National Institute of Standards and Technology
National Construction Safety Team Act
Annual Report
Fiscal Year (FY) 2024

Summary

This annual report to Congress for Fiscal Year (FY) 2024 is required by the National Construction Safety Team (NCST) Act (Public Law 107-231).

In FY 2024, the National Institute of Standards and Technology (NIST) continued to evaluate Hurricane Maria's (HM) impacts on Puerto Rico as part of the NCST investigation launched by the NIST Director on February 21, 2018. The goals of this investigation are to characterize: (1) the wind environment and technical conditions associated with deaths and injuries; (2) the performance of representative critical buildings, and designated safe areas in those buildings, including their dependence on local lifelines; and (3) the performance of emergency communications systems and the public's response to such communications.

In FY 2024, NIST also continued the NCST investigation launched by the NIST Director on June 30, 2021, to investigate the partial collapse of the Champlain Towers South (CTS) Condominium that occurred in Surfside, FL, on June 24, 2021. The goals of this investigation are (1) to establish the likely cause or causes of the partial collapse, (2) recommend any changes to standards, codes, and practices, and (3) recommend any research or other appropriate actions needed to improve the structural safety of buildings.

The Joplin Tornado NCST Investigation[1] resulted in recommendations to develop consensus standards and building code provisions related to tornado resistant design, and NIST has made additional progress on implementing those recommendations.

Highlights of FY 2024 activities include:

- Following completion of the HM NCST data collection in FY 2023, in FY 2024 the NIST HM Team made significant progress in data analysis, including integration of data across projects. They coded more than 35 hours of interview data, completed analysis of the emergency communications household survey data, and quantified hazard levels across Puerto Rico, including the development of a time-dependent rainfall model. In addition, they developed and carried out data analysis plans for weighting of survey data, imputation of missing data, and quantification of uncertainty.

- The HM Team received and reviewed multiple draft contractor reports, including reports on wind-field modeling, wind tunnel testing, public response to emergency communications, and recovery of business and supply chains. They also completed reviews of eight datasets for quality assurance.

- NIST published the wind-field model dataset for Hurricane Maria, providing estimated peak gust wind speeds across Puerto Rico with and without topographic effects.

[1] Report available at: http://www.nist.gov/customcf/get_pdf.cfm?pub_id=915628.

- The HM Team began interviews with infrastructure representatives in the power, water, and transportation sectors to support the HM National Windstorm Impact Reduction Program (NWIRP) project on Infrastructure Recovery.

- The HM Team continued data collection and analysis efforts to examine how Hurricane Fiona in 2022 affected recovery efforts from Hurricane Maria. They developed a wind-field model for Hurricane Fiona, compared rainfall accumulations between Hurricanes Maria and Fiona, and incorporated Hurricane Fiona-related questions in hospital and shelter interviews for the Critical Buildings Project, and in the surveys for the recovery of schools and hospitals for the Recovery of Social Functions Project.

- To support the completion of final datasets and contractor reports for multiple HM projects, NIST modified contracts with Stantec Consulting Services, Inc., and the Horsley-Witten Group, Inc. NIST also awarded a new contract to WeatherFlow for continuation of wind measurements in Yabucoa, a new contract to Lighthouse Integrated Services Corp. for translation and interpretation, and two new contracts to Strativia, LLC: one for stakeholder outreach support and the other for support from outside NCST member Luis Aponte.

- The NIST CTS Team completed all phases of the planned invasive testing program, including the mechanical testing of concrete cores and reinforcing bars and durability-related testing of concrete cores; column cross-section measurements; the historical wind study; and 3D slice subsurface investigation simulations.

- The CTS Team continued technical work by conducting full-scale slab-column and beam-slab-column connection tests and full-scale column tests; conducting accelerated corrosion tests; updating the collapse models and 3D integrated model; and launched a new phase of interviews with those who have knowledge of the building on the nights it collapsed and before; archival research of records; and subsurface materials tests. They also assessed the viability of recovering data from damaged hard drives recovered from the collapse and collected additional digital evidence of the building collapse.

- The CTS Team released additional information on the failure sequence of the building and highlighted evidence, data, and analyses supporting their preliminary collapse timeline.

- To support the goals of the CTS Investigation, NIST modified contracts with Florida International University, Applied Research Associates (ARA), the University of Washington, the University of Illinois-Urbana Champaign, Miami-Dade County, Tourney Consulting Group, and Geocomp. NIST also awarded new contracts to J.R. Harris & Company for project co-leadership of the Building and Code History Project, and Fluency Architecture & Design for creating a 3-D building information model. NIST also executed two work orders with the US Army Corps of Engineers to extract and test subsamples from the building evidentiary debris, and to provide co-leader and project support for the Remote Sensing and Data Visualization Project, and one work order with the Bureau of Reclamation to conduct testing on steel reinforcing bars.

- To support both the HM and CTS NCST Investigations, NIST awarded contracts to FedWriters, Inc. for technical report preparation, and to ESRI for ArcGIS software.

- NIST developed a streamlined internal review process and timeline for NCST reports that adapts the existing NIST Editorial Review Board process by allowing for simultaneous reviews at the technical and policy review levels.

- NIST conducted two preliminary reconnaissance missions in April and May for severe weather outbreaks, specifically focused on warehouse performance in tornadoes in Oklahoma, Nebraska, and Michigan, the latter of which was a co-deployment with the American Society of Civil Engineers (ASCE). An NCST Investigation will not be undertaken, but these missions will support ongoing efforts on the implementation of recommendations from the Joplin tornado NCST Investigation.

- NIST continues to co-lead the ASCE Structural Engineering Institute (SEI) Standards Committee that is developing the new ASCE/SEI/AMS Wind Speed Estimation in Tornadoes Standard. The committee recently approved the chapter on radar estimation of wind speeds and has made significant progress in developing and approving five additional chapters covering other wind speed estimation methods, including a revision to the Enhanced Fujita (EF-) Scale. These activities address Recommendation #4 from the Joplin Tornado NCST Investigation.

- NIST continues to provide support for state and local adoption of the tornado-resistant design standard requirements in the ASCE 7-22 Standard and the 2024 International Building Code. This includes stakeholder outreach, education, and testimony in support of state-level consideration of tornado safety requirements. These activities address Recommendation #5 from the Joplin Tornado NCST Investigation.

- NIST has continued efforts to develop improved performance-based tornado design methodologies. NIST funded and collaborated with ASCE/SEI on the development of a report on state-of-the-art and research needs in design for tornadoes. NIST funded experiments at Texas Tech University and is collaborating on data analysis to compare tornado pressure coefficients on models of several buildings obtained from a tornado simulator with coefficients on the same building models measured in a traditional wind tunnel. These activities address Recommendations #5 and #6 from the Joplin Tornado NCST Investigation.

NIST presented the FY 2024 activities to the NCST Advisory Committee (NCSTAC or Committee) via a hybrid meeting on March 6-7, 2024, and via web conference on September 12, 2024. A summary of these meetings may be found on the NIST NCST website[2] and in the FY 2024 Annual Report of the NCSTAC to Congress.[3]

[2] NCSTAC meeting agendas, presentations, and summaries are available at: https://www.nist.gov/topics/disaster-failure-studies/national-construction-safety-team-ncst/advisory-committee-meetings.

[3] FY 2024 NCSTAC Report to Congress available at: https://www.nist.gov/topics/disaster-failure-studies/national-construction-safety-team-ncst/advisory-committee.

Introduction

In October 2002, the NCST Act was signed into law by President George W. Bush and authorized the Director of NIST to establish and deploy Teams to investigate events leading to failure of a building, or buildings, that resulted in substantial loss of life or that posed significant potential for substantial loss of life.

The purpose of these investigations is to improve the safety and structural integrity of buildings in the United States. A Team shall:

1. Establish the likely technical cause or causes of building failure.
2. Evaluate the technical aspects of evacuation and emergency response procedures.
3. Recommend, as necessary, specific improvements to building standards, codes, and practices based on the findings made pursuant to (1) and (2).
4. Recommend any research and other appropriate actions needed to improve the structural safety of buildings, and improve the evacuation and emergency response procedures, based on the findings and recommendations of the investigation.

Under Section 10 of the NCST Act, NIST is to provide an annual report to the House Committee on Science, Space, and Technology, and to the Senate Committee on Commerce, Science, and Transportation each year. This report is to include:

1. A summary of the investigations conducted by Teams during the prior fiscal year.
2. A summary of recommendations made by the Teams in reports issued under Section 8 of the NCST Act during the prior fiscal year and a description of the extent to which those recommendations have been implemented.
3. A description of the actions taken to improve building safety and structural integrity by NIST during the prior fiscal year in response to reports issued under Section 8 of the NCST Act.

This report summarizes NIST's activities under the NCST Act for FY 2024 as required by Section 10 of the Act.

1. Investigations Conducted Under the NCST Act during FY 2024

a. Hurricane Maria

On September 20, 2017, Hurricane Maria made landfall in Puerto Rico as a strong Category 4 storm, causing fatalities, injuries, and damage to buildings and infrastructure. The NIST Director established a Team (HM Team) under the NCST Act, based on an analysis of the event against the criteria in the NCST Act and its implementing regulations (15 C.F.R. Part 270), to conduct a technical investigation of the building performance and emergency response and evacuation during Hurricane Maria. The goals of the NCST Hurricane Maria Investigation are to characterize: (1) the wind environment and technical conditions associated with deaths and injuries; (2) the performance of representative critical buildings, and designated safe areas in those buildings, including their dependence on lifelines; and (3) the performance of emergency communications systems and the public's response to such communications.

The HM Team members continue to work on four projects that address the investigation goals, as described below:

(1) Hazard Characterization:

The objective of this project is to characterize the wind environment associated with Hurricane Maria's impact on Puerto Rico, including topographic effects, and to document other hazards associated with the hurricane, including storm surge, rainfall, flooding, and landslides in order to understand subsequent building failures. The investigative methods for this project include wind field modeling, wind tunnel testing, field measurements, and numerical simulation.

The wind field modeling is supported by contracts with ARA, awarded in February 2019 and September 2023, which include the development of a time-dependent wind field model of Hurricane Maria's impact on Puerto Rico. In FY 2024, the project team completed updates to the wind-field model, including quantification of uncertainty in the modeled wind speeds; ARA delivered a contractor report documenting the model development; and NIST published the wind-field model dataset at https://doi.org/10.18434/mds2-3184.

Wind tunnel testing of topographic effects on winds was supported by a contract with the University of Florida (UF), awarded in May 2019. In FY 2024, UF delivered a contractor report documenting the wind tunnel measurements, and the NIST project team made significant progress in analyzing the wind tunnel data in conjunction with field measurements and numerical simulations.

Field measurements of topographic wind speedup effects on cell towers in the Yabucoa region of Puerto Rico commenced in March 2021 and were supported for a period of two years through a UF subcontract to WeatherFlow, Inc. In FY 2024, the project team completed a third year of field measurements under a contract awarded directly to WeatherFlow and began a fourth year of measurements under a new contract awarded to WeatherFlow in June 2024.

Complementary to the wind tunnel testing and field measurements, the HM Team has been developing Computational Fluid Dynamics (CFD) models for numerical simulation of topographic effects on winds, including consideration of the effects of terrain surface roughness. In FY 2024, the NIST project team evaluated the influence of forest cover on wind flow in the Yabucoa region by using USGS LiDAR data to quantify the tree canopy as a function of location, both before and after Hurricane Maria, and incorporating this information in CFD simulations.

To support documentation of other hazards in addition to wind, in FY 2024 the NIST project team compiled available rain gauge data from multiple sources for Hurricane Maria and developed a Gaussian process regression model for time-dependent and storm total rainfall as a function of location across Puerto Rico. Through a collaboration with the University of Bristol, the time-dependent rainfall model was used as input for a flood model to estimate inland flooding in Puerto Rico during Hurricane Maria. The NIST project team also used geospatial analysis methods to link hazard information on wind

speed, rainfall, flooding, and landslides with survey data to enable consideration of hazard exposure in data analysis across multiple projects.

(2) Performance of Critical Buildings:

The objective of this project is to characterize the performance of critical buildings in Hurricane Maria by evaluating damage and loss of function for representative hospitals, schools, and storm shelters with respect to the hazards they experienced and by evaluating the selection criteria and design requirements for storm shelters.

Support in evaluating the performance of critical buildings is being provided through a contract with Stantec Consulting Services, Inc., awarded in March 2020, with key personnel including engineering experts based in Puerto Rico. In FY 2024, Stantec submitted draft reports documenting the performance of five hospitals and five shelter facilities selected for detailed evaluation by the NIST project team. The NIST project team completed detailed reviews of the draft reports for quality assurance, and Stantec revised the reports to address NIST comments and ensure consistency in documentation of the information collected. Stantec also conducted follow-up interviews with selected hospital and shelter staff to document impacts of Hurricane Fiona.

Support in evaluating wind loads on buildings is being provided through a contract with UF, awarded in May 2019, which included wind tunnel testing of building models for two hospital facilities, and through contracts with ARA, awarded in February 2019 and September 2023, for integration of the wind tunnel measurements with the Hurricane Maria wind-field model. In FY 2024, the NIST project team and supporting contractors completed a detailed review of the wind tunnel measurements for quality assurance and integrated these measurements with the wind-field model to evaluate resultant wind loads on selected building components during Hurricane Maria.

(3) Public Response to Emergency Communications:

The objective of this project is to investigate the role of emergency communications in public response for those under imminent threat from Hurricane Maria. This project also examines the use of communications during response and recovery (during and immediately after the hurricane).

This project is supported by a contract with the Horsley Witten Group, Inc., awarded in December 2019, with subcontractors Eastern Research Group, Inc., Issues & Answers, Inc., and Albizu University in San Juan, Puerto Rico.

On behalf of NIST, Albizu University has conducted surveys and interviews of households to better understand factors that influenced evacuation decision-making, including the role of emergency communications in those decisions. In FY 2024, the NIST project team completed data analysis of the survey data from 1,523 households, including data cleaning, imputation of missing data, applying statistical weights to represent the population of Puerto Rico, and running models to understand predictors of household decisions.

The household interviews, which are an optional follow-on for survey respondents, were coded and analyzed for major themes in FY 2024. A total of 60 respondents participated in the interviews. The interview analysis is focused on barriers to taking protective action, as well as unmet information needs before and during the hurricane. In FY 2024, the NIST team accepted the final contractor report detailing the data collection effort for the household surveys, household interviews, and emergency communication information provider interviews.

(4) Characterization of Morbidity and Mortality:
The objective of this project is to complete a quantitative morbidity and mortality assessment of Puerto Rico, to better understand how damaged buildings and supporting infrastructure played a role in the injuries and deaths associated with Hurricane Maria. The study results will provide guidance to improve codes and standards as well as to inform future approaches to accurately attribute and predict life loss due to windstorm building failure(s).

This project was supported by a contract with the Milken Institute School of Public Health at The George Washington University (GW), awarded in July 2020, with collaborators at the University of Puerto Rico-Graduate School of Public Health (UPR), and the Institute for Health Metrics and Evaluation (IHME) at the University of Washington. This contract concluded August 2023. The team of contractors supported the Morbidity and Mortality Project's goal of identifying deaths in Puerto Rico directly and indirectly related to Hurricane Maria and, more specifically, the identification of deaths attributed to building and/or building system failure(s).[4] In FY 2024, the NIST project team developed a plan for additional analysis of the integrated database including further examination of deaths resulting from injuries, protective actions taken by decedents, and hospital functionality as well as analyses for integration with other projects on topics such as transportation, electrical power loss, and communications. In FY 2024, NIST co-organized a session and presented at a public health conference in Puerto Rico with GW and UPR colleagues; the conference provided an opportunity to engage local stakeholders for multiple projects. In FY 2024, the NIST project leaders also met with the National Center for Disaster Medicine and Public Health (NCDMPH) to support interagency engagement on topics relevant to the investigation and areas of potential recommendations.

In FY 2023, NIST's Engineering Laboratory received $40M in additional funding from Congress under the Disaster Relief Supplemental Appropriations Act, 2023, as part of the Consolidated Appropriations Act, 2023 (Public Law 117-328) "…to support the development of resilience standards with regard to weather and climate disasters, in addition to the underlying research to support those standards, and for necessary expenses to carry out investigations of building failures pursuant to the National Construction Safety Team Act of 2002". A portion of these funds have been and will continue to support the extension of existing work on Hurricane Maria to consider impacts of Hurricane Fiona, including assessment of the hazard, specifically wind and rainfall; evaluation of Hurricane Fiona's impacts on selected hospitals and shelters being evaluated in the

[4] Under 15 CFR § 270.100(b), "a building failure may involve one or more of the following: structural system, fire protection (active or passive) system, air-handling system, and building control system. Teams established under the Act and this part will investigate these technical causes of building failures and will also investigate the technical aspects of evacuation and emergency response procedures, including multiple-occupant behavior or evacuation (egress or access) system, emergency response system, and emergency communication system."

Hurricane Maria NCST Investigation; assessment of impacts on infrastructure systems and their interdependencies (e.g., power, water, transportation); and evaluation of physical and non-physical impacts of Hurricane Fiona on schools, hospitals, and businesses as well as effects on recovery from Hurricane Maria. Observations from Hurricane Fiona are expected to provide context to inform recommendations that come from the Hurricane Maria NCST Investigation.

The HM Team's efforts in FY 2024 included a focus on data analysis and cross-project integration through a number of activities, including:

- Thematic presentations to the NCST Advisory Committee in March 2024 on hazard exposure, hospital functionality and infrastructure dependencies, and protective actions and preparedness, in which the HM Team presented preliminary analysis from multiple projects around central investigation questions.

- Geospatial analysis planning and coordination to support further integration of data.

- Collaborative work with statisticians to address uncertainty quantification, weighting of survey data, and imputation of missing values in datasets.

- Identification of significant findings and prioritization of potential recommendations.

- Development of new NIST technical report series, HM report outlines, and streamlined internal review processes.

The HM Team continues to provide regular updates of progress through the NIST website.[5]

b. Champlain Towers South Condominium Collapse

On June 24, 2021, around 1:30 a.m., approximately half of the Champlain Towers South Condominium collapsed suddenly in Surfside, FL, causing 98 fatalities. NIST sent a preliminary reconnaissance team on June 25, 2021, to establish relationships and collect information and data to be used to determine whether a further NIST study should be conducted. Based on the recommendations of the preliminary reconnaissance team and evaluation of the criteria listed in the NCST Act and its implementing regulations, on June 30, 2021, the NIST Acting Director established the CTS Team under the NCST Act to conduct a technical investigation of the partial collapse. The goal of this investigation is to uncover factors that contributed to the initiation and sequence of collapse of the building and make recommendations to improve public safety and prevent recurrence of failures like the partial collapse of CTS.

The recommendation to establish the CTS Team was based on analysis of the event against the criteria found in the NCST Act and its implementing regulations (15 C.F.R. Part 270) for establishing a Team and firsthand observations in Surfside made by the NIST preliminary reconnaissance team. The NCST Act and its implementing regulations (15 CFR 270.102) set forth the criteria the Director must use in determining whether to establish and deploy a Team "after an event that caused the failure of a building or buildings that resulted in substantial loss of life or posed significant potential for substantial loss of life."

[5] NIST Hurricane Maria website: https://www.nist.gov/topics/disaster-failure-studies/hurricane-maria

The appointed CTS Team members are working on six technical projects and one management project, related to the investigation:

(1) Building and Code History:

The objective of this project is to assess the entire history of the building from original design through the partial collapse, including relevant codes and standards, design drawings and other documents, construction records, inspections, maintenance, renovations, and loads and environmental conditions.

The Building Code and History project was previously supported by a contract with Strativia LLC awarded in 2022 and again in 2023 to provide the project co-leader, which has been replaced with a contract to J.R. Harris & Company in 2024. It is also supported by a contract awarded to Applied Research Associates in 2023 for the analysis of historic wind loading of the CTS building.

In FY 2024, the NIST project team completed its historic review of wind loads on CTS over its lifetime, via a contract with Applied Research Associates; reviewed documents and other evidence to inform historic and collapse timelines of CTS; and was conducting a final review of an extensive document data set to analyze how well the building's construction complied with the requirements of the original design drawings and specifications.

(2) Evidence Collection and Preservation:

The objective of this project is to use innovative tagging and data collection methods to catalog and organize evidence and ensure the integrity of its origin through proper storage, handling, and sampling. This project also focuses on determining the original locations of evidentiary building debris from the CTS building prior to collapse using identification clues, design drawings and data collected during collapse pile deconstruction. This project leads the effort to extract and document testable subsamples, such as concrete cores and rebar, from evidentiary building debris that are representative from different areas of the building. This project also includes collecting key pieces of evidence by conducting interviews with CTS residents, first responders, family members or others with knowledge of the building condition and collapse events.

The Evidence Collection and Preservation project leveraged the expertise and equipment from the NSF-supported Natural Hazards Engineering Research Infrastructure (NHERI) RAPID Facility at the University of Washington, under a Memorandum of Understanding, who also provided training to NIST staff for the operation of disaster-data collection equipment. This project is currently supported by a contract awarded in 2022 to Miami-Dade County for evidence protection services, a contract awarded in 2023 to Applied Research Associates for invasive testing management, and a contract awarded to Florida International University in 2023 to conduct additional interviews and focus groups. This project is also supported by two work orders under an interagency agreement (IAA) with the Bureau of Reclamation (BurRec) for reinforcing bar testing, by several work orders under an IAA with the US Army Corps of Engineers (USACE) for subsample extractions and materials testing, and by a Memorandum of Understanding with the Federal Bureau of

Investigation (FBI) for multimedia analysis.

In FY 2024, the NIST project team finalized the processing of data and images from the physical specimens retrieved from the collapse site; in collaboration with Project 4, completed Phases 3, 4, and 5 of the invasive testing program; conducted hundreds of tests for mechanical properties of concrete and steel reinforcement samples extracted from the physical specimens; interviewed individuals with knowledge of the history of the building, eyewitnesses of conditions just prior to and during the collapse, individuals involved in the post-collapse activities, and others who might have information helpful to the investigation; and conducted archival research on the construction development environment in the Town of Surfside around the time Champlain Towers South was built.

(3) Remote-Sensing and Data Visualization:

The objective of this project is to analyze data collected from the Champlain Towers South site after the collapse, as well as any available data on the building prior to the collapse. The analyzed 2D and 3D surface, and subsurface data will be compiled, organized, georeferenced, visualized and communicated as part of a geographic information system (GIS) model that will be designed to support the other investigation projects.

The Remote-Sensing and Data Visualization Project is supported by a contract awarded to Tre Altamira, Inc. in 2023 for InSAR data collection and analysis, and a contract awarded to Fluency Architecture & Design, PLLC for development of 3D BIM. This project is also supported by a work order (under an IAA with USACE) that provides project co-leadership and data analysis, and a work order (under an IAA with NSF) for data processing of drone data by Florida State University.

In FY 2024, the NIST project team worked on integrating the data, analyses, test results, records assessment, and interview responses into the 3D GIS model. This visualization effort supports the failure hypotheses' assessment and will ultimately help to communicate the investigation's findings to the public and stakeholders. They also analyzed LiDar scans and tagged images in the investigation database relevant to certain failure hypotheses; and completed an Interferometric Synthetic Aperture Radar (InSAR) study of surface displacements over the eastern coastline of Florida.

(4) Materials Science:

The objective of this project is to evaluate the strength, appropriateness, uniformity, and deterioration of materials used in specific building features and at different floors in the building. This project compares the measured material properties to the characteristics specified in the building design and the measured data will be used in the partial collapse analyses and simulations.

The Materials Science project is supported by a contract awarded in 2022 to the University of Florida to conduct testing of trial concrete mix designs, a contract awarded in 2023 to Tourney Consulting Group LLC for an evaluation of concrete durability and reinforcement steel corrosion, and a contact awarded in 2023 to YA Engineering Services for petrographic examination of concrete materials.

In FY 2024, the NIST project team collaborated with Project 2 in completing Phases 3, 4 and 5 of the invasive extraction program and conducting mechanical tests on hundreds of concrete and reinforcement bar samples extracted from the physical evidence; conducted additional tests on concrete samples extracted from the physical evidence for properties related to the concrete's durability; and analyzed the distribution of material properties throughout the structure, the mechanisms of concrete aging, and the degree and causes of corrosion of steel reinforcement found in the physical evidence collected from the collapse site.

(5) Geotechnical Engineering:

The objective of this project is to evaluate the foundation's design, as-built construction, and current condition. It will also assess geotechnical and soil factors that may have affected the foundation.

The Geotechnical Engineering project is supported by a contract awarded in 2022 to the University of Illinois at Urbana-Champaign to provide the project co-leader, and a contract awarded in 2024 to Geocomp Consulting Inc. for geotechnical support. It has also been supported by multiple work orders (under an IAA with the USACE) to conduct testing, a geophysical investigation, and a site survey. This project was also supported by a work order (under an IAA with NSF) for wave propagation testing by the NSF-supported NHERI mobile facility at the University of Texas at Austin with Utah State University.

In FY 2024, the NIST project team performed testing and analysis to assess whether soil or foundation issues contributed to the failure. This effort included: performing soil-structure interaction analyses in collaboration with Project 6 and conducting tests on foundation materials extracted from the building site. They also advanced work on a Geotechnical Interpretive Report under contract with Geocomp Consulting Inc.

(6) Structural Engineering:

The objective of this project is to use evidence collected from the collapse site, the results of the other projects, and structural engineering and reinforced concrete design knowledge to conduct laboratory load tests and generate computer models to simulate the failure initiation and progression.

The Structural Engineering project is supported by a contract awarded in 2022 to Muttoni et Fernandez Ingenieurs Conseils SA on the role of slab-column failures, a contract awarded in 2022 to Cagley and Associates to conduct building code checks, and a contract awarded in 2023 to the University of Washington, with a subaward to the University of Minnesota, to conduct structural testing.

In FY 2024, the NIST project team built and tested large-scale replicas of columns, slab-to-column connections, and slab-beam-column connections at the two university laboratories; incorporated structural as-built and pre-collapse building condition data into their computer models; and created new analytical models to study details of the partial collapse initiation and progression.

(7) Project Management:
The six technical projects described above are managed by the investigation's co-leads, who provide technical and project oversight to meet the objectives of each project and identify the underlying cause(s) of collapse of CTS.

In addition to the accomplishments described above, all six technical projects collaborated on analyses of video footage taken during the partial collapse, updated the collapse timeline, and advanced the structured analysis of failure hypotheses.

In FY 2024, the CTS NCST Investigation spent approximately $8.6M of the funds provided by Congress under the Disaster Relief Supplemental Appropriations Act, 2023, as part of the Consolidated Appropriations Act, 2023 (Public Law 117-328). The majority (64%) of these additional funds were spent on contracts, travel, and micro-purchases. Many additional individuals at NIST, and outside of NIST, generously support the CTS Team's efforts. The Team has cooperated, collaborated, and coordinated with more than 15 Federal and local agencies.

The Champlain Towers South NCST Investigation is highly visible to the public and media. Families and others impacted by the partial collapse need to know how and why the failure occurred. Owners, residents, managers, building officials, and regulators need to know whether the factors that caused the Champlain Towers South partial collapse have implications for other structures. The team continues to communicate with families directly by email regarding major updates in the investigation.

The Investigation works under continual time pressures to provide results and subsequent recommendations for changes to codes, standards, and practice. The NCST CTS Investigation is one of the most complex and challenging investigations of its type ever undertaken, with dozens of failure hypotheses to pursue and an enormous amount of evidence to analyze. The implications of the findings of the Investigation are far reaching. The Investigation must be thorough.

Investigations like Champlain Towers South have plans, tasks, and needs for resources which evolve as the investigation unfolds. With the extraordinary support of NIST's Acquisition Management Division and other NIST operating units, as well as support of NIST management and leadership, the Investigation has used all possible means to procure materials and services at speeds that align with the investigation's timeline, while continuing to meet the requirements of the Federal Acquisition Regulation. NIST has awarded more than 30 contracts, IDIQ task orders, and IAA work orders in support of the investigation. At the September 12 NCSTAC, the Team announced that they expect the technical work to be completed by spring 2025 and the draft report to be shared for public comments approximately one year later in 2026.

Updates on the NCST Champlain Towers South Condominium Investigation are posted on the NIST website.[6]

[6] https://www.nist.gov/disaster-failure-studies/champlain-towers-south-collapse

2. Summary of Recommendations Made in Reports Issued Under Section 8 of the NCST Act during FY 2024.

During FY 2024, NIST did not issue a report under Section 8 of the NCST Act.

3. Actions Taken to Improve Building Safety and Structural Integrity During FY 2024 in Response to Reports Issued Under Section 8 of the NCST Act.

During FY 2024, NIST did not issue a report under Section 8 of the NCST Act.

The following actions were taken in FY 2024 to implement recommendations in the NCST Joplin Tornado Investigation final report[7] to improve building safety and structural integrity:

- NIST and National Oceanic and Atmospheric Administration (NOAA) staff continued to co-lead the ASCE/SEI/AMS Standards Committee that is developing the new Wind Speed Estimation in Tornadoes Standard. During FY 2024, work was completed on the radar methods chapter, which received final ballot approval by the Main Committee. The Forensic Engineering method chapter had its second Main Committee ballot, and the In Situ method had its first ballot. Four additional Damage Indicators in the Enhanced Fujita (EF) Scale chapter were balloted by the EF-Scale subcommittee. Work on additional chapters for other wind speed estimation methods continued. This standards development activity addresses implementation of Recommendation #4 and supports Recommendations #1 and #2.

- Upon request from the Illinois Department of Labor, NIST provided testimony about building design options for improving tornado safety of warehouses, at their January 30, 2024, Warehouse Safety Task Force meeting.

- NIST staff led the International Code Council's IS-STM Committee through completion and publication of the ICC 500-2023 Standard for Design and Construction of Storm Shelters[8]. This new edition incorporates many elements of the NIST-developed tornado load methodology in the ASCE 7-22 standard. These efforts directly address Recommendations #5 and #7a.

- NIST funded and collaborated with ASCE/SEI to identify research needs for tornado design. The results of this effort are documented in the new publication, *State of the Art and Research Needs in Design for Tornadoes: Structural Engineering Institute Workshop Report.*[9] This report supports advances the implementation of a number of Joplin recommendations across tornado hazard characterization and improved performance of buildings and shelters (Recommendations #1 to #12).

[7] https://www.nist.gov/publications/final-report-national-institute-standards-and-technology-nist-technical-investigation

[8] https://codes.iccsafe.org/content/ICC5002023P1

[9] https://www.nist.gov/publications/state-art-and-research-needs-design-tornadoes-structural-engineering-institute-workshop

- NOAA's National Severe Storms Laboratory (NSSL) has continued to make significant progress toward the development of new grid-based watch/warning hazardous weather forecasting capability for communicating probabilistic threats to advance the Forecasting a Continuum of Environmental Threats (FACETs) paradigm. This effort supports Recommendation #16.

4. Preliminary Investigations

NIST uses a scoring tool to assess the need for preliminary reconnaissance of disasters and failures. The scoring tool utilizes the following key decision criteria: event consequences (substantial loss of life or disabling injury, significant potential for loss of life, hazard intensity, and consequences to resilience); major challenges in evacuation and/or emergency response; international factors (relevance to the United States); feasibility (resources and safety of team); and study impacts (new knowledge gains, and potential impact to existing standards, codes and guidelines). Nineteen domestic and international events were scored in FY 2024, including nine windstorms, nine earthquakes, and one structural failure. These events occurred in Alabama, Arkansas, Colorado, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, Vermont, Virginia, West Virginia, Wisconsin, Afghanistan, China, Japan, Nepal, and the Philippines. Preliminary reconnaissance missions were conducted for tornado damage in Michigan, Nebraska, and Oklahoma. Preliminary reconnaissance missions were not conducted for any of the other events, due to one or more of the following reasons: no clear study objectives that would impact standards, codes, and practices; unsafe conditions for NIST investigators; no primary authority or in-house expertise of hazard type; construction practice and codes for international events are not similar to those used in the U.S.; no new lessons would be gained; minimal impact to building occupants; or limited financial and personnel resources.

5. Conclusion

The NCST Act authorizes NIST to establish and deploy Teams to investigate building failures that result in a substantial loss of life or pose significant potential for loss of life. In FY 2024, NIST assessed 19 events (earthquakes, hurricanes, tornadoes, and structural failures) using a scoring tool that considers: event consequences (substantial loss of life or disabling injury, potential for loss of life, hazard intensity and physical damage) and evacuation and/or emergency response; international factors (relevance to the U.S.); and study impacts (safety of team, new knowledge gains, and potential impact to existing standards, codes and guidelines). After analyzing the data from these 19 events, NIST conducted two preliminary reconnaissance missions, for tornadoes in Oklahoma and Nebraska, and in Michigan.

NIST continues to further investigate the building performance and emergency response and evacuation during Hurricane Maria in Puerto Rico, the partial collapse of Champlain Towers South in Surfside, FL, and continues to pursue actions related to improving building safety and structural integrity that were recommended by the previous Joplin Tornado NCST Investigation. As part of the HM NCST Investigation, in FY 2024 NIST advanced the analysis of data collected on hazards, critical buildings, emergency communications, and deaths associated with Hurricane Maria, the identification of significant findings and priority recommendations, and the preparation of final reports. As part of the CTS Investigation, in FY 2024 NIST reached an inflection point,

having completed the invasive materials testing required to finalize full-scale structural testing and collapse models including as-built conditions. The CTS Investigation is prioritizing and wrapping up technical activities, and will soon fully transition to synthesis and writing, to issue a final report for public comment as soon as the science permits. NIST presented these FY 2024 activities to the NCST Advisory Committee during hybrid and web conference meetings on March 6-7, 2024, and September 12, 2024, respectively.