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A CRITIQUE OF THE NIST SOFA SUPER STORE DRAFT INVESTIGATION REPORT-PART 1

By Richard Schulte

The Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology (NIST) released a draft report on its investigation into the fire at the Sofa Super Store in Charleston, South Carolina on October 28, 2010. The report titled "*Technical Study of The Sofa Superstore Fire-South Carolina, June 18, 2007*" was authored by Nelson P. Bryner, Stephen P. Fuss, Bryan W. Klein and Anthony D. Putorti and is dated October 2010. The following are excerpts from this report:

> "*A fire occurred on the evening of June 18, 2007, in the Sofa Super Store at 1807 Savannah Highway, Charleston, South Carolina. The fire swept from the rear to the front of the main showroom extremely quickly, and then into the west and east showrooms. Nine fire fighters from the Charleston Fire Department were killed in the fire.*" (Executive Summary, Page *xv*)

> "*During the early stages, the fire was unable to access enough oxygen (ventilation limited), which slowed its growth. Due to the lack of sufficient air to allow complete combustion, the fire produced large volumes of partially pyrolyzed fuel in the form of smoke and combustible gases. The large volumes of unburned fuel flowed into the interstitial space below the roof and above the drop ceiling of the main retail showroom. As the interstitial space filled with unburned fuel, the hot smoke also seeped through the drop ceiling into the main showroom and formed a hot smoke layer below the drop ceiling. . . When the front windows were broken out or vented, additional oxygen flowed in the front windows, along the floor, and to the rear of the showroom and became available to the fire. The additional oxygen allowed the heat release rate of the fire to increase extremely rapidly and ignite the layer of unburned fuel below the drop ceiling. The fire swept from the rear to the front of the main showroom extremely quickly, then into the west and east showrooms. Intense heat from sustained burning of furniture in the main showroom weakened the roof joists and supports and resulted in the collapse of a portion of the roof over the main showroom approximately 13 minutes after flames emerged from the front windows (40 minutes after the fire department arrived on scene). Furniture and merchandise in the showrooms and warehouse continued to burn for an additional 140 minutes before the fire was extinguished.*" (Executive Summary, Page *xv*)

"*The National Institute of Standards and Technology (NIST) conducted a study to determine the likely technical causes of the rapid fire growth that led to the high number of fire fighter casualties in that fire. . .The purpose of NIST building and fire safety studies is to use knowledge gained from the studies to help improve safety through recommended changes to codes, standards, and practices. NIST does not have the statutory authority to make findings of fault nor negligence by individuals or organizations.*" (Executive Summary, Page *xv*)

"*. . .The purpose of NIST building and fire safety studies is to use knowledge gained from the studies to help improve safety through recommended changes to codes, standards, and practices.*"

"*The local criminal investigation of the fire took priority over the NIST technical study. NIST access to witnesses and local authorities was limited due to the criminal investigations and civil litigation.*" (Executive Summary, Page *xvi*)

"*Since there were no continuous real-time observations or photos in all locations, NIST conducted computer modeling to fill in the gaps and determine the probable sequence of events based on fire physics, coupled to the fire response time line.*" (Executive Summary, Page *xvi*)

"*The fire began in trash outside the loading dock and spread into the enclosed loading dock. From the loading dock, the fire spread through the merchandise holding area to the rear of the main showroom, then to the front of the main showroom, and then into the west and east showrooms. At the same time, the fire spread into the holding area and through a metal wall into the warehouse.*" (Executive Summary, Page *xvi*)

"*The fire began in trash outside the loading dock and spread into the enclosed loading dock. . .*"

"*The extremely rapid spread of fire through the main and west showrooms trapped six fire fighters in the main showroom and three fire fighters in the west showroom. Although the intense heat from the fire weakened the light weight steel trusses and led to the partial collapse of the roof, the coroner's report indicated that the fire fighters died from thermal burns and/or smoke inhalation, not from compression type injuries that would have been associated with the collapse.*" (Executive Summary, Pages *xvi* and *xvii*)

"***Smoke and flames flowed from the holding area into the space above the main showroom drop ceiling. At a later stage, fire spread either over or through the holding area partition wall and into the rear of the main showroom.***" (Executive Summary, Page *xviii*)

"***Three fire doors between the main and west showrooms activated, but did not close during the fire. Three fire doors between the main and east showrooms activated; two doors closed completely and the third door partially closed.***" (Executive Summary, Page *xviii*)

"*Front windows were broken or vented by the fire department to improve visibility.*" (Executive Summary, Page *xviii*)

"***Fire spread extremely rapidly from the rear to the front of the showroom as additional air flowed through the broken windows, feeding the fire in the rear of the showroom.***" (Executive Summary, Page *xviii*)

"*Three fire doors between the main and west showrooms activated, but did not close during the fire. Three fire doors between the main and east showrooms activated; two doors closed completely and the third door partially closed.*"

"***Intense heat from sustained burning of the furniture weakened roof supports and resulted in collapse of the roof and walls into the warehouse.***" (Executive Summary, Page *xix*)

"***Only three of the seven roll-up fire doors activated and closed fully during the fire.***" (Executive Summary, Page *xix*)

"*There were more than five portable fire extinguishers located in the structure. A store employee discharged two portable extinguishers at the loading dock fire.*" (Executive Summary, Page *xx*)

"*Only three of the seven roll-up fire doors activated and closed fully during the fire.*"

"***The furniture fuel mass loading was estimated to range up to 16 kg/m^2 (3.4 lbs/ft^2) for the showrooms and 52 kg/m^2 (10.6 lbs/ft^2) for the warehouse. The high rack storage in the warehouse contributed to the higher fuel mass loading than in the showrooms.***" (Executive Summary, Page *xx*)

"***The furniture created a unique fire hazard in terms of the type and configuration of the fuel load. Furniture is often displayed in large open areas. As demonstrated in the main and west showrooms and warehouse, displaying large amounts of furniture in large open spaces can contribute to extremely rapid fire spread.***" (Executive Summary, Page *xxi*)

"***The fire department arrived on scene in fewer than 4 minutes after the 911 dispatch received the report of an exterior trash fire behind the Sofa Super Store.***" (Executive Summary, Page *xxi*)

"*The fire department arrived on scene in fewer than 4 minutes after the 911 dispatch received the report of an exterior trash fire behind the Sofa Super Store.*"

"***Up to 5 minutes after arrival, there were no reports of significant smoke or fire observed inside any of the showrooms.***" (Executive Summary, Page *xxi*)

". . .***it took the fire department about 10 minutes to establish a water supply from a fire hydrant to the exterior loading dock area and about 16 minutes from a fire hydrant to the front of the store.***" (Executive Summary, Page *xxi*)

"***The fire department vented the front windows about 24 minutes after arrival.***" (Executive Summary, Page *xxii*)

"***Flames emerged from the front windows within 3 minutes of the windows being vented.***" (Executive Summary, Page *xxii*)

"*The last fire fighters to exit successfully from the front of the store did so within 4 minutes of windows being vented. The roof collapsed over the west side of the main showroom about 40 minutes after fire department arrived on scene.*" (Executive Summary, Page *xxii*)

"*The last fire fighters to exit successfully from the front of the store did so within 4 minutes of windows being vented.The roof collapsed over the west side of the main showroom about 40 minutes after fire department arrived on scene.*"

"*The initial response of the fire department included two engine companies, a ladder truck company, and a battalion chief. With an engineer, a fire fighter, and an officer on each apparatus, the fire department's initial response included 10 people. A comprehensive risk management plan developed according to NFPA 1500 for the Sofa Super Store would likely have identified it as a high hazard occupancy due to the lack of sprinklers and the presence of large open areas and a large fuel load. For high hazard occupancies, NFPA 1710 advocates a minimum crew size of 5 to 6 members for each apparatus, which for this incident would amount to 16 to 19 people for the initial response.*" (Executive Summary, Page *xxii*)

"*The supply of water to the fire fighters was limited to the water on the fire engines for 9 minutes at the loading dock and 15 minutes at the front of the store. . .*" (Executive Summary, *Page xxii*)

"***Venting the front windows of the main showroom did allow the smoke to escape, but it also provided more air to feed the fire and provided a path for the fire to spread.***" (Executive Summary, Page *xxiii*)

"*. . .With an engineer, a fire fighter, and an officer on each apparatus, the fire department's initial response included 10 people. . .For high hazard occupancies, NFPA 1710 advocates a minimum crew size of 5 to 6 members for each apparatus, which for this incident would amount to 16 to 19 people for the initial response.*"

"*NIST recommends that research be conducted to better understand ignition and fire spread on upholstered furniture in order to provide the tools needed by the design profession to improve the fire performance of furniture.*" (Executive Summary, Page *xxv*)

"*NIST recommends that research be conducted to provide the tools needed by the design profession to improve the performance of compartmentalization.*" (Executive Summary, Page *xxv*)

"*NIST recommends that research be conducted to:*

a) *refine computer-aided decision tools for determining the costs and benefits of alternative code changes and fire safety technologies, and*

b) *develop computer models to assist communities in allocating resources (money and staff) to ensure that their response to an emergency with a large number of casualties is effective.*" (Executive Summary, Page *xxvi*)

"*The NIST team had access to the exterior of the Sofa Super Store the day after the fire. Exterior photographs documented the geometry, construction, and materials of the structure. A week after the fire, the NIST team was allowed access to the entire fire scene and collected additional photographs, both interior and exterior. . .*" (Page 1-2)

"*The Sofa Super Store was located at 1807 Savannah Highway, in the West Ashley Subdivision of Charleston, South Carolina. . .*" (Page 1-2)

"*Note that both Station 11 and Station 10 of the Charleston Fire Department (CFD) were located east on Savannah Highway, about 1.3 km (0.8 mile) and 2.1 km (1.3 miles) from the Sofa Super Store, respectively. . .*" (Page 1-3)

"*. . .The main showroom was 38.4 m (126.0 ft) wide and 39.1 m (128.3 ft) deep and with an additional section of 13.5 m (44.4 ft) by 6.1 m (20.0 ft) deep in the southwest corner nearest to the loading dock area. The total area of the main showroom was calculated as about 1585 m^2 (17,100 ft^2).*" (Page 1-6)

"*. . .While there may have been exits on the rear wall when the structure was originally built, all the rear exits had been closed or filled using masonry blocks (see Figures I-4 and I-8). The east and west walls of the main showroom each featured three interior fire doors which allowed customers to move to either the east or west showrooms (Figure 1-4). . .*" (Page 1-6)

"*In addition to the six fire doors leading to the other showrooms, there was an additional fire door which was located in the rear southwest corner of the main showroom that connected to the warehouse. Also, in the rear southwest corner of the main showroom was a non-fire roll up door that provided access to the loading dock area.*" (Page 1-10)

"*. . .The west showroom was 18.2 m (59.8 ft) wide and 35.8 m (117.5 ft) deep for a total calculated area of 652 m^2 (7020 ft^2). The west retail showroom was not part of the original structure. A single exit door was located at the northwest corner of the retail space (see Figure E-8), and a set of double doors at the rear of the showroom led to the loading dock (Figure C-7). . .*" (Page 1-12)

"*. . .The east showroom was 18.2 m (59.6 ft) wide and 35.5 m (116.5 ft) deep for a total calculated area of 645 m^2 (6940 ft^2). The east retail showroom was not part of the original structure. There were two sets of double exit doors located on the east wall of the showroom (Figure F- 7). The wall shared with the main showroom featured three roll-up fire doors (Figures O-33, O-39, and O-48). Employees also used these fire doors between the west and main showrooms to reposition furniture and move furniture from the warehouse into the retail areas.*" (Page 1-15)

"*Aerial images (see Section 1.6) demonstrated that the loading dock, repair areas and warehouse were not part of the original structure, but were added in stages after 1989. . .*" (Page 1-18)

"*Based on dimensions collected at the post-fire scene, the loading dock area was approximately 12.6 m (41.3 ft) east to west and 15.4 m (50.6 ft) north to south for an area of 210 m^2 (2200 ft^2). Aerial images indicated that it was built in at least two sections although building permits could not be located for either addition. As evidenced by post-fire residue, both sections were built with wood framing, a wood deck/floor, and sheet metal siding and roof. The section that shared a wall with the warehouse was added first and featured a 2.7 m (9 ft) ceiling while the portion next to the rear of the west show room had a 3.7 m (12 ft) ceiling.*" (Page 1-18)

"*As determined by measurements and data collected on-site, the warehouse was approximately 36.9 m (120.9 ft) wide and 39.8 m (130.7 ft) front to rear for an area of 1470 m^2 (15800 ft^2). The warehouse was an open clear span structure with poured concrete floor and sheet metal walls and roof. The roof was approximately 8.8 m (29 ft) above the floor. . .*" (Page 1-20)

"*Between the north wall of the warehouse and the rear of the main showroom were two additional repair areas. . .*" (Page 1-21)

"*In the rear southwest corner of the main showroom was a small holding area approximately 15 m^2 (160 ft^2), 2.4 m (8 ft) wide x 6.1 m (20 ft) long. . .*" (Page 1-21)

"*As expected from a store of this type, the inventory of combustible material within the buildings was the retail merchandise. This included a wide range of furniture including sofas, chairs, tables, beds, dressers, lamps, and rugs. . .*" (Page 1-23)

"*As expected from a store of this type, the inventory of combustible material within the buildings was the retail merchandise. This included a wide range of furniture including sofas, chairs, tables, beds, dressers, lamps, and rugs. . .*"

"*Mattresses, upholstered chairs, sofas, recliners, and futons typically contain significant amounts of polyurethane foam* [19, 20]*. Dressers, tables, chairs, and end tables are made of wood or wood products* [21]*. Area rugs and carpeting also contain large amounts of synthetic materials. All of these items contributed to the fuel loading in the store. . .*" (Page 1-24)

"*. . .Retail merchandise which had already been purchased and was awaiting delivery was staged in the loading dock area. . .*" (Page 1-25)

"*There were no records or reports of fire alarms or smoke detectors installed in the showrooms or warehouse. . .*" (Page 1-29)

"*The area in which the Sofa Super Store was located had immediate access to a municipal hydrant system to support fire ground operations. Water hydrants were located along Savannah Highway to the west and east of the store, on Pebble Road behind the store, and at Blitchridge and Wappoo Roads to the north of the store. . .*" (Page 1-29)

"*Remote sensing images or aerial photographs have been routinely recorded by commercial imaging companies and have been used for monitoring land use or in planning new residential areas or commercial facilities. The early remote sensing images were usually black and white and of lower resolution. Aerial photographs taken more recently are typically in color and with better resolution.*" (Page 1-35)

"*These images provide some insight into the chronological order in which the Sofa Super Store was expanded, but since photographs were not available for each year, NIST could not identify the specific years when the loading dock and repair areas were constructed.*" (Page 1-35)

"*An image from 1994 (Figure 1-21) verifies that the west showroom was added first and was constructed before February, 1994. The east showroom, warehouse, loading dock, and repair areas do not appear in the image.*" (Page 1-35)

"*Figure 1-22 is an aerial photograph taken in March 1998 which shows that the west and east showrooms as well as the warehouse had been added to the structure. Examination of the area between the rear of the west showroom and the warehouse reveals that the southern portion of the loading dock area had been constructed, but not the northern section. Neither the paint repair shop nor the wood repair shops had been constructed at this time.*" (Page 1-35)

> "*. . .For South Carolina, this fire was the deadliest fire since 11 people died in the Lancaster County Jail fire on Dec. 27, 1979* [1-2]."

"*The deaths of nine fire fighters on June 18, 2007, in the Charleston Sofa Super Store fire was the single greatest loss of life for the fire service in the United States since 343 fire fighters died in the collapse of the World Trade Center on Sept. 11, 2001. For South Carolina, this fire was the deadliest fire since 11 people died in the Lancaster County Jail fire on Dec. 27, 1979* [1-2]." (Page 2-1)

"*The time lines presented in this chapter identify the specific events that occurred during the Sofa Super Store fire that started just after 6:56 p.m., Eastern Standard Time (EST), June 18, 2007, as well as the order in which they transpired.*" (Page 2-1)

"*Since none of the photographers or videographers was present before the fire began, neither the video nor digital photographs captured the initial stages of the incident. All digital photographs and video were recorded outside the structure and did not provide images of fire growth inside the store.*" (Page 2-1)

"*Interviews with fire fighters provided information about the conditions inside and outside the structure. In combination with the fire department radio transmissions, it was possible to link the conditions to the time line. The arrival time of the fire department units was documented via the radio transmissions from arriving fire units to central dispatch. . .*" (Page 2-1)

"*. . .Investigative reports from Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF)* [13]*, National Institute for Occupational Safety and Health (NIOSH)* [14]*, and the Post Incident Assessment and Review Team* [15] *were carefully reviewed and provided critical insight into how the fire spread. Specifically, the time-linked reports by the fire fighters of smoke and fire conditions within the showrooms were invaluable in developing the time line.*" (Page 2-2)

"*On June 18, 2007, at 6:56 p.m., the time of the first sighting of the fire, the Sofa Super Store was open and employees were inside the showroom and warehouse areas within the structure. The fire was first observed by a passerby driving along Savannah Highway in front of the store and was reported to store employees. . .Upon initial verification of the fire, the store manager discharged a portable dry powder fire extinguisher, but was unable to extinguish the fire. Upon returning to the showroom area, the store manager asked other employees to call 911. The manager subsequently returned with a second extinguisher, found the loading dock more fully involved in fire, and discharged the extinguisher into the loading dock area from outside the loading dock. At 7:08 p.m., a report of a fire at the Sofa Super Store was received by the Charleston County 911 Emergency Center and the Charleston Fire Department was dispatched. . .*" (Page 2-2)

"*Upon arriving on the scene at 7:11 p.m., BC 4 reported a trash/debris fire at the rear of the showroom. Engine 10 was directed by the BC to position the apparatus near the loading dock and begin suppressing the trash fire (Figure 2-1).*" (Page 2-2)

"*Although the roll-up fire door in the breezeway between the holding area and warehouse had activated and closed direct access to the warehouse, the fire inside the enclosed loading dock spread to the front of the warehouse through a shared corrugated metal wall. The fire heated the metal wall sufficiently to cause items inside the warehouse to ignite.*" (Page 2-3)

> "*Upon arriving on the scene at 7:11 p.m., BC 4 reported a trash/debris fire at the rear of the showroom. . .*"

"*At approximately the same time, 7:27 p.m., dispatch notified the Fire Chief of a cell phone call from a man claiming to be trapped inside the store. . .After 7:31 p.m., the AC, rescue team, and rescued employee returned to the front of the store.*" (Page 2-5)

"*During the rescue effort at about 7:27 p.m., several inaudible radio communications suggested that someone was trapped inside. It was not clear whether the calls reported that fire fighters were lost or trapped, or whether the calls were related to the trapped employee. Several minutes later, between 7:29 p.m. and 7:30 p.m., there were additional radio communications that were still difficult to understand, but seem to be one or more fire fighters asking for directions to exit or requesting assistance to escape. Other radio calls were interspersed with calls for help related to getting the trapped employee out. Beginning around 7:31 p.m., additional broken radio traffic more clearly indicated that several fire fighters were in distress. An unknown fire fighter called "Mayday," and dispatch advised the Fire Chief that the L-5 engineer had activated the emergency button on his radio. The Fire Chief radioed, "….we need to vacate the building." "* (Page 2-6)

> ". . .*Beginning around 7:31 p.m., additional broken radio traffic more clearly indicated that several fire fighters were in distress. An unknown fire fighter called "Mayday," and dispatch advised the Fire Chief that the L-5 engineer had activated the emergency button on his radio. . .*"

"*At about 7:35 p.m., the front windows of the main showroom were vented and broken out, heavy brown smoke poured from the broken windows. Less than a minute later, the smoke changed to thick black smoke.*" (Page 2-6)

"*At approximately 7:51 p.m., the roof over the west side of the main showroom collapsed into the main showroom.*" (Page 2-6)

"*The fire was brought under control after 10 p.m. Recovery operations continued until after 4:00 a.m. the next morning, June 19, 2007.*" (Page 2-6)

"*At about 7:35 p.m., the front windows of the main showroom were vented and broken out, heavy brown smoke poured from the broken windows. Less than a minute later, the smoke changed to thick black smoke.*"

"*The fire was ignited in a pile of trash and discarded furniture, which had accumulated on the asphalt outside the loading dock area. The fire spread into or through a wall that had an exterior surface of metal siding, wood studs and framing, and an interior surface of plywood and/or gypsum board.*" (Page 2-11)

"*As the fire grew inside the loading dock, the energy from the fire heated up the metal siding of the warehouse and rear of the west showroom. At the rear of the west showroom, the interior surface was gypsum board mounted on metal studs (Appendix E, Figures E-23 and E-24).*" (Page 2-11)

"*At approximately 7:51 p.m., the roof over the west side of the main showroom collapsed into the main showroom.*"

"*From the holding area, the fire spread into the rear or southwest corner of the main showroom. The rollup fire door between the holding area and the warehouse closed and prevented the fire from spreading from the holding area to the warehouse. The fire growth is shown qualitatively in Figure 2-7 and estimated to have occurred around 7:31 p.m. It is not clear how the fire spread or moved into the rear of the main showroom.. . .There did not appear to be significant fuel in this interstitial space, but the hot gases could have ignited items that dropped through the ceiling into the main showroom and ignited furniture. . .While the exact path is not understood, the fire did spread into the rear of the main showroom, which resulted in additional furniture being ignited.*" (Page 2-12)

"*Partially burned fuel in the form of smoke and combustible gases from the fire on the loading dock filled the interstitial space above the ceiling in the main showroom, and the smoke began to flow through ventilation openings down into the main showroom. At about the same time, the fire spread from the holding area into the rear of the main showroom. The smoke being generated by the fire in the rear of main showroom and the smoke flowing down through the ceiling was forming a layer of unburned fuel below the ceiling of the main showroom. At this stage, the fire did not have access to sufficient oxygen to burn completely.*" (Page 2-12)

"*. . .In order to improve visibility, the fire fighters broke the front windows and allowed smoke to flow out of the showroom. However, breaking the windows also allowed additional air to flow into the main showroom. As this air flowed to the rear of the main showroom, the fire had additional oxygen and began to burn more intensely. The increased burning rate of the fire released additional energy, increased the temperature of the smoke layer, and ignited the layer of smoke and partially burned fuel below the ceiling in the main showroom.*" (Page 2-12)

"*In order to improve visibility, the fire fighters broke the front windows and allowed smoke to flow out of the showroom. However, breaking the windows also allowed additional air to flow into the main showroom. . .*"

"*. . .The three roll-up fire doors between the main showroom and west showroom (doors #2, #3, #4 in Figure 1-8) did not close, and this allowed the fire to move from the main showroom into the west showroom (Figure 2-10). On the east side of the main showroom, two rollup fire doors near the front of the store (doors #5 and #6 in Figure 1-8) did close, and the third fire door near the rear of the showroom (door #7 in Figure 1-8) closed only about one-third of the way down. The fire did not spread through the closed fire doors, but did spread through the partially closed fire door into the rear of the east showroom.*" (Page 2-12)

"*While this overview notes key tactical challenges facing the fire department and how they responded, the NIST study addressed the emergency response only as needed to reconstruct the behavior and time line of the fire. Additional analysis of the fire department response and recommendations were reported in the National Institute for Occupational Safety and Health Line of Duty Death Report 2007-18* [1], the City of Charleston *Post Incident Assessment and Review Team, Phase II Report* [2], and South Carolina Office of Occupational Safety and Health (SC-OSHA) *Report of S.C. OSHA Findings in June 18, 2007 Charleston Sofa Super Store Fire* [3]." (Page 3-1)

"*The Charleston Fire Department (CFD) provides fire suppression services to a community of approximately 108,000 people* [11]. *Emergency medical services are provided for the City of Charleston by two surrounding counties, Charleston and Berkeley.*" (Page 3-2)

"*The department's approximately 237 uniformed personnel operated from 14 stations with a combined response capability of 16 engine companies and three ladder companies* [12]. *For the CFD, a captain is in charge of each company, with an engineer/fire driver, and two fire fighters. . .On June 18, 2007, the department had 61 fire fighters, four BC, and an AC on-duty.*" (Page 3-2)

"*The department's approximately 237 uniformed personnel operated from 14 stations with a combined response capability of 16 engine companies and three ladder companies* [12]. *For the CFD, a captain is in charge of each company, with an engineer/fire driver, and two fire fighters. . .On June 18, 2007, the department had 61 fire fighters, four BC, and an AC on-duty.*"

"*At the time of the fire, the CFD's unit staffing (as noted above) was less than the minimum complement of engine and truck company personnel recommended in the National Fire Protection Association (NFPA) Standards 1500* [13] *and 1710* [14]. . . *Unit staffing levels directly affect the fire fighting crew's tactical performance capabilities, the speed at and duration of which they can be relied upon to accomplish various tasks, such as establishing water supply, advancing hose lines, or effecting rescues, as well as the overall scope and effectiveness of the tactical intervention strategy being applied in a given situation.*" (Page 3-2)

"*CFD procedures indicated that for fires involving structures less than five stories in height, the first alarm assignment was two engine companies, a ladder truck company, and a BC* [1, 8]. *For structures over five stories, the first alarm assignment was three engines, a ladder truck, a BC, and an AC. Procedures also stated that a confirmed report of smoke would trigger the assignment of an additional engine company.*" (Page 3-4)

"*At this early stage in the response, only five minutes after dispatch, the fire department had located the trash fire on the asphalt paved area and had discovered that the fire had spread to the interior of the loading dock. The AC surveyed the interior of the showrooms and did not observe any fire or smoke. Based on observations of the fire fighters in the showroom, the fire did not appear to have spread into the showrooms.*" (Page 3-8)

"*. . .As the team retreated from the loading dock area, the hose line burst or was burned through by the fire near the doorway. The fire fighting team moved through the water spray from the burst hose line and exited the structure through the door adjacent to the warehouse.*" (Page 3-9)

"*After observing the black smoke plume, units from St. Andrew's Fire Department, a mutual aid department, self dispatched to the fire scene. At 7:24 p.m., the mutual aid department arrived and after discussion with the Fire Chief, at least two engine companies and a ladder company from St. Andrew's Fire Department were assigned to the rear of the warehouse. Once the mutual aid units connected to a hydrant on Pebble Road, they deployed their ladder/platform and directed an aerial water stream onto the rear of the warehouse.*" (Page 3-10)

"*After observing the black smoke plume, units from St. Andrew's Fire Department, a mutual aid department, self dispatched to the fire scene. At 7:24 p.m., the mutual aid department arrived. . .*"

"*. . .Since fire crews were pulling the hoses to the rear of the west showroom, the fire department appeared to be focused on suppressing the fire on the loading dock. They did not appear to have evidence that the fire had spread through the open roll-up door into the holding area, into the void space above the drop ceiling, and eventually into the rear of the main showroom.*" (Page 3-11)

"*A second potential path for the fire might have been through the partition wall. However since the wall was constructed out of 12.7 mm (0.5 in) thick gypsum board on both sides, it would have taken the fire some time to penetrate both sides of the partition wall. If the wall was constructed using two layers of fire resistant Type X, 15.6 mm (0.625 in) thick gypsum board on both sides of a metal studs, the wall would have been rated as a one-hour fire wall* [16]*. If the fire team on the loading dock had directed a solid stream of water onto the partition wall then the impingement of the water stream on the gypsum wall would have likely shortened the time to failure of the wall. . .*" (Page 3-13)

"*. . .The CFD did not ventilate the roof, so no vertical pathway existed in the rear of the main showroom. There were no doors or windows on the rear (south) side of the main showroom. Although there were open fire doors between the main showroom and the east and west showrooms, the exterior doors on the west and east showrooms were closed. The fire growth in the rear of the main showroom was slow due to the lack of air.*" (Page 3-13)

> "*. . .The fire growth in the rear of the main showroom was slow due to the lack of air.*"

"*As the fire continued to grow in the rear of the main showroom and the smoke filled the volume above the ceiling, smoke continued to accumulate in the main showroom. As the smoke layer above the heads of the fire fighters continued to thicken and eventually dropped closer to the floor the visibility decreased. The fire fighters within the smoke filled main showroom became disoriented as evidenced by radio transmissions, and at approximately 7: 27 p.m., fire fighters began to request help* [8, 9]." (Page 3-14)

> "*. . .The fire fighters within the smoke filled main showroom became disoriented as evidenced by radio transmissions, and at approximately 7: 27 p.m., fire fighters began to request help* [8, 9]."

"*. . .At about 7:35 p.m. the fire fighters broke the front windows to allow more of the smoke to vent and improve the visibility in the main showroom. After the windows were vented, the smoke changed color and became much blacker. The change in smoke color was still consistent with partially oxidized combustion products from a fire that was ventilation-limited.*" (Page 3-14)

> "*. . .At about 7:35 p.m. the fire fighters broke the front windows to allow more of the smoke to vent and improve the visibility in the main showroom. After the windows were vented, the smoke changed color and became much blacker. . .*"

"*. . .Eventually, the hot smoke mixed with sufficient air to create a layer below the drop ceiling. As the fire at the rear of the main showroom ignited this layer of unburned combustion products, the fire rapidly moved from the rear of the showroom (southwest corner) to the front of the store (Figure 3-9). The fire then spread into the east side of the main showroom before emerging from the front of the store (northeast corner). After spreading to the entire main showroom, video recorded during the fire* [4] *demonstrated that the fire spread through the open fire doors into the west showroom and eventually to the front windows of the west showroom.*" (Page 3-14)

"*. . .The Fire Chief directed two two-man teams to attempt to enter and search for the trapped fire fighters. Both teams entered the main showroom, but were forced to retreat by the intense heat. At approximately 7:38 p.m., the last of the search teams exited the front of the structure.*" (Page 3-17)

"*. . .At about 10:00 p.m. the fire was declared under control and recovery operations were initiated. At approximately 4:00 am the next morning, recovery operations were completed.*" (Page 3-17)

"*As the fire spread to the rear of the main showroom, the fire still behaved as though it was under ventilated. At approximately, 7:35 p.m., the front windows of the store were broken by fire fighters. Shortly after the windows were broken, the fire was provided with additional air either from the vent front windows or through the loading door rollup door. The additional oxygen allowed the fire to spread rapidly from the rear to the front of the main showroom.*" (Page 3-17)

"*. . .The additional oxygen allowed the fire to spread rapidly from the rear to the front of the main showroom.*"

"*. . .The fire department did not appear to set up or designate a specific location as a command post. The fire department did not adopt a traditional incident command structure or paradigm. . .*" (Page 3-18)

"*. . .CFD procedures allow off-duty fire fighters to respond to and participate in fire ground activities. Department procedures required each fire fighter to provide a chief officer with an identification card before participating in fire ground activities. Department procedures did not require that the off-duty fire fighter check in with the incident commander, just a chief officer.*" (Page 3-18)

"*The lack of a single command post and the ability of off-duty fire fighters to check in with different chief officers did not allow easy or coordinated tracking of personnel on the fire ground. . .*" (Page 3-18)

"*Most emergency services providers, and fire departments in particular, develop and operate with the assistance of mutual aid agreements with neighboring departments to augment their capability to respond to incidents when their assets are committed or otherwise unable to satisfy the community's emergency response requirements. . .*" (Page 3-18)

"*. . .All agreements benefit the member agencies by providing emergency surge capabilities (staffing, equipment, etc.) from other agencies that would be prohibitively expensive to operate and maintain in each jurisdiction.*" (Page 3-19)

"*Most emergency services providers, and fire departments in particular, develop and operate with the assistance of mutual aid agreements with neighboring departments to augment their capability to respond to incidents when their assets are committed or otherwise unable to satisfy the community's emergency response requirements. . .*"

"*. . .Jurisdictional differences in equipment, tactics, and communications systems may also present interoperability challenges to the effective use of mutual aid assets, as was the situation at this incident. . .*" (Page 3-19)

"*On-scene mutual aid was provided to the CFD by the St. Andrew's Fire Department and St. Jame's Fire Department. Each of the mutual aid departments responded on their own, not at the request of CFD. . .*" (Page 3-19)

"*Computer simulations, also known as numerical modeling, have been demonstrated to be useful, when properly applied, as a tool to help fill in details of the fire dynamics and to demonstrate the value of alternative building designs and fire safety measures* [1]*. Simulation results are an approximation of the actual event, and are most valuable when considered as qualitative rather than quantitative. In other words, it is likely that the simulations do not return exactly the same results as might have been present in the real world situation, but can provide a reasonable approximation of conditions. These simulated scenarios can then be used to further examine relative differences when simulations that include changes to the modeled environment are compared with each other.*" (Page 4-1)

"*The focus of this simulation was the examination of conditions that may have been present in the Sofa Super Store during the first 40 minutes (2400 s) after the fire department discovered the fire in the loading dock area. For these model simulations, the fire department was on scene at time = 0, the fire was discovered at the rear of the west showroom at 2 minutes, E-12 began pumping water to E-10 (loading dock) at 10 minutes, broken radio calls began to indicate fire fighters in trouble at 16 minutes, front windows were vented at 24 minutes, fire was emerging from front windows at 26 minutes, last fire fighter successfully exited structure at 27 minutes, and the roof over the main showroom partially collapsed at 40 minutes. Each 40 minute simulation covered the time period from fire department's arrival at 7:11 p.m., to just after the partial collapse of the main showroom roof at 7:51 p.m.*" (Page 4-2)

"*. . .The spread of the fire into the showrooms was not reported by the fire fighters for at least 10 minutes after they entered the showrooms.*" (Page 4-2)

"*Automatic water sprinklers are very effective in controlling the growth and spread of fires. Water sprinklers were not installed in the showrooms, loading dock, or warehouse of the Sofa Super Store. . .*" (Page 4-2)

"*Ventilation can significantly impact how a fire grows and develops. The fire service often ventilates a structure by breaking windows or cutting holes in roofs in order to allow the smoke and hot gases to be exhausted from the structure. Less smoke and hot gases can improve visibility and make working conditions more tenable. Ventilation can also provide additional air to the fire and can result in a greater release of heat or energy.*" (Page 4-2)

"*Computer simulations, also known as numerical modeling, have been demonstrated to be useful, when properly applied, as a tool to help fill in details of the fire dynamics and to demonstrate the value of alternative building designs and fire safety measures* [1]. . ."

"*. . .Simulation results are an approximation of the actual event, and are most valuable when considered as qualitative rather than quantitative. In other words, it is likely that the simulations do not return exactly the same results as might have been present in the real world situation, but can provide a reasonable approximation of conditions. . .*"

"*The NIST Fire Dynamics Simulator (FDS) is a computational fluid dynamics model of fire-driven fluid flow. It solves a form of the Navier-Stokes equations appropriate for low-speed, thermally driven flow with an emphasis on smoke and heat transport from fires* [3]. . ." (Page 4-3)

"*Inputs required by FDS include the geometry of the structure, the computational cell size, the location of the fire source, the energy release rate of the fire source, the mass, geometry and thermal properties of walls, ceilings, floors, and furnishings, and the size, location, and timing of door and window openings to the outside of the structure. The selection of thermophysical properties and dimensions for the input parameters can have a significant impact on the outcome of the simulation, and because considerable uncertainty exists in the values of these parameters, a range of values is used.*" (Page 4-3)

"*. . .The selection of thermophysical properties and dimensions for the input parameters can have a significant impact on the outcome of the simulation, and because considerable uncertainty exists in the values of these parameters, a range of values is used.*"

"*. . .The results of the simulation including the spread of fire and smoke within the loading dock, holding area, and showrooms, are compared to the photographic and video record and the statements of witnesses to assess the agreement between the simulation and the actual fire. The input parameters are systematically adjusted and the simulation re-run. This process of refining the input parameters continues until the best possible agreement has been achieved.*" (Pages 4-3 and 4-4)

"*. . .The input parameters are systematically adjusted and the simulation re-run. This process of refining the input parameters continues until the best possible agreement has been achieved.*"

"*Selecting the appropriate cell size required balancing the need to resolve critical dimensions and physical phenomena against the need to budget enough time to perform the hundreds of computer runs necessary to assess the importance of different variables on the outcome. The FDS input parameters were adjusted by comparing the simulation results with the available photos, videos, witness statements and other documentation of the fire. This methodology has been used previously by NIST researchers in post-fire studies* [6-13]*. Over 250 computer simulations were required to match the observed phenomena and time line. The simulation that best matched with observations and time lines is presented as the baseline case. . .Approximately four days were required to generate each 2400 second simulation.*" (Page 4-4)

"*. . .The consumption of fuel in the main and west showrooms was so extensive that the furniture layout used in the model was based largely on post-fire residue and witness accounts. Post-fire residue included metal hardware, steel frames, hinges, and springs. Witnesses described the showrooms as being "crowded" with furniture. The general description of the main showroom placed aisles down the center of the room, from the front door to the rear office area. . .*" (Page 4-6)

"*. . .Over 250 computer simulations were required to match the observed phenomena and time line. The simulation that best matched with observations and time lines is presented as the baseline case. . .Approximately four days were required to generate each 2400 second simulation.*"

"*. . .This sequence of events was used to synchronize the model time line to the physical time line, where time 0 in the simulation is equal to 7:10:53 p.m.*" (Page 4-9)

"*. . .FDS utilizes material properties of the furnishings, walls, floors, and ceilings to compute fire growth and spread. For materials that burn, additional parameters such as reference temperature, heat of combustion, heat of reaction and maximum burning rate are specified. The properties for the materials, to the extent they were available, were taken from published fire data and references.*" (Page 4-9)

"*The assumption was made that all furnishings in the building were composites of foam and fabric, and that this material or composite constituted the entire fuel load. . . .Other fuels such as flooring, wood display shelves, ceiling tile, paper documents, or wood framing, were not included as fuel for these simulations.*" (Page 4-9)

"*Interior finishes were categorized into the following list of materials: gypsum board, concrete block, concrete slab, sheet metal, steel, glass, carpet, ceiling tile, and wood. . .*" (Page 4-9)

"*During the course of a fire, some items within the building may be consumed by the fire or otherwise change position. FDS does not have the capability to calculate burn-through or collapse but the user can remove items during the course of the calculations. Items that are removed can represent objects that fall or are destroyed by fire, or objects that are changed by people such as doors or windows that are opened.*" (Pages 4-9 and 4-10)

> "*. . .Other fuels such as flooring, wood display shelves, ceiling tile, paper documents, or wood framing, were not included as fuel for these simulations.*"

"*. . .A series of photographs documented the removal of the front windows on the main showroom between 7:35:05 p.m. and 7:35:57 p.m. Photos were also used to estimate the times at which the windows on the west showroom failed. These windows failed between approximately 7:38 p.m. and 7:44 p.m. In the simulation, windows were removed at times corresponding to estimates based on photographs and not based on the interior conditions or material properties of the windows.*" (Page 4-10)

"*. . .Flames are also visible and appear to be coming from the roof of the main showroom. Because it was not possible to determine the exact location or size of the holes in the ceiling and roof, several holes were used in the simulations to represent the ventilation that took place. Table K-4 summarizes the ventilation conditions used in the simulations.*" (Page 4-10)

"*The baseline simulation represents an estimate of what actually occurred in the Sofa Super Store based upon the evidence and time line described in the previous chapters. The resulting HRRs in the different portions of the store, visibility as estimated from the predicted smoke flows, and the temperatures and oxygen volume fractions at different elevations are presented in the following sections.*" (Page 4-12)

"*. . .As the fire spread into the rear of the main showroom, the fire became underventilated and began to decrease in HRR. The total HRR continued to decrease until about 1450 s when the removal of the windows in the main showroom, beginning at 1457 s (7:35:10 p.m.), provided a fresh influx of oxygen leading to the subsequent rapid fire growth. The HRR of the fire grew to over 100 MW in the main showroom and 50 MW in the west showroom. The energy release rate of the holding area/rear main showroom increased slightly and then leveled out at about 40 MW. The loading dock HRR exhibited a transient peak at about 50 MW and then decreased to about 15 MW.*" (Page 4-13)

"*. . .As the fire spread into the rear of the main showroom, the fire became underventilated and began to decrease in HRR. The total HRR continued to decrease until about 1450 s when the removal of the windows in the main showroom, beginning at 1457 s (7:35:10 p.m.), provided a fresh influx of oxygen leading to the subsequent rapid fire growth. . .*"

"*. . .The holding area was adjacent to the loading dock and was accessible through an open roll-up door. This room did not have a drop ceiling and had shelves upon which futon cushions were stored. Smoke and heated combustion gases produced by the fire passed into the void space above the main showroom.*" (Page 4-15)

"*Purser* [2] *has published data that identify when conditions become untenable for humans. Purser provides an algorithm for estimating the time to lose consciousness due to low oxygen. At 0.12 volume fraction, the time is estimated at about five minutes. In a closed fire-engulfed environment, toxic gases (such as carbon monoxide) are likely to be present before the oxygen gets this low. Since the simulation tracks the oxygen volume fraction, it will be used as one indicator for tenability. A second indicator will be when the temperature exceeds 120°C (250°F). For each of the simulations, the time for areas to become untenable4 due to elevated temperature or oxygen depletion will be tabulated. These incapacitation criteria are simplifications of complex studies and serve as a basis for appraising the relative effects of alternate fire scenarios.*" (Page 4-23)

"*The NIST study did not include analysis of the threat to protected fire fighters. If a fire fighter in turnout gear is utilizing a self-contained breathing apparatus (SCBA) and has an adequate supply of air, the fire fighter can temporarily survive higher temperatures and depleted external oxygen levels. This safety shell ends when the fire fighter runs out of tank air or remains within the hot fire environment too long.*" (Page 4-23)

"*. . .A second temperature surge, which began at approximately 1460 s (7:35:13 p.m.), was due to the fire entering the west showroom through the open roll-up door as it moved to the front of the main showroom. It should be noted that the focus of suppression efforts was in this area of the showroom, and that the simulation does not take this into account.*" (Page 4-25)

"*. . .FDS has been shown to be able to predict the number of sprinklers activated and the approximate activation times, as well as trends, temperatures, heat fluxes and oxygen volume fractions in reasonable agreement with measured values* [5; Vols. 2&3]. *However, the suppression physics in FDS is simplified and cannot capture all of the details of the suppression process.*" (Page 4-29)

"*The sprinkler system layout was designed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems* [17]. *The system was designed as a light hazard wet pipe system, assuming that the enclosed loading dock area was heated. A light hazard sprinkler system was utilized in order to provide a conservative estimate for the area/water density for the simulations. The locations of the sprinklers within the enclosed loading dock are shown in Figure 4-35. . .*" (Page 4-29)

"*The NIST study did not include analysis of the threat to protected fire fighters. If a fire fighter in turnout gear is utilizing a self-contained breathing apparatus (SCBA) and has an adequate supply of air, the fire fighter can temporarily survive higher temperatures and depleted external oxygen levels. . .*"

"*FDS has been shown to be able to predict the number of sprinklers activated and the approximate activation times, as well as trends, temperatures, heat fluxes and oxygen volume fractions in reasonable agreement with measured values* [5; Vols. 2&3]. . ."

"*The results indicate that as early as 270 s into the simulation, smoke may have begun to flow down through ventilation openings in the drop ceiling and into the rear of the main showroom. By 300 s, there is also a layer of smoke beginning to develop under the drop ceiling in the rear of the west showroom. It cannot be concluded from the simulation whether an observer located in the main showroom would have noticed smoke in the rear main showroom at 300 s, or would have been able to distinguish the source of that smoke. The smoke continued to flow down through ventilation openings and, after forming a substantial layer in the rear of the main showroom, began to spread throughout the main showroom. At about 400 s, the simulation indicates that the smoke layer extended down to near the floor on the west side of the main showroom. As the fire spread from the holding area into the rear of the main showroom at around 500 s, additional smoke was added to the smoke layer in the main showroom. As demonstrated by the rendering of smoke by the simulation, visibility became compromised in the showrooms within 8 minutes to 10 minutes. The simulation results are consistent with the E-11 captain reporting heavy smoke in the main showroom at 7:20 p.m., which would correspond to 555 s into the simulation.*" (Page 4-49)

"*. . .The higher simulation temperatures in the front of both showrooms, as compared to the rear of the showrooms, are consistent with additional oxygen being available in the front of the showrooms, relative to the less ventilated rear areas of the showroom.*" (Page 4-50)

"*In the simulation with automatic sprinklers, the two sprinklers nearest the fire (in the southwest corner of the loading dock) activated early in the fire, at 50 s and 75 s. The two sprinklers controlled the fire and prevented the fire from spreading into the showrooms or warehouse. As a result, the temperatures and oxygen volume fractions remained below untenability thresholds.*" (Page 4-56)

"*In the simulation with automatic sprinklers, the two sprinklers nearest the fire (in the southwest corner of the loading dock) activated early in the fire, at 50 s and 75 s. The two sprinklers controlled the fire and prevented the fire from spreading into the showrooms or warehouse. . .*"

"*A contract was entered into with Koffel Associates, Inc. of Elkridge, Maryland, to identify the current model building and fire codes that were available for application to a structure such as the Sofa Super Store. They were also contracted to identify the model building and fire codes in place at the time the building was constructed and at the times when modifications were made to the structure. Koffel Associates provided comparisons of the requirements of the identified building and fire codes. The analysis and discussion of this chapter focus on areas that are expected to be related to the growth and spread of the fire that occurred on June 18, 2007. Any conclusions and findings that are presented are solely those of NIST.*" (Page 5-1)

"*The model codes may require sprinkler protection for buildings based on a combination of factors including occupancy, building area, construction type, building height, and occupant location relative to exit discharge. . .The fire barriers between the showrooms may have been installed to avoid sprinkler system installation requirements, although the fire barriers may not have met the code definition of a fire wall. Those barriers failed during the fire due to a roll-down fire door not operating properly.*" (Page 5-7)

"*. . .The fire barriers between the showrooms may have been installed to avoid sprinkler system installation requirements, although the fire barriers may not have met the code definition of a fire wall. Those barriers failed during the fire due to a roll-down fire door not operating properly.*"

"*. . .NFPA 80 (§5.2.1) requires that inspection and testing occur not less than annually, and that a written record of the inspection be signed and kept for possible future inspection by the authority having jurisdiction.*" (Page 5-8)

"*The type and amount of fuel, in conjunction with the large open display area, enabled the Sofa Super Store fire to spread rapidly within the building. Both automatic fire sprinklers and compartmentalization can effectively limit how fast a fire spreads within a structure. . .*"
(Page 5-9)

"*. . .NFPA 80 (§5.2.1) requires that inspection and testing occur not less than annually, and that a written record of the inspection be signed and kept for possible future inspection by the authority having jurisdiction.*"

"*For display areas of furniture stores, the maximum floor areas allowed by the model codes do not appear to be effective in sufficiently limiting the magnitude and severity of furniture showroom fires.*" (Page 5-10)

"*Based on allowable area, merchandise sold, and configuration of furniture stores, the maximum amount of fuel that is permitted by the model code does not appear to be effective in limiting the rapid spread and magnitude of the resulting fire to a level consistent with other sections of the code. . .*" (Page 5-10)

"*For display areas of furniture stores, the maximum floor areas allowed by the model codes do not appear to be effective in sufficiently limiting the magnitude and severity of furniture showroom fires.*"

"*In summary, the hazard of a fire spreading rapidly across a large furniture display area can be reduced by compartmentalizing the display area(s), or by installing automatic fire sprinklers which have been demonstrated as an effective method of controlling building fires. The unsprinklered fire areas allowed by the model codes are too large to prevent rapid fire growth and sufficiently limit the magnitude and severity of fires in furniture display areas. Reducing the maximum allowable size of unsprinklered furniture showroom fire areas to 190 m^2 (2000 ft^2) would slow the rate of fire spread within buildings and reduce fire magnitude by compartmentalizing the otherwise open spaces.*" (Page 5-10)

"***Smoke and flames flowed from the holding area into the space above the main showroom drop ceiling. At a later stage, fire spread either over or through the holding area partition wall and into the rear of the main showroom.***" (Page 6-3)

"***Three fire doors between the main and west showrooms activated, but did not close during the fire. Three fire doors between the main and east showrooms activated; two doors closed completely and the third partially closed.***" (Page 6-3)

"***Smoke and flames from the fire on the loading dock and holding area flowed into the space above the main showroom drop ceiling.***" (Page 6-3)

"***During the early stages of the fire (10 minutes to 15 minutes after fire department arrival) the heat release rate of the fire in the rear of the main showroom was slowed by the lack of air; that is, the fire was under-ventilated.***" (Page 6-3)

"*Front windows were broken or vented by the fire department to improve visibility*." (Page 6-3)

"***Fire spread extremely rapidly from the rear to the front of the showroom as additional air flowed through the broken windows, feeding the fire in the rear of the showroom.***" (Page 6-3)

"*Front windows were broken or vented by the fire department to improve visibility*."

"*The lack of automatic sprinklers to suppress the fire during an early stage of its growth and the lack of effective compartmentalization were direct contributors to the loss of nine fire fighters' lives and the loss of the retail showrooms and distribution warehouse. . .*" (Page 6-4)

"***Computer model simulations demonstrated that automatic fire sprinklers in the loading dock would have controlled the fire and prevented the fire from extending beyond the loading dock.***" (Page 6-4)

"***Computer model simulations demonstrated that tenable (survivable) conditions were maintained within the loading dock, showrooms, and warehouse had a sprinkler system been installed on the loading dock.***" (Page 6-4)

"***Only three of the seven roll-up fire doors activated and closed fully during the fire.***" (Page 6-5)

"*There were more than five portable fire extinguishers located in the structure. A store employee discharged two portable extinguishers at the loading dock fire*." (Page 6-5)

"***The type and configuration of the fuels played a role in how fast the fire was able to spread.***" (Page 6-6)

"***The furniture fuel mass loading was estimated to range up to 16 kg/m^2 (3.4 lbs/ft^2) for the showrooms and 52 kg/m^2 (10.6 lbs/ft^2) for the warehouse. The high-rack storage in the warehouse contributed to the higher fuel mass loading than in the showrooms.***" (Page 6-6)

"***The furniture created a unique fire hazard in terms of the type and configuration of the fuel load. Furniture is often displayed in large open areas. As demonstrated in the main and west showrooms and warehouse, displaying large amounts of furniture in large open spaces can contribute to extremely rapid fire spread.***" (Page 6-8)

"***The fire department required about 10 minutes to establish a water supply from a fire hydrant to the exterior loading dock area.***" (Page 6-8)

"***The fire department vented the front windows about 24 minutes after arrival.***" (Page 6-9)

"*The fire department vented the front windows about 24 minutes after arrival.*"

"***Heavy smoke flowed out of front windows within 2 minutes of the windows being vented.***" (Page 6-9)

"***Flames emerged from the front windows within 3 minutes of the windows being vented.***" (Page 6-9)

"*The last fire fighters to exit successfully from the front of the store did so within 4 minutes of windows being vented.*" (Page 6-9)

"*The roof collapsed over the west side of the main showroom about 40 minutes after fire department arrived on scene.*" (Page 6-9)

"*The initial response of the fire department included two engine companies, a ladder truck company, and a battalion chief. With an engineer, a fire fighter, and an officer on each apparatus, the fire department's initial response was 10 people. . .For high hazard occupancies, NFPA 1710* [12] *advocates a minimum crew size of five to six members for each apparatus, which for this incident would amount to 16 to 19 people for the initial response.*" (Page 6-9)

"*The responders did not know when fire and smoke entered the showrooms. The fire department visually checked below the drop ceiling for fire spread. The NIST study was not able to document any fire fighter removing a ceiling tile to check for fire spread above the drop ceiling. . .*" (Page 6-9)

"*The supply of water to the fire fighters was limited to the water on the fire engines for 9 minutes at the loading dock and 15 minutes at the front of the store. When the connection was made to the municipal water supply, the two engines were pumping water to the store through long lines of small diameter 6.4 cm (2.5 in) hose. . .*" (Page 6-10)

"***Venting the front windows of the main showroom did allow the smoke to escape, but it also provided more air to feed the fire and provided a path for the fire to spread.***" (Page 6-10)

"***After the windows were broken, the fire spread extremely rapidly into the main showroom and into the west showroom.***" (Page 6-10)

"*Fire department inspections did not identify the large fuel load, the non-code compliant wood construction, the solvent storage on the loading dock, or the lack of a fire door between loading dock and holding area as significant fire hazards.*" (Page 6-11)

"*After the windows were broken, the fire spread extremely rapidly into the main showroom and into the west showroom.*"

"*Adoption of a model code, in and of itself, is not sufficient to guarantee the safety of a building. . .Recognizing this, model codes need to be robust and contain sufficient redundancies to minimize the chances of loss of life caused by the failure of a building that is built or operating out of compliance with code provisions.*" (Page 6-11)

"*Adoption of a model code, in and of itself, is not sufficient to guarantee the safety of a building. . .Recognizing this, model codes need to be robust and contain sufficient redundancies to minimize the chances of loss of life caused by the failure of a building that is built or operating out of compliance with code provisions.*"

"*If current model codes had been adopted and applied retroactively to high fuel-load mercantile occupancies, the model codes would have required the Sofa Super Store's main showroom and warehouse be sprinklered.*" (Page 6-12)

"*Effective inspections and enforcement of the 2006 model building and fire codes available at the time of the Sofa Store fire would have required the door and walls of the showrooms and warehouse to be upgraded or would have required sprinklers to be installed. . .*" (Page 6-12)

NIST recommends that model codes require sprinkler systems and that state and local authorities adopt and aggressively enforce this provision:

a) for all new commercial retail furniture stores regardless of size; and

b) for existing retail furniture stores with any single display area of greater than 190 m^2 (2000 ft^2).

(Page 6-12)

"*A risk management plan, properly implemented, would have identified the hazards associated with the size and type of fuel load and the large open spaces that existed at the Sofa Super Store.*" (Page 6-13)

"*The acceptance of the recommendations made in this report by the model code and standards organizations and the adoption of any modified provisions of the national model codes into local codes will depend upon the perceived benefits weighed against the costs of implementing any changes. There are a number of areas where the benefits may be obvious and the costs of implementation may be easily determined. . .*" (Page 6-13)

"*There are other areas in which the basis for making changes to local codes is not currently supported by reliable technical information. Continuing research is needed to gain new understanding and to collect the data necessary to ensure that changes are adopted, or rejected, based upon sound scientific findings. . .*" (Page 6-14)

"*. . .Continuing research is needed to gain new understanding and to collect the data necessary to ensure that changes are adopted, or rejected, based upon sound scientific findings.*"

"*In terms of furniture flammability, fire science needs to focus additional research on the development of two types of knowledge: 1) how to make furniture that is less flammable, and 2) how to accurately simulate the burning of existing furniture for forensic use. . .*" (Page 6-14)

"*Improving fire barriers requires that additional research be focused on: 1) how to design products that will contain a fire while at the same time meeting other use requirements, and 2) replicating the performance of existing partitions in forensic models. Fire-resistance testing of walls, floors, ceilings, and doors typically ends when the temperature on the non-fire side exceeds a standard value. There is insufficient understanding of the mechanisms by which partitions and doors pass flames into adjacent spaces, especially for the composite assemblies typical of real construction. Having an accurate modeling capability for how flames pass into adjacent spaces will improve the ability to accurately establish fire time lines and to evaluate the importance of multiple fire paths.*" (Page 6-14)

"*Improving fire barriers requires that additional research be focused on: 1) how to design products that will contain a fire while at the same time meeting other use requirements, and 2) replicating the performance of existing partitions in forensic models. . .*"

"*New knowledge, data, and predictive methods generated in the above research will lead to new technologies and improved fire standards. The selection among alternative fire safety technologies or building design options, and the setting of threshold values in the model codes, can have significant economic ramifications. New tools are needed that can be tailored to specific situations and rigorously account for costs in a manner transparent to competing interests.*" (Page 6-15)

"*. . .New knowledge, data, and predictive methods generated in the above research will lead to new technologies and improved fire standards. . .*"

"*First responders commonly use ventilation is to improve the firefighting environment, increase the survivability of trapped occupants, and reduce property damage. In some cases though, ventilation may improve conditions within a structure, but may also lead to increased fire growth and spread, flashover, or back draft (deflagration). The effects of natural ventilation on the fire environment during fire fighter operations are not well understood.*" (Page 6-15)

"***NIST recommends that research be conducted to:***

a) develop performance and effectiveness metrics for community fire protection;

b) survey effectiveness of existing fire services; and

c) use metrics to optimize development of new technologies."

(Page 6-16)

"*Completing the research recommended will provide a reliable technical foundation for making changes to codes, standards and practices. . .*" (Page 6-16)

"*Completing the research recommended will provide a reliable technical foundation for making changes to codes, standards and practices.*"

Part 2 of this article will include an analysis of the Draft Report.

* * * * *