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Primary Communication Infrastructure System Failures:

How Central Pierce Fire and Rescue Will Operate When all is Quiet

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Certification Statement

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and the appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

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Abstract

Consistent, reliable communication helps ensure a smooth and safe emergency response and operation. The foundation for such success is the communication infrastructure that flows smoothly. However, when the communication infrastructure fails, confusion and chaos can reign. Communication hardware and infrastructure (both emergency and routine business) can be disrupted without notice for any length of time, from a variety of causes. The result is that Central Pierce Fire & Rescue (CPFR) will be hampered in awareness and response to emergencies, and conducting normal business internally as well as with the public.

The purpose of this research was to determine communication hardware and infrastructure failures and recommend alternative methods of communication until normal communications are restored. Research questions were: what causes communication hardware and infrastructure failures, how will Central Pierce Fire & Rescue reduce known communication failures, what secondary systems are available, how CPFR will operate at multi-company emergencies without normal communications, how CPFR will conduct routine business communications when primary systems are unavailable, and what have other fire departments done when primary communication systems are unavailable. This descriptive research project included literature review, a survey, and personal interviews with local subject matter experts.

Recommendations included ensuring redundant telephone lines into Tacoma Fire Communication Center (Tacoma FCC), using Tacoma FCC's mobile command/communications vehicle at planned events, placing portable antenna trailers at fire stations farthest from TFCC, work with private vendors to strengthen relationships and perform cost/benefit analysis for value

added components, add PSTN (traditional telephone lines) into each fire station, and ultimately to consolidate multiple fire communication services within Pierce County, Washington into one communication center.

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Introduction

The ability to communicate effectively is paramount for emergency services. The citizenry needs access to dispatch centers to report emergencies, and those same dispatch centers need to send appropriate resources to mitigate the emergency. While on scene, emergency responders need to communicate if they need additional resources and when they are available for another emergency. This communication cycle is repeated constantly every day, 24/7, throughout the world. With any disruption of this cycle however, chaos can ensue, situational awareness disappears, and safety becomes compromised.

The need to provide timely and reliable information to commanders, whether in the fire service or military, is crucial. In line of duty death reports from NIOSH, communication problems are frequently listed as a causing factor in the death (NIOSH, 2009). Military and terrorist leaders frequently target communication centers at the beginning of an attack to stop and disrupt commander's ability to send units to areas of conflict. Military experts attempt to disrupt their opponents C3 (Command, Control, and Communication) so commanders cannot provide coordinated command of their units once they are attacked (Lee, 2007). At the beginning of Desert Storm, CNN was showing live satellite feed from Baghdad. Commentators stated that primary targets were Command, Control, and Communication in nature. Communication was implied or implicit in both of the other aspects, as without good communication, troops and units cannot report or be sent to areas of conflict.

Without consistent and reliable communication though, how does Central Pierce Fire and Rescue (CPFR) effectively operate? How are emergency responders aware of emergencies and how do they respond and communicate when on emergency incidents? Communication hardware

and infrastructure (both emergency and routine business) can be disrupted without notice for any length of time, from a variety of causes. The result is that CPFR will be disadvantaged and not fully aware when responding to emergencies, and conducting normal business internally as well as with the public. The purpose of this research was to find causes of communication hardware and infrastructure failures and recommend alternative methods to communicate, both for emergency and normal business operations until normal communication methods are restored. The following research questions will be answered using the descriptive research method. What causes communication hardware and infrastructure breakdowns? How will CPFR reduce known communication breakdowns? What technologies are available as backup systems when the main communication systems are unavailable? How will CPFR communicate at multi company emergencies without normal communications? How will CPFR conduct routine business communications when primary systems are unavailable, and what have other fire departments done when primary communication systems and infrastructure were unavailable?

Background and Significance

Central Pierce Fire & Rescue (CPFR) is a fire district in central Pierce County, Washington. CPFR borders the city of Tacoma to the south, and extends in a southerly and easterly direction toward Mt. Rainier. The population of the district is approximately 188,000, and is protected by 12 fire stations with an all-career force (Central Pierce Fire and Rescue, 2009). CPFR formed in 1995 when three fire districts merged into a single entity. In January of 2009, the city of Puyallup Fire & Rescue (PFR) merged into CPFR as the result of a consolidation vote of residents from the CPFR fire district and the city of Puyallup.

Prior to October 2008, CPFR used FireComm, a communications center that dispatched for all fire districts in Pierce County. Pierce County fire districts used only VHF radios for communication. Administered by Pierce County Fire District 2, Firecomm's employees were civilian dispatchers and call receivers.

Beginning in October 2008, CPFR moved to Tacoma Fire Department's dispatch center (Tacoma FCC). Tacoma FCC used 800mhz radios, but agreed to dispatch incidents for CPFR on VHF until CPFR's 800mhz radio network could be completed. Tacoma FCC is staffed with uniformed firefighters, paramedics, and EMT's.

PFR used CityComm, a communications center that dispatched for Puyallup Police and Fire, and several small municipal police agencies. CityComm likewise used 800mhz radios, and has agreed to allow CPFR to use their antennas when the 800 mhz conversion in CPFR is completed. PFR had used both VHF and 800mhz radios prior to merging with CPFR. All CPFR units (including those from PFR) operate on the VHF radio system until the 800mhz infrastructure in CPFR is complete. Pierce County has several Primary Safety Answering Points (PSAP) located within the county. All 911cellular phone calls are received at the nearest Washington State Patrol office and transferred to the appropriate dispatching center. Traditional telephone calls for 911 are received at either LESA (Law Enforcement Support Agency), or the City of Puyallup's dispatch center. Calls are then immediately transferred to the appropriate dispatch center.

The merging of departments and moving to different dispatch centers, all within a compressed time frame, created anxiety for all involved. On the communication side, departments were operating with 2 distinctly different radio systems (VHF and 800mhz) simultaneously. Depending upon the incident and its location, either radio system would be used. To confuse

matters more, when mutual aid was used (and depending on where the mutual aid companies came from), a radio “patch” was employed to allow interoperability. The dispatchers would have to remember to perform the patch, and sometimes it would need to be done several times. The Incident Safety Officer monitored different radio systems and different frequencies in case a May-day was activated.

On the personnel side, PFR personnel were unfamiliar with CPFR operations and what (if any) communication systems within CPFR had redundancies. PFR personnel were not aware of the capabilities of CPFR and Tacoma Fire Department’s communication center.

Prior to the annexation, PFR’s telephone system was a hard-wired traditional system (Public Switched Telephone Network (PSTN)). CPFR used Voice over Internet Protocol (VoIP) phones, and PFR personnel had not used them prior to the consolidation and were unfamiliar with how they functioned.

These changes in normal routines were stress inducing. Transitioning from a nine station to a twelve station department (PFR had three stations), rebidding for new work sites and new work partners, operating new equipment, using two distinctly different addressing systems (city of Puyallup and Pierce County addressing was opposite of each other), and operating on two distinct radio systems have raised the anxiety level tremendously for the entire department. Anxiety can be reduced however, through training and understanding of how these communication systems operate.

Understanding how various communications systems operate, how they can be enhanced, strengthened, and how redundant systems work when the primary systems fail to operate was

significant. The EAFSOEM course primarily dealt with large emergencies in Incident Management Teams. Effective communications were paramount during these exercises as well as evidenced in case studies discussed in class. The EAFSOEM course discussed emergency planning and using mission statements to determine response priorities during emergencies ((FEMA, 2007)SM 4-5 and 4-6). Priorities included protecting life, community, and the environment ((FEMA, 2007)SM4-6 and 4-7). Without knowing the location of the emergencies, responders could not respond with appropriate equipment sent to handle those emergencies. In Chapter 5 of the EAFSOEM manual, analyzing available resources under various risk scenarios [(FEMA, 2007)SM5-11] and assigning critical resources to critical tasks was highlighted. Again, without knowing the type and location of emergencies, the appropriate resource(s) cannot be sent to mitigate the emergency.

When planning for local Emergency Operations Centers (EOC's), communication systems are essential. Some of the issues were methods to alert the public, maintaining contact with other EOC's, two-way communications with emergency responders and other governmental units, and notification of staff ((FEMA, 2007), SM5-19).

The United States Fire Administration's operational objective that this applied research project satisfies regards the appropriate response in a timely manner to emergent issues. The annexation of PFR into CPFR, with changing communication systems through the annexation, is indeed an emergent situation that needed immediate action for the successful and safe operation of the fire district. Without addressing the communication issues through the annexation, CPFR employees would be put in harm's way on emergencies, and the citizens that CPFR serve would be greatly underserved. On a larger scale, communication infrastructure systems can be targets

for terrorism and mechanical disruption. By addressing these issues and how to use backup systems, appropriate and timely response to emergencies can continue with minimal interruption.

Literature Review

Information concerning communication infrastructure situations came from a variety of sources. The framework for Federal preparedness and how systems cooperate together during national or regional emergencies, the National Incident Management System (NIMS), devoted an entire component to communications and information management – Component II (Security, 2008). Sections of Component II included the need for reliability, scalability, resiliency, and redundancy (Security, 2008). Management characteristics of NIMS Component II included strategic, tactical, and public address communications. Strategic communications dealt with resource allocation decisions; tactical communications addressed on scene emergency communication and public address communications dealt with communication with the public. All of these communication types must be effective for emergency response, regardless of communication infrastructure.

Communication infrastructure breakdowns can generally occur due to natural causes, man-made causes, or terrorism (FEMA, 2007). The Yankee Group, in studying Information Technology outages, listed hardware and circuit failures (man-made), software errors (man-made), power outages (various), natural disasters, human error, and fire (various) (Chen, 2008). Hiatt listed four causes of a threat – accident, natural, internal, and armed conflict (Hiatt, 2000).

Intentionally disrupting communication infrastructures occurs both in war and domestic terrorism. Destroying the command and control infrastructure resulted in confusion and lack of situational awareness, which is routinely the first event in a battle (Weinberg, 2003). Prior to

Russia invading Georgia in August 2008, researchers and internet experts were predicting the invasion due to cyber-attacks on Georgian infrastructure, which began occurring in July 2008 (Markoff, 2008). On the domestic terrorist side, unidentified attackers cut fiber optic cables in Northern California on April 9, 2009, disrupting phone and internet connection for up to 24 hours (Gomez, McLaughlin, & Sulek, 2009). State and local law enforcement agencies can assist CPFR by notifying CPFR if increased cyber or internal terrorism has been noticed.

Conversely, the New York Police Department looked at ways to disrupt cellular service and other communication methods during emergencies so involved terrorists will not be able to have real-time information regarding their event (Miller, 2009). This is the result of NYPD studying the Islamic attack in Mumbai, India in November, 2008. If disruptive means are utilized by law enforcement in an offensive fashion, alternative methods of communication will have to be utilized on these emergency incidents by first responders.

Obviously, human caused errors, ranging from an equipment operator digging through a fiber optic line, to inadvertently shutting off power equipment account for a percentage of infrastructure failures. Natural disasters occur frequently in the United States and vary depending upon the region of the country. There were hurricane issues in the Gulf States, tornadoes in the Midwest, snow and ice issues in the Northern region, and earthquakes along the Pacific Rim. Regardless of the issue, weather and natural disasters occur in every region of the United States and throughout the world.

Lessons learned from communication infrastructure failures, regardless of cause, have increased understanding of system failure, and how to overcome inadequacies in the future. In a Department of Transportation report from the attacks on September 11, 2001, and the August 14,

2003 power blackout on the Eastern seaboard, several items were highlighted. These included that a single point of failure disrupted an entire communications system, excess demand overwhelmed the system causing its breakdown, and backup systems used did not have sufficient capacity to operate independently for a long period of time (Transportation, US Department of, 2005). At the Pentagon on September 11, 2001, Verizon cellular experienced up to 100 percent more traffic volume than normal, and Cingular cellular's volume went to 400 percent of normal volume (Network, Public Safety Wireless, 2002). Also according to the PSWN report, the Public Switched Telephone Network (PSTN), the traditional phone network most commonly used throughout the US was also completely overwhelmed and had multiple service delays and interruptions. At the Pentagon site, only two systems operated at near normalcy that day, and those were mobile and portable radios, and the Nextel system of cellular phone/direct connect phones (Network, Public Safety Wireless, 2002).

Learning from Hurricane Katrina in August 2005 also proved valuable from a communications standpoint. Complete destruction of infrastructure was caused by wind and storm surge. Backup batteries were also damaged by the storm surge (Kwasinski, Weaver, Chapman, & Krein, 2006). Six weeks after Katrina, up to 75% of lower Louisiana and the Mississippi coast were without power mains (Kwasinski, Weaver, Chapman, & Krein, 2006). In Mississippi, 43 E-911 call centers were damaged, but were operational by September 4th (Kwasinski, Weaver, Chapman, & Krein, 2006) . One month after Katrina's landfall, 5 E-911 centers in Louisiana were still not functioning (Kwasinski, Weaver, Chapman, & Krein, 2006).

The National Guard's response to Katrina has been well documented, as their helicopters were constantly seen removing flood victims from rising waters. The Guards communications

had also improved since 9/11, and their Civil Support Teams (CST) used mobile communications vans to integrate cellular, data, voice, radio systems, and satellite phones to help coordinate the various response efforts (Melnyk, 2006).

The US Army, learning from their situation at Katrina, improved their response to Hurricane Gustav in 2008. The Army dispatched mobile communication vehicles to the region to assist in the coordination of emergency responders. These vehicles were able to integrate UHF, VHF mobile and portable radios, cellular and other data streams to effectively coordinate efforts (Brewin, 2008).

Portable satellite communications systems were also effectively used post-Katrina. According to the Satellite Industry Association, only 60 percent of cell networks were working properly three weeks after Katrina, and roughly two million calls per day still did not connect (Blaker, 2005). Satellite communications may be the only alternative when power and data lines have been completely destroyed from weather incidents.

Hurricane Charley struck the Orange County, Florida, area on August 13, 2004. During the height of the storm, responses were called off due to the extreme danger to personnel. While the crews returned to their fire stations to wait out the storm, the communications center received requests for service. Once the wind speed slowed to a safe level, emergency crews then returned to a response mode. The 911 call receivers prioritized calls based on a pre-planned procedure. The calls were placed in each company's first due area, and were dispatched by radio, phone and mobile data terminal to the next high priority call (Luke, 2005). During this incident however, the automatic call receiving to the appropriate 911 calling area did not work. Calls to 911 receiving centers are normally routed to their nearest communication center based on geographic

information. During Hurricane Charley however, some of these centers went down, and 911 calls were routed to centers out of the area, creating confusion (Luke, 2005). The call receiving center personnel were not familiar with the caller's location, and could not contact the appropriate receiving center.

Moving from emergency response to routine business communications, Central Pierce Fire & Rescue switched to Voice over Internet Protocol (VoIP) for their telephone system several years ago. The switch was made from the traditional system called Public Switched Telephone Network (PSTN) due to cost and availability to better manage the telephone system within the department. VoIP basically uses a computer, the internet, and its network to communicate with other phones. (Valdes & Roos). The system alters the analog data to digital information and sends it to a computer router that sends the data to the correct telephone connection.

VoIP reliability is less than that of the PSTN, which is deemed to be reliable to 99.999 or 99.9999%. Based on a report by Jiang and Scholzrinne, the VoIP reliability rests only at 98% (Jiang & Schulzrinne, 2003). In a study by network instruments in 2007, 41 percent of the Information Technology personnel surveyed were concerned about their network being able to handle added bandwidth demands, and 36 percent surveyed were concerned about reliability under heavy use (Staff, 2007). When many computer users share the same bandwidth in an area, service slows down, causing reliability issues and concerns.

Accessing a 911 call receiving center on a VoIP system is different from PSTN. Enhanced 911 receiving centers recognize PSTN phone lines that include information regarding address and calling phone number. Because VoIP uses a computer and data lines instead of the traditional hard wired phone lines, calls to 911 may not be received by the correct emergency

receiving center (Federal Communications Commission, 2008). To ensure that 911 calls through VoIP are received by the correct emergency receiving center, each VoIP needs to be registered with the VoIP service provider, and must be reregistered after each location change. Backup power supply and data lines must also be maintained, because the computer needs both power and a data line to communicate over the internet (Federal Communications Commission, 2008). The PSTN lines will normally stay operational during power loss, as the necessary electrical current to operate the service always runs through the lines.

Mueller and Bartlett from Tacoma Fire Communications Center agreed with Lenk and other authors noted regarding the causes of communication infrastructure failures. Lenk saw first-hand failures caused by both terrorism and natural disasters, as he has responded with the Puget Sound Task Force to New York City, Northridge CA, and to Hurricanes Ike, Katrina, and Gustav. Communication infrastructure failures can also occur from failed parts/systems, maintenance, or human error (Lenk, 2009) , and (Mueller & Bartlett, 2009). Mueller and Bartlett stated that Tacoma FCC replaced parts only when they malfunction or break. Bartlett stated that there is generally no way of knowing when an electrical part or component will fail. Mueller and Bartlett stated that Tacoma FCC does have budget provisions for equipment failure and replacement.

In lieu of replacing electrical components that have not failed yet, adding redundancy and strengthening existing infrastructures can assist when communication infrastructures do fail. This is congruent with NFPA 1221, which discussed in multiple chapters primary and secondary components, and automatic switching systems should one system fail (National Fire Protection Association, 2007). Tacoma FCC currently has contract agreements with Qwest telephone that in case of failure, Qwest will send emergency crews to the problem site to begin system repairs

(Mueller & Bartlett, 2009). According to one Homeland Defense Journal Crisis Communication Survey (Homeland Defense Journal, 2008), public-private partnerships were considered the highest challenge for risk and crisis communication. Although both groups have the intent of providing reliable service, public and private sector have diverging interests. Public sector needs reliability regardless many times of cost, while private sector interests are also concerned with profit and return to their shareholders.

According to Mueller and Bartlett, backup systems available to CPFR for emergency notification and communication include a mobile communication vehicle supplied from Tacoma FCC and their various antenna sites throughout the city. Each of the antenna sites has a backup power generator with diesel tanks that will continue to supply power to those sites. If a particular site goes down though, because of the ring architecture that the communication system provides, a communication failure could not occur unless two or more sites fail to operate. If the "normal" station alerting system does not function correctly, Tacoma FCC has the option to use the VHF system (crew will carry VHF portable radio), contacting the stations directly via telephone, or using Nextels, either with direct connect or cellular phone call. Mueller stated that it is possible for King County (county directly to the north) to accept 911 calls from Tacoma should Tacoma's 911 call receiving facility fail.

Pierce County Department of Emergency Management (DEM) also has a mobile communication unit as well as portable deployable antennas that may be available for deployment (Lenk, 2009). The portable antenna sites come equipped with a diesel generator and extra fuel to provide power to the site. If necessary, CPFR could use VHF frequencies licensed to Pierce DEM for operational and dispatch uses. Pierce DEM can allow Tacoma FCC to use these

for CPFR's operational needs on a short term basis (Lenk, 2009). CPFR is in the unique position being able to use both city (Tacoma FCC) and Pierce County communication resources (DEM) if necessary.

Another technology that is available if communication infrastructure fails is CPFR's Sprint/Nextel devices to communicate between dispatch and each emergency vehicle. Nextel (and other cellular carriers) have self contained portable antenna units with extra cellular phones. These units are normally called Cellular on Wheels (COWS). These units are on trailers and are staffed with a cellular technician to set up the operation and configure the cellular phones for local use and to integrate local phones. Nextel also has a portable satellite version called SatCOLTS, the only difference is that connectivity is through satellites instead of ground data lines. Nextel also provides GO Kits, a cache of cellular phones and chargers that can be stored and available on a short call out time (Street, Norman, Lieberman, & Anderson, 2009).

Nextel also offers several Priority Services. These services are available at an additional cost and are dependent upon use and number of subscribers. The Priority Services are Priority Connect (PC), Emergency Talkgroup (ETG), Priority on Group Connect (PoGC), and Wireless Priority Service (WPS). Priority Connect is a priority level service based on FCC guidelines that sets five priority levels- the higher the priority level, the shorter the queuing time. The Emergency Talkgroup feature allows a subscriber to send an emergency call to all subscribers on the emergency talkgroup from a dedicated button located on their cell phone. Priority on Group Connect gives higher queuing level during congested periods, and the Wireless Priority Service allows for priority calls to be placed during congested periods. The WPS is overseen by the

National Communications System, a division of Homeland Security, and requests to be placed in WPS are approved by them (Street, Norman, Lieberman, & Anderson, 2009).

The literature review was invaluable to this project. By understanding what has caused infrastructure failures in the past, and how they have been overcome by newer technology are critical to the success of this research project. The personal interviews aided in the project because these are existing infrastructure pieces for CPFR. In addition, the interviewees are local subject matter experts in the communication infrastructure field, and will be instrumental in accomplishing CPFR's future communication needs.

Procedures

The author used a literature review, personal interviews, and a survey to achieve the results. The literature review used the internet search engine Google and Google Scholar to locate information related to the topics. The author also used the National Fire Academy's on-line Learning Resource Center and card catalog. In addition to that, the Pierce County Public Library was used for items requiring Inter Library Loan.

Questions used in the survey were broad enough to elicit information that could be used to answer the research questions. For research questions that were more specific to Central Pierce Fire & Rescue's (CPFR) needs, the author used personal interviews or local subject matter experts that had specific knowledge of CPFR and Tacoma Fire Communication Center (FCC) functions. The survey questions were designed to be answered by the respondent, not by the department's communications officer or communications personnel. The questions were

designed to attain an overall view of communication infrastructure failures, if any, and their causes.

Survey questions were prepared and emailed to several CPFR Battalion Chiefs to ask for clarity, ease of understanding, readability, and if the questions would help answer research questions. Once the questions were edited, the survey was placed on Survey Monkey for distribution. After verifying the link to the survey was successful, the survey link was emailed to the National Society of Executive Fire Officers (www.NSEFO.org) and was placed on the page for EFO surveys. The link was also forwarded to the Pierce County Fire Chiefs Association and to the Washington State Fire Chiefs Association members for distribution. After three weeks, the link was removed from the NSEFO site at the request of the author. Frequent monitoring of www.surveymonkey indicated that there was no receipt of new material after the 19th day. The survey questions are found in Appendix A.

The survey was designed using 10 questions. One question allowed for multiple answers, eight questions allowed only one answer, and one question allowed for text input allowing for explanation purposes. The final question was for geographical information. The time spent in taking the survey was designed to be less than ten minutes.

Survey question 1 – "How often does your organization experience communication infrastructure breakdown causing a switch to an alternate communication method" deals with research question 2 which is "how will CPFR reduce known communication breakdowns". This survey question indicates if communication infrastructure failures occur, and their frequency. This question will be important when making recommendations regarding secondary and redundant communication alternatives. Five choices were available, from monthly to never.

Survey question 2 – “Where have the majority of the communication infrastructure breakdowns occurred” also helped address research question 2 regarding the reduction of communication breakdowns. By knowing where the systems can fail, either in the telephony 911 system call receiving area, or in the emergency dispatching of units, will be beneficial when making recommendations. Three choices were given, either at the 911 call center telephone side, or the dispatch center sending units to emergencies. The third option was never.

Survey question 3 – “What has caused the majority of your communication infrastructure breakdowns” answers research question 1 regarding the causes of infrastructure breakdowns. The four choices related to the EAFSOEM class material and their communication failure categories – either, human caused, weather, or terrorist caused. The final choice was that the respondents department had never experienced a communications infrastructure breakdown. The question was worded to receive the majority of frequent cause, not each individual time failures occurred.

Survey question 4 – “How long has your longest communication infrastructure breakdown lasted (until completely restored to the primary communication system)” relates to research question 5 – “how will CPFR conduct routine business communication when primary systems are unavailable”. By knowing how long respondents systems have been down will help CPFR plan for communication outages. Redundant and backup systems and their configurations are radically different when the outage is less than 4 hours compared to being on a backup system longer than one month. Six choices were available, from less than four hours to greater than one month.

Survey question 5 – “If/when your primary communication system is down, what backup systems do you have in place” related to research questions 3 (what technologies are available as

backups) and 6 “what have other fire departments done when primary communication systems and infrastructure were unavailable”. Four choices were available for use, and more than one choice could be used. This question related to both backup systems available, and what other departments use as backup systems.

Survey question 6 gave respondents the opportunity to provide clarity to any of their previous answers.

Survey questions 7, 8, and 9 asked respondents to denote which type of radio, telephone, and cellular systems were used. These questions were used to compare what other departments use to what CPFR used. Survey question 10 asked for the respondent’s state. This information was used in the results section and see if weather plays a role in infrastructure breakdowns by region (Bureau, US Census).

In addition to using a survey, the author interviewed local communications authorities who are familiar with CPFR and Tacoma Fire Department’s Communications Center (FCC), as well as Nextel personnel familiar with CPFR and their (Nextel’s) emergency response teams. To gain a broad sense of the situation, the author interviewed Tim Lenk, Communication Director for Pierce County Department of Emergency Management (Lenk, 2009). Mr. Lenk is a member of the FEMA USAR team for Puget Sound, and has responded as a communications team member to the Northridge earthquake, 9/11 in New York City, Hurricanes Ike, Katrina, and Gustav, as well as local responses and team events.

The author also interviewed Captain Kurt Mueller and Joe Bartlett from Tacoma FCC. Captain Mueller is the supervising authority at Tacoma Fire Department’s dispatch center, and

Joe Bartlett is the lead technician for Tacoma's communications equipment. The author interviewed these personnel to get an understanding of how the Tacoma FCC operates and gained insight to answer the research questions (Mueller & Bartlett, 2009).

CPFR uses Sprint/Nextel cellular phones. The author also interviewed several account representatives and systems personnel from Nextel to gain a better understanding how Sprint/Nextel cellular phones with their direct connect function could be used in a communication disruption situation (Street, Norman, Lieberman, & Anderson, 2009).

CPFR assigned personal pagers to all personnel, but this technology was not in the project purview. Immediate, two way communication with immediate feedback was the goal of the project, and paging systems do not afford the verbal feedback sought.

The only limitation the author noted was in the data gathering portion of the survey tool. The cross tabulating between state and cause of infrastructure failures (Question 3) was done manually. For an additional fee, the cross tabulating portion could have been done by the survey tool.

Results

Results from the email survey on www.surveymonkey.com revealed the following information. There were 88 respondents completed all or parts of the survey. Almost half of the respondents stated that communication infrastructure breakdowns requiring the use of an alternate communication method occurred infrequently. Those that noted a more frequent occurrence stated the breakdown would occur at least yearly. Although occurrence of these situations may not be very frequent, communication infrastructure failures are a critical

component of emergency response, and planning for them to occur is still a critical facet. Appendix B shows the complete survey results.

Two thirds of the respondents stated that communication infrastructure breakdowns occur between the dispatch center and responding units. Another twenty five percent stated the breakdown occurred due to incoming 911 lines being down. Based upon this information, the area to focus on first would be the infrastructure between the communications center and responding units. These items would include redundancies in data lines, computer systems and antenna receiving and transmitting sites. The next area to concentrate on would be to harden the incoming 911 telephone and data lines to Tacoma FCC.

The cause of communication infrastructure breakdowns was evenly split between weather related issues and human– non terrorist caused. No respondents indentified terrorism as a cause of their communication infrastructure breakdowns. Weather related causes were not broken down further into categories. These categories were broad enough to give basic information to the author, yet not with such detail as to bog down the respondent with information not readily available to them. Because weather patterns and storm types are different throughout the United States, the importance of the general category of weather was important to the author to show that a weather problem can cause the communication infrastructure failures.

Over half of the respondents reported that their communication infrastructure failures were resolved within four hours. Over ninety percent of the outages lasted less than 24 hours. This information is important for planning purposes regarding logistical and support planning. Based on the respondents answers, since most outages last up to 24 hours, secondary systems need to last at least 24 hours.

Respondents identified multiple methods of backup/secondary communications systems used when their primary system was down. The most common used was a mobile communication/command vehicle followed by portable radio antenna trailers, portable cellular sites, and finally satellite phones. An appropriate use of all of these types of secondary systems may be necessary to accomplish quality communication until the primary system is fully functional.

The primary radio system used by survey respondents was fairly evenly split between both VHF (Very High Frequency) and 800 mhz radio systems. The author anticipates that 800 mhz radio systems will continue to increase in use, as this newer technology and reallocation of VHF frequencies is completed.

Seventy five percent of respondents departments still use the standard telephone system versus VoIP (Voice over Internet Protocol) for routine telephone communication. Only fifty percent of the department's surveyed used cellular phones with a direct connect feature.

Geographically the largest survey response came from the West, followed by the South, Midwest, and the Northeast, again based upon U.S. Census Bureau Regions. One third of the respondents live in Washington State.

Cross tabulating weather results to regions of the country also revealed some interesting results as shown in Appendix C. According to respondents, weather related outage was the greatest percentage in the Midwest at 89%, followed by the Northeast at 57%. Human caused outages were greater in the West and South according to respondents at 56 – 57%. In

Washington State alone, respondents stated that 65% of the outages were due to human-related causes.

Discussion

Based upon the information gathered, communication infrastructure failures were caused by weather, human error, equipment issues, and terrorism. Examples abound from weather related issues; hurricanes Ike, Gustav, Katrina, and the Northridge, CA. earthquake as witnessed by Mr. Lenk. Human caused failures are situations where optic cables were accidently disrupted during construction, equipment was incorrectly used, or operator error. Terrorism was most clearly shown during 9/11 and the recent vandalism of the telephone lines in Northern California (Gomez, McLaughlin, & Sulek, 2009). The survey results were fairly evenly split between weather and human caused elements, with terrorism receiving no marks for causing infrastructure breakdowns. Knowing what caused these failures can help prepare for or delay their eventual happening. Although terrorism did not receive any responses on the survey, communication terrorism does exist (Gomez, McLaughlin, & Sulek, 2009), (Markoff, 2008). As shown in both NFPA 1221 and the FCC guidelines, having redundant systems and connectivity feeds from different routes help when any infrastructure breakdown does occur (National Fire Protection Association, 2007), and (Federal Communication Commission).

CPFR can reduce known communication infrastructure failures only in the areas that can be controlled. Intergovernmental agreements and public-private relationships need to be continued and strengthened between Tacoma FCC, 911 call receiving center, and Qwest so dispatching functions remain uninterrupted and reliable. CPFR controls VoIP in the stations, mobile and portable radios, and cellular service through Nextel. CPFR's Information Technology Division

should be working to assure reliability and redundancy for VoIP and data information (not covered in this project) throughout the fire district. This could be done through using backup operational systems from VoIP with separate routers and by having spare phones available when necessary. Purchasing budgets should be adequate enough to replace equipment at end of life cycle times instead of waiting for complete obsolescence. Routine maintenance and replacement of radio equipment, batteries, and cellular phones can extend the lifecycle of electronic equipment.

Being involved with other county and state fire service and interoperability communication committees will also enhance CPFR's ability to be ahead of equipment failures and know what future equipment will be available when CPFR needs to purchase or upgrade equipment. Continuing to maintain a budget fund for future communication equipment, both new purchases and maintenance/repair, will prevent shortsighted purchasing decisions. Similarly, having inventory of equipment available or being able to access equipment on a short notice will keep communication systems operating. For example, if a primary system part breaks, the redundant system will begin working. The faulty part can be obtained quickly and replaced without having the entire system not operate. Once the equipment is replaced, the primary system is again operated as the primary system.

Based on the research and interviews, two concerns frequently stated were the loss of power and a functioning data line (Lenk, 2009) and (Mueller & Bartlett, 2009). All electrical equipment functions by using power, either battery or connected to a source. Maintaining a continual power feed to this equipment is essential for its successful operation. Past lessons have shown that power was out for extended periods at hurricane and earthquake sites, so all of these systems

need to have fuel delivered to their sites to keep generating electricity. Based on comments by Mueller and Bartlett, contracts with private vendors need to be assured and tested to verify their capability (Mueller & Bartlett, 2009).

In addition to power, a data line is the other crucial component in reducing known communication infrastructure breakdowns. The information sent and received, whether from radios, cellular phones, or VoIP need a working data line. Without it, information will not flow (Mueller & Bartlett, 2009) and (Lenk, 2009).

The availability of backup systems when the main systems are unavailable currently exists with Tacoma FCC and Pierce County DEM. Those systems are the mobile command/communication vehicles (available from both), and mobile antenna trailers available from Pierce County DEM. These units are self contained with external power generation capabilities as well as satellite feeds for data needs if a data line was unavailable. A system similar to those referenced by Brewin, Luke, and Blaker (Blaker, 2005) should function well for (Luke, 2005)(Brewin, 2008) CPFR's needs.

Nextel has multiple options available as backup systems. As mentioned earlier, Cellular on Wheels; portable cellular sites with mobile antenna, SATColt, similar to the COW, but satellite connectivity equipped; GoKits, a cache of preprogrammed cellular phones and supplies that are storable at nearby facilities, and the Priority Services options as outlined earlier. These systems will not be immediately available, but can respond when requested (many of these systems are prepositioned in bad weather areas depending upon the time of year (Street, Norman, Lieberman, & Anderson, 2009).

Street also mentioned that if CPFR's AVL (Automatic Vehicle Locator) mapping system fails, Nextel has a mobile locator service. This service displays the location of gps-equipped Nextel's on a map, assisting with vehicle location. This would be helpful for finding nearest available units during emergency situations. All of Nextel's services are available at an additional cost, and budgeting for them would be required should CPFR desire to investigate any of these services in more detail (Street, Norman, Lieberman, & Anderson, 2009).

The author was surprised in the survey results from the question about cellular versus cellular and direct connect usage, as only 50% of the respondents reported that a direct connect type cellular phone was used. The author assumed that Nextel usage (or another direct connect type phone) would have a higher participation rate. This type of feature is very useful in that several communication methods exist within one unit – both a cellular phone and a direct connect function.

CPFR will continue to operate as they currently do at multi-company emergencies, whether primary or secondary communications systems are working. According to both Lenk, and Mueller and Bartlett (Lenk, 2009) and (Mueller & Bartlett, 2009), CPFR's portable and mobile radios that are currently in all CPFR's emergency vehicles will operate at the close distances that multi-company operations require. CPFR's portable radios transmit and receive at approximately 5 watts, and their mobile radios transmit at between 40 and 100 watts. The broadcast range for these radios will function well where vehicles and/or personnel have to communicate in a close range or line of sight. Communication with Tacoma FCC or units at a greater distance will be dependent upon whether the communication system of fixed or portable antennas is operating. If communication beyond each emergency scene is limited, company officers will have to note

times and other specifics for incident reports. CPFR currently has both VHF and 800 mhz mobile and portable radios in their emergency vehicles and either system will function fine for multi company operations. Lenk also suggested investigating mobile vehicle repeaters, which functions as a local antenna, thereby increasing local system strength, increasing coverage distance, and when operating with 800 mhz, will increase system coverage inside large buildings (Lenk, 2009).

Routine business communications at CPFR are currently conducted via the VoIP telephone system. Should this system fail to operate, CPFR will have several options to maintain some sense of communication normalcy. CPFR administrative personnel, Battalion Chiefs, and company officers at each station all carry Nextel cellular phones. Communication can occur either through the cellular phone portion, or through the direct connect portion of the Nextel, depending upon urgency and length of message.

Another option for communication between stations and personnel would be to use mobile or portable radios, and assign a specific channel for business/administrative purposes only. Other options to consider include satellite phones or their option through Nextel, or connecting a traditional telephone line to each station, as research has shown that this is a more reliable option when power or a data line has been lost.

If 911 telephone service has been lost, citizens can use cellular phones and directly call the 911 receiving center, or if all else fails, resort to “sneaker net” - directly going to a fire station to report an emergency.

Through literature research, personal interviews, and the survey, information regarding how other fire departments, other public agencies, and private companies function when communication infrastructure fails to operate was obtained. It was shown that mobile command/communication vehicles, portable antenna towers, power generating equipment, and satellite systems have been used to provide operating communication systems when the primary systems have failed. Not only should these secondary communication systems be purchased and employed, they need to be tested on a continual basis to ensure user familiarity and to check these systems for operability.

Recommendations

The recommendations stated below are two-fold: to strengthen the communications system within CPFR, its partners, and neighboring fire districts to decrease the chance of lost or unheard communications, and to maintain a reliable system that citizens can use to report emergencies when the main communication infrastructure is not working.

Recommendation: ensure Tacoma FCC has a secondary incoming telephone transmission system from the 911 call receiving center (LESA) that has an alternate routing point into the building. This redundant but alternate routing system will help when telephone lines are cut or damaged between Tacoma FCC and LESA (in different areas of Tacoma from one another). This system needs to be tested on a regular basis to guarantee functionality and to test switching equipment.

Recommendation: ensure functionality of Tacoma FCC mobile communication equipment by using at the Western Washington Fair and other planned events. Using the mobile communications center at the Western Washington Fair during September will help ensure

operator awareness, use equipment for an extended period of time to ensure its functionality, and to test deployment operations under ideal vs. stressful times.

Recommendation: test emergency generating equipment at each fixed antenna site twice yearly for at least 24 hours. This will allow equipment that does not normally get exercised a chance to function and be tested. By testing in the summer and winter, climatic conditions at the facility location can also be tested [air conditioning in these sites is paramount, and several sites failed due to overheating in Louisiana after Katrina (Lenk, 2009)]. By operating on emergency power for at least 24 hours will give logistical planners an idea of how often equipment will need to be fueled, which will also be tested.

Recommendation: annually move dispatch functions to King County dispatch for one hour. This will ensure user familiarity and exercise equipment under normal conditions.

Recommendation: purchase portable antenna trailers, locate at fire stations nearest their use, and test their function twice yearly. Emergency equipment such as this is available through the granting process. By placing these emergency antenna trailers nearest where they need to be located will speed up their deployment and successful use.

Recommendation: meet with Nextel providers and satellite telephone providers to determine cost factors for various system programs and operational plans. Meeting with these providers will assist our finance and operational administrators with cost/benefit situations. Currently, CPFR is not on a priority for Nextel's Priority Services, and would be placed at Level 3, above Public Services and Disaster Recovery Personnel, but below Executive Leaders, Disaster Response and Military operations (Street, Norman, Lieberman, & Anderson, 2009).

Recommendation: increase mobile and portable radio repair, maintenance, and replacement budgetary lines. On a company level, the backbone of the system is in the reliance on these radios. Administrative services should investigate the cost/benefit of hiring or contracting with a radio technician for repair and installation of radio devices. Due to the divergence of Tacoma FCC and the remainder of Pierce County Fire Districts, both 800mhz and VHF radios are a necessity. This is a blessing in disguise however, as the VHF system can be used as a backup when CPFR goes entirely to 800 hmz for their internal operation.

Recommendation: strengthen VoIP system within CPFR by proving redundant power systems, data lines, and routers – all with automatic switching capability. Having automatic switching systems will ensure continued operation. Testing of this equipment and being able to provide replacement parts on an immediate basis is also a necessity.

Recommendation: maintain at least one PSTN telephone line at each fire station, and three at the headquarters fire station. Should the VoIP system go down and remain down for any reason, there is a high probability that the PSTN lines will still be operating. One line per fire station will maintain emergency communication within the system and to external sources, while the extra lines are necessary for administrative functions at headquarters. These lines also need to be tested twice yearly for functionality and user awareness. Install PSTN lines immediately if currently not in each fire station.

Recommendation: install hardwire PSTN lines from Tacoma FCC to each CPFR fire station within six months. Should station alerting and radios fail, Tacoma FCC should have hard wire direct access to each station for emergency dispatching purposes.

Recommendation: provide training on a yearly basis for Tacoma FCC and CPFR personnel on secondary infrastructure systems operations and procedures. By knowing what system to use and under what circumstance will help all responding personnel become more comfortable with and using backup equipment and systems.

Recommendation: consolidate Tacoma FCC and Firecomm (Pierce County Fire Districts Fire Communication Center) within ten years. Regionalizing fire communications for all of Pierce County will result in less duplicity, greater coordination, decreased call processing time, and greater situational and unit awareness. Dispatching of emergency units would be seamless and based on nearest unit available, not based on geography. Currently, there is a delay when requesting resources from a department dispatched by Firecomm for an emergency in CPFR's boundaries. A phone call from Tacoma FCC to Firecomm is made, requesting a resource. Firecomm gathers the necessary information (assuming the resource is available), dispatches the resource, and the responding resource then responds to the CPFR emergency. All of this takes upwards of two minutes to occur.

Many challenges would lie ahead, including facility location, radio systems, personnel contracts (Tacoma FCC personnel are uniformed and Firecomm 's are civilian) and many other items would be necessary to accomplish this task. Better coordination and utilization of resources, quicker response to emergencies, and improved efficiencies will improve fire and medical response for all Pierce County citizens and visitors.

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Appendix A

This survey is about communication infrastructure systems used by emergency responders, and their strength and reliability. Thank you for your participation.

1. How often does your organization experience communication infrastructure breakdowns causing a switch to an alternate communication method?

- ☐ Monthly
- ☐ Twice a year
- ☐ At least yearly
- ☐ At least once every five years
- ◉ Never

2. Where have the majority of the communication infrastructure breakdowns occurred?

- ☐ Incoming phone lines to 911 call center
- ☐ Dispatch center alerting to responding units
- ☐ We never experience these issues

3. What has caused the majority of your communication infrastructure breakdowns?

- ☐ Human caused (non terrorist)
- ☐ Weather related
- ☐ Suspected or known terrorism
- ☐ We don't experience communication infrastructure breakdowns

4. How long has your longest communication infrastructure breakdown lasted (until completely restored to the primary communication system)?

- ☐ Less than four hours
- ☐ Between four and 12 hours
- ☐ Between 12 and 24 hours
- ☐ Up to one week
- ☐ Up to one month
- ☐ Longer than one month

5. If/when your primary communications system is down, what backup/secondary systems do you have in place? Please check all that apply.

- ☐ Portable radio antennas
- ☐ Portable cellular sites
- ☐ Mobile command/communication vehicles
- ☐ Satellite phones

6. Please add any other pertinent comments to provide clarity to any of the above answers.

7. What primary radio communication system does your department use?

- ☐ VHF
- ☐ UHF
- ☐ 800 mhz
- ☐ 700 mhz

8. What style of telephone system does your department use?

- ☐ Standard telephone system (traditional copper wire system)
- ☐ VOIP - Voice Over Internet Protocol

9. Does your department use cell phones with a direct connect feature (Nextel style)?

- ☐ Yes
- ☐ No
- ☐ Unsure

10. What state is your department in?

-- select state --

Thank you for your participation in this survey.

Pat Donovan

Battalion Chief, Central Pierce Fire & Rescue

Appendix B

Survey results using www.Surveymonkey.com charts.

1. How often does your organization experience communication infrastructure breakdowns causing a switch to an alternate communication method? Create Chart Download

	Response Percent	Response Count
Monthly	5.9%	5
Twice a year	16.5%	14
At least yearly	**31.8%**	**27**
At least once every five years	29.4%	25
Never	16.5%	14
answered question		85
skipped question		3

2. Where have the majority of the communication infrastructure breakdowns occurred? Create Chart Download

	Response Percent	Response Count
Incoming phone lines to 911 call center	23.3%	20
Dispatch center alerting to responding units	**66.3%**	**57**
We never experience these issues	16.3%	14
answered question		86
skipped question		2

3. What has caused the majority of your communication infrastructure breakdowns? Create Chart Download

	Response Percent	Response Count
Human caused (non terrorist)	**42.5%**	**34**
Weather related	**42.5%**	**34**
Suspected or known terrorism	0.0%	0
We don't experience communication infrastructure breakdowns	20.0%	16
answered question		80
skipped question		8

4. How long has your longest communication infrastructure breakdown lasted (until completely restored to the primary communication system)? Create Chart Download

	Response Percent	Response Count
Less than four hours	**59.5%**	**47**
Between four and 12 hours	25.3%	20
Between 12 and 24 hours	10.1%	8
Up to one week	2.5%	2
Up to one month	2.5%	2
Longer than one month	0.0%	0
answered question		**79**
skipped question		**9**

5. If/when your primary communications system is down, what backup/secondary systems do you have in place? Please check all that apply. Create Chart Download

	Response Percent	Response Count
Portable radio antennas	56.3%	45
Portable cellular sites	28.8%	23
Mobile command/communication vehicles	**71.3%**	**57**
Satellite phones	22.5%	18
answered question		**80**
skipped question		**8**

6. Please add any other pertinent comments to provide clarity to any of the above answers. Download

	Response Count
Show replies	30
answered question	**30**
skipped question	**58**

7. What primary radio communication system does your department use? Create Chart Download

	Response Percent	Response Count
VHF	42.5%	37
UHF	17.2%	15
800 mhz	**48.3%**	**42**
700 mhz	0.0%	0
answered question		**87**
skipped question		**1**

8. What style of telephone system does your department use?

Create Chart | Download

	Response Percent	Response Count
Standard telephone system (traditional copper wire system)	77.9%	67
VOIP - Voice Over Internet Protocol	22.1%	19
answered question		86
skipped question		2

9. Does your department use cell phones with a direct conect feature (Nextel style)?

Create Chart | Download

	Response Percent	Response Count
Yes	50.6%	44
No	48.3%	42
Unsure	1.1%	1
answered question		87
skipped question		1

10. What state is your department in?

Download

		Response Percent	Response Count
Show replies	State:	100.0%	88
answered question			88
skipped question			0

Appendix C

Results based on manual cross tabulation of region and outage caused either by weather or human causation. Respondents that skipped the question, answered both, or stated that their department did not have equipment failures were not included in these results.

Regions	**Human-Caused**		**Weather**	
Northeast	43%	(4)	57%	(3)
Midwest	11%	(1)	89%	(8)
South	56%	(11)	44%	(7)
West	57%	(16)	43%	(12)
Washington State	65%	(13)	35%	(7)