# Design Principles for Emergency Collaborative Systems: A Situation Awareness Study of Buffalo Plane Crash

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**ABSTRACT**

Due to differences in governance structure, training, applicable polices, legal requirements and culture, the nature of operations vary based on agency, county, population, leadership, etc. This leads to serious challenges during multi-agency response to emergencies. The different agencies are required to work together to effectively and efficiently respond to an emergency incident. The paper contributes to research in areas of inter-agency collaboration and emergency management. With the help of case study, this paper aims to explore factors that impact inter-agency collaboration to generate design principles that are useful to designing better systems to mitigate critical incidents. In addition, with the help of interviews with four experts (two fire chiefs and two dispatchers) and raw incident communication reports, we identify system, communication, information, and interoperability issues.

**Keywords**

Buffalo Plane Crash, Situation Awareness, Inter-agency Collaboration, Emergency Response, Emergency Messaging, Design Science, Design Principles

## INTRODUCTION

Continental Flight 3407, from Newark Liberty International Airport in New Jersey to Buffalo Niagara International Airport in New York State departed late from Newark on February 12, 2009, at 9:20 p.m. EST. On the landing approach to the airport, the plane stalled about 9.3 kilometers, short of the runway and crashed into a house in the northeast Buffalo suburb of Clarence Center at 10:17 p.m. The conditions were freezing. Fifty lives were lost – this included two pilots, two flight attendants, 45 passengers (including one off-duty pilot), and one person in the house into which the plane crashed. Many of the passengers were either members of the Buffalo community or close relatives and the loss was deeply emotional.

It is within this environment that the governmental agencies such as local, state and federal had to respond. However, due to differences in governance structure, training, applicable polices, command and control structures, legal requirements and culture, the nature of operations vary based on agency, municipality or township, county, population, leadership, etc. This leads to serious challenges during multi-agency response to emergencies (Cigler 1988). The different agencies are required to work together to effectively and efficiently respond to an emergency incident. (McGuire and Silvia 2010) describe inter-agency collaboration as vital both before and after an emergency. (Waugh Jr and Streib 2006) argue that effective response is unlikely to happen without collaboration.

The paper contributes to research in areas of inter-agency collaboration and emergency management by generating recommendations and principles using a case study. From a methodological perspective, our work draws inspiration from the work of (Benbasat et al. 1987). They argue that a case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or more people, groups, or organizations. Further, they suggest that single cases are useful in specific instances where (1) situation is inaccessible to scientific investigation and (2) situation is extreme or unique case. The plane crash was the first of its kind of emergency in Buffalo, New York. So, the

situation is both inaccessible and unique. This paper aims to explore various issues in inter-agency collaboration including role and access control, resource management and accountability using a single case. Utilizing interviews with four experts (two fire chiefs and two dispatchers) and raw incident communication reports, we identify the following collaboration issues - system, communication, information and interoperability to develop design principles that are useful in the development of better inter-operable communication systems.

The paper is organized as follows. In section 2, we provide a background of emergency response communication. In section 3, we highlight the research methodology. In section 4, we illustrate the case study of Buffalo Plane Crash. In section 5, we present our analysis of collaboration using Situation Awareness model. In section 6, we discuss the system design issues. In section 7, we provide design principles to address the design issues that are compliant with the Situation Awareness model. Finally, we conclude with limitations and future work for this paper.

## LITERATURE REVIEW

### Emergency Systems

The prior studies in development and improvement of emergency system have focused on complex issues such as communication interoperability issues in fragmented emergency systems (Chen et al. 2008; Hancock and Hart 2002; Seifert 2007). There have been numerous systems developed and improved significantly over the last decade for effective communication during emergency events (Turoff 2002). These systems range from expert-oriented (Valecha et al. 2010) to people-oriented (Chou et al. 2011). (Chen et al. 2005; Chen et al. 2007; Comfort et al. 2004) stress the need for emergence of emergency systems to address coordination challenges during single- and multi-incident management.

### Emergency Collaboration

The area of collaboration has been extensively studied in fields of Systems Science and Computer Science. However, academic work on emergency collaboration is scanty but growing. The expanding literature in this field has focused primarily on identifying issues with multi-agency collaboration (Samba 2010; Chen et. al, 2007) and factors that lead to diminishing collaborative ability (Curra et al. 2009). (Jarvenpaa and Ives 1994; Hollingshead et al. 1993) contribute to a better understanding of responder groups for coordination of knowledge, people, resources, tasks, and technology for improving emergency response. (Majchrzak et al. 2007) make the case for better understanding collaboration of responder groups during an emergency situation. (Turoff 2002) discuss systems such as PREMIS that facilitate effective collaborative action during emergencies. (Diniz et al. 2005) argue that the current emergency response systems should provide collaborative knowledge systems for exchanging professional information between responders. While there have been a number of studies that deliberate design of systems facilitating effective collaboration during emergencies (Janssen et al. 2010), there has been no study that deals with developing design principles based on real experience from the field.

### Situation Awareness

During an emergency, the Incident Commander plays a vital role in coordinating the efforts of responders from various on-scene and off-scene agencies and organizations working in constantly changing environment. In this paper, we use the Situation Awareness (SA) model to analyze the requirements of the situation for the development of valuable artifacts (Endsley, 1995). SA is an important concept developed in the military domain that provides an understanding of the environment as a basis for efficient decision-making. It consists of three levels of cognitive process, namely perception, comprehension and projection. At the first level, the responder strives to perceive relevant elements from the dynamic environment at the crash site. At the second level, the perceived information is comprehended into meaningful understanding about the current state of resources. At the third level, the understanding of the environment is projected into actions for efficient decision-making. Since the incident commander coordinates between agencies with the help of emergency messages, we consider projection of these messages for future actions. This is depicted in the Figure 1 below. For the purposes of this paper, we deal with only the Situation Awareness block.

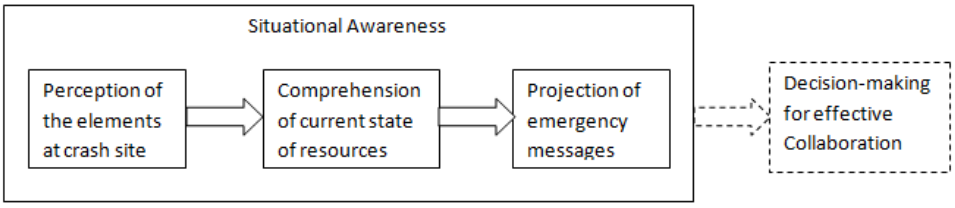


Figure 1: Situation Awareness Model (Starter et al. 2001)

## METHODOLOGY

This research is based on qualitative design in the form of interviews with responders from various agencies, derivations from previous literature on collaboration and incident reports generated during the February 2009 Buffalo plane crash. This research also draws from other collaboration case study articles such as (Samba 2010; Curra et al. 2009) to develop support for better collaboration measures, to avoid reinventing the wheel. Since the crash was the first of its type, the findings are limited by lack of preparedness before the event. In addition, since the method of research is interviews, the findings are generalized in order to be framed as collaboration issues. This case study provides details that are very unique to this incident, however, it also helps to serve as a strong base in identifying weaknesses of multi-agency collaborative response.

## THE CASE OF BUFFALO PLANE CRASH

The Buffalo plane crash that happened on Feb 12, 2009 was a first of its type in Buffalo, New York. The plane crashed into a house in the suburbs of Buffalo just a few miles short of the Buffalo airport en route from Newark, New Jersey. Significant ice build up on the wings and windshield of aircraft as it descended through light snow and mist, were deemed as major contributing factors that led to the crash. In addition to the passengers on board, the plane was loaded with 5800 lbs of fuel. Everyone aboard the plane – 44 passengers, 4 member crew, an off-duty airline employee lost their lives. In addition the person living in the house where the plane crashed also did not survive the crash. About 12 nearby houses were evacuated after the crash and a limited state of emergency was declared.

The incident lasted for about 48 hours. There were 41 responding units that reported on-scene during the course of the incident. More than 200 employees were involved in mitigating the intensity of the incident. Based on Federal Emergency Management Agency's (FEMA), Incident Command Structure, the response to the incident was divided into five roles: The Command was responsible for all activities including developing and implementing the strategic plan, attention to organizing and managing the scene, collaboration for setting priorities for work accomplishment, coordination with other public officials and agencies, and other executive. The Operations was responsible for carrying out the directions of the command including managing all operations of implementing strategic plan on the scene, and maintaining discipline and accountability of materials, resources and responders. The Planning was responsible for collecting and disseminating information including gathering and analyzing situational data along with providing appropriate displays for situational status. The Logistics was responsible for coordinating the information technology and information system needs on the scene, medical care for the incident as well as communication between departments. The Finance dealt with account keeping at various departmental levels. The Figure 2 below, adopted from details of Flight 3407, depicts the different personnel and agencies that were a part of the structure at various levels.

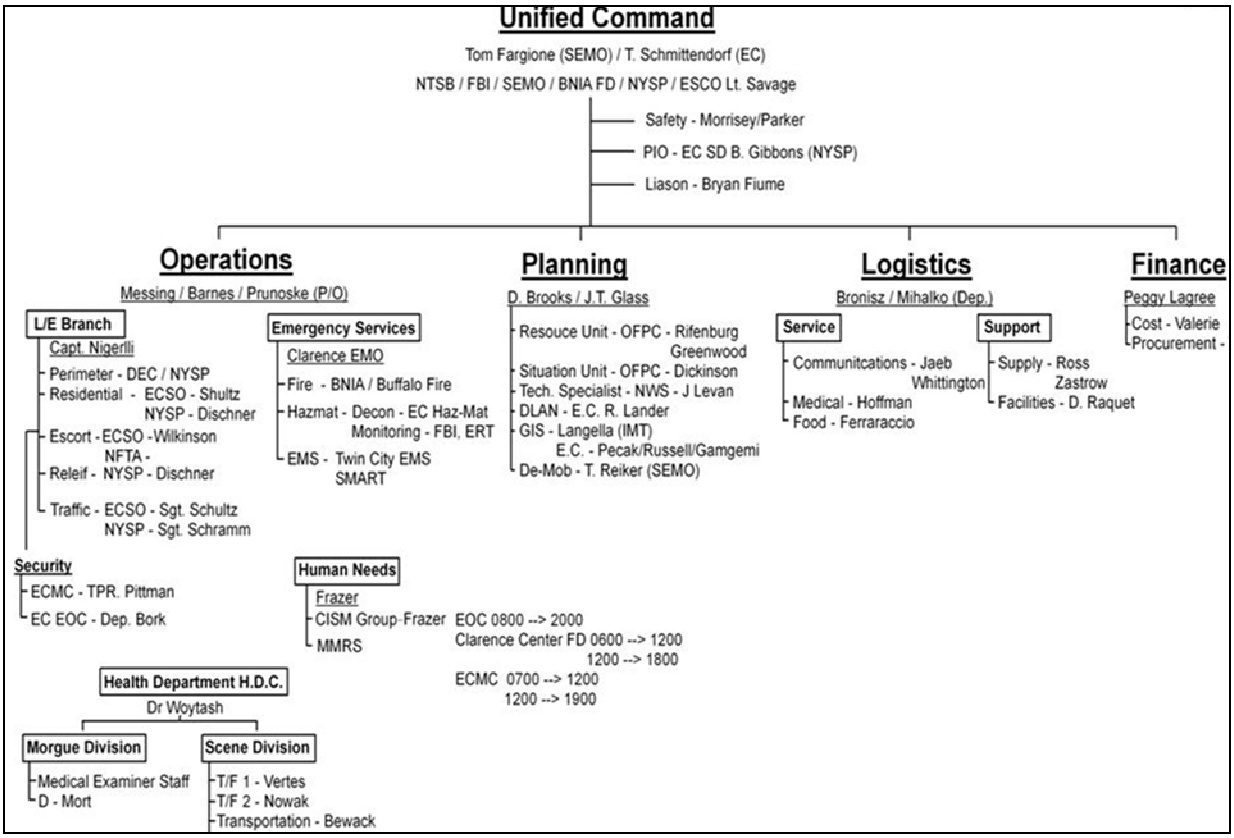


Figure 2: The Incident Command Structure for the Buffalo Plane Crash

The emergency support functions combined the capabilities of various agencies. The Table 1 below highlights the responsibilities of various agencies throughout the incident. During the plane crash incident, the response was segmented into two phases: First, the operations phase beginning with the instant of the crash, continuing till the fire was completely put out. Second, the recovery phase starting immediately after the fire was out. The response i.e. the first phase lasted for about 20 hours, and consisted of events between the incident commander, fire agencies and the dispatch (that acted as mediators). The recovery i.e. the second phase lasted for over 28 hours, and consisted of events between the onsite agencies, not including dispatch. For this paper, we deal with inter-agency collaboration in the first phase. Thus, the responders interviewed were experts from dispatch and fire agencies. The incident commander was not interviewed because of availability of his time. However, the other interviewed responders were a part of incident commander's team and thus could provide valuable insights. These emergency responders were an active part of the operations.

| **Agency** | **Types** | **Responsibility** |
|---|---|---|
| Response Teams | EMS, Fire, Police, Dispatch, Incident Commander | Provide support for critical tasks:<br>EMS – updates to local hospital, support medical activities<br>Fire – respond to fire prevention and control<br>Police – support scene security and perimeter safety<br>Dispatch – mediate operations between chiefs and agencies |
| Health Operations | Medical Examiners, Erie County Health Operation Center, Critical Incident Stress Debriefing Unit, Twin City Ambulance Unit | Provide on-site support to EMS Units<br>Provide physicians for rehab centers<br>Provide on-site treatment and evaluation of responders<br>Minimize stress related injury through education and intervention |

| | | |
|---|---|---|
| Special Team | Incident Management Team, Hazmat Team, SMART, FBI Response Team | Setup Incident Command Structure<br>Providing action against hazardous material<br>Provide Recovery control and investigation |
| Media Relation | Public Information Officer, Western NY 211 | Organize daily press briefings, communicate with local media<br>Handle calls related to victims, crash zones, etc |
| Other Facilities | Cheektowaga Senior Center, Clarence Library, Clarence Center Fire Auxiliary | Provide in-house support for responders including lunches, rescue operations, shelter areas, etc. |

Table 1: Response Agencies for the Buffalo Plane Crash

## SITUATION AWARENESS FOR ANALYZING COLLABORATION

Situation Awareness model provides essential insights for analyzing Incident Commander's decision-making process for effective collaboration during the Buffalo Plane Crash incident. The process for the analysis is explained in this section as follows: First, we identify the dataset of collaborating units as they reported to the scene of the crash. Second, we provide results of our time-series analysis of the dataset that help to identify characteristics of the reporting units. Third, we conclude with the discussion of situation awareness for the process of collaboration.

### Plane Crash Data

The Figure 3 below shows an excerpt from crash incident report. This report is a log of messages that are exchanged between the responders and agencies, and is extremely useful in strategic planning and incident management. The data for the crash was mainly obtained from the "Vehicle Summary" and the "Dispatch Comments" section of the report. The former provides details on the responding agency, and the latter provides messages as exchanged between the dispatch and incident commander. We interpret the vehicle codes with the help of setup values, and the messages with the help of responder interviews. The messages were classified into two main categories based on their objectives, namely notification (that inform about the incident) and update (that update information about the incident). The message classification is not detailed here, since it is not the focus of this paper. From here on, we refer to agencies, resources and responders (ARR) as "ARR units" in order to maintain standard with the incident reports.

Vehicle: ID Number CC2 CLARENCE CENTER 2000 GPM 750 G
Dispatched 15:18:13
Enroute 15:18:13
At Scene 15:18:17
Transport
At Hospital
Available 17:12:29

**Dispatchers Comments**

RICKM 22:18:44 Received: 02/12/09 22:18:10 Phone: 716-741-3910
RICKM 22:18:44 Caller: HARRINGTON, DAVID & RESD
RICKM 22:18:44 Address: 0006050 LONG
RICKM 22:18:44 City/St: Type F
EMS 22:19:48 Unit:240 From:MAPLE RD & TRANSIT RD
EMS 22:19:48 Destination:<None> Mode:A Status:DS
EMS 22:19:48 Date/Time:2009-02-12 22:19:24
RICKM 22:20:05 D

Figure 3: Buffalo Plane Crash Incident Report Excerpt

From the report, it was observed that the Incident Commander was collaborating the efforts of 19 responders, from 13 agencies, utilizing 22 different resource types after the first hour of incident. The Figure 4 below depicts the *available* ARR units as cumulative counts at the end of each time period. The Table 2a provides terminology for ARR units as identified from the incident report. The Table 2b depicts the *additional* ARR units that were reporting every 15 minutes to the scene of the incident, with the help of terminology.

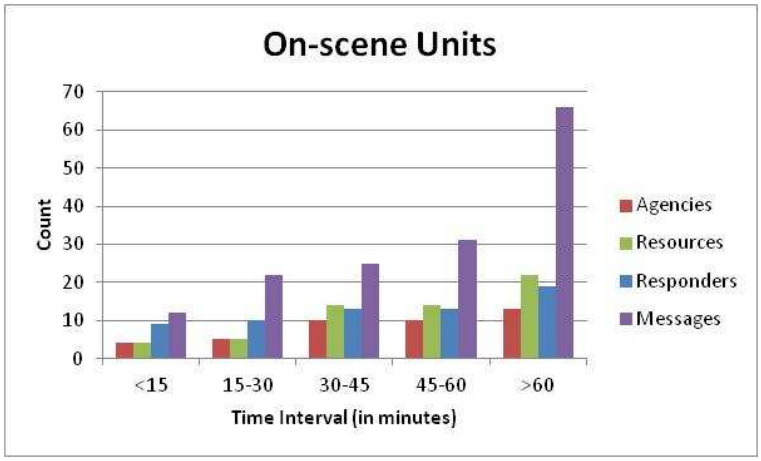


Figure 4: Available ARR Units

| **Agencies** | | **Resource** | | **Responders** | |
|---|---|---|---|---|---|
| CC: Clarence Ctr<br>C: Clarence<br>EA: East Amherst<br>SW: Swormwille<br>R: Rapids<br>HH: Harris Hill<br>G: Getzville | N: Newstead<br>MT: Main Transit<br>NA: North Amherst<br>A: Akron<br>MIL: Milgrove<br>BOW: Bowmansville | 1-4: Pumper<br>5: Heavy Rescue<br>6:Ladder<br>7: Light Rescue<br>8: Ambulance | The alphabetical characters refer to agency.<br>*Example: SW8 – Ambulance from Swormville agency* | 9: Chief<br>91: Chief first assist<br>92: Chief second assist<br>93: Chief third assist<br>94: Chief fourth assist | The alphabetical characters refer to agency.<br>*Example: R9 – Chief of Rapids agency* |

Table 2a: ARR Units Terminology

| | **<15 minutes** | **15-30 minutes** | **30-45 minutes** | **45-60 minutes** | **>60 minutes** |
|---|---|---|---|---|---|
| **Agencies** | CC, C, EA, SW | R | HH, G, N, MT, NA | No additional | A, MIL, BOW |
| **Resources** | EA5, SW5, C5, C1 | SW8 | C8, HH8, G7, R8, R81, N8, N81, MT8, NA8 | No additional | R41, A4, MIL5, N5, SW2, HH5, BOW5, CC2 |
| **Responders** | CC91, C9, CC92, CC93, EA9, SW9, SW92, C91 | R9 | HH9, HH91, NA92 | No additional | SW91, N94, HH9, HH91, SW9, N9 |

Table 2b: ARR Units reporting at scene

### Plane Crash Data Analysis

The illustration of on-scene collaboration is shown in Figure 5a and 5b below. The first figure depicts the pattern of collaborating units, while the second figure depicts the pattern of collaborative messages. The arrival times of the ARR units were used in a time series analysis, along with frequency of collaboration messages. The horizontal axis depicts the timeline with an interval of 15 minutes. The vertical axis depicts the frequency, in percentage of total count. The different colored graphs indicate the different collaborating units (ARR units) and collaborative messages (notifications and updates). The incident has been normalized to one hour for illustrative purposes. Page limitations constraint us from including a more detailed explanation of the figures below.

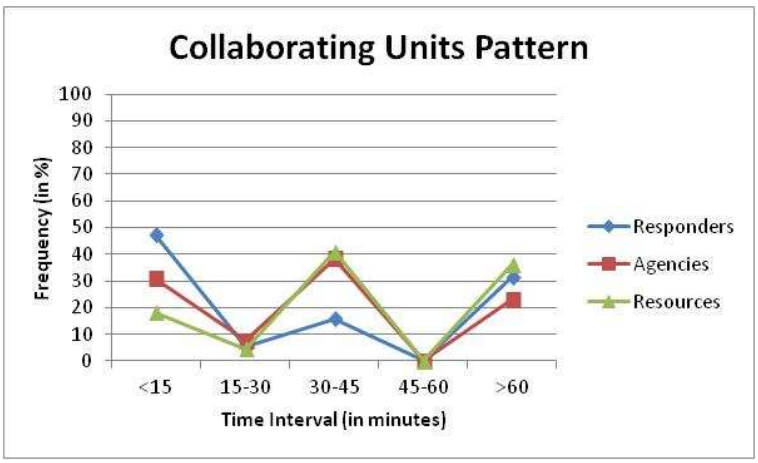


Figure 5a: Illustration of Collaborating Units (ARR Units)

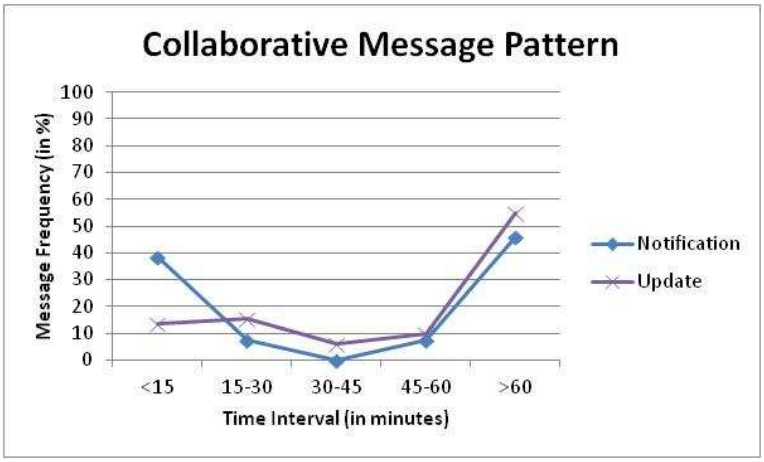


Figure 5b: Illustration of Collaborative Messages (Notifications and Updates)

**Plane Crash Findings**

In general, the frequency of collaborating ARR units depicts an alternating high and low periods. This implies that there was an active run of high number of collaborating units reporting in the first period, followed by a dry run of very few collaborating units reporting in the next period, continuing up to a total of five periods. Additionally, the frequency of messages shared between on-scene and off-scene agencies follows a U-curve. This implies that the number of messages is relatively higher in the initial and final periods and lower in the middle periods.

In the first 15 minutes of the crash, the incident commander perceives the significant intensity of crash/damage and calls for additional help that is observed in higher levels of notifications that leads to higher number of ARR units reporting on-scene. Since the plane was carrying 49 passengers aboard, the incident command perceives support of additional rescue trucks for victims that may be alive. This perception of crash intensity equates to level one (perception) of situation awareness. In the 15-60 minutes time period, the incident commander comprehends the availability of ARR units at hand. In case of scarcity, the incident commander requests additional resources that is observed in higher levels of units arriving at scene with lower levels of messages. Before getting into suppression of fire, the incident commander comprehends the chances of injury, and thus requests additional ambulances to the scene. This comprehension of availability of supporting units equates to level two (comprehension) of situation awareness. Finally, after the 60 minutes of crash, the incident commander projects his/her learning of the incident to further decision-making actions that is observed in higher levels of messages and higher levels of

units reporting to the scene. The incident commander projects the support of pumpers for suppressing fire and thus makes requests accordingly. This projection of actions for efficient decision-making equates to level three (projection) of situation awareness. These results are summarized in the Table 3 below:

| | **Collaboration** | **Messages** | **Objective** | **Resources** |
|---|---|---|---|---|
| **Perception (<15 minutes)** | More emphasis on responders | More emphasis on notifications | RESCUE | More emphasis on rescue trucks |
| **Comprehension (15-60 minutes)** | More emphasis on resources | More emphasis on updates | TREATMENT | More emphasis on ambulances |
| **Projection (>60 minutes)** | More emphasis on agencies | More emphasis on updates | SUPPRESSION | More emphasis on pumpers |

Table 3: Collaboration at each level of Situation Awareness

## SYSTEM DESIGN

In order to make above discussion of situation awareness for effective collaboration, we interviewed responders who were asked questions related to issues in collaborating response with the three agencies including dispatch, fire and police. The interviews took place in multiple rounds with each round lasting for about 90 minutes. Their responses, mostly, fell in the category of system issues, communication issues, information management issues and interoperability issues. These are highlighted below:

### System Issues

Emergency dispatch systems provide essential support to emergency responders that enable dispatch responders to answer more calls, prioritize responses to critical calls, and deal with complexity and pressure in an emergency context. These systems mainly depend on radios for communication between responders and agencies. However, there are several problems associated with radios that call for development of an alternate mode of communication. Following insights, associated with radio issues, are provided by the dispatchers.

> *"Radios are lifelines during emergencies. However, everyone was talking on the radio at the same time. Co-working of radio channels for different operations or different emergencies was extremely challenging"*

> *"Plane crash incident was managed over four channels. Some people faced problems in channel switching owing to 'fat fingers' due to gloves or other hand protections. Some people didn't remember to switch to right the channel"*

### Communication Issues

Center for American Progress' National Security issue of 2005 states that, currently, the US has no system in place to allow emergency response personnel communicate reliably and effectively in a crisis. The current systems in place include radio communicators, cues on paper, and mental notes. The interviews with experts clearly identify the important aspects of communication.

> *"There was large number of responding units. There was large number of incoming calls from the scene. Recognition of the communicator was very important in deciding prioritization of that call. Incident Commander was topmost priority"*

> *"Personal information like Chief's phone number could not be transmitted on air. Thus people needing the information had to request us [dispatchers]. This information was used by media for latest news. This led to influx of calls from media during crunch periods"*

### Information Issues

Lack of information has always limited the efficiency of the response. (Comfort et al. 2004) show that the access to the information also plays a vital role in improving efficiency. This leads to an important argument on how to manage the

information. The interviewed responders provide responses for identification of who is in charge, what is the responsibility and capability of each agency (in term of resource availability) and responder (in terms of training), and what information is accessible to them.

> *"Not all information was routed through us [dispatch]. Due to lack of centralized information, it was easy to get out of loop during peak times"*

> *"The command structure showing 'who is responsible for what' was hard to maintain during the initial operations phase"*

#### Interoperability Issues

Recently, a number of data standards have been developed for effective information exchange (Bharosa et al. 2010). However, emergency systems are still fragmented and disintegrated. The non-interoperable systems have made it difficult to communicate critical information between different departments in a timely manner. Interoperability is one of the important steps in responding to national emergencies. The dispatchers identify how information into and out of the systems was a problem during the incident.

> *"For gas shutoffs in the neighborhood, the Incident Commander had difficulty in identifying the accountable utility company due to lack of information from their systems. This resulted in back and forth between National Fuel and NYSEG (gas companies) arrivals to the scene"*

> *"There was no easy means for information to outside public. It was all routed though us [dispatch], which led to increased volume of calls pertaining to that information"*

The results from situational analysis of the incident, and issues, identified by responder interviews, help in development of design principles that will improve the quality of collaborative systems. These design principles are explained in detail in the following section.

## DESIGN PRINCIPLES

The design principles were derived taking into consideration the levels of Situation Awareness as they translate to system design. In order to address the perception level of Situation Awareness, the system should provide flexible observation capabilities – 'what incident commander sees' – including any conflicts and uncertainty expressed at arbitrary levels of detail. Similarly, to address the comprehension level of Situation Awareness, the system should provide evaluation capabilities – 'what incident commander thinks' – presenting the incident commander with plans, justifications and group reasoning. Additionally, to address the projection level of Situation Awareness, the system should provide capabilities – 'what incident commander wants to execute' – including requests, responses, referrals and recommendations of third parties.

Since the responders are the users of the emergency systems, the issues identified with the help of responder interviews provide adequate base for improving the current state of emergency collaborative system. The fact that the existing systems do not fulfill the demands of the responders using the system indicates that current design principles will prove extremely useful, even though these design principles do not make up an exhaustive list. Thus in this section, we address the issues highlighted by the responders by identifying design principles need to meet all the requirement of the responders.

*Principle 1: Design a computer mediated messaging model that can help transmission of messages without the use of radios.* In order to motivate development of prototype systems other than radios, for on-scene communication, a messaging model is a vital aspect. The development of such a model requires determining various elements that are a part of on-site emergency message, the interaction that exists between the various elements of the message, and process states and transitions of the elements.

*Principle 2: Develop a messaging format considering the communicator, the content and the security level.* During an emergency event, the lack of standardization in a messaging structure renders these messages incomprehensible for the receiver. Thus, the development of a messaging format not only helps in standardizing the messaging structure, but also helps in its reusability and reproducibility. Consequently, the standardized format can lead to appropriate interpretation of the data by other agencies that are a part of the response. The messaging format should identify the communicator and the message objectives. The standardization of the messages should also provide for its semantic interpretation.

*Principle 3: Setup an information structure clearly identifying Who, Whom, When, What and Where attributes of events.* The *who-, whom*-type structure will identify agencies or responders assigned to each task, the *when*-type structure will identify the time instance, the *where*-type structure will identify the location, and the *what*-type structure will identify the resources assigned to each task. Such a structuring will help incorporate the entire command structure in the system that will provide the following: task-prioritization for decision-making, summary of agencies assignments, and allocation of resources to appropriate tasks.

*Principle 4: Implement systems using standardized frameworks like UCORE and NIEM in order to exchange information efficiently.* A standardized system is very important for message encoding and decoding perspective. It allows for providing interoperable solutions for emergency systems. Universal Core (UCORE) provides such a framework that facilitates emergency communication for incidents, such as forest fires, by providing a means for standardizing emergency messages. To address the problem of information exchange across departments, National Information Exchange Model (NIEM) develops and supports information exchange standards for sharing of information during an emergency situation, using XML data model to standardize content between the agencies. The design matrix for improved Situation Awareness is shown in the Table 4 below.

| | **Perception** | **Comprehension** | **Projection** |
|---|---|---|---|
| **Principle 1** | | | ✓ |
| **Principle 2** | | ✓ | ✓ |
| **Principle 3** | ✓ | ✓ | |
| **Principle 4** | ✓ | ✓ | ✓ |

Table 4: Design Principles for improved situation awareness

## CONCLUSION

This paper contributes to research in inter-agency collaboration and emergency management. On the basis of case study, this paper aims to explore various issues in inter-agency collaboration including role and access control, resource management and accountability, and present design principles to address those issues. With the help of interviews with four experts (two fire chiefs and two dispatchers) and raw incident communication report, the collaboration issues are identified in the categories of system issues, communication issues, information issues and interoperability issues. The findings in terms of collaboration issues are generalized to design principles to help support better collaboration by addressing the issues as follows: First, to address system issues, design a computer mediated model to avoid use of radio. Second, to address communication issues, develop a message formats. Third, to address information management issue, setup an information structure. Fourth, to address interoperability issue, implement systems using standardized frameworks.

To further develop this research, we would perform interviews with responders that were a part of the second phase i.e. recovery phase, in addition to performing interviews at each level of incident command structure. This would help base our design principles on interviews with greater number of experts, at more levels of hierarchy, and in more sections of the incident command structure. The paper has certain limitations. First, it considers findings based on a single incident. Second, it considers qualitative data in the form of interviews which have to be generalized to derive the findings. Third, since the plane crash was the first of its type in Buffalo, New York, the details of the findings are unique to only this incident. Some of the future extensions of this paper are as follows: First, implement a prototype system by incorporating the design principles. Second, perform table top exercises with the expert in order to measure improvement in the response time.

**REFERENCES**

Benbasat, I., Goldstein, D. K., Mead, M. 1987 "The Case Research Strategy in Studies of Information Systems," MIS Quarterly (11:3), pp. 369-386.

Bharosa, N., Lee, J., Janssen, M. 2010. "Challenges and obstacles in information sharing and coordination during multi-agency disaster response: propositions from field exercises," Information Systems Frontiers 12 (1) (2010) 49–65

Chen, R., Sharman, R., Chakravarti, N., Rao, H.R., and Upadhyaya, S.J. 2008. "Emergency Response Information System Interoperability: Development of Chemical Incident Response Data Model," Journal of the Association for Information Systems (9:3), p. 7.

Chen, R., Sharman, R., Rao, H., and Upadhyaya, S. 2005. "Design Principles of Coordinated Multi-Incident Emergency Response Systems," in Intelligence and Security Informatics, P. Kantor, G. Muresan, F. Roberts, D. Zeng, F.-Y. Wang, H. Chen and R. Merkle (eds.). Springer Berlin / Heidelberg, pp. 177-202.

Chen, R., Sharman, R., Rao, H.R., and Upadhyaya, S. 2007. "Design Principles for Critical Incident Response Systems," Information Systems and E-Business Management (5:3), pp. 201-227.

Chen, R., Sharman, R., Rao, H.R., and Upadhyaya, S. 2012. "Data Model Development for Fire Related Extreme Events: An Activity Theory Approach," MIS Quarterly. Forthcoming

Chou, C.H., Zahedi, F.M., and Zhao, H. 2011. "Ontology for Developing Web Sites for Natural Disaster Management: Methodology and Implementation," Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on (41:1), pp. 50-62.

Cigler, B.A. 1988. "Emergency Management and Public Administration," Crisis management: A casebook, pp. 10-12.

Comfort, L.K., Ko, K., and Zagorecki, A. 2004. "Coordination in Rapidly Evolving Disaster Response Systems," American Behavioral Scientist (48:3), p. 295.

Curra, T., Bergin, R., Josefek, R. 2009. "A New Role for Emergency Management: Fostering Trust to Enhance Collaboration in Complex Adaptive Emergency Response Systems," Naval Postgraduate School Thesis from http://www.dtic.mil/dtic/tr/fulltext/u2/a514087.pdf

Diniz, V., Borges, M., Gomes, J., and Canós, J. 2005. "Knowledge Management Support for Collaborative Emergency Response," IEEE, pp. 1188-1193 Vol. 1182.

Endsley, M.R. 1995. "Toward a Theory of Situation Awareness in Dynamic Systems," Human Factors (37:1), pp. 32-64.

Hancock, P., and Hart, S. 2002. "What Can Human Factors/Ergonomics Offer?," Ergonomics in design (10:1), pp. 6-16.

Hollingshead AB, McGrath JE, O'Connor KM. (1993). Group task performance and communication technology: a longitudinal study of computer-mediated versus fact-to-face work groups. Small Group Res. 24(3):307–33

Hollingshead AB. (1996). The rank-order effect in group decision making. Organ. Behav. Hum. Decis. Process. 68:181–93

Janssen, M., Lee, J., Bharosa, N., Cresswell, A. 2010 "Advances in multi-agency disaster management: key elements in disaster research," Information Systems Frontiers 12 (1) (2010) 1–7

Jarvenpaa, S. and Ives, B. (1994), "The global network organization of the future: information management opportunities and challenges", Journal of Management Information Systems, Vol. 10 No. 4, pp. 25-33.

Kim, J., Sharman, R., Rao, H., Upadhyaya, S. 2006 "Framework of analyzing Critical Incident Management Systems (CIMS)", Proc. Of Thirty-Ninth Hawaii International Conference on System Sciences (HICSS-39), 2006, Hawaii

Majchrzak, A., S. L. Jarvenpaa, A. B. Hollingshead. 2007. Coordinating expertise among emergent groups responding to disasters. Organ. Sci. 18(1) 147–161.

McGuire, M., and Silvia, C. 2010. "The Effect of Problem Severity, Managerial and Organizational Capacity, and Agency Structure on Intergovernmental Collaboration: Evidence from Local Emergency Management," Public Administration Review (70:2), pp. 279-288.

Samba, M.M. 2010. "Intergovernmental Collaboration in Emergency Management: The Case of the September 2009 Georgia Flood," from http://digitalcommons.kennesaw.edu/cgi/viewcontent.cgi?article=1429&context=etd.

Seifert, C. 2007. "Improving Disaster Management through Structured Flexibility among Frontline Responders," Communicable crises: prevention, response, and recovery in the global arena, p. 83.

Strater, L.D., Endsley, M.R., Pleban, R.J., and Matthews, M.D. 2001. "Measures of platoon leader situation awareness in virtual decision-making exercise," US Army Research Institute for the Behavioral and Social Sciences.

Turoff, M. 2002. "Past and Future Emergency Response Information Systems," Comm. of the ACM (45:4), pp. 29-32.

Turoff, M., Chumer, M., de Walle, B.V., and Yao, X. 2004. "The Design of a Dynamic Emergency Response Management Information System (Dermis)," Journal of Information Technology Theory and Application (JITTA) (5:4), p. 3.

Valecha, R., Sharman, R., Monteiro, J., Rao, H. R., Upadhyaya, S., Keerthana, B., Patel, M., Singh, A., Sharma, K. 2010 " A Prototype of a FIRE-RELATED EXTREME EVENTZ SYSTEM (FREEZ)," Proceedings of WITS, St Louis

Waugh Jr, W.L., and Streib, G. 2006. "Collaboration and Leadership for Effective Emergency Management," Public Administration Review (66), pp. 131-140.