Design Evaluation of Incident Command Systems

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Introduction

We selected the Incident Command System (ICS) for our project because of it is a complex organizational framework and its applicability to current events. ICS is different from the typical design project topics because it is not a single specific user interface. Instead, ICS is an entire team coordination system that the government depends on for successful incident management. This presented some unique challenges, but also gave us the opportunity to conduct a system-wide review and most effective ways to achieve meaningful improvements in the cognitive ergonomics domain. We reviewed additional material to what was presented in class in order to effectively identify the most salient issues and corrective actions. Most notably, we reviewed the subject of grounding, determined how it relates to the team coordination aspects of ICS, and then introduced the topic to the class during our final presentation.

The second reason we selected ICS is because its applicability to current events. We evaluated our project ideas at the beginning of the semester, when Hurricane Florence was bearing down on the coast of North Carolina and the federal government was preparing to activate an ICS organized response. Reading the news about how our project topic was being used to help people in distress served as motivation to find ways to make the system more effective. We took these motivations and examined ICS with a design perspective making recommendations on how to improve common ground and reduce coordination costs.

Incident Command System

A disaster typically leaves behind a multitude of competing concerns for emergency responders that can result in complete chaos. People need rescue and medical attention while large-scale environmental concerns also need to be addressed. Security issues exist while law enforcement officers are preoccupied, and logistical challenges abound in the process of delivering much needed resources throughout the response. There are 29 federal agencies that have an emergency response role and they integrate with numerous state, local, and private organizations involved with an emergency. All of these agencies have their own objectives and biases towards their specific aspect of the mission. ICS is the government's answer for how to best organize and align these agencies in order to create a fast and effective response.[1]

The incident command system is the organizational framework through which the government conducts incident management. An incident is any event that requires emergency response personnel. These events include natural disasters, accidents, terrorist attacks, and even planned events such as concerts or marathons. The framework allows members from different organizations to integrate into a

[1]Edwards, C. (2015, August 27). *Hurricane Katrina: Remembering the Federal Failures.* Retrieved from https://www.cato.org/blog/hurricane-katrina-remembering-federal-failures

unified command structure so that each agency is not attempting to coordinate its own individual response to the incident.[2]

Local fire department, Governor's office, and federal officials collaborated to create ICS in the 1970's as the result of destructive fires in California. The wildfires were a complete catastrophe that resulted in millions of dollars of property damage and numerous casualties. After action reports showed that even though the fire departments had adequate resources and training, poor management and inefficient communication led to an inability to combat the fires. This led to the state of California, local fire departments, and the U.S. Forest Service coming together to create a response system known as FIRESCOPE. The benefits of the system and its applicability to other incident types was quickly realized and ICS was expanded for use by other agencies on a nation-wide scale. The use of ICS by federal agencies became mandatory in 2004 after the passage of Homeland Security Presidential Directive-5.[3]

Several key principles form the basis of the Incident Command System. The four most notable are the use of common terminology, a well-defined chain of command, effective resource management, and well-integrated communications. The reasoning for the inclusion of these principles in the original design of the system was to allow qualified members from any organization to quickly and seamlessly integrate into the unified command structure.[4] Our research discovered that principles and practice in this case do not mirror each other.

The original chain of command structure used in ICS was developed based on an operational system the Navy had been using at the time. In its current form, there are four main branches under the direction of the Incident Commander. The Incident Commander is the person in charge of the entire incident management objective. The four branches are operations, logistics, planning, and finance/admin. These branches are led by a director and have multiple divisions within them. The hierarchical structure of ICS results in a consolidation of decision-making authority at the top levels of the system, which can lead to slower response times.[4] See Appendix 1.

The upper levels of the command structure comprise most of the decision making thereby making communications critical to the success of an incident management operation. If only limited amounts of authority are delegated to lower levels of the system, decisions and authorizations are dependent on the request traveling from the on-scene response up to the designated decision-making authority. The

[2]ICS Review Document. (2008, May). Retrieved from https://training.fema.gov/emiweb/is/icsresource/assets/reviewmaterials.pdf
[3]NIMS and the Incident Command System. (2004, November 23). Retrieved from https://www.fema.gov/txt/nims/nims_ics_position_paper.txt
[4]ICS Review Document. (2008, May). Retrieved from https://training.fema.gov/emiweb/is/icsresource/assets/reviewmaterials.pdf

communications unit leader plays a critical role in the system and is responsible for developing a communications plan for use by all members of the system. The communications plan will define what members of the system should be communicating to each other and what methods they should be using. It will also establish dedicated radio frequencies for different types of communications.

Information flow throughout the ICS hierarchy occurs through paperwork in addition to the radio broadcasts described above. The system uses numerous standardized forms to ensure the correct information is being documented and passed to the responsible authority. This is also how resource tracking is conducted at the headquarters office. A resource could be a helicopter, small boat, oil clean up crew, or any other asset being used in the response. Team members track these resources on index cards referred to as "T" cards. Then team members place cards in a rack to indicate their status and approximate location. Whenever there are changes to a resource, a team member will need to update the tracking card. This system is another reason why communications between the branches are so critical to an effective response.[5]

There are currently two technology-based aids used by federal workers during an ICS-based response. The first is called the Incident Management Handbook (IMH) mobile application developed by the Coast Guard. The IMH app serves as an ICS encyclopedia for workers in the system. It provides information anyone would need to know about how the system functions, includes a glossary for all ICS related terms, and has job aids for all relevant positions within the framework. However, the IMH app does not offer any active incident management tracking capabilities. It is purely an informational guide and does not have any input areas to enter information specific to a real incident.[6]

The second software used by ICS responders is called the Incident Management Software System (IMSS). IMSS is a complex software system used by ICS workers in the field and it is capable of actively managing a real incident. It provides an overall incident map function that can be used to track the status of the incident. This system is detailed, complex, and is used at the headquarters of the incident.[7]

Grounding

As we learned in class and from Hutchins[8], we assign tasks to a teams like ICS because they can handle an increased workload and can also simultaneously work on tasks in parallel. We learned from

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[5]ICS Review Document. (2008, May). Retrieved from https://training.fema.gov/emiweb/is/icsresource/assets/reviewmaterials.pdf

[6]Incident Management Handbook [Computer software]. (2017, March 03). Retrieved from http://allhands.coastguard.dodlive.mil/2017/03/03/coast-guard-incident-management-handbook-now-an-app/

[7]Incident Management Software System [Computer software]. (2017, May 19). Retrieved from http://imss.iapsoftware.com/

[8]Hutchins, E. (1994). *How a cockpit remembers its speed.* Sociologie Du Travail 36.4: 451-473.

Salas that teams consist of members whose tasks rely on each other and on individuals who share common goals. Teams can also cover greater areas in time and space while also taking advantage of a vast increase in diversity of expertise. Redundancy and backups for tasks spread across multiple teammates can also be a great advantage for teams working together. Considering the largely interdependent work of individual members, in aggregate they create a team cognition or macrocognition which is akin to a shared processing of information.

In other words, many of the functions and tasks discussed in the readings and in class where we observed cognitive processing in an individual, many of those principles could be applied to a team as well. On a team, however, those functions are spread across multiple individuals. A major difference between an individual and a team would be the amount of communication that needs to occur within the team to achieve team effectiveness.[9] Despite distinct advantages, there exists a vast amount of research on teamwork and how to effectively get the most out of teams. One concept that is particularly important in the context of the Incident Command System is Grounding.

Hutchins and McNeese both point out in their work that we must determine the unit of analysis that we are examining, especially in context of team-tasks. Since we are not studying how one individual interacts with a particular interface, we instead need to analyze the Incident Command System and its smaller sub-teams and how they interact. "When one shifts the focus from the human information processor to the situational constraints, one quickly discovered that there is no single atomistic level of description that is privileged."[10] We attempt to analyze this dynamic and complex system through multiple levels of abstraction in order to solve some of its most challenging problems which are mostly related to this idea of grounding and establishing common ground.

Grounding is shared knowledge and beliefs that allows members to communicate and cooperate easily. "Initially, language researchers defined common ground as the sum of mutual, common or joint knowledge, beliefs, suppositions, and protocols shared between people engaged in communications."[11] Later as the proliferation of media spread into every type of communication, the newer media altered how researchers approached the grounding process. Instead now many researchers examine the computer-supported cooperative work and how grounding enables communication, coordination, and shared mental models.

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[9]Salas, Eduardo, Nancy J. Cooke, and Michael A. Rosen. (2008). *On teams, teamwork, and team performance: Discoveries and developments.* Human factors 50.3: 540-547.
[10]McNeese, Michael, Eduardo Salas, and Mica R. Endsley. (2008). *New trends in cooperative activities: Understanding system dynamics in complex environments*. Human Factors & Ergonomics Society, Inc..
[11]Carroll, John M., et al. (2008). *Toward a conceptual model of common ground in teamwork.* Letsky M. Warner N., Fiore S., & Smith, C., Macrocognition in Teams. Amsterdam, Elsevier.

In a naturalistic decision setting where the environment is uncertain, dynamic, ill-defined and the stakes are high often Recognition Primed Decision making is what humans use.[12] Team members may draw on their own experiences and the information that can be directly applied to the problem at hand. Once the pattern is recognized, the pattern gets quickly matched to a previous experience and after some mental simulations the person arrives at a decision more quickly. As a result of this rapid decision making, we find that heuristics often enter the process of choosing between alternatives because humans are simply not able to process all the available information. Cues and information enter our working memory and we synthesize them into hypotheses that ultimately lead to choosing an action and making a plan.

This is where grounding can play a major role in combating some of the pitfalls of naturalistic decision-making that occurs in the Incident Command System. When groups and teams grounded in a common knowledge base work together they can avoid some biased decision-making. Drawing from scenarios in the Carroll paper on awareness and teamwork, the reader can imagine two firefighters coming upon a new location. One is wearing a vest from the Sheyenne Fire Company, the other immediately assumes that because he is from the city that he will not know anything about fighting a forest fire. What he fails to realize is that prior to that position, he actually worked many forest fires in a more rural location. The firefighter from Sheyenne immediately loses social capital, trust and credibility and the other firefighter then makes flawed decisions based on his tacit lack of knowledge.

Alternatively, if the firefighters had established common ground prior to the incident then the teammates would have experienced immediate credibility between each other. That credibility and trust would drive further decision-making without bias. Furthermore, "assuming that the forest fighters have mobile devices equipped with maps in the forest fire scenario, we can envision system-provided annotations that reinforce the tacit knowledge of the community, for instance highlighting task-specific features like a creek or already-cleared paths. If the devices are networked, weather tracking information can also be present, enabling the crew to anticipate and respond more quickly to the meteorologist's suggested plan changes."[13] These types of technological innovations are what we suggest for our evolutionary design.

As we will discuss later, many of the problems cited by our expert interviews emerge as grounding problems. When ICS members do not have a clear idea on roles and responsibilities compounded by varying degrees of qualifications, grounding can act as the bridge between team

[12]Klein, G. *Naturalistic Decision Making.* Human Factors, 50(3).
[13]Carroll, John M., et al. (2006). *Awareness and teamwork in computer-supported* collaborations.Interacting with computers 18.1: 21-46.

members. Grounding can significantly reduce synchronization overhead and coordination costs because they are not have to over-communicate their roles, credibility and mission. Sharing that common knowledge of the team's roles and responsibilities increases the collective social capital and trust while also increasing awareness. Similarly when team members have a shared mental model about their tasks, goals, and vision for the task at hand then they are more likely to use that common ground to avoid conflict and work toward that common goal.

Methods

We began our study with a literature review into grounding, computer-supported cooperative work, and existing ICS infrastructure to build a strong foundation before conducting our analysis. With this foundation now in place, we performed our cognitive task analysis by interpreting cases studies and conducting structured and unstructured interviews.

Case Studies

We examined four cases in which ICS was used: the California wildland-urban fires, the Oklahoma City bombing, the 9/11 attack on the Pentagon, and Hurricane Katrina.[14] We will first provide an overview of these events and then observe these events through the lenses of command and control, network capacity, working relationships and grounding.

The California wildland-urban fires refer to the 1993 Laguna fire and the 2003 Cedar fire. Eventually, both of these fires moved towards urban areas and multiple fire departments had to join forces to extinguish the flames. While these fires burned for multiple days, there were minimal losses of life and property. The Oklahoma City bombing was an attack on the Alfred P. Murrah Federal Building when an a truck filled with explosives detonated next to the building. While the immediate impact was devastating, the local fire and police departments were able to contain the damage shortly after the attack. The attack on the Pentagon was when American Airlines Flight 77 crashed into the building, killing hundreds and starting a fire. Much like the Oklahoma City bombing, while the initial impact was devastating, local fire and police departments were able to control the situation. Hurricane Katrina was a hurricane that hit New Orleans in 2005. The results of this of hurricane were that over a thousand people died and many more were left stranded without supplies for weeks. This event is often cited as the worst natural disaster in modern US history.

One of the reasons that the first three scenarios were successful was because of how their control hierarchy was established. For the California fires, there was a shared mental model and clear hierarchy as

[14]Donald P. Moynihan. (2015). *From Forest Fires to Hurricane Katrina: Case Studies of Incident Command Systems*. Network and Partnerships Series.

to how firefighters should act. No firefighter should freelance as that could put the entire mission in jeopardy. They knew to defer to the commander onsite, and the commander onsite knew to listen to what the headquarters were telling them. For both Oklahoma City and the Pentagon, there were not as clearly defined roles as terror attacks are uncommon. The first responder, however, to both Oklahoma City and the Pentagon was the fire chief. Because the fire chief was the first to arrive and manage the situation, other actors such as the police chief and FBI investigators deferred judgement to the fire chief as he knew the most about the situation. In contrast, Hurricane Katrina was not managed as effectively. This is because the mayor of New Orleans, the governor of Louisiana, and the head of FEMA (Federal Emergency Management Agency) were all jockeying for control. As a result, there was not a unified front, and many state and federal officials freelanced and suffered from a great deal of coordination costs and synchronization overhead.

Another reason the first three scenarios were successful was because they had sufficient network capacity to deal with their crises. While the California fires strained local fire departments, the firefighters had enough training and resources to extinguish the fires. Both Oklahoma City and the Pentagon were moments of time where an event occured; after the initial devastation, there were plenty of first responders and volunteers to deal with the aftermath. Hurricane Katrina, however, did not have this luxury. Both the local and federal governments underestimated the impact Katrina would have on New Orleans, so they were woefully underprepared to deal with the disaster. In fact, when first responders went to provide aid, they themselves also often became trapped and needed aid. Overall, this resulted in a lack of resources to aid New Orleans.

The final reason Hurricane Katrina was unsuccessful compared to the other three scenarios was the lack of trust and grounding between relevant actors. The firefighters from the various departments all trusted that they had the requisite training to deal with the fires, and as a result, there were not many conflicts between the different actors. Similarly, the relevant actors in Oklahoma City and the Pentagon had all worked with each other previously and building on this common ground they had the relevant skills necessary to end the disaster. In Hurricane Katrina, however, this grounding did not exist. The local troops did not understand why FEMA wanted to take control away from them, nor did they trust FEMA to correctly manage the situation. Once FEMA did manage to take away control, local officials either undermined or ignored FEMA's orders which led to the further mismanagement of the situation.

Interviews

In order to understand the benefits and drawbacks of ICS, we conducted interviews with two individuals who had previously used ICS. The first interview was Obama administration's former FEMA director Craig Fugate and the second was with LTJG James Coppola from the United States Coast Guard.

We chose these two individuals because we wanted the perspective of someone who was at the higher levels of the ICS framework as well as someone who could provide the more boots-on-the-ground approach.

Interview with Craig Fugate: This interview was conducted over Skype for about 1.5 hours. This interview was intended to be a structured interview; however, after we began to talk with Mr. Fugate, he began to tell stories and his own personal thoughts on ICS. This quickly led to the interview becoming more conversational and unstructured. See Appendix 2 for comprehensive notes from his interview.

We asked Mr. Fugate what his thoughts on ICS were and his main feedback was that ICS was well prepared to deal with emergencies, but not disasters. The difference between the two he explained were the emergencies were events that were contained and familiar to the relevant actors. Disasters on the other hand were large scale events that had never been seen before. This can be seen in the case studies where the fires, bombing, and Pentagon attack were all contained and at least somewhat familiar. Katrina on the other hand was the first hurricane to breach the levees of New Orleans, causing unprecedented floodings. This can also be tied back to Rasmussen's SRK framework.[15] The first three events could be formulated as rule-based, so there was precedent on how to deal with them. Hurricane Katrina was novel and as a result, the actors did not know how to mitigate the disaster. In addition, Mr. Fugate noted that when the event becomes a disaster or novel, there is a lack of grounding between the actors managing the situation. This quickly turns into an organizational issue where the correct actors do not have the all of the information they need to make the correct decisions.

Interview with LTJG James Coppola: This interview was conducted by sending a list of questions over email to LTJG Coppola to answer. These questions can also be seen in Appendix 2. LTJG Coppola has had experience with ICS through managing the Deep Water Horizon oil spill and other incidents in the Gulf of Mexico.

LTJG Coppola's main thoughts on ICS was that it was an excellent framework to track and utilize resources during a crisis. However, his two main complaints were that it was difficult to find qualified individuals to fill positions. Even when they did find qualified individuals, they often left for other opportunities. His other complaint was that in order for ICS to be successful, there needed to be an "aggressive" communications leader. This was necessary so that the relevant actors had all of the information they needed in order to make informed decisions.

[15]Sarter, N. (2018). Lecture *Rasmussen.*

Top Ten Problems Identified

After researching grounding, existing ICS tools and resources, ICS case studies, and performing interviews, we were able to develop a list of the top ten problems ICS faces today. These problems can be segmented into communication problems, common understanding problems, and organizational problems.

Communication Problems

The first problem is physical barriers and coordination overhead. ICS consists of a large variety of organizations that need to communicate during an incident. Often there exists a physical barrier to communicating, whether that be being on the wrong frequency or not having the right equipment, or not having documentation in a format that is usable to the masses. This results in a large communication overhead cost.[16]

The second problem is organizational barriers and synchronization overhead. Different organizations have difficult times communicating with each other as there are many prescribed steps that must occur. This results in synchronization overhead.

The third problem is cognitive barriers, heuristics, and biases. There is a lack of a communications plan, a common language/glossary, and trust. The paperwork can become a burden to people working on the response. This can lead to people using heuristics to lead to suboptimal decisions.

Common Understanding Problems

The fourth problem is roles, responsibilities, and grounding. ICS members do not have a clear idea on what they are supposed to do and what others are supposed to do. This leads to grounding problems.

The fifth problem is situational awareness. There appears to be a need for a common operating picture, sometimes with some type of tracking feature for individuals as not all members know what the overall goal is.

The sixth problem is mission and reducing redundancy. Some ICS members work towards solving the same problem without the knowledge that another team is working towards the same goal.

Organizational Problems

The seventh problem is lack of experience and knowledge in the world. ICS members are often new to their roles, so they do not have the institutional knowledge to do their job adequately. This is exacerbated by the fact that the relevant information is not easily accessible.

The eighth problem is frequent turnover of staff and redirection overhead. As with any organization with high turnover, there is the associated redirection overhead.

[16]Sarter, N. (2018). Lecture *Hutchins and McNeese*.

The ninth problem is the lack of a flat hierarchical structure. This leads to all of the knowledge being concentrated at the top of command chain and a lack of distributed cognition.

The tenth problem is the lack of DoD integration. The DoD does not integrate well with other relevant agencies in the ICS framework, leading to increased coordination costs.

Evolutionary Design

To address the problems of communication, common understanding and organization in ICS, our team developed an evolutionary design making incremental improvements off of the United States Coast Guard Incident Management Handbook mobile application. We used Balsamiq 3 (an interface mockup software) normally used for prototyping. As described earlier, the original application is mostly encyclopedic without any interactive features. After our re-design, the app now has interactive features to induce grounding when working in a disaster operation settings. There are five(5) main interactive features in the evolutionary design, which users can see them when they launch the app, the detailed descriptions for each feature are as follows:

Your Profile

Once the user opens the app and taps 'Your Profile' button (Figure 1-a), the user will go to the 'Your Profile' interface, where the user can see the profile picture (Figure 1-b). If the user clicks the profile picture, the user can either upload their pictures from their own devices or update the photo using the camera on the device. Tapping 'Upload Contact' and 'Upload Credentials' will allow the user to update the contact and credentials manually. The user can also upload or update their information automatically by tapping the 'Resume' or 'LinkedIn' button, which will extract the information from an uploaded resume or the user's LinkedIn profile. Moreover, the user can also view their current tasks across the bottom of the interface. If the user wants to return to the main menu, tap the 'Return' button at the bottom of the interface.

Resource Tracking

Once the user has opened the app and taps the 'Resource Tracking' button, the user will go to the 'Resource Tracking' interface (Figure 2-a). There are three taps in this interface - 'Person Tracking' 'Detailed Info' and 'Area Overview'. The user can switch among those freely by tapping different tabs on top of the screen.

In 'Personal Tracking', the user can find a team member's location on a map (Figure 2-b). When the user clicks the 'Human' sign, the 'Contact Information' page will appear (which will be described in 'People Finder' Section). Here the user can check the status for a specific person and various ways to contact the person if needed. The user can also see the person's current tasks or search by task to see who else is working on something they are also working.

In ‘Detailed Info’, the user can look through an overview of the condition of a variety of infrastructure (e.g road conditions, housing conditions, rescue stations, etc.) (Figure 2-c). When the user clicks on the ‘House’ icon, it will show the detailed information of that specific infrastructure (e.g structure, occupants, function, current condition, etc.) Ostensibly drawing on local law enforcement provided information or census data, the user can browse this information by swiping left or right of the information tab.

In ‘Area Overview’, the user can get a high-level overview of the selected area, including information about the population, resources, main thread, and characterization (Figure 2-d).

People Finder

Once the user has opened the app and taps the ‘People Finder’ button, the user will go to the ‘People Finder’ interface (Figure 3-a). Here the user can browse people in a hierarchical order. The feature allows the user to drill down into each individual’s team to understand the hierarchy. Figure 3-b is the first interface when the user gets into ‘People Finder’, where the black name card refers to the Incident Commander, and the red name cards refer to Section Chiefs, who work under the Incident Commander. These colors are intended to be used universally across the ICS for consistency. The task bar shows the current tasks assigned to the Incident Commander and tapping individuals under the hierarchy will allow the user to explore work breakdown.

If the user wants to know the profile of the specific person (one specific Section Chief in this example) or wants to contact that person, the user can tape the ‘+’ button on the top-right corner of the name card. Then interface Figure 3-d will appear, showing the person’s profile and current position. To contact the specific person, tap ‘Contact’ and interface Figure 3-e will appear. The user can choose call, video teleconference, text or email to contact that specific person.

Glossary

Once the user opens the app and taps ‘Glossary’ button, the user will go to the ‘Glossary’ interface (Figure 4-a). Here the user can browse or search different terms, and get to know the similar terms used across different branches or agencies(Figure 4-b). The translation feature allows for shared knowledge and tacit understanding of operating idioms.

Notification of Change

Once a person or task related to a specific user has changed, the user will receive an push notification to remind the user of the change (Figure 5-a). Moreover, the name card of the changed person will be highlighted in the taskbar (Figure 5-b).

Design Principles and Cognitive Ergonomics Overview

The first feature of our evolutionary design allows users to upload information to their profile such as LinkedIn profiles or resumes, allowing others ICS members to better understand the qualifications for each individual. This feature solves three of our design problems, the first being the organizational barriers and synchronization overhead by reducing short term memory load and establishing common ground [17]. Using this feature, members of the ICS team do not need to memorize who is in charge, phone numbers, and credentials allowing them to quickly access a person's information thus reducing the majority of the load that would normally occur on their short term memory. On the profile page users are also able to view contact information of other people, and the system uses different frequencies for texting, calling, video chat and email. Having this feature promotes grounding, teamwork, allows for direct communication, and builds social capital.

By uploading resumes and LinkedIn profiles, we are also able to solve our problem of roles, responsibilities and grounding. We used Display Design Attention-Based Principles of minimizing information access costs to design this feature[18]. To find this information in the old system users would need to call their manager or specific unit base and ask about a specific individual's credentials, and this is an extremely timely process, thus leading to large time costs for accessing information. Our system allows as user to find people in different ways thus reducing the time it takes to get the necessary information. This also makes capabilities clear by using a combination of the task tracker and credentials description. Users can see what the individual will be good at and what their contribution is to the current situation.

Another problem that this feature solves is the mission, incident action plan and reducing redundancy. Our system outlines clear objectives for the day and promotes the concept of everyone working towards the same goals. Often times in disasters, different companies try to take control of the situation because they think their experience will lead them to success, rather than focusing on specific tasks. In the profile feature, users have a specific task list to understand what their jobs are, which promotes the idea of bounded rationality - owing to the fact that no one person knows how to solve natural disasters, however they can focus on specific tasks that complement their background[19] .

The application as a whole is an Ecological Interface Design (EID) as we are focusing on designing for the work domain and environment rather than using a user-oriented or task-oriented

[17]Salas, Eduardo, Nancy J. Cooke, and Michael A. Rosen.(2008). *On teams, teamwork, and team performance: Discoveries and developments*. Human factors 50.3: 540-547.
[18]Sarter, N. (2018). Lecture *Wickens and Mosier*.
[19]Sarter, N. (2018). Lecture *Reason Error*.

approach[20]. The system makes constraints and complex relationships visible for users, and promotes knowledge based reasoning for unexpected events, as it allows ICS units to communicate across companies in real-time and dynamic situations.

The next main feature that we are using is a glossary feature, which solves our problem of cognitive barriers and biases. Implementing a glossary that spans across different organizations aims to increase communication efficiency between different units of ICS. This feature supports the principle of observability because although the old system had a similar glossary feature, it was hard to find specific terms, leading to having high data availability but it was unorganized and unoptimized[21] . The system we plan on implementing uses search and categorical term finding, which allows for quick access and high observability. This feature also promotes the design principal of striving for consistency, as we are giving all units a common language so their terminologies do not differ in a crisis[22].

The resource tracking feature solves our situational awareness problem because it allows users to find resources and people and gives descriptions of what they are doing. We found in our research that when looking for a resource, a helicopter for example, the ICS teams would only know when the helicopter left so they would have to estimate when it would arrive. This tracking system would allow for an optimized management system, that uses grounding to track important resources and people so everyone knows where everything is. This feature also emphasizes pictorial realism and the naturalness principle as we are displaying a map of the area rather than a radar which does not depict the landscape or landmarks[23] .

Our third feature, the people finder provides an hierarchical structure to the ICS system. When we were creating this feature, we used design principles of reducing the short term memory load, and discriminability between colors. We can reduce the short term memory because now because users will not need to memorize who is on their team and who is in charge of them[24]. It also allows people to move through the interactive web to find leading officers to contact in case of emergency, which again prevents the need to memorize those in higher command, especially since the positions are constantly changing. The structure is set up to be color coded, where the different colors represent different levels of command in ICS which shows discriminability between colors. The colors may appear arbitrary, but we intend to proliferate a consistent color and symbol coding that represent different units and companies working at a disaster site. This is a strong visualization tool that allows discriminability among ranks in the application.

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[20]Sarter, N. (2018). Lecture *EID (Vicente) and CTA and Shneiderman 2018*.
[21]Sarter, N. (2018). Lecture *Norman 1993 and Nielson*
[22]Sarter, N. (2018). Lecture *EID (Vicente) and CTA and Shneiderman 2018*.
[23]Sarter, N. (2018). Lecture *Reason Chapters 3 and 7* and *Wickens 2018*.
[24]Sarter, N. (2018). Lecture *Rasmussen 2018 and Shneiderman 1998*.

The fifth feature of our evolutionary design is the notifications for changing positions. There is a large issue with a frequent turnover of staff and redirection overheads, where staff changes frequently and the relationships need to be renewed as the personnel transfer. To fight this issue we have implemented notifications and change markers in the hierarchical structure to verify that someone has changed positions. If that person is in direct contact with you and your team, there is a feature to acknowledge that you have seen the position has changed. This promotes the idea of redundancy gain as the user is being told numerous times that someone has transferred positions, allowing them to memorize it quickly and continue their work[25].

Lastly, from our interviews we found that there is a large lack in experience when it comes to using these systems, and we understand that we cannot solve all the organizational issues through an application. The best way to solve these issues is to educate ICS members on how to use this application as a tool and promote the idea of grounding in crisis situations[26]. Common ground can prevent decision making bias because in these situations, everyone is presented with the same information, so the decisions can be made with input from the entire system.

Revolutionary Design

Our evolutionary design implements technology that already exists, and if made well could be implemented very soon. The team also looked at making a revolutionary design for emerging technology that could be implemented in 10-15 years with the right tools. We looked at technologies that could widen someones span of control while giving them more sensory input. We turned towards haptic feedback and Augmented/Virtual Reality (AR/VR). By using this technology we hope to increase communication efficiency between leadership and different teams in ICS.

The haptic feedback will be implemented into a users uniforms allowing them to receive commands and warning through haptic sensory input. We are attempting to mix these in with the AR headsets and create a multimodal system using visual, auditory and haptic inputs[27]. There is a lot of work being done with haptics and VR at the moment, and in 10 years we are hoping that these systems will be advanced enough to improve the performance of ICS.

The US Army is currently experimenting with AR technology like the Microsoft Hololens to create interactive maps for lead officers in crisis situations. This is currently an expensive and delicate technology and is only being used for experimental purposes, but as technology rapidly improves and

[25]Sarter, N. (2018). Lecture *Reason Chapters 3 and 7* and *Wickens 2018*.
[26]Salas, Eduardo, Nancy J. Cooke, and Michael A. Rosen.(2008). *On teams, teamwork, and team performance: Discoveries and developments.* Human factors 50.3: 540-547.
[27]Sarter, N. (2018). Lecture *Multimodal Information Processing & Presentation*.

makes the system more robust we believe this type of augmentation can be a very useful tool for field work. Figure 6 in Appendix C shows a mockup of what we believe an AR field view would look like, showing location details, other people in the area, the hierarchical map to contact leaders, and notes on the situation. The Virtual Reality component would be implemented for leaders in headquarters, or offsite. This will allow them to receive real time data about activities on the ground, and allow them to make real-time decisions to prevent confirmation bias, as we do not want ICS leaders making decisions off experience when the problem could be much greater and they don't have all the information[28]. A mobile application is extremely useful in connecting everyone with smartphones, but information receiving is limited to the amount of times people check their phones. Using AR/VR to bypass someones phone could prove to be an efficient way to make decisions and communicate, once the tech has been proven to help.

Evaluation of Design

In order to properly evaluate the new evolutionary and revolutionary design's effectiveness, the team will use a simulation in a field setting. The intent would be to provide a structured environment for an unbiased appraisal of the design against the as-is design. Data already exists on the the as-is design and metrics for effectiveness already exist for leaders to evaluate their teams. After clearly delineating criteria for evaluation and articulated questions, evaluators will construct the the nature of the evaluation. We would want the evaluation environment to not only be able to see the full range of ICS's capabilities at its equilibrium but we also want to be able to highlight exceptions in the system - events that cause the mobile application to perform overwhelming well or poorly. ICS leaders already conduct regular drills and training where the team could layer the mobile application during the drill.

We would want to collaborate with lead practitioners and design goals and specific events that would highlight the application's functions and also design events that would stress the application as well so we could see it at its best and worst. These simulations would be conducted in conjunction with surveys and focus group interviews of the team members before and after the simulation. Ostensibly the application will also be providing real-time feedback so we can quantitatively assess the effectiveness of the application. Usage statistics could reveal when, where, how often and how effective tasks are completed using the application. We would also want to embed evaluators that would periodically observe a behavior of interest, situation or task to see how the application actually performs. For example, without any prior grounding, we could observe how a team interacts with the application in order to establish trust and work towards a common goal. After gathering all this data about the mobile application we would need to compare it to the as-is design of the Incident Command System.

[28]Sarter, N. (2018). Lecture *Reason Error*.

Conclusion and Recommendations

In conclusion, the Incident Command System is a complex with high stakes and multiple human stakeholders in a high risk environment that could benefit from improvements in how teams collective accomplish their mission. Grounding plays an important role in understanding why improvements are necessary. Sharing common ground between team members implies there will be shared mental models, cooperation, social capital and trust. It is clear that the current state of ICS lacks mechanisms to effectively induce grounding and the team members and the mission suffer for that void.

Our team's intent in addressing ICS as a cognitive ergonomics problem is to highlight the ways that teamwork, coordination and collective cognitive processing can be improved with the introduction of a mobile application. Current technological tools available to ICS members are clunky and do not facilitate effective collaboration. We propose that a mobile application for ICS that builds on the design principles we have learned in class along with the lessons in teamwork, coordination, and decision-making will dramatically improve ICS's effectiveness as a system. When team members share a mental model about collective tasks, understand how they support the overall mission, and have established common ground between members they will be able to focus precious time on the crisis. Furthermore, these improvements will prevent pitfalls related to decision-making bias, will reduce synchronization overhead, and other coordination costs.

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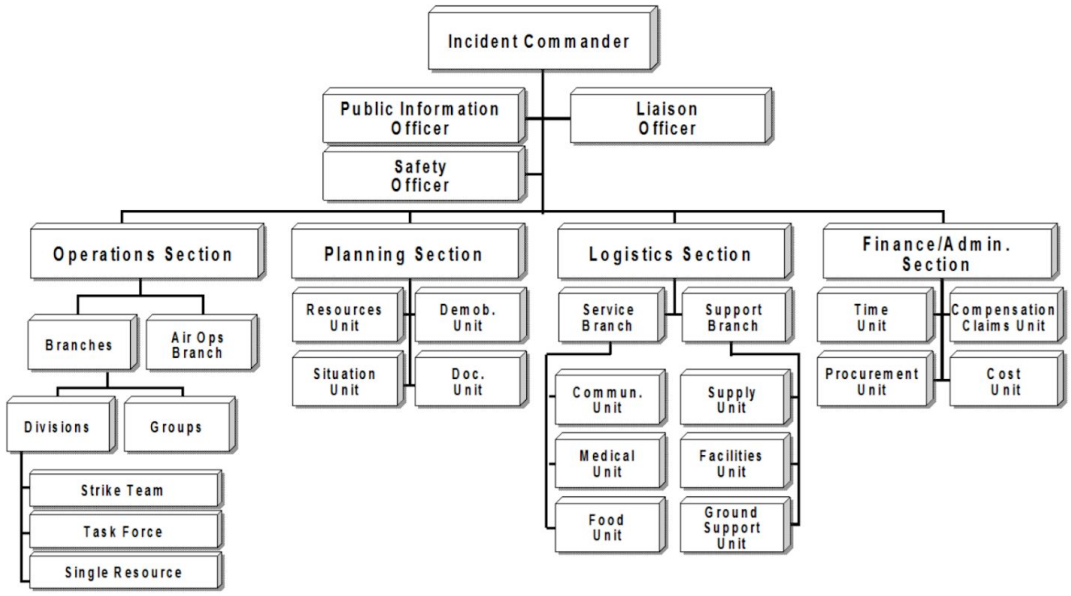
APPENDICES:

Appendix 1:



ICS Review Document. (2008, May). Retrieved from https://training.fema.gov/emiweb/is/icsresource/assets/reviewmaterials.pdf

Appendix 2: Notes from Interviews

Mr. Fugate comments:

- ICS started in the 70's. Fire ground command and ICS started at the same time and were competing systems.
- Homeland Hysteria after 9/11
- ICS became mandatory after 9/11 in order to streamline
- ICS seems to be modified to fit the operation.
- ICS has never been peer reviewed. All examples are anecdotal. Did people do things that weren't really according to ICS in order to solve the problems.
- NASA used management by objectives instead of ICS.
- ICS is rooted in management by objectives (everybody on the team knows and has the same objectives)
- When used appropriately ICS gives everyone the big picture with a feedback loop that allows the people to get progress/updates and challenges that need to be addressed.
    - This is the element that isn't explained very well
- The online courses from FEMA start with the org chart and skip the "why" part
    - This makes the tool less flexible
- ICS is like a spider, it has multiple points of failure

    - It should be more like a starfish where it can keep operating after losing a leg
- State constitutions and local police laws applied to disasters are how emergency management really works in the country
- The governor is treated as a liaison in ICS when governor's are the people who have the actual power to declare disasters and use the National Guard
- ICS can struggle with political dynamics
- Does not work well with elected leadership even though that is where the authority comes from
- Leadership needs to be engaged in the system or else they could become a competing party
- Introduced Governor Bush as the Incident Commander during Hurricane Wilma. Shut down DHS interest in appointing an Incident Commander
- Principal Federal Official was supposed to be an observer and not have real power
- Volunteer Question
    - Disasters exceed
    - Difference between disasters and emergencies is that disasters
- ICS is a government centric problem solving tool
    - Alien outside of government
- Volunteers and private sector are big players
- People generally treat the public as a liability
- ICS is powerful emergency response operating system but has some inherent flaws
- Emergency Management is a network
- Most police powers are vested in the local state constitution
- States do not have interstate commerce powers so Coast Guard gets authority over oil spills
- During deepwater horizon there were too many competing parties. Local governors and Admiral Allen
    - Mr. Fugate wanted to set up unified command with governors, BP, and Allen
    - Dynamics with BP made it difficult
- More authority for states than the federal government
- Only the governor can call out the National Guard or request that the president declare a federal emergency
- ICS is a good tool but not THE tool for disasters
- FEMA just updated the NIMS guidance about Emergency Operation Centers.
- Emergency support functions groups agencies by what their functions are. For example, all the agencies with access to hospitals
- ICS works well for emergencies but not disasters because it is oriented towards one organization running the show with a bunch of other liaisons.
- Don’t apply technology until fundamental bugs are worked out
- Centralized location of unified command helps keep communications working
- ICS tried to adopt military model of command and control. The military is now trying to move more authority out towards the edges so people can adjust faster.
- “ICS is Soviet 101 military doctrine” No one makes a decision until they are told to make a decision.
- What would the app do differently
    - Already an app for filling out forms

    - Make the app, quick and efficient
    - Should not require instructions
- The app should have a targeted audience
    - DOD is a good target
    - Most members haven't heard of ICS
    - The app should be a translator for the ICS framework to the J-Staff
    - Assigned DOD members to the incident can quickly know what they need to do
- Crosswalk between ICS and DOD analogues
- Dual Status Commander
- The military can't fall under the authority of the governor
- Historically the Military response is separate from the state authority and that can cause friction
- The Dual Status Commander solves this issue by having one command over the National Guard and DOD
- Most DOD officers have not heard of ICS
- Most states emergency management act authorizes broad authority for the response
    - No legal process because there is not time
    - Operate with assigned authorities to response to the disaster
- You can do anything that is not specifically prohibited
- ICS is built around "the known" disaster response occurs in "the unknown"
- If legal is part of the ICS response, they are usually put in the admin section
- Biggest challenge with ICS is that people don't know the why and they get buried in the process
- Communications is generally considered a technology issue when it should be a people issue
- Using the same frequency for everything creates noise
- Need to streamline what information needs to be communicated and to who
- If the agencies are not talking before an issue they won't talk during it
- Technology just speeds up the problem
- Comms systems that only work when the techs are there
- Passing information on a 209 form over radios does not work
- Practicing good radio etiquette
- Comms is an issue during every disaster
- You need already established relationships of who is talking to who
- You need to understand what information needs to be passed and what is extraneous
- Can't make cell service the dedicated form of communications in case cell towers are out
- Avoid single point of failure systems
- Don't start with technology for comms
    - Start with who needs to talk to who and what needs to be conveyed
- Seems like we always have to change the ICS structure for each disaster to make it fit the exact scenario.

<u>Interview with LTJG Coppola</u>

1. In your opinion, what is the biggest challenge to the ICS framework during a response?

In my opinion the biggest challenge of ICS is getting enough qualified and experienced personnel to fill the proper positions for real events.

2. What do you believe are the best aspects of ICS?

The best aspects of ICS is the ability to adapt, respond, and plan for any type of incident or natural disaster. ICS is a system that is not exclusive to one governmental department and all levels of government are able to train and fill the ICS spots as needed. In my opinion ICS is also crucial for the adequate tracking and utilization of resources during a response, it provides a level of accountability and ability to plan on a large scale that may not be available at the field unit level.

3. Are there any notable problems with ICS that you encountered during your personal experience with the system?

In my service it is difficult to find people to fill some of the less desirable positions in the ICS structures, it has not really be incentivized.

4. Do you believe that ICS is better suited for certain types of incidents?

I do not believe that ICS should be used for Search and Rescue responses; I believe that it should be maintained at the Sector Command Center. ICS is good for all other incidents.

5. Are there any communication issues that seem to be common across incidents?

When working with agencies that typically operate on land, (ie: police, fire) they usually operated using 800 mhz frequency, while the Coast Guard primarily uses VHF marine band frequencies.

6. Do you have any suggestions for how to avoid communication traffic jams?

Have a competent and aggressive Communications Unit Leader, who is able to develop a proper comms plan.

7. Do you think the selection process for who fills what role in the framework works well?

In my service I feel that key positions in the ICS structures should be identified by billet type. For example if you wanted to be the Chief of Prevention at a Sector you should be required to be a Planning Section Chief prior to obtaining that positions so you are able to fill that spot if your unit needs you for that.

8. Do you think a quick reference app to streamline notifications and provide a quick reference for who is filling what position would be useful?

I believe that something like this may already exist, please look towards the IMSS system and see what they have in terms of Mobile features. I know there is a way for members to submit pictures and updates from the field, I do not know what the entirety of the features includes. You also need a special logon and password to use the system.

9. If the quick reference app was created, are there any features that you think should be included?

A searchable Incident management Handbook, push notifications for meetings, GPS tracking for members in the field. It would have to work on IOS and Android.

10. Do you think a LinkedIn style virtual network for ICS qualified members across a wide range of agencies in a local area would be beneficial?

Yes, if it should availabilities and allowed for interagency training and joint staffing.

11. Have you ever had difficulty working with members from other agencies or do you feel that the ICS framework works well enough to mitigate these conflicts?

I have not had any issues; I worked alongside Oil company employees once, and I feel they may be a bit motivated to protect the reputation and interests of the responsible parties.

12. What is your opinion on volunteers (Like the Cajun Navy) working within a response?

Excellent with additional oversight. A proper Liaison Officer or Agency Rep should be responding alongside of the Cajun Navy in order to help them understand and follow ICS structures and protocol. During Hurricane Harvey, hundreds of Cajun Navy volunteers went to Houston to volunteer; the Coast

Guard sent an Operations Specialist alongside the team, the OS was able to track, and direct the movements of their assets in accordance with the needs of the community. This helped maintain a proper communications and a reference log of areas search and amount of people helped and saved.

13. Do you think more authority should be delegated to lower levels in the command structure?

No

14. Do you have any other comments about your experience with ICS?

I enjoy ICS; every time I worked in an ICS structured I was impressed with the results and organization.

Appendix 3: Figures from re-design

a b

Figure 1 The interface of 'Your Profile': a. main menu; b. 'Your Profile' page


06:38 PM
United States Coast Guard
Your Profile
Resource Tracking
People Finder
Glossary
Incident Management Handbook
Types of Incidents
Multi Agency Coordination
Area Command
Unified Command
ICS Positions
Planing 'P'
Operational Planning Cycle
Forms
Job Aids
06:38 PM
Person Tracking
- -

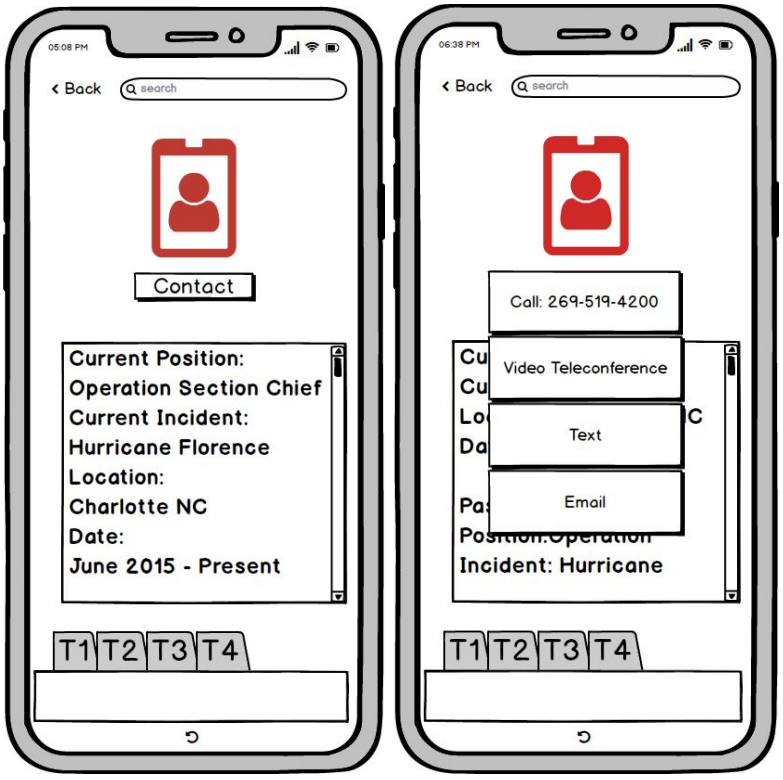
a b


06:38 PM
- Detailed Info -
Occupant
05:08 PM
- - Area Overview
Population
Resource
Main Thread
Characterization

c d

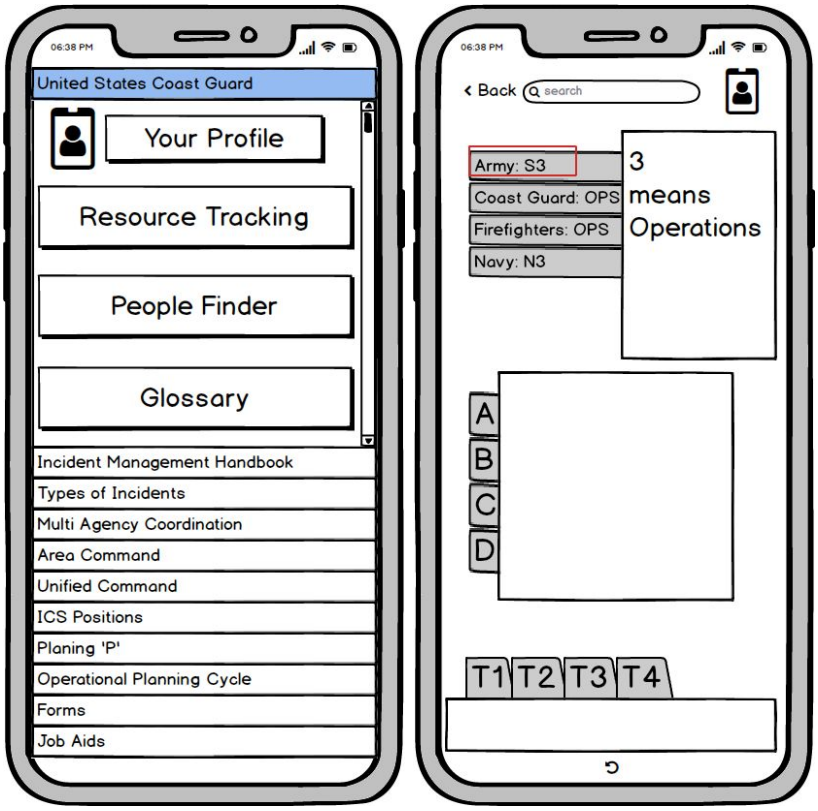
Figure 2 The interface of 'Resource Tracking': a. main menu; b. 'Resource Tracking' - 'People Finder' page; c. 'Resource Tracking' - 'Detailed Info' page; d. 'Resource Tracking' - 'Area Overview' page.

a b c



d e

Figure 3 The interface of 'People Finder': a. main menu; b. 'People Finder' - 'Incident Commander Network' page; c. 'People Finder' - 'Section Chief Network' page; d. 'People Finder' - 'Section Chief Profile' page; e. 'People Finder' - 'Section Chief Contact' page.



a b

Figure 4 The interface of 'Glossary': a. main menu; b. 'Glossary' page.

a b

Figure 5 The interface of 'Notification of Change': a. push notification shown on device; b. highlighted contact example.

Figure 6 The interface of revolutionary design