

**Federal Building and Fire Safety Investigation
of the World Trade Center Disaster**

**Project #8,
The Emergency Response Operations**

September 13, 2005

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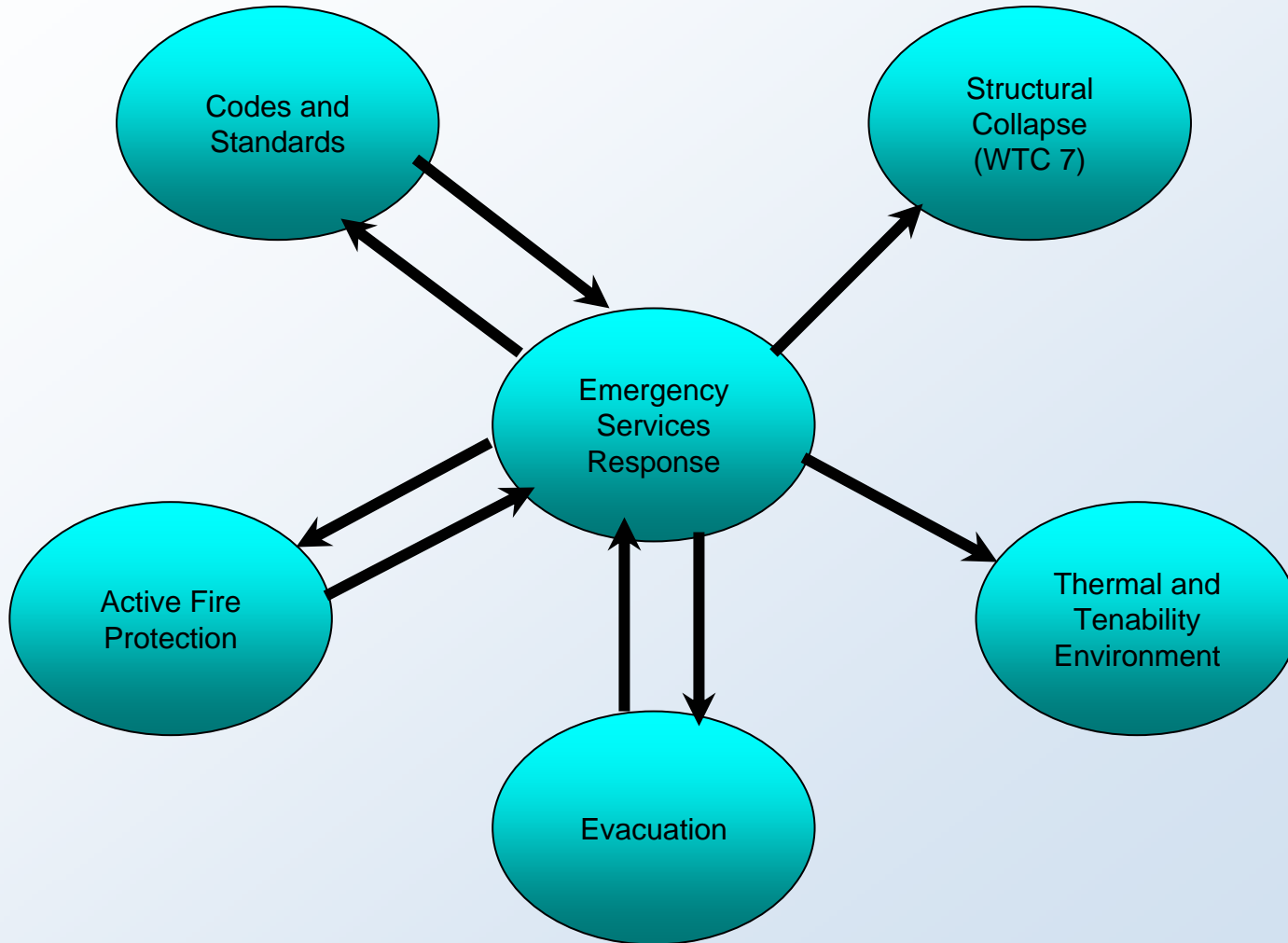
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Interactions With Other WTC Projects



Purpose of Project #8

1. Fully documenting what happened during the response by the fire services to the attacks on the World Trade Center, up to the time of collapse of WTC 7;
2. Identify issues that need to be addressed in changes to practices, standards and codes;
3. Identify alternative practices and/or technologies that may address these issues; and
4. Identify R&D needs that advance the safety of the fire service in responding to massive fires in tall buildings.

Investigative Approach

Collect, Review, and Analyze Existing Data:

- Documentary data: written reports and documents
- Photographic data: photographs and video
- Electronic data: radio and telephone communications recordings
- First-person interview data: FDNY, NYPD, PANYNJ, PAPD and Others

Develop:

- Detailed timeline of events
- Visual representation of disaster site
- Assessment of emergency response factors

Derive:

- Findings
- Conclusions
- Recommendations

Data analysis protocols:

- Fire Fighter Line-of-Duty Death & Injury Investigation, IAFF;
- NFPA 921, Guide for Fire and Explosion Investigation
- Atlas.ti qualitative data management and analysis software

NIST Conducted Interviews: Investigative lead-following protocol

- **Targeted interviews of people with knowledge in the following categories:**
 1. Operational policies and procedures
 2. Dispatch, deployment
 3. Communications
 4. Incident command, control, command posts, fire fighter health and safety
 5. Emergency response equipment and technology
 6. Elevator operations in high-rise buildings
 7. High-rise building operations and procedures, fire fighting, search & rescue before the towers fell, evacuation, roof operations and aviation units

First Person Interviews Conducted

- **New York City**

FDNY Interviews - 68

Command Officers, Company Officers, Firefighters, Rescue Squads, EMS, Communications, Fire Marshals, etc.

NYPD Interviews - 25

Command Officers, Special Operations Division Officers, Communications Personnel, and Aviation Unit Officers

- **Port Authority of New York and New Jersey**

PANYNJ Interviews - 15

PAPD Command Officers, Police Officers, Building Safety Staff, Communications & Vertical Transportation Personnel

- **Other**

Communications, Building Engineers, Fire Safety Personnel and Security Personnel - 8

Total Number of Interviews - 116

**February 26, 1993 Truck Bombing
of the
World Trade Center**

Changes Resulting from the 1993 Bombing

- Office of Emergency Management (OEM) was established to assist with inter-agency operations
- FDNY Incident Command System was upgraded:
 - Addressed the delegation of functions; Command, Planning, Operations, Logistics, & Finance
 - Added Command Staff: Safety, Information, & Liaison
 - Interagency representation at command posts
 - Established a Communications Coordinator
 - Expanded Field Communications Unit operations
 - Added an officer to Field Comm operations
- 800 MHz radios were purchased for FDNY management.

Policy Changes Resulting from the 1993 Bombing

- PANYNJ adopted a policy for implementation of fire safety recommendations made by local government fire departments after a fire safety inspection of PANYNJ facilities.
- PANYNJ adopted a policy for prior review by local fire safety agencies of fire safety systems to be introduced to or modified in a facility.
- PANYNJ entered into an agreement with FDNY which reiterated the above policies and recognized the right of FDNY to conduct fire safety inspections of PANYNJ properties in NYC, provided guidelines for FDNY to communicate needed corrective actions to the PANYNJ, assured that new or modified fire safety systems were in compliance with local codes and regulations, and required third-party review of such systems by a NY State licensed architect or engineer.

Physical Changes Resulting from the 1993 Bombing

FDNY worked with the PA to upgrade WTC fire protection.

- FDNY high-rise radio repeater was installed
- Fire Command Desks installed in WTC 1 and 2
- Elevator intercom system was upgraded
- New Operations Control Center was added to the complex on the B1 level of WTC 2
- Multiple power sources installed for emergency lighting
- New decentralized fire alarm system was installed at the WTC
- Various fire drills were conducted at the WTC and some included FDNY participation

September 11, 2001 Aircraft Attack on the World Trade Center



Role of Each Responding Department on September 11, 2001

FDNY - Established operational control and the Incident Command Post for the WTC operations, conducted evacuation and rescue operations, and fought fires at the disaster.

PAPD - Established security at the WTC and conducted evacuation and rescue operations.

NYPD - Established traffic control, perimeter security at the site, security for command posts, and conducted evacuation and rescue operations inside the WTC. The aviation units supplied observation capabilities and assessed the potential for roof rescue.

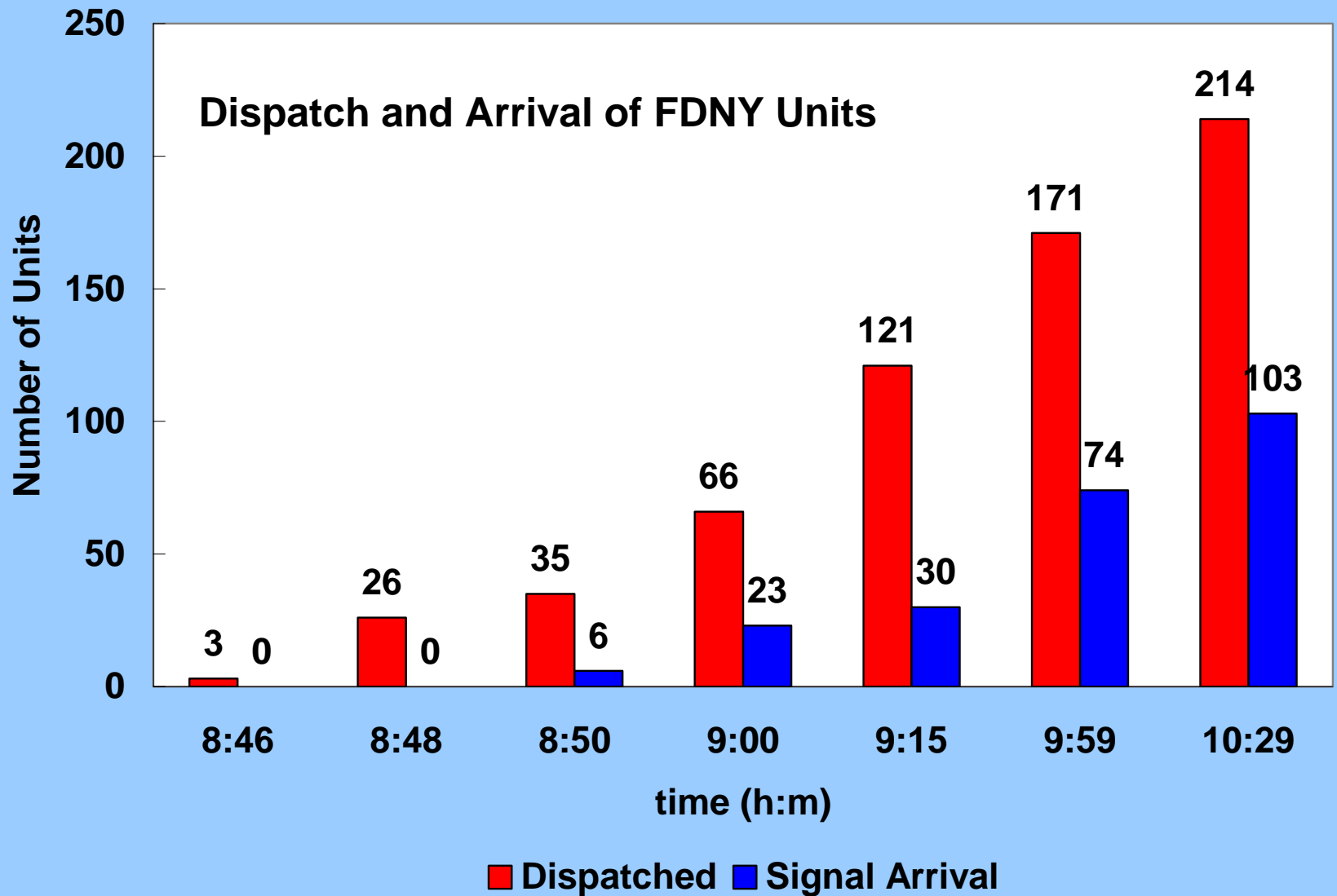
OEM - Functioned as a multi-agency command resource center and provided support for all agencies and departments working at the disaster.

Emergency Responder Operations

FDNY's Initial Size-up of WTC Conditions:

- A large aircraft had hit the WTC 1 building.
- Large fires were burning on multiple floors at and above the impact zone.
- The elevators were not working and people were trapped inside many of the elevators.
- The sprinkler system and standpipe systems were likely compromised.
- It was likely that no water supply was available to fight the fires at and above the impact zone.
- It was likely that many of the occupants trapped at and above the impact zone were already dead or would die before help could get to them.

FDNY Units Dispatch to the WTC



FDNY Operations at the WTC

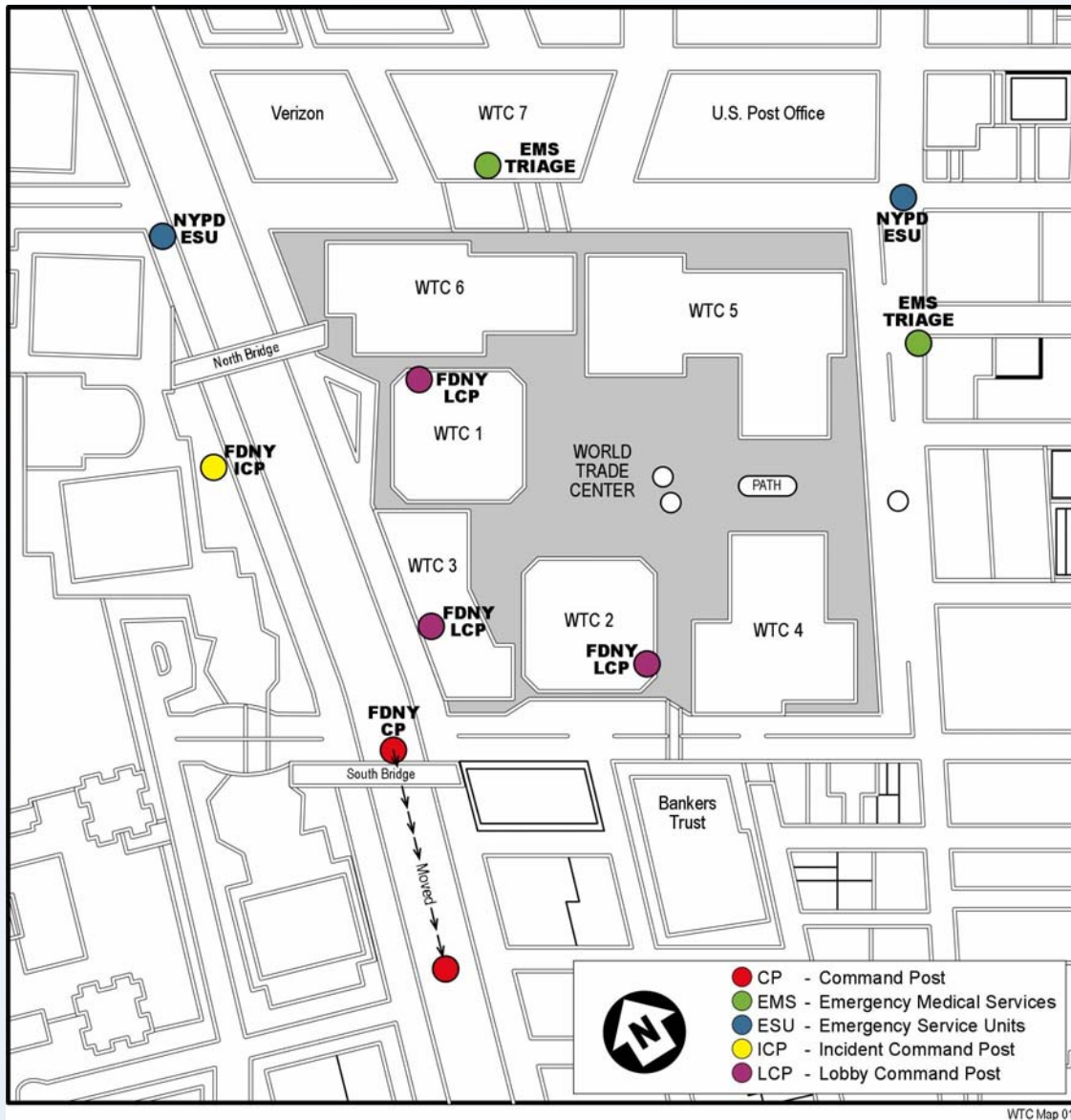
No one interviewed by NIST thought that the WTC towers would totally collapse.

Three operational strategies:

Outside Command Posts & Inside Command Communicating with the Outside Command Post - Fires in the buildings were too large and were located too high in the buildings to accomplish fire fighting activities that could save the lives of occupants above the fires. The objective was to evacuate and rescue all below the fires.

Command Officers for Inside Operations - The fires were too large to extinguish. The objective was to get enough personnel and equipment upstairs to cut a path through the fire to rescue occupants above the fires, and also evacuate and rescue all below the fires.

Company Level Command - Saw this as a conventional but large high-rise fire. The objective was to get up to the fire floors and extinguish the fires. In some cases firefighters were persuaded by higher ranking officers to switch from the idea of fire fighting to evacuation and rescue operations.



Locations of FDNY and NYPD Command Posts

Staging, Assignments, & Personnel Accountability

- Emergency responders generally followed their department protocol related to staging, assignment, and accountability.
- Some freelancing (not officially assigned or directed) was experienced during the emergency response at the WTC complex.
- An Operations Post and staging area was ordered for operations inside of WTC 1. It was to be established by the first arriving FDNY units on the 70th floor of the building.
- FDNY established off site staging areas at different locations in the city for assembling personnel and equipment and for managing units and assignments at the WTC site.
- Many FDNY units assigned to the WTC site did not know which building was WTC 1 and which was WTC 2. The buildings were not well marked.
- FDNY personnel had great difficulty trying to safely get into the WTC towers as a result of falling debris and human jumpers.

Staging, Assignments, & Personnel Accountability

- FDNY maintained personnel accountability on Command Boards located at the lobbies of WTC 1 and 2 and at the Incident Command Post at West & Vesey Streets in front of WTC 2.
- EMS maintained personnel accountability and patient tracking information on paper tablets.
- NYPD maintained a personnel accountability list at each Mobilization Point. This list was typically kept on a clipboard.
- PAPD maintained personnel accountability from the PAPD Police Desk located inside of WTC 5.
- With the collapse of WTC 2, all accountability lists for each department were lost, and no records were maintained beyond the WTC site.
- FDNY fire apparatus and vehicles parked at the WTC complex were destroyed when the WTC towers collapsed. Unit assignment lists (Riding lists) for many of these units were lost.

FDNY Command Board Located in the Lobby of WTC 1



FDNY Operations at the WTC

Access to the buildings:

1. After aircraft impact only two elevators out of 198 were operating inside the two WTC towers. WTC 1, from the lobby to the 16th floor. WTC 2, from the lobby to the 40th floor.
2. The stairways were filled with occupants evacuating the buildings. FDNY personnel and other emergency responders reported difficulty attempting to climb the stairs in the counter flow environment. Also made it difficult to carry equipment up the stairways
3. Counter flow in the staircases caused teams of emergency responders to become separated, causing delays and disrupting team operations.

FDNY Operations at the WTC

Human Physiological Challenge:

1. Firefighters' personal protective equipment weighs approximately 23 Kg (50 lbs).
2. Firefighters carry an additional 23 Kg (50 lbs) of gear with them for high-rise fire fighting, i.e., hose packs, tools, and extra air-tanks.
3. Many of the firefighters were only able to climb the first 10 to 12 stories on the stairways before they had to rest. Subsequent climbing would often require additional rest periods and hydration after ascending an additional 3 to 5 floors. Some firefighters and other emergency responders with light loads were able to climb a second unit of 10 floors before resting.
4. Climbing many floors of stairs and carrying heavy loads up the stairs seriously degrades the physical capabilities of firefighters during high-rise rescue and fire fighting operations.

Video Image of Firefighters Inside the WTC 1 Lobby



Emergency Responders & High-Rise Buildings

- First responding FDNY units took from 4 to 10 minutes to get to the WTC complex. They then got their equipment and received assignments, another 3 to 5 minutes. Time to begin operations 7 to 15 minutes.
- Of the 27 emergency responders interviewed that were inside WTC 1, maximum floor height achieved before WTC 2 collapsed, a time period of 1 hour 13 minutes:
 - 1 – A police officer carrying no extra equipment and in a patrolman's uniform climbed to the 44th floor.
 - 8 – Emergency responders (FDNY, PAPD, NYPD) climbed to the 30's. Two FDNY took an elevator to the 16th floor.
 - 16 – Emergency responders (mostly FDNY) climbed to the 20's.
 - 2 – Emergency responders (NYPD) climbed to the teens.
- **Estimated climbing rate based on a 60 minute climbing period to their maximum height: 1.4 to 2 minutes / floor**

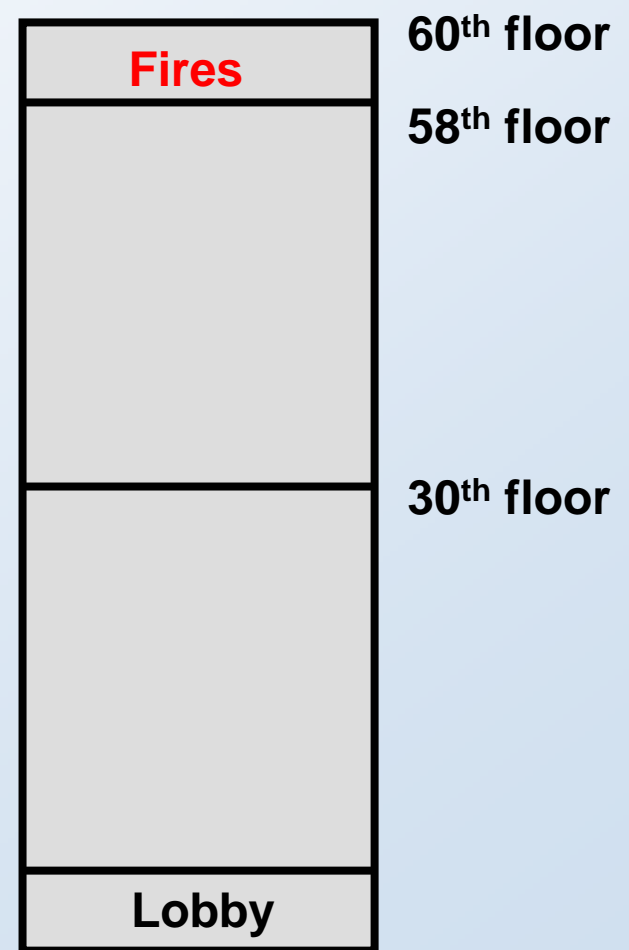
High-Rise Buildings & Emergency Response

Example: Fire department response to a 60 story high-rise building, occupants trapped above fires on the 58th floor and no operating elevators.

Firefighters carrying equipment and wearing PPE ~ 125 minutes
Firefighters carrying no equipment and not wearing PPE ~ 90 minutes

Firefighters carrying equipment and wearing PPE ~ 70 minutes
Firefighters carrying no equipment and not wearing PPE ~ 50 minutes

Firefighters begin to climb 10 minutes
Fire department arrival 4 minutes



Mobility Impaired Occupants

- As the emergency responders started evacuating WTC 1 after the collapse of WTC 2, they found mobility impaired occupants still in the staircases going down.
- Several ambulatory mobility impaired occupants were reported to be walking down the stairs with one hand on each hand rail as they took one step at a time going down. In addition, they were often accompanied by one person, another occupant or an emergency responder. This blocked others behind them from moving more rapidly down the stairs.
- FDNY and PAPD personnel found 40 to 60 mobility impaired occupants on the 12th floor of WTC 1 as they went down and attempted to clear each floor on their way out. These impaired individuals had been placed on this floor in an attempt to clear the stairways.
- Emergency responders were assisting approximately 20 of these mobility impaired people down the staircase just prior to the collapse of WTC 1. It is unknown how many fatalities occurred with this group.

Issues

Emergency Response - Access and Firefighting

- Physiological impact on firefighters with equipment climbing more than 10 to 12 floors during an emergency.
- Adequacy of capacity for egress and firefighter access during full evacuation of fully occupied tall buildings.
- Access to high-rise buildings by first responders is hindered by counter flow, egress capacity, and lack of available safe elevators.

Emergency Responder Operations

Situational Awareness:

Definition: The degree of accuracy by which one's perception of the current environment mirrors reality.

Perception vs. Reality

- View of the situation
- Incoming information
- Expectations & biases
- Incoming information vs. expectations

Factors that Reduce Situational Awareness

- Insufficient communications
- Fatigue / stress
- Task overload & Task underload
- Group mindset
- “Press on regardless” philosophy
- Degraded operating conditions

Emergency Responder Operations

Situational Awareness:

- Emergency responders working outside of the WTC buildings that could view building conditions and communicate over radios had adequate situational awareness.
- Situational awareness for personnel that observed the building damage and fires from outside the buildings before entering experienced difficulty maintaining their awareness after entering the buildings.
- Emergency responders working inside of the WTC buildings, who could not see what was happening outside and had poor radio communications, had poor situational awareness.
- Emergency responders working inside of the WTC buildings who could not see what was happening outside and had good radio communications had better situational awareness over those with poor radio communications.

Fire Fighting Operations at the WTC

Three cases were identified where fire fighting occurred before WTC 2 collapsed.

1. Fireball victims were extinguished with the use of hand extinguishers at the lobby of WTC 1 upon FDNY arrival at the scene.
2. A Port Authority employee was reported as using a hose line to extinguish flames entering a staircase in one of the towers, allowing occupants to evacuate down the staircase.
3. At 9:55 a.m. firefighters on the 78th floor inside WTC 2 reported that they were going to extinguish two fires in the B staircase so that they could get to the A staircase.

Roof Evacuation

- Standard evacuation protocol for the WTC towers as recommended by The Port Authority of NY & NJ stated that building occupants only evacuated down the stairs.
- The Port Authority had no procedures for roof evacuation.
- NYPD had a roof rescue protocol that had been prepared with the cooperation of FDNY. NYPD helicopters evacuated a number of people from the WTC roof during the 1993 bombing.
- FDNY had the same basic roof rescue protocol as NYPD but only planned to use it as a last resort to save the lives of building occupants that may have gotten on to the roof.

NYPD Aviation Units Roof Operations

- NYPD aviation units arrived at the WTC by 8:52 a.m. They checked to see if roof rescue was possible and reported back that they were unable to land as a result of heavy smoke conditions.

First person interviews with aviation unit personnel also indicated that heat from the building's fires was causing the helicopter engine temperature to increase.

An aviation unit called again at 9:38 a.m. for permission to land on the roof of WTC 1. First person interviews indicated that the aviation units were desperate to assist the people trapped and jumping from the upper floors. There was no indication that landing conditions had improved.

Five minutes after the request to land, a senior NYPD officer ordered that no one was to rappel onto the buildings.

Definition: rappel – to descend by means of a rope.

Video Image of WTC Showing Aviation Unit Near WTC 1



Photograph Taken by NYPD Aviation Unit Showing Top of WTC 1



First Person Accounts of Telephone Communications

- Before the attack at the World Trade Center both landline and cellular telephone systems were working.
- Moments after the first aircraft impacted WTC 1 the telephone systems were stressed by increased caller volume.
- Although there was impact damage and fires were burning in the two World Trade Center towers, some landline telephones were working in the buildings.
- After the collapse of WTC 2, a number of cellular phone systems were not functioning in lower Manhattan.
- After the collapse of WTC 2, there were still some landline telephones working within the city block areas adjacent to the World Trade Center.

Emergency Responder Radio Systems

Simplex Communications - direct point-to-point, HT-to-HT, or HT-to-Base Station (HT = Handie-talkie)

Duplex Communications - transmissions are channeled through a radio repeater.

PAPD Operations - Duplex through their dedicated WTC police department repeater.

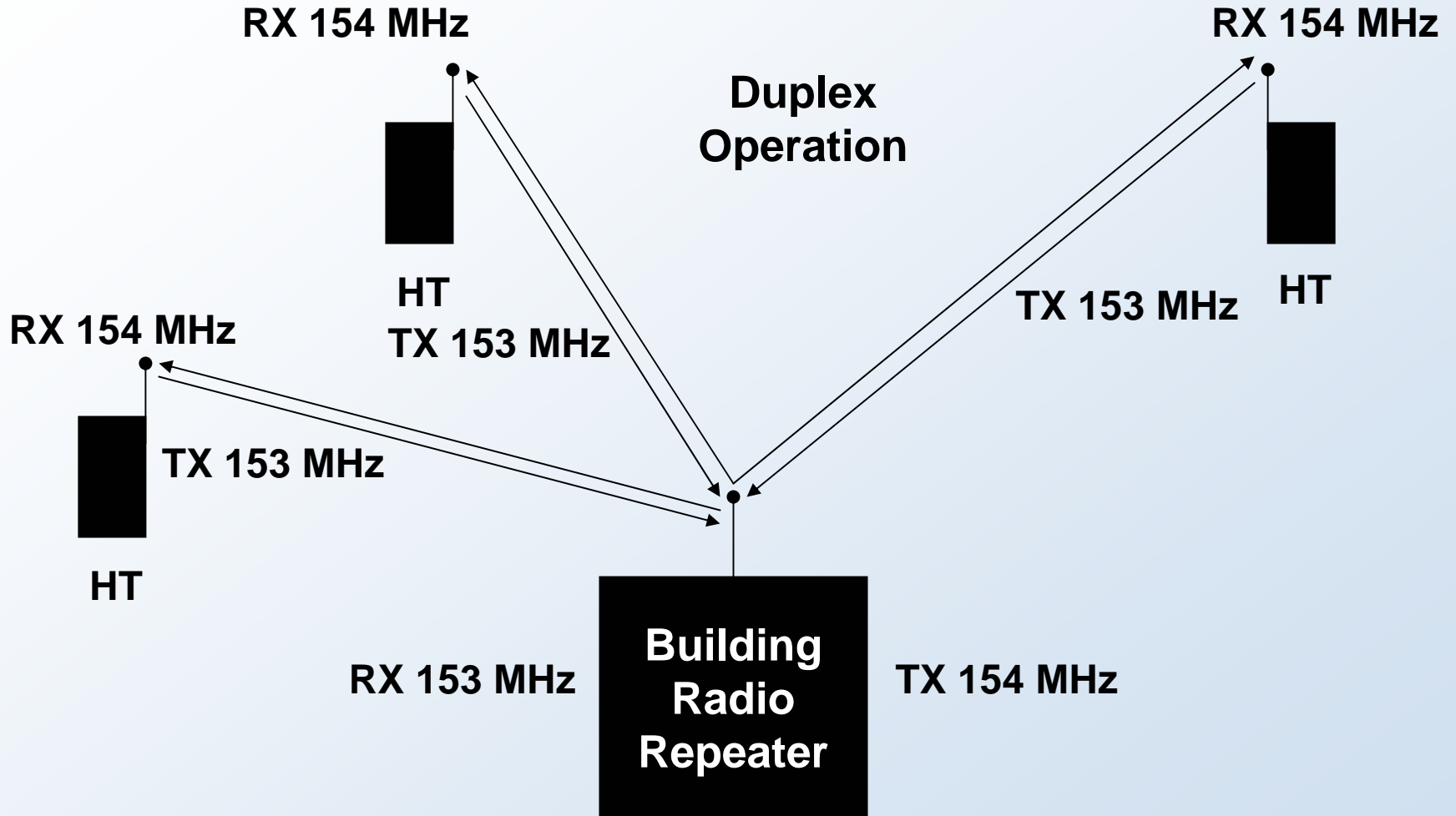
FDNY Operations - Simplex for command channel and tactical operations

- Duplex through their dedicated WTC FDNY high-rise repeater.
- Cross-band through the Battalion Car repeater.

NYPD Operations - Simplex between ESU teams members and the ESU Mobilization Point.

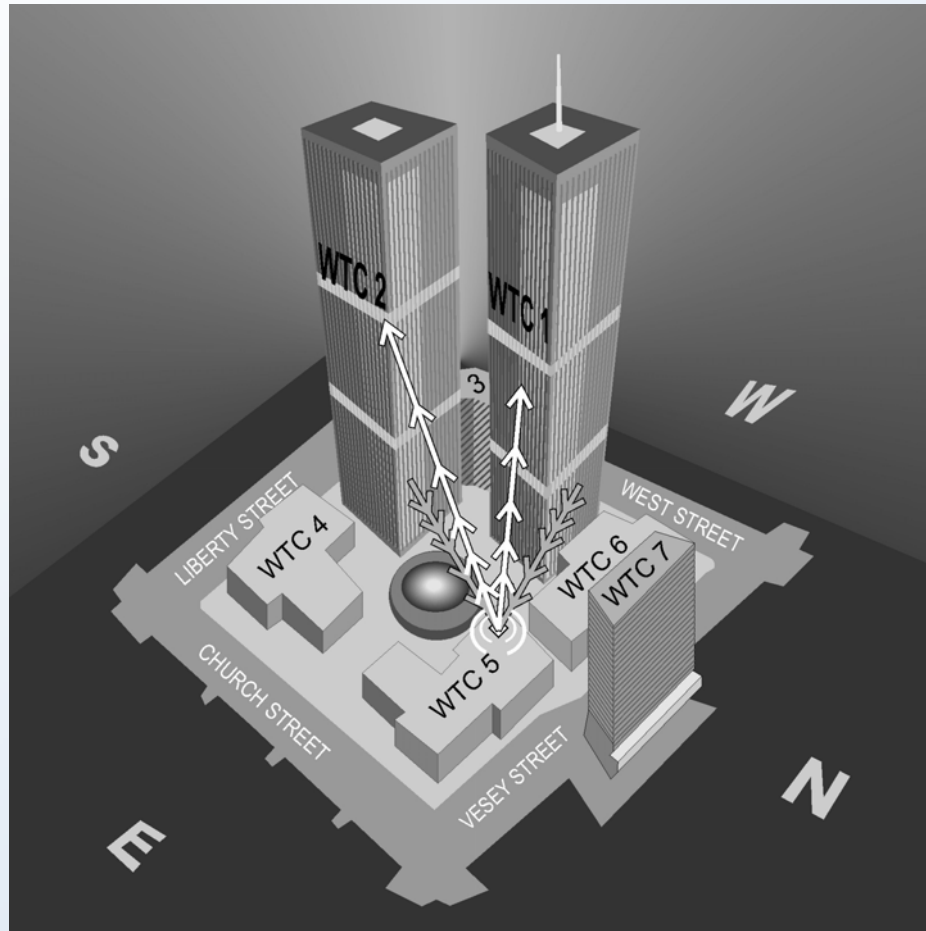
- Duplex through the NYPD SOD and Div 1 repeaters.

Example: Radio Repeater System



Only one radio transmission at a time.

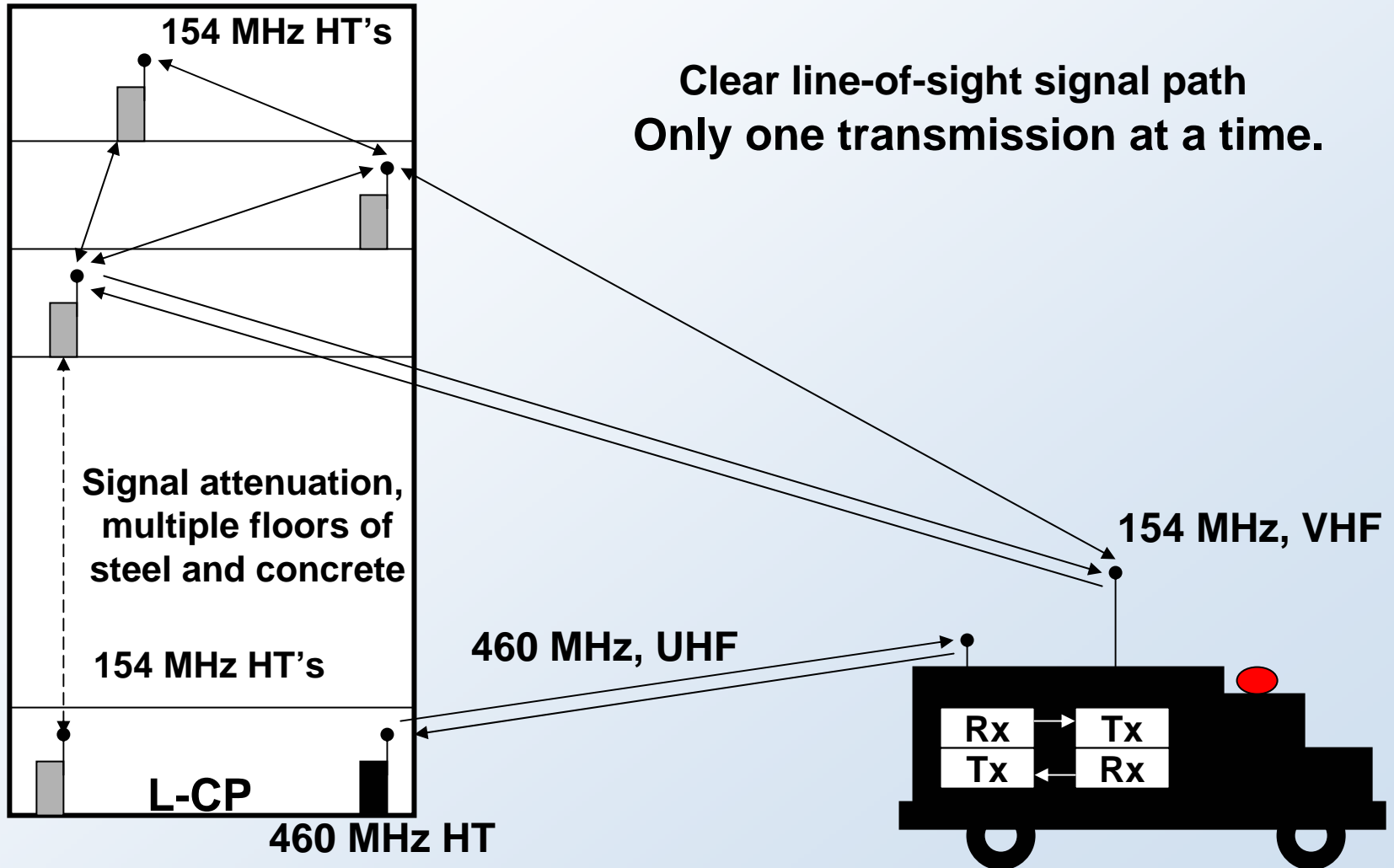
Graphic Showing the FDNY High-Rise Repeater Antenna Location Relative to the WTC Towers



Video Image of FDNY WTC 1 Lobby Command Post Showing a Repeater Phone



Example: Battalion Car Cross-band Repeater



Drawing by NIST base on document by Battalion Chief Orio J. Palmer and original drawing by FF Bill Kristoff, FDNY, WNYF, Repeater Systems, 3rd 1998.

Radio Communications

- All three of the responding departments, FDNY, NYPD & PAPD experienced difficulties with radio communications.
- Each of the departments was aware of the shortfalls associated with their radio communications systems as it related to operations in high-rise buildings.
- Two basic issues with radio communications:
 1. Normal function of the radio equipment in high-rise environments. (Radio signal attenuation in steel and concrete buildings)
 2. The volume of radio traffic.

Video image of EMS responder attempting to improve communications from inside the lobby of WTC 1 by lifting his radio above head level.

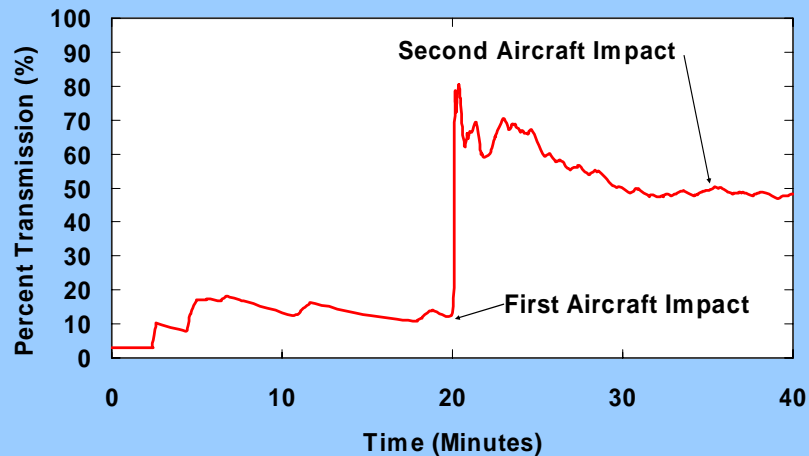


Radio Communications, continued

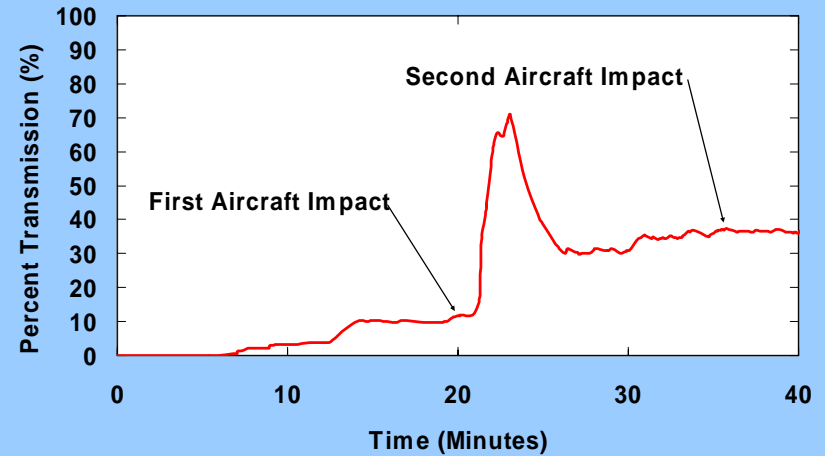
1. After the first aircraft struck WTC 1, there was an approximate factor of 5 peak increase in traffic level over the normal level of emergency responder radio communications, followed by an approximate factor of 3 steady increase in level of subsequent traffic.
2. A surge in communications traffic volume made it more difficult to handle the flow of communications and delivery of information.
3. Analysis of radio communications records indicates that roughly 1/3 to 1/2 of the radio messages during surge conditions were not complete nor understandable.

Radio Traffic Volume – $T\% = 100(\text{Transmission Time}/\text{Total Time})$

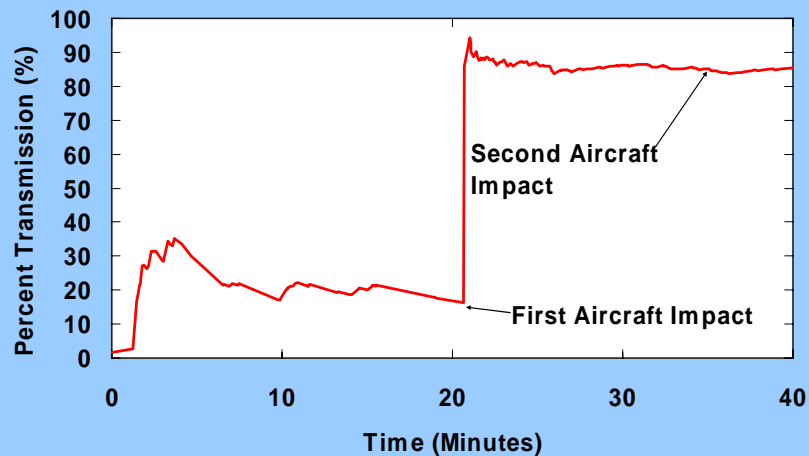
PAPD Channel 26/W



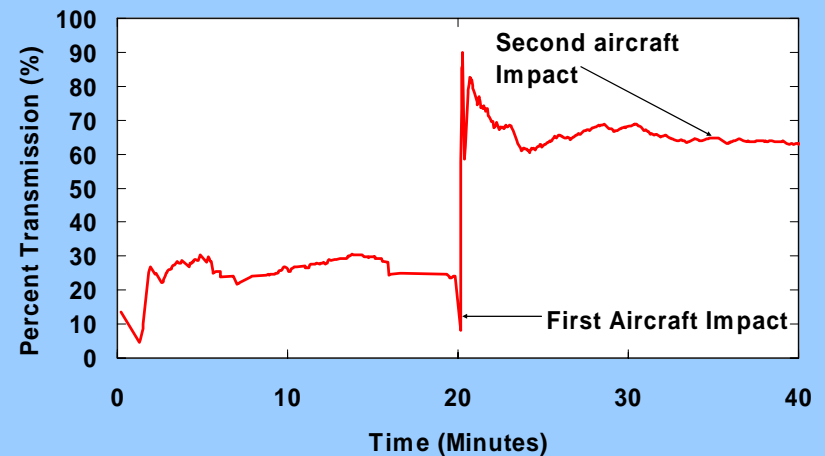
FDNY Ch7/PAPD Ch 30



NYPD SOD Channel



NYPD Division 1



Readability of Radio Communications

Factors affecting communications:

- background noise either at the transmission point or receiving point or both;
- operating health of transmitting and receiving radios and antenna systems;
- doubling or crossing of radio signals caused by multiple transmissions at the same time on the same radio frequency; and
- radio transmissions may be affected by attenuating materials or electromagnetic interference and reflected signals.

Radio Communications, continued

- Both PAPD and NYPD had handie-talkies with open or stuck microphones that produced radio interference. In addition, reports came in from the field indicating that radios were not working well.
- There were many cases where FDNY, PAPD, and NYPD personnel made radio calls, and they never received an answer. This may be attributed to the failure of the radio system or the inability of the person called to answer. There were cases where the person called would answer and would not be heard by the party that originated the call.

Radio Communications, continued

Between when the first aircraft hit and approximately 10:00 AM, emergency responder communications included the following types of messages:

- asking officers to stay off the air
- comments that messages were being cut-off, there was crossing or doubling, and messages were unreadable
- comments that multiple units were talking at the same time and requests that units talk one-by-one

Radio Communications Readability Analysis

Readability, is a communications term used to define the ability of a person to hear and understand a radio transmission.

Readability Scale:

- 1 – Unreadable**
- 2 – Barely readable, occasional words distinguishable**
- 3 – Readable with considerable difficulty**
- 4 – Readable with practically no difficulty**
- 5 – Perfectly readable**

Note: This is a subjective scale related to a trained human's ability to hear and understand communications transmissions.

Ref: The ARRL Handbook for Radio Communications

Readability Summary Before Attack

Dept.	Readability Scale				
	1	2	3	4	5
PAPD Ch 26/W Police Desk	8%	17%	19%	56%	0%
FDNY H-R Ch 7 (PAPD Ch 30) Repeater	n/a	-	-	-	-
NYPD Div. 1	2%	9%	8%	21%	60%
NYPD SOD	0%	0%	14%	23%	63%

Readability Summary During Operations

Readability Scale

Department	1	2	3	4	5
PAPD Ch 26/W Police Desk	9%	24%	43%	24%	0%
FDNY H-R Ch 7 (PAPD Ch 30) Repeater	10%	26%	42%	18%	4%
NYPD Div. 1	11%	26%	32%	23%	8%
NYPD SOD	10%	35%	32%	19%	4%

Radio Communications, continued

- NYPD had relatively good radio communications on their point-to-point communications in the WTC towers because there were only six ESU teams working on the frequency, and
- NYPD's mobilization point that was communicating with ESU personnel inside the towers was set up more than a city block away from the towers allowing for more direct or line-of-sight communications with the towers.
- FDNY was attempting to operate communications systems from inside the WTC towers where building components attenuated radio communications signals.

Radio Communications, continued

- Even though the Battalion Car Cross-band Repeater was turned on at approximately 9:07 a.m. and was to be delivered to the WTC 2 lobby command post, there is no record that FDNY used the cross-band repeater at the WTC site. All known personnel that may have used the repeater died with the collapse of WTC 2.
- There is no evidence that the WTC 1 lobby Command Post used either the FDNY/ WTC high-rise channel 7 repeater or the cross-band repeater to communicate with other personnel up inside the tower.

Radio Communications, continued

- Analysis of the FDNY City-wide, high-rise, channel 7 (PAPD channel 30) repeater recording indicates that the World Trade Center high-rise repeater was operating.
- At approximately 9:05 a.m. the repeater's recording system recorded the WTC 1 Lobby Command Post attempts to check repeater operations. Handset and handie-talkie radio communications were recorded.
- It is possible that one or both of the following conditions complicated the radio check that took place at the WTC 1 Lobby Command Post:
 1. The radio repeater handset earpiece was broken.
 2. The radio repeater handset volume was not turned up.
- It is unlikely that the repeater's antenna was broken or misdirected by debris since radio signals were received during the radio check from inside WTC 1 and the communications that followed from inside WTC 2.
- The repeater system recorded radio communications that took place between several different firefighters and several different FDNY officers as they worked inside of WTC 2.

Emergency Response Equipment at the WTC



Emergency Response Apparatus on West Street

List of FDNY Apparatus Lost at the WTC

Ambulances	5
Ladder or Trucks	15
Engines of Pumpers	18
Satellite Pumper	1
Rescue Vehicles	3
Squad Vehicle	3
High-Rise Vehicle	2
Emergency Crew Vehicle	2
Field Comm Vehicle	1
Mask Service Unit	1
Tac (Tactical Equipment Unit)	1
Sedans	23
Staff utility Vehicles	16
Total Units Destroyed	91

Example of Damaged FDNY Apparatus



Equipment Contributing to Operations

Equipment that influenced emergency responder operations:

- Handie-talkie radios, for transmitting and receiving evacuation and rescue information (for surviving responders). Approximately $\frac{1}{2}$ of the firefighters and police officers interviewed working inside WTC 1 with HT radios received orders to evacuate the building over their radios.
- Flashlights, for providing needed light while evacuating from the WTC complex after WTC buildings collapsed.
- Self-Contained Breathing Apparatus (SCBA), for providing safe air to breathe after WTC 2 and WTC 1 collapsed.

Inter-Agency Cooperation

- A significant amount of evidence (first person interviews, reports, and photographic data) shows that the different agencies were working together during the WTC disaster.
- Data also indicates that inter-agency operations were hampered by the loss of the OEM command center that was located inside WTC 7.
 - OEM functions became dispersed
 - The OEM communications center was lost
 - The computer systems and other equipment used to provide support for emergency response operations was lost
 - Unified operations structure for the emergency response was diminished
- First person interview data and photographic data shows OEM personnel working with different emergency responder departments and located at the various department command posts.
- First responder interviews suggest that inter-department competition had minimal affect on operations at the WTC complex on the morning of September 11th. First person interview data also suggests that some of the problems experienced were due to personnel not understanding operating practices of the other agencies.

Command and Control

- Difficulties with command and control began with the dispatch of large numbers of fire fighters to the WTC before adequate command posts and staff could be assembled to manage them.
- Self-dispatch further complicated command and control at the incident.
- FDNY EMS command and control was affected by many private and volunteer ambulance units self-dispatching.

Command and Control, continued

- Command and control was seriously affected by the lack of good communications.
- FDNY's system for maintaining records of unit assignments at each command post was not capable of managing the numbers of units and personnel being assigned to the incident.
- FDNY, NYPD, and PAPD: there was no means to back-up the unit assignment records generated at the command posts.

Issues

Emergency Response - Command and Control

- Availability of detailed procedures and methods for gathering, processing, and delivering situational information to all first responders, including 911 operators, wardens, incident commanders, etc.; this covers voice, video and data integration.
- Availability of effective codes and protocols for establishment and uninterrupted operation of the incident command and control system and for preservation and dissemination of information managed by command posts.
 - Command posts establishment within the collapse zone of buildings that received serious impact damage and contained large multi-floor fires.
 - Establishing the command post prior to dispatch of needed units
 - Impact of self-dispatch and free-lancing on command & control first responders and ambulances
 - Assignment and tracking (accountability) system for large scale emergencies
- Secure location of state and local emergency operations centers (EOC).

Issues

Emergency Response - Communications

- Lack of rigorous pre-emergency inspection and testing of radio communications systems within high-rise buildings to identify performance gaps.
- Missed opportunities to better communicate information among the occupants, 911 operator dispatch, fire department dispatch, police department dispatch, emergency management service dispatch, and site security. (Inadequate situational awareness)
- Performance requirements for emergency communication systems in buildings.
 - Design, testing, certification standards
 - Maintenance and inspection requirements

Issues

Emergency Response - Communications continued

- Lack of communications network architecture (interoperability) and operational protocols for intra- and inter-agency communication at all levels of organizational hierarchy. This includes:
 - Overall network architecture that covers local networking at incident sites, and dispatching.
 - Scalability in terms of the number of first responders using the system and in providing radio coverage in large buildings with challenging radio frequency propagation environments
 - Interoperability with existing emergency communications systems
 - Techniques to identify first responders within indoor building environments

Questions?

