

Emergency Operations Intelligence Fusion

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Abstract

Hurricanes Katrina, Gustav, and Ike have revealed a deficiency in the ability to coordinate multiple agencies during the relief effort in both pre and post landfall events. The lack of a common operational picture (COP) has limited the ability of a unified effort in disaster response. The solution which can overcome the obstacles of communication interoperability and rapid dissemination of data to all involved agencies is a fully interactive web based mapping tool. The bases for the map is to utilize the wealth of information in the form of Web Feature Service (WFS) and Web Mapping Services (WMS) being supplied by both government agencies and commercial providers, such as, NOAA, NTSB, and utility suppliers. Coupling this information with the positions of resources, critical infrastructure, and incident reporting will yield a visual aide that allows coordination and the ability to quickly identify mission impacts and asset allocation. This web based application presents another capability in that it creates a network centric environment. Web basing allows any first responder with an internet access to become a sensor and provide additional intelligence to enhance relief efforts. The result is better resource management, faster decision cycles, and more importantly a reduction in loss of life due to delay or indecision.

1. Introduction

In 2005, Hurricane Katrina provided an unnecessary reminder of the criticality to establish a common operating picture [1] (COP) for disaster response at all levels of government (Federal, State, and Local). This

was further emphasized with Hurricanes Gustav and Ike in 2008 demonstrating that only marginal progress had been achieved during that time frame. Obtaining a common operational picture is integral when it comes to emergency response management. By obtaining a single identical display of operational information that is visible across the entire enterprise of public safety, government, and military agencies can greatly enhance situational awareness. A COP facilitates collaborative planning and enables new levels of productivity and efficiency in critical operations.

The current philosophy when developing a common operational picture focuses on incident locations and asset placement. While this is critical in decision making it is an incomplete but for the total equation, true situational awareness occurs when an emergency manager can view their resources and the potential impact that the surrounding environment (both natural and manmade) will have on their operations. Additional sources of public infrastructure information such as real time weather, surge models, and traffic information if fused to the common operational picture would create a higher level of understanding and expedite course of action development and execution (this is referred to in the military as a C⁴I system, Command and Control, Communication, Computers, and Intelligence).

Situational understanding is commonly confused with situational awareness (SA). The difference is situation understanding refers to the product of applying analysis and judgment to the decision maker's situational awareness to determine the relationships of the factors present and form logical conclusions concerning threats to mission accomplishment, opportunities, and gaps in information [2]. Situation understanding as it applies to

disaster relief allows one to start the “so what” analysis by having as much relevant information available to visualize the impact of those environmental variables on current and future operations.

Environmental information that is currently available has the capability of delivering the described situational understanding. The main problem lies with the inability to view this information on a common visualization tool that is available to all parties involved in the disaster response. Data feeds and informational products reside within their own stovepiped databases and applications and any fusion is performed by either accessing multiple displays or through manual comparisons between intelligence, including weather, and the common operational picture. Information that is relevant to the mission may be overlooked if it has to be accessed from several sites or sources. This delays action and leads to sub optimal decision with vital assets and personnel that can result in a potential loss of life.

2. The Natural Threat

Hurricane Katrina is to date the most expensive disaster to strike the United States. The cost exceeded 81 billion dollars (2005) in property damage with a loss of life estimated at 1877 (an additional 703 persons listed as missing). The area affected by Hurricane Katrina covered more than 90,000 square miles and stretched across five states in the gulf coast region forcing a mass exodus of more than 1.2 million citizens [3].

The aftermath of the hurricane was plagued with a lack of communication and the ability to coordinate efficiently and effectively. Many rescue and relief efforts worked in a vacuum not knowing the surrounding actions being taken by other agencies. Areas received little assistance while others were overwhelmed by support that the response itself became a hindrance and a drain on supplies.

Many organizations and agencies including local law enforcement, emergency management, State and Federal agencies, and the military found that even with operational communication equipment their ability to share information was not guaranteed due to the incompatibility of many systems across organizations (a problem that still exist) [4]. This is further emphasized by Lt Col Greg Gecowets in his after action review of the lack of communications during the Hurricane Katrina response.

In many cases, key messages were printed and hand carried around command centers to make sure incident managers had the right information. In military terms, government lost its C4ISR capability levels [it] was in effect deaf, dumb, and blind, blundering about and trying to make sense of an endlessly confusing

and rapidly changing situation. This rapidly led to chaos [5].

This blindness produced duplication of effort and many times an asset that could have been utilized was not active because the need was unknown to other relief providers or missions were jeopardized because assets were either ill suited for the conditions and they became a liability. A true COP of the affected area was nonexistent and asset management was being performed at the lowest level where direct C² of those resources existed.

Infrastructure condition and reporting was late. This produced logistic delays in areas as routes had to be reconnoitered for trafficability. Coupled with the communication problems discussed there is no doubt that many of the same routes may have been search by multiple agencies for their own intelligence needs since a single source was not available. This leads to a reoccurring theme; “delayed response due to a lack of situational understanding”.

3. Current Applications

The main focus of current domestic C⁴I (Command, Control, Communications, Computers, Intelligence) systems has been to manage disasters resulting from terrorist incidents. These systems usually access sensitive databases and provide information to the users which necessitate protecting these systems behind multiple firewalls and credentialing to prevent unauthorized access. While this is imperative for the terrorist scenario where information could add value to the defender, as well as, the attacker, it quickly becomes a burden during a natural disaster. Additionally, many of the systems that have been created requiring dedicated thick clients which are either cost prohibited or not feasible for a mobile relief effort which is a hallmark of natural disaster response.

This situation during the Katrina response is described by the Gecowits’ study pointing out that responding DoD elements had trouble creating an unclassified situational awareness picture, since most of their resources are (for understandable reasons) classified. Accessing classified systems from the field and sharing information among emergency centers was often difficult, and in any case, classified systems are usually unavailable to civilians [6].

The main difference between the terrorist threat and the natural disaster is that the terrorist threat can be reduced with increased intelligence. As Todd Sanders research concluded in a recent study about expenditures for combating terrorism, there is a 6% return on investment for every dollar spent on security of facilities while the return on investment is 900% for intelligence [7]. The point being an immense amount of labor and money is being spent on systems that may or may not be used based on the quality of intelligence being collected and the budget being allocated (which may thwart an attack and

negate the need) while hurricanes are expected every season and it is more of a question of when and where the strike will come contrary to the terrorist subject of “if” the attack takes place.

The 2009 hurricane season is estimated by NOAA to have at least 11 named storms with three to six reaching hurricane strength [8]. The more information that can be collected and disseminated on the storm (e.g. storm track, surge levels, expected rain fall amounts) will not alter that storm’s path or impact zone but it will give responders time to prepare, allocate resources and develop courses (COA) of action both prior and post landfall.

The target audience for these two events (terrorist event vs. natural disaster) also differs. Natural disasters will always fall to the responsibility of Local and State government. Federal response will support the States effort as was the case with Mississippi during the aftermath of Katrina. Only in extreme circumstances will the Federal agencies take over the primary lead as was seen with the declaration of martial law in New Orleans when the local law enforcement was overwhelmed.

This difference indicates a need for an alternative approach to a COP/C⁴I system that has the primary mission to convey information to multiple agencies, fast, efficiently, and without being anchored to a proprietary localized software application or multiple layers of agency specific security protocols.

4. Problem

Emergency Operations Centers during natural disasters currently build their situational awareness by gathering information from several disparate sources and internally combing this information through reports, independent products, and mental models. This method leads to misrepresentation of the situation by overlooking many of the underlying effects that may be causing the reported situations. Information gathering is completed partially by the EOC reaching out to multiple sources and pulling this information which places additional burden on the EOC Fig 1. The expertise in the EOC of what critical pieces of information are required to develop a picture of the situation differs from organization to organization based on experience levels and equipment. Therefore, different views of the same situation may exist throughout the area of operation. Each of these different views will produce its own response further adding to the confusion and requiring precious time to identify the true state.

The need for an interactive web-based application which is capable of fusing the common operational picture with real time intelligence is vital for supporting disaster response and emergency management. The ability to view resources and simultaneously overlay real-time data (weather radar, surge models, wind fields) will allow for rapid decision cycles and dissemination to all levels of response. Combining this with points of interest

(logistical distribution areas, infrastructure status) gives a powerful tool that is free of the challenges experienced with many of the current emergency operations management (EOC) tools.

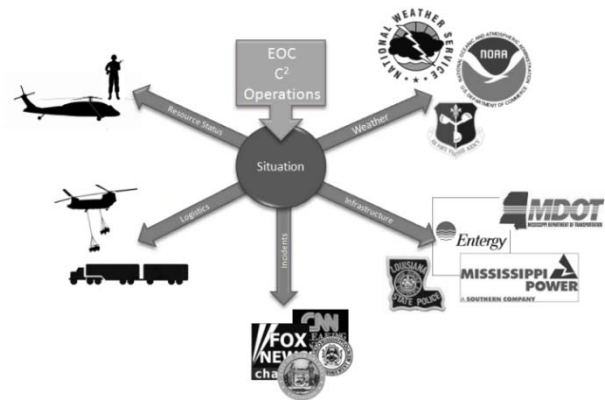


Figure 1. Current situational awareness process for EOCs.

This layering and processing of data allows decision makers to quickly view the area of impact and make educated decision that encompass multiple variables (weather, traffic, assets, infrastructure, contra flow). This leads to shorter decision cycles and places the right resource, at the right location, at the right time.

5. Solution

The interactive web-based application for disaster relief provides the situational understanding required by multiple agencies when reacting to a disaster. Having the tool web based allows agencies to share a common view free from being tied to a single machine. This enables mobility and flexibility when establishing Emergency Operation Centers (EOCs) within the disaster area. Utilizing the web feature services (WFS) and Web Mapping Services (WMS) provided by many government agencies and commercial entities that provide public services, the application is capable of processing georeferenced data feeds and displaying this information on a common base map. Merge this information with asset information (National Guard, EOC, first responder locations), infrastructure status (bridge levee, power grid condition), and areas where events are occurring (displaced personnel requiring assistance) yields a single view which gives full situational awareness Fig 2.

This solution not only increases the situational awareness for the overall incident command/controlling agency but will provide mutual awareness between different agencies as to capabilities, location, and current task loading. For example, a county EOC making a request to the overall emergency manager for supplies at one of its shelters (commonly referred to as a POD site, Point of Distribution) could be viewed by other

organizations viewing the POD location. This mutual awareness would provide reaction time for logistics to gather the supplies and the transportation assets to prepare movement of those supplies prior to the actual task order being issued. This proactive approach continues as infrastructure conditions are evaluated (routes) and weather impacts are quickly assessed to develop the best course of action to implement. Through this example the concept of situational awareness unfolds as the decision makers take the situational awareness gained from the situation displayed on the COP and merges their own experiences and judgments to quickly determine the options that can be executed.

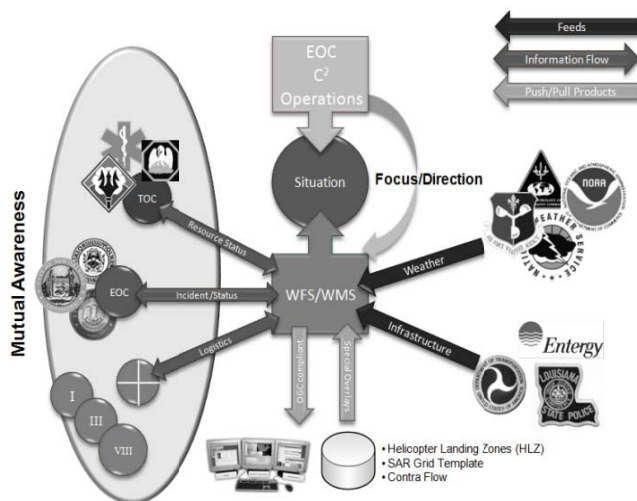


Figure 2. Proposed solution for situational awareness.

Fusing the COP with intelligence feeds National Oceanic and Atmospheric Administration (NOAA) surge models, National Hurricane Center (NHC) Hurricane Model Tracks, and composite radar will allow decision makers to array resources and direct their effort to those regions that will be most heavily impacted without the response becoming a liability themselves. Joining this capability with traffic data, electrical power distribution, and other infrastructure status provides valuable information with respect to logistical movement and the orchestration of pre event posturing and the post damage recovery efforts Fig 3.

5.1. Asset Tracking

In order to become a true C⁴I system the C² portion must be addressed, which can be simply stated from the decision maker point of view: “where are my forces that are available?” This concern has always been a complicated operation for organizations responsible for command and control. The diverse agencies and organizations that arrive in the area of operation (disaster

field) have different capabilities, resources, and assets which need to be inventoried so they can be effectively applied to the relief effort. The location of these assets is usually only known initially by the parent agency or organization and is usually not reported efficiently to other parties involved. Many times its existence may be discovered more by accident than through collaboration.



Figure 3. Combined web map of weather, assets, and infrastructure.

Through a web based service, each node is capable of posting its position and resources to the map through a web interface. Using standard military icon sets (which are clearly defined and d for any disaster situation), the ability to quickly build the common operational picture for the entire network occurs simultaneously as individual groups provide their position, as well as, resources, capabilities, and contact information. This information would be less prone to error since it is maintained by the reporting organization and would not require a support staff at the EOC to constantly collect this data. This furthermore spreads the work load throughout the network with each group of relief workers providing their own information and only to one source. This method reduces redundant communications and frees man hours to concentrate on the mission.

5.2. Net Centric Operations

The ability to access the service via the web supports the net centric warfare model where anyone that has admittance becomes an active source of information. Each responder theoretically becomes a sensor within the network if they have the means to communicate to a node (any machine capably of establishing an internet connection) [9]. The result is unparalleled information sharing network where all levels mutually benefit and perpetuates collaboration among the different entities. Real time data is captured through the first responders and quickly broadcasted to all involved participants. Previous outages which may have seen duplicated effort by

multiple agencies is quickly identified by a single group performing reconnaissance and its status reported to all. For example, Fig 4 represents a scenario that is common on the gulf coast. Once a hurricane passes, bridges have to be visually inspected for damage caused either storm surge or the flooding from swollen streams and rivers due to the immense amount of rainfall delivered in a short amount of time.

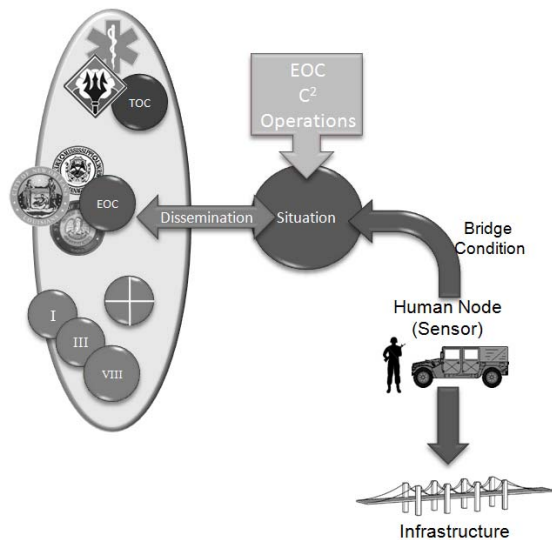


Figure 4. Example of a network-centric scenario for bridge inspection by a unit and reporting the condition into the network for all agencies to have immediately.

This information is critical for determining routes to provide assistance for all the first responders and follow on support. The collection and dissemination of this data can be efficiently executed through a network-centric structure using a web-based COP. The surveyor (the sensor node) would arrive on scene and determine the condition of the structure. This determination would then be entered directly to the map through a laptop or portable device, or radioed back to the surveyor's headquarters to be input through their console. The effect is the bridge's condition is immediately known throughout the area of operation and mission planning can continue for all groups; the cost for everyone involved was a single resource (the surveyor) for a limited amount of time. The feedback to the surveyor is the ability to view results from other nodes within the system from which they can adjust the collection plan accordingly and determine inspection priorities as potential routes which may yield a successful solution take shape. This feedback loop allows resources to quickly be reallocated to maintain the momentum since the surveyor is able to view their surroundings. This is a network-centric environment in its purist form as the surveyors (nodes) are able to take initiative and direction based on the other nodes within the system. The benefit

to the overall management agencies is that the need to micromanage is reduced or eliminated.

The situation understanding that can be gained from having a network-centric web-based EOC service will increase the response of emergency operation centers at all levels. Fusing information from multiple sources and applying that knowledge to affect mission planning will result in better agency collaboration, asset management, and most importantly lives saved during the hurricane response.

6. Extensions

The web-based solution prototype being developed in cooperation with Geocent and the Space and Naval Warfare Center (SPAWAR) in New Orleans currently has the ability to perform all the features required to effectively manage the information visualization requirement for emergency managers. Additional extensions which would further enhance the capability to support complex decision making would be accomplished with geoprocessing.

The described web-based solution has the ability to layer information from multiple sources onto a single display. This layering on a single map allows for interactions and underlying effects to be identified and aid in courses of action development. The next step would involve filtering data to develop capability constraint layers based on user parameters. The following example will use the operational limitations for common rotary wing aircraft (helicopters). Rotary wing assets are considered one of the most critical resource shortly following a hurricane. Its ability to move relatively unrestricted over terrain aids in search and rescue, logistical resupply, and damage assessment. Therefore any restriction of its performance needs to be quickly identified early in the mission planning cycle.

In a first simple case, the wind speed limitations in which many helicopters cannot operate is around 50 knots (35 knots becomes an area of concern for many operators). Using this wind constraint, one could query the current wind speed data and produce an overlay where that constraint becomes active. This quickly identifies areas where helicopter operation is not possible and alternatives will be required until the winds subside.

A more complex layering combines multiple constraints to produce an overlay with three levels of response. Military regulations for helicopter operations require: 3 statute mile of visibility and 1000 foot ceilings. If a decision maker is willing to accept more risk these minimums can be reduced to 1 statute mile of visibility and 500 foot ceilings. Taking the current observations and comparing with these operational constraints can produce a simple three color overlay. For example; green would represent areas where no threshold is active and therefore there are no constraints on helicopter operations,

yellow would represent at least one value is between the two levels (e.g. 1 statute mile < observed visibility < 3 statute mile), and red identifies areas where at least one value is below the minimal requirements for using these assets. This one overlay quickly reduces the need to access multiple products.

Geoprocessing for detailed analysis will yield an array of descriptive information to assist in mission planning. The ability to filter information and display threshold values quickly identifies areas within the solution set that may limit or impede asset deployment. The ability to identify areas based on performance/impact parameters provides decision makers with options as to what assets are suitable given past, current or forecasted conditions and how the relief, rescue, and recovery should be executed reducing wasted time spent planning operations only to find out at the time of execution that the asset is not able to operate in the current environment. This was a painful lesson that unfolded during Hurricane Gustav where many response plans were developed using rotary wing assets only to have the storm stall in northern Louisiana for two days preventing them from being employed.

Additionally, many EOCs may not have the expertise in the usage of an asset that may be available or assigned to their area of operation. By having the asset owner develop the overlay and publish it as an additional layer (to include a linked brief which quickly points all the users to that view) mission planning can continue in a feasible direction early in the process. The reoccurring theme that has always existed in emergency operations is trying to close the cycle between decision and action.

7. Conclusion

The lack to develop a comprehensive COP/C⁴ISR system which all responding agencies and organizations can utilize for disaster management will continue to limit the full potential of a comprehensive and collaborative response to natural disasters. The solution presented achieves many of the requirements being expressed by first responder in the natural disaster management community and shortfalls that occurred during past hurricanes.

A major difficulty identified by the Federal government was the lack of interoperability among the radio equipment used by all the different government bodies, agencies, and first responder organizations [10]. A web based application provides the interoperability required when other means of communication remain incompatible. The requirement to have this capability is a computer or portable device capable of accessing the internet.

The massive storm surge destroyed vital information or limited the access to that information as data storage facilities were either inundated with sea water or were

negated due to loss of power. Having servers and databases co-located in the same location as the potential impact area jeopardizes the foundation of many applications and therefore should be deployed to an area which is geographically separated. This has proved effective with the current prototype which is hosted in a server facility outside the gulf coast region and is therefore unaffected by power outages or destruction due to natural disasters in the area it was designed to support. This could be further enhanced with additional mirrored servers throughout the nation to provide redundant capabilities to reduce the probability of a system wide failure. This means that as EOCs are able to access power and internet service through their mobile communications packages the application will be immediately available to initiate coordination and information dissemination.

The technology used to create the web based application produced a positive financial effect. The application was created utilizing open source and allowed the project to be produced rapidly with relatively low cost. The open source code is non-proprietary and therefore the need to continually pay licensing fees for GIS and communication software is not required making it a feasible alternative when budgeting for small government and communities who may not have the funds. The open source coding means that as changes or enhancement are determined by the user community the actual implementation is not impeded by having to struggle through the conundrum of property rights and sole ownership legalities that plague many software solutions. Since the solution is public the choice becomes who will support the disaster community the best during these events.

The project stayed within the standards of the Open Geospatial Consortium (OGC) ensuring that it will be able to consume and display georeferenced data without error and specific middleware tailoring as feeds become available. Therefore, as information is generated and shared through WFS and WMS feeds the application only has to point at the service in order to make use of the data. This is critical during emergency operations as agencies stand up special products or services that may not have existed prior to the event and need to be accessible immediately.

The capability described in this research has been recently deployed as a working prototype to test its applicability in an actual hurricane event. As more requirements are expressed and captured in this discovery phase work will continue to proceed toward an integrated solution that fosters a higher level of cooperation.

Acknowledgments

The development of this work required the cooperation of several organizations and agencies to successfully utilize their data and understanding the requirements of disaster management. While developing this prototype,

we have made extensive use of NOAA's GIS department for hurricane data, the Mississippi Army National Guard's GIS department, and the support of the Open Geospatial Consortium (OGC), as well as, the open source community. Their combined support and interest to provide emergency data and solutions to facilitate teamwork has grown this project and offers the potential for an applied solution to the current dilemma facing emergency response to successfully accomplish its mission.

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