NIST Disaster and Failure Studies

Why Conduct Disaster and Failure Studies. Buildings, bridges, and other man-made structures are not supposed to collapse or suffer damaged during construction or while in service. But sometimes they do, and for different reasons: fires, earthquakes, high winds or storm surge, errors in design and construction, flaws in materials, and manmade disasters, including terrorist attacks. Extreme events such as these test buildings and infrastructure in ways and on a scale that cannot easily be replicated in a laboratory—buildings and infrastructure are built without being tested at full scale. The "real world" is the laboratory for buildings and infrastructure and disaster and failure events provide valuable data on their performance under real world conditions.

The study of disaster and failure events is essential to improving the performance of buildings and infrastructure, the safety of building occupants, and the associated evacuation and emergency response procedures. The results of disaster and failure studies also help assess the adequacy of codes and standards, current practices, and the state-of-knowledge in these areas. In addition, the results of studies help minimize future risk and increase safety through improved codes, standards, and practices.

The NIST Disaster and Failure Studies Program provides for the establishment of teams to assess building and infrastructure performance and emergency response and evacuation procedures in the wake of disaster and failure events that have resulted in substantial loss of life or posed significant potential of substantial loss of life.

Objectives, Scope, and Type of Studies. The objectives of NIST's disaster and failure studies may include:

1. Establishing the likely technical factor or factors responsible for the damage, failure, and/or successful performance of buildings and/or infrastructure in the aftermath of a disaster or failure event;
2. Evaluating the technical aspects of evacuation and emergency response procedures that contributed to the extent of injuries and fatalities sustained during the event;
3. Determining the procedures and practices that were used in the design, construction, operation, and maintenance of the buildings and/or infrastructure; and
4. Recommending, as necessary, specific improvements to standards, codes, and practices as well as any research and other appropriate actions based on study findings.

NIST studies are documented in technical reports containing data, findings, and recommendations for consideration by private sector bodies responsible for developing relevant national building and fire model codes, standards and/or practices; federal, state and local building and fire officials for adoption and enforcement of national model codes and standards; and research performing organizations such as universities, national laboratories, and private sector entities. NIST promotes, enables, and tracks adoption of recommendations through improved standards, codes, and practices as well as any research and other appropriate actions based on study findings.

The primary focus of disaster and failure studies is on events that occur within the United States and its territories, however, NIST may conduct reconnaissance of international disaster or failure events when

lessons can be learned that are relevant to U.S. construction. NIST's involvement in international disaster or failure studies generally are undertaken in cooperation with other U.S. agencies, industry or private organizations, governments of other nations, or international organizations, for the purpose of establishing and/or improving U.S. practices, codes, and standards. If the Congress or the Administration issues a directive to respond to an event, it will result in a Preliminary Reconnaissance[1] or a Technical Investigation[2] being conducted, based on written criteria and procedures.

To the extent practicable, NIST will deploy a team in a timely manner after a disaster or failure event. The written criteria and guidelines provide a rational basis for evaluating the value of a NIST study. In evaluating practicability, NIST will consider the evaluation results from using the decision criteria as well as factors including staff availability, resource availability, staff safety, and the quality and adequacy of information and artifacts available to conduct a meaningful study.

NIST may use any one or a combination of the study options below in conducting a preliminary reconnaissance or a technical investigation:

- NIST may lead post-event studies. In many cases, these types of studies may involve a preliminary reconnaissance followed by a technical study that may include the characterization of the hazard, the safety and performance of buildings and structures, and the associated emergency response and evacuation procedures. Private sector and academic experts may be involved in these studies through contracts. Other public sector experts may also be involved in these studies.
- NIST may coordinate or participate in post-event studies. These types of studies may involve significant participation and/or coordination by other federal agencies with mission responsibilities and expertise.
- NIST may sponsor or participate in private sector-led post-event studies. In many cases, these types of studies may involve preliminary reconnaissance followed by a technical study that is limited in scope. NIST participation may be limited to guidance, oversight, and/or serving as a technical expert. These types of studies may involve significant private sector leadership and participation augmented with public sector experts.
- NIST may provide technical assistance in the reconstruction process for international disaster and failure events at the request of U.S. agencies, industry, private organizations, governments of other nations, or international organizations.

Independent Studies. NIST has more than 40 years of experience studying building fire and structural failures. Since NIST is not a regulatory agency and does not issue building standards or codes, the institute is viewed as a neutral, "third party" researcher. Other federal agencies and state and local governments, as well as private-sector and non-profit organizations, may request assistance in conducting

[1] Preliminary Reconnaissance—A field study at the disaster or failure site to gather information and to help determine if a technical investigation is warranted.

[2] Technical Investigation—A fact-finding study that may include an assessment of the safety and performance of buildings and infrastructure, associated hazard(s), and/or emergency response and evacuation procedures and will likely result in recommendations for improvements to standards, codes, and practices and/or new knowledge. Studies may range anywhere from limited scope (i.e., based on data collection and interpretation, modest analytical efforts, and judgment of technical experts) to extensive scope (i.e., based on in-depth technical study, including extensive use of data, models, analytical and computational tools, laboratory and/or field experiments, and/or interviews.

post-disaster fire and failure investigations. NIST also is authorized to conduct basic and applied fire research, including through fire investigations, for the purposes of understanding fundamental fire behavior and to reduce losses from fire.

Field and Lab Tests. Typically, NIST researchers conduct an extensive field study at the disaster site to determine conditions before and after the structural failure. Documents such as drawings, specifications, and inspection reports, as well as eyewitness accounts and videos, are reviewed to gain information about the design and construction of the structure, and the events of the actual failure incident. When necessary, laboratory tests are conducted to determine physical properties of failed materials. NIST may fabricate mockups or replicas of structure parts and test these. In addition to laboratory tests, analytical models and computer simulations may help determine likely causes of failure.

The NIST laboratories are well-equipped to conduct investigations. For example, NIST has several types of universal testing machines that can apply tension and compression forces on structural components up to 18 meters (60 feet) tall. Other labs include the National Fire Research Laboratory with the capability of conducting well-controlled experiments in fires releasing heat up to 10 megawatts (typical of a multi-room fire). The capability of the NFRL is being expanded to include fires of up to 20 megawatts and the simultaneous application of loads on structures from single components to two-story structures.

Impact on Codes, Standards, and Practices. By understanding the technical causes leading to structural failures and then making that information public, NIST researchers strive to prevent similar failures in the future. Studies conducted by NIST have led to significant changes in practices, standards, and codes to enhance the health and safety of the American public. Examples include:

- World Trade Center (WTC) Investigation (2001) , a total of 40 code changes, consistent with the recommendations, have been adopted in the 2009 and the 2012 editions of the I-Codes (viz., the International Building Code, IBC, and the International Fire Code, IFC). The I-Codes are a state-of-the-art model code used as the basis for building and fire regulations promulgated and enforced by all 50 U.S. states and key local jurisdictions. The National Fire Protection Association has adopted 10 additional WTC-related changes in the Life Safety Code (NFPA 101)—which is used in 39 states—and two changes in the Uniform Fire Code (NFPA 1)—which is used in 20 state.
- The Station Nightclub Fire (2003), sprinklers, restricted festival seating, crowd manager, and egress inspection record-keeping requirements for new and existing facilities adopted in NFPA 101 (Life Safety Code).
- Jarrell, TX, Tornado (1997), enhanced Fujita (EF) Tornado Intensity Scale adopted by NOAA's National Weather Service.
- Northridge Earthquake (1994), design guidelines for seismic rehabilitation of existing welded steel frame buildings adopted by American Institute of Steel Construction.
- Hurricane Andrew (1992), upgraded wind load provisions adopted in HUD's Manufactured Home Construction and Safety Standards.
- DuPont Plaza Hotel Fire, San Juan PR (1986), passage of the Hotel-Motel Sprinkler Act.
- L' Ambiance Plaza, Hartford CT (1982), improvements in OSHA's safety and inspection requirements for lift-slab construction.

Statutory Authorities. NIST has a number of authorities, including the National Construction Safety Team Act, for conducting disaster and failure studies. NIST uses the authorities most appropriate to the disaster or failure event being studied. The statutes include the following:

- NIST Act (1901, as amended): This law provides for structural investigations as well as research, operations tests, demonstration projects, and investigations in the areas of fire-resistive building materials, mechanisms, structures, components, and systems.
- NCST Act (2002): The National Construction Safety Team Act (Public Law 107–231) provides for the establishment of Teams to assess building performance and emergency response and evacuation procedures in the wake of any building failure that has resulted in substantial loss of life or that posed significant potential of substantial loss of life.
- NEHRP Reauthorization Act (2004): Public Law 108–360, the National Earthquake Hazards Reduction Program (NEHRP) Reauthorization Act, authorizes NIST to ensure that NEHRP includes the necessary steps to promote the implementation of earthquake hazard reduction measures by Federal, State, and local governments, national standards and model building code organizations, architects and engineers, and others with a role in planning and constructing buildings and lifelines.
- National Windstorm Impact Reduction Act (2004): Public Law 108–360 provides for the establishment of the National Windstorm Impact Reduction Program (NWIRP), with the objective to achieve major measurable reductions in losses of life and property from windstorms. NIST responsibilities under The Act include support for research and development to improve building codes, standards, and practices for the design and construction of buildings, structures, and lifelines.