U.S. Fire Administration/Technical Report Series

The World Trade Center Bombing: Report and Analysis

New York City, New York

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Homeland Security

U.S. Fire Administration Fire Investigations Program

The U.S. Fire Administration develops reports on selected major fires throughout the country. The fires usually involve multiple deaths or a large loss of property. But the primary criterion for deciding to do a report is whether it will result in significant "lessons learned." In some cases these lessons bring to light new knowledge about fire--the effect of building construction or contents, human behavior in fire, etc. In other cases, the lessons are not new but are serious enough to highlight once again, with yet another fire tragedy report. In some cases, special reports are developed to discuss events, drills, or new technologies which are of interest to the fire service.

The reports are sent to fire magazines and are distributed at National and Regional fire meetings. The International Association of Fire Chiefs assists the USFA in disseminating the findings throughout the fire service. On a continuing basis the reports are available on request from the USFA; announcements of their availability are published widely in fire journals and newsletters.

This body of work provides detailed information on the nature of the fire problem for policymakers who must decide on allocations of resources between fire and other pressing problems, and within the fire service to improve codes and code enforcement, training, public fire education, building technology, and other related areas.

Under unusual circumstances the Fire Administration is sometimes not able to conduct an investigation after a major fire. Such was the case with the tragic, massive emergency of the World Trade Center explosion and subsequent fire and evacuation in New York City in February of 1993 because of the criminal investigation following the incident and involvement of other Federal as well as State and local agencies in that investigation. Fortunately *Fire Engineering* magazine subsequently published an entire issue containing over 24 articles describing all the major aspects of the incident, fire and EMS operations, building construction features, lessons learned in each area, and actions that have been taken to improve the facility since the incident. The Fire Administration requested permission from *Fire Engineering's* Editor William A. Manning to publish the entire issue, which is how this report came about. Only a few of the photographs from the original issue of *Fire Engineering* were used here; their selection was based on suitability for the xerox-type reproduction used for FEMA/USFA publications.

The United States Fire Administration greatly appreciates the cooperation received from the *Fire Engineering* organization and staff and all of the authors and organizations who supplied materials and agreed to their use for this purpose.

The Fire Department of the City of New York has also prepared and published an extensive after-action report which was published in WNYF (With New York Firefighters), Volume 54, Number 3, which the interested reader will wish to obtain. For copies contact editor Gloria Sturzenacker, WNYF Subscription Department, FDNY Fire Academy, Randall's Island, NY 10035 ($4.00 back issue price).

For additional copies of this report write to the U.S. Fire Administration, 16825 South Seton Avenue, Emmitsburg, Maryland 21727. The report is available on the Administration's Web site at http://www.usfa.dhs.gov/

The World Trade Center Bombing: Report and Analysis

Provided by *Fire Engineering*
William A. Manning, Editor

This is Report 076 of the Major Fires Investigation Project conducted by TriData Corporation under contract EMW-4-4329 to the United States Fire Administration, Federal Emergency Management Agency.

Homeland Security

Department of Homeland Security
United States Fire Administration
National Fire Data Center

U.S. Fire Administration

Mission Statement

As an entity of the Department of Homeland Security, the mission of the USFA is to reduce life and economic losses due to fire and related emergencies, through leadership, advocacy, coordination, and support. We serve the Nation independently, in coordination with other Federal agencies, and in partnership with fire protection and emergency service communities. With a commitment to excellence, we provide public education, training, technology, and data initiatives.

U.S. Department of Homeland Security

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Report from Chief of Department

by Anthony L. Fusco

The City of New York Fire Department has responded hundreds of times to the World Trade Center (WTC) since it was first occupied in 1970. These responses normally consist of minor fires or false alarms but have included major fires such as the one that occurred on February 13, 1975. None of these experiences could have prepared us for what was to occur on February 26, 1993.

The bombing of the WTC was an event of immense proportions, the largest incident ever handled in the City of New York Fire Department's 128-year history — so complex that it was effectively several major multiple-alarm fires combined into one. In terms of the number of fire department units that responded, it was the equivalent of a 16-alarm fire.

As the incident commander, I can attest to the fact that it was the firefighters' tremendous efforts and courage that brought this incident to a successful conclusion.

The statistics are staggering: Six people died and 1,042 were injured. Of those injured, 15 received traumatic injuries from the blast itself. Nearly 20 people complained of cardiac problems, and nearly 30 pregnant women were rescued. Eighty-eight firefighters (one requiring hospitalization), 35 police officers, and one EMS worker sustained injuries.

It is estimated that approximately 50,000 people were evacuated from the WTC complex, including nearly 25,000 from each of the two towers. Fire alarm dispatchers received more than 1,000 phone calls, most reporting victims trapped on the upper floors of the towers. Search and evacuation of the towers finally were completed some 11 hours after the incident began.

A nitrourea bomb, in excess of 1,000 pounds, with hydrogen cylinders to add impact, was detonated in the now-infamous yellow Ryder Econoline van on the B-2 level of the parking garage, causing massive destruction that spanned seven levels, six below grade. The L-shaped blast crater on B-2 at its maximum measured 130 feet wide by 150 feet long. The blast's epicenter was under the northeast corner of the Vista Hotel.

FDNY ultimately responded to the incident with 84 engine companies, 60 truck companies, 28 battalion chiefs, nine deputy chiefs, and five rescue companies and 26 other special units (representing nearly 45 percent of the on-duty staff of FDNY). The fire department units maintained a presence at the scene for 28 days.

FEBRUARY 26, 1993

Snow was falling in lower Manhattan during the noon lunch hour on February 26. Temperatures hovered in the mid-20s. At 1218 hours, an explosion rocked the WTC complex.

Anthony L. Fusco is chief of department and a 33-year veteran of the City of New York (NY) Fire Department. He served as the incident commander for the World Trade Center incident.

Members of Engine Co. 10 and Ladder Co. 10, located in a firehouse directly across from the WTC complex on Liberty Street, felt the rumble of the blast. They responded from quarters on a "verbal" alarm, notifying FDNY Manhattan dispatchers of the incident and their response.

Simultaneously, Manhattan dispatchers received a flood of calls into their office. From initial indications, it was thought that a transformer had exploded in the vicinity of the Vista Hotel; however, from the number of phone calls received and initial reports from arriving units, the "normal" assignment response of two engines, two trucks, and a battalion chief was filled out, sending an additional engine company and Rescue Company 1 to Box 69.

First-arriving Engine Co. 10 and Ladder Co. 10 were met with the classic signs of a below-grade transformer explosion — heavy black smoke rolling from the WTC basement through its garage doors at their location on the West Street side of the building. [See following page for diagram of World Trade Center Complex.] One thing caught their attention, however — the basement garage doors were buckled. The lieutenant of Ladder 10 ordered the buckled garage doors to be opened with power saws for access and better ventilation.

With an apparent working fire in progress, Engine 10 transmitted the 10-75 signal (a working fire). This signal initiated the response of an additional battalion chief, the 2nd Battalion, as well as the deputy chief of the 1st Division.

Under normal standard operating procedures, first-arriving units proceed to the Port Authority (PA) Police station/fire command station on the B-1 level to determine the location of the fire. But because of the damage, this could not be done. In addition, Engine 10/Ladder 10 and the 1st Battalion are equipped with transmitting radios set to Port Authority Police frequencies.

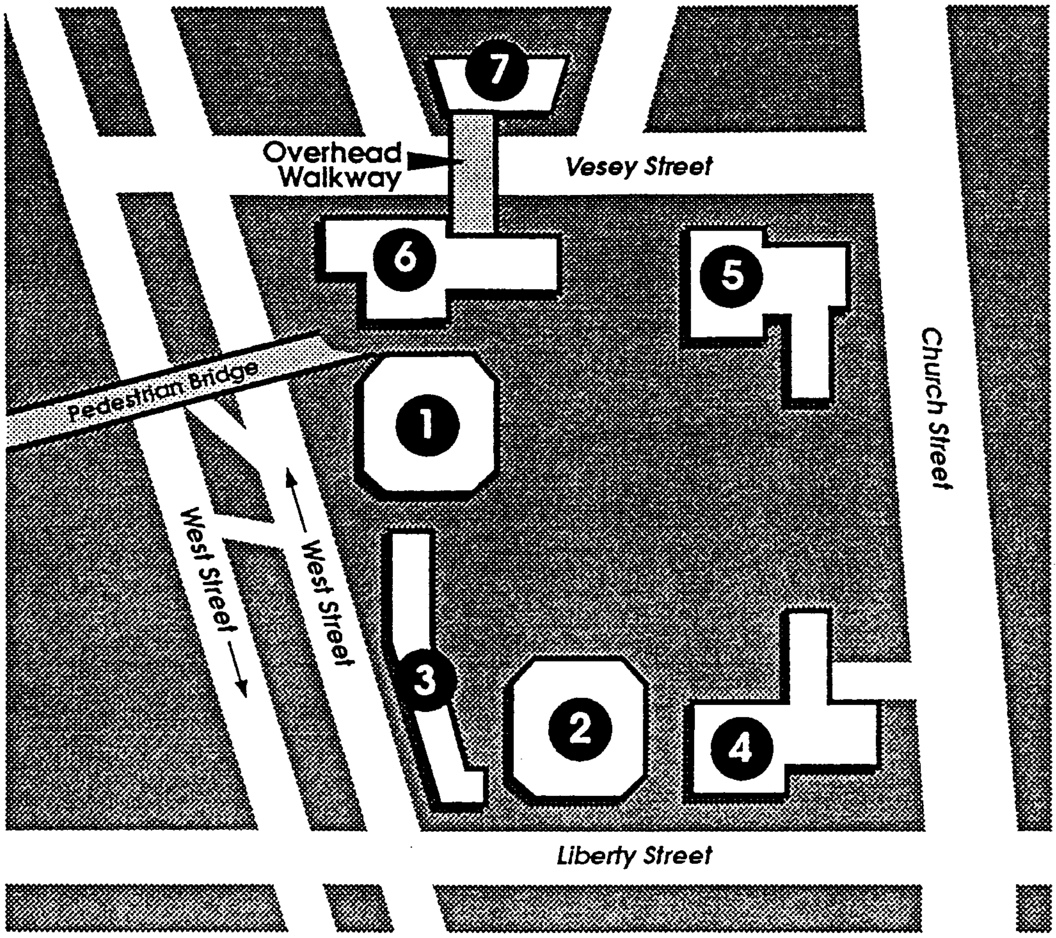
Members entered the building through the garage ramps. They encountered people who were evacuating, several of whom were injured. Once inside, they immediately knew this was not a transformer fire — the damage was too great. A major explosion had occurred in the garage.

Chief John Casey of the 1st Battalion also was becoming aware that this was not a transformer problem. The PA Police radio in his vehicle was reporting an explosion, and Engine 10 confirmed this by reporting heavy damage in the garage. Upon arrival, he noted the heavy smoke issuing from the garage level and immediately transmitted the 10-76 signal (a working high-rise fire) at 12:24 p.m. This brought one additional engine company, two additional ladder companies, Rescue Co. 3, the Field Communications Unit (FieldCom), the Mask Service Unit (MSU), and Engine Co. 3 as the High-Rise Unit. Hazmat 1 also responded.

Two additional boxes (9031 and 9032) were transmitted in conjunction with the 10-76 signal to bring additional units to the scene because of potential (yet typical) traffic problems during the daytime. These units came from Brooklyn, bringing an additional engine, truck, and battalion chief through the Brooklyn Battery Tunnel and another engine, truck, and battalion chief over the Manhattan Bridge.

From all indications, the explosion and resultant fire appeared to be located under the Vista Hotel. Chief Casey assumed command and established his command post in front of the hotel on West Street. Almost immediately after his arrival, he received reports that the Tower 1 lobby was filling with smoke and that people here trapped below grade. He transmitted a second alarm for Box 69 at 12:27 p.m. (due to problems developing in the Vista Hotel) and a third alarm for Box 69 (problems developing in Tower 1) at 12:30 p.m..

World Trade Center Complex



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1 1 World Trade Center – 110-story office tower
2 2 World Trade Center – 110-story office tower
3 3 World Trade Center – 22-story Vista Hotel
4 4 World Trade Center – 9-story office building
5 5 World Trade Center – 9-story office building
6 6 World Trade Center – 8-story Customs House
7 7 World Trade Center – 47-story office building

FDNY has assigned specific box numbers for specific significant buildings. In the case of the WTC, Box 8084 is assigned to Tower 1 and Box 8087 to Tower 2. Since this incident originated at the Vista Hotel, the street box was transmitted initially. As the incident grew and it became apparent that the towers were involved, the specific 8084 and 8087 boxes were transmitted. Dispatchers at the Manhattan Dispatchers Office began to receive a flood of calls regarding smoke problems and trapped people in Tower 1. Therefore, they transmitted an initial alarm for Box 8084 at 12:29 p.m.

Deputy Chief Robert Beier arrived and attempted to gain access to the fire command station on the B-1 level. Besides finding the garage full of smoke, Beier was told by PA Police that the fire command station had been badly damaged. Minute by minute, the incident escalated exponentially. He transmitted a fourth alarm for Box 69 at 12:37 p.m., realizing that a large portion of the WTC complex was involved in the incident. Beier was now receiving a constant stream of reports of trapped people in Tower 1. He dispatched companies to Tower 1 and the below-grade areas as soon as they arrived, attempting to ration them evenly. A second alarm for Box 8084 was transmitted at 12:39 p.m. by Deputy Assistant Chief Kenneth Cerreta, the Manhattan south commander, who arrived shortly after Deputy Chief Beier and assumed command.

My pager began beeping incessantly for each additional alarm—this was "The Big One." I responded from headquarters in Brooklyn, as did several other staff officers.

By now, the battalion and deputy chiefs at the scene began to comprehend the magnitude of the incident. A major fire was burning below grade. People were injured and trapped by the explosion. Communications were lost in the WTC complex. Smoke was contaminating Tower 1 and the Vista Hotel. A major extinguishment and rescue scenario was unfolding. [See building diagram including below-grade levels on following page.]

Deputy Assistant Chief Cerreta was receiving numerous reports of smoke problems in Tower 1 and dispatched a fire company to investigate this specific problem. They reported a heavy smoke condition in the lobby and contamination of vertical shafts, including the stairways and elevators. Occupants were self-evacuating, and some were breaking windows on the upper floors. Assistant Chief Donald Burns, chief of operations, arrived shortly after from Fire Department Headquarters and went directly to Tower 1, establishing a sector command post at that location.

I arrived at the command post at 12:48 hours. I could see smoke pouring out of the parking garage doors of the Vista Hotel. I also noted that the lobby windows of Tower 1 were blackened with smoke.

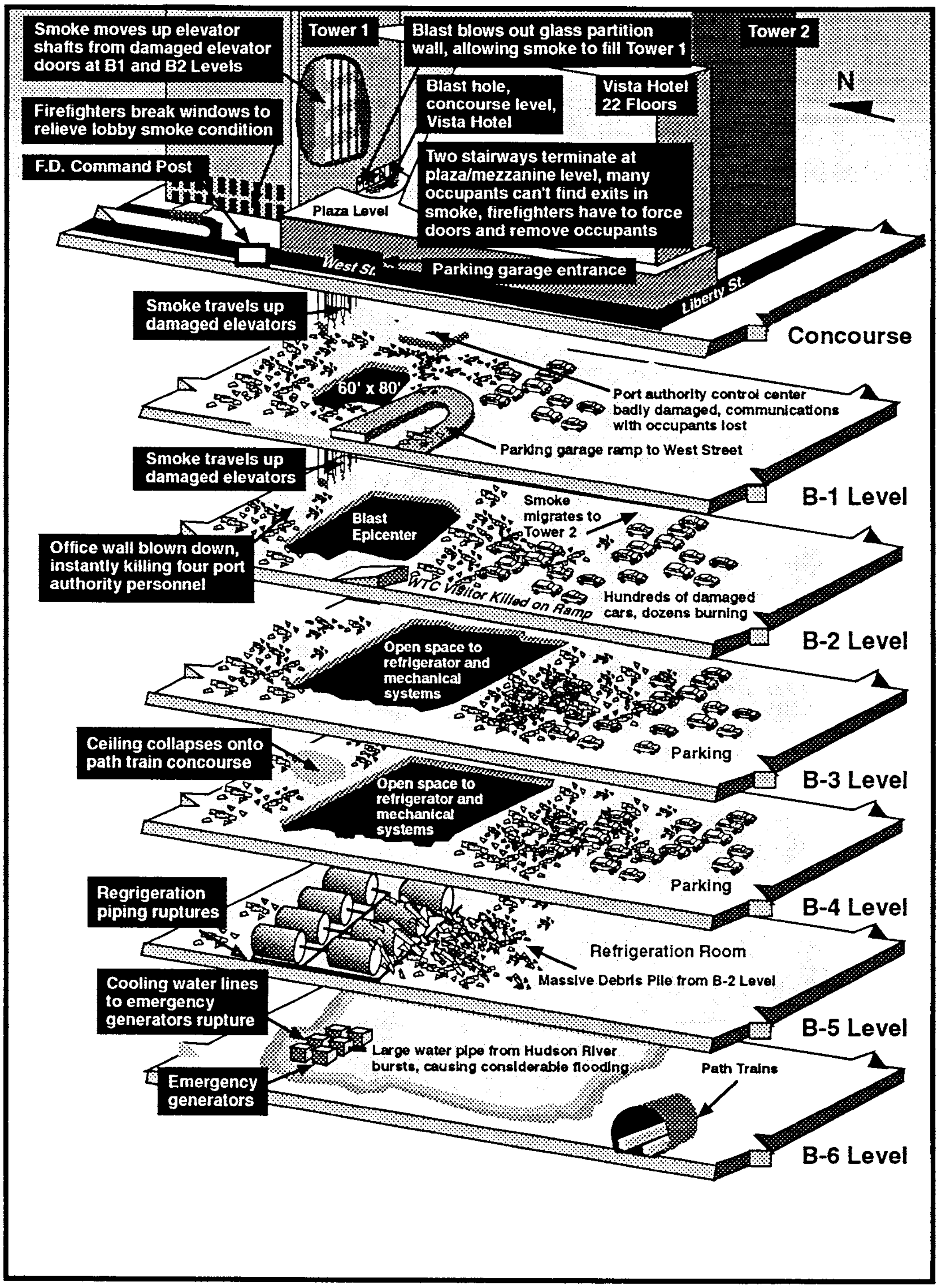
Cerreta briefed me on what information was known. He, Beier, and I discussed their size-up. Reports of a transformer explosion had been given over the department radio, but this had not yet been confirmed. The only known facts were that an explosion had occurred, people were injured, fire was burning on a lower level (or levels), and voluminous amounts of smoke were being produced, with three very large buildings affected.

Deputy Chief Steven De Rosa of the 3rd Division had been directed to establish sector command of the Vista Hotel — I was concerned about the life hazard directly above the explosion/fire area. After my own quick size-up, I asked Deputy Assistant Chief Cerreta if he could try to determine the extent of the operation, exactly what was burning, and what had occurred; he left the command post with that mission.

Very shortly thereafter, Chief Burns reported to me that huge volumes of smoke were entering Tower 1 and that he believed the wall or partition separating this tower from the fire area was blown out and the smoke movement could not be stopped. It was readily apparent, even at this early stage, that a major commitment of personnel would be required. I transmitted a fifth alarm for Box 69 at 12:54 p.m.

I contacted Chief Cerreta and directed him to abandon his reconnaissance mission and take command of fire extinguishment operations below grade. It was very clear to me that without the ability to control the smoke, the fire had to be extinguished as quickly as possible. Fire extinguishment would be the key to stabilizing the incident and protecting lives in the buildings above. As units arrived in response to the additional alarms, they were dispatched to sectors needing additional help.

Blast Damage



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A FIREFIGHTER MISSING

At about the same time that Chief Burns advised me of the missing wall in the Vista Hotel, Assistant Chief Ralph Palmer, who with Assistant Chief Eugene Dockter had assumed command of the Vista Hotel sector, reported that a firefighter was missing. It was believed that he had fallen in a large hole (this turned out to be the explosion crater).

This became a primary concern. Deputy Chief De Rosa, Battalion Chief Richard Rewkowski, Squad One, one rescue company, two ladder companies, and three engine companies ultimately were devoted to this operation. Later, it was determined that Firefighter Kevin Shea of Rescue 1, attempting to reach a trapped victim, had fallen into the crater. He would require major surgery that very day to treat his injuries.

The command post was now receiving reports of smoke in Tower 2 and that people were self-evacuating and were trapped in elevators. Deputy Chief Robert Manson and Deputy Chief Joseph Mills established sector command at Tower 2.

INCIDENT COMMAND

With Tower 2 command established, the framework for command and control was in place: The situation was divided into three primary sectors—Tower 1, Tower 2, and the Vista Hotel, and two subsectors—Firefighter Shea rescue and below grade extinguishment and search. Later, additional sectors would be established to ensure search of all complex buildings and the concourse area.

The sector commanders, in effect, ran their own operations. These chiefs split up their areas of responsibility into manageable parts so that subsectors and sub-subsectors were controlled by chief officers. Each sector reported its progress, problems, and needs to the command post, and the command post would provide necessary personnel and equipment, develop strategy, and implement same through sector commands. In this way, we attempted to operate with reasonable assurance that personnel accountability and safety, as well as fulfillment of operational needs, could be achieved while command strategy was implemented.

From my perspective as incident commander, keeping track of units and status was a major undertaking. I utilized the FieldCom Unit's command board to record unit positions. Two chiefs and the officer of the FieldCom Unit assisted in this effort. Members of the FieldCom Unit established field headquarters, monitored radio and portable radio communications, transmitted progress reports, and maintained a logistics board. Logistics and staging were huge undertakings, and First Deputy Commissioner (now Acting Commissioner) William Feehan directed logistics while Deputy Assistant Chief Donald Ruland handled staging for the incredible number of units already on the scene and still arriving.

I assigned Deputy Assistant Chief Elsworth Hughes as liaison officer. The command post was congested with representatives from many different agencies, including the city's Office of Emergency Management (the citywide disaster task force); PA Police; New York Police Department; New York City EMS; PA management, engineering, and risk management; Consolidated Edison (Con Ed, a local power utility); the Department of Environmental Protection; and many others. Fire department members in many cases worked closely with personnel from other agencies. For example, they worked with the local power utility to conduct gas shutoffs; worked with the Interstate Transportation Department to survey PATH train tracks on B 6; worked with various agencies to establish policy and procedures for potential asbestos release; and, most notably, worked with police and EMS personnel to effect safe rescues and give medical treatment.

With a constant barrage of people trying to gain access to our command post and the snowy weather conditions, it was decided that a more secure location was needed. A large tent was obtained and set up, and the command post was moved there. This tent provided shelter as well as isolation of the command post.

A major detriment to our ability to strengthen control of the incident was fire department on-scene communications. Communications were a serious problem from the outset. With 156 units and 31 chiefs operating at the height of this incident, try to imagine how difficult it was to gain control of the portable-radio operations frequency. Two command channels and one tactical channel were used. In many cases, runners were sent by a sector commander to communicate with the incident commander.

Generally, the problems were caused by one or more of the following factors:

- the number of resources using channels;
- not enough channels for operational areas;
- distance problems — lost messages;
- construction of building interrupted signals; and
- the inability to contact other agencies.

Fireground communications have become a major concern of FDNY, and several initiatives are underway to enhance communications.

Many workers in the twin towers had access to operating telephones. More than 1,000 calls would be made to 9-1-1 (an office within the police department communications center that routes fire calls to the fire department) or the FDNY Manhattan Dispatchers Office. In fact, calls were received by the four other boroughs' dispatch offices as well as fire department headquarters in Brooklyn.

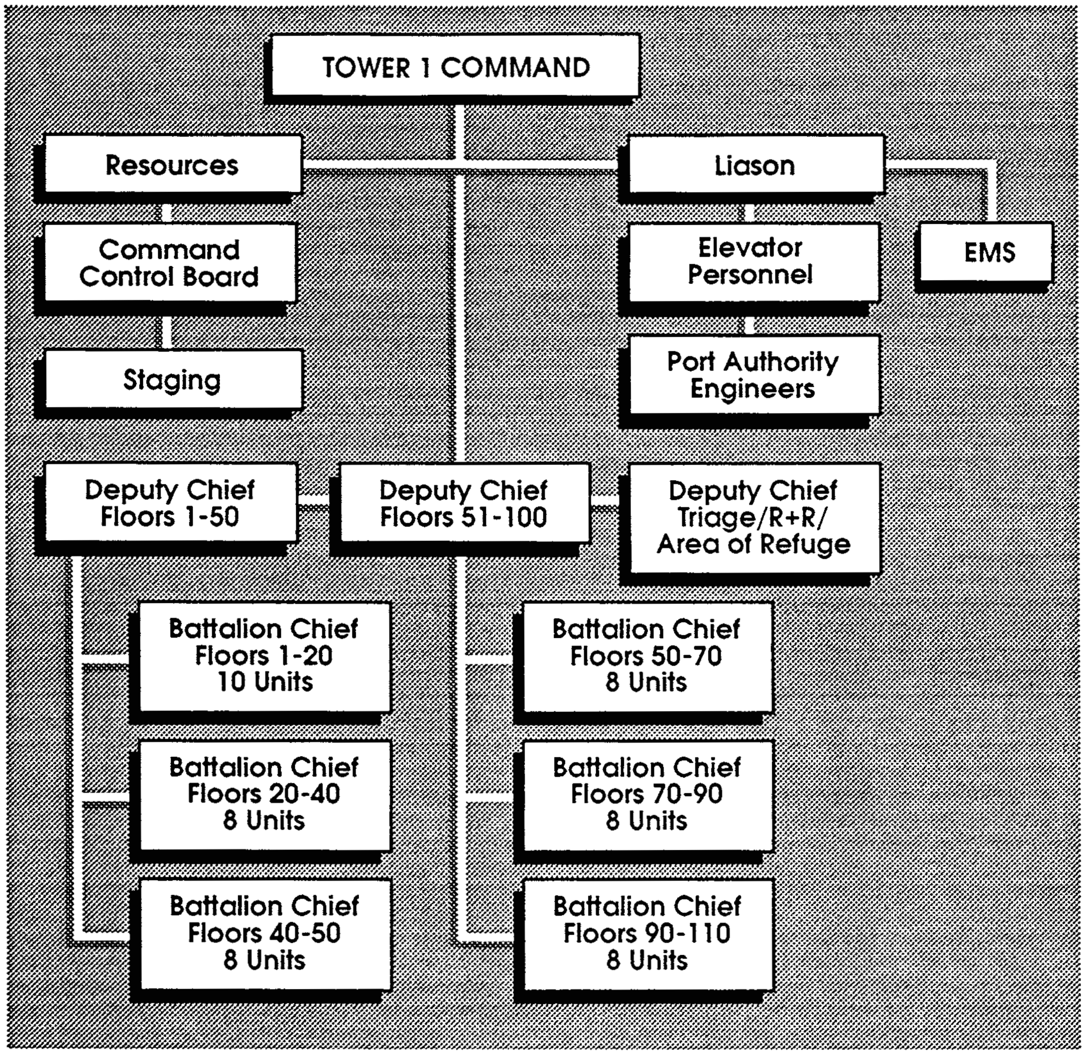
As we received these distress calls through the FieldCom Unit, they were passed to the command post. Every call had to be acted on. I and my staff at the command post determined how to prioritize the calls based on emergency/severity and available resources.

THE PICTURE BECOMES CLEARER

While I worked to establish command and control, reports from sector commanders started to fill out the entire picture, and I began to realize the full magnitude of the incident. Within a short time I knew that

- the complex's fire alarm and public address systems were out of service;
- the PA Police Department fire command station was out of service;
- the complex's standpipe systems was damaged due to destroyed piping on the lower levels but was effective in some areas for some units;
- the automatic sprinkler system was out of service in the area of the explosion and fire;
- significant portions of the electric power to Tower 1, Tower 2, and the Vista Hotel were out of service;
- emergency generators, located in the B-6 level, had their domestic water cooling lines broken by the blast. They ran for 20 minutes, then shut down because of overheating;

Typical Sector Command Post — FDNY



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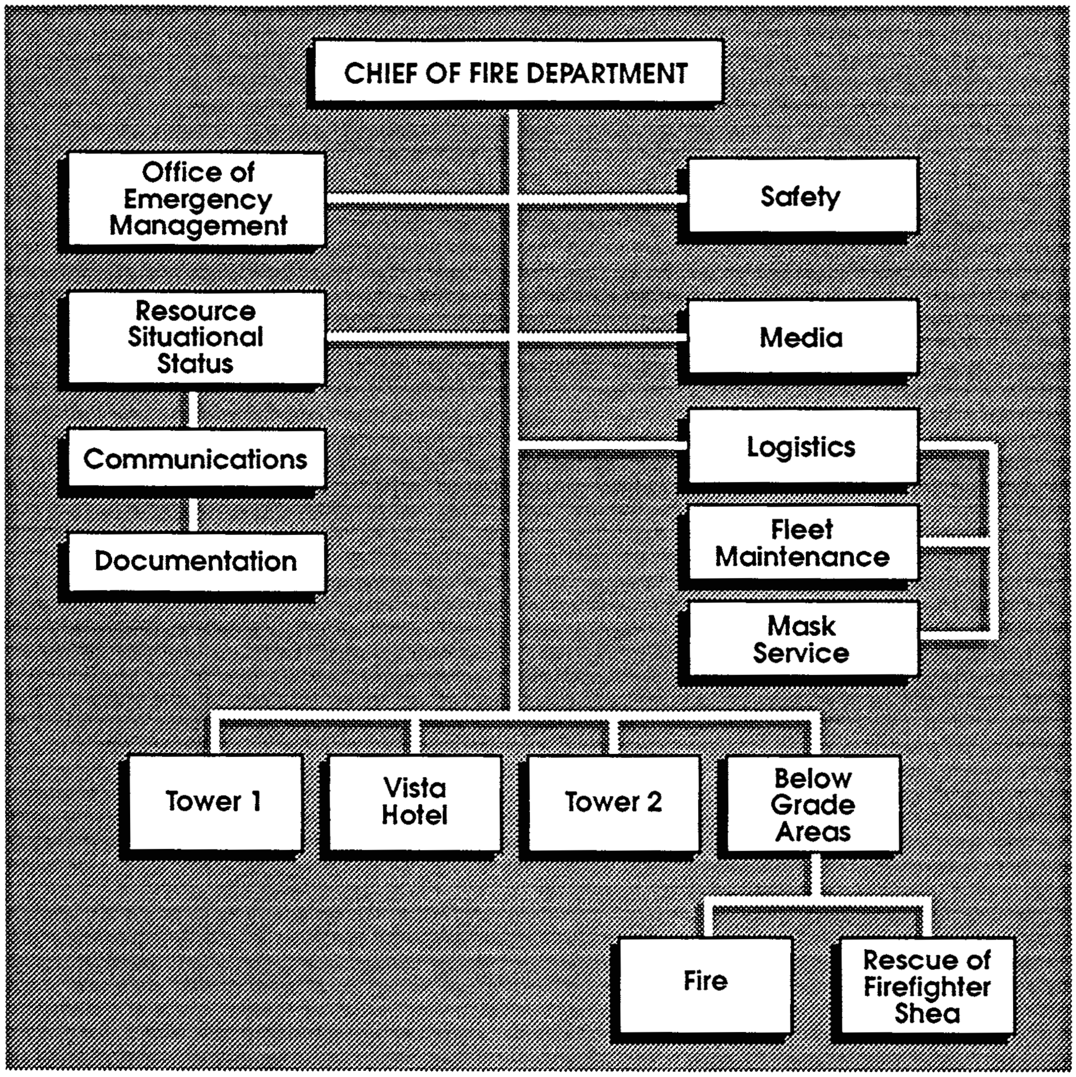
Significant Aspects of Command Structure



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- a plaster ceiling of the PATH train station on the B-5 level had collapsed due to the explosion;
- smoke was moving into many areas of the Vista Hotel, Tower 1, and Tower 2;
- rescuers were removing numerous injured from both above and below in the complex;
- a major evacuation had to be accomplished — once 50,000 people decided to self-evacuate, there was no turning back, not without a working communication system; and
- the potential number of people trapped in elevators was great, and my suspicion was substantiated by the number of elevator rescues that already had been achieved.

Armed with this information, I expanded our response to fill growing strategic needs. I transmitted a simultaneous third alarm, calling 40 additional engine and ladder companies from Brooklyn, a "borough call." This was done to avoid stripping Manhattan of units and also was a quick way of dispatching a large number of units to a location. Over the course of the next few hours, several additional alarms and special calls would be transmitted to meet the ever-increasing demand for manpower.

No mutual aid was requested or called for by FDNY. Some New Jersey as well as upstate New York units responded with equipment and assistance, but they did this on their own and were not utilized by the fire department.

OPERATIONS

Within one hour of my arrival on the scene, the rescue of Firefighter Shea was completed and the fires in the below-grade area were being brought under control. Our focus narrowed to primary search of the below-grade levels (we had reports of still-missing occupants); primary search and evacuation of the towers and the hotel; and an assessment of the damage and stability of the below-grade areas, such as it would impact the safety of personnel still operating there.

Damage/hazard assessment. Lights were brought into the below-grade areas. Damage from the blast was extensive. The B-2 level surrounding ground zero was completely destroyed. Piping and conduit were snapped like twigs. Masonry walls and steel-reinforced concrete flooring were blown apart. Cars were strewn about like toys. Steel columns were shocked but held.

A chief was directed to secure and define the stability of the collapse area. He was to accomplish the assessment with Port Authority engineers. The explosion severed four of the seven operating electrical feeders. This had the effect of disrupting all fire protection systems and also causing sporadic power loss throughout the complex. For reasons too numerous to mention, power shutoff by the FDNY command post was never requested. All train traffic in the area vas stopped, and the gas to the complex was shut down. Members were advised to operate cautiously at all below-grade areas. For reasons unknown to me, power was completely removed from the complex at around 1:30 p.m.

It was determined that operations below grade could continue within reasonable safety limits, but the potential for secondary collapse was ever present.

Below grade. With such extensive damage to the below-grade levels—debris was piled several feet high about the blast area—primary and secondary searches were very difficult and dangerous. Chief Cerreta supervised the search effort. Searches were conducted under the protection of charged hoselines.

Port Authority personnel assisted by establishing a probable victim location in occupied work areas on the B-2 level under the Vista Hotel and Tower 1. The blast destroyed a dividing wall between the garage and this work area (demolished, it was later found, by a steel support beam hurled through it with the unimaginable force created by the blast). A search first was concentrated in this area, and four fatalities were located and removed by FDNY to a temporary morgue established in the Vista Hotel. Five of the six fatalities in this incident were removed within the first two hours. (One victim was found by FDNY on a driveway ramp early in the incident.) The sixth victim was located in rubble by police personnel during their investigation 17 days later.

Members removed 16 civilians trapped under the debris in a locker room near the epicenter of the blast; located and rescued civilians from a demolished room suspended precariously over the crater; rescued victims who fell into the crater; and conducted very thorough, exhausting primary and secondary searches of the blast area, removing scores of injured.

In total, 71 companies were utilized for extinguishment, rescue, primary and secondary searches, recoveries, and logistics support on the below-grade levels.

Above grade. The large quantities of smoke that had been generated prior to the fire's knockdown became a major operational factor. Due to the destroyed elevator shaft doors at the B-2 level, the hole in the Vista Hotel meeting room with the blown-out glass partition wall between the Vista Hotel and Tower 1, and doors being opened on all floors by people evacuating — and with the stack effect working — most floors and all stairways of Tower 1 and the Vista Hotel became charged with smoke. Tower 2 had a smoke condition but to a lesser degree. The smoke condition in Tower 1 was the worst of the three buildings above grade.

The initial commitment of above-grade resources was devoted to the Vista Hotel. This 22-story hotel, in and of itself, would under normal firefighting operations be a major undertaking. At this incident, it would be handled in a most expedient manner (assisted by the time of day when many people had checked out and others had yet to check in) by the building's fire safety directors and our firefighters and fire officers. The building was searched within approximately one hour. Units were directed from the Vista Hotel sector to assist in Tower 1 and Tower 2.

Search and evacuation of the towers became the greatest challenges. Stairways were massively congested. Many occupants could not make the descent under their own power. Pregnant women, older people, people with heart conditions, and people with physical disabilities all required fire department assistance. Firefighters carried people down the stairs some 60 floors or more via stokes baskets, stair chairs, wheelchairs, and office chairs. Groups of children had to be escorted to street level — one group of children from the 92nd floor. Resuscitators and first aid were required for many occupants.

Primary and secondary searches of every floor, each 40,000 square feet, were required. Forcible entry was performed to gain entry onto floors and office spaces. Adding to our difficulties was a reported "bomb scare" on the 65th floor of Tower 1, for which firefighters stretched a line off the standpipe and supported police efforts.

As challenging as stairway evacuation and floor search were, the most difficult part of this operation from the standpoint of strategy and tactics was locating and searching the 99 elevators in each of the towers and the 12 in the Vista Hotel. Many elevators were in blind shafts and between floors. Identification of car location was difficult and time-consuming. Many walls had to be breached to gain entry into elevator cars. Literally hundreds of people were trapped in elevators when the power went down. In one case, 10 elevator occupants in Tower 1 were found unconscious, lying on the car floor — they were resuscitated and safely turned over to EMS personnel. In another case, 72 schoolchildren in Tower 2 were rescued from a car stuck in a blind shaft.

Once outside the building, victims had to contend with falling glass broken by a few occupants on upper floors. This was a real problem over which the fire department had no control. Some of this glass breaking was due to erroneous information disseminated by the media, encouraging people in the towers to take such action.

An unusual aspect of this incident was that a large elevator company has offices within the WTC towers. This company had several maintenance technicians working within the building at the time of the explosion. Knowing that people were trapped in the elevators, these technicians early in the incident began the process of manually moving the stalled cabs to the tower lobbies, but not all of their well-intentioned efforts were communicated to FDNY, at least initially. Had better inter-agency communications existed, elevator searches could have been better coordinated with the fire department.

More than eight million square feet of space were searched in Tower 1, Tower 2, and the Vista Hotel. Tower 1 required the largest commitment of above-grade resources. When other sectors began reducing units, they were told to report to the command post. We would reassign them as necessary unless the members were fatigued, in which case they would be relieved. During the entire course of the incident, 55 companies operated in Tower 1, 27 in Tower 2, and 20 in the Vista Hotel.

Operations continued well into the night. At 11:45 p.m., the last elevator was located and the people removed. They had been in the elevator for more than 11 hours.

Change of tour relief would be handled by the transmission of additional alarms. Some members, due to the fact that they had climbed to the upper floors of the towers, could not be relieved. It took hours to reach the upper floors of the two 110- story buildings, and of necessity, these members would keep working until they could make their way down the buildings, performing secondary searches as they did so.

POWER RESTORATION

Power restoration was critical, not only for the trapped occupants and firefighters but for other reasons as well. The New York Telephone Company had a major telephone exchange at the WTC complex. Besides providing telephone service to a portion of Manhattan, it also provided service for the air traffic control of the three major regional airports.

This telephone equipment had emergency generator backup, but the generator cooling lines had also been compromised by the blast, as had the PA's generators for the WTC complex. Fortunately, battery backup was also provided and kept the telephone system running until power could be restored.

Power began to be restored around 6 p.m. and continued until midnight, when most of the branch circuits in Towers 1 and 2 had been restored. Power restoration concentrated on the elevator banks first, with other sections of the buildings following.

THE MORNING AFTER

FDNY met with high-level PA officials at the WTC early Monday morning after the blast. FDNY advised them and assisted them on the restoration of fire protection systems (standpipes, sprinklers, etc.). We had engine companies hooked up to fire department connections, ready to supply the system if needed.

Our assistance also included establishing what minimum level of protection would be needed before reoccupancy was permitted. Our fire prevention bureau worked very closely with the PA to get the buildings "back on line" as soon as possible.

We would maintain a presence at the scene until March 25, 1993.

LESSONS LEARNED AND REINFORCED

1. **As many incidents throughout history have shown, fire extinguishment is the most effective weapon against smoke generation and, therefore, smoke migration.**

   The decision to attack the basement fires in the initial stages of the incident was the most important decision of the incident in that hundreds maybe thousands of lives were saved due to timely extinguishment of the fires.

   Stretching handlines into the below-grade garage areas of a large public building after a bomb explosion is a challenge for firefighters. Traditional water sources may not be available or used to capacity (FDNY staged a marine unit to draft out of the Hudson River and supply engine companies, had it been necessary); standpipes may be damaged. Quick and easy routes to the seat of the fire will not be available. Units may have to knock down numerous fires (such as fires in individual burning vehicles) before they reach their objective. The volume of fire (depending on the combustibles in the explosion space) and the need to protect engine companies from possible fire dangers (such as ruptured gas tanks, secondary collapse and fire, etc.) dictate the use of handlines that can produce flows greater than 200 gpm.

2. **This was the largest building evacuation ever recorded.**

   The "defend-in-place" strategy did not exist. Building evacuation and human behavior in this incident will be studied for years to come, hopefully yielding new lessons appropriate for inclusion in building codes.

3. **This incident exemplifies the classic high-rise stack effect — vertical upward movement of smoke and heated gases due to the cold temperatures outside and warm temperatures inside.**

   Upward smoke movement was enhanced by the breaching of the Vista Hotel meeting room floor/glass wall as well as breaches in the bottom of elevator and stair shafts. The force of the bomb itself also helped to propel the smoke upward. Finally, people opening doors in stair shafts allowed smoke to migrate from floor to stair shaft or vice versa.

4. **The WTC is a well-constructed complex.**

   In spite of major damage, it withstood the effects of a terrorist bomb. At the time of the explosion, it exceeded some local building and fire code requirements but did not comply with others. An effort should be made through legislation to enforce all local codes in all structures. If the fire department is to fight the fire, the fire department should enforce the codes. This will improve and allow for knowledge and standardization of fire protection features.

   WTC management was very cooperative in working with FDNY and other agencies following the explosion and has made numerous enhancements so that code compliance has been achieved and, in some cases, exceeded. Enhancements include changes in the number of fire command stations and in the organization and training of fire safety personnel within the complex; communications upgrades, particularly a backup wireless communications system and tertiary, battery-powered emergency stairway and elevator lighting; enhanced provisions for smoke evacuation from stairways and elevators; a better means for determining the location of elevators in blind shafts; methods to prevent interruption of emergency generator power; and many others.

The importance of being able to communicate with building occupants cannot be over stressed. Many of the evacuation problems that existed at this incident would have been greatly reduced had some form of communication been available.

5. Fire department communications were severely stressed at this operation.

Department communications capabilities must be established so that they can handle the largest of emergencies that could occur in the jurisdiction. Our standard portable radio tactical frequency was overloaded and ineffective. The same problems were encountered with the command channels. A trunked 800 MHz system would have achieved much better results; FDNY currently is in the process of developing such a system. In addition, equipping division and battalion chiefs with cellular telephones would have made it possible to communicate with units operating on upper floors.

The FDNY incident command system depends largely on its FieldCom Unit. This unit is expected to transmit and receive critical information on the fireground. In the WTC incident, this unit experienced an overload situation. The importance of this unit requires that it be amply staffed with highly trained and experienced officers and personnel.

We must continually seek improvements to our equipment. A specific tone alert for portable radios signaling all radio transmissions to cease would be invaluable, allowing a commander or member to gain control of the network and transmit a mayday or urgent message.

Human message relays were an important method of communication at this incident.

6. Controlling a large-scale incident is beyond the capabilities of any one individual.

The incident command system must be utilized and expanded to ensure adequate span of control and personnel accountability/safety. The system must be flexible and adaptable. The incident command system was expanded in proportion to the size of the incident. The incident commander must take steps to manage the large-scale incident through well-positioned sector and subsector officers.

The incident commander at a major incident has a dual problem: information overload — too much information coming in and very little or not enough time to evaluate and act in a timely fashion — and too many chiefs and officials demanding attention. People will get frustrated when they feel they have important information that is not acted on immediately. This can be overcome by assigning an additional staff chief of appropriate rank to assist the incident commander. This chief should accept the reports and make the IC aware of them in a timely fashion and in priority order.

Another position should be created to handle agencies that will report to the command post offering assistance, be it information, equipment, or other resources — and there were many such offers at the WTC incident. A high-ranking officer should be stationed at the command post to record all this information and develop a system whereby these parties could be recalled at the appropriate time. People came to the command post with generators, pumps, and offers of expert help in one trade or another, but when the time came that we could have utilized that assistance often they had left the area and could not be found.

The portable command post (PCP) given to each division is an excellent control tool for a sector commander. However, lack of highly visible incident command post facilities proved to be a disadvantage at this incident. The fire department is currently pursuing more "operational friendly," visible command equipment that will be the focal point for other agencies at operations where the fire department is the lead agency/incident commander.

7. The fire department does not operate in a vacuum.

Assistance from and interaction with other agencies are essential. Gaining and maintaining cooperation from and coordination with other agencies can be a problem; in this incident, interagency protocols were violated on several occasions. For example, during this incident, it had been reported that several people were trapped on the Tower 2 roof. A few members of the police department stepped outside the protocol of the ICS and conducted an operation to remove these people via helicopter.

To be effective, interagency protocols require routine drills. During drills, friendships will be established and maintained, and a deeper understanding of the other agencies' roles will lead to better interaction during agencies. A better understanding of the incident command system is required by all city emergency responders. With thorough knowledge of the benefits of the ICS, there will be less reluctance on the part of all agencies to use it.

8. Firefighter rest and rehabilitation will be difficult to achieve in operations in which it can take as long as three or four hours to reach an objective.

Make every effort to establish "R & R posts" at key points throughout large buildings.

9. Elevator search and rescue was a major challenge in this incident.

Many elevators were stuck in blind shafts when the power went down, and elevator recall to the sky lobbies (the transfer floors for other elevators serving upper floors) was a slow process. Identification of elevator car locations in the blind shafts was especially difficult in Tower 1 because the shafts were charged with smoke. Several lessons were learned with respect to elevator search, including:

— Elevators on floors with public assembly areas (observation deck, restaurants, etc.) should be a search and evacuation priority. They may have heavy occupancy, in one case, for example, 72 schoolchildren and teachers were stuck in one elevator.

— An elevator liaison officer should be designated for coordinating/controlling elevator companies.

— Coordination with elevator personnel is essential. Interagency pre-planning with respect to elevator control is called for.

10. A public information officer is essential.

The fire department must ensure that TV and radio reports are accurate, especially for people on the upper floors of high-rise buildings who are taking their cues from these reports. Many so-called "experts" on high-rise fire operations, safety, evacuation procedures, etc., were sought by the media, and some of these individuals supplied erroneous information that could have resulted in further operational problems. One noted TV personality encouraged occupants to vent the tower windows by breaking glass; one willing viewer, it has been reported, obliged by throwing a fax machine out the window.

The primary thrust of the public information officer is to present factual information and messages to the media on a timely basis, but this officer also serves to demonstrate to the public that its lead agency in a fire/rescue emergency has the knowledge, ability, and resources to control the situation. As it was, the fire department put itself in a "react" mode concerning media communications.

11. **A major disaster committee or task force should be developed to hold hearings and investigate all facets of a major incident to determine the impact on fire department operations.**

    The task force should include members from operations, fire prevention, support services, communications, the legal division, and any others deemed appropriate by the fire commissioner.

Complex Overview

by Port Authority Risk Management Staff

The World Trade Center (WTC) is owned and operated by the Port Authority (PA) of New York and New Jersey. It was developed and constructed by the PA to serve as the headquarters for international trade within the New York, New Jersey region. The WTC is located on a 16-acre site in lower Manhattan. The complex consists of two 110- story office towers (1 and 2 WTC), a 22- story luxury hotel (3 WTC), two nine-story office buildings (4 and 5 WTC), an eight-story U.S. Customs House (6 WTC), and a 47-story office building (7 WTC). All seven buildings exit onto a five-acre plaza as well as onto the surrounding city streets. The complex is bound by West Street to the west, Vesey and Barclay streets to the north, Church Street to the east, and Liberty Street to the south. The mall at the WTC, located directly below the plaza, is the largest enclosed shopping mall in lower Manhattan, as well as the main interior pedestrian circulation level for the complex.

The WTC complex contains more than 12 million square feet of rentable office space. Each of the 110 floors is approximately one acre (40,000 square feet) in size and is not obstructed by columns, to allow maximum flexibility in office layouts. Tower 1 (North Tower) is 1,368 feet tall and has a 351-foot commercial television antenna mast mounted on top. Tower 2 (South Tower) is 1,362 feet tall. 3 WTC, the Vista Hotel, rises 265 feet above street level and contains 821 guest rooms. 4 WTC, also called the Southeast Plaza Building, rises nine stories, is 119 feet tall, and has 600,000 rentable square feet. 5 WTC, the Northeast Plaza Building, is nine stories, 119 feet tall, and has 700,000 square feet available for rental. 6 WTC is the NY/NJ metro region consolidated Customs House and is eight stories, 130 feet tall, and contains 800,000 square feet of space. 7 WTC is 634 feet high and has 47 floors of office space. The complex has 256 elevators and 72 escalators.

Some 60,000 people work in the WTC complex, and another 90,000 business and leisure visitors pass through the center each day. There are more than 450 firms and organizations represented, including trade and foreign government organizations engaged in such international commerce activity as import, export, freight forwarding, custom house brokerage, international banking and finance, insurance, and transportation. The WTC also is the Manhattan headquarters for the Port Authority of New York and New Jersey.

The complex is served by several modes of mass transportation. The New York City Transit Authority provides direct subway service to the WTC by way of the IRT, BMT, and IND lines; bus service is available from several locations on surrounding streets. Port Authority Trans Hudson, or PATH, provides direct rail service with Hoboken, Jersey City, Harrison, and Newark, New Jersey. Ferry service also is available from Hoboken to the nearby World Financial Center.

Blast Damage

by Steven C. De Rosa

The effects of the blast on the World Trade Center were severe.

PLAZA LEVEL (three levels above the explosion)

- A 100-square-foot section of concrete was cracked and lifted.

CONCOURSE LEVEL (two levels above the explosion)

- A 400-square-foot hole was opened in a meeting/dining room near the Liberty Ballroom of the Vista Hotel.
- Glass windows, the partition between the Vista Hotel and Tower 1 at the concourse level, were blown out from the explosion, creating a pathway for heavy smoke migration from the Vista Hotel to Tower 1.
- A section of plaster-and-lath ceiling above the hole collapsed.

B-1 LEVEL (one level above the explosion)

- A 5,000-square-foot hole was opened on the ramp leading to the parking garage below.
- The Port Authority command/communications center was heavily damaged and rendered inoperable.
- Walls and ceilings were heavily damaged.
- Elevators were damaged.
- Seven steel columns were damaged and left without lateral support.

B-2 LEVEL (ground zero)

- An L-shaped crater, approximately 130 by 150 feet at its maximum points, was opened, collapsing reinforced concrete and debris onto levels below.
- At least nine steel columns were heavily damaged and left without lateral support.
- Many walls collapsed, including a concrete block wall adjacent to the blast area that collapsed onto and killed five WTC personnel.
- Doors/enclosure walls of Tower 1 elevator shafts were heavily damaged.

Steven C. De Rosa, a 29-year veteran of the City of New York (NY) Fire Department, is deputy chief of Division 3 in midtown Manhattan, where he has served for 10 years. He has developed numerous procedures for the department including high-rise tactics.

- Some 200 vehicles were fully or partially destroyed, and many were on fire.
- Primary electrical power feeder lines were damaged.
- Stairway doors and shaft walls were heavily damaged.
- Some standpipes were damaged.
- The sprinkler system in the immediate blast area was destroyed.

B-3, B-4, B-5, B-6 LEVELS (below the explosion)

- Debris from the blast traveled through a three-level architectural opening (spanning B 3 through B 5) and crashed down on refrigeration equipment on B 5.
- A ceiling of the PATH train station on the B-5 level collapsed.
- A 24-inch-diameter water supply pipe from the Hudson River to the air-conditioning chillers, as well as other smaller refrigeration/air-conditioning and domestic water pipes, were ruptured.
- Domestic water lines to the emergency generators were damaged on the B-6 level.

The Materials Involved in the WTC Bomb

by Frank L. Fire

As reported in news accounts of the WTC bombing, it appears nitrourea was used as the bomb's base and cylinders of hydrogen were used to increase the magnitude of the explosion. The following is a brief description of the materials involved.

Nitrourea, a white, crystalline powder, is a Class A explosive. It also is known as m-nitrocarbamide, N-nitrocarbonide, 1-nitrourea, and N-nitrourea. It is a high explosive that presents a severe explosion hazard and is stable until detonated. Although some references say nitrourea is sensitive to heat and shock, the greater likelihood is that it is stable; otherwise, it might be too dangerous to transport by truck (or van).

The power of nitrourea is similar to that of trinitrotoluene (TNT) and picric acid. (TNT and picric acid are used as reference points because TNT is referred to as the "standard" explosive in the United States and picric acid the "standard" explosive in Great Britain.) Nitrourea produces about 90.5 percent of the gas volume of TNT when detonated and has slightly more than three percent more relative power than TNT. It produces about 97.7 percent of the gas volume of picric acid and has three percent less relative power. Its caloric value (power as described by the number of joules of energy per kilogram of weight) is 34 percent greater than TNT's and 19 percent greater than picric acid's.

When compared with ammonium nitrate, nitrourea has about 13 percent less gas volume, about 38 percent more relative power, and about 47 percent more caloric value.

Hydrogen is a highly flammable, nontoxic, colorless, odorless, and tasteless gas. Its flammable range is from four to 75 percent, the second widest range of any common flammable gas. With such a wide range, it is easily ignited. The flame from burning hydrogen has a very high heat content — its flame temperature is 3,700 degrees Fahrenheit. Hydrogen burns with an almost invisible flame, converting all energy into heat energy.

Frank L. Fire is the Vice president of Marketing for Americhem Inc. in Cuyahoga Falls, Ohio. He's an instructor of hazardous- materials chemistry at the University of Akron as well as an adjunct instructor of Hazmat at the National Fire Academy. Fire is the author of *The Common Sense Approach to Hazardous Materials* and an accompanying study guide, *Combustibility of Plastics, and Chemical Data Notebook: A User's Manual*, published by Fire Engineering Books.

Control of Elevator Operations

by Steven C. De Rosa

Many people were trapped in elevators when primary and secondary power was lost. World Trade Center staff stated that 45 occupied elevator cars were stuck, many in blind shafts. The damage to the WTC Command Center made it impossible to communicate with most of the stalled elevator cars, and the sheer size of the removal operation was initially overwhelming.

Three agencies were involved in the removal operation — the fire department, Port Authority Police, and the city police department. Elevator maintenance personnel (who had offices in the WTC complex) played an important role in this removal process. Coordination of these operations proved difficult because it was difficult to determine the location of the elevators in the shafts. It took more than 11 hours to free the last trapped occupants.

It is unlikely that most incident commanders will be confronted with extrication problems of this size — each tower had more than 99 elevators — but a significant high-rise fire may require actions including the following:

- Designate a sector elevator control officer and assign fire department personnel as needed. This officer will coordinate and supervise the extrication operations. When multiple agencies are involved, the fire department should maintain control by requesting radio-equipped agency representatives to work with the elevator control officer.
- Enlist the assistance of building engineers, elevator personnel, or maintenance personnel to determine the number of elevators and location status.
- Elevator cars stalled in blind shafts are difficult to locate without the help of the elevator control panel. Power loss will render most identification systems inoperable. A back-up battery-powered car identification system should be implemented.
- Work with officials of exempt government buildings to design fire protection systems that comply with local codes. The blind shafts in the WTC extended 78 stories. Firefighters had to open the shaft every five floors to locate a car — it was impossible to see more than six floors into the blackness. Some local building codes require openings into blind elevator shafts at three-floor intervals; this feature was not provided in the case of the WTC.
- Elevator car extrication must be strictly controlled. Coordination and communication with building personnel are essential. Unanticipated emergency power restoration can result in severe injuries to rescuers and passengers. Building elevator personnel should be taken to each elevator machine room by fire department personnel. Once there, circuit breakers supplying power to the affected car should be opened to protect both the car occupants and rescue personnel.

Brake releases for the elevators also are located in the machine rooms. If power is cut off and elevators are stuck, the brake is manually released. Then, if the load in the elevator is more than 5,000 pounds, the car will slowly drift down to the bottom. If the load is less, the car will drift up.

Command Analysis

by Jack McCormack

With any fire department operation, the organizational structure of command expands to meet the needs of the incident. Remember, it is not necessarily the size of the incident but its complexity that determines the command structure.

At the inception of the WTC explosion, units arriving at the hotel directed their efforts toward the seat of the fire in the parking garage. Simultaneous with the aggressive direct attack, units were sent to operate in the hotel because of the smoke conditions reported there. As the assessment and size-up continued, the magnitude of the incident was realized. The command structure expanded to meet the complexity of the problem.

The WTC explosion is a prime example of the reason command structures have the flexibility to expand in anticipation of complex developments. As the incident commander, Chief Anthony Fusco had to constantly assess the problem, develop strategic goals, and ensure that tactical objectives to accomplish those goals were achievable with available on-scene resources. Defining the problem requires feedback from all areas of the operation. After determining the parameters, the strategic goals can be formulated. It is the command structure that allows that feedback of information to assist the IC so the strategic goals can be established. The goals of each aspect of the operation must support the 16's strategic goals, and vice versa.

Complex though the WTC explosion was, the command structure implemented by Chief Fusco provided control, supervision, and coordination. It likewise fixed accountability for specific tasks necessary to achieve the tactical objectives in each sector. Complex operations necessitate a tight span of control to ensure the safety of operating members.

The division of command into manageable segments — sectoring— allows for adjustments to tactics. For example, as information was received regarding the extent of structural damage and the presence of the crater created by the explosion, an additional operations sector was created in the below-grade area. Evaluations made close to the area of operations provided the sector command post and the IC with the information necessary to develop strategic goals.

Achievement of multiple tactical tasks requires specific assignments and accountability to each subsector and sector. This provides the chain of command with the status of the operation: what has been achieved; what has not been achieved; what obstacles have been overcome; the resources committed, and where; and reserve status.

The chief in charge of any operation, large or small, must maintain a broad focus and high visibility — likewise with chiefs responsible for sector commands. As a sector officer at the WTC incident,

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Jack McCormack, a 25-year veteran of the City of New York (NY) Fire Department, is a Deputy Assistant Chief and Deputy Commander of the Borough of Queens. He has worked all over Manhattan for 12 of those years, as deputy chief assigned to the 1st Division in lower Manhattan, executive officer to the chief of department, and as battalion chief.

I was well aware of this. Each branch or sector operations command post requires a recognizable command post. Ideally, the command post should be free of encumbrances. This was not the case in the Vista lobby. Numerous units from various departments and agencies passed through the area. Control was difficult.

The use of a unit status board was necessary to account for units operating, relieved, or staged and is essential at each operations post at multifront incidents. It provides a visual view of what the operating structure is and who has which area of responsibility. This board should be similar in format to the fire department communications unit's status board used by the IC.

Adequate lighting is a must at a command post. When the command post is the lobby and the building's power is out, auxiliary sources of light must be provided as soon as possible.

When a command post is staffed by a number of chief officers and chief aides, there is a need for adequate space to accommodate the number of personnel. Control of the command post is essential. Units reporting to a command post can overwhelm it. Unless direction is given to stage members away from the command post area and it is made clear that only officers report in, confusion and interruption of operations will occur.

First Response: Engine 6 Operations Below Grade

by Timothy F. Dowling

The tour at Engine 6 began in a typical fashion on February 26, 1993. No outside activities were scheduled, and the four on-duty firefighters regularly assigned to Engine 6 were performing maintenance tasks related to equipment, apparatus, and quarters. They had been with the department for from six to 12 years.

Also in quarters was an off-duty Engine 6 firefighter who had completed the night tour and was talking on the pay phone to a friend who worked on one of the upper floors of the World Trade Center Complex. At about 1217 hours, the off-duty firefighter was told by his friend that the electrical power had failed at the WTC and that the building shook. The friend knew that Engine 6 would be responding. The firefighter hung up the receiver and shouted, "Get out. Something just happened at the World Trade Center!"

When I slid down the pole to the apparatus floor. He told me what he knew and asked permission to respond with the unit. I granted permission and directed all members, including the off-duty firefighter to gear up a while I notified the Manhattan dispatcher that Engine 6 was heading to the WTC.

At the same instant, the teleprinter alarm began to transmit the following: *Fill out alarm —2nd source. E006 E007 L010 L001 BC01. Box 0069 —West St. — 640' south of Vesey St. Incident #181. 02/26/93. 121852.* The printout specified a location other than that normally given for the WTC. Engine 6 is the second-due engine at alarms for the WTC. The fire alarms transmitted for the WTC instruct the companies to respond to specific locations, according to the location of the reported incident. I directed the engine chauffeur to respond to the location given on the teleprinter printout. This was just the beginning of what was to be anything but a normal incident.

En route, the department radio reported a possible electrical transformer explosion. Engine 6 arrived at the WTC within two minutes — traffic was unusually light. A tremendous volume of black and brown smoke was pushing violently from the street vents and the garage entrance in front of the Vista Hotel.

As we passed under the north pedestrian bridge, which connects the WTC with the financial center across West Street, members of the New York/New Jersey Port Authority Police were exiting the B ramp from the B-2 level of the parking garage. They stopped us and said there had been an explosion on the B-2 level of the parking garage, people were trapped, and numerous fires were burning. They also said their knowledge of and experiences with the WTC complex indicated that "this was not an electrical transformer fire."

Timothy F. Dowling was a member of the City of New York (NY) Fire Department from 1962 until 1993, when he retired. He served as a firefighter with Engines 324, 14, and 6; as a lieutenant with Engines 96 and 295; and as a captain of Division 3 and Engine 6.

I directed the chauffeur to take a nearby hydrant while I began an initial size-up. My primary concerns were the conditions, whether we were at the proper location for attacking the fires, the collapse potential in the area, and conducting a quick surface search for victims while we advanced on the fires.

I directed members, including the chauffeur, down the B ramp for a primary search of the immediate area while I conducted my survey. They were about to enter the garage when an agent from the United States Secret Service told them there was an ammunition storage area on the B-2 level. The question now was; How involved were the munitions in this incident? The agent entered the B-2 level with Engine 6 and showed me the location of the storage area. Although we determined that the ammunition was not part of the fire, we still had to consider its presence when planning operations.

The B-2 level was devastated. Dozens of cars were crushed, thrown about, and fully involved in fire. Walls and ceilings had collapsed. The piping containing electrical wiring was down.

As the firefighters conducted their searches, I moved into the area of devastation. There was a heavy smoke condition and a red glow in the distance. As I continued my survey, I discovered that the sprinkler system had been destroyed. The extent and nature of the damage made it evident that someone had exploded a bomb on the B-2 level.

Under normal conditions, we would use 2 1/2 inch hoselines from a standpipe system when operating in high-rise buildings. Two companies would work together to give the units six lengths of 2 1/2 inch hose on each line. Not today!

The number of cars burning, the large red glow in the distance, and all the rubble and debris present made it necessary to hand-stretch from the apparatus in the street. This line would supply a confirmed, continuous source of water. The volume of water in the stream would quickly knock down the car fires as the firefighters fought their way to the main target —the large, red glow in the distance. The reach of the stream would permit them the luxury of operating in the safest position they could find while still extinguishing the large body of fire awaiting them. Most importantly, the 2-1/2-inch hoseline was their link to the outside: It would guide them out or, in the worst-case scenario, lead responders to them if they became victims.

Quickly returning to the B ramp, I ordered that a 2 1/2-inch hoseline be hand-stretched. The firefighters, meanwhile, had rescued two civilians from the collapsed rubble. Both were severely burned, had suffered lacerations, and were in shock. Shouting orders while on the run, I raced to the apparatus and transmitted the signal "10-45" (victims severely injured and/or burned) on the department radio. The time was 1223 hours.

While the chauffeur was running to the apparatus to begin hooking up to the hydrant, he saw EMS ambulances responding down West Street and quickly went into the roadway, stopped the ambulances, and requested assistance for the two burned victims. With EMS and the police treating the civilians, Engine 6 now was able to turn its full attention to the long hand-stretch.

Reentering the garage dragging the uncharged handline, the firefighters began the struggle of stretching over the collapsed debris, under the downed pipes, and around collapsing walls. During this time, explosions were occurring all around them. It took a few moments to realize that the explosions were caused by burning car tires and were not secondary bomb explosions — at least they hoped it was car tires.

During the stretching of the hoseline, a third victim suddenly appeared out of the flames and smoke, startling the firefighters for an instant. One of the firefighters moved quickly among the burning cars and under the downed pipes to grab the victim, who was heading toward the main fire. After turning the third victim over to EMS, the firefighters returned to continue with the hand-stretch of the hoseline.

ENGINE 7 ASSISTS

Engine 7 arrived at the scene. The lieutenant observed Engine 6's stretching of the hoseline and directed his firefighters to assist. An employee of the New York Telephone Company and a member of the Syosset (NY) Volunteer Fire Department helped with the hand-stretch and then remained for many hours to help Engine 6's chauffeur. The additional help on the handline enabled Engine 6 to begin the attack on the fire.

Engine 7 returned to the street and started a second 2 1/2-inch hoseline down the B ramp. I informed the firefighters that the car fires had to be knocked down as quickly and as safely as possible so that they could address the main target — the big red glow in the distance. Engine 7, in the meantime, would stretch a handline and operate to the right of Engine 6, where many more car fires were encountered.

Engine 6 began its attack. With the firefighters spread out on the hoseline, the nozzleman opened the nozzle, bouncing the water off the interior roofs of the cars, breaking up the stream, and then shooting the water under the cars' hoods and at each wheel well. The fires were quickly extinguished. The nozzle then was shut down, making the line easier and safer to move in the debris while moving on to the next car. With the controlman and the doorman pulling hose while watching everyone and the surrounding area for hazards, Engine 6 repeated this operation again and again until the crew arrived at the main body of fire.

Suddenly, another danger presented itself. The force of the explosion had crushed dozens of cars, rupturing their gas tanks, oil crank cases, and transmission and brake hoses; the floors became covered with gasoline and oil. We became aware of this problem when the nozzleman and the backup man, operating under a heavy smoke condition, began to slide down into a huge crater created by a collapsed portion of the garage floor that was at a 45-degree angle. Flames lapped at their legs, and everyone moved quickly. The doorman and controlman grabbed the backup man, while I grabbed the nozzleman. We almost became victims, however, as the oily floor made it necessary for us to struggle to maintain our footing. The backup man was rescued first. Working together, the crew got the nozzleman back on level ground. Moving back a short distance, Engine 6 regrouped, pulled the hoseline back, and repositioned themselves at another point on the edge of the bomb crater.

ARRIVAL AT THE PRIMARY FIRE

We had reached our main target. The reach of the 2 1/2-inch hoseline now was brought into play. The bomb crater was huge, and a tremendous fire was burning. Our 45-minute SCBA air pack alarms began to ring. Our chauffeur appeared with spare cylinders. Concerned about our safety, he made repeated entries into the bomb area. Engine 7's officer and chauffeur were working as a team to monitor pumper operations.

I was unable to contact the command post on the street level from our below-grade location. As senior officer at the location, I checked on the safety and progress of Engine 7 and the members of ladder 1, who were conducting primary searches of the burned cars. Moving around the area — climbing over, under, and around all the hazards and debris — was extremely dangerous, but the safety of the members was of paramount importance.

MAIN GOALS: PROTECT AND EXTINGUISH

Early in suppression operations, Firefighter Kevin Shea fell into the bomb crater. When this occurred, Engine 6 was the only unit with the necessary water pressure and volume operating into the bomb crater. Our primary focus, therefore, became the protection of Firefighter Shea and his rescuers in addition to the extinguishment objective. For the good part of an hour, Engine 6 firefighters worked to accomplish these goals, rotating positions on the handline numerous times in an effort to conserve as much strength as possible without jeopardizing safety and operations. As more units arrived on the scene and advanced toward the bomb crater, the crater fire began to darken down. Shea was removed from the hole, and the main body of fire was extinguished.

Relief units arrived on the B-2 level after 1400 hours, and the first-alarm operating units were able to leave the area. As Engines 6 and 7 emerged up the B ramp after almost two hours on the B-2 level, their members confronted a scene that was unbelievable. The quantity of equipment and number of personnel on the scene were mind boggling.

During operations, the members were so intently focused on extinguishing the many fires and protecting each other that they did not realize the beating they had taken: smoke inhalation, traumas from falling concrete, hitting downed pipes, and falling over collapsed debris. Engine Companies 6 and 7 were taken to St. Vincent's Hospital in Greenwich Village, where the hospital's disaster plans were in full operation.

LESSONS LEARNED AND REINFORCED

1. **For engine companies, the decision to apply water and knock down the fires, thereby reducing smoke development, played an important role in the outcome of the incident —just as important as locating victims in and removing them from the immediate blast area.**

2. **Company commanders play an important role in relaying initial conditions of their "slice" of a major incident — in this case, for example, relaying information on the extent of the explosion to help the incident commander establish the magnitude of the incident.**

3. **Although the 2 1/2-inch handline is more difficult to maneuver, speed was not compromised due to the need to move slowly around the crater — leaking vehicle fuels, water, and so on made the floor and surfaces very slippery, threatening to plunge members into the crater.**

   The 2 1/2-inch hoseline placed greater physical demands on firefighters, but it provided the volume and reach needed for fire extinguishment and member protection.

4. **Gather as much information from a variety of sources as possible in making size-up determinations and tactical decisions.**

   Many factors entered into the decision to operate down the B ramp and hand-stretch our line, including information from the off-duty firefighter, the teleprinter, the department radio, Port Authority Police, and the Secret Service Agent, plus a number of on-scene tangibles and intangibles, including:

— the visual inspection of the blast site;

— the nonoperating sprinkler system;

— achieving a positive, confirmed water supply:

— the training and experience of members;

— our ability to adapt and be flexible;

— our members' awareness that they were operating in a very dangerous environment and that they had to be alert for worsening conditions;

— confidence in the firefighters and their abilities and firefighters' confidence in the officers;

— the importance of getting the first hoseline into operation; and

— teamwork and communications between the first-arriving units that made it possible to get water on the fires more quickly.

5. Appropriate levels of safety and accountability must be achieved for every incident.

PASS devices and good flashlights were mandatory during this operation. In a major operation, communications may be difficult, particularly from below grade, and it may take time to fill positions within the ICS in the initial stages of the incident. It is incumbent on senior company officers to assume a "global" responsibility for member safety during such situations.

Rapid Intervention at the Vista Hotel, Above Grade

by John J. Walpole

On Friday, February 26, 1993, at 12:18 p.m. a powerful explosion took place on the B-2 level of the World Trade Center in New York. The New York Vista Hotel almost immediately became impassable due to the resulting thick black smoke, fallen walls and ceilings, blocked exit doors, and a totally uprooted garage floor with substantial damage from the plaza level down to the B-6 level.

It became immediately evident that this was an extraordinary explosion — it seemed to be effective — everywhere at the same time. The service and guest elevators of the hotel were out of commission, with the service elevator walls in a collapsed condition. The walls of the laundry room on the B-1 level collapsed, and pipes were hanging from the ceiling. The employee locker rooms, employee cafeteria, receiving area, garage and garage office, police station, operations office, and area leading to the loading dock all were destroyed. Visibility was close to zero within the B-1 area.

At the time of the explosion, I was waiting for an elevator with another individual on the B-1 level. An invisible blast wave emanated from the elevator shaft, immediately followed by an onrush of air back into the elevator shaft. It was when the backrush of air occurred — not during the initial blast — that building materials and debris began to fall around us.

Immediately following the explosion, I collected myself and also took charge of the ensuing chaotic situation. An immediate evacuation directive was radioed to the hotel fire command station in the lobby, where an assistant fire safety director was on duty as per the hotel's fire safety plan.

With help from the assistant chief engineer and assistant director of safety and security, I conducted an evacuation of the B-1 area. The 120 employees located within the area were directed by voice and light to the only exit that could be cleared for evacuation due to the extensive damage in the area. One employee was temporarily blinded by office glass that exploded in his face; another employee fell and suffered a leg injury. All were removed by security personnel to the safety of the street, where medical aid was available.

Our emergency generator and public address system were still functional after the explosion, and the assistant fire safety director made forceful evacuation announcements to building occupants over the PA system. The emergency generator later was shut down because of concern that it was supplying damaged, energized electrical equipment in the below grade areas, potentially subjecting people to injury. In addition, the generator itself was in a damaged area that was subject to collapse.

John J. Walpole is Director of Safety and Security for Hilton International's Vista International Hotel, an 829-room, one-ballroom, three-restaurant hotel in the World Trade Center. His professional experience includes serving as Assistant Director of Investigations for the New York Racing Association, as a Special Investigator with the Nassau County District Attorney's Office, and with the Federal Drug Enforcement Administration (DEA). Walpole is a certified protection professional who has a bachelor's degree in criminal justice and has received various specialized training through the DEA and the New York City Police Department.

Security personnel used quick-response equipment located throughout the hotel, such as portable lights and tools, as directed in the fire safety plan. The smoke was so thick and black in places that using lights to guide personnel was ineffective at times. Individuals in the B-1 area — both hotel employees and Port Authority personnel — were in a state of shock but evacuating in an orderly file. Concern was raised that another explosion would take place and that the already-damaged walls and ceilings could collapse further, causing additional damage and injury. After the B-1 area was secured and no longer occupied, I proceeded to the lobby area to take charge of the fire command station and put in place additional search and rescue efforts by hotel security/fire safety personnel.

After reaching the lobby area of the hotel and assessing the damage, I realized that the hotel had suffered tremendously. [See diagram of lobby level of Vista Hotel on the following page.] A meeting room (adjacent to the Liberty Room ballroom), directly over the point of explosion on the B-2 level, had a large hole in it. At the time of the explosion, guests and attendees in the ballroom areas were evacuated without incident or injury by the security/fire safety personnel on duty in the area. The Plaza Level area, consisting of two restaurants and the executive offices for the hotel, was damaged. Security personnel searched the guest room and public facility areas of the hotel to evacuate and locate any possibly injured guests or employees. The entire evacuation took about 10 minutes, with minimal injury — a very professional job. The time of day (around the noon hour) helped in that the hotel was minimally occupied.

After attending to the evacuation and head count of guests and employees, the hotel safety/security and engineering staff, along with managerial personnel, began to assess the physical and structural damage to the hotel. At this time, emergency personnel were responding to the scene. Firefighters conducted their search operations. During the physical-damage assessment, it became evident that numerous resources had to be mobilized to protect the hotel and property.

BASIC DAMAGE ASSESSMENT

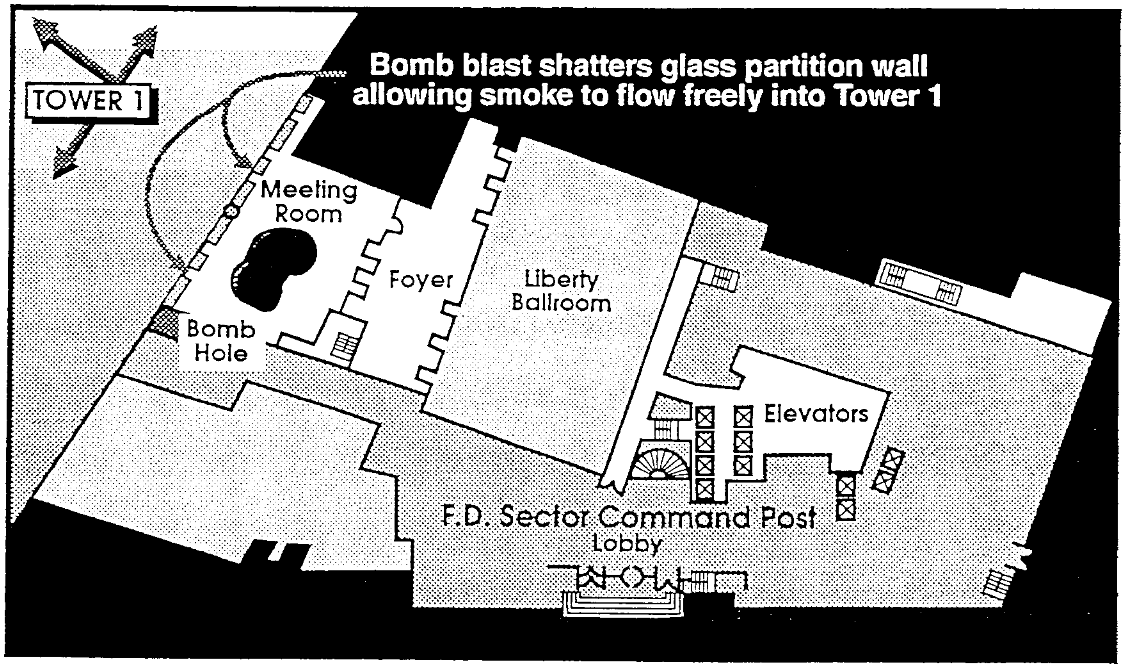
All power for the hotel was knocked out. Telephone service was down. The building's heat plant was out. No water was available, so sprinkler and standpipe systems were not operational. The fire alarm system was inoperable. Building security was breached — i.e., doors had been blown off and were not functional. The structural integrity of several areas of the building was in question.

RECOVERY EFFORTS

Hotel engineering immediately arranged for consultative and contractual assistance to help correct the results of the blast. We then took the following steps:

- contacting mobile electrical generating facilities to arrange for a tie-in to the hotel's electrical system;
- arranging for mobile steam-generating units and the appropriate tie-in to the hotel systems to safeguard against pipes freezing;
- contracting with all major trades (i.e. electrical, plumbing, carpentry, steam-fitting, and cleaning) to deactivate any live wires, cap any services required, and provide temporary barricades and, enclosures from the elements, as necessary
- contacting the fire alarm company to assess damage and reactivate the fire alarm system;

Vista Hotel — Lobby/Concourse



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- hiring a private security firm to aid in the protection of hotel property and render fire watch assistance:
- contacting architectural and engineering consultants to examine the damages and provide a full assessment of immediate and long-term repairs; and
- providing all labor necessary to remove hazardous conditions — i.e., falling walls and ceilings and so forth, to render the site safe for further demolition and repair.

The efforts of hotel personnel and on-site engineering contractors were successful in that all precautions were taken and engineering expertise was present for professional assessment. Although damage resulting from the explosion was critical, personal injury was minimal.

The success of the hotel evacuation and recovery was due to professional engineering response professionals were on-site and immediately available. In addition, security and fire safety personnel had participated in collective training and planning. The hotel is scheduled to reopen in mid-1994.

Below-Grade Fire Extinguishment and Victim Recovery

by Kenneth Cerreta

I was relieved as incident commander of the World Trade Center explosion by Chief of Department Anthony Fusco approximately 30 minutes into the incident. He directed me to assume command of the fire extinguishment operation. Until that point, I had been concerned mostly with operations in the Vista Hotel and the thousands of people self-evacuating out of this giant complex in almost total darkness; smoke conditions in the stair towers and on the floors; and our rescue effort. Now I took leave of the command post, accessed the B stairs in Tower 1 to the B-2 level, and prepared to coordinate the firefighting actions below ground.

The scene that greeted me can only be described as surrealistic. Heavy smoke poured out from a deep, wide crater and from burning debris and automobiles around it. I realized that the damage could only have been caused by a large explosive device. The thought of a second explosion crossed my mind but was quickly put aside by the urgency of the situation.

Fire extinguishment at the WTC explosion was critical to the safety of the building occupants. There almost certainly would have been more injuries and deaths in this incident had members not halted the generation of smoke from numerous below-grade fires. Rescue and removal operations in the towers would have been much more difficult, and the occupants would have been exposed to greater amounts of smoke for longer periods of time.

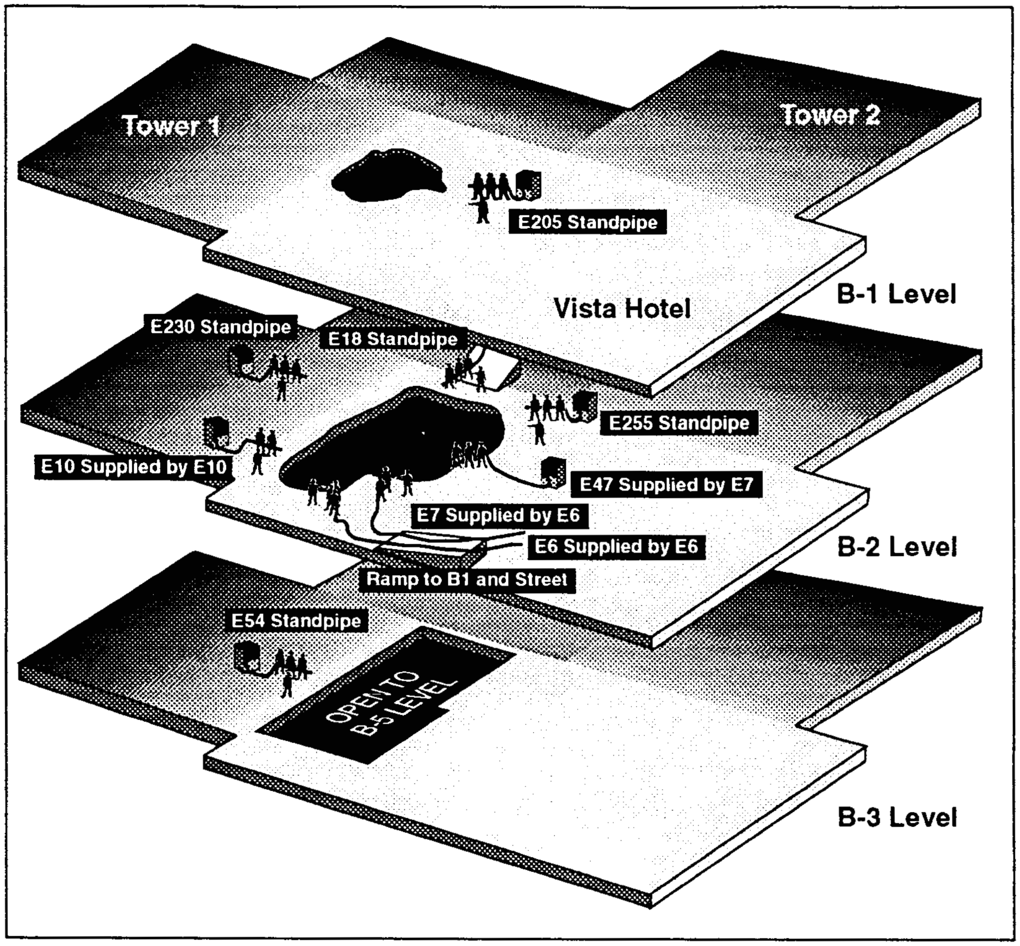
Handlines — all 2 1/2-inch lines, as per high-rise SOPs — were operated in the lower levels from the initial stages of the incident. Firefighters who manned these handlines did so under extremely dangerous conditions; the potential for secondary collapses or additional explosions was a constant threat.

There were numerous fires on both the B-2 and B-3 levels. Members extinguished fires in offices, a cafeteria, locker rooms, workrooms, free-burning rubble, and at least 50 burning automobiles; lines also provided protection to Firefighter Kevin Shea, who had fallen into a crater and was vulnerable to numerous fires burning around him. As they advanced, firefighters on the attack lines searched for, and in some cases removed, victims from cars and under rubble.

Size-up was hindered by poor visibility, the size of the crater and extent of the damage around it, and difficulty in communicating via portable radio. Lighting in the below-grade areas came from the fires themselves. Individual units on the B-2 level, in this very difficult environment, were unaware that there were other lines in operation near the crater. As the incident progressed, firefighters forced entry into automobiles and turned on their headlights for additional light. Fortunately, the area of the crater was so large that opposing streams were not a danger.

Kenneth Cerreta is Deputy Assistant Chief of Manhattan Borough for the City of New York (NY) Fire Department. In his 30-year career, he has worked in all five boroughs of the city. He has a bachelor's degree in fire science from John Jay College of Criminal Justice in New York and was an instructor of the fire department's incident command course. At the time of the World Trade Center explosion, he was commander of Manhattan South Fire Command

Handlines Deployed in Fire Extinguishment



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I made my way around the periphery of the crater and personally communicated with units operating on the fires. Through these conversations and visual observation, I determined that the fires were being controlled by the surrounding handline attack. I relayed progress reports to the command post primarily through runners, though I delivered a few messages personally so as to confer with Chief Fusco.

EXTINGUISHMENT SUMMARY

Only four hydrants were readily available to initial-operating units, and portions of the buildings' standpipe systems were damaged in the blast. Nevertheless, water supply was never a serious problem because local fire companies had an excellent knowledge of the area hydrant system through preplanning, experience, and training. This was a critical factor in ensuring a rapid, continuous water supply, which, in retrospect, was our only real defense against smoke generation and, therefore, smoke movement within the buildings. Automatic sprinkler systems in the area around the explosion were either destroyed or overwhelmed by the blast; we worked with a Port Authority engineer to isolate damaged portions of both the sprinkler and standpipe systems so that undamaged sections would be functional if needed.

Engine Company 10, observing smoke pushing from the Vista Hotel garage doors, entered the K-1 stairs in the hotel and connected the first handline to a standpipe riser on the B-2 level. This did not produce a satisfactory stream — the standpipe was damaged and the resulting pressure inadequate. Assisted by members of Engine Company 5, this hoseline was connected to Engine 10's apparatus in the street. Engine 10 operated this line for approximately two hours, extinguishing numerous car fires.

Engine Company 6, arriving very soon after Engine 10, immediately connected to a hydrant and stretched a handline down the B garage ramp to the B-2 level, where the members rescued several victims, extinguished numerous car fires, and operated on the fires in the crater. Their water was supplemented from a manifold by Engine 5, whose crew members provided relief to Engine 6.

Engine Company 7 assisted Engine 6 with their stretch, then stretched a handline of their own and operated on the fires in the crater and the automobiles. They also pulled a victim out of the crater debris.

Engine Company 18 connected to a hydrant and supplied the standpipe system, partially operational, then stretched a handline off the standpipe on the east side of the crater. Engine Company 209 assisted in advancing this line and eventually relieved Engine 18. These units also removed a trapped civilian and assisted in the removal of Firefighter Shea.

Engine Company 205 stretched from the standpipe on the B-3 level (south side of the crater). This handline was stretched and filled in with the assistance of engine companies 204, 202, and 55. It was used to extinguish fires and protect Firefighter Shea during his removal.

Engine Company 47 stretched and operated a line from Engine 7 down the Vista fire stairs to the B-2 level on the crater's southwest side.

Engine Company 230 proceeded down the B stair in Tower 1 to the B-2 level. They stretched a line from the standpipe to the "building service area" and extinguished fires in an office and locker room area. This is the area from which four of the six fatalities were recovered.

Engine Company 255 stretched and manned a line off a standpipe in the Vista Hotel and operated on the southwest side of the crater.

Engine Company 54 stretched off the standpipe in the B-1 stairs at the B-3 level and operated on the west side of the crater.

Fourteen engine companies operated nine handlines to extinguish all below-grade tires in approximately one hour. The below-grade tires were declared under control at 1:48 p.m.

VICTIM RECOVERY

As the incident progressed, I was directed to coordinate the victim recovery operation in addition to fire extinguishment.

Two fatalities (numbers two and three; the first fatality already had been located early in the incident by FDNY) were recovered from the building service area of Tower 1 during the initial search and extinguishment operations. This area is adjacent to where the explosives were detonated, separated by a concrete block wall. Once fires in this area were extinguished, we called for a PA supervisor to identity the bodies. He positively identified them, and they were moved to a temporary morgue set up in the Vista Hotel.

The PA supervisor reported that three additional employees were thought to be in the general vicinity of the building service area at the time of the explosion. He provided us with names, descriptions, and last known locations, and we initiated a systematic search. Under the supervision of a battalion chief, units searched the rubble, starting from the area immediately surrounding the crater. It was a herculean task, considering that the rubble, piled two to three feet high, was a mass of broken concrete, twisted steel beams, mangled piping, and smashed wall board, lockers, and office furniture. A six-foot-wide strip around the crater was cleared by hand and searched, then the debris was moved back into this area and the search perimeter extended another six feet, and so on. Rotation and relief were imperative for this heavy manual work.

Two fatalities, numbers four and five, were recovered by the fire department using this method. Another victim would be found approximately two weeks later; meanwhile, the search through the rubble had to continue until the entire area had been combed — there was always the possibility that a person not yet reported missing was visiting or passing through the area.

LESSONS LEARNED AND REINFORCED

1. **The extinguishment of the fires on the B levels had a tremendous impact on the outcome of the incident.**

   The fire extinguishment diminished the quantity of smoke generated and, as a result, diminished the amount of smoke traveling into the buildings above, without this relatively quick knockdown. The injury and death statistics would have been much different.

   Officers easily can be overwhelmed by the magnitude of the evacuation effort at large-scale incidents, but always must remember a basic rule of firefighting: Timely handlines operated aggressively from the interior between the life hazard and the fire often are the best protection against the effects of fire.

2. **Local fire units' knowledge of hydrant locations, building layout, and fixed systems is an invaluable asset in high-rise/industrial incidents.**

   Time spent during building and hydrant inspections and local familiarization drills saves valuable time and effort when an incident occurs.

3. **When normal fireground communication methods are ineffective, we must improvise by using relays, runners, cellular phones, etc.**

4. **When operating at a large-scale operation, members, including incident/sector commanders, may not always be aware of the location of every unit.**

   It is important that each phase of the operation be under the control of chief officers who can network with the incident/sector commander for a more complete picture. Be sure to call enough chiefs to the scene.

5. **As soon as possible, ascertain the number of people thought to be in the fire and/or explosion area from supervisors, coworkers, or security personnel.**

   Information including the names, descriptions, and last known locations can assist in pinpointing and organizing a systematic search. It will help speed up operations and, in turn, increase the chances of victim survival.

6. **Risk analysis is ongoing throughout any incident, but once fire is extinguished and those reported missing are accounted for, it becomes especially important to remove personnel on a timely basis if there is any doubt as to the stability of the involved areas.**

7. **Use large handlines for large bodies of fire.**

   The maneuverability of smaller handlines was sacrificed for the quick knockdown capability of larger lines. This requires a manpower-intensive effort. Relief, rotation, and crew augmentation must be considered — and practiced — by officers.

8. **When explosions take out a portion of a standpipe system, it often is possible to isolate the damaged section through the use of riser isolation valves and/or sectional control valves.**

   Preplan these operations so you know the valves' locations and the areas they control, and drill local units in their use.

Operations in Tower 1

by Donald J. Burns

I was at FDNY Headquarters in the borough of Brooklyn when the World Trade Center (WTC) explosion occurred. I was notified of a second alarm at the WTC and that there had been some type of explosion. Usually, a report of an explosion in a high-rise indicates an electrical problem such as a large short or a transformer explosion. After notification of a rapid escalation to a third alarm, I responded with Deputy Chief Edward Dennehy.

As we crossed the Brooklyn Bridge into lower Manhattan, a fourth alarm was transmitted, along with an additional alarm for Tower 1. The fire department radio traffic told me something big and unusual was taking place — this wasn't the "run-of-the-mill" high-rise fire.

I approached the WTC and drove past the entrance ramp to the loading zone/parking garage under the building. Smoke was issuing from the opening, and firefighters were removing people from the area and stretching lines into the lower levels.

As I crossed West Street to the command post, I could see smoke drifting around and over Tower 1. I also could see people evacuating, tower windows being broken by the occupants, and a lot of confusion on the street. I reported to Deputy Assistant Chief Kenneth Cerreta at the command post, but I declined to assume the role of incident commander because I knew Chief of Department Anthony Fusco would be arriving soon and would be in command. I concentrated instead on Tower 1 and in finding solutions to the problems we had there.

I was not prepared for the scene that greeted me when I entered the lobby: the smoke condition was so black and thick that visibility, even with a flashlight, was no more than three feet. The lobby was filled with people trying to evacuate. Fire, police, Port Authority, and EMS personnel had formed a human chain to funnel the people out of the stairway to the exit. Deputy Chief Dennehy and Battalion Chief Richard Picciotto were trying to establish a sub-command post near the entrance to gain control over responding units.

After a quick reconnaissance of the lobby, I determined that I had to stop the smoke from being drawn into Tower 1, if possible. I took a company and went to the exposure #4 side, next to the Vista Hotel, where I knew there was a passageway connecting the tower and the hotel. I hoped that somebody hadn't closed the doors and that was the reason smoke was getting in.

We soon found that not to be the case: The explosion had blown a hole through the floor in an area of the Vista Hotel adjoining Tower 1 and had blown out a number of large plateglass windows that were designed to act as a barrier between the two buildings. We would not be able to stop the move-

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Donald J. Burns is a 32-year veteran and assistant chief of FDNY, currently serving as the department's chief of operations. He has served as assistant chief of support services and as chief in midtown Manhattan. Burns developed and was the first director of the New York State First Line Supervisors Training Program. He is a New York State-certified instructor and has taught high-rise firefighting at the New York State Fire Academy in Montour Falls.

ment of smoke. I knew that Tower 1, because of the stack effect, would act as a chimney for the fire down in the lower levels and that doors opening onto the stairway and smoke travel through elevator shafts would allow tenant spaces to become contaminated.

On our way back to the entrance, one of our members suggested that we remove the front windows. Normally in a high-rise fire I wouldn't break out the windows, but in this case I felt that removing them would allow some fresh air into the lobby and stairways and might change the smoke patterns, keeping the smoke from being drawn into the tower, so I approved that action.

I proceeded to the lobby command post and told the chiefs that the smoke could not be stopped and we would have to search the entire building — all 110 floors and 99 elevators. The explosion blew many elevator doors off their tracks and severed electrical cables, bringing all elevator service to a stop and trapping anyone in an elevator at that time.

At this point, the people exiting from the stairway were choking from the smoke and complaining that there were no communications or lights. Reports from the evacuees indicated that smoke was heavy up to at least the 20th floor, possibly beyond that.

We would have to rely primarily on firefighters to communicate with occupants. The WTC's central fire command station was located on the B-1 level. The single control room had worked fairly well over the years, but when the blast knocked the control room out of service, the drawbacks of having only one control room for the entire complex were brought to the forefront. With the control room inoperative, communication between command and the floors became impossible. The Port Authority's portable radio system could not be used, since it operated on a relay system that passed through the control room. The only communication with upper floors was via civilian radio or telephone system — or emergency workers. Telephones were a problem because those on a private telephone switching station operate on power from the building.

I left the building and reported my findings to Chief Fusco, now in command of the incident. I requested 30 to 40 units as soon as possible, then went to assume command of the Tower 1 sector.

As I was leaving the command post, someone directed my attention to the walkway between the Tower 1 mezzanine and the Vista Hotel patio, specifically to a Tower 1 door located at that level. He said people were banging on the door and couldn't get it open.

When the WTC was designed, I don't think anyone envisioned that someday 25,000 occupants would have to evacuate using only the stairways. Tower 1 was designed with only three evacuation stairways; only one of these runs the full length of the building to the lobby level. The other two stairways end at the mezzanine in the lobby of Tower 1, the exterior plaza level of the WTC. A walkway connects the Tower 1 mezzanine with the Vista Hotel's outside patio. Most occupants of the WTC had never entered the stairways before the incident; if the stairs were used, it was only for a floor or two. The stairs are not used as a regular means of egress.

I ordered a truck company to the Tower 1 door leading to the walkway patio to force open the door. A tower ladder was parked nearby, and I ordered a member to raise the bucket up to the patio in case we needed it to assist evacuees. When the door was forced open, we found people piled up against it. Some were unconscious due to the smoke. They had come down the stairways that ended on the mezzanine level. Because of the heavy smoke, they couldn't find the exits after they got to the mezzanine.

After the lobby windows were broken out, the smoke condition in the lobby and mezzanine improved considerably. It was then that I discovered some lights were still working. They stayed operational for only a short time, until the emergency generators went out and, with them, the lighting.

As companies reported in to Tower 1 sector command, they were given five-floor sectors to search and were directed to take a specific stairway to those floors so we could provide relatively uniform coverage to each of the three evacuation routes. The searching firefighters, as expected, had to force numerous doors both from the stairways and on the floors.

I directed Battalion Chief Picciotto to assist at the command post in coordinating assignments. By the time our operation was in full swing, we had two deputies, each covering half of the tower; five battalion chiefs responsible for 20 floors; and approximately eight to 10 units operating per 20 floors.

A representative from Port Authority engineering reported to the sector command post and informed me that he had a number of elevator mechanics available to climb the stairs to the machinery rooms on floors 48 and 74, where they could release the brakes on the cars and bring them up to the sky lobby to be checked. I detailed a truck company to accompany the elevator personnel to search the elevators.

All units started from floor one and had to climb the stairs to whatever floors they had been assigned. At a rate of one minute per flight of stairs, it would take an hour to reach the 60th floor. But during such an emergency, with people using common stairways to evacuate, it really takes closer to two or three minutes per floor. We had to allow approximately two to three hours for a climb to the 60th floor. Chiefs on the stairs reported progress/status and the conditions they found through a relay system. My portable radio was good up to about 43 floors, so I stationed a deputy chief at that position to relay information from above, down to me. I received periodic updates from messengers with MDT printouts of the calls from occupants of upper floors. I sent these messengers back to the command post with requests for additional units and progress reports.

All afternoon, I was receiving reports of people trapped or in need of help. All these reports were investigated. People on the lower floors could be helped fairly easily, but it is very disheartening to get a message about people needing help because of a heart condition or disability when you know that nobody can reach them for a couple of hours. Nevertheless, emergency personnel accounted for all those who needed extra help. In some cases, nonambulatory civilians or civilians with health problems were carried down the stairs to ground level from upper floors. EMS (stair) chairs and regular office chairs were used in many carries. Furthermore, late-arriving engine companies were requested to bring resuscitators to upper floors.

The operation in Tower 1 was a massive search and evacuation effort. High-rise firefighting often calls for a defend-in-place strategy whereby occupants are sheltered in safe areas of the building while the fire is extinguished and essential building systems/services are restored, if necessary. In this case, however, because occupants felt the explosion, followed a few minutes later by smoke throughout the building, almost everyone started to self-evacuate. The fire department made the decision to order a complete evacuation anyway, due to the nature of the incident and the unlikelihood that building electrical power and fire protection systems would become operational in a suitable period of time.

Approximately four hours into the operation I stopped sending companies up the stairs, since companies already had made it to the 80th floor and could reach the top much faster than companies starting from the bottom. We already had more than 40 companies operating in Tower 1. At 1800 hours — the change of tour — the issue of relief arose. I decided not to relieve the units, instructing them to perform secondary searches on the way down. Some units had been in the building for more than eight hours by the time they got back to the street.

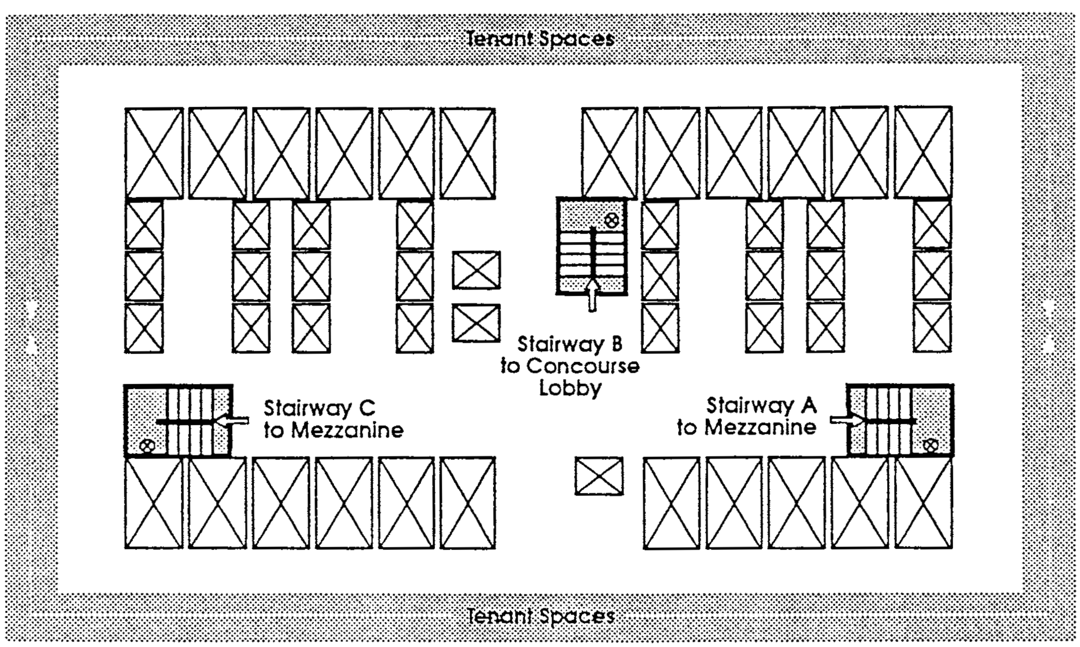
As time went on, problems developed that are inevitable in any extended operation — flashlight batteries died, radio batteries started getting weak, firefighters were getting hungry, and exhaustion was setting in. We decided that as soon as members reached the lobby area, they would take up and go home.

The firefighters who operated in Tower 1 accomplished remarkable things. Some climbed 110 floors to search. Some carried people down 60 or 80 floors. Members responded to about 20 maydays for people in serious trouble. They searched 99 elevators and, in the end, 25,000 people were evacuated.

When I first went into the tower and saw the smoke condition, I expected to have a big problem — people collapsing and maybe even a few deaths. As time went on, conditions improved and, except for a few cases of exhaustion and chest pains that were quickly handled, the pressure on everyone lessened.

On that Friday, I believe anybody who responded went through a whole range of emotions, from fear of a large loss of life to anxiety, exhaustion, and, finally, exhilaration. It was an operation that few who were there will ever forget.

Elevator and Stairway Configuration, Towers



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LESSONS LEARNED AND REINFORCED

1. **With barriers between below grade areas and Tower 1 breached, stack effect in control, and the force of the explosion behind it, smoke migrated to upper floors through shafts within minutes.**

   A crucial early action was the removal of the lobby windows, allowing some smoke to escape and that which remained inside the tower to be diluted. This "short-circuiting" made the evacuation route more clear and cut down on the quantity of smoke on the upper floors.

2. **Without elevators, sending companies to upper floors in large high-rise buildings is measured in hours, not minutes.**

   Chief officers must call for and coordinate resources accordingly.

3. **There is no perfect building.**

   Having the two stairs discharge to the mezzanine lobby, rather than directly to the exterior, was a major building design flaw. With visibility at less than a few feet due to smoke, people could not find their way out once they reached the mezzanine. Exits must be continuous — safely leading people to a public way.

4. **Rest and rehabilitation pay a critical role in operations that place great physical demands on firefighters.**

   Early in the operation, doctors and nurses from the Port Authority health clinic in Tower 1 set up a space in the cafeteria on the 43rd floor for medical attention and rest and rehabilitation. This was used by civilians and emergency personnel and became an important area because it could supply soft drinks and food to those who needed them.

5. **One of our biggest problems was communications.**

   All building systems went down when the command center was knocked out. For operations involving very tall buildings or below grade areas, consider using a relay system for communications. Preplan and build contingency plans — our effectiveness is only as good as our ability to communicate.

6. **Congested stairways made the use of stokes baskets for victim removal impractical.**

   Fortunately, no victims required immobilization, so EMS chairs and office chairs were functional in transporting nonambulatory/incapacitated civilians. In the future, it would be extremely beneficial to emergency personnel to have medical supplies, EMS chairs, resuscitators, etc., available at various locations throughout these large structures for possible use during an emergency.

7. **Elevators represent both the primary and secondary means of egress for nonambulatory/incapacitated occupants of large high-rise buildings.**

   Moving nonambulatory occupants down the stairways was a very difficult, manpower-intensive task. We were able to evacuate approximately 15 to 20 nonambulatory civilians from Tower 1, but what would have happened if we had to accommodate a 100 or more? Serious thought must be given to providing these individuals greater self-sufficiency in egressing large public buildings.

8. **Sizes of the avenues of egress must be able to handle the occupant load.**

   Evacuees were moving down the stairs as quickly as they could, but that was slow — like toll booths during rush hour in a big city. People from upper floors waited as long as an hour at certain points along the way while lower-floor occupants filed out. Not until 1630 hours did the steady stream of evacuees from the stairways lighten up.

9. **Duplication of search efforts was a problem — among different emergency agencies and the fire department itself.**

   Greater attention to marking stairwell entrance doors to searched floors is important.

10. **Entry into the building by non-emergency personnel and members of private concerns (such as the media) must be controlled.**

    This aspect was handled well by Port Authority Police located at building entrances.

Operations in Tower 2

by Robert Manson

At 1218 hours on February 26, 1993, the occupants of the World Trade Center (WTC) Tower 2 knew immediately, from the concussion of the explosion, "that something had happened." Moments after the building shook, a light to moderate smoke condition began to develop on all floors, as smoke from the explosion and fires contaminated the tower through elevator shafts and other natural channels. Most of the approximately 25,000 tower occupants did what people do when they feel they may be trapped in a burning building: They tried to leave the building.

Unfortunately, a number of people on that day either forgot about or ignored the elevator warning signs and entered the elevators in an attempt to escape. Within a very few minutes of the first signs of smoke, Tower 2 had a partial power failure — elevators and emergency communication and ventilation systems went down, and portions of the building lost lighting. The occupants who had made it into the elevators were trapped; some would be trapped in those prisons for as long as 11 hours. While there was confinement, terror, and discomfort within these elevators, there fortunately were no serious injuries or fatalities. Had there been a working fire on a lower floor in Tower 2, the death toll may have been in the hundreds.

I was working a day tour in the 12th Division (borough of Brooklyn) on the day of the explosion. The 12th Division was directed by Brooklyn Communications to respond to the WTC complex, Tower 2, at approximately 1250 hours.

The enormity of the event was immediately evident on arrival. From every point of view, hundreds of people were either lying on the ground, sitting on sidewalks, or wandering around in a state of confusion. Too numerous to count were New York City EMS, police, and fire vehicles throughout the streets. Many of the lobby windows of Tower 2 had been broken out by firefighters, and a light smoke condition existed throughout the large lobby area. Numerous people were lying on the lobby floor, some were being treated by EMS personnel, some by other civilians, while others were still unattended. Hundreds of people in various states of trauma were exiting the stairways, streetlight was the only light for the lobby area, adding to the eeriness of the scene.

The only good sensed or felt on arrival was that whatever had caused all of this havoc was over with — it had done its damage. In Tower 2, there was fire to control, and the smoke condition on upper floors improved dramatically as below-grade fires there extinguished about an hour into the operation. Locating, treating, and removing the injured and trapped victims constituted the incident.

Deputy Chief Joseph Mills of the 11th Division also was assigned to Tower 2. Chief Mills asked me to issue the lobby command position in Tower 2 while he operated on the upper floors as the operations chief.

Robert Manson is a 33-year veteran of the City of New York (NY) Fire Department, currently serving as a deputy chief of the 12th Division, in the borough of Brooklyn. From 1984-1991, he served as a staff chief, and his assignments included Manhattan borough commander and chief of fire prevention, before returning to the rank he now holds.

The most immediate problem was treating the unattended civilians in the lobby area. Horizontal ventilation of the lobby early in the operation relieved conditions considerably, producing a very workable area for triage and treatment for those who had self evacuated to the lobby. With the arrival of additional EMS personnel, this was soon effected. We also were receiving reports that numerous people on various floors were suffering possible heart and asthma attacks and that at least two women were in labor, one of them reported to be hemorrhaging on the 98th floor. This woman was brought to the roof and removed by a NYPD helicopter.

I contacted the ranking EMS officer in the lobby and asked him to establish a triage center on the 34th floor. The 34th floor was chosen because one of our fire units reported it to be an open floor with good outside lighting.

A male occupant fell while descending the stairs on the 68th floor and broke his leg. He first was carried to and treated at triage and then chair carried to the lobby for removal to the hospital.

A fire unit also reported that more than a hundred civilians, many of them young children, were on the 107th-floor observation deck. Having been previously informed that electricity for the elevators might not be restored for a number of hours, if not days, the units were instructed to remove the civilians by stairway. During the removal, which took more than two hours, additional fire personnel were stationed throughout the stairwell to provide lighting and support to the children evacuating.

The number and configuration of stairways in Tower 2 were essentially the same as those in Tower 1: There were three stairways, one of which traveled the length of the building and two of which terminated (or began) at the mezzanine level. But, unlike Tower 1, the smoke condition in Tower 2 was not so severe that occupants could not find exterior doors once they reached the mezzanine level.

SEARCH AND REMOVAL

The major problem for search and removal in Tower 2 during this incident was the trapped elevator occupants. There were 99 elevator cars in the tower; almost two-thirds of them traveled through blind shafts. All the elevators had to be searched, and there were no elevators located at the lobby when power went down. One of the FDNY members performing search and evacuation of the elevators in Tower 2 was Lieutenant James Sherwood, an off-duty firefighter who had volunteered his services. While performing this duty, he became aware of an occupied elevator within a blind shaft on the 42nd floor, at approximately 1730 hours. He searched around the core of the building at each floor, tapping on the walls and calling out for a possible response. When he received a response on the 42nd floor, he informed the "voice" that he would soon have him out. The lieutenant asked how many were in the elevator. The response was 72, most of them schoolchildren ages five and six.

Having carried a maul during his search, the lieutenant was able to breach a small hole in the wall and to see a small portion of the top of the elevator car. He could make out the forms of numerous people in the car. He passed his flashlight into the car and then widened the hole so that he could enter the shaft onto the top of the elevator car. When on the car, he realized he was next to an open adjacent shaftway — if he fell, it would be a 42-story fall. He opened the elevator car's hatchway, reached down, and began to pull children up one by one. He passed the children to Port Authority police officers, who now were on the other side of the wall. After 12 of the children had been removed, the elevator car began to slowly descend without notice; power to one elevator bank was restored, and elevator personnel were bringing down the car. The lieutenant climbed into the elevator car to calm the now very fearful occupants. After a number of panic-filled minutes, the elevator car reached the lobby, and the occupants finally were removed to awaiting EMS personnel. The lieutenant has been recommended to the NYC Fire Department's Board of Merit for a commendation.

During the entire operation in Tower 2, FDNY operated with several battalion chiefs and 27 companies. While the search-and-rescue challenges in Tower 2 were indeed significant and sizable, fewer firefighters were required for this tower, as compared with Tower 1, because, as noted, the smoke condition in Tower 2 did not present an urgent, life-threatening situation. At 1800 hours with the change of tour, seven fresh truck companies were special-called to relieve the day-tour units. These units were special-called for a relief, to continue initial search and evacuation, and to perform a secondary search of all floors. With power restored to some of the elevators at approximately 1800 hours, we were able to send fresh units to the 50th floor by elevator. We also were able to procure master floor/office keys for entry into locked offices. The remainder of the search, while exhausting, went relatively smoothly. The last elevator occupants were found and removed at approximately 2300 hours, almost 11 hours after the beginning of the incident.

LESSONS LEARNED AND REINFORCED

1. **At any high-rise incident, once occupants begin to self-evacuate, it is almost impossible to stop them without good communication to the floors and stairways.**

   Occupants terrified for their lives will not readily listen to instructions to stop their exiting — which they truly believe will save their lives. Even if reversing self-evacuation were possible, fire department assessment of the extent of damage to vital building systems and the probability or improbability of restoring services within a reasonable time must factor into the decision. Unless absolutely necessary to protect life, it is advisable to assist (emergency personnel presence) in this self-evacuation to alleviate panic and to remove occupants from the stairways and building as soon as possible.

   Once building occupants reach the lobby, the noise from these occupants will interfere with the incident management. (For those who make it down safely, extreme tension easily gives way to an almost festive mood.) In large-lobby buildings, remove the occupants to a distant part of the lobby, away from the lobby command post. In smaller-lobby buildings, remove the occupants to the outside if breaking glass and weather are not issues of concern.

2. **At all high-rise incidents involving evacuations, the incident commander and sector officers must maintain stairway control, using them to the fullest advantage.**

   There was no fire in the towers at this incident, so designating "attack stairs" and "search-and-evacuation stairs" was not necessary however, command directed companies to specific stairways to provide maximum coverage during the search effort and, based on communications with upper-floor officers, to address particular rescue problems in the most expedient manner. Personnel resources must be such that sectoring of officers achieves stairway control.

3. **Common sense dictates that when units are special-called to high-rise buildings for search and evacuation under *nonfire* conditions (relief units at this incident), they should be advised in quarters, via command order through dispatch, to respond with street shoes.**

   A 30-, 60-, or 90-story climb will tax even the best-conditioned firefighters, and reducing the weight carried by firefighters will cut down on injuries and enhance the operation. Seven-pound boots translate to 35 pounds of "back weight."

4. **As in any fire operation, a secondary search of all areas of the building must be made by fresh units to ensure that all occupants have been found, treated if necessary, and then removed from the building.**

   When possible, these units should be provided with master keys to facilitate this secondary search, if these keys were not made available to the initial unit(s).

5. **The natural chaos at an incident of this magnitude will work against an incident commander's ability to plan ahead for potential problems involving personnel from other agencies.**

   Every effort must be made to communicate with other agencies personnel and coordinate actions. The rescuer-accountability challenges are also magnified; with search parameters so large, it is imperative that company officers achieve control at the company level and communicate developments as often as necessary through a well-defined communications relay system.

6. **Tools are an important aspect of search-and-rescue effectiveness.**

   Firefighters must have the necessary tools before ascending the stairs — the 50th floor is not the place to remember the hydraulic door opener. Doors and elevators had to be forced, walls had to be breached, etc.

7. **Assess medical needs early in the incident.**

   Establish a forward triage area, if possible, which will allow for a prioritized patient-assessment and removal process.

8. **Rescuing people through an elevator cab roof is performed only under extraordinary circumstances, such as those of the WTC incident.**

   If power is restored to a stalled elevator involved in such an evacuation, such as that which occurred during the evacuation of the cabful of schoolchildren, rescuers and trapped occupants are placed in an extremely dangerous position.

   All elevator cabs have an "on top of car inspection switch" as well as an emergency stop button on top of the car, which will keep the cab from moving if power is restored. These switches/buttons should be activated if rescues are conducted through the top of the cab. Activation of these switches/buttons will not, however, prevent a cab from being moved manually from the elevator machine room.

Search and Rescue: An Overview

by Ray Downey

Within minutes of the initial explosion and resulting fire, rescues had begun. Port Authority personnel, including police officers at the command center on the B-1 level and maintenance personnel who had been having lunch on the B-2 level, received a major blast impact. A number of victims had to be removed from beneath the rubble by their fellow employees.

Firefighters arrived on the scene within minutes. By the time handlines were positioned and advanced toward the below-grade fires, rescues were taking place. As firefighters made their way down into the garage area, they were finding victims trapped under rubble piles, while other victims could be heard hollering for help. Although six people lost their lives, the potential for a much greater catastrophe was diminished by the heroic efforts of those involved in the rescue and suppression operations.

Self-evacuation of the towers had begun minutes after the explosion. Occupants of the upper floors reported as smoke entered their office spaces minutes after they felt the effects of the initial blast. The fire department command structure implemented for this operation provided for, in addition to the main command post, individual sector and subsector commands within the primary areas that required immediate search and rescue. The sector command posts were located in the Vista Hotel, Tower 1, and Tower 2. Subsector command was established at the lower levels for fire extinguishment and the rescue of Firefighter Kevin Shea.

Vista Hotel. All 829 rooms in the hotel had to be searched. After hearing and feeling the explosion, a number of occupants surprisingly remained in their rooms. Many others were found in the hallways and stairways and had to be assisted to safe locations. In addition, where master keys were not available, firefighters had to force numerous doors.

Tower 1. In Tower 1, where the smoke condition was the heaviest, those conducting a massive search and rescue operation were encountering a multitude of problems that had the potential for disastrous results. Each of the 110 floors had to be searched and occupants had to be assisted in evacuating. In many cases, firefighters physically removed victims to the street. Adding to these problems were 99 elevators that had to be located and searched; victims, some unconscious, were found in numerous elevators.

Tower 2. The search and rescue operation in Tower 2 was similar to that in Tower 1. All 110 floors and 99 elevators had to be searched and victims located and removed to the street. Fortunately, the

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smoke condition in Tower 2 was not as severe as that in Tower 1, but this didn't reduce the problems encountered. Thousands of occupants were self-evacuating, and the search of elevators and tenant spaces was equally exhausting.

Below grade. Major firefighting and search and rescue operations were required below grade near the large blast area. The parking garage, with a total capacity of 2,000 vehicles, was about half-filled at the time of the explosion. Many cars were involved in fire, creating the additional danger of exploding gas tanks. The search effort in this area also required checking each vehicle for possible victims. Victims rescued from rubble piles reported that a number of fellow employees might be trapped in the same area; this was later confirmed by Port Authority management. The destruction from the explosion prevented rescuers from using some stairways to the lower floors, forcing them to find alternative means of reaching victims. Usually this meant climbing over and through debris. The search and rescue operation below grade was complicated by the fact that firefighting efforts required the use of nine handlines for final fire extinguishment.

Firefighter rescue. During the rescues below grade, one of the firefighters himself became a victim. Firefighter Kevin Shea, while making his way toward the sounds of a trapped victim, fell through flooring into the crater formed by the blast. After falling more than 40 feet and being severely injured, he still was able to direct rescuers to his location. Firefighters conducted an all-out operation to reach him, and he was successfully removed from this precarious position while fire extinguishment operations were still underway.

CONTROLLING THE OPERATION

What are the means by which such an enormous rescue operation is controlled? An expanded incident command system that ensures adequate span of control but yet is flexible and adaptable. Sectoring and subsectoring the incident were critical. The sector commanders split up their areas of responsibility into manageable parts, each under the control of an officer. For example, the commander of Tower 1 split the building in half and designated two chiefs for those areas; then he designated several officers responsible for coordinating the search and rescue operations on 10 to 20 floors. Approximately 8 to 10 units were assigned to each of these areas. This type of coverage was designed to ensure that all floors would be searched in a controlled mode.

Since each floor was equivalent to an acre in size, search would be a time-consuming job. Although the majority of occupants were ambulatory, those who were disabled, elderly, pregnant, or in need of immediate first aid; required assistance that eventually reduced the number of rescuers available, creating the need for additional personnel and requiring the transmission of additional alarms. Well-coordinated communications within the command structure were required so the incident commander could keep informed of the needs of his subcommands.

Staffing was an ongoing problem throughout the operation. Tasks such as removing victims in wheelchairs from upper floors required four firefighters. Rescuers also were required to assist in evacuating occupants down the smoke-filled stairways to the street. Factors such as these required that the subcommands and the incident commander adjust and adapt the operational plan accordingly.

ELEVATOR SEARCH AND RESCUE: A UNIQUE PROBLEM

Locating the elevators in each of the buildings required a coordinated effort. Normally, building maintenance personnel would have been able to provide invaluable help at the very outset of the incident. Unfortunately, many maintenance personnel had been located in the area of the blast when it occurred. It would be hours before some of them were available to assist with elevator rescue operations. Even in buildings where elevator personnel were available, in some cases they still had to climb 110 flights to reach the uppermost sky lobby and recall some elevators — and the climb could take four hours.

The elevators serving the local floors had discharge doors that could be opened easily, and rescuers could look into the shafts for elevator locations. However, the heavy smoke condition was traveling up the shafts to the upper floors, causing additional problems for rescuers trying to locate elevators, each shaft had to be checked at every possible access opening for locations.

Locating express elevators in blind shafts presented the biggest problem. As these blind shafts pass through the floors, there is no visible indication of shaft location at each floor. Those rescuers assigned to locate elevators, lacking the assistance of building maintenance personnel, had to rely on their experience, knowledge, and training to accomplish this most difficult assignment. Even after locating a shaft, heavy smoke conditions required rescue teams to make floor-by-floor inspections into the shaft until they eventually found the elevator in a shaft. Fortunately, through rescuers' efforts, numerous trapped occupants were saved. In one case, a firefighter located an elevator, forced open the doors, and found 10 victims lying unconscious on the car floor. All the victims were successfully resuscitated because of the rescuer's efforts.

The search, rescue, and evacuation of the World Trade Center was the largest and most complex operation to which FDNY has responded. The effective implementation and utilization of the incident command system, the resources available to FDNY, and the training and professionalism of its members enabled this department and its rescuers to accomplish one of the most successful search and rescue missions in fire service history.

At the Bottom of the Crater

by Kevin Shea

Rescue 1 responded to the World Trade Center on February 26 on the initial alarm. When we arrived, the incident already had grown to a second alarm. We were waved over to the Vista Hotel lobby by hotel employees, who reported that people were trapped. We proceeded by stairway from the concourse to the B-1 level to search. We encountered offices whose ceilings had come down and lockers that had been overturned. We thought initially that we were dealing with a transformer explosion and fire.

As I was about to search around the lockers, my officer, Lt. Jack McAllister called for help — he had found a live victim. The lieutenant was in a small, tight, cage-like area that contained air cylinders; he was perched on top of some of the overturned bottles. He told our company to look for another way to approach his location.

I went around a cubicle wall and opened a door. It was black and smoky inside. I yelled and the same victim responded. I knew this was an alternate way to reach him. With my partner, Gary Geidel, I went down what I thought was a long hallway — the door was a normal size, not unusually wide, and the floor didn't change surfaces (for example, from carpeting to tile or from tile to concrete) to indicate I had left the hallway. Then the floor angled up, and I felt broken concrete underfoot. Small chunks of concrete fell from the ceiling. I saw an orange glow ahead and felt the heat.

I thought we had a fire on the floor and might need a handline, so I turned to tell my partner. Suddenly the floor underneath me, gave way, and I fell into the crater.

IN THE CRATER

I fell 45 feet straight down, from the B-1 level onto rubble piled on the B-5 level. When I fell, I grabbed onto reinforcing bars sticking out of concrete, but I couldn't hold on. I hit debris on the bottom at a 45-degree angle, feet first, then fell on my back. My leather helmet saved my life: My face smashed into the concrete when I fell. I was conscious the entire time.

I landed a few feet away from fire — cars were on fire, but they were so mangled they were completely unrecognizable. My shoulder was slightly burned from being so close to the fire. I didn't realize how far I had fallen or how big the crater was.

I saw bright lights of fire all around me. I also heard explosions that were so loud I could feel them in my chest. I still thought a transformer was involved.

I tried to sit up but couldn't. I felt numb and thought I was impaled on something. I checked my body and determined I was not impaled, but I thought both of my legs were broken. The bone in my left knee was protruding through my boots.

Kevin Shea is a nine-year veteran of the City of New York (NY) Fire Department and a firefighter with Rescue Company No. 1 in Manhattan.

Although my radio was banged up, it still worked. I radioed for help, because I didn't know if my partner had fallen through the floor with me. I also didn't know my location.

I immediately activated my PASS device, but I couldn't hear the radio with it on and it echoed in the crater. My rescuers couldn't hear where my alarm was coming from anyway, as it had to compete with numerous activated car alarms.

At the time of my fall, I had had two handlights — the one I was carrying was lost when I fell, but I had another one strapped to my wrist. I put that one down so I could see what I was doing. I was trying to unmask, because the bracket on my air pack was hung up on some debris.

Then a piece of concrete fell down on the handlight, smashing it. I was able to work myself free of the mask anyway. At this time, the smoke was rising, so I was able to breathe. I decided to abandon my tangled air pack. I was able to see horizontally and vertically only about six or seven feet up.

I then had to move away from the fire, so I took my PASS device off my air pack and began to crawl. Debris was still falling and I still heard popping noises from the explosions. I was 10 to 15 feet away from water. I crawled over to it to protect myself from the fire, especially in case I lost consciousness.

The radio communication was sporadic. They apparently could hear my transmissions but I couldn't hear them, so I did a lot of yelling to communicate. At one point I was worried that I might drown from the water pouring in. I thought it was coming from handlines being used to extinguish fires, so I yelled for them to be shut down. However, the water was coming from broken piping.

I knew they could hear me: Streams were crisscrossing from different floors to hit the fire around me and protect me, and I verbally directed them to hit the fires. These engine operations really helped save my life.

Then I heard a call for help. I apparently fell past the first victim (that my lieutenant had originally found); this was the voice of another victim. I tried to crawl to him, but my protruding bone got caught on some debris. I crawled and slid over some big panels with metallic finish that once had been a part of the hotel's refrigeration area. (This second victim was located at the same time I was, and he was taken out before I was.)

My horizontal visibility was 15 to 20 feet; vertical visibility was still only six feet. I heard loud banging as things fell around me.

I was down in the hole for approximately a half hour. Lt. John Fox of Squad 1 was lowered by rope in the same spot where I fell. Other rescuers held the rope as he descended. Fox couldn't see me at first, so I yelled directions to him. A second rescuer, Jack Tighe, crawled to my location. Then fire and police personnel converged on my location from different directions. They put me in a stokes basket and carried me out in the following manner: We crossed over the rubble on an entire level, then they hoisted me up a ladder to the next level, then we went across the rubble of that level, then up another ladder to another level, and so on. The crater was configured differently in different areas. Where I fell was a shear drop; not so in other parts.

I was taken to the hospital. It was in the emergency room that I was first told of a bombing.

My injuries included a broken left kneecap, a broken right ankle, a broken nose, a broken bone in my forehead (which would have caused my death if it weren't for the helmet I was wearing), and many muscle tears and pulls. I have had two operations and might require additional surgery. I currently undergo daily physical therapy.

The Rescue of Firefighter Kevin Shea

by Steven C. De Rosa

Lt. Jack McAllister and the members of Rescue Co. 1 had been assigned to the Vista Hotel by the command post. When they entered the lobby, they were told by building personnel that some workers on the lower levels could not be located. The smoke condition in the hotel lobby was light, but the smoke rising from the stairway was heavy and obscured visibility.

Rescue 1 proceeded down the smoke-filled stairway to the B-1 level. While searching the rooms adjacent to this corridor, Firefighter Kevin Shea and Firefighter Gary Geidel heard someone calling for help. The sound seemed to be coming from the garage area, and both firefighters started moving toward the call for help, stepping over and onto piles of rubble as they went. Visibility was extremely poor in this location.

Suddenly, Shea fell some 40 to 50 feet through the rubble and fire.

All rescue firefighters are equipped with portable radios; and as soon as he could, Shea transmitted a "mayday" signal over his radio. Then he crawled away from the fire to a safer location. Geidel called out to Shea and told him he was going for help. He went to the hotel lobby and informed me that Shea was trapped and a hoseline was needed immediately, as Shea had fallen in proximity to the fire in the hole.

Meanwhile, McAllister tried to maintain contact with Shea by leaning ever the edge of the crater and holding his radio over the pit. (Portable radios do not function well in concrete and steel-reinforced areas below grade. Line-of-sight communication is required; we routinely use relay transmissions for subway operations.)

I was placed in command of the firefighter rescue subsector at the below-grade levels of the Vista Hotel. The rescue effort to locate and remove Shea was complex and dangerous due to many factors:

- Initially, we did not know how to get to his location, as units could not see him due to the smoke condition.
- We did not know the depth of the crater.
- We knew there were fires burning around him, but the extent of the fire in the crater was unknown.
- There was a possibility of additional collapse and further injury to rescue personnel.

Initially, the only units available to Vista Hotel command were engines 205, 55, and 204. I directed these engine companies to stretch a 2 1/2 inch line from a standpipe connection in the hotel lobby down the stairs to the B-1 level and to the edge of the crater.

Steven C. De Rosa, a 29-year veteran of the City of New York (NY) Fire Department, is Deputy Chief of Division 3 in Midtown Manhattan, where he has served for 10 years. He has developed numerous procedures for the department including high-rise tactics.

I then assigned Chief Richard Rewkowski, Battalion 32, the task of supervising the rescue attempt from the B-1 level. Rewkowski, accompanied by Lt. McAllister, made his way down to the edge of the crater by following a search line stretched by Rescue 1. They made verbal contact with Shea.

Conditions at this point were severe, with dense, black, irritating smoke escaping from the fires still burning below. The concrete edge of the crater was jagged, and broken pieces of reinforcing rods protruded out over the void. Rewkowski surveyed the situation and decided to attempt to reach Shea by lowering a firefighter down to his location. By this time, additional units arrived at the scene and were dispatched from the hotel lobby command post to the below-grade area.

I assigned Squad 1, commanded by Lt. John Fox, to attempt the rope rescue and directed ladder companies 101 and 6 to assist by clearing the area of debris and providing portable lights. As the ladder companies and the squad prepared for the lifesaving rope operation, the engine companies worked to get their hoseline into position.

The smoke continued to be a problem, along with the high noise level from broken water mains and activated car alarms. Through the dense smoke, members could see fires burning at many different locations. In light of these severe conditions, I assigned Chief Anthony Adamo, Battalion 8, to assist Rewkowski in supervising operations. Lt. Fox knew the extreme danger involved in attempting this rescue. He chose to be the person lowered.

There was no substantial object to tie off to. It was decided to create a human anchor. A firefighter took the turns on the life belt and sat down on the concrete in proximity to the crater. Two firefighters held him by placing their arms around his chest and shoulders, and another firefighter placed his body over the anchor firefighter's legs. Other personnel held the other end of the rope.

Fox crawled backward toward the crater's edge as a member held the antichafing device in place at the edge. Fox had to maneuver over the protruding reinforcing rods before he dropped into the pit. His weight caused the concrete slab to tilt down toward the crater, and he dropped several feet. With the shift in the slab, Rewkowski moved as many people back from the edge as possible as Fox was lowered to the crater floor. Fox, climbing over debris, located Shea and then informed Rewkowski of his position.

While the rescue attempt via rope was being conducted, Rescue Company 5 was assigned to find another way into the area. Personnel proceeded down a stairway to the B-2 level and started to search for Shea. In the process, they found and removed an injured civilian.

Firefighter Jack Tighe of Rescue 5 managed to make his way through and over the debris and burning cars into the pit where Shea lay injured. He arrived soon after Fox and together they quickly examined the injured firefighter. They decided to move him out from under the tilting concrete slab and away from the broken, gushing water mains. Fox called for a stokes basket to remove Shea.

It was decided to use 20-foot straight ladders to build ramps over which the basket could be moved upward to a safer area. Members of Ladder 15 and Rescue 5 entered the crater and completed this task. By guiding the basket along these ladders, they were able to slowly bring Shea up and out of the crater.

Numerous units were involved in this complex and lengthy rescue. The method used was unconventional and dangerous. It was successfully completed due largely to the competency, bravery, and leadership demonstrated by the firefighters, company officers, and chief officers at the point of operations.

Above-Grade Tactics and Procedures for Search, Rescue, and Evacuation

by John P. O'Connell

Since the elevator service in the WTC was knocked out of commission almost immediately, the stairways became the main means of egress for anyone trapped in the complex.

At this point, firefighters' primary concern was for the safe evacuation of all civilians from the towers. Since all the fire was contained in the below-grade levels and the stack effect was causing the smoke to rise through both towers and the Vista Hotel, a large part of the operation was committed to search and evacuation. Every hall, floor, staircase, room, and elevator had to be searched — a monumental task that required tremendous coordination and literally hundreds of firefighters.

STAIRWAY OPERATIONS AND LAYOUT

The stairways in both towers are laid out identically, three stairways are enclosed in the center core of each tower. Stairways A and C terminate at the mezzanine level and lead to the interior plaza level; stairway B terminates on the concourse or grade level. People using the B stairs had no problem exiting to the street and receiving medical attention, if necessary. However, this was not the case with civilians using the A and C stairways. As these people exited the stairs, some wound up in a balcony area off the mezzanine and had to be taken out of the building in tower ladder buckets.

Some civilians were able to make their way from the A and C stairs to a hallway that intersected with the B stairway. Unfortunately, as these additional people tried to enter the B stairway, they encountered a stairway already filled with people coming down from the interior. As the hallway got congested and civilians log-jammed, anxiety started to set in. After the fire department arrived, firefighters were placed in strategic locations to guide civilians to the proper egress area. This action helped alleviate confusion and ensured that the evacuation would continue in a smooth and safe manner.

The problem was that these civilians normally come to work, enter the lobby, and take elevators to their floors, never realizing they should be aware of stairway locations in case of a fire or emergency. Consequently, many of them were not familiar with the stair layouts and became disoriented.

During the initial stages, operations in the stairways themselves were at best difficult. Many civilians started to self-evacuate immediately after the explosion occurred and the building started to fill with smoke. It was a major problem for firefighters to ascend the stairs against the mass of people coming down at them. The stairways simply were not wide enough to accommodate that many civilians

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coming down and firefighters in full gear with tools trying to go up. Congested stairs slowed down operations; firefighters became frustrated since it literally was an uphill battle to get anywhere.

For the most part, people coming down the stairways moved in an orderly fashion. Some were more frightened than others, and some gave helpful information and informed firefighters of the locations of disabled and distressed people. Firefighters were constantly giving directions and calming civilians descending the stairs. The fire department's main concern at this time was to concentrate on rescuing civilians who were in immediate peril. There were reports of several people with cardiac problems who would require resuscitators. In addition, a number of disabled civilians were trapped with no way to get down except to be carried. A number of pregnant women were in the building. Firefighters prioritized the removal of people with special needs based on their conditions and the areas in which they were located. One woman who was six months pregnant was carried down 20 floors in a stokes basket to the safety of the street. Another woman was taken down from the 44th floor to the triage area staffed by doctors and nurses on the 33rd floor, where she was treated.

Numerous disabled people located throughout the structure had to be dealt with immediately. According to existing codes, elevators may be considered a primary egress for physically challenged people; however, since all elevator service was knocked out for extended periods of time, disabled people were stranded on whatever floors they happened to be on when the explosion took place. Those people in need of medical attention had to be carried down the stairways — not an easy task given the situation. Two firefighters carried one wheelchair occupant down to the street from the 19th floor. Members of a ladder company took turns with the strenuous task of carrying another wheelchair user down 35 flights of stairs. Other firefighters carried down people with cardiac problems, using whatever means were readily available. People were carried down in stokes baskets and stair chairs, as well as whatever was available on the floors where the civilians were located, such as office and cafeteria chairs.

Of the numerous items pressed into service, the stokes baskets proved to be the most demanding to employ. Due to the lack of maneuverability in the stairways, only two firefighters could descend with the stokes at any given time. This made handling the stokes a fatiguing job; the firefighter at the bottom had to handle most of the weight while the firefighter at the top tried to balance the stretcher. If someone coming up the stairs knocked into one of the firefighters or the basket, or the victim himself moved it, firefighters had an extremely difficult time keeping the stokes from tipping over. Overall, this made for very slow descents. Every several floors, the firefighters carrying the basket had to be relieved.

When the emergency lighting went out in the stairwells, many people became scared because of the darkness. Only when firefighters started to use their flashlights and talked calmly to the civilians did their fear start to subside, and the civilians once again proceeded in an orderly manner to the street. The operation became much more difficult after the lights went out because people had to slow their descent and needed constant reassurance that everything would be all right.

FLOOR SEARCHES

To ensure that no one had been overcome or trapped in the hotel and towers, methodical searches of all floors, halls, rooms, and offices had to be done. This involved the systematic floor-by-floor primary and secondary searches of several million square feet of habitable space — an extensive and time-consuming task. The firefighters used two main tools to gain entry into these rooms and offices — the traditional set of "irons," an axe and a halligan tool. In some cases, a maul or sledgehammer would be substituted for the axe to provide extra striking power for heavier doors. The other tool used with great success was the hydraulically operated forcible entry tool (i.e., Rabbit Tool), consisting of a hand-operated pump and a set of jaws that exert more than four tons of force. This type of tool is designed primarily for use on doors that open inward. An extremely valuable tool, it can be used over and over again without fatiguing firefighters. It is especially useful in heavy smoke conditions where it is extremely difficult and dangerous to swing an axe.

The entire complex itself had more than 4,000 doors, many of which were locked and had to be forced. As is the case for most offices in the metropolitan area, security and safety concerns dictated that most companies leave their doors open on the inside but locked on the outside.

When many civilians exited their offices and started to self-evacuate, their doors all locked behind them. As the firefighters came upon each office, they had no way of knowing if victims were inside these offices; each office had to be checked. It is FDNY's policy to conduct two searches of each area — a primary search and a secondary search. The primary search is conducted as soon as conditions allow, usually by the first-in ladder company. Performed while the fire is still in progress and in heavy smoke conditions, primary search is a search for life. The second type of search, secondary search, normally is done when fire conditions have abated somewhat. It is a much more thorough search, designed to make absolutely sure no one is trapped or overcome. This search generally is performed by another company for ease of operations.

The towers were erected with a central core system design — that is, the elevators and stairways are in the center of the building on all floors. This led to some logistical problems. After the installation of the core system, an open compartment area almost one acre in size was left. Also, each area was laid out differently according to the needs of the tenants on each floor. Both situations made for slow progress in the searches. In addition, many business offices had interior rooms, many with locked doors. Firefighters had to gain entry to every one of these areas to ensure no one was in jeopardy or needed medical assistance. One ladder company that searched numerous floors throughout the day forced more than 100 doors — a labor-intensive and time-consuming operation.

COMMUNICATIONS

The most important aspect of any fire situation is communications. Good communications is what makes the job work smoothly and efficiently, since conditions in emergency circumstances change constantly. The WTC disaster was no exception. If anything, communications were even more important than usual, due to the size and complexity of the operation.

The portable radios FDNY currently has in use are of the VHF type. They come in a leather case with an adjustable harness, complete with an extension piece that allows firefighters to carry the speaker microphone up higher and in front of the right shoulder. A five-inch, rubber-encased helical antenna makes adjustment to the body easier and affords greater comfort to the wearer. There are two knobs located on the top of the portable radio itself. One is a selector switch that permits the use of six separate channels; the other is an adjustment knob for squelch, which helps tune out interference. To reduce damage and protect the portable radio from smoke, heat, and adverse weather conditions, the unit is worn under the turnout coat.

Six portable-radio channels are available for firefighter use. Channel 1 is the universal portable radio channel — that is, it is used by all boroughs. The other channels firefighters use share frequencies that the mobile field units use to communicate with the Manhattan Dispatchers Office. The use of these channels requires authorization at each particular incident.

CHANNEL USAGE

Four main channels are used for major incidents like the WTC disaster; they also can be implemented for other situations. Two of the four are tactical channels and two are command channels; they can be used in any combination, depending on the situation. Channel 1 is the primary tactical channel and the initial channel used by all units. The secondary tactical channel is used by certain units when Channel 1 is heavily taxed, which was the case at this incident; the channel varies from borough to borough. The incident commander can order this channel's use at any time.

The two remaining channels are command channels. The primary command channel is restricted to use by chief officers; it is designed to permit better operations coordination and supervision and presents the fire commander with an effective span of control. The secondary command channel is used by chief officers who need to communicate when the primary command channel is taxed. In the WTC incident, both command channels were used heavily.

ELEVATOR OPERATIONS

Since the elevators in the twin towers are the primary means of moving between floors, many people were trapped when the bomb knocked out the buildings' power. From a rescue standpoint, elevator operations were the most extensive and time-consuming part of the rescue attempt.

The incident involved 210 elevators, all of which had to be searched. Each tower has 99 elevators, local and express; the Vista Hotel has another dozen. The towers are broken down into three main elevator zones. Zone 1 started at the concourse level, zone 2 at the sky lobby on the 44th floor, and zone three at the sky lobby on the 78th floor. Transfers to local elevators took place at these levels. Within each zone were local and express banks. The express cars were the larger of the two types, with a capacity of 55 people; the local cars could handle considerably fewer people.

Only three elevator cars — one freight and two passenger — serviced the entire height of each tower. Although this was a novel idea in elevator design at the time the elevators were built, it was not at all helpful to firefighting forces. The following are some of the problems encountered:

- When power was knocked out, the elevators were stalled everywhere.
- There were no floor indicators in the lobbies to show the floors on which the elevators were stranded. This caused major delays. It was time consuming just to find out where the elevators were stuck before rescue attempts could be made.
- The express elevators to the sky lobbies were located in "blind" shafts, meaning there is no access to that shaft between the entrance and exit points of that elevator. The only way to get at these cars was to breach the shaft walls.
- Since we were dealing with a core system, with all the elevator banks constructed on top of one another, the smoke from the explosion and fire found its way to the upper floors. The shock waves from the explosion blew down the doors in the subbasement shaft, giving the smoke full access to the elevator shaft. Numerous people trapped in these elevators suffered from smoke inhalation.

The rescue of trapped civilians started as soon as the firefighters entered the lobby. A Hurst tool was used to force open several of the car doors, releasing numerous people. A local car hoistway door was forced open because voices inside were heard asking for help. Firefighters were a bit shocked, after forcing the door using two Rabbit Tools and a halligan, to find no car — only two men standing on steel support beams in the shaft, both with bleeding hands. They had somehow entered the shaft from above and slid down the cables to the concourse level — an extremely dangerous operation; they were lucky they were not killed.

Many companies breached the shaftway walls to rescue trapped people with conventional tools. The Hurst tool, Rabbit Tool, and conventional set of irons all were used to open the elevator doors. One company forced a door on the 47th floor and nine semiconscious victims fell out of the elevator like a set of dominoes, into the waiting arms of the rescuers. Firefighters opened another elevator on the 44th floor and found 10 unconscious victims. Happily, all these people recovered from their ordeal. As the operation progressed, elevator mechanics in the building helped fire department personnel. They were able to manually move some of the cars to a higher or lower termination point, depending on the counterweight. Their help was invaluable, and it made the operation move along quickly and more efficiently.

Search Tactics and Procedures Below Grade

by John P. O'Connell

As the fire was being controlled and the extent of the explosion became clear, Rescue Co. 3, FDNY's primary building collapse unit, was assigned to search the massive destruction caused by the bombing. A tremendous amount of crushing debris had been caused by both the explosion and the subsequent collapse of several floors of reinforced concrete, each more than a foot thick; thus, a high victim survival rate was not likely. However, the possibility that even one victim was trapped alive justified the operation.

As information with regard to the whereabouts of workers slowly was reported in, we found out that close to two dozen maintenance personnel were having lunch in a cafeteria in the vicinity of the blast center only minutes before the blast. We also considered the possibility that several workers and civilians may have been located in the parking garages when the blast occurred.

As Rescue Co. 3's void search team was being assembled, a staging area for our tools and equipment was set up in a safe area close to our chosen point of entry into the bomb crater. Each firefighter checked his own equipment and all tools and instruments to be utilized in the search. Each firefighter's equipment included full turnout gear, since smoldering fires from cars and debris still were burning; handlights which would be our main source of illumination while searching the rubble; portable radios so we could remain in constant contact with each other if necessary, and SCBAs.

Each team also laid out and checked the equipment it would use — the thermal imaging camera and search camera, carbon monoxide meters, oxygen indicators, explosimeters, search ropes, and hand tools.

Four two-man sections were organized and briefed. For obvious safety reasons, they were to keep in visual and voice contact at all times. Team one was assigned the unit's thermal imaging camera; team two the search camera; and teams three and four each had the various meters and worked in conjunction with teams one and two. The main objective of these void search teams was to locate and extricate any victims who may have been caught in the blast area at the time of the explosion. An initial surface search of the entire area was undertaken for two reasons:

- to determine the extent of the damage and evaluate the dangers in the operating environment, and
- to determine how many and what types of voids were created by the blast and whether they could be effectively searched for survivors.

John P. O'Connell has been a firefighter with the City of New York (NY) Fire Department for 14 years and, as a member of Rescue Company 3 in the Bronx, has more than six years of collapse rescue experience. He is an instructor of shoring and building collapse at FDNY's Training Academy and has been involved in writing and teaching the department's collapse and shoring training curriculum. O'Connell is a New York State-certified fire instructor and spent more than 10 years in the building construction industry. He conducts seminars around the country on collapse search and shoring operations.

Since each rescue firefighter was equipped with a radio, one team member stayed on the primary tactical channel to monitor the overall operation and listen for problems, condition updates, or any other pertinent information that was being relayed continually by the command post. The other search team member switched to a secondary tactical channel that gave the teams direct access to each other and the void team officer on a less-crowded frequency. This way, new information could be immediately relayed to each team.

COLLAPSE VOIDS

When the teams were ready, we descended into the lowest level of bomb damage via a flight of stairs unaffected by the blast. The majority of the debris had settled at this location. Our entry point was blocked almost from the start; in the access doorway to this level, about two-thirds of the way up the opening, one of the sections of concrete floor from above, about 50 feet wide and 80 feet long, had come to rest in a supported lean-to collapse. As we slowly penetrated the area, the awesome destruction caused by the explosion began to unfold. As we entered the blast area by hoisting ourselves on top of the slab blocking the doorway, we stopped momentarily to examine the destruction. Immediately to our left stood a shear wall, constructed mainly of large steel beams and some masonry block. This was one of the stabilizing walls in the building; the steel "H" beams were roughly four by four feet, and every other set of columns was diagonally cross-braced for strength. The columns themselves were undamaged; however, very little of the masonry building material was standing. This material created a debris pile approximately 15 feet high along the entire face of the wall. It would be extremely difficult to search and climb through.

Diagonally across on our left, the entire side of the crater lay in a lean-to collapse supported either on top of machinery or directly on the lowest level. This had resulted in tons of debris being deposited into the bottom of the crater. Numerous objects hung precariously on these tilted sections of concrete — several automobiles, equipment, tables, chairs, and lockers from a destroyed locker room were just some of the items ready to come crashing down at any time. In one section, a vehicle was hanging over the edge of broken slab, ready to fall into the area where the rescue teams were operating. The only thing stopping it from falling was a group of reinforcing bars sticking out of the concrete — not exactly a substantial holding device.

Directly across from the stairwell entrance, all the levels that had been destroyed were sheared off in an unsupported lean-to fashion. The slabs were leaning precariously, with sections of loose concrete hanging by only a few strands of reinforcing bar, an extremely dangerous condition. On our right side, where the ramps for the parking garage were located, we discovered similar conditions. Unsupported sections of concrete were hanging but, in this case, without a large amount of debris accumulated on the floors, since they had been in continuous use as the parking lot egress up until the time of the explosion.

Directly to the right of the stairway entrance was the most dangerous area within the crater. Two levels were hanging in a totally unsupported lean to position; and a large section of the flooring, about 30 by 40 feet, was hanging by only a few pieces of reinforcing bar. Just above this area was a storage section, where dozens of chairs and tables were stacked more than 10 feet high and leaning dangerously towards the blast crater. This area was monitored closely throughout the operation.

The lowest level of the blast damage was a machinery room. Maneuvering along this level was extremely dangerous since it was filled with openings that normally were hoistways to the level below for replacement of large piping and machinery. They usually were covered by steel gratings, most of which had been dislodged or were missing after the blast.

One void search team concentrated on this level, where tons of debris had come to rest on top of and around the large machinery, creating dozens of individual voids. Each of these voids had to be systematically searched, since it was highly possible that workers may have been trapped in one of them. As these individual voids were being searched, the search camera proved to be an excellent tool for probing into smaller voids that firefighters could not physically penetrate.

The four void search teams from Rescue Co. 3 searched the entire explosion area and perimeter for more than two hours in some of the most severe collapse conditions ever encountered. Moving around the collapse area was extremely time-consuming and difficult due to the mass of broken concrete and debris, and much of the area was unstable. Conditions had to be evaluated and monitored with each step as the search team firefighters methodically covered the entire collapse area. Operations also were hampered by the fact that lighting was limited to handlights and some portable lights.

Conditions were so dangerous that when the Federal Bureau of Investigation and the Bureau of Alcohol, Tobacco, and Firearms took charge of the scene after the fire had been extinguished, their personnel were not permitted to operate in the area until the situation was made safer by removing the hazards. This took several days.

The Thermal Imaging Camera

by John P. O'Connell

The thermal imaging camera was developed in the 1980s by engineers from Great Britain. The system is based on a concept called the "pyro-electric effect." In simpler terms, this means the camera can pick up minute variations in the electrical polarization of an object resulting from the difference in temperature between it and the objects around it. By differentiating objects by their thermal temperature, the camera is able to "see" through smoke and darkness. It enables its user to identify fire sources or the images of overcome victims much faster than conventional means can.

The camera is in a cylindrical container constructed of injection-molded plastic, which provides protection against damage. The container is waterproof and sealed to conform with specifications for use in flammable atmospheres. The display is presented on a three- by five-inch cathode ray tube surrounded by a protective hood. It is a hand-held, battery-operated instrument weighing less than nine pounds. It lasts up to two hours on one set of batteries.

It is ideal for use in darkness; it can sense a living person from up to 200 feet away. However, it cannot "see" through objects. In heavy smoke or darkness, the camera will be able to distinguish objects by their thermal differences, but it will not "see" past obstructions such as concrete and masonry, even drywall will block any readings.

As we operated in the bomb crater itself, the camera was an excellent tool for "panning" the entire surface for exposed victims in a timely fashion. After this search was completed and the intensive search into the heavy debris of concrete slabs, destroyed cars, and other supplies and equipment was begun, the camera's effectiveness was diminished due to the heavy mass of debris blocking any signs of trapped victims.

The Search Camera

by John P. O'Connell

FDNY recently placed a search camera on Rescue Co. 3's collapse apparatus. The mobile search camera, easily operated by one firefighter, is a highly technical system designed to locate trapped victims in building-collapse situations. The search system combines a miniature video camera with a sensitive microphone, allowing rescuers to examine, and listen for trapped victims in, collapse voids — even if the void access is too small for firefighters to physically penetrate.

The system consists of three main items — the search probe, the chest monitor, and the component pack. The search probe consists of a telescoping pole with the camera housing and control handle attached on opposite ends. The telescoping pole, consisting of four sections, can collapse to a length of 32 inches and can be extended beyond seven feet. The dustproof and water-resistant camera housing contains the camera, the microphone, the light, and the speaker element and is connected to the probe by a two-way articulating joint. This construction allows the camera housing to rotate more than 180 degrees to the right or left and is remotely controlled from the probe's handle. The light and audio systems also are digitally controlled by switches on the handle. The telescoping search probe allows the search team firefighter to insert the camera head through void holes as small as two inches in diameter. The search team firefighter looks for any visible signs of trapped victims on the chest-mounted video monitor and listens through the headphones. The integrated two-way communication system allows the rescue firefighter to talk directly with any possible victims.

A high-resolution video camera and monitor comprise the video system. Light is provided by a variable intensity lamp system, which allows the video system to operate in areas of total darkness. The camera's most effective viewing distance is from six inches to 20 feet. The chest-mounted monitor features a black and white screen measuring seven inches diagonally. It enables the search team firefighters to easily determine what is happening by manipulating the probe. The monitor is enclosed in a pouch equipped with quick-release buckles that are attached to the component pack harness.

The audio system consists of a sensitive microphone with an amplifier. The firefighter operating the tool can wear headphones with a boom microphone attached to them. A speaker element is attached to the camera housing at the end of the probe, enabling two-way communications with survivors to take place.

The component pack contains a sealed lead acid battery, good for four hours of continuous use, along with the unit's electrical subsystems. It is housed in a harness worn on the back and is equipped with shoulder and waist straps. For ease of operation, the chest monitor is attached to this harness and is fully adjustable.

Response by Manhattan Dispatchers

by Herb Eysser

On the day the World Trade Center (WTC) was bombed, the Manhattan Dispatchers Office was involved in its usual routine of transmitting numerous fire alarms. There are more than 1,000 high-rise buildings on the island of Manhattan, and alarms are received from a number of them on a daily basis. Most do not result in fire duty and are classified as emergency unwarranted alarms. However, our office had been unusually quiet for February. In the past 10 days, there had been only one greater alarm in Manhattan. Usually, the Manhattan Dispatchers Office is a "winter borough," with a large percentage of our annual fire activity taking place between Thanksgiving and St. Patrick's Day. After that, activity falls off sharply as the warm weather approaches.

An hour before the WTC bombing, another dispatcher and I had gone out to buy the office's lunch. On our way back through the snow-covered paths of Central Park, I had remarked that our office had been quiet for the month of February. Shortly thereafter, I ate those words along with my lunch.

The WTC has always been one of our best "customers." Daily, the Manhattan dispatchers transmit boxes 8084 and 8087, box locations for WTC Tower 1 and Tower 2, respectively, for various types of alarms. Over the years, the WTC had been the scene of several greater-alarm fires and quite a few all-hands (one-alarm working) fires. However, nothing had ever reached the magnitude of what was to happen that afternoon, February 26, 1993.

A DELUGE OF CALLS

All hell broke loose at 1218 hours. All at once the incoming fire phones started ringing. With only three dispatchers available to answer some 15 incoming fire phones all ringing at the same time (five other dispatchers were doing radio and computer duty), our jobs became overwhelming from the beginning. I picked up the first call and was told by a woman that an explosion had occurred in the basement of the Vista Hotel on West Street. Based on this information, Box 69 was transmitted. However, Engine 10 and Ladder 10, whose quarters are directly across the street from the WTC, had heard the explosion and responded as the street rapidly filled up with a very heavy smoke condition.

The Manhattan Dispatchers Office reacted quickly to the unending flood of incoming fire calls and urgent messages received from the field. The foremost thing for a fire dispatcher to remember is to keep cool and set out to deal calmly with the unfolding major emergency. For the first 10 minutes after the explosion, I continued to answer the incoming phone calls. After several minutes, it became clear that the 22-story Vista Hotel, known as 3 World Trade Center, was not the only building filling up with heavy smoke. Almost immediately after transmitting the initial alarm, we began to receive frantic calls from the two 110-story Twin Towers, known as 1 World Trade Center (Tower 1) and 2 World Trade Center (Tower 2).

Herb Eysser, is a Manhattan fire alarm dispatcher with 26 years of experience with the City of New York (NY) Fire Department. He also serves as research director for the Uniform Firefighters Association in New York City.

In my 26 years as a Manhattan fire alarm dispatcher, I had never before spoken with so many people from one incident who thought they were going to die. Their dire situation was magnified by the fact that the explosion had knocked out all power to the huge complex. Without lights, elevators, or fire alarm communications, more than 100,000 workers and visitors were convinced that the Twin Towers would become their "Twin Tombs." Many of the hundreds of telephone calls our office received were from 1 WTC, where the explosion had blown down walls, allowing heavy smoke from the Vista Hotel's basement to quickly enter the tower's stairwells and elevator shafts, moving up in a chimney-like effect.

Our main mission was to provide the units rapidly being ordered by the chief officers at the scene while continuing to answer the tidal wave of frantic calls from those trapped in the towers. By 1254 hours, Box 69 had escalated to a fifth alarm. Box 8084, transmitted at 1229 to cover 1 WTC, escalated to a third alarm by 1252 hours.

The numerous reports we were receiving of people trapped in 2 WTC were at first merged with the 1 WTC operations. However, as the 2 WTC reports became more numerous, we decided to make it a separate incident, transmitting Box 8087 for 2 WTC. Although there were serious problems within 2 WTC, they were not as severe as those in 1 WTC; Tower 2 was located farther away from ground zero. About this time, the chief of department requested 40 additional engine and ladder companies to cover 1 WTC. We were ordered to obtain the additional units from Brooklyn.

ASSIGNMENT, DISPATCH, ROUTING CALLS

By this time I had switched positions in the office and was controlling the actual assignment and dispatch of companies to the various boxes. I requested the Brooklyn Dispatchers Office to transmit a third alarm from one of its box locations not too far away and then direct the units to respond to the WTC. This is a borough call (the name is a relic of the old "bell telegraph" dispatch system). I also was ordered to transmit a second alarm from a box within Manhattan and send those units to the WTC. I complied by transmitting Box 100 at the Staten Island Ferry Terminal. This is known as a simultaneous call, after the old bell system.

Our office had reached peak operational levels. All eight dispatchers on duty had their hands full. We had extended ourselves to the maximum. At no point, however, did we lose control of the situation. We complied with hundreds of requests from the field. The three dispatchers receiving incoming calls answered hundreds of calls from people trapped on various floors of the towers: "400 people trapped on the 90th floor," "300 people trapped on the 75th floor," and so on were common communications. We received numerous reports of locations of pregnant women, people with heart problems, and so forth. Such calls were continuous for at least 2-1/2 hours.

It should be noted that when all 15 incoming fire phone lines are busy, additional calls are rerouted to other borough fire dispatch offices. Those offices enter the information received into the city's fire dispatch computer for subsequent dispatch by Manhattan dispatchers (the dispatch messages show up on Manhattan Dispatchers' computers).

FDNY operates a Field Communications Unit (FieldCom) to coordinate communications at major incidents. Manned by a fire alarm dispatcher and a fire officer, the unit responded to the WTC incident. The Manhattan Dispatchers Office relayed numerous trapped occupant reports through the FieldCom Unit, which then were hand-carried to the FDNY command post. FDNY dispatchers first transmitted these reports via radio and later to computer mobile display terminals in the FieldCom Unit.

COMPUTER TROUBLE

However, in the middle of this major disaster, our computer alarm dispatch started to fail, creating a major problem for us. It should be noted that before the explosion, a repairman had been in our office attempting to repair a part of the fire dispatch computer. As the WTC bombing reached the 16-alarm level and hundreds of telephone calls and orders from the field were entered into the computer, it simply could not handle the volume.

We took a big gamble and decided to stay with the computer rather than switch to the old manual dispatch system. We weighed the decision carefully. We knew we had sent a small army of firefighters to the scene and that, therefore, the fire should be controlled in a short time. We also felt that enough time had passed to allow firefighters to reach the upper floors, which would stop the high rate of telephone calls. Also, several dispatchers had been called in from home on overtime and were arriving at the office to give us a hand. In addition, the president of the dispatchers union had arrived and was setting up the manual chip board, in case the computer crashed.

In addition to land units, FDNY's fireboats were dispatched to the incident. A member on one of the boats that responded on the second alarm for Box 69 from the North River berth reported he could see trapped WTC occupants many floors up, waving bright red drapes to get attention. At the same moment the fireboat was transmitting his message, I looked up and saw these same trapped office workers on live TV coverage from the scene. This gave all of us in the Manhattan Dispatchers Office a good visual idea of what was going on. Live shots also were being shown of WTC office workers fleeing the towers, most of them with faces blackened from the heavy smoke produced by the burning automobiles in the Vista Hotel's basement garage.

As the incident entered its third hour, the overall situation began to improve. Extra dispatchers were on hand, the dispatch computer was now holding its own. and we felt the worst had past. However, we still were receiving reports of many people trapped on the very high floors, which we continued to pass on to the command post. Dispatchers had constantly maintained coverage for the rest of Manhattan through requests to the boroughs of Brooklyn and Queens. These other boroughs dispatched fire companies to relocate into empty Manhattan fire stations.

Two chief dispatchers arrived in the office to assume command and also give us a hand in more routine matters. As 1500 hours approached, we started to feel that the situation was becoming more stable. We also felt a great sense of accomplishment — we had weathered a very serious situation. Although six persons died below grade as a direct result of the explosion, not one life was lost above the lobby floor.

LESSONS LEARNED

In reviewing the entire operation during subsequent tours of duty, the Manhattan Dispatchers Office came to the following conclusions and lessons learned.

1. **On the day of the WTC explosion, the Manhattan Central Office was staffed with a supervising dispatcher and seven dispatchers — the minimum staffing level adequate to handle most incidents that occur.**

   However, when an emergency like this one does strike, it is extremely important to order additional dispatchers and supervisors into the office to assist with the actual dispatch operation and to provide relief for the initial dispatch group, as traditionally has been done in the cases of civil disturbances, major storms, and extremely heavy fire periods, and which was done for the WTC incident.

2. **The Computer Assist Dispatch system has been in use by FDNY since 1977, when it was installed in the Brooklyn Dispatch Office.**

   Several years later, it was installed in the Manhattan office. It is a first-class aid assisting the dispatching force in transmitting fire alarms. However, it does have its limitations during a major emergency. This raises the question, In the middle of a major fire emergency, do you switch to the manual mode? If you do, you gain some control of the situation. However, the manual system works at a slower rate; it takes some time to set everything up and, in reality, not everyone is proficient in its operation, as it is a difficult system to learn.

   In the case of the WTC incident, staying on a computer system that could possibly crash caused some anxious moments. One major concern was that the computer would lose some of its memory. One of the main reasons we stayed with the computer was that our supervisors wanted a computer record of all activity at the WTC.

Those of us who "stood on the bridge" the day the WTC was bombed all feel we did our best at a time when our office turned into a madhouse within minutes of 1218 hours. I have worked for some other major incidents, including the civil disturbance and firestorm after Martin Luther King, Jr. was killed in 1968 and the night the city went totally dark in 1977, triggering large-scale fire activity and looting. Nothing, however, compares with working during the 16-alarm WTC bombing.

EMS Response to the Explosion

by Zachary Goldfarb and Steven Kuhr

The detonation of the terrorists' bomb under the World Trade Center (WTC) complex on February 26, 1993, created the largest technological disaster New York City had ever experienced. The bombing also initiated the most significant emergency medical service (EMS) response in the city's history.

NYC*EMS

The New York City Emergency Medical Service (NYC*EMS) is a third-service public safety and health care agency whose mission includes the provision of prehospital emergency medical care and transportation throughout the five boroughs. NYC*EMS operates the 9-1-1 communications and control center responsible for coordinating the response of municipal, hospital-based, and mutual-aid resources to medical emergencies and is the municipal agency responsible for coordinating and directing prehospital care resources and operations during a disaster.

Responding to more than 2,800 requests for service daily from 16 ambulance stations citywide, NYC*EMS operates some 220 ambulances on the day shift. Field supervision is structured through a uniformed chain of command. Each station is commanded by a deputy chief who is responsible for EMS operations within the district served by that station. Each station has a captain serving as executive officer and fields one or more patrol supervisors (lieutenants) on each shift. Patrol supervisors' responsibilities include all field activities within their response areas, with special emphasis on immediate, proactive response to multiple casualty incidents (MCIs) or unusual events.

DISASTER PREPAREDNESS

NYC*EMS responds to several MCIs daily. Our Emergency Medical Action (disaster) Plan is activated when an incident produces more than five patients or exceeds the capabilities of a two-ambulance response. NYC*EMS has used the incident command system (ICS) since 1982; it is used during all MCI operations and unusual events.

An MCI preplan program is in place; its goal is to identify and develop response plans for MCIs at locations with above-average potential for their occurrence, such as transportation hubs, high-occupancy locations, and hazardous-materials storage sites. The plans consider the best approach routes, staging locations, command posts, special hazards, obstructive characteristics, and resources avail-

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Steven Kuhr, CEM, EMT-P, is a Deputy Chief of the New York City Emergency Medical Service —Bronx Borough Command. He is a nationally certified emergency manager and served as the mutual-aid coordinator and planning division officer at the World Trade Center disaster. He writes and lectures on EMS and disaster-related topics.

able on site. Plan data are carried by supervisors on patrol and maintained in the communications center for transmittal to field units. The WTC preplan has been in existence since 1985 and had been exercised on a regular basis through routine incident responses to the complex.

INITIAL RESPONSE

Immediately following the WTC bomb's detonation, first calls to 9-1-1 reported an explosion and many injuries. Our earliest notice came seconds before, when our communications center monitored FDNY Engine 10 (quartered around the corner on Liberty Street), which reported the blast and transmitted a signal for a working fire.

Preliminary reports indicated that an electrical transformer had exploded under the Vista Hotel, located in the WTC complex. A transformer explosion is not a particularly unusual event in a high-rise building. Based on our experience with such events, our primary concern was potential polychlorinated biphenyl (PCB) contamination from transformer oil.

The initial EMS assignment to the WTC was one basic life support (BLS) unit and a patrol supervisor. The assignment was upgraded to an MCI signal within three minutes, based on additional calls to 9-1-1. Three additional BLS units, one advanced life support (ALS) unit, three patrol supervisors, one chief officer, one major emergency response vehicle (MERV), and two squads were assigned by 1223 hours.

The first-arriving ambulance encountered several patients in serious condition and began triage. The crew later reported a "feeling of impending doom" as the wounded surrounded them. The first-arriving officer was at the scene within five minutes. He assumed command and initiated the ICS. [See diagram of command organization on the following page.]

In sizing up the incident, still thought to be a transformer explosion, he determined that the preplanned staging area was not well situated to serve the needs created by this incident. He established a staging area remote from the preplanned location and directed the initial crew to transport two critical red-tag patients, who had been in a car at the entrance of the parking garage when the force from the blast hit them. Actions such as this one were instrumental in restricting the loss of life to those lost in the immediate blast.

Additional responding units arrived and encountered patients everywhere, as people fled the buildings or were removed to fresh air. Respondents were overwhelmed by the number of patients brought to them. Crowds of patients exited the buildings; others were simply lying in the street, exhausted and overcome. The first-arriving officer emphasized that triage was critical to the operation's effectiveness, as it enabled him to allocate resources and make quick, logical transport decisions.

CASUALTIES

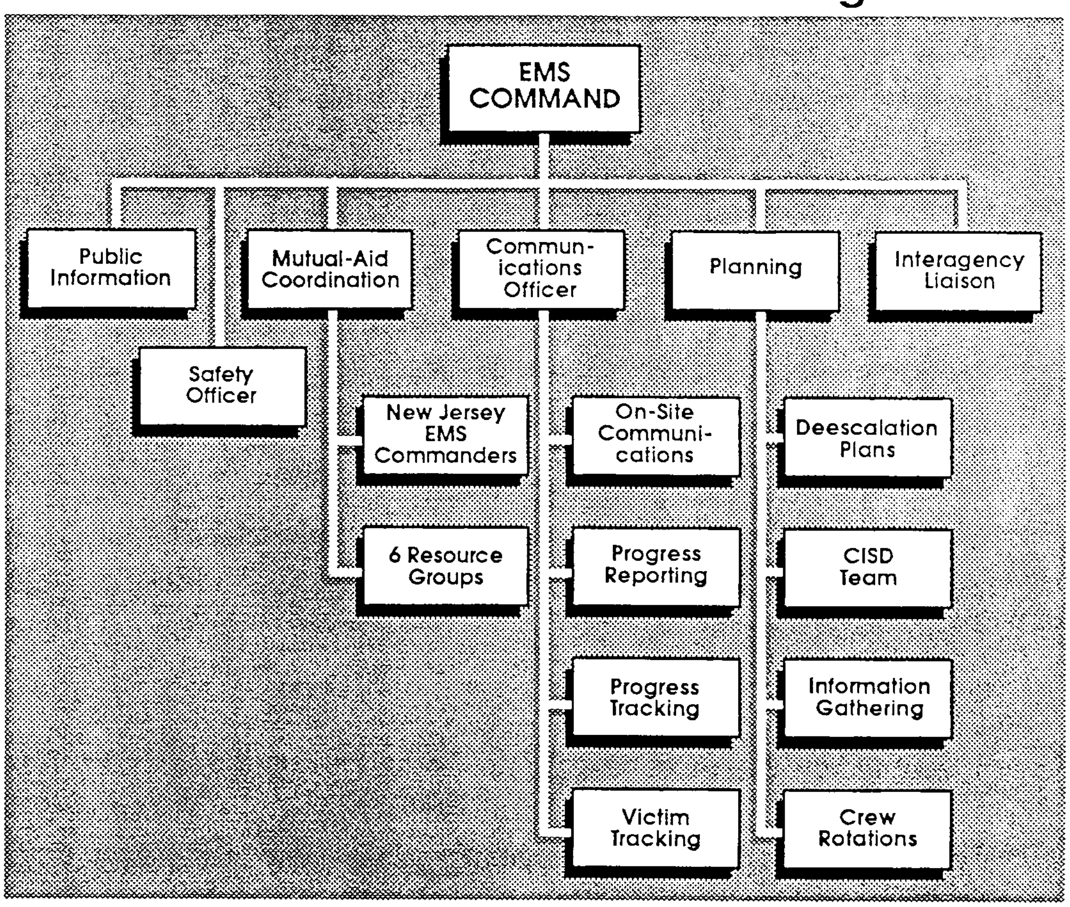
A small number of the patients had sustained major multiple trauma and burns from the blast effect. Most of the patients emerged from the buildings with classic "soot masks" on their faces and were suffering from smoke inhalation. There were many cases of minor trauma, including injuries sustained from falling glass and debris or while rapidly evacuating via darkened airways in extremely crowded conditions.

In addition to trauma, many people suffered exhaustion as a result of walking down from the upper floors. Preexisting medical conditions, especially asthma, chronic obstructive pulmonary disease, cardiac disease, and hypertension, were aggravated. In other instances, medical difficulties were associated with pregnancy.

EMS URBAN SEARCH AND RESCUE

Victims disentangled from the debris and rubble in the parking garage area were brought out to waiting EMS triage teams. While the fire and police departments conducted search and rescue, the NYC*EMS Urban Search and Rescue Team was activated. This team is the medical component of the FEMA-sponsored New York City Urban Search and Rescue Task Force. The Task Force, consisting of members of the City of New York (NY) Fire Department, New York City Police Department, and New York City EMS, is one of the 25 teams ready for deployment to domestic disasters when multiple structural collapses have overwhelmed the local resources. The medical team, consisting of paramedics and supervisors, remained on the scene for 23 days after the initial incident to provide medical support to the large number of law enforcement investigators and demolition crews operating below ground at the blast site. During this phase of the operation, NYC*EMS treated an additional 90 victims.

NYC*EMS Incident Command Structure
World Trade Center Bombing



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HELICOPTER MEDEVACS

Among the scores of people who fled to the roofs of the towers, 28 with medical problems were airlifted by New York City police helicopters and brought to a landing zone adjacent to the EMS staging area. The landing zone was sectored as an EMS operational unit to allow for victim triage, stabilization, and transport. Victims were removed to medical facilities through the staging area.

Some controversy relating to the safety and operational benefits of helicopters has resulted in the fire and police departments' reviewing helicopter operations at high-rise emergencies.

COMMAND AND CONTROL

As previously noted, ICS has been used by NYC*EMS to manage mass casualty incidents since 1982. Over the years, the NYC*EMS ICS, derived from other nationally recognized incident management systems and modified for medical disaster operations, has been employed at hundreds of disasters and MCIs — including preplanned events such as rock concerts and the annual 26-mile New York City Marathon. Although some of these responses required the on-site evolution of an extensive ICS model, none were as detailed and complex as the ICS structure developed for the WTC response.

Due to the scale and complexities of New York City, the often vast scope of the emergencies that occur, and the size of the city's agencies, a unified command structure is used. Agencies command their own tactical efforts at the operational level, while interagency strategy development and activities occur at the command/senior management level. At this disaster, the city's Office of Emergency Management established a strategic interagency command post. Senior managers from all agencies and disciplines were brought together to make policy and create a commonality of objectives throughout the operation.

The NYC*EMS ICS, which is modular in design, is structured to allow it to be readily integrated with the unified interagency command structure at any type of emergency. This approach facilitates responses to every day emergencies and major events, making them smooth and effective.

Taking a top-down approach, geographic and functional management units — sectors and divisions — were implemented as needed to meet the rapidly evolving and expanding situation. From a tactical command post located aboard the NYC*EMS Field Communications Unit, the EMS incident commander, a deputy chief from the Special Operations Division, unfolded an ambitious command structure to satisfy the obligations of patient care and provider control needs to ensure an efficient EMS response. Serving as senior advisor, the EMS chief of operations remained at the command post to oversee the incident's management.

Dozens of divisions and sectors were deployed to meet geographic and functional objectives. Thousands of people, hundreds of whom required medical intervention, were evacuating from countless exits throughout the 16-acre complex. In addition to conducting triage and treatment at these locations, issues such as communications, safety, and medical equipment logistical support needed to be addressed.

Divisions, established with all the necessary sectors to satisfy their specific requirements, were set up at Tower 1 (1 World Trade Center), Tower 2 (2 World Trade Center), the Vista Hotel (3 World Trade Center), 5 World Trade Center (a nine-story office building), and the Winter Garden atrium. Each division was headed by a division commander who reported directly to EMS command.

EMS command itself was a tremendous undertaking. The EMS incident commanders immediate staff was managed by a deputy chief from the Manhattan Division, who also served as the communications officer. Other command staff positions included those of interagency liaison, public information officer, and mutual-aid coordinator and planning.

Although strategies were developed at the command level, independent strategy development was necessary at the division level as well. While tactics essentially were similar at each division, the scope and magnitude of the problems in each building were different. The basic objectives of each division were to collect, triage, treat, and transport the victims. Because the operation was spread over such a large area, no single strategic or tactical effort could be employed infirmly throughout the divisions. Independent thought, coupled with intense interdivision coordination and communication, was necessary to ensure that each division was functioning in a harmonious manner.

TRIAGE

Triage was performed utilizing the Simple Triage and Rapid Treatment (START) system, which employs an extremely rapid clinical evaluation algorithm for patient evaluation and categorization into one of the four classic categories. All triaged victims were tagged using METTAGs, enabling us to track their condition and to avoid the need for multiple redundant assessments as the patients were moved.

Each of the geographic triage sectors was established in a location where a steady flow of building evacuees was passing through a natural funnel or choke point, such as the building exit. Since all did not require EMS services, touch-triage assessment was used. Touch triage, which has been used for years at major annual events such as the New York City marathon, involves closely monitoring, but not interfering with, the egressing group by EMS personnel assigned to triage. When a person appearing to require assistance or EMS services is identified, the EMT makes contact with the person; performs a rapid assessment; and, if appropriate, removes the victim from the flow of evacuees into the triage area, where triage is completed. In this way, a large number of rapidly moving people can be assessed quickly without impeding the flow of egress.

As the buildings became tenable and the flow of evacuees lessened, forward triage sectors were established in the building lobbies and, ultimately, on the upper floors of the tower buildings. These forward triage sectors enabled EMS teams to respond quickly to reports of casualties on the upper floors and ultimately evolved into casualty collection points (CCPs).

CASUALTY COLLECTION POINTS

The initial CCP was established very quickly following EMS arrival at the complex. An officer assigned to reconnaissance saw that many evacuees were leaving the complex in apparent distress, without their coats, in the snow and 20-degree temperature. As he investigated where they were going, he noted their migration to the Winter Garden, an enclosed atrium and food court in the World Financial Center across the street. On entering the Winter Garden, he observed a large crowd of people requiring medical assistance. This operation naturally evolved into the Winter Garden Division.

Additional CCPs were established in the lobbies of nearby buildings and on commandeered transit buses in the surrounding streets. The forward triage areas on the upper floors of the towers gradually evolved into CCPs, as victims on the upper floors were gathered there to receive care and await emergency evacuation down the stairs or the restoration of power for elevator egress.

TREATMENT

In the CCPs, paramedics and EMTs primarily administered oxygen, assessed patients, and gave psychological first aid. Most patients did well with this supportive therapy, but some required ALS care, including cardiac monitoring, intravenous line placement, and parenteral medication. When critical patients were detected through the triage process, where evacuation was possible, they were treated and transported rapidly to area hospitals. In several cases, critical patients were treated for extended periods of time on the upper levels of the towers until the logistics of their evacuation could be put into place.

Ordinarily, NYC*EMS paramedics utilize standing orders to provide initial ALS care and then are required to contact the EMS Telemetry Control Center physician for clearance to implement medical-control options. At this incident, the EMS medical director authorized the implementation of all medical-control options as standing orders, eliminating the need for telemetry contact and streamlining patient care in many cases.

Similar issues arose with those paramedics who responded from New Jersey on mutual aid. With the authorization of a New York State Department of Health representative at the scene, the New Jersey resources were permitted to utilize their standing orders and communicate with their own medical control in New Jersey, allowing them to provide a full spectrum of ALS care without burdening the New York City system.

TRANSPORT

Patients requiring hospital care were transported to one of 17 hospitals in three boroughs. To minimize radio congestion, each division was directed to make its own hospital selections. Although this was potentially problematic, the geographic layout of the scene facilitated each division's routing of patients in a different direction from the incident, avoiding a major impact on the hospitals in all but two cases.

Initial transport resources included police cars and buses as well as school vehicles that were waiting for several visiting kindergarten classes whose children were trapped in the south tower. Many of the early-arriving ambulances were deadlined in the staging area, as their crews were put to work inside the complex. Ultimately, mutual-aid ambulances performed many of the transports to hospitals, enabling NYC*EMS members to continue operating at the scene.

HOSPITALS

Immediately following an assessment of the situation at the WTC, all of the New York City 9-1-1 system-receiving hospitals were notified by the EMS communications center to anticipate incoming casualties. Many activated their external disaster plans, holding over their day shift staff, clearing emergency departments and operating rooms, and bringing in additional personnel and supplies.

While some victim self-referral to area hospitals was anticipated, the volume of walk-in cases from this incident was staggering. The "self-referral phenomenon" was particularly evident at New York Downtown Hospital, located several blocks from the complex, which ultimately received almost 200 patients over 13 hours — many of whom were not transported by ambulance.

Several hours into the incident, as the extent of the self-referral phenomenon became apparent, NYC*EMS officers and police officers were dispatched to every hospital in the city and the surrounding counties to account for and track additional victims. Many of these people had left the complex following the emergency, made their way home, and began to feel symptomatic as their adrenaline wore off. In all, some 411 patients were identified as having arrived at hospitals in all five boroughs and the outlying suburbs through alternate means.

PATIENT TRACKING

Experience has shown that the best way to track patients at a disaster scene is by name, which enables emergency personnel to definitively ascertain the disposition of individuals and to determine which people remain unaccounted for. Under normal MCI procedures, this is done at the scene by NYC*EMS.

At this incident, however, the sheer volume of patients precluded the use of name tracking, although it was attempted at the beginning. Accurate number tracking was done from the scene, and all ambulance crews were directed to call their patients' names into the communications center following their transport to a hospital.

COMMUNICATIONS

Communications at the scene were coordinated through the NYC*EMS Field Communications Unit. A second field communications unit, provided by Ridgefield Park, New Jersey, served as the coordination point for the EMS mutual-aid response.

Early communications were hampered by the partial loss of cellular telephone and pager service in the area when power was shut down in the WTC complex and rooftop antennas were disconnected to allow helicopter operations on the tower roofs.

Many 9-1-1 calls were received from callers trapped in the towers who had access to cellular phones. Communications center operators stayed on the line to calm and advise these callers, and their information subsequently was relayed to the command post to assist in the search and evacuation processes.

Two types of radio networks were used for on-scene communications. A command network between the incident commander and command post and the geographic division commanders, functional sector officers, and command staff made it possible to coordinate activities at the strategic level.

On a tactical level, individual tactical networks were employed to facilitate communications between the division commanders and tactical operations posts, geographic sector officers, task force leaders, and division staff. Face-to-face communications and runners also were used effectively within the divisions.

The Field Communications Unit maintained contact with the communications center and coordinated the information flow by monitoring radio traffic on the incident ground networks. Periodic progress reports were compiled there and broadcast from the scene.

EMS MUTUAL AID

Although there was no precedent for mutual aid coming into New York City, mutual aid was monumental and contributed heavily to the success of the medical operation. Through informal mutual-aid plans, NYC*EMS has participated in mutual-aid exercises and has sent resources to assist neighboring communities but has never had an occasion to require it. In addition to the contribution mutual aid resources made to the disaster effort, mutual aid at the incident scene ensured uninterrupted 9-1-1 coverage to the unaffected communities of New York City. On February 26, 1993, the day of this disaster, NYC*EMS received 3,015 requests for EMS service unrelated to the disaster. The WTC bombing was just one of 3,000 incidents handled that day.

EMS commanders from New Jersey remained at the mutual-aid command post (located adjacent to the EMS command post in the command post area) and proved to be invaluable in the execution of this effort. When the dust settled and the smoke cleared, we determined that the State of New Jersey had committed 52 EMS agencies, sending a total of 69 EMS units into Manhattan to assist.

In addition to the mutual aid received from the State of New Jersey, mutual aid came from 12 community volunteer ambulance corps from within the city. These units, some of whom have formal mutual-aid agreements with NYC*EMS, are not routinely part of the 9-1-1 system. They provide service within well-defined community boundaries — but on February 26, they saw no boundaries.

Mutual aid also was provided by 12 of the city's commercial ambulance providers, which sent 49 ambulances. Commercial ambulances in New York City handle private EMS contracts and have the market on hospital-to-hospital transfers but do not operate within the 9-1-1 system.

PLANNING

Planning and administration tasks were assigned to a planning sector. At the command staff level, the planning sector officer reported directly to the EMS incident commander. The team consisted of chief officers, line officers, and staff personnel. The sector's responsibilities included developing plans for the deescalation of the large number of resources present and operating; rest and rehabilitation, which included critical incident stress debriefing (CISD) and crew rotations; and commencing data collection for the postincident report.

Experience has shown that it is important to thoroughly document the response effort. This serves three principal objectives: maintaining a historical reference document for critique, research, and legal purposes; providing information to law enforcement investigative agencies — in this case local, State, and Federal; and documenting expenses incurred for the response. Included in the postincident report were a detailed breakdown of the command structure; a compilation of resources, both human and logistical; and victim tallies, including their dispositions.

LOGISTICS

NYC*EMS maintains six logistical support units (LSUs). These trucks are strategically located throughout the city and serve as mobile medical equipment caches. All of them were deployed to the scene and supplied the divisions with medical hardware and software as requested. Under the control of a captain serving as the logistics sector officer, the LSUs were instrumental in ensuring adequate supplies, especially portable oxygen tanks, as well as oxygen delivery devices and systems.

MEDIA RELATIONS

The dissemination of public information was done from the command post by a team of public information officers (PIOs). Public information was a monumental and difficult task because most sound bites were live and because of constant changes and updates in information due to the rapidly evolving situation.

In addition to the on-scene release of information, a PIO remained at EMS headquarters answering telephones and providing on-air commentary. This was significant in providing accurate information to WCBS-TV, the single remaining on-air television station in the greater New York area (all other stations with transmitters atop the WTC were knocked off the air when the power was lost) and is believed to have contributed to lower 9-1-1 call volume in the uninvolved communities of the city.

EMS EMERGENCY OPERATIONS CENTER

We learned from past experiences, such as the two recent USAir crashes in New York and a major subway disaster, that an interagency emergency operations center (EOC) is of tremendous benefit. The EMS EOC served as a focal point where agency-specific needs were addressed behind the scenes. The EOC staff functioned as a direct medium between the EMS operations and support services bureaus, shortening the lines of communication. This was necessary to monitor the situation in the other areas of the city to take action to satisfy incident logistical demands; and to handle administrative duties, thereby freeing field commanders to focus on medical operations. The EOC, located at EMS headquarters, maintained direct communication with the EMS command post and was managed by the deputy chief of operations.

REHABILITATION

The EMS commanders were very conscious of the need to monitor personnel for critical incident stress during this incident. Efforts were made to limit any individual's exposure to gory or bizarre scenes. A rehabilitation sector was established, and transit buses or other facilities were designated at each division as locations at which members could rest between assignments. Through the assistance of the American Red Cross, Salvation Army, American Express Company, and others, refreshments and full hot meals were provided to the personnel.

Early on, the NYC*EMS CISD team was activated and responded to the scene. Informal sector demobilization assessments were conducted during operations and by the officers when sectors were secured. On-site evaluations and assistance were provided by peer team members and professional staff.

Within a week following the bombing, the CISD team had conducted formal debriefing sessions for officers, municipal EMS providers, hospital-based personnel, and the various mutual-aid responders.

LESSONS LEARNED

The EMS response to this extraordinary incident, the most significant disaster in the history of the service, was on a massive scale. The scope and complexity of the response presented exceptional challenges to veteran emergency response personnel, who responded in kind with exceptional commitment. The successful outcome of the response, as well as the limited loss of life, is a testament to the extraordinary efforts and effective coordination of all those who responded.

EMS and fire services must plan and prepare for these eventualities. Keep in mind that terrorism is not isolated to urban centers. Firefighters and EMS providers in rural and suburban areas must be prepared as well. Readiness is the key to success. Planning will help to ensure that your fire department and EMS system respond in the safest and most efficient manner possible.

Through the use of a well-exercised ICS; written and practiced operational and mutual-aid plans; site-specific plans for sensitive locations such as shopping malls, sports arenas, and transportation hubs; and plans for massive casualty distribution, the impact of a terrorist event on any community and its emergency response forces will be significantly reduced.

The terrorist bombing of the World Trade Center has illustrated that we must anticipate a worst-case scenario in our communities. We must make all efforts to be prepared to respond to these incidents in the most efficient and safest manner possible.

Many lessons were learned and reinforced in the aftermath of this incident. They have value for large and small communities, as we have seen that terrorism can strike anytime, anywhere. This was further exemplified by the recent investigation and arrest of members of an alleged terrorist plot to carry out a massive day of terror in New York City. Some lessons follow.

1. **The need for a medical incident command system cannot be overstated.**

   Span of control is critical to maintaining the ability to manage; no manager should have anything but a reasonable reporting relationship, with 1:5 being optimal. This arrangement enhances operational efficiency and communications and reduces the burden of information and responsibility overload.

2. **A command team concept, with deputy incident commanders and a well-trained command post staff, can assist in executing operations, as well as in receiving information.**

3. **If you expect your personnel to do something in an emergency, be sure they are accustomed to doing it routinely, especially in the case of incident command.**

   Therefore, use it at all routine incidents.

4. **Consider implementing a "management liaison" at the command staff level to brief and interact with senior management and political leaders.**

   This will allow the incident commander to focus on operations.

5. **In the World Trade Center incident, both the medical and fire operations were extensive enough to require intense management.**

   Fire departments that have emergency medical service (EMS) responsibility should closely examine their medical disaster management procedures to ensure their ability to manage both major elements simultaneously.

6. **Clearly delineating duties, especially at a major incident, is critical to ensuring that all responders know their roles.**

7. **Consider the need for multiple staging areas to ensure the best access to multiple sides of an incident.**

   Consider the routes vehicles will use to return to the scene.

8. **At major incidents to which numerous vehicles will respond, categorize the vehicles by type.**

   Separating basic life support ambulances, advanced life support ambulances, specialty units, and support vehicles will make it easier to deploy them.

9. **Major incidents, or those that produce multiple patients over an extended period of time, necessitate making decisions regarding transporting truly critical patients before the end of the triage process.**

These patients may deteriorate rapidly or expire if they are not managed aggressively from the outset. These decisions, however, must be balanced against the resources available.

10. **Triage tags really work — use them regularly.**

11. **As we learn more about the ill effects of entrapment and compression on the human anatomy, it is clear that crush syndrome must be addressed while rescue and disentanglement is underway.**

    Crush syndrome (trauma to muscle tissue that can cause shock and renal failure) can debilitate or kill victims if they are not treated by specially trained medical personnel before being removed from their entrapment site. Paramedics are well-equipped to deal with the effects of crush syndrome and must be included in any urban search and rescue effort.

12. **The issue of medical control should be considered and included in the mutual-aid plan. Do not leave this area for speculation.**

    Allow mutual-aid providers to use their own protocols and medical control when possible. Disaster medical control protocols are recommended so that the need for physician contact is eliminated during a disaster.

13. **Transport decisions should be made on an incident wide basis — not by individual divisions.**

14 **EMS personnel should be trained in landing zone operations and safety. Safety is critical when operating around helicopters.**

    All personnel, especially the landing zone sector officer, must observe hazards.

15. **Despite pressure to track every victim, name tracking at the scene may not be feasible.**

    Include a strategy for acquiring victim pedigrees in the disaster plan; consider incorporating the use of law enforcement personnel or volunteers.

16. **There is no way that fire/rescue and medical communications could have been conducted within a single tactical network.**

    Traffic overload would have severely interfered with the efficiency and safety of operations.

17. **Division progress reports to command are vital.**

18. **EMT trainees from our Division of Training formed a staircase-relay mechanism.**

    These teams were placed every two to three floors from the lobby to forward triage areas and casualty collection points on the upper floors. They were used to move equipment up and patients down without exhausting individuals who would otherwise have to do multi-floor carries.

19. **All portable radios must be able to function on designated tactical networks.**

20. **Dynamic re-deployment plans are needed to backfill area units drawn into an incident.**

21. **Preplan alternative procedures for situations when your infrastructure communications systems (cell phones and pagers, for example) fail secondary to the incident.**

22. **Consider the need for additional staff at the communications center.**

23. Develop mechanisms for disseminating information to hospitals rapidly and continuously.

One approach would be to include radio links monitored by hospital staff for broadcast updates (also voice alarm or voice pager system). A computer link in medical facilities and telephones with automatic speed dialers with messaging and acknowledgment features would aid in this process. Hospital-notification problems that must be addressed include the following: calling several hospitals at a time, providing informational updates, notifying hospitals when the alert is concluded, and controlling patient flow. Hospitals must provide feedback to the communications center: "We can handle everything" vs. "We're drowning in patients" vs. "You didn't send us enough."

24. Never underestimate the need for mutual aid — even in large cities.

25. Joint training and exercises in MCI operations and incident command are required for mutual-aid responders.

26. Mutual-aid plans addressing activation and lines of authority must be formalized.

27. Mutual-aid resources left in staging and not used will be frustrated.

Crews should be debriefed and given an understanding of the incident and their essential role of standing by in reserve.

28. Mutual-aid plans not only should cover the response to a disaster but also should provide for continued emergency service coverage to unaffected communities.

29. Common mutual-aid frequencies would have been beneficial.

30. Plans for managing ongoing routine 9-1-1 operations, such as holding over shifts, as well as for managing the incident, are needed.

31. Documenting the response is critical in cases where Federal disaster declarations are likely.

32. Plans to control and reduce equipment loss and conduct equipment recovery are needed.

33. Advance agreements with vendors to replenish oxygen supplies at the scene or to stay open at a local site so that bottles can be refilled as needed could be beneficial.

34. Multilators, devices that deliver oxygen to multiple patients, are great and are available commercially.

35. Being self-sufficient through measures such as bringing power and lighting to the scene, will allow EMS objectives to be met without depleting other agency resources.

36. If you have a reserve ambulance fleet, spare equipment must be available and be vehicle-based so extra units can be placed rapidly into service.

Remember the need for ALS equipment and portable radios.

37. Have "high-rise" logistics kits available for remote treatment areas.

38. Logistical support units (mobile medical caches) are essential.

LSUs stock rapidly consumable medical hardware items such as backboards and oxygen, as well as software. Four of NYC*EMS LSUs were constructed from retired/modified ambulances, reducing costs significantly.

39. **Well-intentioned media personnel may transmit improper instructions, such as to break high-rise windows.**

    At the WIC incident, a public information officer (PIO) at EMS headquarters conducted a campaign to decrease the routine call load on the EMS system, reducing the call volume during the disaster and making it possible to render efficient service to the rest of the city.

40. **Crews must be monitored for their use of safety equipment (helmets, coats. etc.).**

41. **Mobile safety officers are an asset and would have been beneficial in each division.**

42. **All issues cannot be addressed on site during a disaster.**

    An emergency operations center (EOC), especially if it is well-coordinated with the command post, can address many matters, including unit redeployment and personnel and staffing requirements for the disaster, as well as for routine community 9-1-1 service, and a host of administrative and operational needs as they arise.

43. **Consider the possibility of terrorist-related hazards, including the presence of "kill bombs" designed to draw crowds and rescuers and then to "take them out."**

    Keep in mind that terrorism is not just an urban problem — terrorists can strike anywhere.

44. **Rest and rehabilitation at the WTC disaster included CISD and rotation of crews.**

    They were essential to preserve the health and well-being of responders — especially since the crews were physically exerted by climbing to the upper reaches of the towers.

45. **When planning for rest and rehabilitation, do not forget officers.**

    Remember to meet their needs, as well.

Forward Triage on the 34th Floor

by Jack J. Murphy, Jr., and Jack J. Delaney

On the day of the World Trade Center (WTC) incident, several of the early morning radio transmissions from the emergency medical service (EMS) dispatcher were preceded by sounded alert tones, warning the paramedic units about hazardous road conditions.

At 12:21 hours the alert tone again sounded, but this time, the EMS dispatcher transmitted a smoke condition at the WTC. An EMS lieutenant and several paramedic units responded. They were advised to give a status report on the NYH-EMS citywide frequency. The first-arriving paramedic unit transmitted a report that this was more than just a smoke condition. This unit immediately became involved with a cardiac arrest and transported the patient to the hospital. Once the EMS lieutenant arrived, he requested all available resources to respond to the incident. This unusual request and the grave inflection in his voice prompted the EMS dispatcher to increase the response to the incident.

Shortly thereafter, the New York Hospital/Cornell Medical Center EMS was requested to respond to the WTC EMS staging area. Under the guidance of the hospital EMS director, a mobile task force was assembled, consisting of four ambulances, two rapid response units, one mobile emergency response vehicle (MERV) — a mobile triage unit that stabilizes patients for primary care —15 paramedics, one emergency room doctor, and the hospital fire safety engineer, who was designated the safety officer for the task force. To maintain the primary hospital EMS response, all off-duty staff members were ordered to report to duty.

The NYH Task Force was deployed onto the FDR Highway southbound. (While en route, many ambulances where transporting patients northbound to local hospitals. This tactical highway approach was east of the WTC, which enabled the NYH Task Force to circumvent the WTC under the Battery Park tunnel. Thus, the task force advanced into the staging area without any vehicle congestion.

AT THE SCENE

From the staging area, EMS command assigned the NYH Task Force to WTC Tower 2. The operations chief for Tower 2 directed the task force to set up a forward triage on the 34th floor, where the task force encountered a woman in premature labor being transported down from the upper tower level. The Tower 2 operations chief also directed the MERV unit to relocate in front of Tower 2 (side 1).

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Many patients from Tower 2 were treated in the MERV unit before being transferred to an appropriate level of prehospital care.

Prior to ascending the stair tower, the paramedics gathered emergency medical equipment, including portable oxygen cylinders, cardiac monitor defibrillators, advanced and basic life support equipment, a portable pulseoximeter (for measuring the oxygen saturation of hemoglobin in a blood sample), and nonmedical but necessary equipment such as floodlights, rope, and flashlights. Each task force member was assigned several pieces of equipment to transport on their backs up to the 34th level, since the tower's electricity and emergency lighting were not operational.

Smoke filled the stair tower from the lobby level upward. At intermittent levels, emergency personnel provided some light and guidance to WTC occupants who were evacuating. Scores of people were making their way down the stairs; their emotion increased as they approached the exit. Emergency crews instructed the evacuees to stay to the right side of the stair tower; rescue personnel used the left side to ascend. The climb to the 34th floor took 40 minutes. On several occasions, task force members had to stop to rest.

On arrival at the 34th floor, the NYH Task Force was directed to a corporate conference room filled with numerous patients. One patient, in her late 20s and in an agitated state, was lying on the floor with her legs flexed. She was alert and oriented and complained of a severe headache. Her companion informed the medical team that the patient was seven months pregnant, had made routine visits to her physician, and had had no prior complications from this pregnancy. Further evaluation revealed that the patient was extremely hypertensive. She was diagnosed with preeclampsia and immediately was placed on a high concentration of oxygen and started on an I.V. She began to exhibit petit mal seizures. The seizure activity did not subside, and the patient began to exhibit central cyanosis and a palpable systolic blood pressure of 240, which prompted the decision to pharmacologically intervene to control the seizures. The unavailability of extrication equipment made it necessary to strategically secure the patient in a stokes basket (under normal conditions, strapping a pregnant patient is not done to avoid possible injury to the mother and unborn child) to protect the patient and baby as the rescuers carried her down 34 floors. Just before her departure, her blood pressure was measured at 190/100 and central cyanosis was abolished. The NYH Task Force transferred the patient to another paramedic team, which continued her care throughout the vertical evacuation. The patient subsequently was transferred to a New York hospital, where she gave birth by a cesarean section. The mother and her premature infant were reported to be doing well.

Other patients located in this area exhibited a wide range of medical conditions including smoke inhalation, asthma, chronic obstructive pulmonary disease (COPD), exhaustion, and hysteria. Without delay, the NYH Task Force performed a primary survey, triaged patients, and began treatment of the most severely afflicted under the medical direction of the team physician.

Several EMS teams were deployed to the upper levels to evaluate nonambulatory patients. Patients assessed as having possible cervical spine injuries requiring immobilization — but who had no other medical complications and were in no immediate danger — were left with rescue workers to be mobilized when additional resources became available. Patients requiring immediate medical attention were transported to the forward triage station. EMS personnel deployed from the forward triage station to a specific location were monitored by the safety officer to be reassigned. In addition, the safety officer organized a group of rescue personnel to go on scavenger hunts throughout the various floor levels to acquire bottled water, cups, first-aid kits, ice, oxygen cylinders, portable-battery radios, and other needed items.

SECOND TRIAGE CENTER

Later into the incident (during the latter part of the afternoon), additional EMS personnel arrived at the forward triage area. A second triage area for ambulatory patients who had minor medical conditions, such as exhaustion, was established on the floor. After a brief rest, these people could continue their trek down to the lobby. During these operations, reports of another device exploding on the 65th floor surfaced. They were disproved after a thorough search had been made. This false report may have heightened the anxiety levels of our personnel, but it did not deter them from administering the medical care that was needed.

Using the area along the exterior wall as the triage center enabled us to use the natural daylight as lighting and to preserve our battery power for nightfall. Since portable lighting was limited and there was no indication of when utility power would be restored, the patient population was consolidated and the work area reduced. Ambulatory patients needing no assistance were released after a quick rest and some refreshments. Ambulatory patients needing assistance were released with other evacuees capable of assisting them. Nonambulatory patients or those with medical conditions that could have been exacerbated by their self-evacuation were packaged and transported by fire/police personnel and accompanied by EMS personnel.

Hours after the initial blast, the lighting on part of the floor was restored. The forward triage function was moved laterally to the lit area. Patients presented at this time had no severe medical complications. They were evaluated, permitted to rest, given refreshments, and sent on their way. The last group, all young children, had walked down from the observation deck on the 110th floor. They were in excellent spirits, and the attending physician, a pediatrician, interacted with the children and determined that they were fine.

Approaching the end of the initial incident day, the NYH Task Force waited for the search and rescue crews to secure the floors above the 34th level and then demobilized. They were able to use an elevator to descend to the lobby.

Several hundred people were treated for various ailments during the forward triage operation. The behavior exhibited during this incident was uplifting, as people reached out to help all in need.

Experiences of the Chief Engineer of the Port Authority

by Eugene Fasullo

On February 26, 1993, at 12:18 p.m., I was taking the elevator down from my office on the 72nd floor of 1 World Trade Center to go to lunch. Somewhere between the 61st and 44th floors (in an express elevator shaft), the elevator came to a halt. Inside were seven engineers (myself included) and two lawyers.

DIGGING OUR WAY OUT

After 10 minutes, we smelled smoke. After 20 minutes, smoke began pouring into the bottom of our elevator. During this time, we pressed the elevator's emergency button. Usually this elicits a response from a live person who says help is on the way. This time, however, we got a recorded message over and over again that said, "Message received; please be patient." Since we didn't know how long it would be before help arrived, we decided to force the elevator doors open ourselves.

In 1960 I was involved in the original planning and design of the WTC. From this experience I knew that the walls behind the elevator doors were made of two-inch-thick gypsum board, rather than solid concrete or concrete block, with steel studs 12 inches on center. Thus we figured we could dig our way out.

We forced open the elevator doors with our hands and used our car keys to dig. When the lights went out, we dug by the little red lights of our beepers. It took us two hours to dig through that wall. When we broke through, we were able to gulp some fresh air from the hole we had made. Then we came upon a second wall approximately 12 inches farther in. As we dug through this wall, we could hear tiles falling on the other side of the wall. We figured we were tunneling through to a bathroom. After an hour, we dug right through a stall and stepped onto the toilet bowl and then down to the floor.

We then proceeded to walk from the 58th floor down the dark and smoky stair tower to the bottom, often holding hands for safety. We arrived there between 4:00 p.m. and 4:30 p.m. We all suffered various degrees of smoke inhalation, but we all made it out of the building safely.

ASSESSING THE DAMAGE

Outside was mass confusion. I reported to the command post in the Vista Hotel. Our only information at first was that there had been a transformer explosion in the basement. A maintenance worker accompanied me down to the crater. This was the first time I saw the tremendous devastation. The crater was smoldering, and water was pouring in from broken pipes. Then I realized it must have been a bomb that caused such massive destruction.

I quickly evaluated the structural condition of the building around the crater. On visual inspection, I decided the columns supporting Tower 1 were not damaged — there was no cracking in the connec-

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tions or signs of distortion. The secondary steel members were damaged, but they were not critical to structural integrity. As for the primary columns supporting the Vista Hotel, the floors that braced them were destroyed, and the columns' load-carrying capacity was greatly reduced. These were the most critical elements to repair.

There were piles of concrete debris at the bottom of the crater, which were keeping the columns from buckling laterally. Therefore, we allowed no debris removal to take place until the columns could be reinforced with steel braces.

REPAIR WORK IS BEGUN

Seven columns were in bad shape. Braces were installed in the following manner: Three- by four-foot holes were cut in the floor of the ballroom of the hotel around each column to gain access and to lower bracing members (six-inch steel tubes 35 feet long). A two-man cage was positioned over the large blast hole for lowering workers to weld the braces to the columns. These braces were welded horizontally and diagonally to the columns. During the welding, two fire posts were set up around the clock to extinguish any small fires caused by the welding operation. This project lasted from Sunday through Friday.

Only then did we allow debris removal. A hole was made in the plaza level outside between Tower 1 and the Vista Hotel, and a crane stationed on that level began removing debris. We estimated there were 2,500 tons of debris. As removal took place, bracing was done continuously. In all, 200 braces were put in. Debris removal took about two weeks to complete.

Much debris was on top of the air conditioning equipment. Seven units that provided 7,000 tons of air-conditioning needed to be made operational in two months, in time for summer. We needed first to get at them and then to fix them. Meanwhile, we rented temporary units. This project was completed in mid-May.

Other equipment was damaged by the blast and needed replacing as well. The transformers were damaged, as were elevator doors and equipment. Walls in the stair towers had been blown down by the explosion. Concrete slabs 100 feet away were cracked (these will be demolished and rebuilt by the end of this year).

The fire department played an integral role in reviewing the building systems — such as the smoke-removal system and the communication system — and helping to bring them up to speed so the building could be reoccupied.

More than 3,000 workers were employed around the clock to clean 10 million square feet of office space damaged in the blast. Just feeding all the workers removing debris, welding, and performing electrical work and other duties around the clock was a major logistical task.

Vendors around the country interrupted their production to send us parts and equipment. All pulled together to get the job done in record time.

After the buildings were cleaned and their systems tested and functioning, tenants were allowed to move back into their office space, some as early as two weeks after the incident.

All of our facilities have routine drills to prepare for emergencies, but no one — not police, fire department, or Port Authority personnel — had ever encountered the effects of a 1,000-plus-lb. bomb put in the basement of a building. The effects were awesome and overwhelming.

The World Trade Center Complex

by The Port Authority Risk Management Staff

The World Trade Center (WTC) complex was designed by Minoru Yamasaki and Associates of Troy, Michigan, and Emery Roth and Sons of New York. Site excavation began in August 1966, and construction of the towers started two years later. The first tenant moved into Tower 1 in December 1970, even though construction was not completed. In January 1972, the first tenant moved into Tower 2. The official opening of the Vista Hotel in July 1981 marked the complex's completion.

The foundations that support the WTC are truly gigantic. They are the "strong shoulders" that rest in bedrock 70 feet below ground, and they carry 1.25 million tons of building. In the area that contains the twin 110- story towers, more than a million cubic yards of earth, rock, and subterranean miscellany were removed to make way for a basement 980 feet long, 510 feet wide, and 70 feet deep to provide for the PATH commuter rail station, mechanical equipment rooms, storage for tenants, and parking for 2,000 cars.

Prior to excavation, the entire eight-block area required under-ground walls down to and into the bedrock to withstand the external water and earth pressure and to prevent the undermining of adjacent buildings and streets. Conventional construction methods were considered before selection of the slurry trench method.

This technique had been used extensively in building construction in Europe and Canada but was new in the United States. The soil surrounding the site resulted in the decision to use this new approach.

SLURRY TRENCH METHOD

First, excavating machinery carved out a three-foot-wide trench, the same width of the basement wall to come. As material was removed, it was steadily replaced by a slurry mixture of water and bentonite (a fluffy, expansive, gray clay that comes largely from Wyoming). The slurry has the consistency of pea soup and was constantly churned as the excavation rig deepened the trench. The mixture held back the ground water and maintained the sides of the trench without the need for shoring. The drilling and removal process continued down into the bedrock.

Next, preassembled seven-story high cages of reinforced steel, weighing 25 tons, were lowered into the slurry. This formed the skeleton for the concrete that displaced the slurry. Then the concrete was placed at the bottom of the trench through a pipe with a big hopper at the top. Engineers call it a *tremie*, which is French for "hopper" or "funnel." As the concrete wall, three feet thick, rose to ground level, the slurry was forced out on top. The same slurry then was piped to other trench segments. The final result, as the parts were joined, was a reinforced concrete underground cutoff wall around the site to be excavated.

The work was done in 22-foot-long segments, 152 in all, which allowed accommodation to the varying rates of building removal and utility line relocation, since the construction stages were interrelated. One depended on the other, just as new telephone vaults had to be provided in West Street (also by the slurry trench method) before the basement perimeter wall could be started, which in turn was a preliminary to foundation excavation and then the actual erection of buildings. In effect and in appearance as the excavation proceeded, this became a big bathtub — with water kept on the outside.

During excavation, the PATH railroad operated as usual, even though the old tubes under Fulton and Cortlandt Streets became completely exposed as a result of the work. As digging proceeded, the tubes rested safely in protective cradles with deep-rooted underpinning. Later on, new tracks were built into the new and bigger PATH terminal west of Greenwich Street.

As the "bathtub" excavation line lowered and sections of the rectangular 3,100-foot concrete perimeter wall came into view, a system of rock anchors was installed. Holes were drilled diagonally downward and outward through the wall, through the surrounding earth, and into bedrock. Steel tendons were inserted, one end socketed in the rock and the other end anchored to the wall. The purpose was to brace the wall against exterior pressure and provide unimpeded working space inside the "bathtub."

The excavated material was dumped into the Hudson River to create 23.5 acres of new land, extending six blocks along the waterfront from Cortlandt Street to below Rector Street and an average of 700 feet into the river. This landfill replaced abandoned piers and the old Central Railroad of New Jersey ferry slip at Liberty Street. The material was dumped behind a cellular steel cofferdam retaining structure. The new real estate became the property of the city of New York at no cost to the city, and is Now Battery Park City and the World Financial Center.

Gradually, as excavation proceeded and the "bathtub" area was dug out. The footings for the building foundations were carried into bedrock. From this base, six floors below ground level, the buildings began to rise. The basement floors braced the perimeter wall, and the rock anchors were no longer necessary.

STRUCTURAL STEEL SYSTEM

In terms of their structural system, the twin tower buildings depart completely from other high-rise buildings. Conventional skyscrapers, since the 19th century, have been built with a skeleton of interior supporting columns that supports the structure. The buildings are not only physically striking — a pair of 209-foot-square towers with almost an acre of space on each of the 110 floors — but they are radically different in structural design, as the exterior wall is used as the loadbearing wall. The only interior columns are located in the core area, which contains the elevators.

The outer wall carries the buildings' vertical loads and provides the entire resistance to wind. The wall consists of closely spaced vertical columns (21 columns 10 feet apart), held together by massive horizontal spandrel beams that girdle the towers at every floor. On the inside of the structure, the floor sections consist of trusses spanning from the core to the outer wall. The towers are literally gigantic square box beams of enormous strength, designed to withstand 150-mph winds and sway up to three feet.

ELEVATOR SYSTEM

Elevator service within the towers was designed to maximize the use of floor space; each tower is divided into three zones, and each has its own lobby. Zone l's lobby is located on the concourse level, one level below the plaza, and permits access from the ground up to 44. Zone 2's sky lobby (the transfer floors for other elevators serving upper floors) is 44 and services 44 to 77. Zone 3's sky lobby is located on 78 and serves 78 through 110. Express elevators (the fastest of their size ever built) are available from the lobby and serve both the 44 and 78 sky lobbies; each has a capacity of 55 people. The elevator system was designed to limit local runs to one-third of the building. Thus, three local elevators operate at different levels within a single shaft. Each tower has a total of 99 elevators.

SUBGRADES/UTILITIES

The subgrade area of the WTC functions as the heart of the complex. In addition to the public and government parking areas, the subgrades house the refrigeration plant, which is three stories high; various types of telecommunications equipment; and office/locker space for the Port Authority and contract staff who monitor and maintain the complex's systems.

Electrical power and steam are supplied to the complex by Consolidated Edison of New York (Con Ed). Electrical power is distributed to the towers through eight feeders. The electrical systems are constructed so that service is not interrupted even though power loss may occur at any particular substation. A majority of the feeders are located in the ceiling or floors at the B-1 and B-2 subgrade levels. These feeders are surrounded by concrete to their individual substation throughout the WTC complex and are connected to the subgrade power distribution center. From the power distribution center, service is provided through substations on floors B 1, 7, 41, 75, and 108. In the event of a service disruption, the complex has six primary backup generators located on the B-6 level. These backup generators have the ability to use either domestic water or river water for cooling in the event of a water main failure and supply interruption. Steam is distributed to all mechanical equipment rooms, located throughout the complex.

Natural gas is supplied to the complex but is in limited use, mainly in the Vista Hotel's kitchens but also in restaurants located on the concourse of 5 WTC and the coffee tasting room at the New York Commodities Exchange in 4 WTC. No natural gas is used in the two towers.

Domestic water is fed into the complex at several locations from street level into the subgrade. From the subgrade, water is distributed throughout the complex and is used for restaurants, hotel rooms, the hotel swimming pool, cleaning, fountains, landscape maintenance, the sanitary system, refrigeration plant chillers "makeup water," cooling emergency generators, and fire protection systems (reserve tanks, standpipes, and sprinklers). Conservation of the region's precious water resources was the primary motivator in the design and construction of a system that uses Hudson River water for cooling the refrigeration plant chillers. This system involves pipes and pumps that transport the water from the Hudson under Battery Park City, under West Street, and into and out of the B-5 refrigeration plant. This system enables the refrigeration plant to cool the complex without using potable water.

Two systems often overlooked are sewage and storm water. Both are gravity systems in the WTC complex. All aboveground sewage lines lead into the municipal sewage line; however, below-grade lines feed into sewage ejectors, which pump up and into the city line. The storm water system leads into a 36-inch storm line, which eventually feeds into the return to Hudson River from the B-5 refrigeration plant.

FIRE SAFETY FEATURES

The WTC complex has the following fire safety features:

Smoke detection. The WTC complex is protected by smoke- detection equipment that operates as free-standing units or in conjunction with other systems. The smoke-detection equipment, for example, has been built into the heating, ventilation, and air-conditioning systems, which automatically trigger alarms indicating the presence of smoke. The complex has more 3,000 smoke detectors.

Break-glass emergency alarms. An emergency call box system is installed on each floor and, when activated, provides immediate two-way voice communications with the Fire Command Center, which is staffed 24 hours a day.

Smoke purge systems. A smoke purge system built into the WTC tower's ventilation system is activated in the event of fire. The system draws smoke out of tenant areas and at the same time pumps 100 percent fresh air into the public corridors. This system is designed to assist individuals evacuating an area as well as those responding to the scene.

Emergency fire exit stairwell system. Each tower has three independent emergency fire exit stairwells. These stairs are designated A, B, and C. Stairwells A and C run from 110th floor down to the lobby mezzanine, which provides access to the plaza. Stairwell B runs from the 100th floor down to the B-6 level of each tower. These stairwells provide three widely separated evacuation alternatives in the event of fire and give firefighters safe passage upward to fight fires. Each of these fire stairways has a standpipe, walls of fire-resistant construction, fire doors, and lighting fed by the emergency generators. Similar fire exit stairwells also are installed in the other buildings in the complex.

Standpipe system and fire pumps. The fire standpipe system in the WTC is an arrangement of piping, valves, pumps, tanks, and hose stations. Its function is to provide a reliable means of applying water streams on a fire in the shortest possible time. The hose stations are situated so that any area of a floor can be reached by a stream of water from a hose station in that area.

The source of water for the fire standpipe system in the WTC is the domestic water supply system. The water is transported to all buildings and subgrade areas in the WTC by two eight-inch loopmains (loops). Also in the system are manually controlled fire pumps and reserve tanks. The function of the reserve tanks is to provide water for the hose stations during the initial period of firefighting, before the fire pumps can be started.

The WTC has two fire standpipe eight-inch water distribution loops. One loop is in the ceiling of the concourse level and the other is in the ceiling of the B-1 level. The first loop supplies water to the risers in 5 WTC and 4 WTC and their sublevels. The other loop serves 1 WTC and 2 WTC, the hotel, the Customs House, and the subgrades. The loops are connected at two points on the truck dock of the Customs House at the north central portion of the WTC and in the southern portion of the WTC.

Vertical risers emanating from the loops carry water up into the towers and the other buildings in the WTC and down into the sublevels and subgrades. Risers connected to the loop on the concourse level carry water up into 5 WTC and 4 WTC and down into their sublevels.

In addition to the piping in the standpipe system, there are seven water storage tanks. The storage tanks supply water to the hose stations during the initial period of firefighting before the pumps can be started. The pumps are required to supply the additional water needed to fight larger fires.

There are 15 fire pumps in the fire protection system in the WTC. Twelve are centrifugal pumps and three are jockey pumps. Eight of the centrifugal pumps are for the standpipe system (located on floors B-1, 7, 41, and 75 in each tower), and four are for the sprinklers (located on floors B-1 and 108 in each tower). The three jockey pumps are for the sprinkler system — one on the B-1 level and one in each tower on floor 108 (for pressure maintenance).

Sprinkler system. The design of the sprinkler system in both towers is similar. Generally, the direction of water flow in the risers is downward. There are three separate risers in each tower, with each riser serving different groups of floors.

The risers are designated A, B, and C. Riser A supplies the uppermost floors, 99 through 110; riser B supplies floors 32 through 98; and riser C supplies floors 1 through 31.

The risers pass through the floors in the service closets on each tenanted floor and deviate from plumb vertical only as required by changes in building construction at various elevations.

Two different capacity holding tanks — 10,000 gallon and 5,000 gallon — are used in the same sprinkler system. The 10,000-gallon tanks supply the sprinkler system exclusively and are located on the 110th floor; the 5,000-gallon tanks serve both the sprinkler and fire standpipe systems and are located on the 110th and 42nd floors.

The sprinkler tanks supply water to inlets of risers A and B and are automatically refilled by the domestic water system via float-control valves. The fire standpipe tanks supply water to risers A, B, and C and normally are also refilled by the domestic water system. Riser C in 1 WTC is cross-connected with riser C in 2 WTC via a four-inch pipe from the siamese connections. The function of the cross connections is to provide FDNY with the capability to supply water to the C risers in both towers and control their pressures.

The sprinkler centrifugal pump in each tower on the 108th floor has a dual purpose. Its main function is to increase the pressure of the water to the sprinklers on the floors closest to the holding tanks (floors 107 to 99) to that required for operating the sprinklers. However, the pump also is used to supply water to some of the fire hose racks (FHRs) on the 110th floor.

As the downward distance from the holding tanks increases (floors 98 and below), the pressure (head) of the water in the risers increases to the point where the additional pump pressure is not required.

The rest of the complex — namely, the subgrade levels, 5 WTC, and 4 WTC — is part of a second sprinkler system completely separate from the one of the towers. This second system consists of a large loopmain with risers going down into the subgrades and sublevels and rising up in 5 WTC and 4 WTC.

The function of the fire pumps and the jockey pump is to maintain the water pressure in the system at 155 psi.

Of the three sprinkler fire pumps (two centrifugal and one jockey) on the B-1 level, one centrifugal pump and the jockey pump are located in a pump room under 1 WTC; the other centrifugal pump is located in a pump room under 2 WTC.

Fire hose and extinguishers. One-and-a-half inch fire hose stations and fire extinguishers are located inside the emergency fire exit stairwells. The WTC Port Authority Police also have pre-positioned firefighting equipment carts in the ski lobbies of the towers. These carts are equipped with three kinds of fire extinguishers (water, carbon dioxide, and dry chemical), fire hose and nozzles, self-contained breathing apparatus, turnout gear, entry tools, resuscitators, and first-aid equipment.

Emergency power supply. The WTC complex is provided with emergency power, when needed, by six 1,200-kw emergency generators. The emergency generators are located on the B-6 level and are checked on a routine basis to ensure they will operate properly when needed. This equipment provides an emergency power supply for communications equipment, elevators, emergency lighting in corridors and stairwells, and fire pumps.

Elevator recall and firefighter service. An automatic elevator "over-ride" system, detector-activated, commands all elevators serving or affected by a fire area to immediately return to the ground or their sky lobby. The elevators then are operated manually under the direction of the FDNY officer-in-charge.

Public address system. Public address speakers are installed in the corridors to provide tenants and visitors with instructions and updated information in the event of an emergency. This system is operated from the Operations Control Center, which is staffed 24 hours a day.

WTC fire brigade. The Port Authority Police at the WTC have been trained as firefighters and respond to any location within the complex to investigate smoke detector activations, smoke reports, or reports of actual fires. They work hand-in-hand with FDNY to investigate reported conditions and take the appropriate actions for correction.

Fire safety floor wardens. On each floor of the complex, individuals have volunteered to be fire safety floor wardens and are provided with specific training to fully understand their responsibilities during fire drills and actual fire emergencies. Mandatory fire drills are scheduled biannually. WTC fire drills are more detailed than those required by the City of New York.

FDNY siamese connections. The WTC complex has 24 siamese connections, located at street level, for use for FDNY apparatus. Water is taken from the street main, enters the fire department apparatus, and then is pumped under high pressure into the piping system to supply sprinklers and the standpipe system. Each of these siamese connections serves various portions of the complex and is identified.

Flammability standards. The risk management group of the PA's Treasury Department assists WTC-based PA staff by providing technical advice on the flammability of furnishings prior to tenants moving in or updating work areas. In addition to office furniture being evaluated, displays, carpeting, draperies, and decorations also must be tested to meet specific PA flammability standards prior to installation.

THE BOMBING AND ITS AFTERMATH

The bombing resulted in the following:

- six fatalities (four PA employees, one hotel employee, one parking lot patron);
- 1,042 injuries;
- collapsed subgrade concrete slabs;
- approximately 2,500 tons of debris covering the refrigeration plant;
- severe smoke and soot condition throughout the towers;

- four of seven of the electrical feeders supplying the complex faulting and due to safety concerns, the remaining three feeders being secured 1 1/4 hours after the explosion (one additional feeder was "down" for routine maintenance — there were eight total feeders into the complex);
- loss of the PA Police Desk;
- loss of the Operations Control Center, fire alarm system, and elevator two-way communications system (from elevator to Operations Control Center);
- loss of automatic smoke-detection capability
- loss of automatic sprinkler protection, primarily in subgrade areas;
- loss of standpipe system, primarily in subgrade areas;
- severed pipes creating a flooding condition of approximately two million gallons of water on the B-6 level;
- elevators getting stuck between floors, trapping almost 500 passengers;
- broken windows on the plaza and lobby levels and in the towers;
- fire stairwell doors/jambs forced open and damaged;
- the largest FDNY response in history;
- a massive personnel and equipment response from NYPD and NYC*EMS (first mutual-aid request — first Code Zebra involving 500 or more injuries) — 174 ambulances, 12 volunteer ambulances, 49 commercial ambulances, and 69 units;
- loss and damage to hundreds of government and privately owned vehicles in the parking levels; and
- massive temporary relocation of tenants to other sites.

RECOVERY AND RESTORATION OPERATIONS

The bombing of the WTC was the worst terrorist attack ever to occur in the continental United States. The criminal investigation that began that afternoon required personnel from Federal, State, and local law enforcement at all levels to work together for an extended period. Mobile command posts from these agencies were positioned on West Street in front of the Vista Hotel and 1 World Trade Center, and their operations were coordinated from this common location. The criminal investigation required law enforcement personnel to work in conjunction with civilian staff of almost every conceivable discipline. The media also were extremely interested in the hour-to-hour progress that was to be reported and were provided with frequent updates by PA media relations.

Concurrent with the criminal investigation were the following almost herculean tasks:

- stabilizing the subgrade blast zone;
- pumping out almost two million gallons of water from the B-6 level;
- removing debris;
- coordinating all activities at the site;

- relocating police, operations, and maintenance offices that had occupied subgrade office space;
- restoring and recertifying elevator service;
- isolating and restoring the fire protection system in the blast zone;
- cleaning smoke- and soot-damaged areas;
- removing and relocating vehicles that had sustained damage;
- removing and releasing undamaged vehicles from the parking lots;
- providing meals for law enforcement, fire, construction, and other staff working at the site;
- reconstructing collapsed and destroyed slab areas;
- determining the repairs needed to the B-5 refrigeration plant;
- designing and implementing an access control system to allow authorized staff to gain access to the blast site; and
- dealing with the media and providing escorts to individuals needing access.

As the rescue operations were ongoing, representatives from all the agencies began to assemble in the Vista ballroom. The groups then were repositioned into what had been the "big kitchen," located on the main concourse near the PATH escalators. Activity within the big kitchen only could be described as amazing. Tables were being constructed out of 4 x 8 plywood sheets and 2 x 4s, new telephone cables were being strung from the ceiling, new phones were being installed, chairs were being brought in, ceiling lighting was being upgraded, new power lines were being installed, supplies were being assembled on the concourse, and communications equipment was being installed. This level of activity and teamwork among people who did not know one another was never before witnessed during peacetime. The big kitchen became the focal point and the nerve center or the recovery and restoration activities. Twice a day, briefings were held to assess the progress made and determine the steps to be taken next.

PA engineering staff, assisted by consulting engineers (some of whom had been involved in the original construction), determined that the columns that were no longer braced by horizontal concrete slabs should be braced as soon as possible. Immediately, Karl Koch Engineering began welding box beams, six inches square by 35 feet in length, onto the columns horizontally and diagonally for support. A total of 200 beams were used to provide support. The criminal investigation then moved into high gear once the additional support was in place. Blast debris was removed from the B-5 refrigeration plant area by two routes — through the plaza by crane and out on PATH railroad flatcars. At the same time, Turner Construction Company was pumping out the almost two million gallons of water that had collected in the B-5 and B-6 levels at the same time.

The WTC mechanical staff began evaluating the condition of the refrigeration plant on the B-5 level as soon as they could safely gain access. They determined that the plant had sustained serious enough damage and recommended that backup units be obtained for the summer season. Temporary backup units were installed on Liberty and Vesey streets, and structures were built around them to limit noise to the surrounding area. These temporary chillers allowed the B-5 plant to be repaired and recertified without a reduction in cooling capacity.

A major task that had to be undertaken was restoring the fire protection system. Major sections of the below-grade standpipe and sprinkler system were damaged and had to be repaired. The damaged and destroyed sections of the standpipe and sprinkler systems were isolated by a crew of Ogden mechanical employees who worked around the clock. A team of 20 Hatzel & Buehler electricians tested the 3,000 smoke detectors, working 24 hours a day for one week, to verify that all were functioning properly. Under normal conditions, such a detail would have taken up to six months to complete. Simultaneously, another team of electricians reconnected many hundreds of feet of severed wire that led to the fire alarm system. While the towers were closed and fire protection systems were being brought back on line, FDNY connected pumpers to siamese connections to allow 4, 5, and 6 World Trade Center and the concourse to be open for business the Monday morning following the blast.

The dense smoke from vehicles burning in the subgrade parking lots traveled up the towers through the breached elevator shafts. The PA made arrangements with M. F. Bank/The Restoration Company (TRC) to supervise the cleaning of interior space damaged by smoke and soot. TRC coordinated the activities of Ogden, Modern, Nelson, and Altus contract cleaners. A total of 3,000 workers were used — 1,000 per shift. They accomplished the cleaning tasks in seven days for Tower 2 and 10 days for Tower 1. Tower 2 reopened March 18 with the return of New York Governor Mario Cuomo's office. Tower 1 reopened March 29, when employees of the Brown & Wood law firm returned to their offices.

The bombing of the WTC forced people from many diverse backgrounds to work together as a team as they never had before. Their resolve and determination to get the job done was inspirational to all who have witnessed their work.

POSTBOMBING ENHANCEMENTS

The bombing at the WTC truly was a "worst-case scenario" in which the primary and backup systems were disrupted. The following enhancements subsequently made to the WTC have made the complex one of the safest in New York City.

- 1,600 emergency battery-powered lighting units have been installed in exit stairwells, elevator lobbies, and all elevator cabs.
- Secondary backup generators are available in case primary and backup generators fail.
- A New Jersey Public Service Electric & Gas utility feeder cable will be routed through PATH tunnels to provide an additional backup should New York electrical service be interrupted.
- Phosphorescent signs have been installed to guide the way to floor entry doors in fire stairwells.
- Phosphorescent tape-paint has been applied to stair threads, handrails, and the perimeters of doorways in the fire stairwells.
- Vertical patrols (personnel responsible for checking obstructions, safety hazards, and systems throughout stairwells and corridors) have been created.
- Six satellite communications control stations, staffed by deputy fire safety directors, are in operation.
- Evacuation chairs to assist mobility-restricted people are available.

- New Radiax cable and antenna have been installed so that FDNY can use its radios in the towers.
- Cellular phones have been issued to each fire floor warden. The phones are to be used as a backup should the public address system fail.
- Delta Barriers have been installed to prevent unauthorized vehicles from gaining access into the subgrades.
- An access-control ID card system and a visitor check-in system have been implemented.
- A battery backup system to the elevator car position indicator will enable passengers to see which floor they're on if the elevator gets stuck in an express shaft.
- The elevator emergency call button will be tied into a battery power supply on top of the elevator car; thus, in the event of a power loss, WTC personnel can communicate with trapped elevator passengers.

Fire Prevention and Building Restoration Activities

by Dave Corcoran

After any major fire incident, an assessment of the building and its fire protection systems' performance usually is made. The assessment involves a review of building and fire codes, looking closely at specific code provisions to see how they affected the outcome of the incident. The World Trade Center (WTC) bombing incident provides a case study for such activities.

The Port Authority (PA) of New York/New Jersey, a bistate agency, is not required to comply with the building and fire prevention codes of New York City. However, a review of fire department records reveals that the department has had a long-standing relationship with the PA concerning life and fire safety conditions at the WTC. This relationship dates back to the design and construction phases of the WTC and includes a joint protocol, signed in 1986, for inspection activities.

Despite the fact that the PA is not required to follow local codes, the WTC, on February 26, 1993, was in substantial compliance with New York City's Local Laws (LL) 5, which went into effect in 1973, and 16, which became effective in 1984, which address life and fire safety in high-rise office buildings.

FIRE PROTECTION/CODE COMPLIANCE

Immediately following the bombing incident, I was assigned to analyze WTC Buildings 1 (Tower 1), 2 (Tower 2), 4, and 5. In April, I prepared a point-by-point analysis of these buildings' compliance with LL 5 and 16. Following are synopses of the major findings contained in the report.

Noncompliance Areas

The major areas in which the WTC was at variance with city requirements (and the subsequent corrections) are the following:

Lack of fire command stations (FCS) in each building. Prior to February 26, 1993, a centralized FCS for buildings 1, 2, 4, 5; the concourse; and subgrade levels was located at the B-1 level in the Operations Control Center.

Fire control stations presently are being installed in the lobbies of Buildings 1, 2, 4, and 5. An FCS, which will cover the concourse and subgrade levels, will be installed in the concourse level.

Lack of manual pull stations at each exit in Tower 1 and 2. At the time of the bombing, a combination voice/manual station was located in a corridor only near Stairway B.

Six new approved "Class B" fire alarm and communication systems to service Towers 1 and 2, Buildings 4 and 5, and the basement and concourse levels are being installed. They will provide

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for a manual pull station at each exit. All systems will have been decentralized and separate control centers located in the lobby of each high-rise building, and these stations will be staffed 24 hours a day. Although all six systems will have separate detection capabilities, each system will be able to provide voice communications and strobe-light activation for all of the complex's systems.

Access stairs unenclosed for more than two stories (nonegress convenience stairs). Code permits access stairs to be unenclosed for not more than two stories. Several locations exceed the two-story limit.

These locations are now protected by closely spaced sprinklers in combination with draft stops, per National Fire Protection Association (NFPA) 13, **Installation of Sprinkler Systems**.

Areas Where WTC Requirements Exceeded New York City Code Requirements

WTC requirements exceeded those stipulated in the NYC code [LL 5/73, *Fire Safety Office Buildings* (27-4267, *Fire Prevention Code*)] in the following areas:

Emergency power for exit lights and signs. Existing buildings (prior to LL 16/84) are permitted to use battery storage equipment or emergency power sources. However, circuits separate from the general lighting and power circuits taken off ahead of the main switch also may be used. The WTC had emergency generators as the power source and, since February 26, 1993, has additionally installed battery-powered capacity.

Additional emergency power capacity. Emergency power to fire and booster pumps, at least three elevators at one time, alarm systems, communications systems, and emergency lighting were in place prior to the bombing.

However, under the code, existing buildings are not required to provide emergency power, except as in No. 1 above. WTC is an "existing" building (prior to LL 16/84) and need not comply.

Compromised by the Explosion

The explosion damaged or destroyed several fire safety features within the WTC complex, including the following:

Fire alarm and communications systems. Feeders connecting the Operations Control Center at the B-1 level with the fire protection systems in Buildings 1, 2, 4, and 5 ran through the subgrade levels destroyed by the explosion. As a result, the fire alarm signal and communications systems were rendered inoperable.

Standpipe and sprinkler systems. The looped water main supplying the standpipe system for Buildings 1, 2, 4, and 5; the concourse; and subgrade levels was damaged. However, water from gravity tanks, fire department pumpers, and city connections permitted the standpipe system to be used during extinguishment.

The sprinkler piping in the explosion area was damaged, affecting protection in the subgrade area. The above-grade piping subsequently was isolated, restoring systems to serviceability.

Fire pumps in the subgrade levels. These pumps were damaged. During a survey of building systems, the gravity tanks in the towers were found to be empty. A fire department pumper was used to refill tanks, thereby providing a source of water for systems in the towers.

However, fire pumps supplying buildings 4 and 5 were not restored for 10 days.

Emergency generators. They operated for a short period and then shut down due to lack of cooling water, caused by the damage to the piping.

RESTORATION PROCESS

The compromising of the fire protection systems in Buildings 1, 2, 4, and 5 made it necessary to strictly control all movement of personnel into these areas. The fire department, in consultation with PA personnel, established minimum requirements for controlling movement into these buildings.

A deputy chief was assigned as an on-scene coordinator between fire department and PA personnel. Many issues were resolved without the need to refer them to higher levels. When necessary, the coordinator served as a liaison between high-level fire department commanders and the PA.

Fire Department Command Post

A fire department command post was established on the WTC concourse level. It was staffed 24 hours a day for approximately four weeks. Battalion chiefs experienced in high-rise operations and having an intimate knowledge of the WTC supervised day-to-day fire department operations. In many cases, they were able to resolve day-to-day issues without referral to higher levels. The command post provided continuity; a log book recording day-to-day operations was maintained there. The following records were maintained: the arrival and departure of units; the status of the fire protection systems; and the movement of tenants, cleaning personnel, etc. into the towers.

Command post personnel, in consultation with PA personnel and law enforcement agencies, established the protocol for controlling fire department personnel. A fire department presence was necessary near the explosion area to control the many minor fires caused by torch operations. However, movement into the blast area had to be controlled and monitored so that the crime scene would not be compromised.

Command post personnel monitored housekeeping conditions during restoration operations and consulted with the PA concerning fire protection/prevention matters in general, particularly hazardous operations.

Commodities Exchange Center

Buildings 4 and 5 of the WTC requested permission to open for business on the Monday morning following the explosion. Since the fire protection systems (standpipe/sprinkler pumps, fire alarm, and communications systems) in the building were down, it was necessary to survey them and establish criteria for providing an acceptable level of protection. Roving fire guards (certified by the fire department) were stationed throughout the buildings, and a reserve pumper to supply the standpipe and sprinkler systems had to be dedicated to each building. Both buildings opened on Monday morning.

Cleaning Personnel

Hundreds of cleaning personnel were present on various floors (prior to restoration of the fire protection systems). Their movements had to be strictly controlled. Records of their locations were maintained in the building lobby and at the fire department command post. Personnel moved from floor to floor in one group, accompanied by a fire guard. Stairways were monitored by roving fire guards, who each were equipped with a PA radio and bullhorn and an emergency pack, which included emergency flashlights. Fire guards similarly equipped would be alerted to an emergency and they, in turn, would use the bullhorn to summon personnel.

HIGH-RISE PROGRAM

The fire commissioner and his staff, with the assistance of Frank McGarry of the New York State Department of State Bureau of Fire Prevention, submitted a proposal for Federal funding to address the issue of "Fire preparedness in high-rise fires and emergencies." Among topics included in the proposal are establishing effective lines of communication within the incident command structure at the fire scene, educating employees working/living in high-rise structures, instructing municipalities nationwide on the appropriate fire operations to employ at a high-rise fire, and examining and evaluating the impact of such programs on fire safety.

RECOMMENDED ADDITIONS/ENHANCEMENTS

At a meeting with NYC Fire Commissioner Carlos Rivera, FDNY fire chiefs, and other fire department personnel in the days immediately after the WTC explosion, Stanley Brezenoff, executive director of the PA, committed the PA to "implement all findings for the improvement of safety systems and procedures made by the fire department." The introduction of safety systems was reviewed with the fire department. The areas in which the WTC was at variance with city codes also were addressed to the satisfaction of the fire department, as previously mentioned.

The fire department reviewed the enhancements proposed by the WTC to provide additional redundancy to correct the problems — such as the lack of communication and information and the lack of light, especially in the stairways — that surfaced at the time of the explosion, causing occupant concern.

In accordance with the training they had received, WTC occupants expected to hear instructions via various communication methods during the emergency and to see lights indicating the means of egress. Neither was available. They were forced to make decisions while functioning in an information vacuum.

The following enhancements for improving fire/life safety have been made in the WTC complex:

- Installation of a city-approved Class E fire alarm/communications system, including the installation of fire command stations for each building (1, 2, 4, and 5), the concourse, subgrade levels, and secondary command stations in the sky lobbies.
- Expansion of the public address system into tenant areas, including replacement of the "whoop" signal. The system previously served only corridors and stairways.
- Magnetic reentry locks that automatically release when power is lost.
- An FM wireless communications system that will provide emergency communications between fire command stations, lobbies/sky lobbies, and stairwell reentry floors. The system might be extended to each stairway, elevator cars, and other critical areas such as fire pump and elevator machine rooms.
- At the time of the bombing, all elevators were equipped with phase 1 and 2 capability. Elevator modernization to include installation of a three-position key switch that includes a "hold" position in all elevators is taking place.

- Emergency power for smoke purge fans.
- An additional power source from New Jersey's Public Service Electric & Gas utility via PATH (rail system) facilities through to the Consolidated Edison (power supplier for the WTC) distribution system. Excess power provided by the emergency power source possibly could be made available to tenants as standby power.
- Installation of an antenna system (Channel 7-FDNY handheld radios) to improve fire department communications. Recent field tests of the system in the entire complex proved highly successful.
- Installation of phosphorescent signs in elevator cars (indicating the car number and intercom button) as well as in exit stairwells to identify reentry points and exits from the stairwells.
- Accelerated rate of sprinklerization of nonsprinklered floors. Nonsprinklered floors in Tower 1 must have asbestos removed before sprinklers are installed. There is no asbestos in Tower 2. (At the time of the explosion, 1 WTC had sprinklers in 98 percent of the building — including all below-grade areas — and 2 WTC had sprinklers in close to 90 percent of the building — including all below-grade areas.)

Note: Floors not fully protected by sprinklers have certain areas (storage rooms, janitors' closets, for example) in the core protected by sprinklers.

- As discussed earlier, access stairs (nonegress interior convenience stairs) not in compliance with 27-375(i)(2) of the NYC Building Code were provided with enhanced protection is specified in NFPA 13 (installation of 18-inch deep draft stops and closely spaced sprinkler heads around stair openings). Immediate emphasis was placed on stairs that penetrated three or more floors.
- Battery-pack light fixtures in elevators and stairways as a backup to emergency light fixtures supplied by emergency generators.
- "Vertical patrol" personnel to check for safety of stairwells and corridors (including fire safety checks).

CODE IMPLICATIONS

The WTC incident reinforces the fact that many government buildings are not required to comply with local codes. This could lead to a lack of standardization in building construction and fire protection systems. No inference is made that such buildings do not use recognized national standards. (WTC sprinklers were installed according to NFPA 13, referenced in the NYC Building Code.) Local codes, however, provide a "systems" approach to life and fire safety. Agencies free to choose piecemeal from national standards and codes might not produce a "systems" approach. To address this situation, the city will be submitting legislation requiring that local codes be followed.

The city has established a code committee, which includes representatives of the applicable city agencies and the private sector, to identify the changes needed, especially since existing codes do not consider terrorist acts. The committee will research ways to guard against an explosion's incapacitating a building, such as having an emergency power source established at a remote location.

The fire safety areas of the applicable codes will be reviewed to explore the availability of technological advances that would make buildings safer and the need for additional safety systems.

Proposal for Federal Funding to Address Fire Preparedness in High-rise Fires and Emergencies

After the World Trade Center bombing, the City of New York Fire Department, in consultation with the New York State Department of State Bureau of Fire Prevention, submitted a proposal for Federal funding to address fire preparedness in high-rise fires and emergencies. The major components of the proposal, estimated to cost around $9.75 million, are as follows:

Mobile command post (MCP). The center would provide information that would allow the tactical field commander to deploy units effectively and efficiently and to keep pace with evolving threats and missions as operational requirements dictate.

The MCP consists of the following four major subsystems: computer system, external communications, power, and vehicles.

Other conmusnicadon needs. FDNY has secured "talk group" on the citywide 800-MHz trunked radio system. It is seeking additional "groups" to permit a dedicated tactical channel and administrative common frequency for routine operations. Existing VHF frequencies would be allocated for fireground use.

High-rise fire safety course for building employees. The objective of this proposal is to have 30 FDNY lieutenants trained in the provisions of local Laws 5, 16, and 58, which cover the required fire safety features in high-rise buildings and the basics of fire safety pertaining to these buildings, so they can instruct building employees in fire safety and ultimately evaluate building employees' abilities to perform effectively in emergencies on an ongoing basis.

High-rise fire command and management course. Chief officers across the nation would be prepared to effectively organize, manage, and control high-rise fires using a combination of classroom lectures, on-site observations, and interactive simulations. Instruction areas would include how to implement an incident command system and how to most effectively use a building's fire defense, fire suppression, communications and command, and transportation systems.

The WTC and National Codes

by Glenn P. Corbett

In all likelihood, national code-writing bodies will examine the WTC bombing incident very closely. The review of revelations arising from the WTC incident need to be addressed as new code provisions, as well as verification of inadequacy/inappropriateness of existing code text, will be a necessary charge of a national code-analysis committee.

Redundancy of fire protection systems. The need for a multilayer approach to fire protection is quite evident. "Backup" features are important, since we don't get a second shot. For example, normal lighting fixtures are backed up by emergency lighting fixtures powered by emergency generators, which, in turn, are backed up by battery-pack light fixtures. Cost concerns pale when the effects of the absence of such redundancy become strikingly apparent during an incident.

As a related issue, a proper mix of "passive" and "active" fire protection features are called for. A building with totally automated fire protection equipment places great reliability requirements on the equipment.

Fire safety and security. Fire safety and security issues are becoming increasingly intertwined. In some cases, fire safety and security concerns are not in agreement. Model building code organizations must tackle this "hot potato" — it won't go way.

Defend in place strategy. The high-rise "defend-in-place" strategy canonized in fire protection texts failed during the WTC incident when building occupants began to self evacuate. Human behavior characteristics must find their way into the model codes. People do not always react as we would like them to.

Stairwell design and use. Numerous issues concerning stairwell design and use at the WTC must be addressed. Stairwell widths were inadequate at certain points due to occupant overload caused by multiple-floor evacuations. Do the model building code stairwell requirements anticipate large portions of buildings or entire buildings being evacuated? Do the stairwell provisions take into account the types of people using the stairs and their differing rates of descent?

Continuity of stairwell egress paths is important — the stairwells should provide a continuous path directly to the outside. Model building codes allow for discharge of 50 percent of exit stairwells into a fully sprinkler-protected office building lobby. How about when the lobby is heavily charged with smoke, as in the case of the WTC?

Terrorist design issues. Building codes should consider acts of terrorism in the design of "significant" buildings. Such design requirements could include glazing specifications, separation of critical building equipment (emergency generators and wiring for public address and alarm systems, for example), building access, and other features affecting safety and operations. Some terrorism issues directly involve/affect fire protection features.

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Evacuating People with Disabilities

by Edwina Juillet

In the confusion and alarm of a terrorist bombing, how does a deaf person interpret emergency instructions? How does a 250-lb. man with quadriplegia whose wheelchair weighs 100 pounds get down the stairs? How do people with such medical conditions as asthma, heart problems, and a history of blackouts cope with the enormous stress of an emergency evacuation through a smoke-filled environment?

Representatives of the National Task Force on Life Safety and Persons with Disabilities and the City of New York Fire Department, with the resource assistance of the Port Authority of NY and NJ, interviewed 27 people with disabilities who were evacuated from the World Trade Center complex after the bombing, as part of a postincident evaluation. Of those interviewed, 14 had mobility impairments, three had impairments of sight or hearing, three were pregnant, two had cardiovascular problems, and seven had respiratory problems.

EVACUATION TIME

On average, the 27 interviewees with disabilities took 3.34 hours to complete evacuation. Evacuation times ranged from under one hour to more than nine hours. A person on the 19th floor, who has left hemiplegia and wears a leg brace and uses a cane, reported an evacuation time of under one hour. When interviewed, he explained that he made it down to the 5th floor via stairs and then began to experience leg cramps and dizziness. He was carried down the rest of the way.

Five people reported evacuation times of between 40 and 90 minutes. A deaf person on the 71st floor reported he first was alerted to the emergency when his computer lost power. He did not hear or feel the explosion but observed coworkers' reactions. He learned from a deaf coworker that there was smoke and evacuated via stairs.

A man in a wheelchair with a bilateral above-the-knee amputation reported the longest evacuation time: more than nine hours to get down from the 70th floor. He reported that he chose not to evacuate — based on his concern over the issue of liability and his coworkers' lack of experience — but rather to wait for emergency personnel. His manager and a few coworkers remained with him. As the smoke grew denser, they retreated farther back into the offices. They waited one hour and tried calling Port Authority police, but the lines were busy. At 4:30 p.m., a scout patrol arrived and called for help on a hand-held radio. The first police officer arrived two hours later. At approximately

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This article was written in collaboration with Bill Scott, founder and president of Abilities Unlimited, Inc., a disabilities issues consulting firm, and Marianne Cashatt, a longtime disabilities awareness and public relations consultant.

8:30 p.m., police and emergency personnel arrived and carried him down to the 43rd floor staging area. They rested there and then carried him the rest of the way. An emergency responder carried the wheelchair down separately so once at the bottom the man could, in his own words, "resume his mobility."

Four interviewees reported evacuation times ranging from five to nine hours. One man on the 69th floor, a wheelchair user with quadriplegia, estimated his evacuation time at a little more than six hours. He reported his experience: "Everyone evacuated except my manager and the fire warden. We went to an executive office where there was no smoke and waited for about 45 minutes. Then we went into the stairway, where I commandeered three men coming down the stairs who carried me and my wheelchair [combined weight, 350 pounds] to the 48th or 49th floor. The smoke got worse and the heat increased as we descended, and then the lights went out permanently. The stair landings were very narrow and seemed to switch from one stairwell to another. We got down to the 43rd floor, and I was transferred to a stretcher and carried the rest of the way out. It took approximately 15 people taking turns to carry me down. It was a very slow process. But I heard no one complain about the delay due to my evacuation."

LESSONS LEARNED

1. **Breathing difficulties.**

   Neither the emergency personnel nor the people with respiratory difficulties considered what emergency procedures should be in place to deal with problems of pulmonary function disorders. Seven people interviewed described respiratory difficulties, explaining that the onset of symptoms can be triggered by stress, exercise, dust and smoke, or any combination.

   One person reported the following experience: "I have severe asthma. I was very fearful about going down stairs into smoke. My asthma was aggravated by respiratory conditions, not stress. I shared my medication with other asthmatics. I was not sure that I would be able to survive the ordeal. The emergency medical division did not have any of the medications I needed; *asthma was not treated as a life-threatening disability.*"

   One interviewee said: "I have severe asthma and chronic bronchitis. I left my medication in the office. I got nervous and upset as my asthma worsened while descending through the smoke-filled stairway. I was directed to the 43rd floor, where other people with disabilities were located. I also exited the stair at a floor where the air was better; the windows had been broken. Someone shared an inhalator with me."

   Another person related the following: "I have difficulty breathing due to pneumonia I had in 1991. I cannot walk fast and did not request any assistance. I encountered heavy smoke in the 50-plus stairways. I was instructed to take a wet cloth and cover my nose. On the 13th floor, I felt air and saw light. I may have been better off staying in my original location."

   The American College of Chest Physicians and the American Association of Respiratory Care can assist in developing emergency medical procedures for people with breathing disorders for inclusion in the emergency management plan.

2. **Confusion on the stairs.**

   Lack of familiarity with the stairs caused a number of problems. One person noted that she stumbled at the stair landings in the darkness, in part because the handrails did not continue the full length of the stair flight. Other complaints involved not being aware of the following: the existence of interior convenience stairs; no reentry from the stairway for security reasons (the locked doors frightened many people); and "crossover" or extended landings, which, given the poor-visibility conditions, made people fear they might be trapped (some crossovers extended 50 feet and required going through a door).

One person reportedly counted out loud the number of steps as people were using them to evacuate. This let visually impaired people know what to expect and was said to have a calming effect on them. This is also how it was discovered that the flights of stairs had inconsistent numbers of steps, adding to the confusion of some with disabilities. (We later went into one of the stair towers to see what was being described. At our point of entry, there was a flight with 11 steps followed by flights with six, eight, seven, nine, and five steps; followed by a crossover measuring approximately 20 feet separated from the next flight by a door; followed by flights of six steps, 13 steps, and so on.)

Some people kept one hand on the handrail for guidance and support and the other hand on the shoulder of the person in front of them for support and to avoid stepping on that person's heels.

3. Poor visibility.

When the lights went out, one deaf person could not receive instructions during the stair evacuation. In the dark, he was unable to lip-read or use sign language. He reported that if he had had a small flashlight he could have illuminated a speaking person's face and lips, enabling him to "see" what the person was saying. He also has begun teaching sign language to his coworkers and has suggested emergency personnel recognize basic signing.

Overall, coping behavior seemed quite remarkable in the face of having to evacuate down flights of stairs that no one had seen before and at times in total darkness and in the presence of smoke.

4. Wait for help to arrive.

In hindsight, many people interviewed admitted that if they had had some reassurance from qualified individuals (police, firefighters, WTC security) that help was on the way, they would not have evacuated within minutes of the blast but would have waited for emergency personnel to assist in their evacuation. However, in the absence of communications by authorities, they gladly accepted assistance — from colleagues and even from complete strangers — in evacuating. These caring groups of people who assisted the disabled protected their "charges" until they were safely evacuated and moved away from the building.

5. Not part of emergency plan.

Prior to the incident, some of the people interviewed said that in the interest of privacy or because they felt they did not need special assistance, they had opted not to identify themselves to be among those listed as disabled in the emergency management plan.

6. Phoning home.

Some of the interviewees were able to call home and give news of their safety. This alleviated the anxiety of friends and relatives as well as of the evacuees themselves. It also may have reduced the traffic of incoming calls and may even have prevented some distraught families from going to the WTC in person.

Vulnerability of Buildings to Blast Damage and Blast-Induced Fire Damage

by Ronald J. Massa

The popular conception of an explosion, as depicted in TV action movies, generally is more dramatic than accurate. The big fireball, resulting fire, and apparent chaos at the blast scene do not accurately characterize the high-explosive detonations of materials such as TNT or C-4.

First, building fires usually are not a dominant effect of high-explosive detonations. If the detonation occurs outdoors, in a well-ventilated area, the hot gases from the initial detonation rarely ignite anything, although they can cause charring of nearby materials. If an explosive is detonated outside but in a car (i.e., a car bomb), the result will depend on the size of the explosive. The expanding hot gases from smaller (lower charge weight) explosive detonations will ignite flammable materials in the car, such as upholstery, fuel, and tires. The smaller explosive charges will do less mechanical damage to the car and often will result in a concentrated fire within the confines of the vehicle. As the charge becomes larger, more mechanical damage will be done to the car, and fire effects will be less concentrated. For example, expanding gas pressure will propel the engine and transaxle apart from the rear axle and wheels, and relatively small fires will appear as a number of the car's components come to rest at (perhaps) widely separated locations.

Unless the detonation is specifically designed to be incendiary, only locally available combustible materials will be ignited. The particular difficulty with explosion-induced fires is that ignition can occur at almost the same time at widely separated locations because the hot gas cloud expands and propels ignited or ignitable objects away from the center of the blast.

Building fires generally are not an issue when explosive detonations occur outside of buildings. And except in cases where detonations are incendiary in nature, building fires generally are not a major issue when detonations occur inside of buildings. Interior explosion-induced fires generally are caused when something within the building is ignited by the explosion. The problem is like the ignition of gas lines in an earthquake — the earthquake's mechanical effects themselves do not directly cause fires.

When the detonation occurs inside a building *and* in a confined and fuel-rich space, such as in a parking garage, the hot gases from the detonation cannot expand freely to mix with an ever-increasing volume of cooler air. The shock effects and mechanical damage from the explosion will overturn

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vehicles, fracture gas tanks, break pipes, and breach walls, exposing a variety of materials to the hot gas cloud. Many of these will ignite, generally on the periphery of the affected space, where the expanding gas causes the least local oxygen deprivation.[1] Thus, suddenly the detonation will spawn many separate fires. From that point on, the building will respond as it would had each of the fires been set with a match. However, if the building were severely damaged by the blast, life safety systems may be incapacitated, gas lines severed, and electrical systems disturbed, all of which will increase the fire vulnerability of the building.

All things considered, while severe explosion-induced fires are unlikely from exterior detonations, interior detonations, particularly those in confined, fuel-rich spaces, frequently result in fires that are exacerbated by damaged building systems. Whether inside or outside, blast effects such as shock waves, expanding gas, and heat frequently dissipate within a second.[2] Discreet fires ignited in this interval generally will require a much longer period (typically several minutes) to become serious building fires.

Unfortunately, there are other adverse factors to consider. Ignition at many locations simultaneously and damaged life safety systems already have been mentioned. But the blast also may blow out windows, providing undesirable venting to the fire. If the detonation is a "dirty" one, using a low explosive or smoke-producing components, toxic smoke can be rapidly propelled throughout the structure, creating an instant, additional hazard to building occupants at locations where they are safe from the direct effects of the blast.

PRECAUTIONS AND PREPLANNING

All of these issues make it desirable to assess the expected performance, in response to both blasts and blast induced fires, of major habitable structures before such incidents actually occur. The tools to sort out the apparent chaos of a blast scene and determine specific damage to buildings arising from credible — but hypothetical — attacks exist. BombCAD, for example, is a computer software that permits the user to model a building or complex of buildings and then expose the computer model to a specific interior or exterior detonation. BombCAD makes detailed predictions of blast damage and human injury.

These estimates can be graphically presented on a window-by- window, wall-by-wall, space-by-space basis. Special computation routines concentrate on specific damage aspects, such as glass damage from exterior bombs, the dominant source of damage, and injury from terrorist bombs. Analyses made with BombCAD will define the precise circumstances (explosive type, weight, and location) that result in no damage, specific glass damage, specific surface damage (wall, floor, or roof), or potential structural collapse from a particular bomb detonation.

[1] Local oxygen deprivation caused by high-explosive detonation actually is a method commonly used to extinguish oil well fires and other fires that cannot be effectively extinguished with water and chemical suppressants.

[2] Shock waves travel typically at several times the speed of sound (about 1,100 feet/second). Thus, an unconfirmed shock wave is about 1,000 feet from the detonation point in a second. The expanding gas moves more slowly, at about the speed of sound, but both its temperature and pressure drop with the volume of ambient air into which it expands. A 10:1 volume increase decreases the maximum gas pressure by about 10:1 as well.

Generally, building structure types can be classified in terms of vulnerability to a bomb blast. These types, from most vulnerable to least vulnerable, are the following:

- wood-frame,
- ordinary construction,
- reinforced concrete, and
- steel frame.

BombCAD's gas expansion routines also predict smoke transport potential for blast products as well as initial conditions for stack-effect calculations and other conventional fire and smoke transport modeling tools. Ultimately, BombCAD will incorporate fire-related analysis routines. The resulting resource, FireCAD, will permit both explosive and fire effects to be modeled separately and collectively (when they arise from the same source).

Today, the hopeless chaos routinely depicted on TV at blast sites is only a characteristic of the rubble. The ability to analyze and minimize the consequences of such events is neither hopeless nor chaotic.

Protecting Buildings Against Terrorism

by Eve Hinman and Matthys P. Levy

Although the probability of a terrorist attack is low, the cost of such an attack can be extremely high, as the incident at the World Trade Center (WTC) shows. In that case, the tally included lost rent for an extended period, relocation costs for tenants, costs of emergency around-the-clock structural repairs and debris removal, contending with numerous federal agencies, insurance claims, and lawsuits.

For management of commercial and public buildings/institutions, the risk-benefit analysis of terrorist attacks can pose a dilemma: What level of protection is appropriate for an event that is highly unlikely yet undeniably devastating? For these buildings, easy entry and egress, free circulation of pedestrians and vehicles, and an attractive and open environment are important for doing business. Security measures seem antithetical to these requirements and bring to mind a bunker or prison without windows surrounded by guards and walls. However, it is possible to work effective and economical security into the design of a modern-day commercial building in a manner that can minimize its intrusiveness. Although it is easier to implement a security system during the design stage of a new building, much can be done to renovate existing buildings to provide increased protection.

Security measures may reduce the chance that attack will occur simply by making a building an unappealing target. And they provide the added benefits of increasing the feelings of confidence and morale of those working there.

On the other hand, security measures that are too intrusive could decrease employee morale and business by making access to the building difficult. They also could cause a potential terrorist to escalate the level of attack to match the level of protection provided. The challenge, of course, is to provide an effective design that does not interfere with the fundamental functions of the building or attract too much attention.

Providing protection against a particularly devastating threat, such as a car-bomb attack, inherently provides protection against a wide range of other, lesser threats as well. However there always will be some threats against which we will be unable to protect ourselves, such as that posed by a nuclear weapon. Also, depending on the current fashion among terrorists, such threats may change during the life of the building.

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DEFINING THE THREAT

The first step in developing a balanced security design is to clearly define the target and the threat scenario. Depending on the building, the threat of most concern could be a car bomb in an underground parking garage, such as was the case at the WTC; a letter bomb in the mail room; or a briefcase bomb in the lobby or corridor. Typically, places that are easily accessible to the public are the most vulnerable. On the other hand, depending on a building's function, the target could be the control center where the communication and emergency power lines of a facility converge. Clearly, these vital functions should not be placed within easy access of the public and should be in a protected environment.

When assessing the vulnerability of a building to terrorist attack, look for the weakest link in the building's design, such as lack of controlled access or underground parking. What is the most accessible place where a terrorist could cause the greatest devastation? The lobby? The elevators? The toilets? Although a building cannot be made completely terrorist proof or bombproof, there are ways to make it more difficult to execute certain types of attacks. By reducing the chances of the most devastating types of attack, such as a car-bomb attack, the threat can be reduced to a manageable level. For instance, prohibiting vans from parking in underground parking garages will limit the size of a potential explosion to that caused by the amount of explosives that can fit in a smaller vehicle. Weighing vehicles can further control the possible size of the weapon. The use of dogs to screen packages at airports is another example of how the size of potential explosions can be limited.

DESIGN OBJECTIVES

Once the threat is defined, you must establish your design objectives. Is your primary objective to protect people, functions, or the contents within the building? Typically, a combination must be considered. In a building such as the WTC, for instance, where thousands of people work and thousands more come and go during the course of the day, the primary objectives may be to save lives, reduce injuries, and facilitate to evacuation and rescue. A secondary objective might be to regain function of the building as soon as possible after an attack, and a tertiary objective might be to reduce the damage to equipment and contents within the building. For another facility, such as a communications or power facility, where employees are few but the loss of function could affect millions, the primary objective may be to regain the function of the facility as soon as possible or at least to be able to shut down safely after an attack. For a storage facility, clearly the primary focus is to protect its contents.

One of the most effective ways of providing a balanced security design is to provide several layers of protection between the attacker and the target. This "onion-skin" approach has several advantages. It deters an attacker by making the building a less appealing target. It physically distances the attacker from the target. It provides redundancy, so that if one line of defense fails, others are still in place. It provides delay time, enabling the mobilization of security forces to stop the attack before it occurs or mitigate its effects by causing it to occur under less than ideal conditions for the attacker.

If all else fails and an attack occurs despite all precautions, the last line of defense is walls, floors, and a framing system designed to resist the effects of a certain level of explosives. A blast-resistant building still will require structural repairs after an attack, but the damaged area will be more localized than if no structural protection had been provided. If structural damage is limited, the volume of debris will be reduced, facilitating the rescue of persons trapped underneath the collapsed portions of the structure and expediting repairs.

OPERATIONAL AND PHYSICAL COUNTERMEASURES

Two types of countermeasures can be employed to contain an attack — operational and physical. Operational countermeasures are those that require human intervention. Physical countermeasures are architectural or structural devices built into the facility they do not require human intervention to operate. An integral security design uses both types of countermeasures to provide protection to the building, requiring the integrated effort of several types of specialists — security specialists, planners, architects, and engineers.

One example of an operational countermeasure is stationing guards at a building's access points to inspect packages and vehicles. Other examples include electronic devices such as closed-circuit surveillance TVs, intrusion-detection devices, metal detectors, and automated barricades, all of which need monitoring.

Physical countermeasures include strengthening the structural components discussed previously, but they also include providing architectural devices that help facilitate operational countermeasures and useful obstacles to keep a potential terrorist from easily accessing the intended target. Such obstacles include guard booths, inspection stations, perimeter fences or walls, bollards and planters on the sidewalk, and fountains or staircases at critical entry points — all of which work to keep vehicles from getting close to a building. Other physical countermeasures include providing off-site parking or arranging for the vital internal functions of the building to be placed away from easily accessible areas.

Because many injuries during car-bomb attacks are caused by broken glass from windows, it is worthwhile to give some attention to a building's window design. Smaller and fewer windows will reduce this risk; however, this approach is often unwelcome for commercial buildings.

Another alternative is to use tempered glass or glass-clad polycarbonate windows, which are less apt to fail; when they do fail, it is in a less lethal manner. Windows specifically designed to resist the effects of an explosion are another alternative.

Buildings are "forever," but memories of disasters are short-lived. Stories of the World Trade Center blast were front-page news around the world, only to be displaced within a week by the standoff in Texas between Federal agents and David Koresh's Branch Davidians. The initial shock in the wake of an explosion caused by a few radicals is quickly forgotten. The Uffizi Gallery in Florence reopened a month after being gravely damaged by a car-bomb explosion; the St. Paul's area of London was wiped clean of broken glass after an IRA bomb shattered windows across several square blocks; and the World Trade Center and Vista Hotel are now fully functioning, while undergoing continuing repairs and renovations. However, the underground parking garage is closed to transient visitors and may forever remain closed unless foolproof security measures can be devised to prevent the reoccurrence of last winter's disaster. Unfortunately, with the passage of time there comes a return to openness and trust, a quality inherent to the human spirit. However, security and protection can be incorporated into buildings to act as a passive, nonintrusive shield to random terrorism.

Appendix A

Photographs

Photo courtesy of Port Authority Risk Management

Damaged elevator doors and enclosures on the B-2 level presented a vertical channel for smoke spread into Tower 1.

Photo by FDNY Photo Unit.

The scene on West Street within the first hour of the incident. The Vista Hotel is to the far right, and Tower 1 is next to it. The parking garage entrance is visible. Note also the tower ladder raised to the plaza level to remove occupants trapped at that level.

Photo by Arthur Knobloch

A view of the parking garage entrance on West Street, through which first fire companies launched the initial fire attack.

Photo by Robert Knobloch

Firefighters remove a victim of smoke inhalation from the plaza mezzanine level. Two of the three stairways in each tower ended on that level, but with a heavy smoke condition occupants had difficulty finding the exits to the exterior plaza. Forcible entry was required on at least one of these plaza doors in Tower 1.

Photos by FDNY Photo Unit

Above, Chief Anthony Fusco at the command post. Below, he confers with chief officers. Control of any large incident is beyond the capabilities of one person—a flexible and adaptable incident command system is essential.

Photo courtesy of Port Authority Risk Management

A view of the crater from the B-1 to B-5 levels. Noe the steel column. Horizontal supports were destroyed in some cases, but the columns did not give.

Photo courtesy of Port Authority Risk Management

The crater, looking from the B-2 level down to B-5, taken during the investigation/restoration phase.

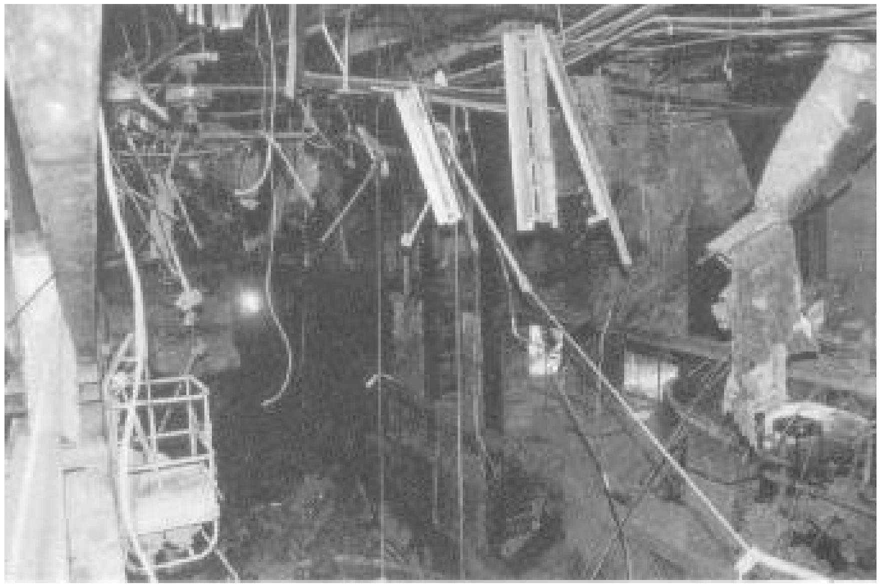

Photo by FDNY Photo Unit

Firefighter Shea's fall was a long one—some 40 feet. The smoke condition in the crater was such that visible contact with Shea was impossible.

Photo by FDNY Photo Unit

Building systems in the vicinity of the blast were destroyed. Here, twisted electrical conduit has landed on top of what was once a car.

Photo by FDNY Photo Unit

The sloping, hanging steel-reinforced concrete floor at the perimeter of the crater was a major hazard for units operating on the crater fire, particularly in the heavy smoke condition.

Photo courtesy of Port Auhority Risk Management

This destroyed office area on the B-2 level is typical of the debris piles faced by searching firefighters.

Photo courtesy of Port Auhority Risk Management

The explosion collapsed a portion of ceiling on the B-5 level onto a PATH train concourse.

Photo courtesy of Port Authority Risk Management

The Port Authority Command/Communications Center on the B-1 level, approximately 50 feet from the blast hole on that level, was damaged and communication with occupants in the towers was lost.

Photo courtesy of Port Authority Risk Management

Emergency generators on the B-6 level. Cooling water lines for these unit were ruptured by the blast, shutting down all emergency power.

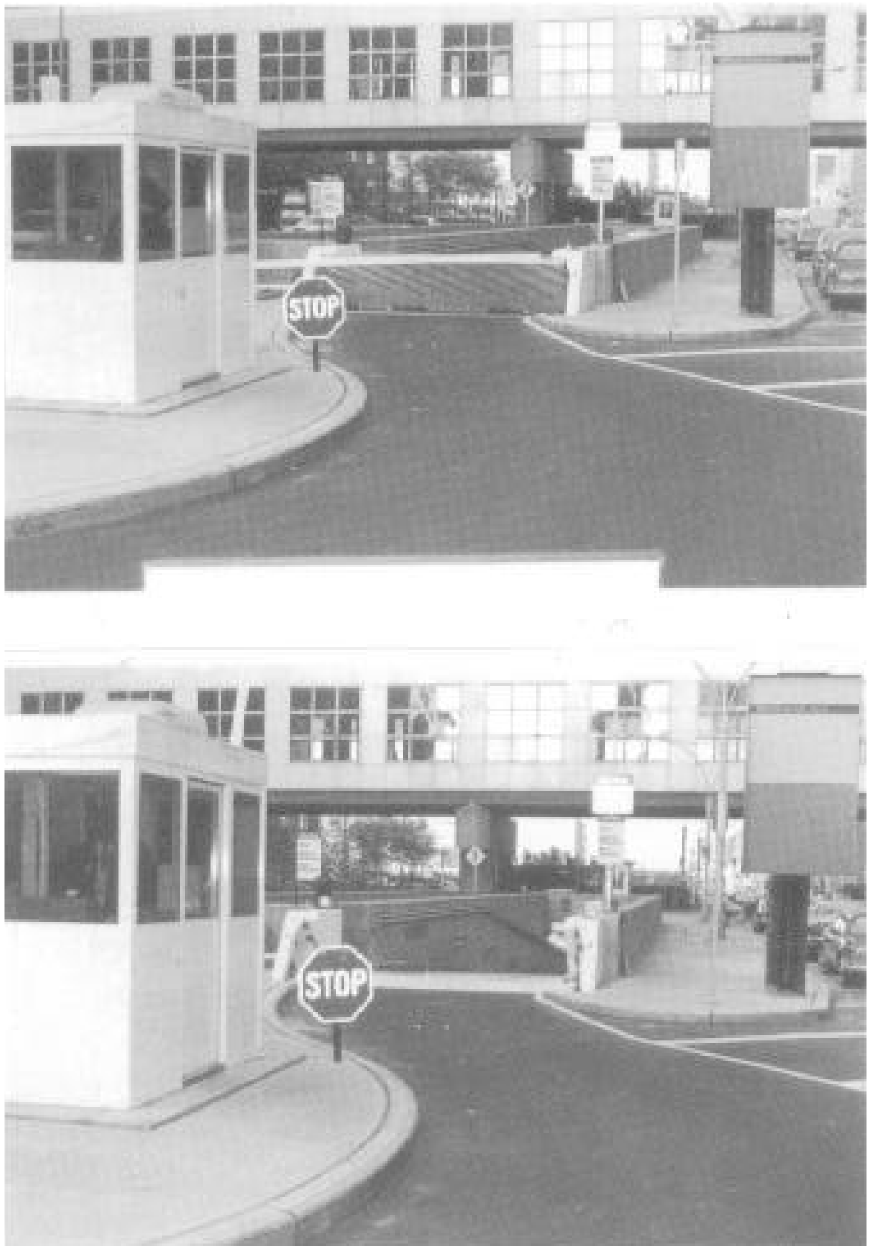

Photo courtesy of Port Authority Risk Management

Controlling access to public buildings is a major concern for building management. After the incident, Port Authority, in addition to many security changes, installed substantial barriers to unauthorized vehicle access. The barrier, controlled by security personnel in the booth, folds down when the driver has been cleared to enter.