Fire Update Support Engine (FUSE):

Visual Integration of Information within the Complex Environment of Emergency Response

by Erin Hueston

A thesis submitted to the Faculty of Graduate and Postdoctoral Affairs in partial fulfillment of the requirements for the degree of

Master of Design in Industrial Design

Carleton University Ottawa, Ontario

ABSTRACT

The amount of information flowing throughout an emergency response environment creates a level of complexity which could lead to a disaster within the response process. One of the key problems is that operators are often burdened with collecting all the information from various sources to use it effectively and safely. Providing all the information concerning the current situation in an integrated fashion can prevent any loss of information and mitigate loss in situational awareness. By combining research underlying information design, information processing, and ecological interface design, the objective of this study was to create a visual design that integrates the critical information within the environment in a way that can facilitate information collection and decision making. By employing a multi-method, iterative user centered design approach, the information needs and requirements of users in a forest fire response command and control center were gathered and analyzed. These were addressed in two iterations of information visual designs. Users assessed the designs, and it was demonstrated that the visual integration of the critical information was effective in informing users about the situation.

Keywords: emergency response, information design, information processing, ecological interface design, situational awareness, user centered design.

ACKNOWLEDGMENTS

I would like to thank Avi Parush and Anthony Whitehead for their hard work and assistance throughout the development of this thesis. Their comments and opinions were able to guide the research towards a successful compilation of the work that you now hold in your hands. The time and effort put into this thesis by these two very busy professors has been invaluable and is greatly appreciated.

Many thanks to all the team members from the Ministry of Natural Resources. Thank you to Susan Reany-Iskra and Pat Payette, for your flexibility and availability throughout the many exercises, it is beyond appreciated. Thanks to Rob McAlpine for arranging the proper connections for the development of this thesis, and to all the individual team members who were available to provide the comments and opinions that assisted in the full development of this study.

Thanks to Thomas Garvey for his assistance in the preliminary development of the study and the assistance with the directed study course that lead to this research. Thank you to Valerie Daley for answering my numerous questions and helping me through every step of the final processes. And thanks to the Carleton University's School of Industrial Design for proving an outlet in which to conduct this research.

Finally a huge thank you to all of my family and close friends who supported me throughout this entire process. To Jeff and Sheri who were willing to test out the designs in their preliminary stages and assist in proofreading many large documents. To all of my supportive friends who helped me push through the many challenges that I faced throughout the development of this study. And finally, because I promised, to Ryan for letting me use his computer mouse in a crucial time in the design process.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The amount of information that the average person is required to absorb on a day-to-day basis is growing every day. In an average work environment, an individual is confronted with information coming from all directions. Within a complex work environment such as emergency response, this level of information is increased in quantity and the speed with which it is coming in to the user. The individual within a complex work environment is required to absorb, interpret and react to a high quantity of information that is traveling throughout their environment and use it to make important decisions. The main difference with the complex work environment is what is at stake when it comes to a response to the information. In the case of an emergency response environment there are resources and potentially lives at risk if the information cannot be absorbed, understood, or reacted upon in an efficient and effective manner.

The environment of emergency response presents many different degrees of complexity when it comes to information flow and communication amongst individual users. One of the biggest challenges with researching this environment is the constant change of information and the unpredictable behavior presented by emergencies. This constant fluctuation and flexibility provides challenges for any researcher, or designer, wanting to assist in the facilitation of communication of the information within this dynamic environment.

To ensure that decision-supporting information is collected, absorbed, and reacted upon effectively, the supporting information must be laid out in a way that facilitates decision making. The layout of the information is critical to the interpretation and understanding of the big picture. If the individual within the emergency response environment is unable to access and collect the required information their understanding of the overall situation and their resulting decisions could be detrimental to response

efforts. The methods within this study revolved around locating and evaluating the problematic areas within the complex environment of emergency response, and presenting an approach to best address these concerns.

1.1. Thesis Framework

Figure 1. The conceptual framework for this study.

The problem presented within the scope of this study was derived based on complex environments, the way in which the environment is organized, and the situations within the environment that the users must deal with on a regular basis (see Figure 1). When a complex situation arises the collection of information can be more problematic due to the number of variables playing a role in the emergency response procedures. For the purposes of this study, information collection refers to the locating and combining of information that relates to a specific scenario so that the information can be used for decision-making and response purposes.

Collecting all the important information related to the current situation can be challenging, especially when all of that information is located in different areas within the environment. When an individual has difficulty in collecting all of the information there is an opportunity for information loss. Loss of information provides poor decision-making support and the loss of situational awareness, or a loss in the understanding of the situation within the environment. When the individual does not possess

all of the information related the current situation then the individual could develop a poor sense of situational awareness. Without a strong sense of situational awareness the individual will be unable to make informed decisions that will benefit the individuals, resources, or response objectives as a whole. The reaction to a situation that is not completely understood due to a loss of situational awareness could lead to a disaster, increasing the level of complexity within the environment.

The area of focus for this study was the information collection process. The solution presented by this study focused on assisting with the information collection process and ultimately breaking the links to the loss of information and situational awareness, and ultimately preventing any disasters. This can be done by allowing the users to have proper access to the information within the environment. Easy access to information allows for effective information collection and efficient development of situational awareness. The final goal of this study was intended to integrate all the information on the current situation and present it to the user in a way that will prevent the loss of information and mitigate the loss of situational awareness. The proposed solution to the problem involved literature in the areas of information architecture, information presentation and ecological interface design. Information architecture, the presentation of information is a way that facilitates understanding, helped to organize the information. While information presentation, the appearance of information within different interfaces, assisted in the visual layout of the information. Ecological interface design, a study developed to provide information support to create adaptive problem solvers, was in place to assist in understanding how to present the information within the complex environment. To break the pattern presented by the research problem, a usable ecological interface design, with the help of information architecture and presentation, was developed to prevent the loss of situational awareness within the complex environment of emergency response.

1.2. Study Environment and Participants

For the purposes of this study, the environment within the regional forest fire response offices at the Ministry of Natural Resources (MNR) in the province of Ontario was used. There is a wide of variety

of information that comes through the regional response office, many individuals using the information, and diverse uses for each piece of information. All of these variables create a complex environment where the application of this study would be beneficial. The information gathering methods for this study were designed so that they could be transferred to any type of emergency response environment.

The MNR is responsible for researching, protecting and interacting with the wildlife of Ontario. Different areas of study within the MNR include water, energy, wildlife, natural parks, and forest management. One of the main areas of responsibility for the MNR throughout the summer is forest fire response. Due to the size of Ontario, the province is divided into two regions, Eastern (Sudbury, Ontario) and Western (Dryden, Ontario). The regional offices are responsible for overseeing the response to all of the fires within their geographic region. Both the Eastern and the Western regions are divided into smaller sectors managed by sector response offices, which are responsible for providing and dispatching resources to fires within the assigned geographic region.

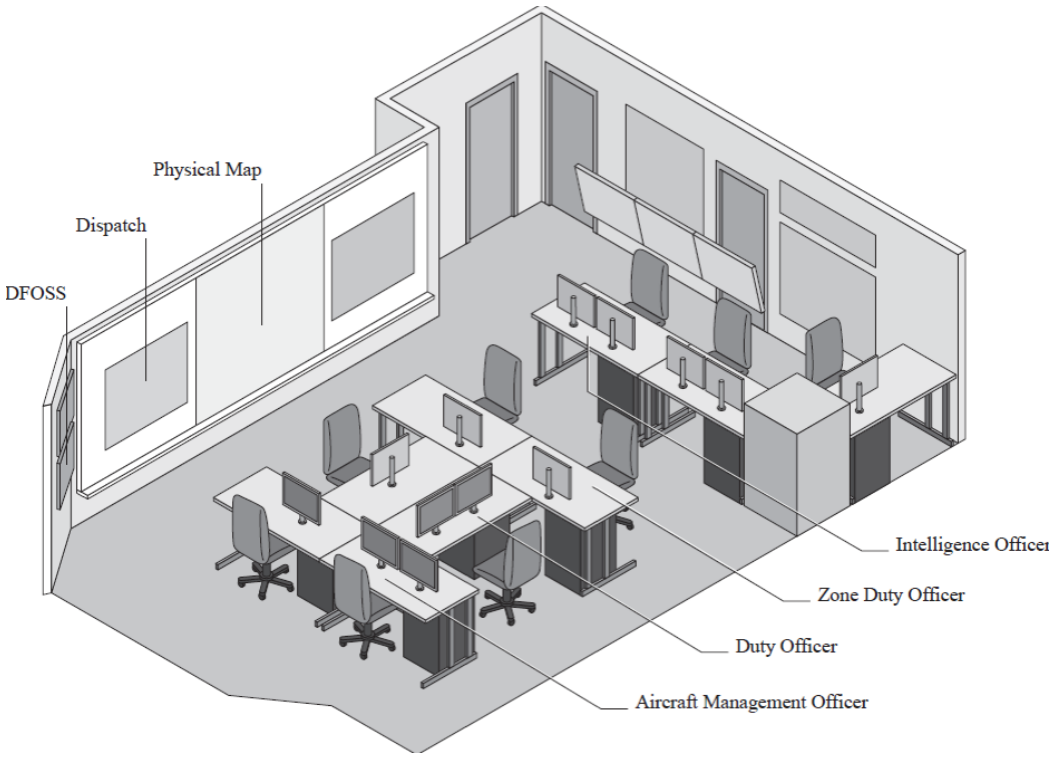


Figure 2. Room layout of the regional response room in Dryden, Ontario.

The response rooms where the research for this study was conducted are situated at the regional level (see Figure 2 for the layout). It is within these regional response offices where decisions are made concerning the response to forest fires within the geographical region. A team of individuals is situated within the regional response room throughout fire season, each with their own role in the process:

- Duty Officer (DO): The DO is the head of the regional response team; all important decisions go through this individual before being processed. DOs are responsible for maintaining an overall sense of situational awareness within the room. This individual is aware of the current situation and is responsible for organizing where resources are able to go while maintaining a level of flexibility in the case of multiple fires.

- Aircraft Management Officer (AMO): The AMO is responsible for the organization and deployment of all the aircraft within the region. The duties of this individual involve assigning the alert status to the different aircraft, dispatching the aircraft to the respective locations, and managing the timing on each aircraft to ensure that there are always aircraft available to respond to any forest fires.

- Intelligence Officer: The intelligence officer is responsible for keeping the information in the room up to date. It is the intelligence officer who provides the rest of the team with the Strategic Operating Plan and the Strategic Operating Plan Update each day. The intelligence officer is also responsible for collecting the required weather updates and the input of new fire information into the Daily Fire Operating Support System.

- Zone Duty Officer: The zone DO is not a permanent member of the team. The zone DO is brought onto the team when there is an overload of fires. When there are too many fires for one

DO to deal with at any one time then the region is divided amongst two DOs. This allows for a better overall sense of situational awareness and for better division of resources and crew.

Each one of these members of the team requires information relating to the forest fire response process. All of this information is available to each of the team members in different areas of the regional response room, nowhere is all of this information integrated. All response rooms across the province are at a different stage of technological advancement but all the rooms generally include: a map of their geographic responsibility, a list of the fires and reported incidents, and access to the databases that provide information about available resources (see Figure 3 for an example of information presentation). These databases are available to the team members within the room and can provide any level of detailed information at any time throughout the response process.

Figure 3. Information presentation within the regional response office in Dryden, Ontario.

• Dispatch (see

•Figure 4): Dispatch is the current tool responsible for maintaining situational awareness within the response room. It is the first attempt at bringing all the information related to the region into one location within the regional response office. The Dispatch map displays the location of current fires and aircraft. The number of levels and the type of map used within this database can be changed as the user requires. This information is updated regularly as the information is put into the system.

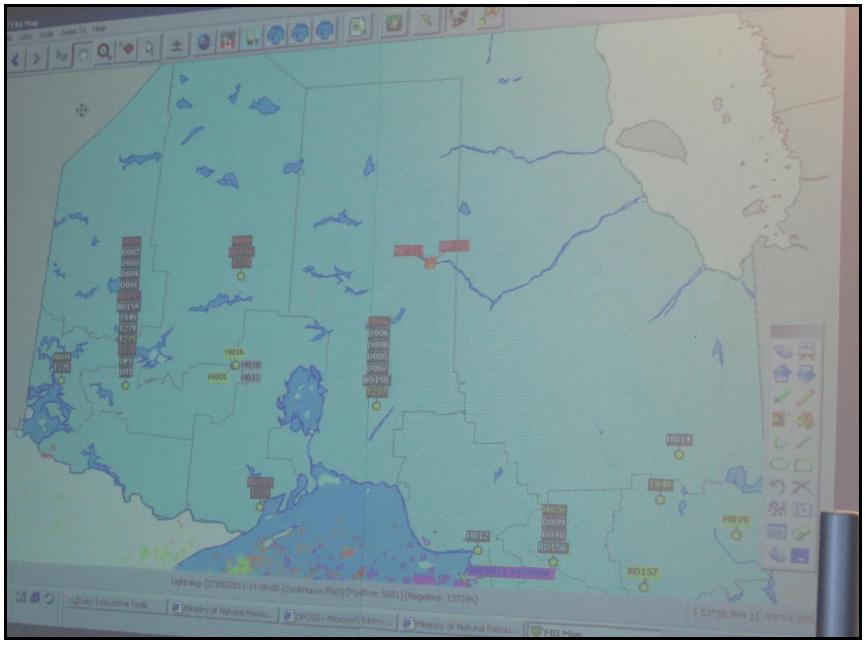


Figure 4. Information display within Dispatch database.

• Daily Fire Operating Support System (DFOSS): DFOSS (see Figure 5) is responsible for all the information related to fires and reported incidents throughout the season. This is where fire information is input and the full history of the fire is recorded until the fire is out. The information held within this database includes the time, fire size, location, and response.

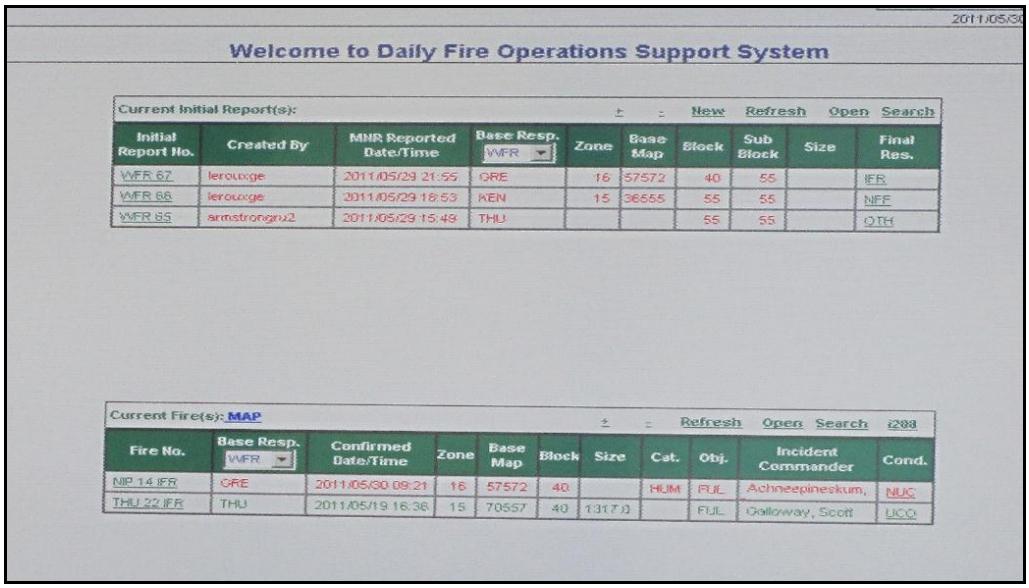


Figure 5. Information display within the DFOSS database.

• Personnel Information Management System (PIMS): PIMS is the software that holds all the information regarding the different crew members and their locations. The information held within this system includes the crew name, members, and timex information (amount of time until they are required to take days off). This information is rarely displayed within the room. It can be accessed by any team member on their desktop computer should they require the information.

• Aircraft Information Management System (ACIMS): Mostly used by the AMO, ACIMS contains all the information regarding the aircraft within the region. The information within this software informs the user of the location and history of each aircraft. This information is rarely displayed within the room; the AMO can access this information on their desktop.

The individuals within this environment are constantly dealing with a variety of information that is coming to them in a variety of ways. This complex environment presented by the MNR was one to which the framework of this study could be applied.

1.3. Contributions

This study was developed in a way that showed a fully empirical way of collecting and gathering all of the required information. The combination of empirical research methods and iterative design and testing assisted in the development of the final integrated information design. The intent was to assist the users in finding different methods of information presentation within their day to day processes. The different levels of contribution are outlined here:

- Needs Assessment Outcomes
    - Interactions with users provided a detailed insight on the information they require, how they use it, and how it was presented to the users.
    - The use of multiple empirical methods resulted in a unique list of the needs that were transformed into a set of requirements for a final integrated design.
- Information Integration
    - This thesis represents a first attempt within this specific environment, to the best knowledge of the researcher, to develop a fully integrated information presentation within the field of forest fire response.
    - The efficacy of the integrated information design was demonstrated in an empirical evaluation.

1.4. Thesis Organization

The introduction was the presentation of the framework and background to this study. The layout of the regional response rooms described the team members and databases involved in forest fire response. The contribution of this study was outlined to describe where the research fits into the related areas of study.

The literature review is the second chapter of this study. Here the studies that relate to this research are laid out in connection to the problem and the solution. The area of situational awareness is described with the level of importance and challenges that face researchers and designers when trying to maintain it. The information research follows as the described solutions to the problem. Information architecture and processing are explained to describe a method for organizing and presenting the information to the user. Ecological interface design is used to explain the application of the design to a complex environment. Information related to the development of a successful interface design is also included in this section in order to guide the development of the guidelines supporting the layout of the preliminary and final designs.

The third chapter revolves around the methodologies used within this study. This chapter provides a layout of all the different methods used and their purpose within the study. The methods include a focus group, ethnographic observation, sorting activities, surveys, and a final round of testing with the design. The layout of this chapter includes the procedures used within all the methods and the description of the users involved. All of these methods provided guidance on the following activity and the information involved within it. The result of each method provided more insight as to the structure and requirements of the final design.

The fourth chapter revolves around the predesign processes, or the information gathering methods before the development of the preliminary designs. The results of the focus group, ethnographic observation, affinity activity, and information prioritization survey are all described and laid out in a way that shows their value in the organization of the information. Each research method led to the next by outlining the area of focus, gradually narrowing the field of focus.

The fifth chapter describes the beginning of the design process. The beginning of this chapter describes the information gathered from the previous activities that was used in the development of the preliminary designs. Each of the initial design proposals are described in this chapter, explaining the benefits of each. The end of this chapter describes the results of the design selection survey, where the users were asked to select the design, or designs, that would be used for the final round of testing.

The sixth chapter details the features and final layout of each of the designs to be used in the final round of testing. Each of the designs is described in comparison to the studies that produced the results (comparison to the information survey results, for example). Finally, this chapter describes the results of the testing and final questionnaire. The results describe the participant opinion and experience with each of the designs.

The seventh and final chapter is the conclusion. This is where all the key points and results from this study are described. The relationship between the results and the initial problem are described, as well as future research opportunities within this area. This final summary of the overall study provides the overall findings, lessons learned, and the contribution of this thesis.

2. LITERATURE REVIEW

In today's world, individuals are constantly being inundated with information coming at them in all shapes and forms. With the focus on technology intensifying, and with all the tools available to the world on a daily basis, this information is coming in faster and in larger quantities every day. Taking all of this information in, absorbing it, and then doing something productive with it becomes more challenging as information continues to flow in from every direction.

The scope of this study revolves around the environment of emergency response, or a complex environment. This is an environment with a variety of information coming in and going out. The activity levels within this environment can change quickly, ranging anywhere from little to no activity, up to the need to delegate certain areas of focus to different users. Generally, within these environments there are a variety of information displays, each detailing an important piece of the information puzzle. This level of information, if not displayed properly, can cause an information overload, confusion, or misunderstanding within the environment and amongst the users. With this in mind it is important that all of the information present within this environment is displayed in a way that is effective and easy to interpret for the user (Chen et al. 2011 and Lindell et al. 2005).

The complexity level of a situation makes information collection much more difficult because of the different ways users can gather the information. Information comes in a variety of forms, from verbal to digital, and is found in a variety of locations. When there are problems with information collection, some of the important information can be lost in the transfer. When the users are not working with all of the information they will not have a proper sense of the situational awareness (SA) which could lead to improper response to forest fires (Chen et al. 2011, Lindell et al. 2005, and Parush 2011). A study of the

literature related to SA assisted in developing an understanding of the factors that need to be preserved or focused on when attempting to maintain a strong sense of SA.

2.1. Situational Awareness

One of the main areas of concern within complex environments is the user's ability to develop a strong understanding of the overall situation. SA is one of the most difficult things to maintain and yet one of the most crucial with a majority of today's interfaces (Endsley 2006). A good sense of SA helps the user to make educated decisions and solve problems quickly.

SA is defined as the "perception of elements of the environment within a volume of time and space, the comprehension for their meaning, and the projection of their status in the near future" (Wickens and Carswell 2006). Endsley provides the definition as "an internalized mental model of the current state of the operator's environment" (Endsley 2006). In other words, SA is an internal model developed by the user based on their understanding of the current overall situation and information presented to them. Maintaining SA throughout the development of this study and the resulting designs was important to the participants of the research. It was very important that SA be maintained and not destroyed, as SA is a state that the users require to make the proper educated decisions throughout complex scenarios.

2.1.1. Importance of Situational Awareness

In a complex environment, it is important for the information system within it to be as error free as possible. Repeated errors can cause confusion and the development of a skewed idea of the current situation. An incomplete understanding of what is going on within the environment can cause the user to make decisions that could make a situation more dangerous, complex, or problematic. To prevent these types of scenarios it is important to keep the individuals involved in that environment engaged in the control of the information (Parush 2011). If the user is not engaged with the system then important changes in information could be missed or misinterpreted, creating uninformed decisions and a loss in

situational awareness. In order for the team to work together efficiently and coordinate actions, all information must be shared amongst the users to achieve a common goal. Otherwise, there is a risk that everyone will understand the current situation in a different way (Parush 2009). To facilitate this process all aspects of the environment must be brought together in one location (Endsley 2006). Having all of the information required to make an educated decision gathered in one location will reduce the amount of search time required to reach a proper conclusion. This process of integration must be done carefully. If there is not enough important information present then the user will not be able to make a well-rounded decision and will not be able to develop a strong sense of SA. However, presenting too much information will impede the development of SA if the information cannot be interpreted and taken in successfully by the user.

According to Endsley (2006) there are three levels of SA. The first level involves the perception of the elements; this is where the user begins to understand the connections, status, and qualities of the important aspects of the environment. Next is the comprehension of the current situation, the understanding of the role played by the individual aspects of the environment in achieving the final goal. Finally, at the highest level of projecting to the future status, the user can predict the near future of the behavior of the elements in the environment. This third level is the result of the well developed and thorough understanding of the first two levels.

SA "involves perceiving critical factors in the environment, understanding what those factors mean, particularly when integrated together in relation to the operator's goals and at the highest level, an understanding of what will happen with the system in the near future" (Endsley 2006). On a higher level of SA, users are able to be more effective in their actions and decisions regardless of complexity (Endsley 2006). The higher level of SA will allow for a stronger understanding of what is happening with all the information within the environment. With this understanding of the situation the users are equipped to make decisions that will benefit the situation rather than cause future problems. This understanding allows the users to foresee the consequences of their decisions in consideration of the system. They can

do this because they are able to understand every aspect of the situation and the role each aspect plays within the system.

SA plays a key role in the successful maneuvering and understanding of a complex environment. Without a clear sense of SA it is difficult to make an educated decision based on the presented information. Any decision made within the complex environment without a clear sense of SA could create more problems and increase the complexity of the environment later on (Parush 2009). To prevent loss of SA, a combination of information architecture, information presentation, and EID will be developed as part of this study. Information architecture assisted in organizing and prioritizing the information. Information presentation assisted in understanding how the information should be laid out and presented to the users. This presentation of information can include abstract representations of the complex information through the application of information visualization. Finally, EID provided the justification for the combination of the literature and the final presentation of the information to the users.

2.2. The Design of Information

A variety of studies (for example, Armitage 2003, Miller and Vicente 2001, and Parush 2009) have been developed around organizing large amounts of information within different working environments. There are many different ways in which organizing information can be approached; there could be an addition of technology, removal of current technologies, or reorganization of the information. In this study the focus revolves around the visual design of the information. When researching this topic, it is a challenge to find which theories and studies can facilitate an information display within a specific type of environment or scenario. This is a challenge because different information design studies accommodate different scenarios, some focus solely on the user while others focus on the environment in which the information is being used. The development of an understanding of the different options narrows down the scope which will create a more focused selection to apply to this complex environment. The first contributions to the development of this understanding were information design and architecture, followed by information presentation, and ecological interface design (EID).

2.2.1. Information Design and Architecture

Information design, a presentation of complex information in a way that makes it easier to understand, was one of the earlier disciplines within the area of study related to the layout of visual information. Information design was one of the first areas where researchers attempted to develop a visual method that would be more effective for the user's purposes. The intent was to make complex content present more meaning to the user. The visuals include information such as a chart or graph that is used to facilitate the learning and understanding of a specific, and sometimes complex, set of information. For this information to be effective the content needs to be positioned properly within the context, effectively assembled, and presented in a way that will benefit the user (Albers 2003, Armitage 2003, Knemeyer 2003, and Mazur 2003).

The term 'information design' is difficult to clearly define as it is interdisciplinary. The combination of graphic design, writing, illustration, and human factors helps to make information easier for the user to understand. To develop an effective design, the designer must first research and develop an understanding of what information is important to the user, how that information is obtained, how that information relates to other information, and how to present this information in a way that will maximize these discovered relationships. This process involves working closely with the users of the system, the system developers, and the actual systems (Albers 2003).

One of the many challenges of information design is the presentation of the information that is important to the users. It is necessary to find what pieces of information are important to the majority of users within most of the scenarios. Defining which pieces of information are the most important requires working closely with the users, both individually and as a team. "The main rationale of the method is to systematically and meaningfully reduce the scope of all information exchanged in teamwork into minimal, yet essential, subset of information required for effective teamwork" (Parush 2009). Keeping the information display minimal requires displaying only the information that is essential to the users within the current scenario.

Taking the idea of information design one step further is the study of information architecture. Information architecture, in its simplest form, is information design with the added bonus of interactivity through the study of navigation and design. The goal of information architecture is to develop a document that works for the user. It is the art and science of presenting information so it is understandable and easy to use. The study involves organizing information and labeling it in a way that makes the information easy for the user to find, while reducing the chance that a user might get lost while navigating the interface. Information architecture includes the "elements of information, mental models, and navigation" (Armitage 2003). Information architecture presents borders in which the design can be developed in order for the result to be effective and efficient for the user to interact with. The result from the development of information architecture should be information that is presented in a way that is effective, efficient, and attractive to the user. The development of this revolves around the content and the idea of invisible design. Invisible design has been achieved when the user is completely unaware of the design before them and they are able to naturally flow through the information. Ultimately, like many other information research theories, the goal is to make the complex clearer for the human user (Albers 2003, Armitage 2003, Toms 2002).

The investigation into information architecture involves research that points out the information requirements of the user; only after this has been discovered can the medium that will be presenting the information be chosen. The success of the design is based on the user's experience with the design presented to them. This approach relies heavily on the final step of the design, which in most cases is the ultimate test of the design. The inclusion of the user within the development stages of the design can be extremely valuable in the production of a desired result. The user is more familiar with the system and the information that is falling under the microscope; therefore, their opinion will be the most educated and more likely to produce a usable result (Armitage 2003).

In order for users to work together efficiently and coordinate their interactions, information must be shared amongst team members with the intent of achieving a common goal. Otherwise, the risk is run that everyone related to the information will understand the current situation in a different way. "The

effectiveness of the team is often reflected by the degree to which members engage in processes for sharing information" (Parush 2009). In other words, the more information that is shared amongst the users, the more effective their understanding, reaction, and response will be. "One potential answer to this need is a team-oriented information display that should support information sharing, situational awareness, and facilitate effective teamwork" (Parush 2009). The information display should present only the information that is important to the final goals of the team, and the system should be focused on supporting this. Maintaining this level of focus will prevent distraction and confusion when working with the wide range of information present within the room. This proposed display should present information while being visible to everyone at all times. "The challenge is defining the requirements for a team-oriented information sharing display" (Parush 2009).

The research around information design and architecture assisted in the understanding of how to organize and prioritize the information that is currently used within the regional response rooms. The application of information architecture to the information within regional response rooms can lead the way to presenting the information more effectively and efficiently. The way in which the information is presented and organized should also be done in a way that promotes the sharing of information between the different members of the team within the regional response room. Having the required information gathered and organized will prepare for the next step which involves information presentation.

2.2.2. Information Presentation and Processing

The appearance of information within different interfaces has been studied in the past to develop guidelines for different forms of information presentation. A study on web page layouts that was done by Parush et al. (2005) found relationships between their study results and the Graphic User Interface (GUI) guidelines. The GUI guidelines are vast and vary depending on the area in which information is being researched and manipulated. One discovery in this comparison was that, "uniform density has a positive impact on search performance. Such a guideline is in agreement with similar GUI design guidelines" (Parush 2005). In other words, if the designer were to lay the information out in a way that prevented

confusion and clutter then they would be able to assist the user by facilitating their search for specific information. Laying the information out uniformly on the screen will allow the user to find the information that is required with less difficulty and cognitive strain. Another of the main discoveries of the study by Parush showed that, "a greater amount of links on the page degrades performance, which is in line with the GUI guidelines" (Parush 2005). This indicates that providing the user with too many options can hinder the ease of use of the overall system. This hindrance occurs by complicating the situation or confusing the user when it comes to their overall final goal. Preventing performance issues is the goal of this research and has guided the investigation into different forms of information presentation.

Studies have been performed to evaluate different layouts of interfaces and their effectiveness in creating a system that is easy to use. "The primary finding of many empirical studies is that the visual design of the interface has a strong impact on task performance in general and on visual search in particular" (Parush et al. 2005). A study on screen complexity performed by Parush et al. (1998) showed that, "alignment and grouping had a relatively larger impact on visual search as compared with factors such as density." This means that the grouping of similar and related information made the overall system easier to maneuver compared to the searches done with a more densely presented group of information. Keeping in mind the information that is to be displayed and how that information is used by the user will dictate how the information should be presented and displayed. This presentation will greatly affect the interaction with the system. It is important to make sure that the proper selection of information is being displayed and that it is laid out in a way that will make it beneficial and effective for the user (Sutcliffe 2005, Vanderdonckt 2003, and Van den Berg 2008).

The details of information processing can influence the user's ability to maneuver within a proposed system. The speed with which a user performs a task will depend on the level of uncertainty they have with the outcome and their overall skill level as a user. The speed and accuracy of the overall performance can also be changed by the number of choices that can be made and information that is required by the user. Keeping in mind the fact that an increase in information can also increase the opportunity for errors, designers should not give more options than are essential to the user. Users also

respond more slowly to events that are unexpected and where greater information processing is required due to unfamiliar content. Therefore, an increase in information within an unfamiliar scenario can greatly decrease the speed with which the user is able to complete a task successfully (Vanderdonckt 2003 and Wickens and Carswell 2006).

The aspects of information presentation and processing provide input on the different layout approaches that have been studied and can be applied to the information layout. These studies are able to provide layout possibilities for the information that was organized with information architecture. The application of these layout suggestions will allow the information to be presented in a way that will simplify the complex information within the regional response room. Some of the information would benefit from a different visual approach due to the level of complexity of the content; these areas would benefit from the application of information visualization.

2.2.3. Information Visualization

One of the longest studied forms of information presentation is that of information visualization. In today's world, information visualization is defined as "the use of computer-supported interactive visual representations of abstract data to amplify cognition" (Card et al. 1999). This form of visualization is helpful when it comes to monitoring large amounts of information in real time and within an environment that requires problem solving and decision making. Information visualization uses the connections and relationships between pieces of information and presents them in a more abstract fashion to promote understanding (Card et al. 1999 and Van den Berg 2008).

Visualization has been proven to increase cognition through the use of perception. Larkin and Simon (1987) conducted a study that compared diagram and non-diagrammatic representations. The results of that study showed that diagrams were more helpful to information processing in three different ways. Within the design presented in the Larkin and Simon study, information that was used together was grouped together visually; this allowed the user to avoid large searches and reduced the amount of time taken to find a desired result. The visualization also grouped information by location; there was no need

to match symbols or labels, and this reduced the search time and the strain on the working memory. The study also showed that the diagrams were able to support perceptual conclusions that are easy for humans to reach (Larkin and Simon 1987). Upon further research Card discovered that visualization can amplify cognition in any or all the following six ways: it can increase memory and processing resources available to the user, reduce searches for information, enhance the detection of patterns, enable simple conclusions based on visual information, use perceptual attention mechanisms for monitoring, and encode information in a controllable medium (Card et al. 1999).

Information visualization supported the presentation of the complex information to provide a result which assisted the potential users with the processing and understanding of its content. By collecting the organized data and displaying it in a way that supports the understanding of the information, the user will be able to apply the information in a way that will support efficient and effective forest fire response. Connecting the user to the environment of forest fire response through the use of EID can assist the user in making connections in the information and facilitating the use of the information.

2.2.4. Ecological Interface Design

EID is a more specific form of interface design that focuses on assisting the user in maneuvering through an interface within a complex problem solving and decision making environment. This look into interface design can be applied directly to the field of emergency response. The specific nature of the study allowed for a more connected relationship between the theory and the research of this thesis.

The basis of EID begins with the research of James J. Gibson, the study of ecological psychology and how it applies to the study of epistemology (the study of human knowledge; its origins, scope and limitations). Gibson's theories state that, "animals and their environments are differentiable but not entirely independent. Animals and their environments are different entities and should not be confused with one another, but they also are so mutually dependent that one should not imagine a thorough account of one without the other" (Mace, 2005).

Gibson used the relationship between the individual and the environment to observe how individuals are able to pick up on certain information and use it effectively to guide the action within their current context. As a result of this relationship, Gibson presented the theory of direct perception. According to Gibson, "Direct perception names something we'd like an account of and not just the account itself" (Mace 2005). Within direct perception, action and understanding are treated as a coupled system by describing knowledge, or affordances, through action possibilities. The result is that perception is viewed as a means of selecting the appropriate action to reach a certain goal (Mace 2005 and Vicente 2003).

The use of the term ecological can present confusion in how it is used within this context. Burns explains that, "by an 'ecological' or 'ecologically sound' design we are referring to an interface that has been designed to reflect the constraints of the work environment in a way that is perceptually available to the people who use it" (Burns and Hadjukiewicz 2004). Users are able to take action with the interface and have a better understanding of how actions will lead to objectives. In this sense the term ecological refers to the field of ecological psychology, not biology or ecosystems; it is the study of human environments, interactions, and human perception (Burns and Hadjukiewicz 2004).

Kim J. Vicente and Jens Rasmussen have used Gibson's research to develop and bring EID forward as a new form of interface design for complex work environments. The definition and explanation provided by Burns and Hajdukiewicz is that, "the EID framework was deliberately developed to help designers provide workers with information support that can help them play the role of adaptive problem solvers." The design based on EID should be able to facilitate adaptation to the properties within the environment in an effective and efficient manner (Burns and Hadjukiewicz 2004, Czaja 2006, Duez 2005, Pawlak 1996).

The approach to EID begins by looking at the environment instead of the user; the environment is the system that will be controlled by the user. This definition of the system boundaries influences the displays to be developed, problems and tasks to be performed by the user with those displays, and inclusion of the information that users want control over. The use of psychology when developing an

interface will also help in the understanding of how people think about and process information. In a paper written by Christoffersen et al. (1998) the authors describe two design phases of EID, the first being the research of what information should be at the forefront of the interface, and second, presenting the visualization of this information and how it is to be controlled. EID attempts to lay out the requirements of a design by taking into account the human properties of cognition and supporting them (Burns and Hadjukiewicz 2004, Christoffersen 1998 and Rasmussen and Vicente 1989, 1992).

EID has been applied to many complex environments, such as nuclear plants and hospitals. These studies have shown the value of EID and the difference it can make within a complex environment. The studies, however, have yet to expand to the environment of emergency response, an environment which also presents a high degree of complexity. Within this type of environment there is a constant change of information, forever incoming and outgoing. The team members are involved in an ever changing collection of information and it is important that everyone involved be aware of the overall status of the current situation. Otherwise, it is likely that an improper response will be sent to deal with the emergency at hand (Andersen 2003, Rasmussen and Vicente 1989, 1992).

The emergency response environment is one where EID can assist in maintaining the connection between the individual and the environment. A strong understanding and connection with the information will increase clarity and reduce the room for error within this fast paced environment. This research will further the EID application possibilities and the value of the research. The application of EID to the complexity of emergency response assists in addressing the needs of the design while considering the environment and how it is controlled by the user. The information to be presented in the design was organized based on the requirements of information architecture. In the meantime, the visualization was developed through the appropriate applications of the theories behind information presentation and information visualization. The contribution of EID to the result of this study was provided through the final presentation of all the gathered information in a way that made it effective and efficient to use.

2.3. Successful Interface Design

There have been different studies (examples, Ahmed *et al.* 2006 and 2009, Galitz, 2007) in the area of interface design that have resulted in different lists of guidelines that should be followed in order to develop an effective interface design. The presented guidelines of feedback on actions while using the interface, avoiding complex navigation to information, supporting all levels of knowledge and learning, and overall consistency were mention regularly across the areas of study. These guidelines, detailed below, were applied in the development of the preliminary and final designs.

2.3.1 Feedback on actions

While navigating an interface it is important for the users to received feedback on their actions. If the user does not see a change within the system in response to their actions then they may not understand that their task has been completed. For example, if a user is required to input information into the database then the interface should display the information immediately or inform the user of the success of the information input. Having reliable feedback will assist the users in efficiently maneuvering through the system by reducing any confusion in relation to their actions and their results as they relate to the interface (Ahmed *et al.* 2006 and 2009).

2.3.2. Avoid complex navigation

The users should be able to maneuver through the interface with minimal delays. If the user is looking for a piece of information related to decision making it is important that this information be as easily accessible as possible from any area of the interface. The users should be able to get from any point within the interface to another with minimal effort and challenge through the use of the tools available to them. If navigation tools, such as zoom or scroll, are available then they should be clearly presented to the users to avoid any misunderstandings (Ahmed *et al.* 2006 and 2009, Galitz 2007).

2.3.3. Support all levels of knowledge

It is important that the interface be designed in a way that allows for all users to use the information effectively. Generally in a work environment there are new workers and experienced workers, it is important that the interface accommodate this range of knowledge. The system should be easy enough for the newer members to use effectively but not so easy that it would be frustrating for the more experienced users to use. This can be remedied through integrating shortcuts into the design or providing a customizable layout for the more experienced users (Ahmed *et al.* 2006 and 2009).

2.3.4. Consistency

Consistency throughout the design of the interface is important to the understanding of the contents of the information. Consistency can be related to the terms that are used, the meanings behind certain colours or shapes, and the location of certain information. If the users can rely on related information being positioned within the same location on the interface, or a certain colour portraying a specific meaning, then they are able to more effectively locate and understand the information that is at hand. With this stronger understanding the users can use the information more effectively in decision making and problem solving (Ahmed *et al.* 2006 and 2009, Galitz 2007).

2.4. Summary of Literature

The goal of this literature review was to develop support for the framework which laid out the research problem of this study (see Figure 1). The loss of SA presents a dangerous scenario for anyone related to the response to an emergency. Presenting the required information to the user in a way that will reduce the loss of information, and as a result, the loss of SA would be beneficial to the users and the response process as a whole.

There were a variety of different suggestions throughout the literature as to what methodology approaches to use in the development and execution stages of the design. The designer needs to

understand what works for the user and what creates more problems than solutions. Past studies also suggest that throughout this process and the rest of the development stage, the users should be closely involved in the design process. This collaboration will allow for the highest level of understanding of what happens within the environment and the systems that are currently used to run it. Running tests with the user directly, throughout the development process, can ensure that the design moves towards a result that the users are able to work with effectively during the course of their daily jobs.

The final design was developed based on the contributions provided by the studies of information architecture, information presentation, EID, and the guidelines to the development of a successful interface design. The combination of these approaches assisted in the development of a design that would ultimately enable the user to collect their data and view it in a way that assists and supports proper decision making.

3. METHODOLOGY

3.1. General Approach

3.1.1. User Centered Design

The approach to information gathering and analysis for this study followed a user centered design (UCD) approach. This method revolved around having the user involved throughout the entire design development process. Any changes made to the technology present within the user's environment were made with the goal of facilitating interactions. The methods involved in UCD require the involvement of the user early on in the process, in the evaluation of presented prototypes, and ultimately in the final design adjustment and testing. These steps could be broken down into three sections: predesign research, design development, and final design and testing. The predesign process involves working directly with the users to develop an understanding of their daily tasks, environment, and system requirements. This information would help to support the development of the design. Upon the development of the design the users are asked to interact with the design and provide comments on their experience. The final analyses of the qualitative data lead to the development of the final designs and to the ultimate testing of these designs with the users (Johnson *et al.* 2005, Noyes and Baber 1999, Rubin and Chisnell 2008, and Torres 2002).

The empirical methodology used for this study was developed based on the requirements that satisfy UCD. The ultimate users of the system were encouraged to provide any opinion that would assist in the development of an efficient and effective presentation of the information. The research process consisted of three phases: predesign, design, and final design (see Figure 6). The list of the methodology used for this study is outlined in Table 1. A detailed description of the procedures involved in each of the methods is presented in Section 3.2.

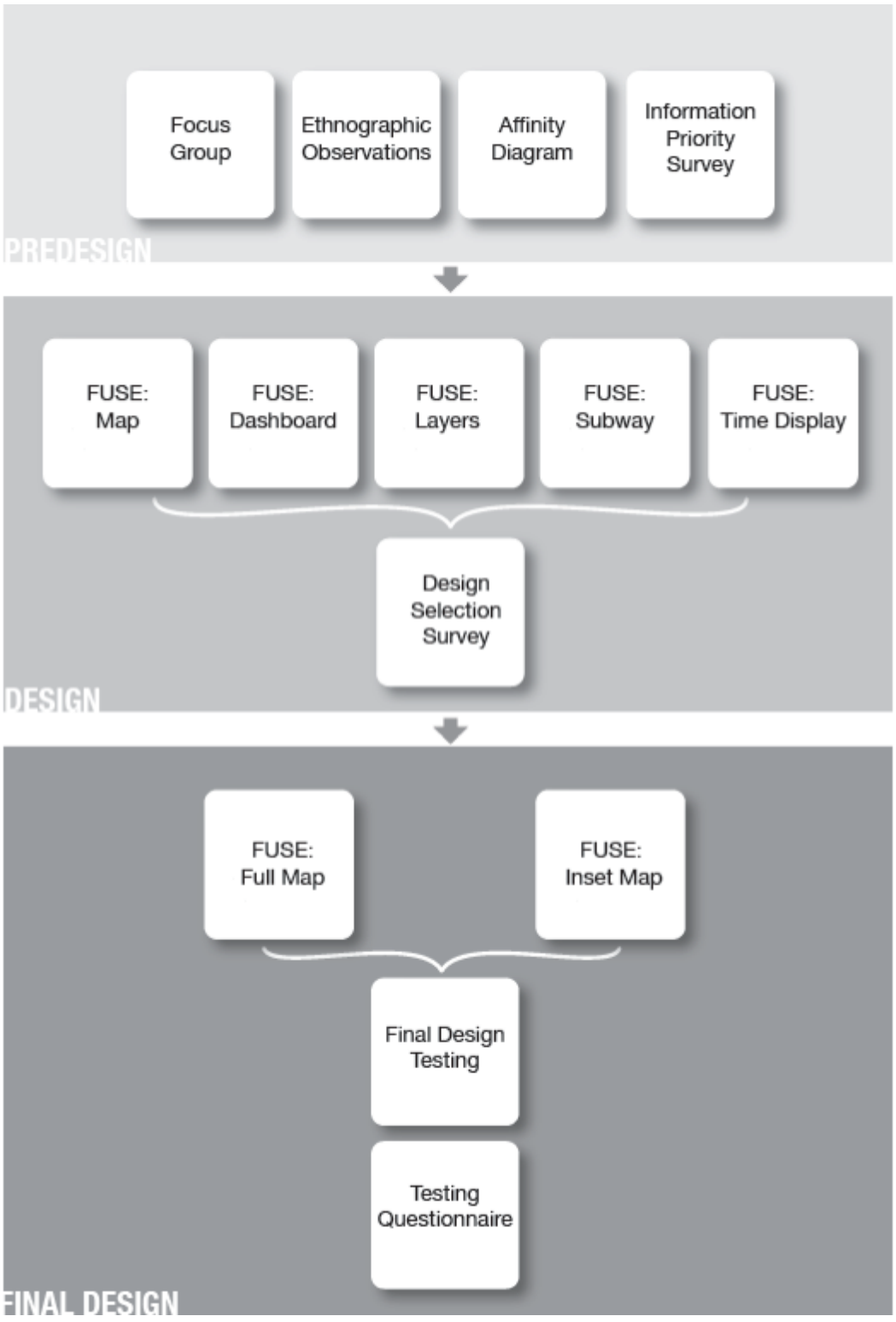


Figure 6. Methodology used for this study.

Method	Definition	Objective
Focus Group	- A group of participants discussing potential approaches and ideas. - The breakdown of how the system works will also be discussed.	- To locate where the users are finding any problems within the current processes. - Develop a preliminary understanding of what the key functionalities are within the system.
Ethnographic Observation	- Observing the users while interacting with the current information displays. - Observing the users within their natural work environment. - Develop understanding of the tasks and goals within this environment.	- Confirm statements made within the focus group. - Locate problematic areas within the design that were not brought forward in focus group. - Develop a deeper understanding of the information flow amongst the users within the regional response rooms.
Affinity Diagram Activity	- Participants are asked to sort a set of information cards to demonstrate importance and grouping of the information within the current processes.	- First step to organizing the important information within the response room - Group information and concerns into categories. - Use the information collected in focus group and ethnographic observations to create the information cards. - Participants sort the cards to demonstrate where the potential for a final design is located.
Information Survey	- Activity designed to better understand the potential user and their preferences concerning the information within the system.	- Collect all the pieces of information that are used within the regional response rooms for decision making. - Participants rate each piece of information in a way that will organize the priority within forest fire response. - Supports information architecture in organizing the information in how it should be presented within the system.
Preliminary Design Development	- Results from previous exercises combined in the development of the preliminary designs	- Gather all the information from the previous exercises to assess the information and visualization needs of the users.
Design Selection Survey	- Activity designs to better understand the potential user and their preference concerning the presentation of information within the system.	- Prioritize the information within the response room systems. - Present the users with the design possibilities. - Allow the participants to express which design and features are preferable.
Final Design Development	- Results from previous exercises combined in the development of the final designs.	- Using the comments provided by the participants of the survey to develop final designs to be used for the final round of testing.
Final Design Testing	- Observe the participants while using the product to complete realistic tasks.	- Observe the participants while they interact with the final designs. - Observe where any areas were problematic or helpful to the users.
Final Questionnaire	- Ability to discover the opinion of the participants within the study.	- Allow the participants to provide comments related to their experience within the testing of the design. - Develop a better understanding of how the participants felt about the design.

Table 1. Methods used within this study.
References include (Noyes and Babar 1999, Rubin and Chisnell 2008, and Torres 2002)

3.1.2. Participants

All of the participants within this study were employees of the Ministry of Natural Resources (MNR) in Ontario, Canada. It was a requirement throughout this study that any of the participants had to have worked in the regional response offices during fire season at some point during their career. Having participants that were familiar with the current system would ensure that they were able to compare the processes, both current and proposed, and relay the proper information requirements based on current decision making processes. The number of participants in each activity is described in each procedure description.

The majority of the participant roles included the Regional Duty Officer (DO), Aircraft Management Officer (AMO), and Fire Intelligence Officers. The various levels of response and areas of work presented by the participants provided the study with a well-rounded knowledge of what processes were in place at the time of the study. Throughout these activities the participants were encouraged to elaborate on what was being developed at the time of this study and what was coming down the line as far as information and system development for forest fire response were concerned.

3.2. Predesign Procedure

3.2.1. Focus Group

The initial visit to the regional response room was held in Dryden, Ontario with a variety of members from the MNR. This office is the regional forest fire response headquarters for Ontario's Western Region. A focus group activity was held inside of the regional response room so that the information and processes being discussed could be seen and described in a clear and concise way. The focus group activity was held in this room so that the researcher could develop a good mental picture of where information was located and how it would be shown to the members of the team occupying the

room while responding to forest fires. This session was organized and held outside of fire season to ensure that interruptions were not being made to the fire response operations within the room.

The focus group session was held over two business days and began with an introduction to the members of the MNR and their role within the forest fire response team. The roles of the twelve participants included: DOs, AMOs, intelligence officers, information technology specialists, and members of the detection team. These introductions were followed by a summary of the study and all of the research done to that point. After all introductions and clarifications were completed, the floor was opened for discussion. The discussions were unscripted and left open for anyone involved to provide any information related to this study. The discussions began with the members of the team bringing forward any ideas or suggestions of where they felt any adjustments or improvements could be made within their current forest fire response processes. The team members explained their recommendations and the way their suggestions could improve processes and communications.

After the first day of the focus group activity, all of the ideas that were presented were collected and sorted. This collection and sorting was done to develop an understanding of where the suggestions were coming from and where the most potential existed for further research. On the second day, the topics were more focused and they were discussed by all parties in greater detail. The exploration into these topics explained where the main concerns were and where there was the most potential for improvement, all of which revolved around the information currently being presented to the users in the response rooms. The information that was used within the rooms and the systems responsible for relaying this information were also discussed and explained. This second round of focus group discussions led to a stronger overall understanding of the specific information that was presented to the user when an important decision needs to be made. As the topic moved towards the information systems and databases that were in the room, each was displayed in the way that it would be presented within a forest fire response scenario. This allowed for each information system to be explained thoroughly and to show how each one contributes to the forest fire response process.

Overall, the results of the focus group provided the information required to narrow down the scope of the study. The participants within this activity were able to clarify what areas within the current processes and systems required the most attention as it related to the facilitation of the information flow within the response rooms.

3.2.2. Ethnographic Observations

The second round of research came as an ethnographic observation of the forest fire response procedures. The intent of this research was to gain a first-hand experience of the processes and the execution of those processes from within the regional response room. The observations were not only intended to confirm the statements made by the participants of the focus group, but also to open the scope to the possibility of new issues that users may or may not be aware of on a day to day basis. The ethnographic research was held in the two regional response offices in the province, the East Fire Response Office (Sudbury, Ontario) and the West Fire Response Office (Dryden, Ontario). The rooms were observed over two business days per location over the span of four days. The observations involved six participants from Dryden and seven from Sudbury. This allowed for a comparison of processes and protocol, ensuring that no assumptions would be made based on one certain location or team.

The environment, in which the ethnographic observations were conducted, for both regions, was the regional response room. Being at the center of where all the decisions were made assisted in developing a better understanding of how the information supporting those decisions was being presented. Being immersed in the natural environment allowed for a better understanding of where information was coming from, where everyone was looking to get it, and how the information was used to develop response objectives.

While observing the individuals at work within the response rooms it was important that all movement and information sharing happen naturally. All movement within the room was documented with both audio and video recordings. The audio was used to record dialogue between team members, phone conversations and different forms of communication that were happening throughout the day, as it

applied to forest fire response. The video information was used for the visual forms of communication between team members, documenting what information individuals were looking at during their discussions or decision making processes. This information was collected with minimal interference to the natural movement within the room. All the results from this data collection were used for information gathering purposes only; all the members involved in the observations were kept anonymous throughout the analysis of the results.

3.2.3. Affinity Diagram Activity

The discussions and observations done with the members of the response team resulted in a large assortment of information to be used for the further development of this study. To analyze the main issues being presented within these sessions, and to justify the need for an information integration system, an affinity diagram was developed. An affinity diagram allows for many different notes and points, coming in from collaboration and discussion, to be sorted into groups to be reviewed and analyzed. This activity was the first step in organizing the information within the study.

The development of this affinity diagram involved taking all the notes from the focus group activity and ethnographic observation sessions and picking out all the mentions of information presentation, needs, problems within the system, and suggestions for improvement. Each one of these instances was written on a separate piece of paper. All of these notes were then grouped together based on related connections which were guided by the opinions of the participants. To make the categories specific, the number of notes per category was limited to a maximum of five. After all the categories were created, and all the notes were used, they were each given a title that best described the contents of that category. After all the categories had a title, these were then grouped together based on related connections guided by the opinions of the participants. Again, to ensure that the groups were not too broad, the number of categories per new group was limited to a maximum of three. These new groups were then given a title that best described the overall contents. The final set of titles would describe the main areas of focus within all the original notes.

To ensure that there were no biases in the layout of the affinity diagram based on proximity to research or background training, members of the response team were asked to participate in the same activity. All the notes that were gathered to develop the first affinity diagram were inserted into the study and sent out to members of the response team through Web Sort (www.websort.net). Web Sort allows for items in a list to be grouped by participants according to the similarities that are found between the different items. The groups can be given a title by the participants, indicating the reasoning behind that grouping. The participants were sent instructions (see Appendix A) on how to complete the activity, with the request that the activity be completed by response team members only. Participants were able to visit the activity online through a provided link to begin sorting through the notes. The participants were asked to group all the notes, located on the side bar, by clicking and dragging them onto the main screen. Once all the notes were situated into groups, the participants were able to name their categories in a way that described the contents best. None of the participants were able to see the names of the categories that were developed by other participants. In the end there were nine participants in this activity from Dryden, Ontario and Sudbury, Ontario.

3.2.4. Information Survey

The results from the affinity diagram exercise provided the research with a direction as well as a base on which to lay the ground work of an information integration display. The affinity diagram was able to lay out the basic information that should be prominent within an information integration display. To gain a better understanding of the prioritization of this information, a survey was developed. The survey results would provide a detailed and more specific idea as to what information was the most important to the different users. At the end of this activity there were nine participants from Dryden, Ontario and Sudbury, Ontario.

The information survey was developed with the intention of finding out what pieces of information were important to specific members of the team during specific scenarios. The survey was sent to the participants through Survey Monkey (www.surveymonkey.com). Each question laid out a scenario that

would come up in the regional response room (see Appendix B for a full list of questions). These scenarios were developed based on the information collected within the focus group and ethnographic observation sessions. A series of scenarios was presented to the participants of the survey, along with a list of information related to each scenario which the participants would rank in level of importance.

One of the goals of this survey was to discover what information was the most important to the largest variety of people in a given scenario. The participants were asked to rate each piece of information based on the level of importance it holds to their position within the regional response room, and the level of importance they feel that piece of information holds to the other members of the team (1 being not important at all, 7 being very important information). The overall intent of this survey was to find out what pieces of information were the most important to include in the forefront of the final design.

3.3. Design Development Procedure

3.3.1. Preliminary Design Development

The development of five different versions of the preliminary design came as the result of the previous research activities. All the features and layout decisions were based on the research results and reactions from the participants to the different activities. Each of the preliminary designs showed the important information, as decided by the information survey, in a new and different way from the next.

The development process revolved around keeping all the important information, as provided by the research, close to the surface. The goal was to keep all related information in close proximity to reduce search times for information. Having all the information grouped in one location would assist the user in making connections between pieces of information. Facilitating the location and understanding of information directly applied to the list of requirements for the information integration display. To ensure that the design that would be present in the final round of testing would benefit the users, the reaction of the regional response team members to each of the designs was critical at this stage.

3.3.2. Design Selection Survey

A design selection survey was developed with the intent of finding out which of the visual approaches to the information were preferred by the potential users of the design. The final analysis of the survey would dictate the design, or designs, that would be presented to the users for the final round of testing. In the end there were fourteen participants who took part in this activity from the regional response offices in Dryden, Ontario and Sudbury, Ontario.

The goal for this exercise was to present the information within each of the designs in a way that would allow the users to picture the system within their current processes. To do this, a storyline was developed based on how activities would play out within a regular day. This story was related to the different pieces of information that the user may be looking for throughout a typical day and that could be found within the respective designs. A video for each of these designs was developed to show the participant where they would find information within that design and how that information would ultimately be laid out for them to see. Each video was one and a half to two minutes in length with no audio. A survey was also developed through Survey Monkey (www.surveymonkey.com) and sent to the participants. Each of the questions asked the participant to view a specific design video and then describe what they liked and/or would change about the presentation of information within that design (see Appendix D for full survey). This process was done for each of the design videos. Once this was complete, the participants were asked to rank all the designs in order of preference (1 being most desirable and 5 being least desirable).

The main goal of this activity was to reduce the number of options for the final design development and testing. The response related to the separate designs was intended to show what features and what forms of information presentation were preferred by the potential users. The final prototype, or prototypes, would be used in the final round of testing for this study.

3.4. Final Design and Testing Procedure

3.4.1. Final Design Development

All the previous activities led to the design and development of the final prototypes that were to be tested with the participants of this study. The final designs were developed using the comments and suggestions provided by the participants in the design selection survey. All of the features that remained within the final designs were based on the reactions and opinions of the participants.

The development of the final designs maintained the different levels of information hierarchy and grouping that existed during the development of the preliminary designs. Grouping all related information into one location was intended to reduce the amount of time spent on information searches. The more connections that can be made across the information the more effective the design will be in assisting the decision making process.

3.4.2. Final Design Testing and Questionnaire

The final round of testing was intended to ensure that the design was meeting all the requirements of the users as well as all the requirements for the study. The final round of testing was different from the other activities in that the users were given the opportunity to interact with the designs and the information that was being displayed within those designs. By allowing the users to interact with each of the designs they can better predict how this form of information presentation can fit into the current information processes within the regional response rooms.

The tests were run over WebEx and conference calls. This allowed all the participants to run the test one at a time throughout the day. There were ten participants in this activity, five from Dryden, Ontario and five from Sudbury, Ontario. Each participant was provided with a copy of each of the prototypes and displayed their screen in a way that allowed the researcher to view their movements on the screen in reaction to the provided tasks.

Each round of testing ran for approximately 20 - 25 minutes in length. The test was run one on one between the researcher and each of the participants. Each of the sessions was recorded with video and

audio for analysis after the testing was completed. All of the results were kept anonymous throughout the writing and analysis portions of this study.

Before the testing began each of the participants was given a summary of what would be happening throughout the testing process; they would be running through each design one at a time, completing small tasks that were read to them, and at the end of the process they were to be given a questionnaire to fill out that would better describe their experience with the testing and the designs. Each of the participants was asked to talk through their thinking and understanding of what was going on while they were interacting with each of the designs. This would help in further understanding where and why they were experiencing any difficulty with the prototypes. The tasks provided to the participants were developed in a way that would present comparable results for the study. These comparisons showed where the participants had difficulty with the visual presentation of the information.

The order in which each of the participants interacted with each of the prototypes alternated with each test of the designs to remove any preconceptions related to the interactions with the previous design. Before the participants were run through the list of tasks they were provided with a small training session on the design with which they were about to interact (for full script see Appendix F). The points mentioned during the training were based around the way that the participant was able to interact with the present design. Explanations on visuals were provided when it was felt that the participant would be unable to understand the visuals on their own. This training session took no more than two to three minutes for each design and was intended to familiarize the participants with the designs before they were asked to interact with the designs.

Each participant was asked to complete nine small tasks for each of the design prototypes. These tasks revolved around finding information related to fires, crew, and aircraft while interacting with the prototype (for full list of questions see Appendix F). The ultimate goal of the testing was to ensure that the information was meeting the requirements of the study, that the presentation was satisfying the needs of the participants, and that it was being understood by the participants overall.

Upon completion of the testing all the participants were asked to complete a questionnaire that was related to their experience with the designs. The purpose of the questionnaire was to explain which of the designs was preferable, where the participants found any concerns, and where the participants felt that the design could be of value to their current processes. The results of the questionnaire were intended to elaborate on the experience of the participant throughout the testing of the prototypes.

4. PREDESIGN

4.1. Focus Group Results

The focus group involved the members of the forest fire response team at the Ministry of Natural Resources (MNR) in Ontario. In the initial consultations with the response team, members were encouraged to bring forward any of their own concerns with the current system and discuss them in detail. A variety of issues and concerns were brought to the table. These areas of concern were all sections in which the participants felt improvements could be made with information flow, access, and communication within the response process.

The discussions were unscripted and left open for anyone involved to provide any information related to this study. The team members explained the suggestions that they brought forward and how those suggestions could improve their processes and communications. A list was made of all of these suggestions and each point was discussed in further detail with the rest of the participants. This discussion provided a background to the current use of the suggestion, its place within the forest fire response process, and explaining all, if any, concerns associated with its function and/or application. On the second day of the focus group these topics were reduced to two areas that were discussed in finer detail: forest fire information and situational awareness. The described results are a summary of the findings throughout the two days of research.

The improper input of information was one of the main concerns brought forward by participants; this can cause a series of problems for the user. When initial information from a fire is not provided, the information that follows an incident report cannot be put into the system. This input delay quickly causes information to become outdated. This is an area where much time is spent and many issues have arisen.

Another one of the concerns that was brought forward by participants in the discussions was related to the information flow within the response offices, specifically data entry. There are individuals within each of the response offices in the province who are responsible for entering data into the separate systems but, if there are multiple fires, the information can get backlogged and data input reduced as a result. This backlog can cause many instances where the Duty Officer (DO) cannot react efficiently to the problems at hand and thus the DO will not be sufficiently equipped to make a well-educated decision when responding to a forest fire. At the time of this study, the proper technology devices were not yet in place province wide to facilitate this form of data entry.

Any delay in data entry is an issue that could negatively affect the information flow within the response room. Without access to the full story, the communication and collection of information within the room could be reduced, influencing the actions and decisions of the emergency response team members. This can cause misunderstandings regarding the status of the fires within the region, and could create the development of a poor level of situational awareness. Without a strong sense of situational awareness the people within the response room will be unable to make well informed decisions. All of these consequences show the level of importance that should be placed on the information flow and information access within the room. These findings presented an opportunity for the proposal of a design intended to facilitate the information collection with the regional response rooms.

The focus group discussions were able to validate the framework for this research (see Figure 1). The members were able to discuss and elaborate on the challenges within the room and the consequences should the challenge become too severe. After talking with the members of the response team it was clear that information collection and accessibility was a large concern within the daily processes in the response room. This knowledge assisted in narrowing the focus of the research that would be conducted in the next stage, which would be the ethnographic observation.

4.2. Ethnographic Observation Results

The ethnographic observations provided an insight into the true processes conducted throughout the regional response rooms in Dryden, Ontario and Sudbury, Ontario. The main observations within this method were related to the integration of information and the current process of information updates.

The members of the response team at the MNR have access to many different databases of information and each of these databases has a different purpose. There are many individual systems where a team member can locate information regarding any fire, crew, resources, and aircraft. To get this information the team members have to go into each individual system to retrieve it. Nowhere is all of this information fully integrated and displayed.

The regional response team at the MNR currently works in shifts. Each transition from shift to shift requires a transfer of information from one individual to another and, depending on the number of fires on the board this could be a very time consuming process. In the case of a quiet fire week, where few fire reports are coming in, the incoming DO will get updates from the previous DO through written notes. In the case of a busier fire week the on duty DO would email, phone, or update the oncoming DO in person. When there are multiple fires, both DOs will come in for the morning of duty handover to ensure that the transfer of information is smooth.

The current process of getting information updates within the response room involves a wide range of communication styles: phone, e-mail, and verbal, to name a few. These can create problems within the response portion of the process as they can be very time consuming and sometimes unreliable. In the case of multiple ongoing fires this might cause frustration, distraction, and the possibility of incorrect information being transferred. These concerns show the need for an information update system which can be displayed anywhere within or outside of the response room.

The most time consuming process observed in the method of information gathering was the information update and collection process. Getting caught up on the current situation, whether it was after an hour, day, or week, can take a considerable amount of time away from the fire response process depending on the current fire situation. Focusing this research on making the process of gathering

information for updates less time consuming was found to be an area where the result would be of value. If the users are presented with an information update system that provides all the information regarding the current fire response situation, it will save time searching for information, reduce distraction when someone needs an update, and increase the ability to develop a strong sense of situational awareness.

Figure 7. Information flow while responding to a fire report.

The ethnographic observation, in combination with the results of the focus group, gave a strong idea on how information flowed through the room during the process of forest fire response at the time of this study (see Figure 7 for detailed layout). The notes gathered based on the observations were used to begin the organization of the information to be used within the final design. The collection of this information was used in the development of the next activity, the affinity diagram (see Table 2 for notes gathered from the study to be used for the affinity diagram).

Category	Key Points
Situational awareness	• Maps to maintain situational awareness • Need to maintain the overall picture • Have to ask to find the number of new fires • No alert of what is important to look at
Information integration	• Need to pull the information together • Connect the databases
Decision support	• Decision making support • Phase guidelines • Information in one place
Data entry	• Incomplete data entry • Feeding the monster (data entry issues)
Information access	• Easily accessible information • Narrowing down the possibilities • Mapping layers of information
Information collection	• Proper information collection • Have to dig for information • Information collected in various formats
Fire information	• Fire occurrence prediction • Values at risk • Fire prioritization • Fire behaviour analysis
Resource management	• Resource preparedness • Correct resource placement • Losing track of resources

Table 2. Key notes within the ethnographic observations.

4.3. Affinity Diagram Activity Results

The discussions and observations carried out with the members of the response team resulted in a large collection of information to use for further development of this study. To analyze the main issues being presented within these sessions, and to justify the need for an information integration system, an affinity diagram was developed.

The participants were presented with a list taken from the results of the previous activities and then asked to group the notes using the website Web Sort (www.websort.net). The way that the participants grouped the different notes showed the opinions held on the different pieces of information. When all of the notes were gathered into their respective groups, the notes within the group dictated whether the participant saw the note as an area of concern, an area needing improvement, or part of their everyday process. The result showed the researcher the information the participants are the most concerned about or would like to change.

Web Sort allows for a cluster analysis, or tree diagram, of all the results from the participants and the groups that they created. The analysis would allow for the development of an overall affinity diagram based on the input of all the participants. The final affinity diagram is presented by Web Sort through the use of statistical methods.

The resulting affinity (see Table 3) showed where the participants placed most of their concern regarding the information flow within the response rooms. The participants in this activity laid out their concerns with information gathering and integration, the information that is used for planning and issues that are related to their current information flow within the room.

Information				Visual in the Every Day	
Information Gathering	**Planning**	**Issues**	**Information Integration**	**Visuals**	**Every Day Preparedness**
• Need to pull information together • Proper information collection • Easily accessible information • Incomplete data	• Fire behaviour analysis • Fire occurrence prediction • 2 hr. on SOP • Information gathered in SOP	• Cannot get information on a specific resource • Information collected in various formats • Data entry • Lots of places to get information but not one place to get it • Have to dig for information	• Connect the databases • "How do we integrate all of our systems in a way that really supports the way that we do our business?" • Information in one place	• Mental information out into a visual • Not alert of what is important to look at • Maps to maintain situational awareness	• Maintain the overall picture • Resource preparedness • Correct resource placement • Resource and time limitations • Decision making support • Fire prioritization • Values at risk

Table 3. Final affinity diagram.

The results of this activity provided information on the way the users see the response room and the information within it. The main issues that were pointed out regularly and consistently throughout this activity were the current processes of gathering information and the need for information integration. These categories were the most important outcomes of this activity. These results can contribute to the type of design that should be developed, in this case a form of information integration. The information that should be presented within this information integration system was also laid out within the results of this activity. The participants consistently grouped together the pieces of information that are used within the everyday processes within the response room. These results from the affinity diagram activity were valuable in guiding a direction for the design to be developed and what type of information should be displayed within the final design.

The affinity diagram exercise was the first step in the application of information architecture to the design. This first step involved organizing the information that would be present within the final integration design. The categories created by the users were able to present an outline of where specific

information would be presented within the final design and what information was essential to different processes currently present within the everyday activities in the regional response rooms.

4.4. Information Survey Results

The intention of the information survey was to narrow down the pieces of information that are the most important to the members of the response team as a whole within specific scenarios. The decision as to which pieces of information were the most important was made based on which pieces of information were consistently ranked on the higher end of the scale (5+) for both personal use and the use of other team members. The information within the results tables included the personal ranking for each piece of information as provided by the participants as well as the overall ranking of that piece of information, which provides an average of how each individual rated the information and how important they felt that piece was to the rest of their teammates.

The layout of the scenarios within this survey provided an insight as to the ranking of information within different sections of the final design. The first scenario provided a priority scale of the information that is important to the overall understanding of the current situation. The scenarios that follow provided insight for what the priority would be within these different contributors to the overall understanding. The order in which the results are presented reflects the priority provided by the users.

Keeping the idea of the large scale of the region in mind, the first question on the survey revolved around what information was the most important to the participants when an update on the entire region was required (see Table 4). When the different positions within the regional response room were compared, it was shown that the Intelligence Officer ranked the importance of the different pieces of resource information lower than the DOs. This could be due to the information that is of interest to the different positions; because the DO is more concerned with the dispatching of resources, they will be the ones to rate these pieces of information as more important.

Regional Information	Personal Ranking	Overall Ranking
Non actioned fires	7.0	6.9
Weather	7.0	6.7
New fire arrivals within x time	6.9	6.6
General hazard	6.9	6.5
Fire priority	6.8	6.4
Number of active fires	6.2	6.1
Aircraft availability	4.9	5.9
Number of open incidents	6.6	6.0
Outstanding resource requests	4.3	5.6
Crew availability	4.9	5.6
Resource status	4.3	5.3

Table 4. Regional information ranking.
All numbers are averages where a higher number indicates a high preference.

The participants were then asked what information they would use when an update on the current situation was required after they had been away from the room for any amount of time. The pieces of information were rated higher on level of importance for the Duty Officers (DO), when the results from the DOs were compared to the results from the Intelligence Officers. The two areas where this was the clearest were in the case of aircraft and resource locations; this is due to the pieces of information that each of these individuals are responsible for. The DO's position relates more closely to the dispatch of resources to a fire while Intelligence works more closely with the weather and hazard information related to a fire. Regardless of these differences, the ranking order of each of the pieces of information is very similar for what information an individual team member is looking for when they have been away from the room for any amount of time (see Table 5).

Update Information	Personal Ranking	Overall Ranking
Number of fires	7.0	6.6
Weather	6.2	6.5
Aircraft locations	4.7	5.8
Resources in motion	4.8	5.7
Ranking of fires	6.1	5.4
Crew locations	4.4	4.9
Outstanding Resource Request	3.7	4.8

Table 5. Update information ranking.
All numbers are averages where the higher number indicates a higher preference.

Fire Information	Personal Ranking	Overall Ranking
Fire behaviour	7.0	7.0
Weather	7.0	6.6
Size of fire	6.4	6.5
Values at risk	6.7	6.3
Current fire status	6.4	6.2
Fire priority	6.2	5.9
Fire location	5.8	5.7
Resources assigned	5.2	5.4
Responding personnel	5.0	5.2
Response objective	5.1	4.9
Fire number	4.8	4.6

Table 6. Fire information ranking.
All numbers are averages where a higher number indivates a higher preference.

The participants were then asked to rate the pieces of information that were the most important to their role when an update was required on a specific fire (see Table 6). The pieces located on the lower

end of the rating scale were placed there because these pieces of information do not always relate to every fire that is on the board, while the other pieces are strong factors in planning the response objective for every active fire.

The information that was related to an update on a specific crew was rated lower than the rest of the pieces of information provided throughout the rest of the survey (see Table 7). In all the scenarios, information revolving around crew and crew placement were rated on the lower end of the scale. The members of the response team were mostly concerned about the hazards presented by the fires that are currently burning; this helps them to decide the plan of action in response to the fire and then choose what resources to send in response. Specific information on crew was stated in comments on the survey to be more important to the sector response offices, not as much on the regional level of command.

Crew Information	Personal Ranking	Overall Ranking
Crew type	4.6	5.2
Crew availability	3.9	5.0
Last days off	2.9	4.3
Current function on fire	2.6	3.7
Crew name	2.6	3.2
Crew members	1.6	2.9

Table 7. Crew information ranking.
All numbers are averages where a higher number indicates a higher preference.

When asked what information was required when wanting an update on the resources on a fire, the crew information was ranked a little higher for the first time (see Table 8). The lowest ranked pieces of information are ones that would be of most interest to the sector response offices, as they are responsible for equipping and keeping track of the crews that are being dispatched to the fires.

Fire Resource Information	Personal Ranking	Overall Ranking
Incident Management Team	5.9	6.0
Aircraft assigned	4.8	5.8
Total number of personnel	4.4	5.3
Type of crews on fire	4.6	5.2
Number of crews on fire	4.4	5.1
Suppression Equipment	3.0	4.4

Table 8. Fire resource information ranking.
All numbers are averages where a higher number indicates a higher preference.

The overall outcome of this survey was the ranking of the pieces of information that are important to the participants and their fellow members of the response team. The results presented a usable list that was able to dictate which pieces of information should be more prominent, and which pieces could be placed deeper within the design. The order of the items on the list was dictated by the average rating of each item overall as it compared to the personal rating. The items that were ranked as high were above the neutral zone which was decided as a ranking of 5 or higher. The information that was labeled as most important was information that was consistently ranked high across the positions within the team. This list helped in the development of a design that will address the user's needs and requirements from an integrated information system. By analyzing what information is the most important to the decision making process within certain scenarios, a system that accommodates these processes can be developed to assist the user in making important decisions within the forest fire response environment.

5. DESIGN

5.1. Description of Initial Designs

5.1.1. Development Process

The combination of all of the information collection processes and the study of different information displays resulted in the development of the final design. FUSE, the Fire Update Support Engine, is a system that is intended to integrate all of the currently separate information systems into one efficient and effective design. As all of the information was spread out across the regional response room, it was the intention that this system would reduce the time spent on information collection, improve the updating process, and facilitate information communication amongst users.

The initial steps of the design development for this study included gathering the information provided by the forest fire response team through discussions, observations, the sorting activity, and the survey, all of which were taken into account. These information-gathering activities were able to provide insight into what types of information presentation were best suited for the users and where they look to collect information when making a decision. The information that was included in the designs in the end was determined by the results of the information survey (see how each design addresses the survey results in Table 9). The level on which certain pieces of information were located within the design was decided based on the survey results as well as the allowances of a chosen design.

To explore a variety of options for visuals and information display approaches, multiple design layouts were developed. In the end, five design layouts were chosen to represent the different information approaches presented in initial sketches and designs. Below is a description of each design and the approach taken by each to display all the valuable information within the response room and presenting it to the users in an effective way.

	Map Based FUSE	Dashboard FUSE	Layered FUSE	Subway FUSE	Time Display FUSE
Information to provide an update on the current situation.					
Number of fires	Displayed in the fire menu. Opened by clicking the arrow on the left hand side of the screen.	Always located within the inset map on the bottom right hand corner of the screen.	Located within the fire window. Opened through selecting fire icon.	Located on the right hand side of the screen.	Displayed in the center of the image on the screen.
Weather	There is no information related to weather within this design.	The weather layer may be turned on through selecting the weather icon on the left hand side of the screen.	There is no information related to weather within this design.	There is no information related to weather within this design.	Located in the top left hand corner of the screen.
Aircraft location	Aircraft are always displayed in their current location on the map.	Aircraft are always displayed in their current location on the map.	Displayed within the aircraft window. Opened through selecting aircraft icon.	Select the related fire, then the desired aircraft to display actual location.	Select the related sector, fire number, then desired aircraft for details.
Resources in motion	Resources are always displayed in their current location on the map.	Resources are always displayed in their current location on the map.	There is no information related to the resources in motion within this design.	Displayed on the relative fire lines.	There is no information related to resources in motion within this design.
Ranking of fires	Presented on the fire list in order of priority.	There is no information related to the ranking of fires within this design.	Displayed within the fire window.	Located on the right hand side of the screen.	There is no information related to the ranking of fires within this design.

Table 9. Application of information survey to the preliminary designs.

	Map Based FUSE	Dashboard FUSE	Layered FUSE	Subway FUSE	Time Display FUSE
Information related to a specific fire.					
Fire behaviour	Found by selecting the fire icon on the map or fire number on the fire list. The window will display the current behaviour of the fire.	Found through selecting the fire icon on the map. This will display further details in the top right hand corner of the screen.	Displayed within the detailed fire window. Opened through selecting the desired fire number.	Select fire line, then the fire number to display the details of the fire.	Select the related sector, then fire number for more details.
Size of fire	Found by selecting the fire icon on the map or fire number on the fire list. The window will display the current size of the fire.	Found through selecting the fire icon on the map. This will display further details in the information window, located in the top right hand corner of the screen.	Displayed within the detailed fire window. Opened through selecting the desired fire number.	Select fire line, then the fire number to display the details of the fire.	Select the related sector, then fire number for more details.
Fire location	Fire icons are always displayed in their current location on the map.	Fire icons are always displayed in their current location on the map.	Displayed within the detailed fire window. Opened through selecting the desired fire number.	Select fire line, then the fire number to display the details of the fire.	Select the related sector, then fire number for more details.
Resources assigned	Resources are always displayed in their current location on the map.	Resources are always displayed in their current location on the map.	Displayed within the detailed fire window. Opened through selecting the desired fire number.	View on the main map. Select fire line for more details.	Select the related sector, then fire number for more details.

Table 9. Application of information survey to the preliminary designs.

	Map Based FUSE	Dashboard FUSE	Layered FUSE	Subway FUSE	Time Display FUSE
Information to provide an update on specific crew.					
Crew type	Found through selecting the crew icon on the map or the crew name on the crew list.	Found through selecting the crew icon on the map.	Available within the crew window. Opened through selecting the crew icon.	Select fire line, then the crew name to display the details of the crew.	Select the related sector, fire number, then desired crew for details.
Crew availability	Displayed within the crew menu. Opened through selecting the arrow on the right hand side of the screen.	Shown to the user in the information window when fully zoomed out on the map.	Available within the crew window. Opened through selecting the crew icon.	There is no information related to the percentage of available crew within this design.	Displayed in the center of the image on the screen.
Information to provide an update on the situation within the region.					
New fires	Found on the fire list. Found through selecting the arrow on the left hand side of the screen.	There is no alert as to new fires within this design.	Displayed in the fire menu. Opened by clicking the arrow on the left hand side of the screen.	List of fires is displayed on the right hand side of the screen.	There is no alert as to new fires within this design.
New fire arrivals within x time	The timeline is opened through selecting the arrow on the bottom of the screen.	There is no timeline feature within this design.	The timeline is located on the left hand side of the screen.	There is no timeline feature within this design.	Timeline located on the bottom right hand side of the screen.
Aircraft availability	Displayed within the aircraft menu. Opened through selecting the arrow located at the top of the screen.	Shown to the user in the information window when fully zoomed out on the map.	Displayed within the aircraft window. Opened through selecting aircraft icon.	There is no information related to weather within this design.	Displayed in the center of the image on the screen.
Number of open incidents	Located within the fire list. The incidents are displayed in a different colour from the active fires.	Available to the user in the information window when fully zoomed out on the map.	Displayed within the fire window. Opened through selecting fire icon.	There is no information related to the percentage of available aircraft within this design.	Displayed in the center of the image on the screen.

Table 9. Application of information survey to the preliminary designs.

5.1.2. FUSE: Map Based

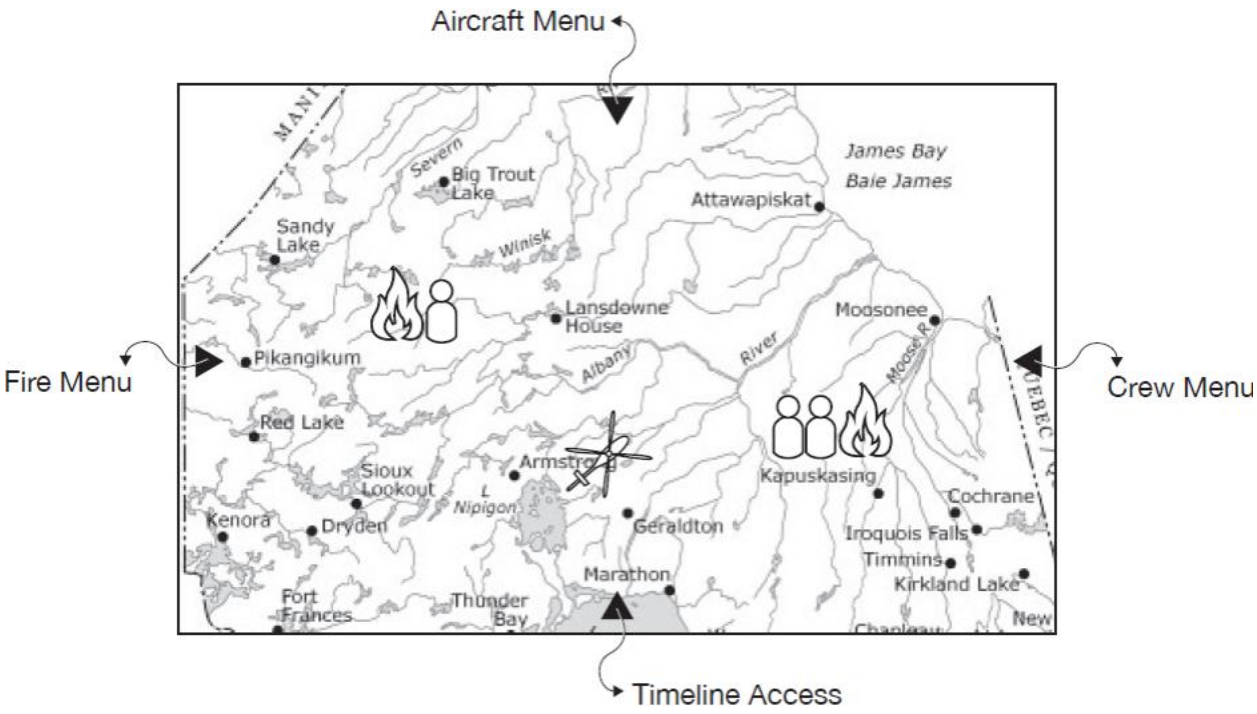


Figure 8. Main screen of Map Based FUSE design.

The Map Based layout of the FUSE design was based around the displays used within the regional response rooms at the time of this study. The overall design was based around a map background with icons representing the location of fires, crew, and aircraft. On the main screen (see Figure 8) resources and fires are placed on the map based on their location within the region. The resources that have been assigned a specific fire are displayed next to the relevant fire icon; this was done to support an understanding of what resources have been applied to certain response objectives. All of these icons are selectable and, when selected, display further information related to that item. There is an arrow on each side of the screen, each opening a side bar with further information on a different set of information (for further details see Appendix C.1.).

All of the information presented on the main screen of this design was intended to present the user with a general idea of the current situation across the region. This display of the information relates to the study of ecological interface design as it provides the information required to support decision making within the complex environment. The different levels of information are present to prevent confusion when focusing on one area of the response objective as well as allowing the user to collect more detailed information easily should the need arise. This approach to the design followed the guidelines within information design and situational awareness. The information that should be presented within the designs was determined by the information survey.

The menu located on the bottom of the Map Based FUSE screen holds the timeline feature. Every time a change is made to an aircraft, crew, or fire a new block is added to the timeline. If the user would like to see what has happened at any time they can select the desired period by clicking and dragging between the desired time intervals on the timeline. Once the desired period has been selected, a window appears on the screen with more detailed information regarding what has happened within the region within that specific period. Descriptions of changes made to availability, dispatch of aircraft, and the report of new fires, are all examples of the information that could be displayed within this window.

The timeline tool was not in place within the regional response rooms at the time of this study. The idea for this tool stemmed from the research leading up to the design development stages, mainly within the ethnographic observation stage. The goal of this tool was to reduce the amount of time that was required to get caught up on detailed updates, as well as the interruptions that this process sometimes includes. This tool will allow the user to get caught up on the information that is important to their interests and continue as required without distracting other team members or taking too much time away from the response to forest fires.

The Map Based FUSE display was intended to be used in the same way that the maps are currently being used within the response rooms. This design will keep the process familiar for the users as their current Dispatch display works in a similar way. This design is different from Dispatch in that it has more information built into the system; Dispatch does not display the location of any crew or any overall

listings related to resource availability. There are also different features that were developed, such as the timeline, to accommodate the requests and suggestions of the response team members that were discovered and observed in the previous research. The addition of these tools and ways to visualize the information was intended to support the further development of the level of situational awareness and decision making abilities within the regional response rooms.

5.1.3. FUSE: Dashboard

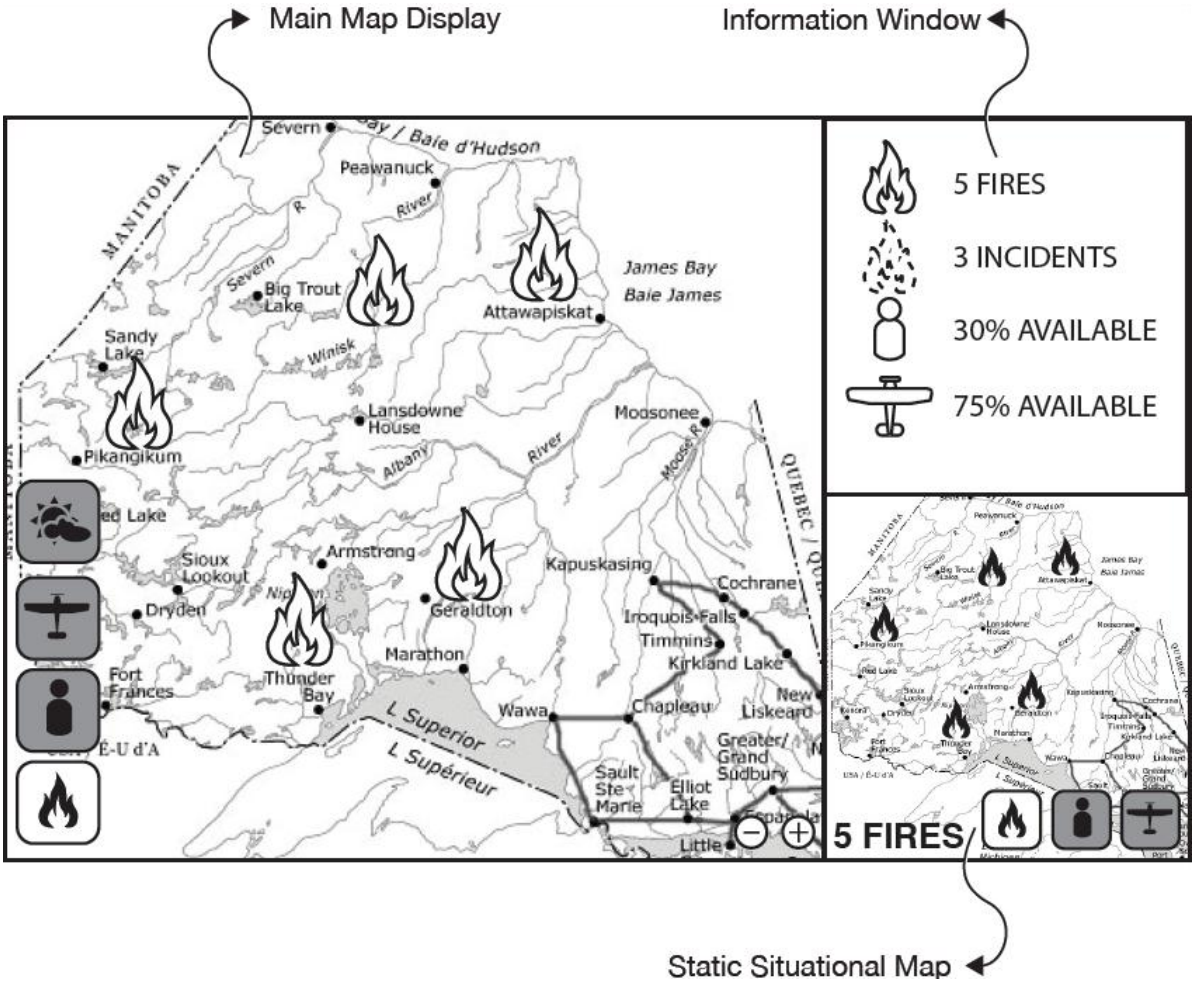


Figure 9. Main screen of Dashboard FUSE design.

The Dashboard FUSE design takes the idea of the map display a little further with displaying different levels of information simultaneously with the overall spatial display. This display was based on the maps that are currently present within the regional response rooms. The screen is made up of three windows, each displaying different levels of the information simultaneously (see Figure 9). The user can manipulate the three windows on the screen to gather different levels of information on the current situation (for full details see Appendix C.2.).

The layout of the information into three different information windows was intended to address any concerns around having too much information in one location. Having a large amount of information in one area of the screen can cause confusion or misunderstandings related to what the current situation is with the forest fires and the response objectives. The three different windows allow the user to use one, two, or all three of the windows simultaneously to develop a stronger sense of situational awareness. The maps can be customized based on what information they are displaying concerning fires and resources. The user is able to turn the different layers of information on and off. This will allow for the information to be clarified based on the user's role and objective.

The window located in the top right hand corner provides the user with details on all of the information displayed within the borders of the main screen. The level of detail within this window depends on the zoom level the user has chosen for the main map.

The third information window located in the bottom right hand corner of the screen contains a static map of the region. The purpose of this map is to ensure that the users are always able to see the big picture, or the overall situation within the region at that time, further supporting the development of situational awareness. This window will tell the user how many fires are currently burning across the region.

The purpose of the Dashboard FUSE design was to show as much information at one time as possible without creating confusion for the user. With this display the user can simultaneously access different levels of information regarding the current forest fire situation. This display also allows for multiple users from different positions to use the system at the same time, as everyone may be looking for

different information. This design was intended to use ecological interface design principles by gathering all of the required information to support proper decision making within the complex environment of the response rooms.

5.1.4. FUSE: Layers

The Layers FUSE design takes on more of a widget style design. The main layout of this design revolves around the need for constant access to all of the information while maintaining easy maneuverability. The layout of the design allows access to all four main information systems: the Daily Fire Operating Support System (DFOSS), the Personnel Information Management System (PIMS), the Aircraft Information Management System (ACIMS), and Dispatch (see Figure 10). The intent of this design is to provide fingertip access to the lists of information that are related to resources throughout the region (for full details see Appendix C.3.).

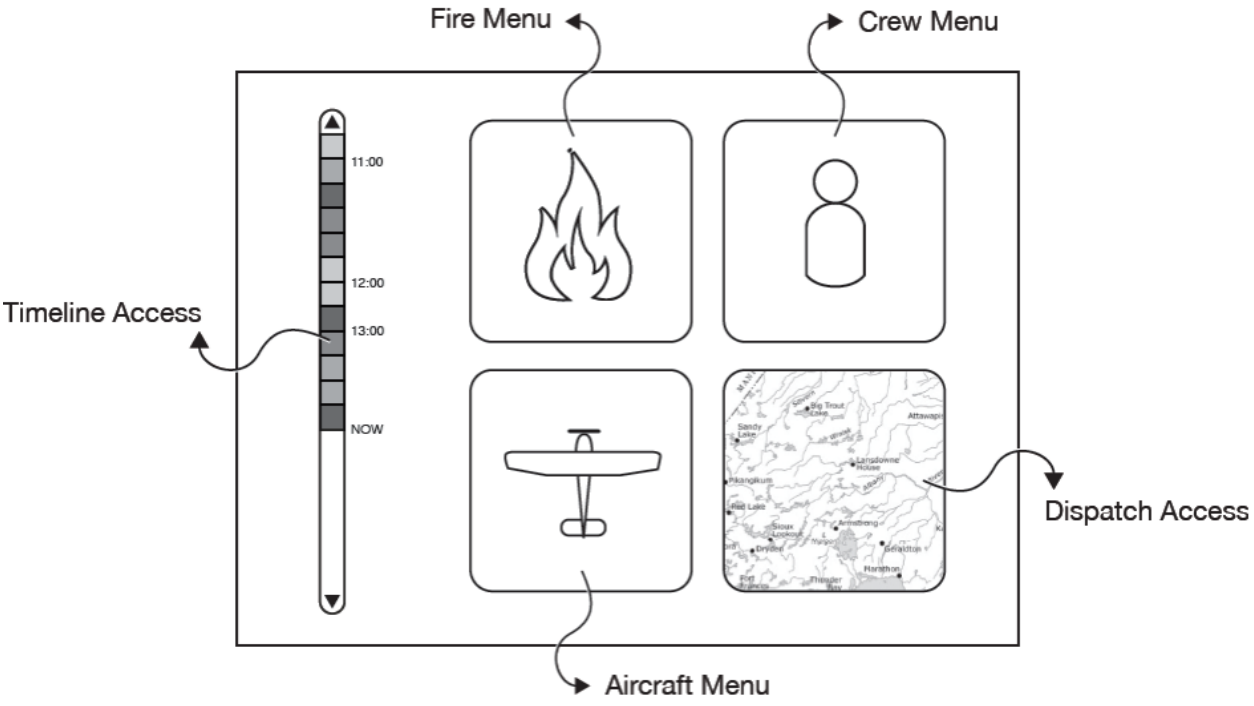


Figure 10. Main screen of the Layers FUSE design.

The Layers FUSE design was intended to bring all the information together into one location. This design allowed for easy access to all of the information that is used on a day-to-day basis within the response room. This design also gives the user direct access to the related databases should finer detail be required, saving the user from having to take the time to open each database separately. The Layers FUSE design has been presented with the intention of making the information quick and easy to access under any circumstance.

5.1.5. FUSE: Subway

The first of the information visualization approaches to the design was the Subway FUSE design (see Figure 11). This design was inspired by the subway maps in London, England and Toronto, Ontario. When developing the different layout options, it was of interest to the study to see what the reaction would be to a visual design that would be unique to the current processes within the regional response rooms. The goal of this design was to present the information in a primarily visual way, reducing the amount of text and clutter that can be present in the current processes within the regional response rooms (for full details see Appendix C.4.).

Grouping all of the information related to one fire in one location was intended to assist the user in developing an idea of the situation within the environment of that fire. This information presentation was important to show the user which resources and pieces of information were related to the selected fire by gathering all the information into one location.

The overall goal of this display was to gather all of the information in one place in a way that brings a level of simplicity to the design. There are instances where there can be large numbers of fires in one area; visually this can be confusing and disorienting. By using information visualization to approach the data in a mainly visual and abstract manner, it can become easier to absorb the information in a short amount of time. Showing information in an abstract form can assist in making connections between different pieces of information and reduce the clutter and complexity of the final information display.

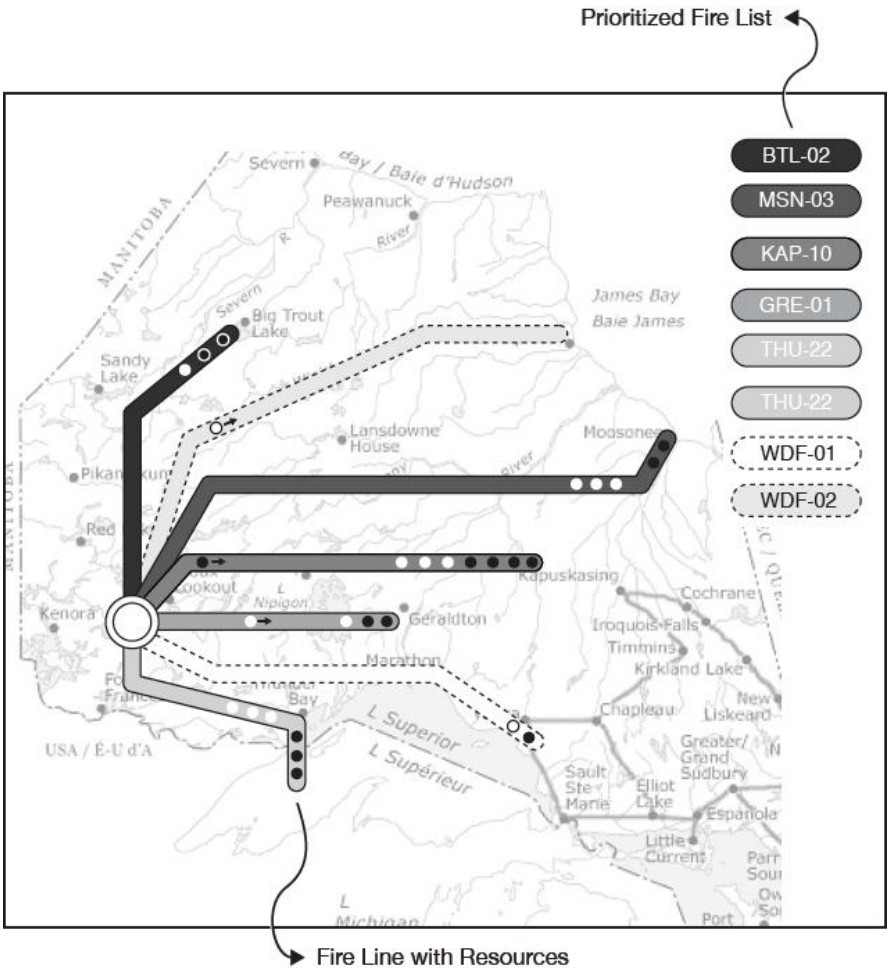


Figure 11. Main screen of Subway FUSE design.

The Subway Map FUSE design was intended to assist in developing situational awareness at a quick glance instead of having to sort through cluttered information which is displayed with text over a more visual form. The intent was for the user to be able to see what was happening with each fire quickly, on the main screen, without having to go deeper unless the situation requires.

5.1.6. FUSE: Time Display

The Time Display FUSE design (see Figure 12) grew from the previous subway map inspired design and works in a similar way. The differences between the displays are the complete removal of the map and the meaning behind the lines. While in the subway map inspired design the lines roughly

indicated where the fire was located and the route the resources took to get to it, within the Time Display FUSE design the lines represent the amount time that a fire has been burning. The goal of this design was to create a completely visual sense of the information. This design removes as much text as possible as well as the spatial sense of the information. The goal was to see the value of the map within the processes and to see if the pure raw information would be enough for the users to use to make an effective decision.

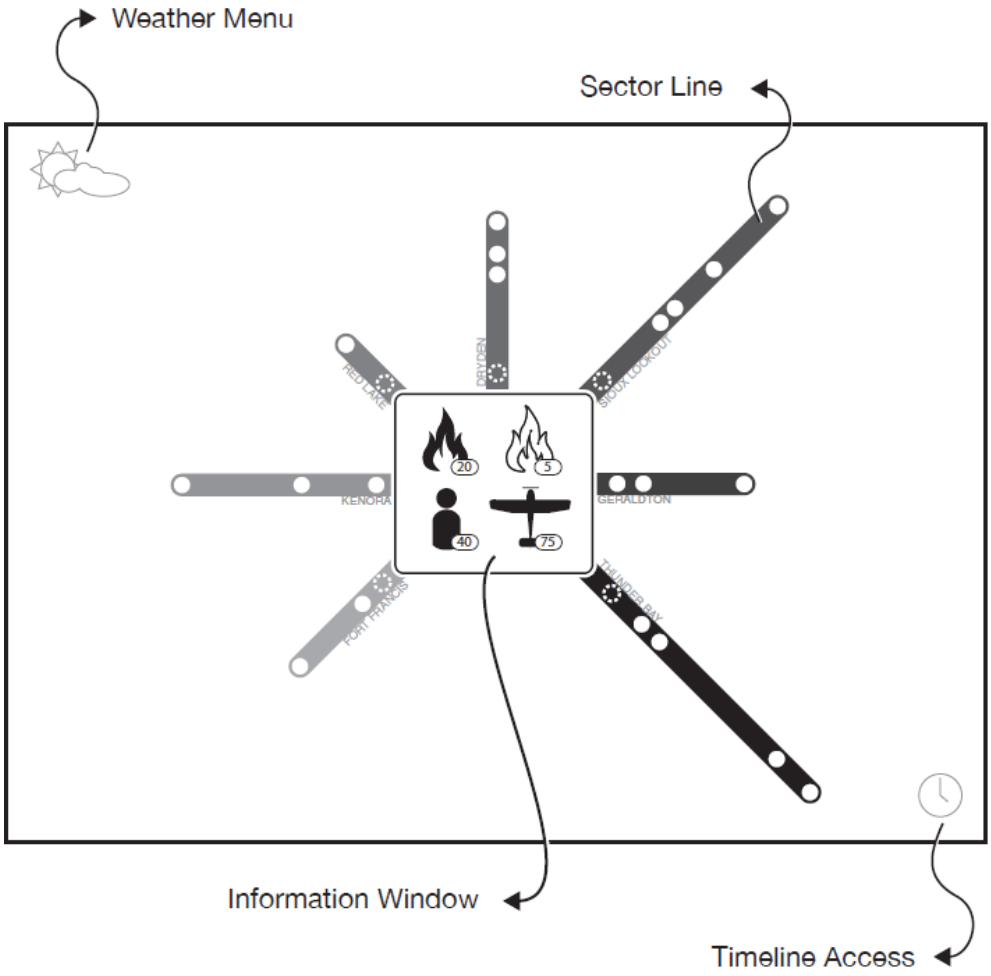


Figure 12. Main screen of the Time Display FUSE design.

On the main screen there is a link to the weather information, on the top left hand corner of the main screen. The weather window, when opened, displays the current weather, the predicted weather for the week and the lightning screen. The weather information can be used by the regional response team to

assess potential areas of hazard throughout the region, showing them where potential fires may start burning and where there is potential for already burning fires to get out of control. This information can support the user when a decision needs to be made about changing the location of some of the resources or the changing the status of certain fires.

The user is able to view what has happened within a certain period of time by selecting the clock icon on the bottom right hand corner of the main screen; doing this will expand the timeline menu. All the blocks on the timeline represent changes that have happened throughout the day, whether to a fire, aircraft, or crew. The user can then select a certain period of time in which they would like some more specific information on the changes that have happened. They can do this by clicking and dragging in between the desired time intervals. Once the period has been selected then the fires that have had changes made to them (through fire, aircraft, or crew) will be highlighted.

The abstract approach to this display was intended to show as much information as visually and simply as possible. The line length, which represents time here, can hold many different possibilities for potential meanings to the users; there could be a more direct meaning from which the users could derive more benefit. This design is intended to show all of the fires as related to the different sectors of the region. This will help the user to see the number of fires that are burning and the priority levels of each one. One of the main goals of this design was to observe the reaction to the application of information visualization and the complete removal of the map from within the design. This design was intended to show the study what level of importance was placed on the map and the spatial awareness it provided.

5.2. Design Selection Survey

5.2.1. Results of Survey

The intent of the design selection survey was to narrow down which of the preliminary designs or features within the designs were preferred by the participants, as they compare to the current processes within the regional response rooms. The goal was to ensure that the designs were practical applications of the suggestions and acceptable presentations of the information that is used every day for forest fire

response. The participants in this activity were asked to describe their opinions of each of the five designs that were presented to them (see Table 10 for breakdown of comments). The decision as to which designs would be developed for the final round of testing would be based on a consistent ranking at the top of the scale and the qualitative results of the comments that were related to each of the designs.

Design	Positive	Negative
Map Based FUSE	• Timeline feature • Having all the information in one location • Visual layout of the information • Ease of finding information • Overall simplicity	
Dashboard FUSE	• Large map for information display • The ability to manipulate the map • Variety of information being shown to users • Fingertip access to the information	• Screen was too cluttered
Layers FUSE	• Preferred having all the information in one location	• Less intuitive information layout • No map for spatial awareness • Prefer a more visual presentation • Too much text compared to images
Subway FUSE		• Weak map for spatial awareness • Confusing visual layout • Difficult to read the information
Time Display FUSE		• No map for spatial awareness • Confusing visual layout

Table 10. Breakdown of comments related to the design.

When the participants were asked to comment on the Map Based FUSE design a majority of the comments were positive and many of the participants provided different suggestions for further improvements. The participants stated that it was good for situational awareness to see where the resources were currently located and to see that the design was a one stop location for information regarding resources and fires. The Dashboard FUSE design was also well received by the participants of this activity. The participants mentioned that the maps assisted in understanding the context in which the

information is being shown. The purpose of the inset map was not always clear to the participants; however, one of the participants realized its value in maintaining the focus on the big picture rather than getting too focused on the smaller variables within the region.

When it came to the comments related to the Layers FUSE design the participants were less enthusiastic. The lack of a map was the biggest comment about this version of the design. Even though the design was developed with access to the Dispatch database the users felt that the lack of an immediate spatial view of all the resources was a negative quality in this design. Many of the participants stated their approval on having all of the information in one location but would have preferred to have the information presented to them in a more visual way; there was too much text compared to images within this design.

The Subway and Time Display FUSE designs were the most negatively received of all five of the preliminary designs. The main concern with these two designs was the fact that there was no strong map in either one. Many of the comments showed that there was a variety of understandings on what information was being presented on each of these displays. The participants did not find the same level of situational awareness or intuitive response abilities within these designs as they found in the previous three.

Design	Mean Score	Median
Dashboard FUSE	1.6	1
Map Based FUSE	1.7	2
Layers FUSE	2.8	3
Subway FUSE	4.3	4
Time Display FUSE	4.7	5

Table 11. Final rating of each of the preliminary designs.
Numbers are based on a preference scale from 1 to 5, 1 being more preferred and 5 being least preferred.

The final question in the survey asked the participants to rank the different designs in order of their preference (1 being most preferable and 5 being least preferable, see Table 11 for final rating of each design). The ranking of the designs was consistent with the reactions that were described within the separate questions related to the individual designs.

All of the results within this activity showed what information and what features were important to the potential users of this system. The value that was intended to be present within the designs where information was presented in a more abstract way, the Subway FUSE design and the Time Display FUSE design, was not always clear to the participants of this activity. Not understanding the information being presented within the design can lead to the disintegration of a clear idea on how the design will assist the participant in their day to day activities. There was, however, an overwhelming positive response as the results related to the designs where the information surrounded a map: the Map Based FUSE design and the Dashboard FUSE design. Having all the information related to forest fire response integrated into one location on a map was one of the main features to which the participants responded positively. In many cases where a participant would not support the overall design, different features would be commented on as preferable. These features, most frequently the timeline feature, were made known as being preferable within the designs. When these features were mentioned they were noted as something that the participants would like to see in the final design.

All of the results from this survey assisted in developing a better understanding regarding what information and features were of interest to the participants of the survey, and which resulted in confusion. The results of this survey, in combination with the information survey results, developed a framework within which the final designs could be developed.

6. FINAL DESIGN AND TESTING

6.1. Final Design Development

Considering the results of the design selection survey, two design prototypes were developed for the final round of testing. The decision to develop two designs came from an interest in comparing the ease of interaction with each of the designs. Having the users interact with the two designs showed what was more natural for each user when it came to the level of intuitive response they could achieve when interacting with each of the designs.

The final two designs are based around the Map Based FUSE design and the Subway FUSE design. The Map Based FUSE was chosen based on its high ranking throughout the previous activity. The comments concerning the Map Based FUSE design were positive and were accompanied by suggestions on how to further improve the design for the purposes of testing. The Subway FUSE design was ranked fourth on the final ranking scale of the survey. This design was developed to observe the reaction to a new way of displaying the information within the response room. There were consistent comments within the survey results which mentioned confusion about the information that was being shown within the design. It was thought that if the users were given the opportunity to interact with the design then they could develop a better understanding and appreciation for the way that the information was displayed within the Subway FUSE design.

Both of the designs were developed in a way that would accommodate the needs and suggestions brought forward through the results of both surveys (see Table 12). The two designs became the Full Map and the Inset Map design.

	Full Map FUSE	Inset Map FUSE
Information to provide an update on the situation.		
Number of fires	Always displayed in the top right hand corner of the screen.	Always located within the inset map on the bottom right hand corner of the screen.
Weather	Found through selecting the weather icon on the right hand side of the screen.	Found through selecting the weather icon on the right hand side of the screen.
Aircraft location	Found through selecting the aircraft icon on the right hand side of the screen.	Aircraft are always displayed in their current location on the map.
Resources in motion	Found through selecting the aircraft or crew icons on the right hand side of the screen.	Resources are always displayed in their current location on the map.
Ranking of fires	Found through selecting the fire icon on the right hand side of the screen.	Opened through selecting the fire icon on the right hand side of the screen.
Information related to a specific fire.		
Fire behaviour	Found by selecting the fire icon on the map or fire number on the fire list. The window will display details on the desired fire.	Displayed through the colour intensity of the icon. Also displayed within the fire list.
Size of fire	Found by selecting the fire icon on the map or fire number on the fire list. The window will display details on the desired fire.	Displayed within the fire list.
Fire location	Fire icons are always displayed in their location on the map.	Fire icons are always displayed in their current location on the map.
Resources assigned	Found through selecting the aircraft or crew icons on the right hand side of the screen.	Resources are always displayed in their current location on the map.
Information to provide an update on specific crew.		
Crew type	Found through selecting the crew icon on the right hand side of the screen.	Opened by selecting the crew icon on the right hand side of the screen.
Crew availability	There is no information related to the percentage of crews available within this design.	Displayed within the overview menu which can be opened through selecting the arrow icon on the right hand side of the screen.
Information to provide an update on the situation within the region.		
New fires	Always displayed in the top right hand corner of the screen.	Always located within the inset map on the bottom right hand corner of the screen.
New fire arrivals within x time	The timeline is opened through selecting the clock icon on the right hand side of the screen.	The timeline is opened through selecting the clock icon on the right hand side of the screen.
Aircraft availability	There is no information related to the percentage of aircraft available in this design.	Found through the arrow icon on the right side of the screen.
Number of open incidents	Always displayed in the top right hand corner of the screen.	Always displayed in the top right hand corner of the screen.

Table 12. Application of the information survey to the final designs.

6.1.1. Full Map Design

The Full Map design (see Figure 13) was developed by incorporating many of the features from the Subway FUSE design and combining the comments and suggestions from the design selection survey. The comments regarding the layout of the design and the accessibility of the information were considered in order to accommodate the needs of the potential users.

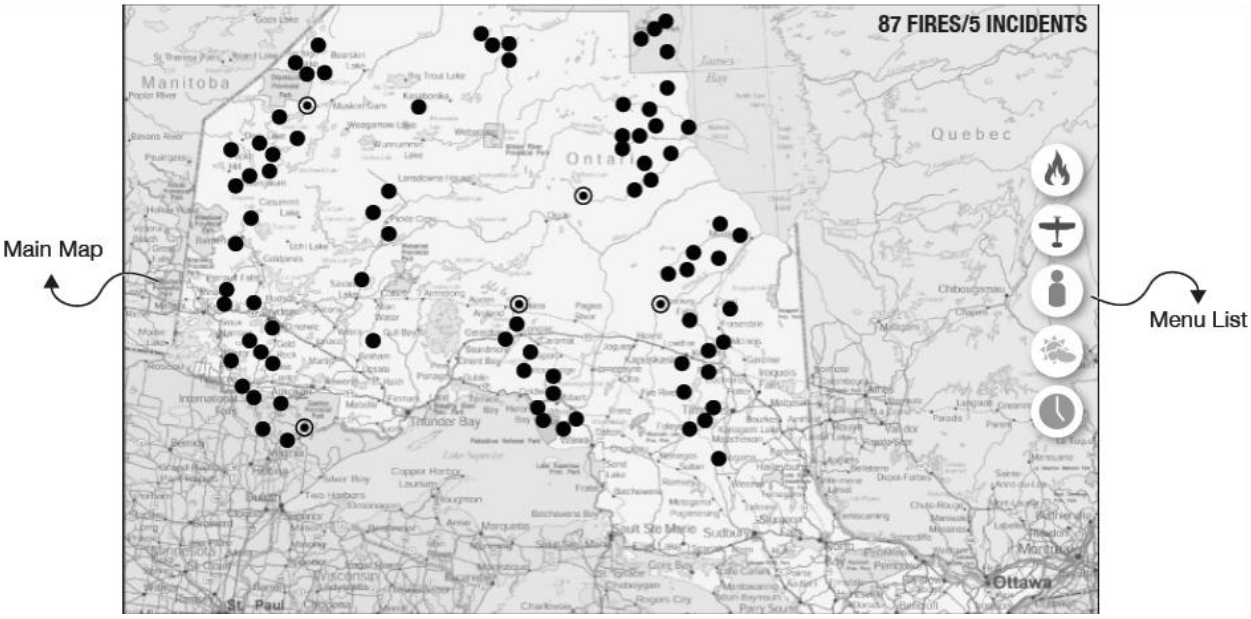


Figure 13. Main screen of Full Map FUSE design.

The introduction of the stronger map to this design was required based on the comments within the previous survey. Few participants supported the removal of the map and the spatial awareness that it provides to the users. Some participants mentioned that the map was important to show the users where the fire was in connection to values, road access points, and potential landing areas for the aircraft. None of this information was included within the preliminary development of these designs, so without the map the user was presented with an incomplete set of information which did not support their decisions and information collection process.

The Full Map design was developed with the intention of gathering all of the information required to respond to the forest fires being managed within the room while taking a slightly different approach to how the information was grouped and presented. The intent was to take a less is more approach and keep the information being displayed as informative but minimalist. The presentation of the fire information used the layout of the Subway FUSE design (see Figure 14). This form of visualization was used to see how the participants would interact with an information presentation that was different from their current process (for full details see Appendix E.1.).

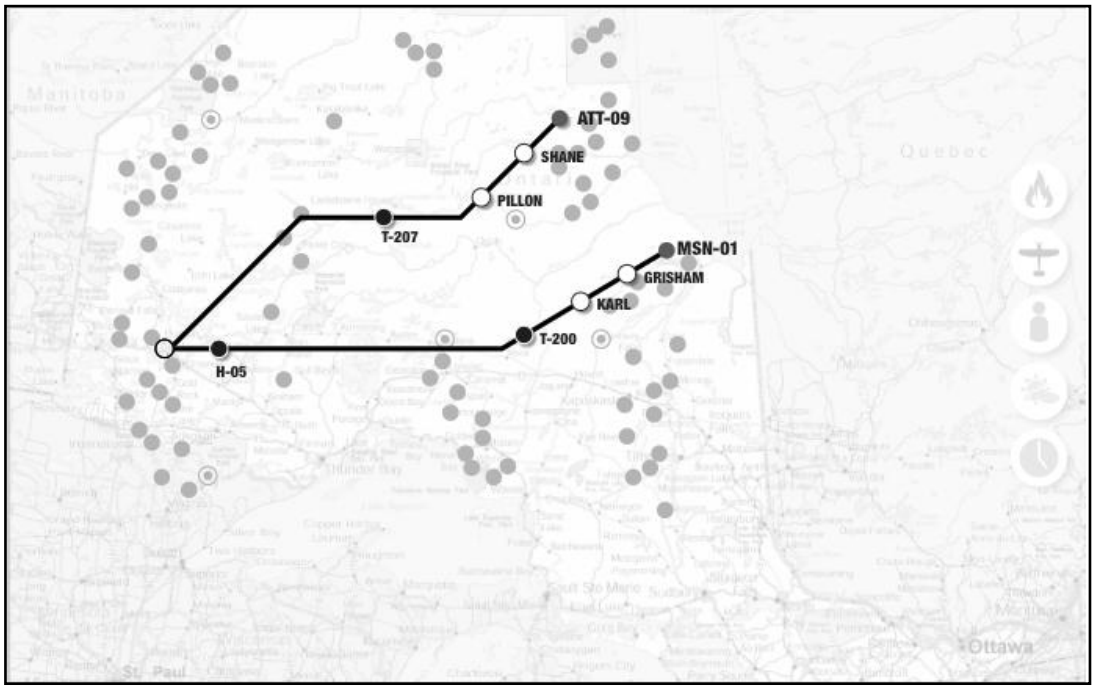


Figure 14. Fire information window in the Full Map FUSE design.

6.1.2. Inset Map Design

The Inset Map design (see Figure 15 was developed based on the features that were present within the Map Dashboard FUSE design. The comments and suggestions that were provided by the participants through the design selection surveys were considered when deciding what features were to be used and

changed within the design. The menu style presentation of the information remains true to the Dashboard FUSE design (see Figure 16 for presentation of fire information).

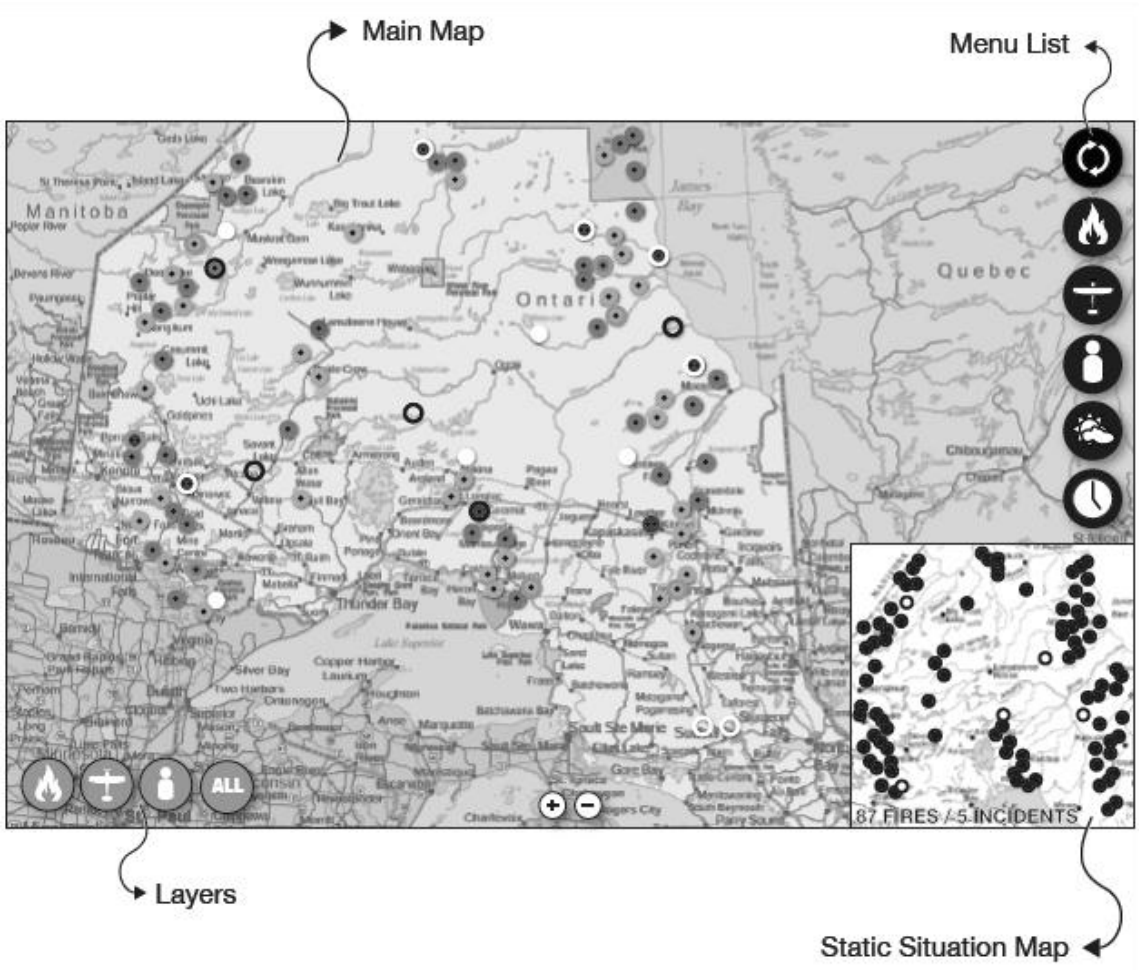


Figure 15. Main screen of Inset Map FUSE design.

The Inset Map design was developed with the intention of gathering all of the information related to forest fire response into one location. The small windows within the design were developed in a way that would allow for multiple pieces of information to be displayed at one time to the user. This combination of displays was intended to assist the user by having all of the information that was required to make a decision at their fingertips and visible within one screen. The combination of information windows allowed for the possibility for multiple users to gather information from the display at one time,

allowing for a wider sense of situational awareness throughout the team. The display and layout of this design was based around the information that was displayed within the regional response rooms at the time of this study (for full details see Appendix E.2.).

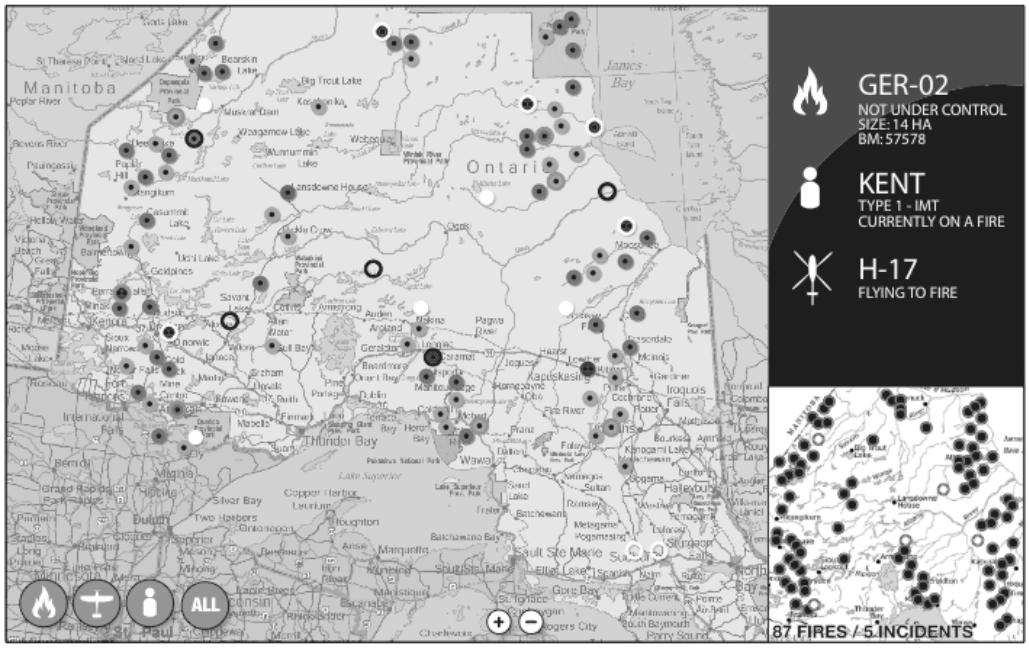


Figure 16. Fire detail window in the Inset Map FUSE design.

6.2. Evaluation of the Designs

6.2.1. Testing Results

The results of the testing were based on the observations made throughout the individual interactions with each of the designs. The way in which each of the participants reacted to each of the tasks was observed and recorded. The time taken to complete each task was also recorded throughout the testing sessions. When the time results were analyzed and compared there was no consistency in what the times were showing. No strong relationships could be developed between the times and the performance while using either of the designs. Therefore, all of the time results were left out of the final analysis of the final designs.

Each of the tasks that were completed by the different users was analyzed based on the number of errors that the participant made throughout the task, and whether the participant arrived at the correct answer to the provided question. Each of the participants, for each of the tasks, was labeled as efficient and effective (provided the correct answer with no errors), inefficient but effective (provided the correct answer but made errors on the way), or inefficient and ineffective (provided an incorrect answer and made errors on the way). The results for each of the designs were consistently comparable to one another, providing a better insight as to which design was more user friendly and intuitive (Table 13 for comparison of the results).

Task	Full Map	Inset Map
Resource alert status	2	6
Location of aircraft	0	0
Current fire status	7	1
Number of burning fires	5	6
Changes with given time	1	6
Resources on a fire	0	2
Totals	15	21

Table 13. Testing results for final designs.
Tasks are based on the questions presented to the participants throughout the testing of each design. The numbers represent the number of errors within the different tasks for each of the designs.

The testing results showed that the participants were able to locate information regarding different fires, location of resources, and the status of those resources with limited difficulty and errors. Any errors that were made in the process of answering resource and fire related questions were generally due to trying to understand the information that was present within the design, or understanding what information the task required. There were some errors that were made due to the nature of the wording of the question. For example, in a task presented within the Full Map design, the question begins by referring to the number of fires coming into the room and the question then moves on to mention that

some of the crew may need a change of alert and asks how many crew are currently on yellow alert. The errors that were created in response to this task were generally due to the participants focusing on the number of fires first and then going to the crew list to find how many were on yellow alert. Overall, the questions where the participants were asked to look within the menus for information were met with a high level of effectiveness and efficiency (see full results tables in Appendix F).

Considering the results of the comparable tasks within the tests, the participants had more difficulty with the Inset Map design when it came to finding information. This was decided based on the number of participants that were effective and efficient concerning the response as opposed to those who were ineffective and inefficient in their response. The explanation as to where the participants found the designs to be valuable or problematic was intended to be found within the results of the questionnaire.

6.2.2. Questionnaire Results

The questionnaire was filled out by each of the participants upon the completion of the testing of both designs. The questions were based around their ease of understanding and maneuvering through the design, their opinion on the comparison between the designs and their current processes, and their opinions on the design both positive and negative. Many of the questions asked the participants to rank their opinion on a scale of 1 to 7 (1 being the most negative while 7 was the most positive, on that question). When the two designs were compared, the Full Map design presented a few more challenges. The participants mentioned that the presentation of the information was confusing and they did not support the application of the design. The overall opinion of the Full Map design was that there was a little more hesitation in reading the data as compared to the Inset Map design (see Table 14 for response breakdown).

Comments	Inset Map Design	Full Map Design
Ease of understanding the displayed information.	- Average Rating: 6.1 - Median: 6 - Like the more visual information. - More immediate information regarding the current situation. - "Wasn't sure about the relationship between the fires on the large map and the fires on the inset map"	- Average rating: 5.0 - Median: 5 - Prefer the visual of the Inset Map. - "Not as much information available on the default display for the Full Map map."
Ease of finding information.	- Average Rating: 6.1 - Median: 6 - More immediate information for the user. - Inset Map design was easier to manipulate.	- Average Rating: 5.6 - Median: 5 - Process is straight forward. It is easy to determine when you have made an error and how you can fix it.
Potential support in maintaining situational awareness.	- Average Rating: 6.3 - Median: 6 - Inset Map does a better job due to the default information shown on the map. - Timeline allows for filling of the gaps if attention is drawn away from monitoring the current situation.	- Average Rating: 5.6 - Median: 6 - Prefer the Inset Map design.
Suggested changes to the designs.	- Colour for fire conditions, rather than intensity. - Add a legend for icons.	- Colour code the dots. - Add a legend for information. - Not in favor of the line design for the fire information. - Would like more information on the default map display.
Where did you have difficulty with the system?	- Initial confusion regarding the number of fires shown. - Could use a legend to better describe the icons.	- Slightly harder to get a quick summary. - Not a fan of the format for resource displays. - Understanding what the lines meant.
How did the interaction with the proposed designs compare with your experience with current processes? Please rate and explain.	- Average Rating: 5.9 - Median: 6 - Everything is in one location. - Inset Map design had an easier flow.	- Average Rating: 5.3 - Median: 6 - One stop for information needs. - Little more hesitation reading data. - "More information in a single view than with current systems"
Would either design be a valuable addition to your current system?	- User friendly and intuitive. - "With some minor changes the Inset Map design would be a valuable addition to the response center for improved situational awareness." - Like the timeline feature.	- Would rethink the "line" layout.

Table 14. Breakdown of questionnaire responses to the two designs.

After analyzing all of the opinions expressed through the questionnaire about the designs, it was clear that based on this exercise the Inset Map design was the most preferred by the participants. Although the Inset Map design came out on top as the most preferred, the Full Map design was close behind in the rankings. Overall, the participants expressed that, "with some minor changes the Inset Map design would be a valuable addition to the response center for improved situational awareness."

6.2.3. Overall Testing Results

When the results from the testing and the questionnaire were compared, each study presented a slight preference for one design over the other, each section providing a different design of preference. These results could be due to the users expressing their level of comfort with the design rather than their actual experience throughout the tasks. Due to the familiarity of the information layout within the Inset Map design the users were more likely to express their comfort level with the information rather than expressing their performance results which were weaker than that of the Full map design.

However, as the questionnaire was designed to provide a better understanding of the experiences of the participants with each of the designs, it was clear that the overall preference of the participants was the Inset Map design.

The Inset Map design provided the users with more information up front to use when making decisions related to the current situation within the region. The participants expressed their interest in having the information as close to the surface as possible for it to be of value to them in the decision making process. The comments also expressed the fact that the tools that were available within the Inset Map design were able to provide much better support when it came to developing and maintaining situational awareness as compared to the Full Map design.

Considering the comments and the observations made throughout both sections of the testing of the final design it became clear that the Inset Map design was the best presentation of the information for the users and their needs and the goal of this study. The users found the information layout to be intuitive and

easy to use, and after a certain amount of time spent getting familiar with the design they found that all of the information was easily accessible.

7. CONCLUSION

7.1. Overall Outcomes

The objective of this study was to develop an effective visual design of integrated information based on the needs and requirements of forest fire emergency response team members. The visual design approach followed studies of ecological interface design, information design, and information visualization. The intent was to show that the application of visual information studies to emergency response could lead to a design that can facilitate information collection and mitigate loss of situational awareness.

The approach in this thesis started with becoming familiar with the environment of study. The researcher conducted focus groups and observations to develop a clear understanding of the information flow within it, further evaluate where any problems with information collection occur, and understand the potential consequences. All of the participants subsequently sorted all of the information used in their everyday process and rank the level of importance of that information to each role and scenario that they were provided with. These activities assisted in understanding what information was the most valuable in supporting decisions made regularly within that environment.

This thesis addressed the needs and requirements by developing a detailed concept of a Fire Update Support Engine – FUSE. Specifically, the preceding research activities led to developing five alternatives of integrating the information in a visual design. The participants then selected two of the designs for a re-design based on their comments and opinions. The final designs were then tested directly with the users, providing the research with an understanding as to which design would be the most efficient and effective within the environment.

The results of the testing showed that the participants preferred having as much information as possible available to them within one location as opposed to having to perform actions in order to access the information. When it came to the process of information collection and maintaining situational awareness, all the participants felt that having the information all located in one place would prove to be very beneficial to both their saving time and making their response efforts more effective and efficient. The visual presentation of the information was able to display to the users what the current situation within the region was, providing them with all of the tools necessary in developing a strong sense of situational awareness.

7.2. Addressing the Problem Statement

The goal of this study was to address some of the problems associated with complex situations within emergency response environments. Specifically, the task of information collection could burden users and result in loss of information and situational awareness (see Figure 1) leading to potential detrimental outcomes. The proposed solution set out to assist with the information collection process, ultimately breaking the link to the consequences of information loss, loss of situational awareness, and ultimately preventing the consequential disasters.

The development of the final design of integrated information involved gathering and organizing the information through information architecture, and presenting it in a way that was based on the study of information processing. This proposed solution to the research problem was able to assist the users in their information collection by having all of the information available to the user in one location. By removing the need to collect all the information that was required to support the response objectives, the users were able to spend that time and energy observing the situation within the region with the few clicks of a button. The information support of this design provides the users with the ability to see the overall picture in a range from the entire region down to a specific resource on a fire, allowing them to become familiar with the entire situation in as much detail at they require. Having all of this information available

for the user allows them to develop of a strong sense of situational awareness through better understanding of how their decisions may influence the response objectives in the near future.

7.3. Contributions

The result of this study was a design that integrates the information used within the regional response rooms when responding to forest fires. According to the comments made within the focus group and ethnographic observations, this is the first full integration of the information related to this specific environment to date.

This study provides a thorough empirical investigation into the information flow within the complex environment of emergency management. The application of information architecture was able to organize the information based on level of importance before placing it into the final design. The multiple methods used within this study were able to provide an in-depth description of how information was used to make decisions and where it was displayed within the response room. This knowledge assisted in the development of an in-depth understanding of what was happening within the present systems and the information collection processes within the regional response room.

7.4. Future Research Opportunities

The research conducted as part of this thesis shed light on the different areas within the regional response room where information sharing and collection can be a problem. These areas can include more detailed information sharing within the different resource related databases. There is room to study further the dispatch of aircraft, for example, to provide a new formula for the dispatch of aircraft and the assigning of different alert statuses. Looking closer into each individual grouping of resources could further facilitate the information presentation within the FUSE design.

The research methodology used for this study was employed in such a way that it can be applied to other areas of emergency response for further study. The different areas could include police, municipal

fire response, a hospital, or an airport environment. All of these environments require the collection of a wide variety of information for making educated decisions in response to their respective emergencies. The application of the integrated information design has the potential to facilitate all of the information within an emergency response environment and to further reduce the level of complexity within that environment.

REFERENCES

Ahmed, S.M., C. McKnight, and C. Openheim. “A review of research on human-computer interfaces for online information retrieval systems.” *The Electronic Library* 27, no. 1 (2009): 96-116.

Ahmed, S. M., C. McKnight, and C. Oppenheim. “A user-centred design and evaluation of IR interfaces.” *Journal of Librarianship and Information Science* 38, no. 3 (2006): 157-172.

Albers, M. “Introduction.” In *Content and Complexity: Information Design in Technical Communication*, eds. M. Albers and B. Mazur, 1-13. Mahwah, NJ: Lawrence Erlbaum Associates Inc., 2003.

Andersen, V. “Ecological user interface from emergency management decision support systems.” *International Journal of Emergency Management* 1, no. 4 (2003): 423-430.

Armitage, J. “From User Interface to Uber-Interface: A Design Discipline Model for Digital Products.” *Interactions.* (2003): 18-29.

Beaudouin-Lafon, M. and W. Mackay. “Prototyping Tools and Techniques.” In *The Human-Computer Interaction Handbook Second Edition*, eds. A. Sears and J. Jacko, 1017-1039. New York, NY: Lawrence Erlbaum Associates Inc, 2008.

Burns, C. and J. Hajdukiewicz. *Ecological Interface Design*. USA: CRC Press, 2004.

Card, S., J. Mackinlay, and B. Shneiderman. *Readings in Information Visualization: Using Vision to Think*. San Francisco California: Morgan Kaufman Publishers, 1999.

Chen, R., R. Sarman, H, Rao, and S. Upadhyaya. "An exploration of coordination in emergency response management." Communications of the ACM. (2011).

Christoffersen, K., C. Hunter, and K. Vicente. "A longitudinal study of the effects of ecological interface design on deep knowledge." *International Journal of Human Computer Studies* 48 (1998): 729-762.

Czaja, S. and S. Nair. "Human Factors Engineering and Systems Design." In *Handbook of Human Factors and Ergonomics 3rd Edition*, ed. G. Salvendy, 32-49. Hoboken, NJ., 2006.

Duez, P. and K. Vicente. "Ecological interface design and computer network management: the effects of network size and default frequency." *International Journal of Human Computer Studies* 63 (2005): 565-586.

Endsley, M. "Situation Awareness." In *Handbook of Human Factors and Ergonomics 3rd Edition*, ed. G. Salvendy, 528-542. Hoboken, NJ., 2006.

Feinberg, S., M. Margaret, and J. Duda. “Applying Learning Theory to the Design of Web-Based Instruction.” In *Content and Complexity: Information Design in Technical Communication*, eds. M. Albers and B. Mazur, 103-128. Mahwah, NJ: Lawrence Erlbaum Associates Inc., 2003.

Fratus, M. “Achieving High Reliability in a Complex Work Environment.” *Fire Engineering* (2008). www.fireengineering.com/articles/print/volume-161/issue-3/features/achieving-high-reliability-in-a-complex-work-environment.html (last accessed April 19, 2012).

Galitz, W. *The Essiential Guide to User Interface Design: An Introduction to GUI Design Principles and Techniques 3rd Edition.* Indianapolis, Indiana: Wiley Publishing, 2007.

Gibson, J. J. *Reasons for Realism*. Lawrence Erlbaum Associates Inc., 1982

Gould J. “Designing for Usability: Key Principles and What Designers Think.” Communications of the ACM. 28, no. 3 (1985).

Johnson, C., T. Johnson, and J. Zhang. “A user-centered framework for redesigning health care interfaces.” *Journal of Biomedical Informatics* 38, no. 1 (2005): 75-87.

Knemeyer, D. “Information Design: The Understanding Discipline.” *Boxes and Arrows.com*, (2003). www.boxesandarrows.com/view/information_design_the_understanding_ discipline (accessed March 6, 2012).

Kujala, S. “Effective user involvement in product development by improving the analysis of user needs.” *Behaviour and Information Technology* 27, no. 6 (2008): 457-473.

Larkin, J., H. Simon. “Why a Diagram is (Sometimes) Worth Ten Thousand Words.” *Cognitive Science* 11 (1987): 65-99.

Lindell, M. K., R.W. Perry, and C.S. Prater. “Organizing response to disasters with the incident command system/incident management system (ICS/IMS).” International Workshop on Emergency Response and Rescue. (2005).

Mace, W. “James J. Gibson’s Ecological Approach: Perceiving What Exists.” *Ethics and the Environment* 10, no. 2 (2005): 195-216.

Mazur, B. “Information Design in Motion In *Content and Complexity: Information Design in Technical Communication*, eds. M. Albers and B. Mazur, 15-38. Mahwah, NJ: Lawrence Erlbaum Associates Inc., 2003.

McNab, A., T. Hess, and J. Valacich. “Designing Interfaces for Faster Information Processing: Examination of the Effectiveness of Using Multiple Information Cues.” Proceedings of the Fifteenth Americas Conference on Information Systems, San Francisco, California, 2009.

Miller, C. and K. Vicente. “Comparison of Display Requirements Generated via Hierarchical Task and Abstraction-Decomposition Space Analysis Techniques.” *International Journal of Cognitive Ergonomics* 5, no.3 (2001): 335-355.

Nielsen, J. *Usability Inspection Methods*. Morgan John Wiley & Sons, 1994.

Nielsen, J. “Usability 101: Introduction to Usability.” *Jakob Nielsen’s Alertbox*. www.useit.com/aertbox/20030825.html (accessed September 9, 2011).

Noyes, J. and C. Baber. *User-Centered Design of Systems*. London: Springer-Verlag, 1999.

O’Donnell, P., G. Scobie, and I. Baxter. “The use of focus groups as an evaluation technique in HCI.” In *People and Computers* VI, *eds.* D. Diaper and N. Hammond, 211-224. Cambridge: University Press, 1991.

Parush, A., C. Kramer, T. Foster-Hunt, K. Momtahan, A. Hunter, and B. Sohmer. “Communication and team situation awareness in the OR: Implications for augmentative information display.” *Journal of Biomedical Informatics* 44, no. 3 (2011): 477-485.

Parush, A., K. Momtahan, T. Foster-Hunt, C. Kramer, A. Hunter, and H. Nathan. “A Communication Analysis Methodology for Developing a Cardiac Operating Room Team Oriented Display.” Proceedings of the Human Factors and Ergonomics Society 53rd Annual Meeting, (2009): 728-732.

Parush, A., R. Nadir, and A. Shtub. “Evaluating the Layout of Graphical User Interface Screens: Validation of a Numerical Computerized Model.” *International Journal of Human-Computer Interaction* 10, no. 4 (1998): 343-360.

Parush, A., Y. Shwarts, A. Shtub, and M.J. Chandra. “The Impact of Visual Layout Factors on Performance in Web Pages: A Cross-Language Study.” *Human Factors and Ergonomics Society* 47, no. 1 (2005): 141-157.

Pawlak W. and K. Vicente. “Inducing effective operator control through ecological interface design.” *International Journal of Human-Computer Studies* 44 (1996): 653-688.

Pejtersen, A. and J. Rasmussen. “Design and evaluation of user-system interfaces or of user-task interaction.” In *Empirical foundations of information and software science IV: empirical methods of evaluation of man-machine* interfaces, eds. P. Zunde and J. Agrawal, 33-62. 1987.

Quesenbery, W. “The Five Dimensions of Usability.” In *Content and Complexity: Information Design in Technical Communication*, eds. M. Albers and B. Mazur, 81-102. Mahwah, NJ: Lawrence Erlbaum Associates Inc., 2003.

Rasmussen, J. “Skills, Rules, and Knowledge; Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models.” *IEEE Transactions on Systems, Man, and Cybernetics* 13 no. 3 (1983): 257-266.

Rasmussen, J. and K. Vicente. “Coping with human errors through system design: implications for ecological interface design.” *International Journal of Man-Machine Studies* 31 no. 5 (1989): 517-534.

Rubin, J. and D. Chisnell. *Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests 2nd Edition*. Indiana: Wiley Publishing Inc., 2008.

Sutcliffe, A., S. Kurinawan, and J. Shin. “A method and advisor tool for multimedia user interface design.” *Human-Computer Studies* 64 no. 2006 (2005): 375-392.

Toms, E. “Information Interaction: Providing a Framework for Information Architecture.” *Journal of American Society for Information Science and Technology* 53 no. 10 (2002): 855-862.

Torres, R. J. *Practitioner’s Handbook for User Interface Design and Development*. New Jersey: Prentice Hall PTR, 2002.

Van den Berg, R., W. Cornelissen, and J. Roerdink. “Perceptual dependencies in Information Visualization Assess by Complex Visual Search.” *ACM Transactions on Applied Perception* 4 no. 22. (2008).

Vanderdonckt, J. “Visual Design Methods in Interactive Applications.” In *Content and Complexity: Information Design in Technical Communication*, eds. M. Albers and B. Mazur, 187-203. Mahwah, NJ: Lawrence Erlbaum Associates Inc., 2003.

Vicente, K. “Ecological Interface Design: Progress and Challenges.” *Human Factors* 44 no.1 (2002): 62-78.

Vicente, K. “Beyond the Lens Model and Direct Perception: Toward a Broader Ecological Psychology.” *Ecological Psychology* 15 no. 3 (2003): 241-267.

Vicente, K. *The Human Factor: revolutionizing the way people live with technology*. New York: Routledge, 2004.

Vicente, K. and J. Rasmussen. “Ecological Interface Design: Theoretical Foundations.” *IEEE Transactions on Systems, Man and Cybernetics* 22 no. 4 (1992): 589-606.

Wickens, C. and M. Carswell. “Information Processing.” In *Handbook of Human Factors and Ergonomics 3rd Edition*, ed. G. Salvendy, 111-149. Hoboken, NJ, 2006.

Williams, R. “Cognitive Theory.” In *Handbook of Visual Communication: Theory, Methods, and Media*, ed. K. Smith, 193-210. Mahwah, NJ: Lawrence Erlbaum Associates Inc., 2005.

APPENDIX A

Affinity Diagram

A.1. Web Sort Implementation Instructions

Thank you in advance for deciding to participate in this valuable step to my research. As a brief introduction, in case you are not already familiar with my work, my research is based around attempting to facilitate information communication within the forest fire response room. I have been working with the members of the response team at the MNR and gathering information regarding the current processes and any areas that are causing any issues. My goal is to integrate all the information that is currently located separately throughout the current systems.

This section of my study requires an understanding of how to gather these research notes into categories. This grouping exercise will help me to understand where you see priorities, areas of concern, and areas of interest. Here are the instructions on how you can become involved in this study:

Go to the link: http://websort.net/s/8C96A9/

From here follow the instructions on the screen.

You will be presented with a list of notes. Your task is to gather these notes into groups in a way that makes sense to you. Just click and drag the notes onto the large area of the screen. Please try to limit the number of notes per category to a 4 or 5 note maximum to allow for very specific groups.

Once you have completed the categories please create a title for each one. Choose a title that best describes the grouping of notes.

Once you have grouped all the notes and labeled all the categories, click the “I’m Done!” button.

Thank you again for participating in this section of my research, your input is very valuable to my work. Please be reassured that all the information provided will remain anonymous. If you have any questions, concerns, or further input please feel free to contact me at: ehueston@connect.carleton.ca .

APPENDIX B

Information Prioritization Survey

B.1. Survey Implementation Instructions

Thank you in advance for deciding to participate in this valuable step to my research. As a brief introduction, in case you are not already familiar with my work, my research is based around attempting to facilitate information communication within the forest fire response room. I have been working with the members of the response team at the MNR and gathering information regarding the current processes and any areas that are causing any issues. My goal is to integrate all the information that is currently located separately throughout the current systems.

This section of my study requires an understanding of how information is prioritized within certain scenarios. This exercise will help in my understanding of what information is most important to you and your team members. Here are the instructions on how to complete this study:

Go to the link: http://www.surveymonkey.com/s/KDLMM8S

From here follow the instructions on the screen and complete the questions honestly. All information provided will remain anonymous.

In the questions you will be presented with a scenario and then a list of information pieces that might be used in that scenario. In the answers there are two columns, the first column will allow you to rate the

importance of that piece of information to your role, then you can use the second column to rate how important you think that piece of information is to your fellow team members.

Thank you again for participating in this section of my research, your input is very valuable to my work. Please be reassured that all the information provided will remain anonymous. If you have any questions, concerns, or further input please feel free to contact me at: ehueston@connect.carleton.ca .

B.2. Survey Questions

1 - Not Important at all **7 - Very Important**

1. Please state your position with the forest fire response team.

2. What databases are the most important to your current processes and understanding of the overall fire situation? (select all that apply)

IMIS (Inventory Management Information System)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

DFOSS (Daily Fire Operating Support System)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

DISPATCH

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

ACIMS (Aircraft Information Management System)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

PIMS (Personnel Information Management System)

Importance to your role:	1	2	3	4	5	6	7

Importance to others on your team:	1	2	3	4	5	6	7

3. After being away from the response room for any period of time, what is the information that you look for to get caught up to the current situation?

Aircraft locations

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Ranking of the fires

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Crew locations

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Outstanding resource requests

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Number of fires

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Resources in motion

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Weather

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

4. If you want an update on a specific fire, what information are you looking for?

Fire number

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Location of the fire

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Current fire status

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Size of the fire

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Is there a FAR?

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Resources assigned

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

What personnel are responding?

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Response objective

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Values at risk

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Priority

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Weather

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Fire behaviour

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

5. If you would like an update on a specific crew, what information are you looking for?

Name of the crew

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Crew number

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Crew members

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Their last days off

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Current function on a fire

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Availability

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Crew type

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

6. If you wanted an update on the resources assigned to a fire, what information are you looking for?

How many crew?

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

What type of crews?

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Incident management team assigned

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Total number of personnel (crew/overhead)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Base camp infrastructure (full/part)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Forest Fire Suppression Equipment (pumps/hose/kits)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Aircraft assigned

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

7. If you wanted an update on what is happening across the region, what information are you looking for?

How many incidents are open?

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

How many active fires?

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

What is the priority?

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

New fire arrivals within x amount of time

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

New fires that are not actioned

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Outstanding resource requests (personnel/aircraft/equipment)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Resources (committed/available/etc.)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Crews (types/incident management teams)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Aircraft (helicopters/tankers)

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

General hazard

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

Weather

Importance to your role:	1	2	3	4	5	6	7
Importance to others on your team:	1	2	3	4	5	6	7

APPENDIX C

Preliminary Design Layouts

C.1. FUSE: Map Based Description

① The main screen of the Map Based FUSE design displays the map of the region. All the fires that are currently burning or being investigated are located on the map and indicated by the fire icons. The resources that are dispatched throughout the region are indicated by the crew and aircraft icons. All the icons are situated in the geographical location of the resources on the map.

② Fire information can be found through the fire menu. The access point to this menu is located on the left hand side of the screen. The list that is displayed indicates the priority order of the fires and incidents throughout the region. Prioritization is a decision that can be made by the user through clicking and dragging the fire number into the desired order.

Once a fire number or fire icon is selected the fire detail bubble will open at the geographical location of the fire. The fire information bubble displays the fire number, location, size and status. The resources that have been assigned to the fire are listed with links to each of their detail windows. There is also a link to the fire database, DFOSS, in case further information is required by the user.

③ Access to the aircraft menu is located at the top of the main screen. The aircraft are meant to be displayed with the colour of their alert status. Each of the aircraft numbers can be selected to show more information regarding the history of that aircraft.

The aircraft menu also displays the percentage of aircraft that are available to the response team for dispatch. The aircraft that are classified as available are those that have not been dispatched to other fires and are not out of province or in for maintenance.

Once an aircraft number or icon is selected an aircraft bubble will open on the main map at the geographical location of the desired aircraft. This information bubble will display the aircraft number,

pilot, status, and fire number (if applicable). There is also a link to the aircraft management database, ACIMS, in case further information is required by the user.

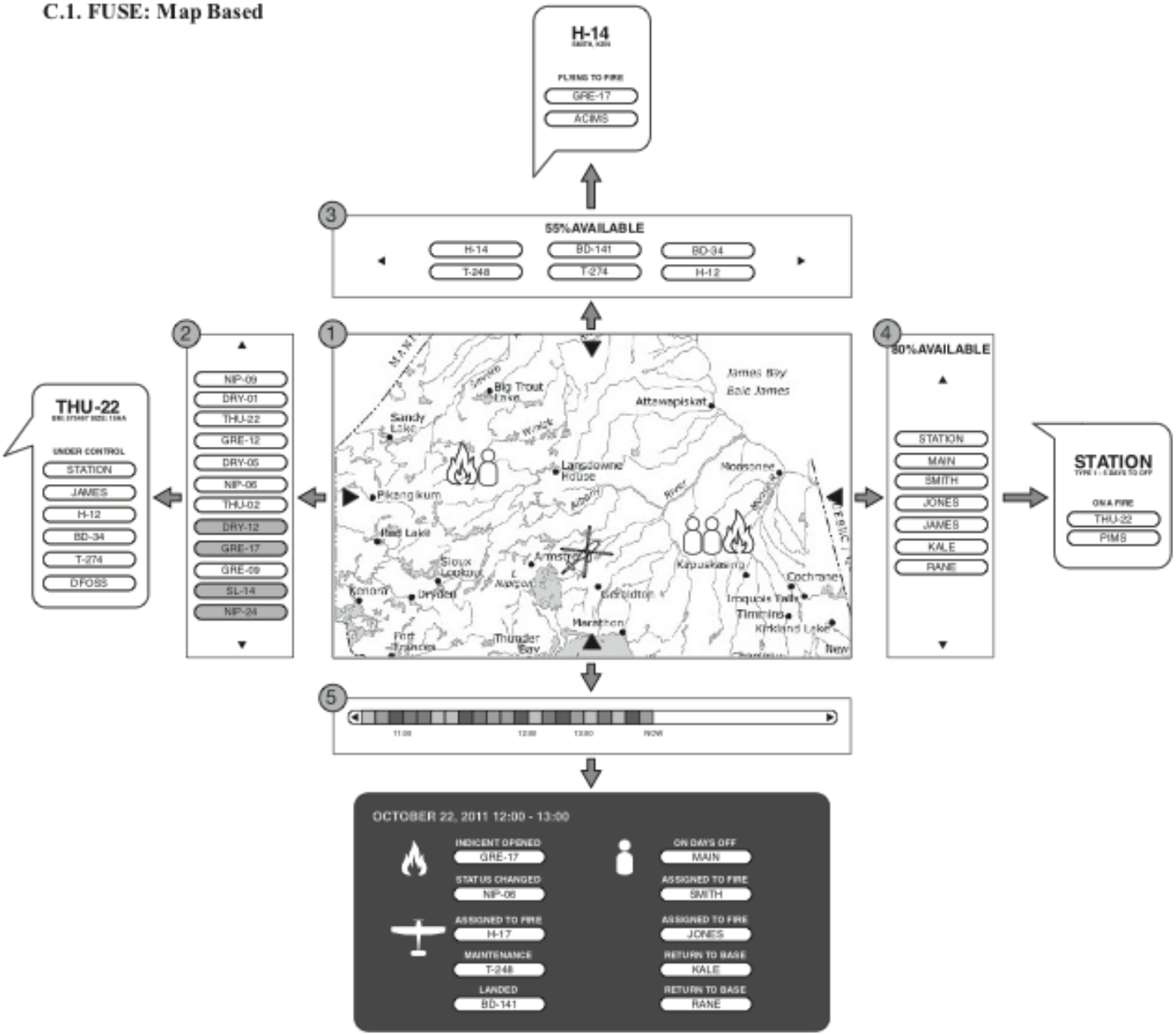
④ The access point to the crew menu is located on the right hand side of the screen. The crew are meant to be displayed with the colour of their alert status. Each of the crew names can be selected to show more information regarding the history of that crew.

The crew menu also displays the percentage of the crews that are available to the response team for dispatch. The crew classified as available are those that have not been dispatched to other fires and are not out of province or on days off.

Once a crew name or icon is selected a crew bubble will open on the main map at the geographical location of the desired aircraft. This information bubble will display the crew name, type of crew, number of days until days off, status, and fire number (if applicable). There is also a link to the crew management database, PIMS, in case further information is required by the user.

⑤ The timeline feature can be accessed on the bottom of the main screen. The timeline displays the different changes that have happened concerning crew, aircraft and fires in the region. The changes are displayed in the order that they have happened compared to the time that they happened. For more detailed information on these different changes the user can select the period of interest by click and dragging in between the desired time intervals. The timeline information window will open displaying the changes and link to each one so that the user may access further details if they desire.

C.1. FUSE: Map Based



C.2. FUSE: Dashboard Description

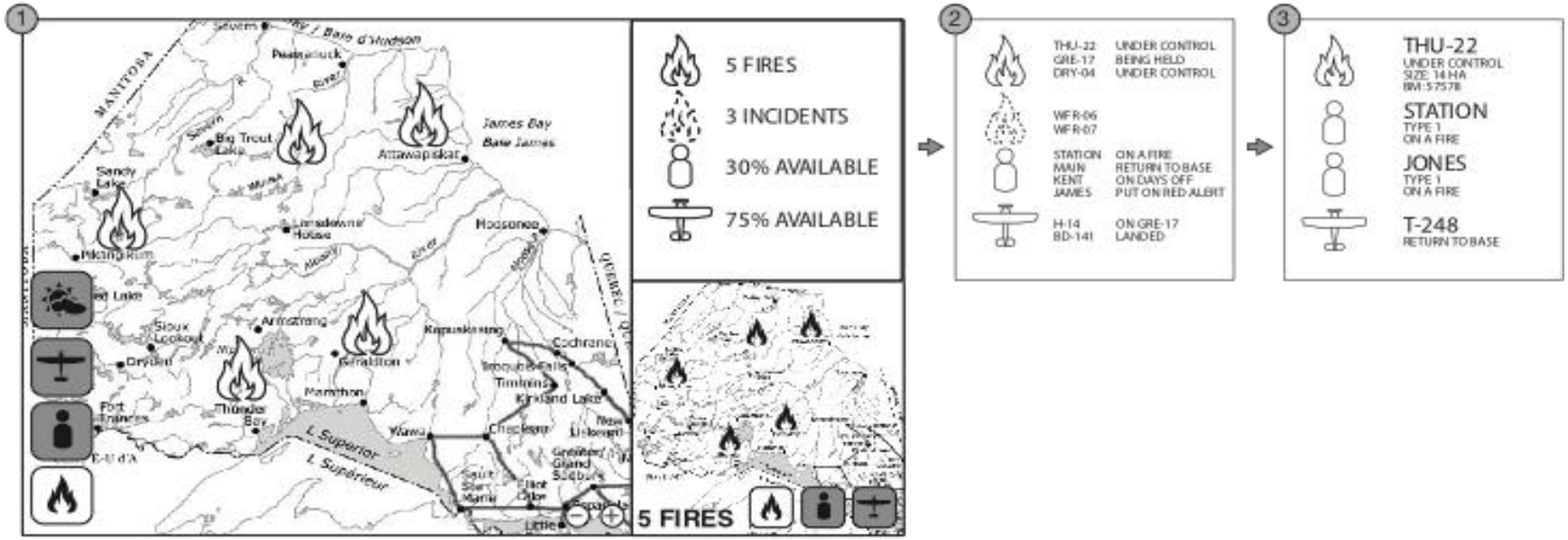
① The main screen of the Dashboard FUSE design is split up into three different windows to increase the amount of information that can be displayed at one time. The main window is the map of the region and indicates the location of the fires and resources throughout the region. The user can zoom in on this map and customize the information that is displayed by turning the different layers of information on and off.

The window on the bottom right hand side of the screen is the static overview map. This map does not allow for zooming as it is intended to keep the user aware of the big picture while they are focusing on the details of a fire or resource. The number of fires that is burning throughout the region is displayed on this map as well so that the user can find this information quickly.

The information window is located in the top right hand corner of the screen. Depending on the zoom level of the map this window will display different types of information. When the map is fully zoomed out it will display the overall situation within the region. The information that is displayed in the window shows the user the number of burning fires, the number of incidents under investigation, percentage of available crew, and the percentage of available aircraft.

② When the user begins to zoom in on the map the information within the information window changes. The information will provide further details on the resources that can be seen within the boundaries of the main map. This information will include the fire number and status, crew name and status, and aircraft number and status.

③ When the user would like more details on a specific fire or resource they can select it on the map or they can zoom right in to it. The information within the window in this case will include the fire number, fire status, fire size, fire location, crew name, crew type, crew status, aircraft number, and aircraft status.


1
MANITOBA
Severn
Big Trout Lake
Sandy Lake
Pikangikum
Lansdowne House
Attawapiskat
James Bay
Baie James
Hearst
Hoosonee
Sioux Lookout
Armstrong
Dryden
Geraldton
Kapuskasing
Cochrane
Timmins
Kirkland Lake
Marathon
Thunder Bay
Fort Frances
L. Superior
L. Superieur
Wawa
Chapleau
Sault Ste Marie
Elliot Lake
Greater Sudbury
Grand Sudbury
5 FIRES
3 INCIDENTS
30% AVAILABLE
75% AVAILABLE
5 FIRES
2
THU-22 UNDER CONTROL
GRE-17 BEING HELD
DRY-04 UNDER CONTROL
WFR-06
WFR-07
STATION ON A FIRE
MAIN RETURN TO BASE
KENT ON DAYS OFF
JAMES PUT ON RED ALERT
H-14 ON GRE-17
BD-141 LANDED
3
THU-22
UNDER CONTROL
SIZE: 14 HA
BM: 575 78
STATION
TYPE 1
ON A FIRE
JONES
TYPE 1
ON A FIRE
T-248
RETURN TO BASE

C.3. FUSE: Layers Description

① The main screen of the Layers FUSE design displays the different pieces of information that are available to the user through this system. The main screen provides access to fire, crew, aircraft, Dispatch, and timeline information. All of these pieces of information are accessible through each of the windows in the design.

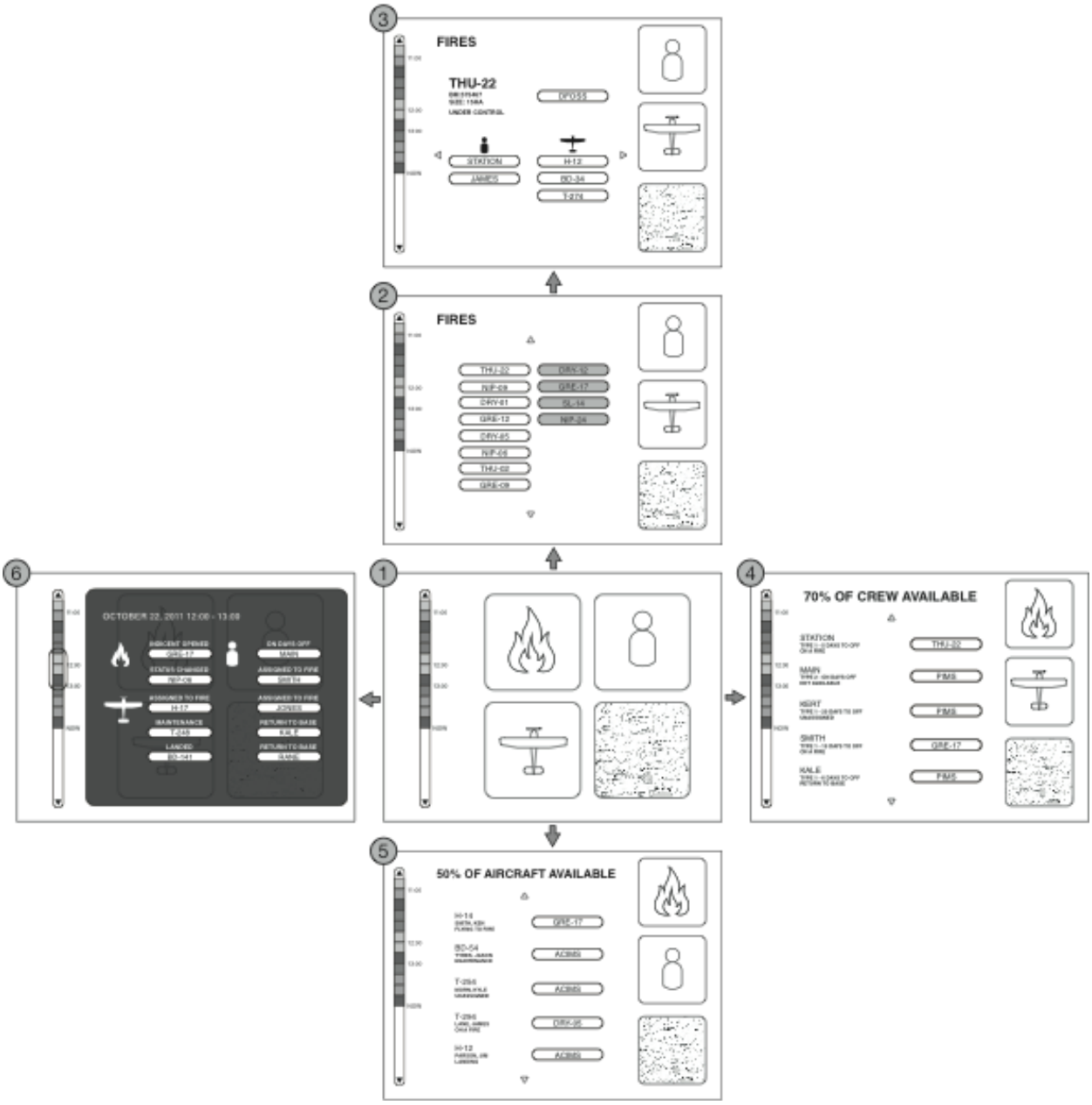
② The fire menu is accessed through selecting a button with the fire icon on it. The first fire screen displays a list of burning fires and incidents under investigation in order of priority. The priority of each fire can be decided by the user through clicking and dragging the number into the desired location on the list.

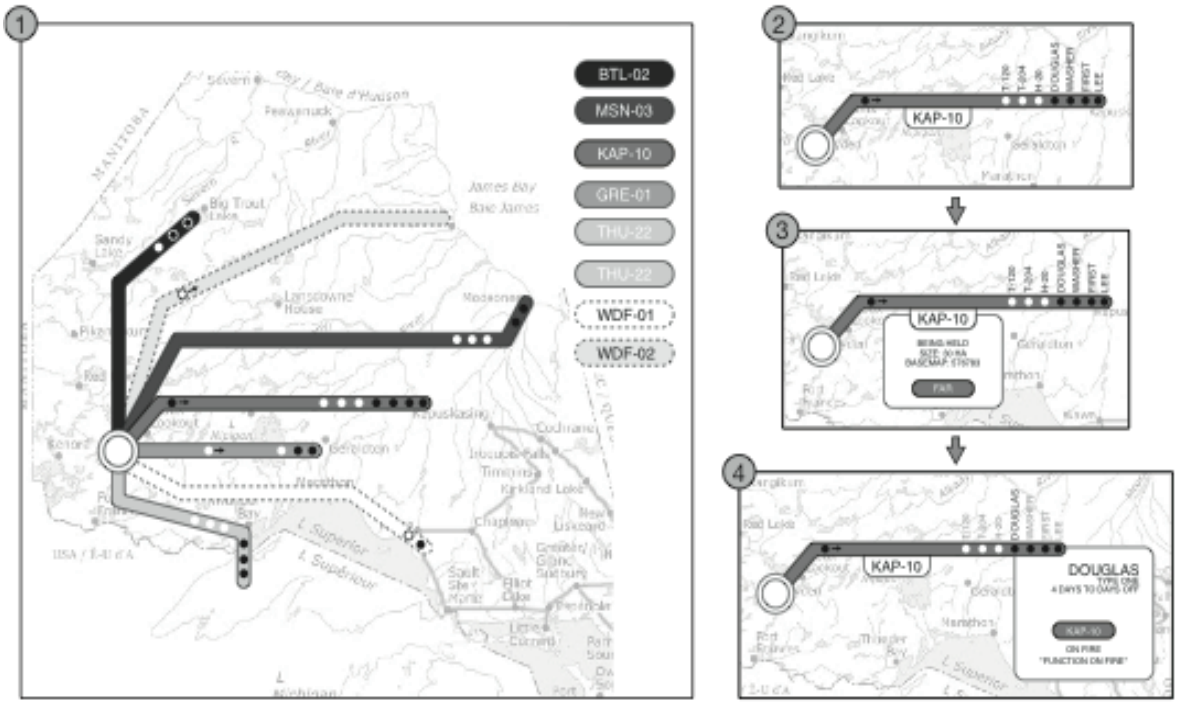
③ Once a fire number is selected anywhere throughout this design the detailed fire window will be displayed. The information within this window displays the fire number, location, size, and status. A list of the crew and aircraft that are assigned to that fire are listed on the detailed screen. Each resource can be selected to display further details on the status and location. This detailed fire window also provides a link to the fire database should the user require more information than is displayed on the screen.

④ The crew menu can be accessed through selecting a button with a crew icon or through selecting a crew name anywhere in the system. At the top of the crew menu is the percentage of crew that are available to the user for dispatch throughout the region. The list that is displayed in the crew window is a scrollable list which displays details related to all the crews within the region. The information that is displayed for each crew includes the crew name, type of crew, number of days until off, status, access to fire number (if assigned to a fire), and access to the crew database, PIMS (if not assigned to a fire).

⑤ The aircraft menu can be accessed through selecting a button with an aircraft icon or through selecting an aircraft number anywhere in the system. At the top of the aircraft menu is the percentage of aircraft that are available to the user for dispatch throughout the region. The list that is displayed in the aircraft window is a scrollable list which displays details related to all the aircraft within the region. The information that is displayed for each crew includes the aircraft number, name of the pilot, status, access to fire number (if assigned to a fire), and access to the aircraft database, ACIMS (if not assigned to a fire).

6 The timeline feature can be accessed on the left hand side of the screen. The timeline displays the different changes that have happened concerning crew, aircraft and fires in the region. The changes are displayed in the order that they have happened compared to the time that they happened. For more detailed information on these different changes the user can select the period of interest by click and dragging in between the desired time intervals. The timeline information window will open displaying the changes and link to each one so that the user may access further details if they desire.





C.4. FUSE: Subway Description

1 On the main screen of the Subway FUSE design there are lines that represent the fires and the incidents in the region, a solid line represents a fire and a broken line represents an incident. The ends of the lines indicate the geographic location of the fire. On each of the lines are a series of dots, these dots represent crew (black dots) and aircraft (white dots) assigned to that fire. The dots with the arrows beside them indicate an assigned resource that is on route to the location of a specific fire. On the top right hand side of the screen is a list of all the fires, the fires can be arranged based on priority by clicking and dragging the fire number into the proper place on the priority scale.

2 To get some more information about one of the fires the user can simply select the fire line or the fire number within the fire list. Once this is done that fire line is brought forward and everything else in the display is knocked to the back, drawing the focus into the fire and the resources assigned to it. The names of the crew and aircraft assigned to that fire will appear as a list of resources, each one of the items on this list can be selected to find more detail on them.

③ If the user would like to find more information relating to the fire itself they can select the fire number on the fire line. Doing this will display the fire status, size, and location, along with access to the Fire Assessment Report (FAR), if applicable.

④ If the user would like to have more information concerning the resources that are on the fire they can select the resource name or number on the fire line. When a crew or aircraft name are selected then a window will open displaying the status, number of days until off, and function on the fire.

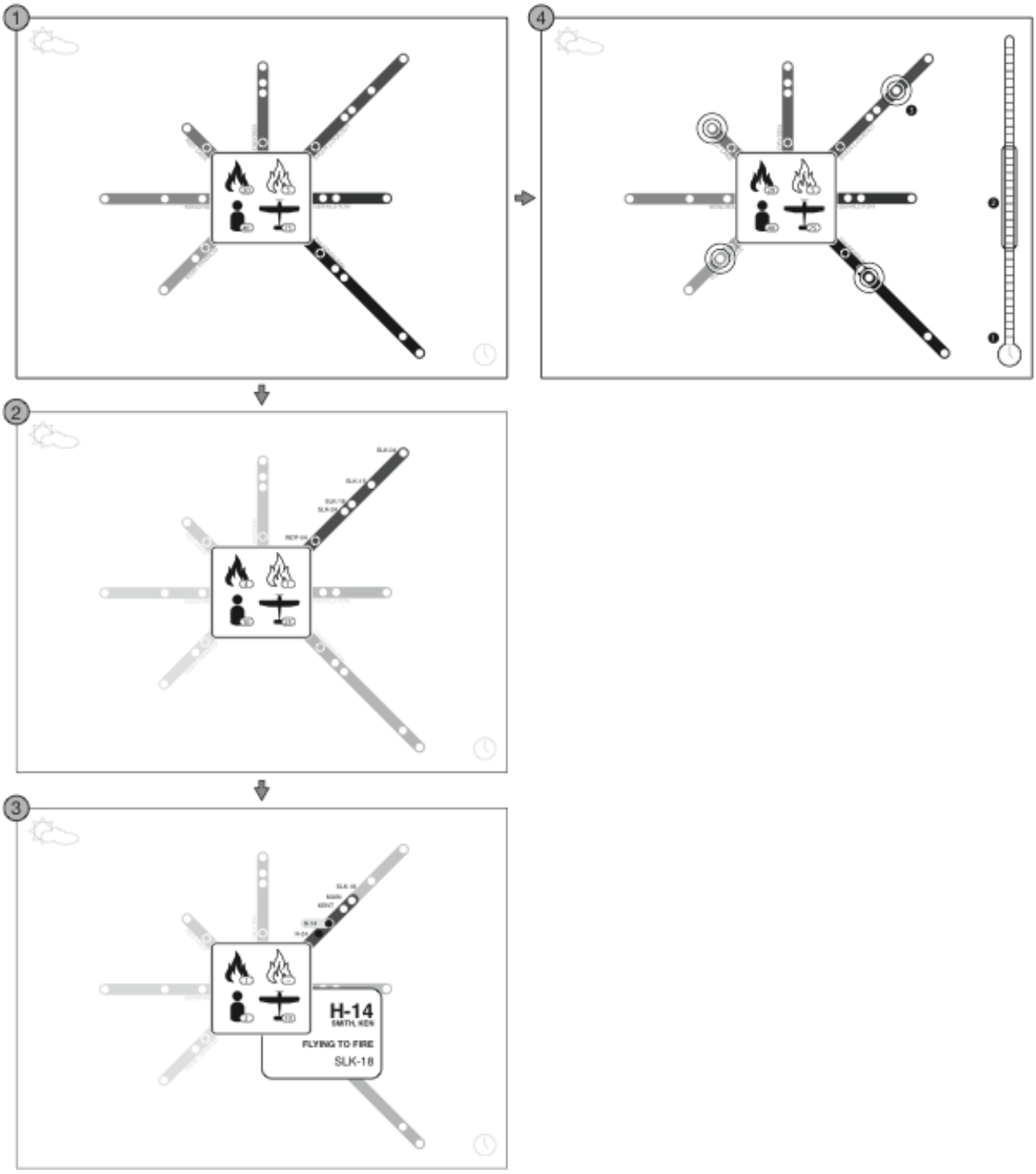
C.5. FUSE: Time Display

① The main screen of the Time Display FUSE design shows seven lines, each represent the different sectors within the region. The dots represent the fires (hollow circles represent incidents), their location on the line represents how long that fire has been burning. The center of the screen details the total number of fires and incidents, the percentage of crew available, and the percentage of aircraft available across the region.

② To find more information about the fires within a specific sector the user can select the fire line. This will bring up the list of the fires that are burning within that sector, each dot on the line being labeled with the appropriate fire number. The information displayed in the center of the screen will change to accommodate the desired sector.

③ To find out more information regarding a specific fire, the user can simply select that fire dot, again altering the information within the center display to accommodate for that fire alone. The fire line will detail the resources assigned to that fire, here the white dots represent the crew on the fire and the black dots represent the aircraft. The information can provide more specific information on the assigned resources. For example, when an aircraft dot is selected, a window will open providing the aircraft name, name of the pilot, and its status. To go back to the main screen the users just have to click anywhere within the screen.

④ The user is able to view what has happened within a certain amount of time by selecting the clock icon on the bottom right hand corner of the main screen, doing this will expand the timeline menu. All the blocks on the timeline represent changes that have happened throughout the day, whether to a fire, aircraft, or crew. The user can then select a certain period in which they would like some more specific information on the changes that have happened, they can do this by clicking and dragging in between the desired time intervals. Once the period has been selected then the fires that have had changes made to them (through fire, aircraft, or crew) will be highlighted on the fire lines.


1
4
2
3
H-14
SMITH, KEN
FLYING TO FIRE
SLK-18

APPENDIX D

Design Selection Survey

D.1. Design Selection Survey Instructions

Thank you in advance for deciding to participate in this valuable step to my research. As a brief introduction, in case you are not already familiar with my work, my research is based around attempting to facilitate information communication within the forest fire response room. I have been working with the members of the response team at the MNR and gathering information regarding the current processes and any areas that are causing any issues. My goal is to integrate all the information that is currently located separately throughout the current systems.

This section of my study requires your input on the selection of the final design(s). There are currently 5 designs in the works, they are currently in their basic linear stages to show the functionality of each. The purpose of this study is to narrow the list down to one or two designs. The chosen designs will be fully developed and rendered into a complete prototype that will be tested in the final stages of research.

Here are the instructions on how to complete this study:

Open the survey link: http://www.surveymonkey.com/s/HX623RP

Watch all design storyboard videos. There are 5 in total.

After watching each video please provide feedback on what you like and/or what you would change about the presented design. Please do this within the survey.

After completing steps 1 and 2 for each of the videos please rank all of the videos in order of preference (1 being the most preferable).

Thank you again for participating in this section of my research, your input is very valuable to my work. Please be reassured that all the information provided will remain anonymous. If you have any questions, concerns, or further input please feel free to contact me at: ehueston@connect.carleton.ca .

D.2. Design Selection Survey Questions

1. Please follow the link to watch the "FUSE - Map Based Storyboard."

   http://www.youtube.com/watch?v=YV0YLbTU4qE

   What do you like/would you change with this presentation of information?

2. Please follow the link to watch the "FUSE - Layers Storyboard."

   http://www.youtube.com/watch?v=QYmVrzRvZXQ

   What do you like/would you change with this presentation of information?

3. Please follow the link to watch the "FUSE - Dashboard Storyboard."

   http://www.youtube.com/watch?v=kx3ydXVaoj0

   What do you like/would you change with this presentation of information?

4. Please follow the link to watch the "FUSE - Subway Storyboard."

   http://www.youtube.com/watch?v=aBpxnadI0T0

What do you like/would you change with this presentation of information?

5. Please follow the link to watch the “FUSE - Time Display Storyboard.”

http://www.youtube.com/watch?v=zVQjEVEBU9Q

What do you like/would you change with this presentation of information?

6. Now that you have watched all the videos please rank them in order of preference (1 - most preferable). The most important ranking should be the design that you think would be the best addition to your current processes.

Map Based

Layers

Dashboard

Subway

Time Display

APPENDIX E

Final Design Layouts

E.1. FUSE: Full Map Design

① The main screen of the Full Map FUSE design displays the fires and the incidents within the region. The full black circles are the active fires and the circles with the rings around them are the incidents being investigated. In the top right hand corner of the screen the total number of fires and incidents is displayed, this is displaying the current situation within the region, not the total of fires throughout the season. This display of fire totals is always displayed on the main screen so that the user can access this information immediately. Located on the right hand side of the screen are the different menus available to the user so that more detailed information may be found.

② The fire menu in the Full Map design presents the users with more information regarding the fires that are currently active and incidents that are being investigated. The list that shows up when the fire icon is selected is a priority list of fires. The priority can be decided by the user through clicking and dragging the fire name into the desired location. The fire numbers that can be seen on the list are highlighted on the map using colour and the fire name so that the users may see there the fires are located, the selection of fires that are highlighted will change as the user scrolls through the list. All the fires are colour coded to match their alert status, red is not under control (NUC), yellow is under control (UCO), and the blue is being held (BHE). All the fires are selectable on the fire list and on the map.

Selecting a fire number on the list or on the map will open the detailed fire information screen (see image below). The detailed fire screen will provide the user with a list of the resources that are assigned to that fire whether it is crew (white dots) or aircraft (black dots). The line shows the rough transportation line to the fire starting at the location of dispatch to the location of the fire. If there were multiple locations from which resources were dispatched then there would be multiple lines connected to the fire location. This feature will show where the resources are all coming from concerning that fire. All the dots on the fire line are selectable, this allows the users to find out the finer details related to the resources and the fire.

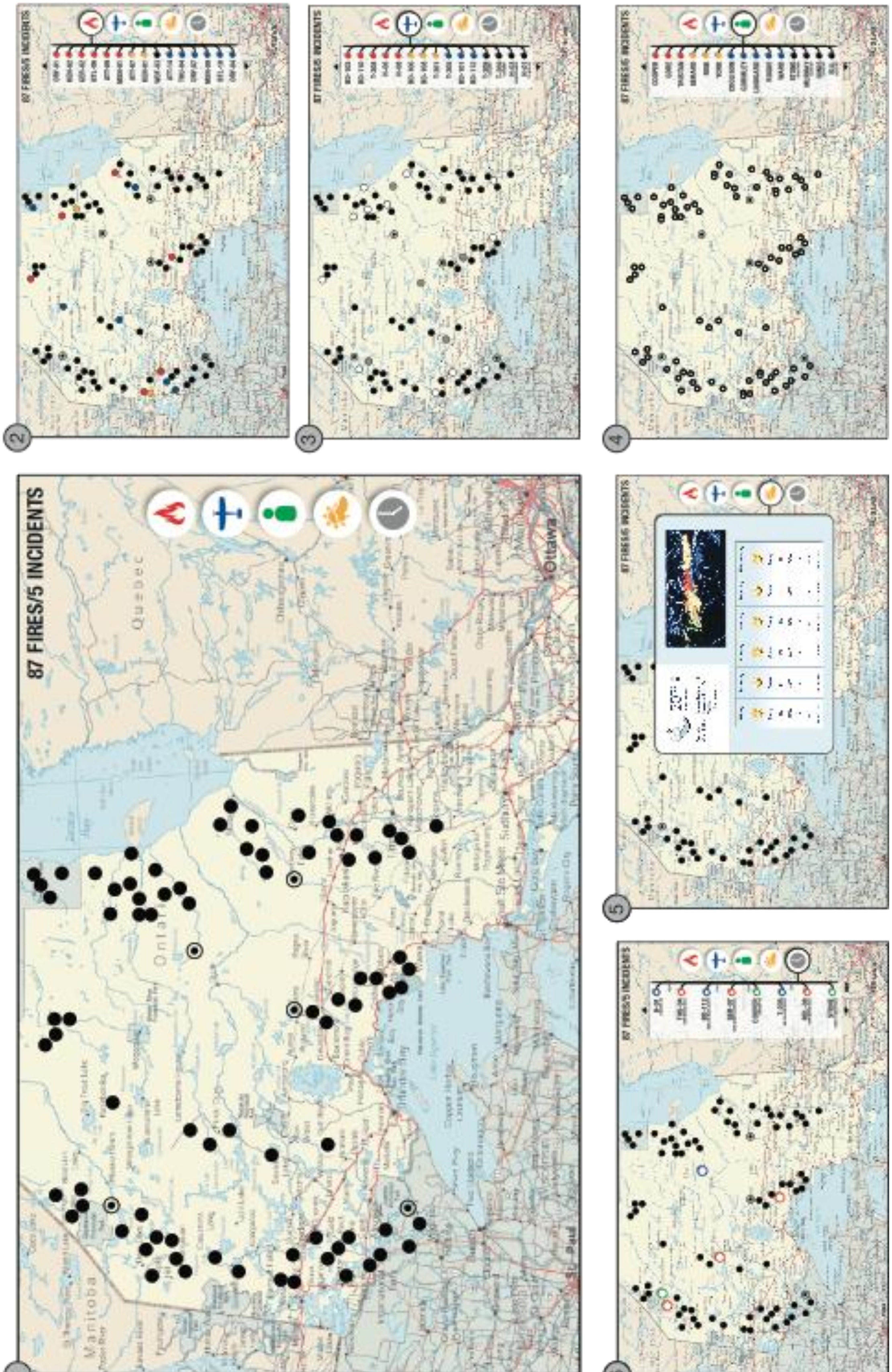
Detailed windows within the fire screen provide the users with some finer details concerning the fire and the resources that are assigned to it. When the users select the fire number the users are provided with the fire status, fire size, size of the fire, and location of the fire. When a crew name is selected then the user will see if the crew is an incident management team on that fire, the type of crew that they are, and where the crew is located compared to the fire. The details that relate to an aircraft are the name of the pilot and the aircraft location compared to the fire.

③ The list of aircraft can be opened by selecting the aircraft icon on the right hand side of the screen. The list that opens when the icon is selected is the list of the aircraft that are available to the region for dispatch. The aircraft are grouped according to their level of availability, at the top of the list are the aircraft that are ready to be dispatched immediately and lower on the list are the aircraft that are not available for dispatched due to having already been assigned or taken off for maintenance. The aircraft that are highlighted on the map are the aircraft that have already been dispatched to the fires within the region. The white dots are the fixed wing aircraft such as tankers and bird dogs, and the gray dots are the helicopters.

④ The crew list can be opened by selecting the crew icon that is located on the right hand side of the screen. This menu works similarly to the aircraft list. The list that opens when the icon is selected is the list of the crew that are available to the region for dispatch. The crews are grouped according to their level of availability, at the top of the list are the crew that are ready to be dispatched immediately, lower on the list are the crew that are not able to be dispatched due to having already been assigned or being on days off. The crew that are highlighted on the map are the crew that have already been dispatched to the fires within the region. Multiple circles in the area of a fire represent multiple crew being assigned to that fire.

⑤ The weather menu displays the information that is related to the weather within the region. This menu displays the current weather, the predicted weather for the rest of the week and the lightning map for the region.

⑥ The timeline feature can be found on the bottom right hand side of the screen. This feature shows the users the changes that have happened with the information in the regional response room within a given amount of time. The timeline list shows any changes to fires, crew, or aircraft concerning their status or location.


1
87 FIRES/5 INCIDENTS
Ottawa
2
3
4
5
6

E.2. FUSE: Inset Map Design

1 The main screen of the Inset Map design displays all the fires that are burning, incidents being investigated, and the resources that have been dispatched throughout the region. In this design the coloured circles represent the fires; their level of intensity reflects the status of that fire. The small black dots are the crew; the number of crew on a fire is reflected through the number of dots shown at that location. The shaded rings represent the aircraft, white represents the tankers, gray represents the bird dogs, and black represents the helicopters. All the resources that are visible on the map are resources that have been dispatched away from their respective headquarters. On the bottom left hand side of the screen are the layers buttons, these buttons allow the user to customize the information that they are viewing on the main screen.

The map that is located on the bottom right hand side of the screen displays the overall situation within the region, including locations of fires, incidents, and the total number of each across the region. This map is in place so that the user may have an idea of what is happening across the region while they are zoomed in on a specific fire or resource, preventing the user from getting too focused on small details and losing focus on the bigger picture. On the top right hand side of the screen are the links to the different menus that are related to fires and resources located within the region.

2 The menu that is located at the top of the list is the overview menu. When the icon is selected a window will open to display the number of fires, incidents, percentage of available crew, and percentage of available aircraft. The overview menu will show the user the details related to the information that is displayed within the screen at the current time. The overview that includes the number of fires and incidents will open if the user is fully zoomed out across the region. If the user would like to see more details related to the fires within a specific sector they can zoom into that area and the information in the overview window will change to accommodate the fires that are seen within the window.

3 The fire menu within the Inset Map design displays a list of fires in order of priority. The user may rearrange the fires into their level of importance by clicking and dragging the fire numbers into place. All the fires that are displayed on the list are highlighted on the map with their fire number; this way the user will be able to see where their most important fires are located within the region. On the fire list the users can see the fire name, the fire status, the fire size, and the location of the fire. If the user would like more detailed information related to the specific fires they may select the fire on the list or on the map to open the detailed fire window. The detailed fire window will provide the user with all information related to

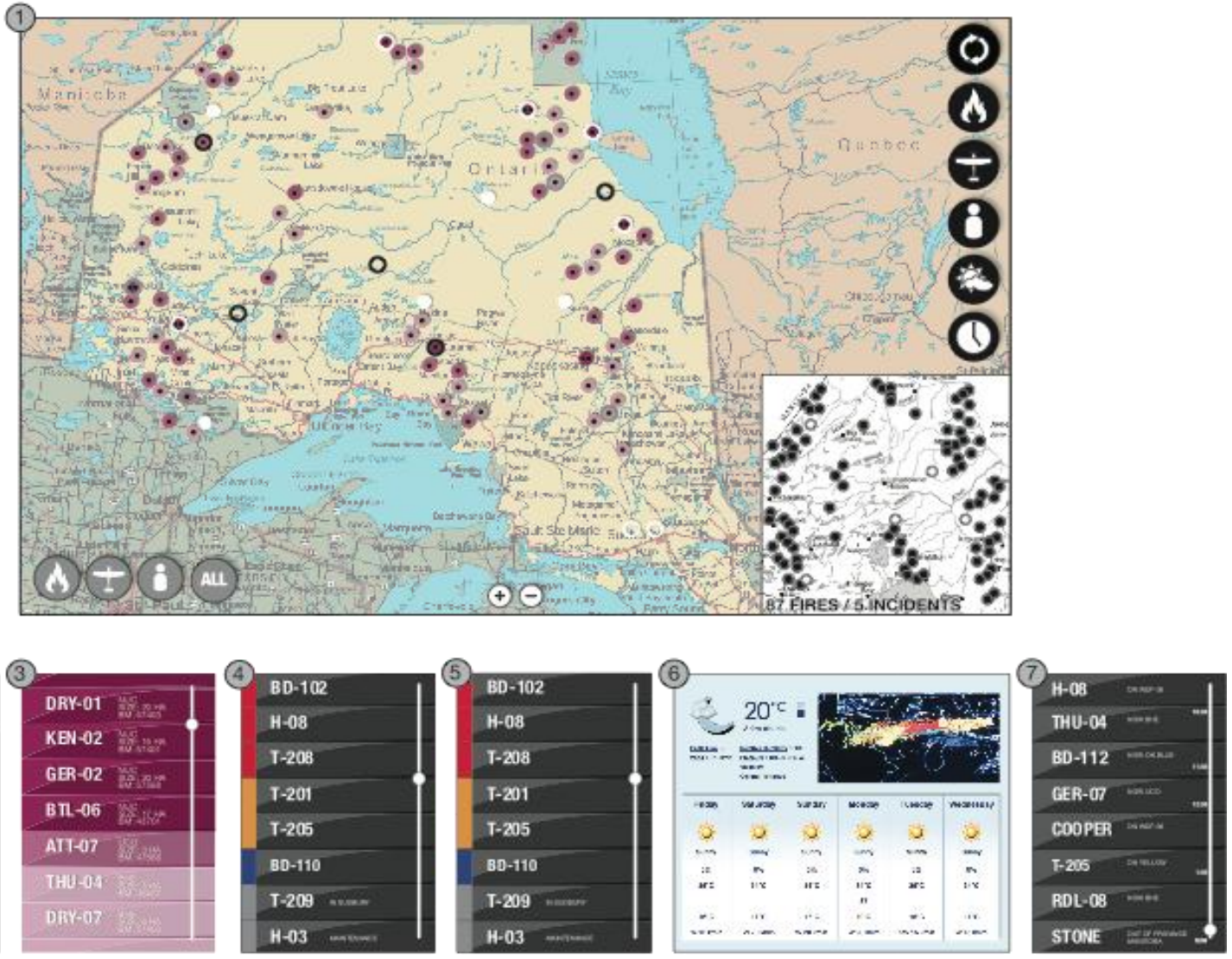
that fire which includes the fire status, size, and location. The detailed fire window will also show the user what resources have been assigned to the chosen fire and a breakdown of their information. The crew names are displayed along with the type of crew, whether they are the Incident Management Team, and where they are currently located compared to the fire. The name of the aircraft is also displayed alongside their status compared to the location of the fire.

 The aircraft menu displays a list of all the aircraft that are available for dispatch across the region. The aircraft are placed in order of most available to unavailable for dispatch, aircraft may be unavailable due to dispatch to another location or maintenance. The aircraft are displayed within this list alongside the colour related to their alert status, this information will show the users how many aircraft they have on alert and available to them for dispatch.

 The crew menu displays a list of all the crew that are available for dispatch across the region. The crew names are placed in order of the most available to unavailable for dispatch, a crew may be unavailable due to dispatch to another location or being on days off. The crew names are displayed within the list alongside the colour that is related to their alert status, this information will show the user how many crew they have on alert within the region. The crew list also tells the user the type of each crew that is available; this will inform the user what the availability is when compared to the different types of crew within the region.

 The weather menu displays the information that is related to the weather within the region. The menu displays the current weather, the predicted weather for the rest of the week and the lightning map for the region.

 The timeline feature can be located on the bottom right hand side of the menu list. This feature shows the users the changes that have happened with the information within the regional response room within a given amount of time. The timeline list shows any changes to fires, crew, or aircraft in comparison to their status or location.


1
Manitoba
Ontario
Quebec
ALL
87 FIRES / 5 INCIDENTS
2
87 FIRES
5 INCIDENTS
15% AVAILABLE
32% AVAILABLE
3
DRY-01
KEN-02
GER-02
BTL-06
ATT-07
THU-04
DRY-07
4
BD-102
H-08
T-208
T-201
T-205
BD-110
T-209
H-03
5
BD-102
H-08
T-208
T-201
T-205
BD-110
T-209
H-03
6
20°C
7
H-08
THU-04
BD-112
GER-07
COOPER
T-205
RDL-08
STONE

APPENDIX F

Final Testing and Questionnaire

F.1. Testing Script

Hello! Welcome to the test of the two versions of the FUSE design. I would like to start off by thanking you for taking the time to participate in this exercise.

This exercise has been developed with the intent of studying the effectiveness of the designs that have been developed for this thesis. For the purposes of this test I would like to mention that not all the icons are active. During this exercise we will be going over the two designs that have been developed one at a time. I will be providing you with a series of small tasks to complete using the present design. Once the series of tasks is completed for each design I will then ask you to complete a questionnaire, further explaining your experience with each of the designs.

You should see in front of you now, a small package which contains your consent form for this study. Please take a quick moment to read through and sign at the bottom of the page. Please let me know once you have completed this step.

Inset Map Design Training:

Thank you! I am now going to draw your attention to the screen in front of you. Here you will see what the research refers to as the Inset Map Design. I am going to run through the basic interaction principles of the design with you before we start the test.

First, the interaction within this design works as a point and click layout. If you click on a menu icon, located on the right hand side of the screen, it will open to provide more information directly related

to that specific topic. For example, if I open the “Overview” menu you will be provided with a summary of the current situation within the region.

When you open either the aircraft or the crew menus, the information that is displayed there will be the resources that you have available for dispatch. These listed items will not be found on the map, as the map is currently only displaying resources that have already been dispatched to different areas of the province. The other menus available to you are your fire list (listed in order of priority), your weather, and your timeline, which provides you with an update on what has happened and changed with the system throughout the day.

When you are looking at the map you will see a series of circles on the map. The coloured circles represent your confirmed fires, their intensity of colour represents the status and behaviour of that fire. The rings represent your aircraft, white are the water bombers or tankers, grey are the birddogs, and white are the helicopters, they are displayed at their location in the region. Finally, the small black dots represent your crew, the number of dots on a fire represent the number of crew. All the items on the map can be selected. If you select a fire on the map, a window will pop up providing more detail on the chosen fire.

The information that is on the map can also be customized. The different layers of information that are displayed can be turned on and turned off, by clicking on the relevant icon at the bottom left of the screen, at any time while using the system.

I will show how the layers work in the system. Removing this from the actual activity within the system.

Inset Map Design Testing:

Ok. Now it is your turn to move through the testing of the design. While we move through this process it is important to keep in mind that this process is intended to test the design, not you. There is no wrong answer in this process and you are not being timed so please take your time. If you are ready I will start off with the first task.

1. We, as a team, want to know more about the GER-02 fire. Please provide the system's break down of the resources on that fire.

2. Now, there are many phone calls coming into the office, all reporting different fire incidents. What is the percentage of crew that we have available to us?

3. With all of these incidents coming in we might want to change the alert status of some of the aircraft. How many aircraft do we currently have on blue alert?

4. The number of fires is building. If the Stone crew is in Dryden they can be dispatched immediately. Where is the Stone crew located?

5. Right now there is no aircraft assigned to fire ATT-07. If that fire is not under control we should send an aircraft to help with response. What is the status of ATT-07?

6. There has been a request from out of province for water bombers. Aircraft T-209 just came off from maintenance and can be flown out immediately. Where is aircraft T-209 currently located?

7. After a meeting that took place away from the response room you would like a quick update. What has happened in the region since 1:00?

8. You get a phone call from the provincial office and they need an update on our status. How many fires are currently burning?

9. And, one last thing before you go home for the day, has anything changed on GER-02 since we last checked?

Thank you for testing the first of the two designs. Please take a moment while I load the second design test.

Full Map Design Training:

Thank you! I am now going to draw your attention to the screen in front of you. Here you will see what the research refers to as the Full Map Design. I am going to run through the basic interaction principles of the design with you before we start the test.

First, the interaction within this design works as a point and click layout. If you click on a menu icon, located on the right hand side of the screen, it will open to provide more information directly related to that specific topic. For example, if I open the "Weather" menu you will be provided with an summary of the current situation within the region.

When you open either the aircraft or the crew menus, the information that is displayed there will be the resources that you have available for dispatch. These listed items will not be found on the map, as the map is currently only displaying resources that have already been dispatched to different areas of the province. The other menus available to you are your fire list (listed in order of priority) and your timeline, which provides you with an update on what has happened and changed with the system throughout the day.

All the items on the map can be selected. If you select a fire on the map, a window will pop up providing more detail on the chosen fire.

Full Map Design Testing:

Ok. Now it is your turn to move through the testing of the design. While we move through this process it is important to keep in mind that this process is intended to test the design, not you. There is no wrong answer in this process and you are not being timed so please take your time. If you are ready I will start off with the first task.

1. Before we get started, could you please describe how you interpret the information that is currently displayed on your screen.

2. Thank you! We, as a team, need to know more information related to the fire ATT-09. Please provide the system's breakdown of the resources on that fire.

3. There are two aircraft on fire MSN-01. If that fire is under control you should call one of the aircraft back to headquarters. What is the status of fire MSN-01?

4. The Oak crew may need some assistance on their fire. Are there any aircraft flying to that fire to assist? If there is can you please name the aircraft.

5. After returning from a lunch meeting you'll want to know what has happened in the time that you are away. What has changed with your resources since 12:00?

6. There is a large numbers of reports coming in reporting a variety of potential fires. You only have three crew on red alert right now, maybe you should update the status of a few more crew. How many crew do you have on yellow alert?

7. With this large number of fire reports coming in to the response room you decide that it might be best to have as many resources available as possible. You are looking for T-206 and T-209, where are they currently located?

8. In keeping with having as many resources available as possible, you would like to take one of the crew off of the fire MSN-01. Which crew is the Incident Management Team (I.M. Team) and therefore should stay on the fire?

9. You get a phone call from the provincial office and they need an update on our status. How many fires are currently burning?

Wrap up:

That brings us to the end of the testing of the two FUSE designs. Thank you again for participating in this portion of the study. For more information regarding this study please refer to the debriefing form included in the provided literature. I will now ask you to please take a few minutes to complete the questionnaire that was included in the package with the consent form that we looked at earlier. Completing this questionnaire will help in my understanding of your experience today with the designs. It will only take a few minutes and I appreciate you taking the time. Once you have completed the questionnaire please provide them to Susan/Pat and they will ensure that I receive them.

If you have any further questions regarding this study please feel free to contact me through the information provided on the consent form. Again, thank you for your participation!

F.2. Consent Form

Carleton University
INFORMED CONSENT FORM for RESEARCH

Title of Study: FUSE: Design for Fire Communication

Principal Investigator: Erin Hueston Faculty Sponsor: Avi Parush

We are asking you to participate in a research study. The purpose of this study is to investigate effectiveness of a team display designed to augment communication and enhance teamwork in a command and control environment. We are interested in whether the presence of an integrated information display will make a difference in people's performance. In this study we are specifically interested in assessing the understanding of and differences between two display design versions.

INFORMATION
If you agree to participate in this study, you will be asked to participate in a final testing of the design that is based on the findings from the previous two surveys and the information sorting activity.

RISKS
There are no physical or emotional risks and discomforts to participating in this study.

CONFIDENTIALITY
The data collected in this experiment is strictly confidential. All data is coded such that your name is not associated with the responses you provide. Any identifying information associated with your code will be confined to a single page that will be separated from your questionnaire, and kept in a separate, secured file by the research investigators, who will keep this information confidential.

CONTACT
The following people are involved in this research project, and may be contacted at any time if you have questions or concerns: Erin Hueston (email: ehueston@connect.carleton.ca), Dr. Avi Parush (Faculty Sponsor, email: avi_parush@carleton.ca). Should you have any ethical concerns about this research, please contact Dr. Monique Sénéchal, at monique_senechal@carleton.ca (613-520-2600 ext. 1155). For other concerns, please contact Dr. Anne Bowker, (Chair, Department of Psychology, psychchair@carleton.ca, 613-520-2600 ext. 8218).

DURATION and LOCATION
The final testing will take place online through Webex and last approximately 30 minutes to complete. The testing activity can be completed at your own workspace.

PARTICIPATION

Your participation in this study is entirely voluntary. At any point during the study, you have the right to not complete certain questions, or to withdraw from the study without penalty.

This study has received clearance by the Carleton University Psychology Research Ethics Board (Reference 12-215).

CONSENT

I have read the above form and understand the conditions of my participation. My participation in this study is voluntary, and I understand that if at any time I wish to leave the experiment, I may do so without having to give an explanation and with no penalty whatsoever. Furthermore, I am also aware that the data gathered in this study are confidential and anonymous with respect to my personal identity. My signature indicates that I agree to participate in this study.

Participant's signature_____ Date _____

Researcher's signature_____ Date _____

F.3. Debriefing

What are we trying to learn in this research?

We want to test if a unified information display can improve information communication and understanding within the environment of forest fire response. In this study we wanted to assess you understanding and ability to interact with and find required information from two proposed display designs.

Why is this important to scientists or the general public?

In fields such as firefighting, collaboration and communication is made difficult by the fast paced environment and amount of information flowing in on a regular basis. At the same time, members of the team are required to search in multiple locations to find different pieces of information, resulting in increased time required to reach understanding of the situation and make well-informed decisions. Given the demanding safety-related requirements in this field, a carefully designed and tested information display is desirable.

What are our hypotheses and predictions?

We predict that the knowledge of the situation at large as well as of the specific situation and needs of their team-mates will be increased by the team-display. Further, we predict that this will make for better cooperation, which in turn, will increase performance.

We predict that the knowledge of the "big picture" as well as the specific situation and needs of all aspects of the forest fire response will be increased by the integrated information display. Further, we predict that this will make for better understanding of the links between all required response information.

Where can I learn more?

There have been many studies done on interface design and information displays. Here are a few examples:

Burns, C. and J. Hajdukiewicz. (2004). Ecological Interface Design. USE: CRC Press.
Card, S., J. Mackinlay, and B. Shneiderman. (1999). Readings in Information Visualization: Using Vision to Think. San Francisco California: Morgan Kaufman Publishers.
Vicente, K. and J. Rasmussen. (1992). Ecological Interface Design: Theoretical Foundations. *IEEE Transactions on System, Man and Cybernetics.* 22(4). 589-606.

What if I have questions later?

If you have any remaining concerns, questions, or comments about the experiment, please feel free to contact Erin Hueston (Principal Investigator), at: ehueston@connect.carleton.ca, Dr. Avi

Parush (Faculty Sponsor), at: avi_parush@carleton.ca. Should you have any ethical concerns about this research, please contact Dr. Monique Sénéchal (Chair, Psychology Ethics Board, monique_senechal@carleton.ca, 613-520-2600 ext. 1155. For other concerns, please contact Dr. Anne Bowker, (Chair, Department of Psychology, psychchair@carleton.ca, 613-520-2600 ext. 8218). This study has received clearance by the Carleton University Psychology Research Ethics Board (Reference 12-215).

Thank you for participating in this research!

F.4. Questionnaire

Thank you for completing the test of FUSE. Please complete the following questionnaire to enhance the understanding of your overall experience while working with FUSE. Please answer as honestly as you can, these answers will assist in the development of a reliable, efficient design. This is strictly a test of the system, not of you. The answers will help in finding where the system worked well and where there may be room for improvement.

1. On what date and time did you take this test?

2. Please state your role within the response room at the MNR.

3. How long have you been working at the MNR?

4. How did the interaction with the proposed designs compare with your experience with current processes? Please rate and explain.

Inset Map: 1 2 3 4 5 6 7

(More Difficult than current) (Much Easier than Current)

Full Map: 1 2 3 4 5 6 7

(More Difficult than current) (Much Easier than Current)

5. Describe your overall impression of the separate designs. Please rate and explain.

Ease of understanding the displayed information:

Inset Map: 1 2 3 4 5 6 7

(Very Hard to Understand) (Very Easy to Understand)

Full Map: 1 2 3 4 5 6 7

(Very Hard to Understand) (Very Easy to Understand)

Ease of Finding Information

Inset Map: 1 2 3 4 5 6 7

(Very Hard to Find) (Very Easy to Find)

Full Map: 1 2 3 4 5 6 7

(Very Hard to Find) (Very Easy to Find)

Potential support in coordination, collaboration, and communication with others.

Inset Map: 1 2 3 4 5 6 7

(Very Unsupportive) (Very Supportive)

Full Map: 1 2 3 4 5 6 7

(Very Unsupportive) (Very Supportive)

Potential support in maintaining situational awareness.

Inset Map: 1 2 3 4 5 6 7

(Very Unsupportive) (Very Supportive)

Full Map: 1 2 3 4 5 6 7

(Very Unsupportive) (Very Supportive)

6. What do you like about the systems? Please explain.

Inset Map:

Full Map:

7. What would you change, if anything, about the systems? Please explain.

Inset Map:

Full Map:

8. Do you feel that either of these designs would be a valuable addition to your current system? Why or why not?

Inset Map:

Full Map:

9. How do you feel about the graphic emphasis of the designs over the current text heavy system? Please rate and explain.

1 2 3 4 5 6 7

(Very Negative) (Very Positive)

10. Where did you have difficulty with the systems? Please explain.

Inset Map:

Full Map:

F.5. Testing Results

Test Results for Inset Map Design
Table is displaying the number of errors in finding required information.

- Tests that did the Inset Map design second, after the Full Map design

#	Question	1	2	3	4	5	6	7	8	9	10
1	We, as a team want to know more about the GER-02 fire. Please provide the system's break down of the resources on that fire.	1	0	0	0	0	0	0	0	0	1
2	There are a lot of phone calls coming into the office reporting different fire incidents. What is the percentage of crew that are available to us?	1	NC	1	2	1	2	0	NC	5	0
3	With all of these incidents coming in we might want to change the alert status of some of the aircraft. How many aircraft do we currently have on blue alert?	1	0	2	0	2	0	0	0	1	0
4	The number of fires is building. If the Stone crew is in Dryden they can be dispatched immediately. Where is the Stone crew located?	0	0	0	0	0	0	0	0	0	0
5	Right now there is no aircraft assigned to fire ATT-07. If that fire is not under control we should send an aircraft to help with response. What is the status of ATT-07?	0	0	0	0	0	0	0	1	0	0
6	There has been a request from out of province for water bombers. Aircraft T-209 just came off from maintenance and can be flown out immediately. Where is T-209?	0	0	0	0	0	0	0	0	0	0
7	After a meeting that took place away from the response room you would like a quick update. What has happened in the region since 1:00?	0	NC	2	0	0	0	3	0	0	1
8	You get a phone call from the provincial office and they need an update on our status. How many fires are currently burning?	0	NC	2	0	2	0	NC	0	0	2
9	One last thing before you go home for the day, has anything changed on GER-02 since we last checked?	---	---	---	---	---	---	---	---	---	---
	TOTAL	3	---	7	2	5	2	3	1	6	4

NC - are answers that the participant answered incorrectly or did not complete.
--- shows the answer to the question could not be assessed for errors due to the nature of the question, or in this case the nature of the results

Test Results for Full Map Design
Table is displaying the number of errors in finding required information.

 - Tests that did the Full Map design second, after the Inset Map design

#	Question	1	2	3	4	5	6	7	8	9	10
1	Could you please describe how you interpret the information that is currently on your screen.	---	---	---	---	---	---	---	---	---	---
2	We, as a team, need to know more information related to the fire ATT-09. Please provide the system's breakdown of the resources on that fire.	0	0	0	0	0	0	0	0	0	0
3	There are two aircraft on fire MSN-01. If that fire is under control you should call on the aircraft back to headquarters. What is the status of fire MSN-01?	0	1	3	0	0	0	NC	0	2	1
4	The Oak crew may need some assistance on their fire. Are there any aircraft flying to that fire to assist? If there is can you please name the aircraft.	0	7	0	0	4	5	2	NC	0	2
5	After returning from a lunch meeting you'll want to know what has happened in the time that you were away. What has changed with your resources since 12:00?	0	0	0	0	0	0	NC	1	0	0
6	There is a large number of reports coming in reporting potential fires. You only have three crew on red alert right now. How many crew do you have on yellow alert?	0	0	0	1	0	0	0	0	1	0
7	You decide that it might be best to have as many resources available to you as possible. You are looking for T-206 and T-209, where are they currently located?	0	0	0	0	0	0	0	0	0	0
8	You would like to take one of the crew off of MSN-01. Which crew is the Incident Management Team and therefore should stay on the fire?	0	1	0	0	0	0	0	0	0	1
9	You get a phone call from the provincial office and they need an update on our status. How many fires are currently burning?	0	NC	1	0	1	1	NC	1	1	0
	TOTAL	0	9	4	1	5	6	2	2	4	4

NC - are answers that the participant answered incorrectly or did not complete.
--- shows the answer to the question could not be assessed for errors due to the nature of the results, or in this case the nature of the question

Testing Results - Comparison between tasks within each design

 - Tests where the participant was on their second design

Design	Question	1	2	3	4	5	6	7	8	9	10	Tot.
Inset Map	What has happened in the region since 1:00?	0	NC	2	0	0	0	3	0	0	1	6
Full Map	What has changed with your resources since 12:00?	0	0	0	0	0	0	NC	0	0	0	0
Design	**Question**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Tot.**
Inset Map	How many fires are currently burning?	0	NC	2	0	2	0	NC	0	0	2	6
Full Map	How many fires are currently burning?	0	NC	1	0	1	1	NC	1	1	0	5
Design	**Question**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**T/A**
Inset Map	Where is T-209 currently located?	0	0	0	0	0	0	0	0	0	0	0
Full Map	Where are T-206 and T-209 currently located?	0	0	0	0	0	0	0	0	0	0	0
Design	**Question**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**T/A**
Inset Map	What is the status of ATT-07?	0	0	0	0	0	0	0	1	0	0	1
Full Map	What is the status of fire MSN-01?	0	1	3	0	0	0	NC	0	2	1	7
Design	**Question**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**T/A**
Inset Map	How many aircraft do we currently have on blue alert?	1	0	2	0	2	0	0	0	1	0	6
Full Map	How many crew do you have on yellow alert?	0	0	0	1	0	0	0	0	1	0	2

Design	Question	1	2	3	4	5	6	7	8	9	10	T/A
Inset Map	We, as a team, want to know more about the GER-02 fire. Please provide the system's break down of the resources on that fire.	1	0	0	0	0	0	0	0	0	1	2
Full Map	We need to know more information related to the fire ATT-09. Please provide the system's breakdown of the resources on that fire.	0	0	0	0	0	0	0	0	0	0	0

F.6. Questionnaire Results

Comments	Inset Map Design	Full Map Design
How did the interaction with the proposed designs compare with your experience with current processes? Please rate and explain.	Average Rating: 5.9 Everything is in one location. Inset Map design had an easier flow.	Average Rating: 5.3 One stop for information needs. Little more hesitation reading data. “More information in a single view than with current systems”
Ease of understanding the displayed information.	Average Rating: 6.1 Like the more visual information. More immediate information regarding the current situation. “Wasn’t sure about the relationship between the fires on the large map and the fires on the inset map”	Average rating: 5.0 Prefer the visual of the Inset Map. “Not as much information available on the default display for the Full Map map.”
Ease of finding information.	Average Rating: 6.1 More immediate information for the user. Inset Map design was easier to manipulate.	Average Rating: 5.6 Process is straight forward. It is easy to determine when you have made an error and how you can fix it.
Potential support in coordination, collaboration, and communication with others.	Average Rating: 5.9 Curious about the weather information.	Average Rating: 5.1 Looking for weather data. Like the ‘big picture’ while being able to look into specific elements.

Comments	Inset Map Design	Full Map Design
Potential support in maintaining situational awareness.	Average Rating: 6.3 Inset Map does a better job due to the default information shown on the map. Timeline allows for filling of the gaps if attention is drawn away from monitoring the current situation.	Average Rating: 5.6 Prefer the Inset Map design.
Likes about the designs.	Good visual display. Easy to use. Felt at ease. Simplicity. More information on the initial screen. Intuitive.	Good visual display. Some information is harder to see Easy to understand. User friendly. Do not favor digging for fire information.
Suggested changes to the designs.	Colour for fire conditions, rather than intensity. Add a legend for icons.	Colour code the dots. Add a legend for information. Not in favor of the line design for the fire information. Would like more information on the default map display.
Where did you have difficulty with the system?	Initial confusion regarding the number of fires shown. Could use a legend to better describe the icons.	Slightly harder to get a quick summary. Not a fan of the format for resource displays. Understanding what the lines meant.
Either design a valuable addition to your current system?	User friendly and intuitive. “With some minor changes the Inset Map design would be a valuable addition to the response center for improved situational awareness.” Like the timeline feature.	Would rethink the “line” layout.