strategic Committee, which meets bi-weekly to report, discuss, and plan the variety of activities undertaken by the NCO. Additionally, a representative from the User Forum (described under GOVERNANCE) also attends regularly to facilitate communication between the NCO and this governance group. Interaction with another governance group, the Council of NHERI principal investigators, is accomplished through monthly meetings and the NCO director is the convener. The third governance group, the Network Independent Advisory Committee, meets twice a year where the NCO both facilitates and reports at these meetings. Under the same Governance category shown in Figure 2 approximately 5% of the total NCO budget is allocated to support international collaborations in the form of support for participants to attend research collaboration planning meetings, workshops and international conferences. Aside from the Strategic Committee, there is a facility scheduler and operations coordinator whose activities fall under Governance, a communications manager, software engineer, and half-time research assistant who handle the bulk of the Communications effort, and specialists in education and engineering education that focus on the Educational and Outreach aspect of the NCO. Several Strategic Committee members serve in multi-faceted roles overseeing the Education, Communication, Science Planning, and Technology Transfer functions of the NCO. All efforts by NCO personnel are equivalent to the work of 4.5 full-time employees per year. A breakdown of funded personnel by NCO activity is presented in Figure 2. Communications uses the largest portion of the personnel at 46%, while the education and governance

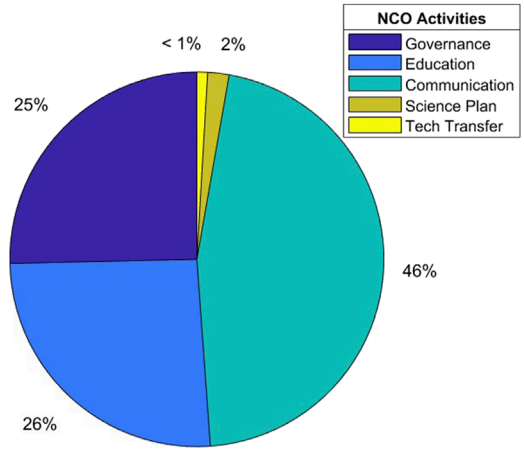

FIGURE 2
NCO personnel breakdown. The NCO activities of governance, education, communication, science planning, and technology transfer shown as a percentage of the total 4.5 full-time employee annual effort of the NCO.

functions consume 26% and 25% of the personnel, respectively, of the NCO effort. The other activities, Science Planning and Technology Transfer rely on partnerships with external volunteers to carry out the mission of these activities.

While personnel costs of the NCO Education effort are incredibly streamlined and efficient, approximately 50% of the total NCO budget is allocated to Education, which is largely to support participants in network-wide activities to strengthen the career development pathway in natural hazards engineering. The NCO subsidizes approximately 30 participants who attend the network's annual Summer Institute for early-career researchers and the 30 undergraduates selected for the network's 10-week Research Experiences for Undergraduates (REU) summer program. These educational activities developed and executed by the NCO have created pathways for emerging natural hazards professionals to experience research opportunities as undergraduates, graduate students, early career faculty, and additionally impacts career promotion and success in obtaining NSF awards.

In addition to NHERI, there is only one other NSF operational Mid-Scale Research Infrastructure that involves multiple, distributed facilities, the National Nanotechnology Coordinated Infrastructure (NNCI). NNCI contains 16 distributed facilities across the nation and a coordinating office at Georgia Tech University; two other mid-scale distributed, multi-awardee networks have been funded by NSF but are in the implementation stage. The NNCI coordination office has a number of similar constructs as the NHERI NCO. For example, NNCI Coordination includes an Executive Committee and an External Advisory Board, analogous to the NCO's NHERI Council and Network Independent Advisory Committee (NIAC), detailed in the "GOVERNANCE" section. While NNCI has Associate Directors overseeing the areas of education and community outreach, computation, and entrepreneurship, the actual implementation of programs and activities seems to occur at a working group level between network participants, a very different construct than that of the NHERI NCO.

While the NHERI network is focused on natural hazards engineering, its successful programs can be emulated and leveraged by other large, distributed research network. This paper elucidates key elements of the NHERI network coordination office, the facility that sustains and advances a nationally distributed network of 12 NSF-funded research facilities at 11 R1 institutions (dotted blue lines in Figure 1). Note, for classification as an R1 (Very High Research Activity) university by the Carnegie Classification of Institutions of Higher Education, a university must spend at least $50 million on research and development annually and award at least 70 doctoral research degrees annually. We will discuss the particulars of NCO network governance, network-wide educational programs and community outreach, network communications, science planning, and research technology transfer. Importantly, we will detail the impact NCO efforts have had on the natural hazards research community. For a list of NCO faculty and staff, visit the NCO website.

Governance

In this section the three governance groups are described, and examples of the positive impact of activities lead by the NCO through these governance groups are provided. With the NHERI network spanning 12 universities (dotted blue lines in Figure 1) and consisting of components that vary widely in their capabilities, the goal of an NCO-supported and coordinated governance is to empower NHERI components into a coherent and collaborative network where the outcome is greater than the sum of the individual component's contributions. The NHERI NCO's charge is to build and engage the natural hazards community, educate and train future researchers and professional engineers, and effectively disseminate information to the NHERI community. Effective governance requires regular engagement from all network principal investigators and feedback from independent external reviews. Successful network governance relieves the individual components from negotiating the network's international partnerships, supports them in establishing independent user satisfaction, and enables transparent user access to the network research laboratories. In the 8 years since its establishment in 2016, the NCO has led NHERI via a governance structure consisting of the Council of NHERI awardees, the Network Independent Advisory Committee (NIAC), and the User Forum (UF). Each of these groups with a specific role is described next.

NHERI Council

It comprises all network principal investigators (PIs) and meets monthly to discuss network-wide events, research initiatives and projects, partnerships, and related items that affect NHERI. The meeting chair rotates through the network PIs. Each of the PIs are nationally recognized in their field, and have significant research and leadership experience managing experimental facilities at R1 universities. The Council provides collective and coordinated leadership for NHERI as a national facility.

Network Independent Advisory Council (NIAC)

The NIAC provides high-level, independent guidance and advice to the NHERI Council. The NIAC is a group of representatives from the broad scientific and engineering communities, composed of practicing engineers, engineering faculty, and representatives from federal agencies such as the Army Corps of Engineers; their successful engagement with NHERI components has resulted in a number of significant accomplishments benefitting the NHERI community broadly, and the users of the components in particular. For example, the NIAC has placed an emphasis in NHERI on 1) ensuring a good balance of fundamental engineering studies and applied or transferable research, 2) interdisciplinary work encompassing the full spectrum of natural hazards research, and 3) eliminating barriers to external use of the experimental facilities.

The NIAC has achieved this through its engagement with all the NHERI components in virtual and in-person individual interviews. For instance, the NIAC had its face-to-face 2023 meeting in San Diego, CA, at the NHERI UCSD facility on May 22–23. The NIAC group toured the recently upgraded LHPOST6 shake table and witnessed 6 different tests of the Tallwood project (Pei et al., 2017). While on-site, the committee also held virtual meetings with 6 NHERI facilities, including the NCO, and held an executive session in preparation for writing its annual report to the NCO and the NHERI network. Two of the NIAC's conclusions are that "both internal and external research is carried out at most [NHERI] facilities and the facilities are fully invested in serving as national resources for large scale testing and research" and that "interviewed sites are receiving good support from the NCO". In 2025, the NIAC conducted its review from Florida International University's Wall of Wind facility during the period 24–25 February.

User Forum (UF)

Members of the NHERI User Forum are elected by the natural hazards community and represent the earthquake, wind, coastal and storm surge, and social science interests. They include nine individuals from universities and government agencies, practitioners and educators. The role of the Forum is to monitor, via annual surveys, user satisfaction of the NHERI facilities. In addition, the User Forum raises awareness about NHERI research and its impact.

The User Forum has led the execution of the annual User Satisfaction Survey and the results are posted on the NHERI platform for cyber-collaboration (DesignSafe-CI) here. For NHERI Y5 (FY 2021) through Y7 (FY 2023), a module was developed specifically to be incorporated in the Exit Survey of researchers at the NHERI facilities, to increase the response rate of the survey. The implementation consisted of a module of questions appended to most experimental facility user surveys beginning on Jan 1; collection occurs throughout the year on a rolling basis. Added to the UF survey were "4 big questions", which are designed to yield a broad-level overview on user satisfaction. Questions featured mixed-response options that captured both qualitative and quantitative data. As in 2022, the user satisfaction subcommittee opted to send the 2023 survey to a targeted population of known

NHERI facility users. Known NHERI facility users were identified with assistance from NHERI facility PIs at NHERI experimental facilities. The User Forum is preparing the FY 2025 User Satisfaction Survey, with plans to include in the survey questions about the NHERI Graduate Student Council. The User Forum meets monthly, including an in-person meeting at the NHERI Summer Institute convened in San Antonio, TX, on June 23, 2023. The approved minutes of the Forum meetings can be found at the User Forum webpage in DesignSafe-CI.

The combined efforts of the Council, NIAC, and User Forum have led to: (i) development of NHERI-wide metrics that illustrate the participation of the user community and the support NHERI provides to its research efforts, and these have been implemented with concurrence from NSF; (ii) dissemination of the impact of NHERI while continuing to build a community of satisfied multi-hazard users, and (iii) execution and publication of the Y-7 User Satisfaction Survey.

Outcomes of collaboration

The effective collaboration of all governance groups, with the leadership of the NHERI NCO, has brought to reality a number of network-wide efforts. In September 2024, NHERI leaders held sessions at the United Nations General Assembly (UNGA 79) Science Summit. Additional efforts have been funded by NSF through award supplemental activities in the annual work plan of the Council. Examples of these activities are the community-driven NHERI Science Plan (Robertson et al., 2023) and two successful community-wide research summit events.

The first Natural Hazards Research Summit took place October 6–7, 2022 at the National Academy of Sciences in Washington, DC. Day one consisted of a town-hall style visioning session in which attendees took deep dives into the research needs and priorities for the profession and the communities we serve. On day two in focused workshops and discussions, summit attendees provided ideas and specific input toward the future of natural hazards engineering research (Bridge et al., 2023). On May 14–15, 2024 at the University of Maryland, a second Natural Hazards Research Summit highlighted findings from the much anticipated NHERI Decadal Visioning Study 2026–2035 (Schneider and Kosters, 2024). In summit talks and concurrent sessions, attendees learned about new and interdisciplinary research underway; a special panel engaged attendees in discussions of technology transfer for natural hazards research projects.

Initiating international partnerships

Such a large research network as NHERI brings the benefits of scale to partnerships with international research organizations for research collaboration, shared-use facilities of mutual benefit, data exchanges, and workforce development contributions aimed at preparing the next-generation of leaders in the field. On behalf of NHERI, the NCO initiates, executes, and maintains formal NSF agreements with leading research organizations in Japan, Taiwan, and Europe for research collaborations in earthquake, wind, and coastal engineering. For current international collaborations, three letters of agreement (LoAs) are listed on the NHERI DesignSafe-CI website (https://designsafe-ci.org/facilities/nco/partnerships/). The first is with the National Research Institute for Earth Science and Disaster Resilience (NIED, nicknamed "E-Defense") in the city of Miki, north of Kobe, Japan. The second is with the National Center for Research on Earthquake Engineering (NCREE) in Taiwan. A third is with the non-profit European Centre for Training and Research in Earthquake Engineering (EUCENTRE) in Pavia, Italy. Since the beginning, the EUCENTRE involvement in over 30 research projects funded by the European Commission has led to the development of fruitful and lasting collaborations with about 300 European partners, including the most important research centers in the field of earthquake engineering and seismology. The latter two partnerships with NCREE and EUCENTRE are currently undergoing renewal.

In January 2024, at a planning meeting hosted by the NHERI UC San Diego facility, an important new phase of the U.S.-Japan earthquake engineering research collaboration began. Following this productive reunion in July 2024, a Memorandum of Cooperation was signed by Japan's National Research Institute for Earth Science and Disaster Resilience (NIED) and Purdue University on behalf of the NSF-funded NHERI Network Coordination Office. The NCO and NHERI firmly believes that collaboration between American and Japanese researchers provides an incredibly strong mechanism for accelerating the pace of discovery and development in engineering that is needed to prevent natural hazards from becoming societal disasters. Specifically, this U.S.-Japan partnership focuses on earthquake engineering with interest on the physical and economic harm that hazards are having on our communities, including cascading effects among multiple hazards. For more than a half century, U.S. and Japanese researchers have a history of smooth and effective collaborations. They began with the NSF-funded George E. Brown Jr. Network of Earthquake Engineering Simulation (NEES) and E-Defense in 2004, and then continued with the NHERI and E-Defense partnership in 2017. Now, we are enthusiastic about our renewed U.S.-Japan collaboration.

The historic NHERI-E-Defense collaboration has led to many landmark shake table tests; the most recent is the large-scale test of a reinforced concrete structure under the Tokyo Metropolitan Resilience Project. Several U.S. researchers participated in this test through payload projects that allowed the evaluation of new data acquisition techniques never before tried in an experiment of this scale. Other tests have led to the implementation of new retrofit techniques and the performance identification of protective technologies. Moreover, data from more than ten large-scale experiments have been made public already in the DesignSafe-CI Data Depot, going back to the predecessor of NHERI, NEES.

Scheduling experiments

The NHERI NCO ensures smooth and transparent access to the network's eight experimental research facilities. To assist researchers planning to use network facilities, the NCO has developed a Facility Scheduling Dashboard tool. With this web-based tool, researchers and the general public can view research projects taking place at NHERI experimental facilities. This centralized approach has a number of benefits to the research community:

- It limits schedule conflicts between researchers
- Researchers outside of the facility's home institution have equal priority
- Small 'payload' projects can identify larger projects to collaborate with
- Stakeholders can see the ongoing value and impact of the NHERI experimental facilities
- All projects are searchable
- Collaboration between researchers is enhanced due to visibility of experimental resources

The scheduler leads to more collaboration between researchers both inside and outside NHERI and maximizes utilization of the shared-use research facilities that comprise NHERI. One project that exemplifies the value of the NCO's centralized scheduling model within NHERI is the University of Florida-led 'Sentinel' instrument development (Phillips et al., 2023). This project was developed in collaboration with multiple NHERI experimental facilities and included field testing, as well as the involvement of NSF's Research Experience for Undergraduates (REU) students.

Education and outreach

Like all NSF awards, NHERI has a broad mandate to educate the next-generation of researchers. Within the NCO, a centralized education and community outreach (ECO) committee is comprised of representatives from each of the NHERI network components and led by the NCO. The ECO Committee ensures vital network-wide input into NHERI's educational programming. The NHERI ECO enables individual research facilities to focus on providing research opportunities centered on their own capabilities. In turn, the NCO ECO group shoulders the work of organizing network-wide educational programs. This includes organizing the annual Research Experiences for Undergraduates (REU) program and the annual NHERI Summer Institute (SI) for Early Career researchers. The ECO handles the task of organizing, managing, and reporting on the success of the NHERI network's educational efforts.

The NHERI ECO collects longitudinal data on these efforts, which have shown outstanding impact on the field of natural hazards engineering, as well as on the researchers and students who have participated in the REU and SI programs. Find the detailed outcomes in Nelson et al. (2025). Specifically, the NHERI ECO has had significant impact in engineering education. One example is NHERI's REU program, which has introduced 166 undergrads to natural hazards research. After the first 7 years of the program, 35% of these undergraduates went on to pursue graduate degrees with 8% already in PhD programs.

The NHERI ECO provides a diverse, connected pathway for academic engineering workforce development. The annual programs train and mentor elementary (ages 5-12) through secondary (ages 13-18), otherwise referred to as Kindergarten through 12th grade or K-12, educators, undergraduates, graduate students, and early career faculty. With a focus on broadening participation, the NHERI ECO encourages diversity in participants and recruits from non-R1 research institutions. NHERI strives to reach students at less elite research institutions where exposure to research opportunities are not commonplace. The NHERI ECO provides training in a wide array of natural hazards research, including geotechnical, wind, coastal, and structural engineering; field investigation; computational programming and analysis; simulation and modeling; and social science disaster studies.

Undergraduate education

The NCO's ECO helps plan logistics for the annual REU internship, in which each NHERI component mentors 2-4 undergraduates for 10 weeks. The students receive hands-on research opportunities at NHERI's world-class facilities as well as the community experience of fellow REU students, graduate student and faculty mentors. The ECO team provides the interconnections for all REU students across sites and ensures that all students have impactful educational outcome experiences. The NCO education team helps guide an inclusive recruitment and selection process and hosts mentorship training activities for site personnel. Throughout the internship experience, the education team holds weekly network-wide virtual activities for career and research skill development and then organizes an in-person research symposium at a selected NHERI site at the conclusion of the program.

Early-career training

The annual NHERI Summer Institute is a 3-day crash course in navigating NSF-funded academia for early career researchers. Participants learn how they may use NHERI facilities and get hands-on practice designing and writing an NSF grant—which often includes K-12 components to help promote broader impacts of the designed research work. K-12 teachers also participate in the Summer Institute. They partner with early career faculty to design effective K-12 lessons plans that guide early-career faculty and can be used in their classrooms.

Graduate student mentorship

The NHERI Graduate Student Council is a new addition to the NHERI community. It was created in October of 2021 and is administered by 19 graduate students on the Executive Committee: 7 officers and 12 Standing Committee Chairs and Vice Chairs. The 600-member Council is run by elected representatives, meets monthly on research topics, and holds an annual research conference. The Council participates in many NHERI activities, including the Summer Institute and NHERI Summits, and also presents NHERI work at related conferences to help broaden the impact of NHERI activities.

The impact of the centralized NHERI ECO is more than significant. Program managers from the National Science Foundation point to NHERI's programming as an example of a well-run educational pathway to STEM careers. Participation in NHERI's educational programs has also furthered the reach of the NHERI brand by engaging students and researchers from every state in the U.S.; the Graduate Student Council reaches international academic partners, as well.

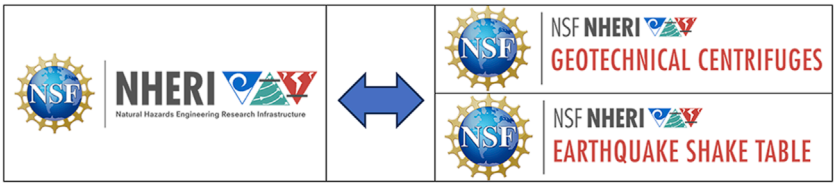

FIGURE 3
The NSF NHERI facility logos are derived from the NHERI logo, giving coherence to our 12-member network. Above see examples from two experimental facilities.

Communications

As part of its community outreach efforts, the NCO provides news and information that engages NHERI researchers and the broader natural hazards community. These centralized communication efforts unite the research community and amplify NHERI's impact, as well as the impact of the U.S. National Science Foundation.

Unifying the community

Since 2016, the NCO communications group has steadily built an audience for natural hazards engineering research. Starting from scratch, the NCO now reaches a broad audience that includes natural hazards researchers, practicing engineers, students from high-school through graduate school—as well as policymakers and people who may use NHERI-derived tools and techniques to mitigate damage. The general public also is interested in learning how NHERI researchers work to mitigate damage from events like hurricanes and storm surge, earthquakes and tsunamis. Ten years ago, very few people knew anything about "natural hazards engineering." Today, NHERI NCO messaging reaches 7,000 email subscribers and 8,500 social media followers. These figures are significant for an NSF-funded research award of its size and funding level.

The NCO publishes a bi-monthly newsletter that broadcasts current NHERI research and educational activities to the natural hazards engineering community. Initially, engagement was low; there was natural resistance to "yet another email." But over time, the NCO has earned the trust of the community. Currently, 40% of newsletter recipients now open and read this bi-monthly publication.

The NCO also distributes actionable email messages, such as invitations to join NHERI workshops and webinars. With centralized email broadcasting, the NCO enables the individual NHERI facilities to leverage the network to reach much larger audiences. For example, the NCO broadcasts customized emails for recruiting participants to NHERI workshops and webinars. On average, 70% of NHERI webinar registrations are the result of the NHERI NCO email broadcasts. In other words, the NHERI NCO communications team directly enables NHERI Network components to fulfill a key NSF mandate to train and educate users.

Another unifying role of NCO communications is maintaining and encouraging use of the network's visual branding standards mandated by NSF. Partnering with DesignSafe, NHERI's cyberinfrastructure component, the NCO maintains a branding toolkit for the NHERI community with NSF-approved logos and other communications tools. Each facility has a logo that reflects the NSF NHERI brand (e.g., Figure 3). Research faculty and staff use their logos in email signatures, on research posters, and in communications about facility events and opportunities. In the next 10 years of the NSF NHERI grant award, the NCO reckons that the NSF NHERI brand will be widely recognized as a key NSF-funded research organization.

Amplifying impact

To reach audiences beyond NHERI, including reporters and the public, the NCO publishes news stories to the NHERI website newsroom on DesignSafe-CI.org, the cyberinfrastructure hub of NHERI. Several other NCO communication activities expand the reach of NHERI. These include the following:

- a bi-monthly podcast called DesignSafe Radio, also published on YouTube, that features NHERI researchers and students;
- a strong social media presence on multiple platforms—including X, LinkedIn, and Facebook—that engages the greater natural hazards community, including government and non-government organizations;
- and a NHERI conference booth, which the NCO deploys at high-level engineering and natural hazards meetings.

NHERI NCO social media accounts tally thousands of followers. On the X platform alone, the @NHERIDesignSafe account has about 2,600 followers and averages 5,500 engagements each month. This reach is amplified by about 15 NHERI-affiliated accounts on X; these include accounts for the ECO Committee, the Graduate Student Council, the User Forum, and the podcast, DesignSafeRadio, as well as accounts associated with each of the NHERI facilities. Content shared on social media includes our news stories, podcast episodes, and a wide variety of events and opportunities initiated by NHERI facilities–such as workshops, research solicitations, and student internships. These engagements on X extend into LinkedIn, where NHERI receives 5,000 to 7,000 impressions each month, with a respectable two-percent engagement rate. Indeed, with its active social media presence, the NCO communications team is making NHERI, the NSF-funded natural hazards research network, a household name in the research community.

Supporting NSF research

At the heart of NCO communications are planned, strategic communications campaigns featuring the research and educational activities of the individual NHERI components. The campaigns consist of news stories, podcasts, and social media posts, all aimed at raising awareness of the ongoing research at an individual NHERI component. There are typically three campaigns ongoing at one time; they are driven by NHERI component priorities to maximize effectiveness. These targeted communications campaigns ensure all NHERI components have opportunities to broadcast specific research and education impact to both the public and the natural hazards community. Because most NSF-funded research awards do not have communications staff or budget, the NCO campaigns provide vital support—and much greater exposure for NHERI experimental facilities and their research.

Publishing NHERI facility research

The NCO tracks the impact made by the researchers who use NHERI facilities and data. Specifically, this translates to journal publications. Since 2014, more than 700 research papers have mentioned or acknowledged the Natural Hazards Engineering Research Infrastructure network, or NHERI. The NCO also coordinates special collections of research papers in the journal, *Frontiers in Built Environment*. This activity enables individual NHERI facilities to ensure high-impact projects taking place at their location can be peer-reviewed and published. Three such collections have taken place:

1. The collection entitled *Natural Hazards Engineering Research Infrastructure (NHERI) 2016–2020: Mitigating the Impact of Natural Hazards on Civil Infrastructure and Communities* is an introduction to NHERI and includes 16 articles. [Chowdhury et al., 2021; https://doi.org/10.3389/978-2-88971-186-4] This collection has experienced 140K topic views, 117K article views, and 117K article downloads.
2. The second collection is entitled *Technology Transfer from the Natural Hazards Engineering Research Infrastructure (NHERI).* It contains 6 articles and highlights examples of technology transfer from NHERI [Blain and Ramirez, 2023; https://doi.org/10.3389/fbuil.2023.1269036]. To date, this collection has 29K topic views, 24K article views, and 3,065 article downloads.
3. The final collection, currently in progress, is entitled *NHERI 2015–2025: A Decade of Discovery in Natural Hazards Engineering*, [https://www.frontiersin.org/research-topics/65402/nheri-2015-2025-a-decade-of-discovery-in-natural-hazards-engineering]. Its soon to be twelve articles that detail key research experiments and discoveries from the NHERI components over the award's 10-year existence.

Given the attention shown to these articles on NHERI facility research, the NCO's strategy to promote network research publications are a success–and a useful NHERI-centric complement to the numerous papers published each year by NHERI researchers.

In summary, the NCO's centralized communications efforts ensure opportunities for all components to engage with the research community and the public, given that individual NHERI components may not have a dedicated mechanism for sharing important news and information. Further, centralized communication reduces duplicative efforts, ensures uniformity in branding, and amplifies individual component activities and accomplishments. With NCO-managed communications, each component relies on NCO communications to "get out the message" on current research and events taking place at their facility.

NHERI's science vision

The NHERI Science Plan, its third edition published in November 2023, presents the long-term vision for the natural hazards research community, which includes NSF and other funding agencies. The Science Plan serves as a roadmap for future high-impact, high-reward, hazards engineering and interdisciplinary research at NHERI facilities. Research directions outlined by the Science Plan are targeted to mitigate damage and reduce casualties from natural hazards while promoting community resilience. The Science Plan can be downloaded from the NHERI DesignSafe Data Depot (Robertson et al., 2023).

The first edition of the Science Plan was published in 2017 based on a compilation of the individual science plans from each of the NHERI facilities. In 2019, the NCO organized an international workshop with participation of researchers from Taiwan, Canada, Japan, Italy and England to guide the development of the second edition of the Science Plan published in 2020. In 2022, another Science Plan workshop was held to develop the third edition of the Science Plan.

The primary objectives of the Science Plan are to:

- Incorporate the width and breadth of experimental capabilities of each NHERI facility, including sample research projects.
- Incorporate perspectives from interdisciplinary science and engineering as well as from social science aspects of hazard mitigation and management through an enhanced focus on interdisciplinarity, equity and inclusion, and collaborations with researchers from the NHERI CONVERGE facility;
- Incorporate input from extreme event reconnaissance and research (EER) networks coordinated by CONVERGE;
- Incorporate publicly available simulation tools developed by the NHERI SimCenter;
- Address the effects of climate change on natural hazards and associated infrastructure impacts;
- Encourage greater engagement of practitioner experience in proposal development, research execution, and implementation of research results;
- Provide a roadmap to assist researchers as they develop their research teams and proposals, perform the research, and shepherd implementation of their research findings into practice; and
- Provide examples of successful transfer of NHERI research findings to practice.

Members of the NCO take editorial responsibility for this key publication. For the third edition, an NCO team organized and formalized input from the nation's natural hazards community.

The team convened a workshop as well as an editorial task group consisting of 17 subject-matter experts that included engineering researchers, social scientists, and practicing engineers. The NCO also coordinated the broad dissemination of the NHERI Science Plan to the natural hazard community through an extensive communications campaign that included workshops, webinars, podcast appearances and video testimonials.

The NHERI Science Plan provides a bold vision for research to support an integrated view of hazard mitigation. It is designed to promote ongoing and meaningful engagement with practice, the leveraging and extension of NHERI components, and the professional development of a broad and diverse range of researchers and practitioners. It builds upon NHERI's prior success while engaging current and likely future trends in advanced methodologies, data, and supporting technologies. The sense of purpose, combined with ethics and ingenuity, are among the research community's greatest assets, so this document is not intended to constrain or limit ideas, but rather to identify high-value research needs and spark the development of meaningful research proposals. The Science Plan is meant to serve as a living document - one that will continue to be reviewed and updated to reflect new funding streams, projects, and challenges as well as new scientific breakthroughs and opportunities for further exploration.

Grand challenges

The Science Plan presents three grand challenges for the natural hazards research community.

- The first is to identify and quantify the characteristics of single, co-occurring, and compounding natural hazards - whether of geophysical and/or atmospheric origin - that have the potential to harm people, damage civil infrastructure, and disrupt communities.
- The second grand challenge is to assess the exposure, vulnerability, and adaptive capacity of civil infrastructure and social systems in areas threatened by natural hazards.
- The third grand challenge is to invest in a diverse hazards workforce and develop the technologies and tools to support the design, construction, retrofit, and operation of equitable, sustainable, and resilient civil infrastructure for the nation.

All three grand challenges are addressed through six, proposed key research questions. Each research question is discussed in detail in the Science Plan, including examples of research that would advance one or more of the grand challenge objectives. Successful implementation of many of the technologies and tools developed by NHERI researchers are highlighted below and in the following section on Research-to-Practice.

Success stories

For examples of high-quality natural hazards engineering research, the Science Plan includes five success stories where innovative research ideas have been investigated using NHERI facilities and transferred into everyday engineering practice. These include three research projects initiated by observations from field reconnaissance after Hurricane Maria in Puerto Rico, Hurricane Michael in the Florida panhandle, and hurricane storm surge effects on coastal fuel storage facilities. The other success stories feature the 10-story NHERI Tallwood building tested on the UC San Diego shake table in 2023, and the field verification of liquefaction mitigation using a microbially induced desaturation improvement technique with the help of the NHERI mobile shaker facility from the University of Texas. The Science Plan also features the success of the Babcock Ranch community in Florida that weathered the effects of Hurricane Ian with minimal disruption, serving as an example of the resilience provided by modern building codes and hazard-resistant residential subdivision planning.

Community engagement

To date, more than 1,000 copies of the Science Plan Third Edition have been downloaded from NHERI DesignSafe-CI.org. Early career researchers in particular are encouraged to cite the Science Plan in their grant proposals. At the annual NCO Summer Institute, early-career researchers are familiarized with the NHERI Science Plan. The NCO shares ways to leverage and cite the Science Plan when writing NSF proposals. Additionally, NCO members regularly speak on the Science Plan and how to use it at network-inclusive NHERI Summit meetings and at NHERI Graduate Student Council events.

Science plan user feedback

Researchers have referenced the NHERI Science Plan in their research proposals and provided valuable feedback on their experience with the Science Plan.

- Elaina Sutley, Associate Professor at the University of Kansas says "I think the Science Plan is really helpful, particularly for newer, more junior researchers. It certainly helped me understand how my research ideas fit into the bigger picture of natural hazards engineering research, and what is seen as important from our research community."
- Petros Sideris, Associate Professor at Texas A&M University says "I cited the NHERI Science Plan in my recently successful proposal. I think it is important to continue emphasizing the need for novel computational simulations informed by physical testing."
- Barbara Simpson, Assistant Professor at Stanford University commented that she cited the NHERI Science Plan in her successful research proposal as "*Thus, the work plan considers the NHERI Science Plan's objective to reduce reliance on experimental data through the development of more detailed numerical simulations and through the shake-table specimen re-use opportunity.*"

Ultimately, this plan is designed to spark new ideas and to facilitate use of the NHERI components and research infrastructure, all with a vision of a more resilient built environment and a

reduction in the harm and suffering caused by geophysical and atmospheric hazards.

Research-to-practice

Focus on technology transfer

A fundamental purpose of natural hazards engineering research is to develop new, sustainable designs and have them adopted into engineering practice, as well as to influence policies that enhance resilience. These engineering improvements may manifest as code changes, software tools, or new building components that can reduce damage from natural hazards. Specifically, these improvements in engineering practice and design strongly support the third grand challenge to extend the research and tool development through transfer of research into practice. For example, the NHERI SimCenter at the University of California has taken significant research findings and incorporated them into open-source numerical tools to characterize significant natural hazards and develop solutions to minimize the effects of those hazards on communities.

In a novel approach to technology transfer, the NHERI NCO appointed and led a Technology Transfer Committee (TTC) to guide and encourage NHERI researchers to envision the transfer of their research findings to practice. The Technology Transfer Committee is comprised of volunteer engineering practitioners and decision-makers who focus on strengthening ties between NHERI researchers and the implementers of NHERI-developed new knowledge. The TTC members are experienced in contributing to the development of design guidelines, technical briefs, building and infrastructure codes and standards, and technical seminars.

Educating the community

The TTC has provided a white paper detailing mechanisms for the implementation of NHERI research results that would facilitate technology transfer (NHERI Technology Transfer Committee, 2020). The TTC also offers free consultation services to researchers. They review NHERI research projects and speak directly to researchers to better understand issues that they face.

To increase awareness of the NHERI program and its research results, the TTC has created a database of the ten years of NSF Awards. This database encourages and facilitates potential implementor's investigations for applicable research results. The database also allows researchers, particularly early-career faculty, to review all NHERI projects and discover colleagues with similar interests.

As noted above, in 2023 the NHERI NCO sponsored a special collection of journal papers on NHERI technology transfer (Blain and Ramirez, 2023) entitled Technology Transfer from the Natural Hazards Engineering Research Infrastructure, NHERI. This collection includes six articles detailing the research-to-practice process associated with several NHERI projects and has had more than 29K total views.

Examples of research-to-practice impacts

High-profile NHERI projects that are resulting in technology transfer include:

- Mass-timber products as resilient material. "A Resilience-based Seismic Design Methodology for Tall Wood Buildings," also known simply as Tallwood, involved several NSF Awards stretching over almost a decade (Pei et al., 2017). The goal was to enable construction of seismically resilient tall buildings using sustainable wood material, known as mass timber systems. The culmination of the collaborations was shake table testing of a full scale 10-story Tallwood structure that included a "rocking wall" seismic resisting system and took place at the University of California San Diego NHERI facility. These successful tests point to future adoption of this new structural system.
- Incorporating building designs into ASCE7 standards. An NSF NHERI RAPID Grant (Sutley et al., 2020) facilitated the collection of valuable field data on damage to low rise buildings, particularly those elevated to avoid flood waters following Hurricane Michael in Florida in 2018. This data plus subsequent experimental wind tunnel testing at the NHERI facility at Florida International University, led to a determination of expected wind pressure loading on the floor undersides of elevated buildings for the first time. Results from this research were incorporated into the ASCE7 national standards for design of such structures, and will result in improved performance in future hurricanes.
- Incorporating wind speed maps into ASCE7 standards. The wide variety of experimental capabilities in the NHERI Network creates opportunities to coordinate and cooperate with other government agencies. Co-occurring funding from the National Institute of Science and Technology (NIST), FEMA, through the Strategic Alliance for Risk Reduction, and an NSF funded NHERI project "Exploring Machine Learning and Atmospheric Simulation to Understand the Role of Geomorphic Complexity in Enhancing Civil Infrastructure Damage During Extreme Wind Events", Masters et al. (2018) enabled characterization of the surface wind field over geometrically scaled models of Puerto Rico and the municipal islands of Vieques and Culebra. In these projects, the wind tunnel at the University of Florida and the DesignSafe cyberinfrastructure at University of Texas, both NHERI facilities, were utilized. Research results led to changes in the ASCE 7 standard wind speed maps for Puerto Rico.
- Influencing policy changes in Texas. Above ground storage tanks are subjected to wind, water, and debris impacts during windstorms, storm surge, and other events. A NHERI project developed probabilistic models of tank performance in severe storms (Bernier, C. and Padgett, J.E., 2020) using the advanced computational resources of the NHERI DesignSafe cyberinfrastructure, filling a major gap in risk assessment. The research helped influence new Texas State legislation on tank safety and is adopted by the U.S. Corps of Engineers when evaluating multi-billion-dollar investments in coastal protection.

The NCO's technology transfer efforts directly assist the National Science Foundation in achieving its goals. In fact, the NCO's Technology Transfer Committee could be viewed as a precursor of the NSF's 2022 new directorate: Directorate of Technology, Innovation, and Partnership, TIP.

Summary and future advances

The Network Coordination Office (NCO) is the core of the Natural Hazards Engineering Research Infrastructure (NHERI), the national, 12-component, distributed network. The multi-faceted role of the NCO includes network governance, education and community outreach, centralized communication, science visioning, and research-to-practice initiatives.

The leadership and guidance provided by NHERI's Network Coordination Office (NCO) fosters unity across the network through the NHERI Council, provides network feedback via external reviews by the Network Independent Advisory Council (NIAC), and gauges user satisfaction through activities of the User Forum. Furthermore, the NCO governance has facilitated coordination of two network-wide Summits in 2022 and 2024, negotiated international partnerships with research groups in Japan, Taiwan, and Europe, maintained a transparent network-wide scheduling tool, and produced multiple evolutions of a decadal science plan for natural hazards engineering research.

The NCO-led centralized education and community outreach (ECO) committee, comprised of representatives from each of the NHERI network components, organizes the annual Research Experiences for Undergraduates (REU) program and the annual NHERI Summer Institute (SI) for Early Career researchers. The NCO also established a unique, self-governing graduate student council as a means of mentorship. NSF recognizes NHERI's NCO educational programming as an example of a well-run educational pathway to STEM careers, including products for K-12 education to the inclusion of undergraduates, graduate students, and early career faculty.

The centralized communication efforts of the NCO unite both NHERI researchers and the natural hazards research community. Bi-monthly NHERI-centric newsletters, podcasts, e-mails, news stories, social media outreach, and publications all amplify the impact of NHERI's research and ensure opportunities for all components to engage with the research community.

The NHERI Science Plan presents a long-term vision for the natural hazards research community. It outlines a roadmap for high-impact, high-reward, hazards engineering and interdisciplinary research at NHERI facilities. Under the NCO's guidance, the Science Plan is designed to promote ongoing and meaningful engagement with practice, the leveraging and extension of NHERI components, and the professional development of a broad and diverse range of researchers and practitioners.

In a novel and effective approach to technology transfer, the NHERI NCO appointed and led a Technology Transfer Committee (TTC), comprised of volunteer engineering practitioners and decision-makers, to guide and encourage NHERI researchers to envision the transfer of their research findings to practice. TTC has shared a white paper on technology transfer detailing various mechanisms for implementation of NHERI research results with the NHERI community. Furthermore, the TTC has created a database covering 10 years of NSF NHERI Awards to encourage and facilitate potential implementor's investigations for applicable research results.

NCO activities engage all facilities within NHERI, uniting the network's diverse components. As "coordination" implies, the NCO team unifies and strengthens the network by guiding, educating, communicating, organizing—and overall amplifying the impact of this multifaceted NSF research network.

The NHERI NCO is presently undergoing a renewal and is prepared to continue guiding the NHERI network from September 2025 through September 2035. Knowing that the number of natural hazards events is ever rising and that new areas of concern within the nation's infrastructure are continually being identified, the need to organize and grow the natural hazards research base is stronger than ever. An expansion of the hazards to include wild urban interface (WUI) fire and inland floods is being considered for future work. There will continue to be a need to support and mentor the next-generation of natural hazards scientists and engineers at early points of their careers. The emphasis of our programs will need to adapt to the use of new technology and climate impact on the resilience of infrastructure to support activities and needs of communities. Moving forward, the NCO plans to continue and enhance ways to leverage international partnerships to continue accelerating findings, establishing new areas of growth, and honing best practices for network coordination. For the NHERI network itself, the future will likely include upgraded and expanded facilities, and the NCO must find ways to closely connect research in its infancy with future building codes and commercial outlets so that the latest new knowledge can translate into specific actions that protect people and property.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

CB: Conceptualization, Writing – original draft, Writing – review and editing. JR: Project administration, Writing – original draft. BE: Writing – original draft. WH: Writing – original draft. ML: Writing – original draft, Writing – review and editing. RN: Writing – original draft. IR: Writing – original draft. DZ: Writing – original draft.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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