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into the World Trade Center Disaster

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National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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National Institute of Standards and Technology
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Summary

The National Institute of Standards and Technology (NIST) announced its 24-month building and fire safety investigation of the World Trade Center (WTC) disaster on August 21, 2002. NIST also released the final plan for its investigation at the same time. This plan, which reflects comments received in writing and at a June 24, 2002 public meeting held in New York City may be found at <http://wtc.nist.gov>.

This public update summarizes the progress made by NIST and the cooperation it has received from a variety of organizations since the August announcement. This report covers:

- Availability of funding to support the investigation element of the NIST public-private response plan;
- Passage of the National Construction Safety Team (NCST) Act and new authorities for the WTC investigation;
- Progress toward the establishment of an Advisory Committee as called for by the NCST Act;
- Access to the work of technical experts involved in the insurance litigation related to the WTC towers;
- NIST's use of a balance of analytical, experimental, and numerical tools to evaluate alternative collapse hypotheses;
- Progress in identifying and collecting materials relevant to the investigation from the building owner, leaseholder, their consultants and contractors, New York City authorities, and other sources, with more information still needed;
- Selection of external experts to augment the NIST team in the area of occupant behavior and evacuation;
- The outline of a systematic data collection methodology for studying occupant behavior, evacuation, and emergency response;
- Status of steel and its analysis, photographic and video image collection and analysis, and contracting plans;
- Exchange of information and discussions with the New York City Department of Buildings related to the activities of its World Trade Center Building Code Task Force; and
- Progress in NIST's concurrent WTC Research and Development (R&D) Program and the Dissemination and Technical Assistance Program (DTAP).

The highlights of this update include:

- initial NIST efforts to identify steel recovered from the WTC towers and characterize the elevated temperature properties of the primer paint used on perimeter columns;
- outline of a three-pronged sampling methodology developed by NIST to obtain new data on evacuation and emergency response through face-to-face interviews, paper and web-based questionnaires, and focus group interviews with occupants, first responders, and families of victims;
- important types of documents obtained by NIST from the owner, leaseholder, insurers, and local authorities, and the specific documents and materials that have not yet been located or provided to NIST;

- a summary of NIST's photographic and video image collection efforts, the need for access to unpublished photos and non-broadcast video footage from media sources, and call for specific types of photos and videos to document initial damage and subsequent fire growth;
- NIST's use of a balance of analytical, experimental, and numerical tools to evaluate alternative collapse hypotheses for the WTC towers; and
- the status of the Advisory Committee that is being established pursuant to the National Construction Safety Team Act (P.L. 107-231) signed into law October 1, 2002 by President Bush and that provides NIST with lead agency authorities to investigate building failures.

Goals of WTC Investigation

- To investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the WTC disaster.
- To serve as the basis for:
 - Improvements in the way buildings are designed, constructed, maintained, and used;
 - Improved tools and guidance for industry and safety officials;
 - Recommended revisions to current codes, standards, and practices; and
 - Improved public safety, and business and insurance stability.

Objectives of WTC Investigation

The objectives of the NIST investigation of the WTC disaster are to:

1. Determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft and why and how WTC 7 collapsed;
2. Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response;
3. Determine what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1, 2, and 7; and
4. Identify, as specifically as possible, areas in current building and fire codes, standards, and practices that warrant revision.

Fact-Finding Focus of Investigation

NIST is a non-regulatory agency of the U.S. Department of Commerce. The NIST investigation is focused on fact-finding, not fault-finding. No part of any reports, data, and findings resulting from a NIST investigation can be used in any legal proceedings (15 USC 281a; P.L. 107-231).

NIST Public-Private Response Plan

The NIST public-private response plan consists of three program elements. The first is a 24-month **building and fire safety investigation** that will study the factors contributing to the probable cause (or causes) of collapse of the 110-story WTC towers (WTC 1 and 2) and the 47-

story WTC 7 and to the associated fatalities and injuries. What is learned in examining WTC 1, 2, and 7 is expected to benefit new and existing buildings.

Parallel to the investigation is a proposed **research and development (R&D) program** to provide the technical basis for specific improvements to building and fire codes, standards, and practices, particularly to facilitate implementation of recommendations that result from the WTC investigation. This program addresses work in critical areas such as structural fire safety, mitigation of progressive collapse, building vulnerability reduction tools, and equipment standards for first responders. This includes experimental validation of computer analysis tools. The rate at which the recommendations of the investigation can be implemented will depend on the level of funding available to the R&D program.

An industry-led **dissemination and technical assistance program (DTAP)** is the third part of the NIST response plan. The DTAP is designed to engage leaders of the construction and building community in the implementation of proposed changes to practices, standards, and codes. Also, it will provide technical guidance and tools to better prepare facility owners, contractors, architects, engineers, emergency responders, and regulatory authorities to respond to future disasters. The DTAP is a crucial for timely adoption and widespread use of proposed changes to practice, standards, and codes resulting from the WTC investigation and the R&D program.

Funding Status for the WTC Public-Private Response Plan

On September 9, 2002, \$16 million in funding to support the WTC investigation was transferred to NIST by the Federal Emergency Management Agency (FEMA). These funds were made available from the emergency supplemental appropriation passed by Congress and signed into law on August 2, 2002.

In FY 2002, total funding of \$19.4 million was allocated to support NIST's WTC response plan, including the above \$16 million for the investigation.

In FY 2003, the President's budget requests \$4 million to support selected portions of the WTC response plan, focused on the R&D and DTAP program elements. This request is currently pending in Congress. Like much of the federal government, NIST is operating on a continuing resolution. This provides NIST with about one half of the requested level of funding in FY 2003 until a final appropriation is received.

National Construction Safety Team Act

The National Construction Safety Team Act (P.L. 107-231) signed into law October 1, 2002, by President Bush establishes NIST as the lead agency to investigate building failures. The Act, modeled after the National Transportation Safety Board (NTSB) for investigating transportation accidents, provides NIST with significant additional authorities. The NCST Act applies to the NIST WTC investigation in response to the attacks of September 11, 2001.

The NCST Act provides for the establishment of investigative teams to assess building performance and emergency response and evacuation procedures in the wake of any building failures that has resulted in substantial loss of life or that posed significant potential of substantial loss of life. The purpose of investigations conducted under the Act is to improve the

safety and structural integrity of buildings in the United States. The Act gives NIST the responsibility to dispatch teams of experts, where appropriate and practical, within 48 hours after major building disasters. Investigation teams will include outside experts.

Consistent with NIST's public-private WTC response plan, the Act gives the teams an explicit mandate to:

- Establish the likely technical cause of building failures;
- Evaluate the technical aspects of procedures used for evacuation and emergency response;
- Recommend specific changes to building codes, standards, and practices;
- Recommend any research or other appropriate actions needed to improve the structural safety of buildings, and/or changes in emergency response and evacuation procedures; and
- Make final recommendations within 90 days of completing an investigation.

NIST will report to Congress on actions taken as a consequence of its recommendations.

The Act gives NIST and its teams comprehensive investigative authorities to:

- Access the site of a building disaster;
- Subpoena evidence and witnesses;
- Access evidence such as records, documents, materials, and artifacts; and
- Move and preserve evidence.

The Act also authorizes that NIST may confer with employees and request the use of services, records, and facilities of state and local governmental authorities.

NIST plans to work with all interested parties in an investigation and, if necessary, judiciously exercise its new subpoena authority. NIST will issue subpoenas if needed to obtain documents, materials, oral testimony, or other evidence.

Establishment of the NCST Advisory Committee

The Charter for an Advisory Committee to be established pursuant to the National Construction Safety Team Act was approved November 5, 2002. The Committee will advise the NIST Director on carrying out the responsibilities assigned to NIST under the Act. This Advisory Committee applies to the WTC investigation and to future NIST investigations under the Act. Both the Act and the Charter for the Advisory Committee may be found at the NIST WTC web site at <http://wtc.nist.gov>.

On November 12, 2002, NIST issued an announcement requesting nominations of individuals for appointment to the National Construction Safety Team Advisory Committee by November 27, 2002. NIST has received a large number of excellent nominations in response to this request, in addition to nominations previously submitted. NIST is reviewing potential candidates for appointment to this select committee that will consist of at least five but no more than 10 members. A total of 84 nominations have been received. Announcement of the selections will be made as soon as the vetting process for appointments under the Federal Advisory Committee Act is complete. The NIST Director will make the selections and his decisions are final. Portions of the Committee's meetings are expected to be open to the public. One or more of the meetings are expected to take place in New York City.

Access to Technical Information Developed in WTC Towers Insurance Litigation

In July 2002, representatives of Silverstein Properties, the leaseholder for the WTC towers and WTC 7, offered to provide NIST with full access to critical information, materials, and data relevant to the NIST investigation. This included the large body of technical work completed by its experts as part of the insurance litigation involving the WTC towers.

In early October 2002, the group of insurance companies involved in the same insurance litigation offered to provide NIST with the technical work completed independently by its experts.

Technical experts for Silverstein Properties provided detailed briefings to the NIST investigation team on October 8, 2002 and the technical experts for the insurance companies did likewise on October 23, 2002. NIST also has been provided a large variety of documents, including reports on the structural collapse, fire spread and severity, and wind tunnel test results for the WTC towers by both parties. In addition, the experts discussed the tenability environment and the evacuation processes in the buildings.

The structural collapse scenarios discussed in those reports are among the critical issues NIST has included in its investigation plan. In addition, the NIST plan goes beyond those considerations to include issues of evacuation, emergency response, and engineering practice.

NIST is reviewing the information and reports that have been provided and incorporating what is learned into its investigation. When NIST issues its analysis at the conclusion of the investigation, it will make certain that the different scenarios are examined, either alone or in combination, and compared with available evidence to establish the facts rigorously and in an unbiased way.

The leading scenarios under consideration recognize that aircraft impact caused damage to perimeter and interior columns and to floor systems. While the full extent of this damage is unknown and can only be estimated through analysis, it led to redistribution of the building loads among the columns (e.g., from the damaged columns to the undamaged columns, aided by the hat truss at the top of the towers) and with the floor systems.

At this stage, one hypothesis suggests that the load carrying columns were weakened by the fires and failed, initiating overall building collapse without the need for any weakening or failure of the steel truss floor system. Another hypothesis suggests that significant portions of one or more trussed floor systems sagged, as they were weakened by fires, and pulled the columns inwards via the connections, initiating overall building collapse through bending failure of the columns. A variation of this hypothesis suggests that the sagging floor system failed in shear at its connections with the columns, before overall building collapse initiated through buckling failure of the columns. Load eccentricities introduced by partially damaged floor systems could also have contributed to buckling failure of the columns. Combinations of these hypotheses present other possibilities.

Based on an initial assessment of the expert studies conducted as part of the insurance litigation and other relevant data, NIST considers it to be premature to exclude any of the potential hypotheses related to the sequence of events between the aircraft impact and the collapse of each WTC tower. Further work is needed to ensure that the results of any analysis can adequately explain the observed behavior. First, neither tower collapsed immediately upon aircraft impact. Second, the buildings collapsed only after fires had burned and advanced

through the buildings for about 55 minutes in the South Tower (WTC 2) and about one hour and 42 minutes in the North Tower (WTC 1).

Any analysis that suggests rapid loss of stability or collapse without the need for a sustained fire would be biased in favor of a critical collapse-initiating role for structural components damaged by aircraft impact (e.g., columns) and a lesser role for components weakened by fire (e.g., floor trusses and connections). Likewise, any analysis that delays loss of stability to well beyond the observed time-to-collapse for each tower would be biased in favor of a critical collapse-initiating role for structural components weakened by fire and a lesser role for components damaged by the initial impact of aircraft.

Balanced Use of Analytical, Experimental, and Numerical Tools

NIST is using a balance of analytical, experimental, and numerical tools to help unravel the extremely complex physical phenomena associated with the events of September 11, 2001 and to support or refute alternative collapse hypotheses.

Among the key factors that need to be considered are:

- the variability in the speed, direction, orientation, and point of impact of each aircraft and the mass dispersion of the jet fuel following impact;
- the mass of the steel, concrete, heavy machinery, and non-structural building materials and contents that shared in absorbing the energy imparted during aircraft impact;
- the effects of gravity loads and the energy carried by debris fragments in the aircraft impact analysis;
- the performance of the steel components and connections, at the high rates of loading during aircraft impact and at elevated temperatures during subsequent fires, and the associated failure criteria;
- the performance of the fireproofing at high temperatures and the extent to which the fireproofing may have been missing or knocked off during aircraft impact; and
- the growth and spread of fire through the towers and the resulting temperature of the structural steel as a function of time and location, including the coupling of the fire dynamics and thermal-structural response analyses.

In its re-construction of the thermal and tenability environment, NIST is taking into account:

- the fire load provided by the building contents and other sources such as jet fuel and fuel storage tanks;
- the ventilation available for combustion; and
- the inter-compartment fire growth through partitions, ceiling/floor systems, and air passages within the buildings.

NIST is conducting a complementary experimental effort that provides critical input to its analytical and numerical work, including the validation of those results. These studies include:

- the mechanical properties of steel (columns, spandrels, trusses, truss seats, welds, and fasteners) at high strain rates to support aircraft impact damage analysis;
- the thermal-insulation properties of the fireproofing materials and the ability of the fireproofing materials to withstand shock and impact;
- the mechanical properties of steel (columns, trusses, truss seats, bolts, welds) at high temperatures to support the analysis of structural response to fires;

- fire tests to study the floor truss-to-column connections and the local load-transfer properties of the interface between the steel truss and the concrete deck in the composite floor system; and
- fire tests in large compartments (12 ft x 12 ft x 24 ft) to measure the heat release, distribution, and heat transfer rate to the compartment gases and steel specimens (steel truss and columns, both with and without fireproofing) for validating fire dynamics and thermal-structural analyses, including the coupling between the two analyses.

NIST is also reviewing previously completed tests on open-web steel truss systems, including their performance under gravity loads and fire. The past performance of open-web steel trusses in fires is being documented using available fire incident and insurance investigation reports.

Status of Data Collection Efforts

NIST is basing its review, analysis, modeling, and testing work for the investigation on a solid foundation of technical evidence. This requires access to critical data such as building documents, video and photographic records, emergency response records, and oral histories in addition to the samples of steel that have been recovered.

NIST has received excellent cooperation from a variety of organizations in the discovery phase of its investigation. It has begun to receive large volumes of documentation from the Port Authority of New York and New Jersey and its consultants and contractors; Silverstein Properties and its consultants and contractors; and the group of companies that insured the WTC towers and their technical experts. NIST also has begun to receive information from the Fire Department of New York (FDNY) and the New York City Office of Emergency Management (OEM).

The above documents and other information relate to the design, construction, operation, inspection, maintenance, repair, alterations, emergency response and evacuation of the WTC complex. They include information such as:

- the original design drawings (structural, architectural, mechanical, electrical, plumbing) and the original fabrication and construction drawings for the WTC towers;
- tenant alteration application (TAA) reports, including drawings and specifications, for the WTC towers and WTC 7, and associated construction audit reports;
- tenant design standards manuals for structural, architectural, HVAC, fire protection, plumbing, electrical, fire alarm, and construction review;
- emergency evacuation procedures manuals, including fire safety guide;
- operations manuals for the fire protection system, including sprinklers, standpipes, alarm system and communication protocols, water and power supply;
- operations manuals for the heating, ventilating, and air-conditioning systems;
- reports on facility condition surveys and structural integrity inspections for the WTC towers and WTC 7;
- recent inspection and maintenance reports for the elevators and escalators in the WTC towers;
- reports on pre-design tests of structural components including dampers for the WTC towers;
- reports on wind tunnel tests of the WTC towers and wind speed measurements near the WTC site;
- reports on the 1993 bombing damage assessment and repairs, and documentation of changes made to the evacuation system after 1993;

- documents related to the location, approval, and inspection of fuel tanks in WTC 7;
- documents related to fire rating and fireproofing of structural steel members in the WTC towers;
- documents related to Port Authority building and fire code requirements and practices;
- documents related to the lease of the WTC towers by Silverstein Properties;
- reports prepared by McKinsey and Company for FDNY and NYPD;
- basic FDNY dispatch data, including time of dispatch and unit identification; and
- firefighter fatality and injury data from FDNY.

NIST has a number of requests for materials that are currently pending with several organizations. They include those listed above and the New York Police Department (NYPD). NIST is working with these organizations to gain access to important information, specifically that related to emergency response and evacuation on September 11, 2001, including communication and operational records.

The important documents and materials that have not yet been located and/or provided include:

- the original contract specifications for the WTC towers that were completed in the early 1970s (the structural steel and concrete specifications for the WTC towers have been located);
- the final design drawings used for construction bid for WTC 7 (NIST has documents dated near the end of the design cycle but their status relative to the final drawings is unclear);
- the as-built drawings of the WTC towers and WTC 7 (NIST has the original contract drawings for the WTC tower *structures* that were revised to document significant changes during construction and early tenant modifications; NIST also has been offered access to supplementary drawings that document the majority of the WTC tower *structural* tenant modifications);
- the construction logs for the WTC towers and WTC 7;
- the maintenance records for the WTC towers and WTC 7;
- documents related to the ability of the WTC towers to withstand the abnormal load condition of a Boeing 707 aircraft impact that was considered in the original design;
- records of the video surveillance system used for security purposes at the WTC complex;
- fire alarm panel sensors and modules; and
- photographic or video documentation of the south face of WTC 7 on September 11, 2001.

The Port Authority and Silverstein Properties have informed NIST that most of the documents cited above were destroyed in the collapse of WTC 1, which housed documents for the Port Authority, and in the collapse of WTC 7 and WTC 1, which housed documents for Silverstein Properties. As such, those documents are not available with them. Both organizations have also informed NIST that the video surveillance records and fire alarm panel modules were destroyed at the WTC complex and none of those materials were recovered from the debris.

The Port Authority is trying to locate the complete set of original contract specifications for the WTC towers from its contractors and former employees. Silverstein Properties is trying to locate any as-built drawings, construction logs, and fire alarm records or remote logs for WTC 7. NIST will continue to work with the Port Authority's structural contractor to locate and obtain documents related to the WTC towers ability to withstand a Boeing 707 aircraft impact.

The NIST investigation team is reviewing and analyzing the valuable and voluminous information already in its possession. As an example, one task involves the creation of a detailed timeline of the issues related to fireproofing of the WTC towers. Another task involves

using data generated by technical experts for Silverstein Properties as initial input to the fire dynamics simulation. This includes the timeline of fire events on the external faces of the WTC towers and the state of initial damage in these buildings.

Selection of Experts in Occupant Behavior and Evacuation

NIST has selected three world-class experts as contractors to augment its investigation team in the area of occupant behavior and evacuation. Chosen from a competitive contract solicitation, these individuals bring extensive expertise, including strengths in psychology and sociology, and experience in the use of state-of-the-art sampling methods and in field data collection strategies. These individuals are:

- Dr. Norman Groner, an independent consultant from California. He has a doctorate in psychology and 25 years experience in the human factors field, much of it in the area of cognitive factors related to fire safety and emergency planning. He also has expertise and experience in interviewing techniques. He is coordinator for the independent World Trade Center Evacuation Initiative.
- Dr. Dennis Mileti, Director of the National Hazards Research and Applications Information Center within the Institute of Behavioral Science at the University of Colorado at Boulder. He has a doctorate in sociology and 28 years experience in risk communication and social psychology of public action. He also has expertise in statistical sampling methods and questionnaire design and methods.
- Dr. Guylene Proulx, Research Officer from the Institute for Research in Construction at the National Research Council of Canada. She has a doctorate in environmental psychology and 15 years experience in evacuation and emergency communications. She also has experience in post-fire egress analysis using questionnaires and interviews. She studied the evacuation of the WTC towers following the 1993 bombing incident.

Systematic Data Collection Methodology for Evacuation and Emergency Response

NIST's study of the World Trade Center evacuation and emergency response requires a systematic collection of first-hand data from survivors, families of victims, and others with operational or command authority on September 11, 2001.

The data accumulated from this effort will be used to evaluate the role of occupant behavior, and evacuation and emergency response technologies and practices for tall buildings, including decision-making and situation awareness, time-constrained evacuation strategies, communications, fire protection and firefighting, role of fire wardens and fire safety directors, and issues concerning people with disabilities. Additionally, observations of fire and smoke conditions or structural damage from within the building will be sought.

NIST will soon release a solicitation and a white paper describing a multi-disciplinary, three-pronged data collection methodology that includes face-to-face interviews, paper and web-based questionnaires, and focus group interviews. This multi-faceted approach based on well-established statistical sampling techniques is designed to increase confidence in the findings, enable systematic hypothesis testing and generalization, probe specific information of particular value to the investigation, and enhance memory recall and accuracy.

The data collection will be conducted by a yet-to-be-selected contractor and is planned to begin as soon as the necessary pre-work is complete. This includes preparation of the questionnaire and detailed survey strategy, training of contractor staff, and approval by NIST and the appropriate Institutional Review Board (IRB) to assure compliance with federal requirements for the protection of human subjects. NIST will use established procedures to review all survey and interview questions, data collection methods, and safeguards for maintaining privacy and confidentiality of all instruments before proceeding with these critical data collection efforts.

The white paper identifies specific populations and the size of samples to be included in the data collection effort. The exact numbers and populations may be modified to better suit the investigation as additional details of the methodology are finalized by NIST with the panel of experts and the yet-to-be-chosen contractor.

NIST plans to perform up to 600 face-to-face interviews of occupants. The sample population will include people near the floors of impact in the WTC towers, in elevators and lobbies, and from WTC 7; those with disabilities; floor wardens, fire safety directors, and others with responsibility for safety and egress; and family members of victims who called from the WTC towers.

The interview protocol is planned to include four steps:

- an unimpeded open-ended narrative account where the participant recounts his or her "story" chronologically to the interviewer;
- a structured narrative account where the participant reviews the story in cooperation with the interviewer to tabulate the logical sequence of actions by identifying cues that initiate an action, the action itself, and the reason for taking the action;
- probing for specific information of particular value to the investigation using open-ended questions; and
- close-ended questionnaire items at the end of the interview session to determine whether there are systematic differences among the various data collection approaches.

NIST also plans to conduct face-to-face interviews with up to 150 first responders from FDNY, NYPD, the Port Authority Police Department (PAPD), and the firm that provided security to the WTC complex. The FDNY population will be stratified among firefighters, company officers, and operational command officers. A similar stratification will be considered for other responder organizations.

NIST plans to collect data via approximately 800 returned web-based questionnaires from a whole building stratification of the WTC towers and WTC 7. The population will be selected randomly from eight sampling strata. The towers will be segmented into three strata each comprising an equal number of floors representing the top, middle, and lower third of the buildings. WTC 7 will be divided into two strata with an equal number of floors representing the top and bottom half of the building.

NIST also plans to collect data via approximately 450 returned mailed questionnaires from a selected-floors stratification of the WTC towers and WTC 7. Three floors will be selected from each of the WTC towers – one from each of three strata with an equal number of floors below the floors-of-impact. Two floors will be selected from WTC 7 – one from each of two strata with an equal number of floors.

Focus groups will elicit accurate group representations of specific events or themes (e.g., the experience of unique types of people in unique places in the buildings). Occupant focus groups in approximately five specialized categories will be conducted with between five to 10 participants per group. Examples of such specialized groups include:

- people with special responsibilities (floor wardens, fire safety directors, etc);
- people on a specific floor such as the 78th floor of WTC 2 and the 91st floor of WTC 1 – just below impact;
- people in the lobbies of WTC 1 and WTC 2; and
- people who escaped from above the floors of impact in the WTC towers.

First responders will constitute a second set of focus groups, and will include FDNY, NYPD, and PAPD. Ten first responder focus groups will be conducted with five participants per group, the typical size of an operating unit such as a fire department company.

Status of Steel and its Analysis

NIST has in its possession over 200 pieces of World Trade Center steel. The vast majority of the pieces are of significant size and include perimeter prefabricated column-spandrel elements, rectangular box beams, wide flange sections, truss sections, and channels. NIST also has in its possession several smaller pieces, such as bolts. NIST has cataloged most of the pieces and is in the process of completing a database with photographic records and member markings. In addition, NIST is reviewing additional steel and other artifacts stored by the Port Authority at JFK airport to identify pieces of interest to its investigation.

Based on a correlation of information on the grades of steel used in the WTC towers and identifying marks on the recovered steel, it has been possible to locate nine of the 12 steel strengths used for the perimeter columns and nine of the 11 steel strengths used for the spandrel beams. An ongoing effort is seeking to locate pieces of the remaining steel grades.

Also, approximately 250 chemical analyses have been conducted. The analyses indicate that the majority of the perimeter columns were made of WEL-TEN 60, 70, or 80 steels. These columns were fabricated from steel obtained from Yawata Steel, now Nippon Steel.

Nippon Steel representatives have offered to cooperate fully in assisting NIST and have begun to provide useful information to the investigation, including the proprietary specifications for their steels. So far, tests by NIST indicate that the higher strength steels are micro-alloyed steels (similar to modern pipeline steels) or CrMo steels that would meet U.S. specifications for heat resisting steels. Metallographic analysis shows a range of structures, including coarse and fine ferrite/pearlite structures and bainite and/or tempered martensite.

NIST also has identified the fabricators of the steel floor trusses (Laclede Steel) and has met with representatives of the firm. The firm has been fully cooperative in providing information on the steels used and the design and tests of the trusses. Laclede documents show that the trusses were fabricated with ASTM A36 and ASTM A242 or A441 steels and that Laclede's A36 steel was routinely made at yield strengths of 50-55 ksi (well in excess of the 36 ksi yield strength in the specification). The other two types of steel have minimum yield strengths of 50 ksi.

NIST has characterized the effects of high temperature on the primer paint used on the perimeter columns. This work indicates that microscopic "mud-cracking" of the paint occurs at approximately 250 °C. At this temperature there would be little or no visible discoloration or damage to the primer paint. The paint becomes friable and can easily crumble or become powdery at a temperature of about 700 °C. At this temperature there would be visible discoloration and damage to the primer paint (and the steel would likely have softened significantly). Thus steel that shows little visible evidence of discoloration or damage to the primer paint still could have experienced high temperature levels due to the fires. NIST is continuing to investigate other methods to measure the temperature excursions of the steel.

Status of Photographic and Video Image Collection and Analysis

Photographic and video images of damage and fires in the WTC towers and WTC 7 are critical to developing guidance on the initial conditions for modeling the fires, the rates of fire spread through the buildings, and the floors on which the structural collapse may have begun.

The NIST investigation team continues to seek photographic and video images that could help it better document the initial damage and subsequent fire growth in the WTC towers and WTC 7. NIST is especially interested in WTC 7 and views from the South and West faces of the WTC Towers.

Also, there continues to be a dearth of photos of the south side of WTC 7. It has been suggested that it is the south side of WTC 7 that was struck by debris from the collapse of WTC 1, and that debris may have ignited the fires that led to the ultimate collapse of WTC 7. Some eyewitness accounts describe fires on many floors of WTC 7 while photos show only localized fires on other sides of the building.

Those who are aware of or in possession of such materials are encouraged to contact NIST by electronic mail (wtc@nist.gov), facsimile (301-975-6122), or regular mail at WTC Technical Information Repository, NIST, 100 Bureau Drive Stop 8610, Gaithersburg, MD 20899-8610.

NIST has compiled a preliminary searchable database of over 1,900 still photos that were obtained from 55 private or independent photographers. The collection is expected to grow to multiples of the current size before it is complete. The photos are organized by major traits such as buildings shown, location and direction of shot, faces of towers that can be seen, date and time recorded, time uncertainty, rough measure of distance, photographer, copyright information, and original source of material. Also special characteristics are identified such as "collapse", "street scene", "debris", "fireball", "thermal plume", "people and location", and "presence of first responders".

NIST also has collected copies of several video recordings. Efforts to gather photos or videos from media sources, especially unpublished photos and non-broadcast video footage, are in progress. NIST believes that the public and media could significantly assist in this public safety investigation by sharing unpublished photos and video footage. NIST will be following up with specific news media organizations and encourages them to contact us about photos and videos they are willing to provide to the investigation.

NIST has begun to characterize and analyze the photographic and video evidence already in its possession. Initial analyses suggest that close-up photographs of the aircraft impact on each of the towers can be used to determine important parameters such as exactly where each aircraft

struck and its orientation, as well as the actual in-flight deformation of the loaded wings of the aircraft as it entered the buildings.

It is also noticeable from these external observations that the fires grew, moved, and ebbed (not necessarily in that order) during the period between the aircraft impact and the collapse of the towers. Further refinement of these observations will be pivotal in estimating where the thermal conditions presented significant threats to the occupants and the structural components of the towers. In addition, NIST has identified some images that could be helpful in better understanding the possible collapse mechanisms for the towers.

NIST is still in the early stages of its effort to obtain, catalog, and analyze photographic and video evidence and will share the analysis results broadly once the work is complete.

Status of Contracting Plans

NIST has assembled a seasoned world-class team to carry out the investigation. This team has the needed technical expertise as well as experience from significant prior investigations. Over two dozen NIST experts will be involved over the course of the investigation. In addition, NIST is augmenting its in-house staff with external experts in its project teams as contractors. The bulk of these contract solicitations will appear in the coming weeks. A few have already appeared and those solicitations are now closed. Contracts have been awarded for one solicitation.

NIST will rely on full and open competition as the preferred contracting process in most cases. Solicitations for the investigation will be posted on the NIST WTC web site at <http://wtc.nist.gov>. They will be based on statements of work prepared by NIST as a result of a careful and deliberate process to identify and define in detail the specific technical areas in which external expertise is needed to carry out each investigation project. The final investigation plan released August 21, 2002 with descriptions of the eight component projects is available at the above referenced web site. By going to that web site, potential offerors may request to be added to a mailing list that notifies them of new solicitation postings and awards.

Competitive proposals will be reviewed on a best value basis considering the technical and management proposal, business proposal, and cost proposal. Offerors will be required to disclose potential organizational conflicts of interest and to suggest an acceptable mitigation plan for dealing with these potential conflicts where needed. The solicitation will specify the technical evaluation factors. All proposals will undergo a review and selection process consistent with all federal procurement laws and acquisition regulations.

Information Exchange with the New York City Building Code Task Force

On May 17, 2002, NIST representatives met with senior officials of the New York City Department of Buildings and with the executive committee of its World Trade Center Building Code Task Force. At the meeting it was agreed that NIST and the City would maintain communication and exchange information relative to their respective activities in areas of mutual interest.

NIST representatives subsequently participated in the August 13, 2002 forum organized by the Building Code Task Force. Also, the Federal Emergency Management Agency (FEMA)

provided city officials with a copy of the code comparison study completed earlier this year by NIST for FEMA. That study compared:

- the earthquake provisions of the 2001 New York City Building Code with the 1997 National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions;
- the wind provisions of the 2001 New York City Building Code with the American Society of Civil Engineers standard ASCE 7-98;
- the fire provisions of the 2001 New York City Building Code with the national model codes issued by the International Code Council (2000 International Building Code) and the National Fire Protection Association (2000 Life Safety Code); and
- the fire provisions of the 2001 New York City Fire Code with the 2000 International Fire Code and the 2000 NFPA Fire Prevention Code.

On November 26, 2002, New York City officials briefed NIST representatives on the draft recommendations of its Building Code Task Force. NIST representatives informed City officials on the status of its investigation and broader response plan and discussed ways in which NIST could support the city's ongoing activities.

Update on WTC Research and Development Program

The WTC research and development (R&D) program will provide the technical basis for specific improvements to building and fire codes, standards, and practices, particularly to facilitate implementation of recommendations resulting from the WTC investigation. The program involves experimentation, analysis, verification and demonstration of improved tools to guide the building and fire safety industries, and feeds into the voluntary consensus process that is used to develop building and fire codes and standards in the United States.

The R&D program addresses work in critical areas such as structural fire safety and the mitigation of progressive collapse, building vulnerability reduction from chemical and biological attack, equipment standards for first responders, and human behavior, emergency response, and mobility. This includes experimental validation of computer analysis tools. The rate at which the recommendations of the investigation can be implemented will depend on the level of funding available to the R&D program. Initial efforts have focused on developing detailed plans for the multi-year R&D effort through workshops and partnering arrangements as highlighted below.

NIST recently released a report (NISTIR 6890, September 2002) summarizing the proceedings of an international workshop held earlier this year at NIST on "Fire Resistance Determination and Performance Prediction Research Needs." The specific objectives of the workshop were:

- to review current practices for achieving fire resistance;
- to explore the potential of fire dynamics simulations and structural behavior predictions at elevated temperatures;
- to identify new fire resistance options stimulated by advances in materials science;
- to identify applications and needs in advanced computational methods; and
- to identify application and needs for emerging measurement, instrumentation, and test methods.

The results of this workshop, attended by nearly 70 international experts, will guide the R&D effort and contribute to NIST's planning efforts to establish the needs for a possible National Structural Fire Resistance Laboratory.

In addition, NIST is working through international organizations to address the global needs for improvements to structural fire safety standards, codes, and practices. Thirteen fire laboratories across the globe have already indicated their interest in such an effort. They include laboratories in the United Kingdom, Sweden, France, Canada, Poland, Australia, New Zealand, Japan, China, and Taiwan.

On July 10-12, 2002, NIST sponsored a workshop to develop a national R&D plan to provide the basis for national codes and standards for design to prevent progressive collapse. The proceedings of the workshop, attended by nearly 70 industry leaders, are in the process of being finalized and will be available in the near future.

NIST also has developed a collaborative effort with the Risk Management and Decision Processes Center at the Wharton School of Business to develop cost-effectiveness tools for evaluating the management of terrorist risks for buildings, industrial facilities, and infrastructure. Risk mitigation strategies are based on enhanced building practices, risk transfer through insurance or self-insurance, and economic incentives such as tax write-offs, insurance premium reductions, and public-private cost-sharing arrangements. The tools will provide decision-makers with the basis for generating a disaster mitigation plan.

Update on WTC Dissemination and Technical Assistance Program (DTAP)

The industry-led dissemination and technical assistance program (DTAP) is designed to engage leaders of the construction and building community in assuring timely implementation of proposed changes to practices, standards, and codes. It also will provide technical guidance and tools to better prepare facility owners, contractors, architects, engineers, emergency responders, and regulatory authorities to respond to future disasters. The DTAP is crucial for timely adoption and widespread use of proposed changes to practice, standards, and codes resulting from the WTC investigation and the R&D program.

NIST was a sponsor of the September 23-24, 2002 workshop on Critical Infrastructure Protection Priorities organized by a group of industry associations and federal agencies that was led by the Civil Engineering Research Foundation and the White House Office of Science and Technology Policy.

Over 90 senior industry leaders and government officials exchanged information on the security of the built environment and worked to address key topics of concern, raised in publications such as *Making the Nation Safer* by the National Research Council. From 17 prospectuses that were developed, four were assigned top priorities. They are to develop and implement:

- guidance on risk assessment;
- recommended practices for addressing terrorist threats for buildings;
- facility knowledge systems for first responders; and
- a collaborative infrastructure security matrix.

NIST also was a sponsor of a November 13-15, 2002 Capital Projects Technology Roadmap Workshop organized by the non-profit industry-led FIATECH Consortium. A key focus of this workshop was to update a recently developed industry roadmap to assure coverage of homeland security issues and to develop specific project plans for implementing R&D to achieve the goals defined in the roadmap. The workshop drew representatives from a range of construction interests, including industry, research, academia, and regulators.

In addition, NIST has funded an effort to benchmark homeland security construction practices that is led by the Construction Industry Institute, a non-profit research organization representing the nation's top 100 facility owners and contractors.

The study will focus on chemical manufacturing, oil production and refining, natural gas processing and distribution, power generation and distribution, water treatment, and possibly other critical industries needed to support the nation's infrastructure. Information collected as part of a series of regional workshops and field site visits will be used to:

- establish a basis for identifying best practices related to the security of infrastructure capital facilities; and
- provide the basis for assessing the impacts of these practices on key project outcomes of cost, schedule, and safety.