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on
"The National Windstorm Impact Reduction Program"

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Introduction

Chairwoman Stevens, Ranking Member Waltz, and Members of the Subcommittee, it is a privilege to appear before you today to discuss the important role 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 investments contribute to the economic and national security interests of the nation, and development of a future-focused science and engineering workforce that draws on the talents of all Americans.

Over the past seven decades, NSF has funded 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, and even the polymerase chain reaction testing technique that has been critical in the fight against COVID-19 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, quantum information science, advanced manufacturing, advanced wireless and biotechnology, to name a few -- are rooted in sustained NSF support for research at the frontiers of science and engineering.

NSF is unique in carrying out its mission by supporting research across all fields of science, technology, engineering, and mathematics, and all levels of STEM education. This ability to leverage expertise across disciplines allows NSF to facilitate partnerships that 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. This also allows the agency to tackle 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.

Investing in Resilience

For decades, NSF has been investing in fundamental research and innovation to improve resilience to all sorts of natural hazards, including windstorms like hurricanes, tornados, and nor-easters. NSF-funded researchers examine the fundamentals of how windstorms form, move, change, and interact with earth, water, and climatic forces in order to improve prediction and risk assessment. They examine the behavior of buildings, infrastructure, and the natural environment in the face of wind forces, 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, communities, tribes, cities, states, and, of course, the nation.

In addition to the array of programs we will discuss today, a great deal of NSF's support is provided in response to proactive or "unsolicited" proposals from researchers throughout the country. This flexibility and responsiveness to the community allows scientists and engineers to submit their best research ideas without significant additional guidance or constraint. These are reviewed for their intellectual merit and also for their broader impacts that benefit society, such as relevance to disaster resilience. Standing programs across all our directorates – including education, biological, computing, physical, engineering, social and geosciences – receive and fund innovative proposals relevant to windstorms and other natural hazards and will continue to do so. Improved resilience is the sort of broader impact that advances NSF's mission.

Windstorms affect the entire nation, though the particular types of wind hazards vary regionally and their impacts vary enormously depending on what sorts of communities, industries, and infrastructures are in place. Our portfolio of unsolicited windstorm-relevant projects is thus, not surprisingly, highly varied. Across fiscal years 2020 to 2021, unsolicited research projects addressed challenges presented by hurricanes, tropical cyclones, storm surge, tornados, derecho, and chinook. 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.

In addition to funding unsolicited research, NSF issues special solicitations relevant to natural hazards and also funds major- and mid-scale infrastructure that enables new research questions

and solutions. One special opportunity that is pertinent to windstorm hazards is NSF's Coastlines and People (CoPe) solicitation. CoPe seeks proposals for research hubs that examine interactions between coastal processes – including storm surge and flood risks – with human dynamics and built environments. CoPe enables researchers and communities to collaborate closely as they take a problem-solving approach to coastal hazards. Together, researchers and communities develop research questions and produce important new knowledge. For example, one CoPe award is supporting a Research Coordination Network to find ways to improve the sustainability of Great Lakes communities to climate-driven disturbances like intensified storms.

Two other special solicitations that are important to NWIRP's goals are both partnerships with other agencies. The first solicitation, the CIVIC Innovation Challenge, like CoPe, solicits projects where communities and researchers co-define problems and solution approaches. CIVIC focuses on the creation of pilot technologies and tools to impact community-identified priorities. One of the two focus areas for CIVIC proposals, Resilience to Natural Disasters, is a partnership with the Department of Homeland Security. Recent CIVIC awards will enable, for example, the development of rural resilience hubs in Florida and new community tools for recovery from storm damage in Virginia's Hampton Roads area. The second solicitation that is particularly important for NWIRP is called Disaster Resilience Research Grants (DRRG). DRRG is a partnership with NIST that funds research to advance fundamental understanding of disaster resilience in support of improved, science-based planning, policy, decisions, design, codes, and standards. Of several hundred project ideas submitted, about a third were focused on windstorm and relevant to NWIRP goals. We look forward to announcing these awards in fiscal year 2022.

In terms of research infrastructure pertinent to NWIRP priorities, NSF funds a distributed, multi-user, national Natural Hazards Engineering Research Infrastructure (NHERI) facility network that includes experimental facilities, high-performance computational and data management assets and tools, training and networking opportunities relevant to facility use and disaster-relevant research, as well as significant educational opportunities and public engagement. National leadership of these activities is the responsibility of NHERI's Network Coordination Office, based at Purdue University. NHERI currently includes two experimental facilities for wind hazards and one for coastal hazards, as well as a computational modeling simulation center and a facility that provides equipment and support for post-disaster, rapid-response research.

NHERI's Boundary Layer Wind Tunnel for Scaled Wind Hazard Research at the University of Florida provides users access to one of the largest and most diverse suites of wind hazard experimental research facilities in the world. Through a 40-meter long, reconfigurable boundary layer wind tunnel, researchers have flexibility in their test configurations while supporting high-throughput testing and data collection. The NHERI Wall of Wind (WOW) at Florida International University (FIU) enables scientists and engineers to perform hurricane mitigation research to better understand how wind speeds impact civil infrastructure systems and how best to prevent wind hazards from becoming community disasters. The NHERI WOW facility is powered by a combined 12-fan system capable of repeatable testing in up to 157 mph wind speeds through its flow management system. This facility was recently used by researchers at Iowa State University and Lehigh University, who devised a semi-active control system to improve the resilience of buildings to extreme wind forces. Their system enables building cladding to act as a mass damper to mitigate the effects of high winds, blasts, and earthquakes. The researchers worked with an exterior wall construction firm to ensure that their approach would be viable for real-world cladding design practices, and they tested their prototype in the NHERI Wall of Wind. Their

findings are now being translated into performance-based design procedures for wind and earthquake hazard mitigation.

For coastal engineering research, the O.H. Hinsdale Wave Research Laboratory at Oregon State University includes a Large Wave Flume and a Directional Wave Basin that, together, enable multidimensional study of wind waves and also tsunamis. The facility is instrumented to assess wave conditions, velocity, and response variables such as stress, strain, load, scour, and erosion.

NHERI's Computational Modeling and Simulation Center (SimCenter), based at 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 so far developed loss models for major hurricanes in Atlantic City, New Jersey, and Lake Charles, Louisiana.

The NHERI Natural Hazards Reconnaissance Facility (referred to as the "RAPID Facility") is a collaboration between the University of Washington, Oregon State University, Virginia Tech, and the University of Florida. This facility equips natural hazards and disaster researchers with the capabilities to conduct advanced rapid response investigations into building and civil infrastructure performance and community response to natural hazards. The data are used to evaluate the effectiveness of design methodologies, calibrate simulation models, and develop solutions for resilient communities.

The agency also funds seven standing networks, called Extreme Event Reconnaissance (EER) Networks, that are ready to deploy as disasters unfold to ensure that crucial data are collected. These networks connect with each other through the NHERI CONVERGE hub at the University of Colorado, Boulder. 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, for example, NOAA, NIST, and the Army Corps of Engineers were among the agencies coordinating with others through the Slack channel created by the Structural Extreme Event Reconnaissance Network (StEER) and hosted on NHERI's DesignSafe cyberinfrastructure facility.

It is vital to support research as natural disasters unfold in order to record and preserve information that would otherwise be lost and 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 Rapid Response Research (RAPID) funding mechanism. Any NSF program can fund a RAPID 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 funded research in the immediate aftermath of several major windstorms, including: wind-rainfall interaction in Hurricanes Florence and Michael in 2018; the Easter Sunday 2020 tornadoes; and the U.S. Midwest 2020 derecho.

Researchers may also apply for EArly-concept Grants for Exploratory Research (EAGER) funding, which are utilized to support exploratory work in its early stages on untested, but potentially transformative, research ideas or approaches. This work may be considered especially "high risk, high payoff" in the sense that it, for example, involves radically different approaches,

applies new expertise, or engages novel disciplinary or interdisciplinary perspectives. A recent EAGER award to the University of Notre Dame from NSF's Strengthening American Infrastructure program will examine the perspectives and experiences of diverse homeowners who reside in coastal communities that are subject to hurricanes, and how they make decisions about strengthening their homes against hurricane risk. The findings are expected to help local stakeholders incentivize homeowners to strengthen residential infrastructure in areas that are subject to natural disasters.

It is important to note that extreme weather research, including windstorm research, relies on basic understanding of weather and climate patterns and trends. Over many years, NSF investments have documented and examined climatic phenomena, enabling improved predictions and helping communities address challenges associated with mitigation, adaptation, and building resilient futures. NSF investments in climate research date back to the International Geophysical Year in the 1950s, shortly after the agency's creation by Congress. Continued investments in atmospheric and Earth system research have enabled new insights and more detailed models of how climate trends matter to extreme weather, changing ecological and zoonomic patterns, and even land use. To enable such work, NSF supports a variety of research observing networks and modeling that complement, and are dependent on, the climate monitoring systems maintained by our federal partners.

Initiated following the 1982-1983 El Niño, NSF's Tropical Ocean Global Atmosphere program, known as TOGA, studied ocean phenomena in the tropical Pacific for nearly a decade. TOGA was planned at a time when the tropical Pacific had become recognized as a profound influencer of climate and global weather patterns, ranging from monsoon variability in Asia and Africa to droughts in Africa and South America. The resulting breakthroughs in seasonal climate forecasting and predictions of El Niño (the warming) and La Niña (the cooling) of tropical Pacific Ocean waters provide extra months of preparation, helping to reduce the level of economic and human losses that often result from these events.

NSF's Role in the National Windstorm Impact Reduction Program

The National Windstorm Impact Reduction Program (NWIRP) is a science- and engineering-based program with the stated 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 the National Institute of Standards and Technology (NIST), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), and the Federal Emergency Management Agency (FEMA). The coordinative discussions, planning activities, and briefings enabled by NWIRP keep NSF well informed of current and emerging issues related to windstorms and their effects. They also enable agency officials to share ideas, best practices, and lessons learned that are used to improve the effectiveness of activities both within NSF and across the interagency group.

NSF's specified responsibilities within NWIRP are to support research 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

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.

Improving understanding of windstorm processes and hazards – NSF funds unsolicited and solicited fundamental research into basic science and engineering and, as a result, has a particularly important role for this NWIRP strategic goal. In addition, since 2020, NSF has participated in the Interagency Council for Meteorological Services, where agencies from NWIRP and beyond meet to coordinate priorities for improving the nation's meteorological enterprise. By including NSF, both NWIRP and ICAMS allow the agency to ensure that our university-based research capabilities are included and contribute to progress.

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. 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. Although activities were paused due to the COVID-19 pandemic, once restarted, it is expected that NOAA will use the data collected to improve conceptual models of supercell thunderstorms.

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/tornadoes.

Improving understanding of 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. Many other types of investment also enable better understanding of disaster impacts and potential ways to mitigate them.

NSF's previously mentioned Structural Extreme Events Reconnaissance (StEER) research network has developed quick-response datasets and reconnaissance reports for more than 20 windstorm events including hurricanes, tornadoes and cyclones. 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 Ida, StEER deployed a three-person team to the Louisiana coast to conduct a field assessment of structural impacts using a street-level car-mounted panoramic camera, unmanned aerial systems, and other equipment. Meanwhile, an 11-member virtual assessment team gathered data through reported news, social media outlets, the National Weather Service, and other sources. The teams prepared a joint report on damage to buildings and infrastructure, with a recommended research response strategy, and shared their data on NHERI's

website[1], where it is available to the research community, government agencies, and other stakeholders. StEER's assessments will inform other research, such as studies of the performance of electric power infrastructure in the region.

NSF regularly seeks input on research challenges and opportunities from the academic community and other stakeholders through workshops. In August 2020, an NSF-funded workshop led by Florida International University explored research infrastructure concepts for a national, full-scale, 200-mph wind and wind-water testing facility with capabilities beyond the wind speeds and scales that are possible with current U.S. testing facilities. Because storm surge is the principal life safety threat in hurricanes, the workshop identified ways to integrate storm surge and wave actions into the potential facility design. Long-term, the workshop will help NSF advance wind engineering research and enhance the hurricane resilience of the built environment.

In 2018, NSF established CONVERGE at the University of Colorado Boulder as a new component of NHERI that advances social science, engineering, and interdisciplinary hazards and disaster research. CONVERGE houses both social-science and interdisciplinary oriented extreme event reconnaissance networks which focus heavily on disaster impacts on humans and communities. CONVERGE also offers training and tools that help researchers conduct field research using best practices for safe, ethical, and rigorous extreme events research.

NSF has also funded a multi-university Industry-University Cooperative Research Center (IUCRC) led by FIU and Texas Tech. NSF IUCRCs perform pre-competitive, basic research to advance technology areas of interest to their members, who are primarily from industry. The Wind Hazard and Infrastructure Performance (WHIP) IUCRC addresses NWIRP-relevant research questions. The WHIP Center's Industry Advisory Board members are drawn from insurance, risk-modeling, and construction industries. The Board ensures that WHIP research pertains to real-world problems, facilitates the transfer of new knowledge from research to practice, and develops long-term strategies to enhance windstorm resilience. Although WHIP is just three years old, several industry partners are reported to be already assessing the potential to integrate WHIP findings to improve their products.

Improving the windstorm resilience of communities 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.

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.

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

The previously mentioned CIVIC Innovation Challenge flips the usual community-university dynamic by asking communities to identify priorities ripe for innovation then partner with researchers to address those priorities. The initial stage-one planning grant competition attracted several hundred natural hazards/disasters proposals, including many that were focused on coastal storms, surge and inland flooding. Now in stage-two, 11 teams from across the country have been selected to focus on resilience to natural disasters in the context of equipping communities for greater preparedness to and response after disasters such as floods, hurricanes, and wildfires. For example, a team of researchers led by Old Dominion University is working with the Hampton Roads Community Foundation and local governments to help families after severe weather, such as a hurricane, inflicts widespread structural damage to homes. The team will create and share a platform that helps organizations efficiently match the supply of donated materials and volunteer labor with the repair needs of displaced households.

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 and earth-systems approaches to research. The facilities, basic research, and researchers supported by NSF are – and will continue to be – key to achieving our shared goal of preventing natural hazards, including windstorms, from becoming societal disasters.

We see some emerging areas where NSF can make significant impacts through coordination and partnerships with the other 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 windstorms,
- 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.

New NSF programs and activities will provide even greater opportunity to bring the science and engineering research communities to bear on pressing societal problems such as windstorm impacts. For example, through the Artificial Intelligence Institute Program, NSF has invested in 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. AI2ES leverages dedicated partnerships in academia, government, and private industry to multiply the strategic impact and societal benefit of the institute's groundbreaking integrated research in trustworthy AI, environmental sciences, and risk communication. 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.

Through NSF's proposed Directorate for Technology, Innovation, and Partnerships, NSF will engage academia, private industry, non-profits, and local governments to identify pressing societal

needs and develop innovative solutions on a wide range of topics. For example, NSF plans to invest in Regional Innovation Accelerators (RIAs) around the country to build and expand capacities for innovation at the level of individual communities and/or regions. These RIAs will tackle use-inspired, solutions-oriented research and innovation in a range of technology areas from artificial intelligence to advanced manufacturing, semiconductors as well as in a diverse set of national-challenge areas. These types of public-private partnerships, focused on using science and engineering to address local and regional needs, hold great promise for hazards resilience and many other national priorities.

Windstorms 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 our resilience research. NSF's commitment to equity is also important for the future of resilience research. We are growing opportunities to bring diverse 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 with those individuals who are historically underrepresented and underserved. NSF's Excellence in Research program, for instance, strengthens research capacity at HBCUs by funding research projects aligned with any of NSF's research programs. One example aligned with windstorm research, at Tennessee State University, is investigating the effects of hurricane structure, track, and landfall features on storm surges.

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 have enabled NSF to increase funding for 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 windstorms, their impacts on communities, and the windstorm 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.