Information Collection in Forest Fire Response Operations;

A Foundation for Situation Awareness

by

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A thesis submitted to the Faculty of Graduate and Postdoctoral

Affairs in partial fulfillment of the requirements

for the degree of

Masters of Arts

in

Human Computer Interaction

Carleton University

Ottawa, Ontario

Abstract

The management of an emergency response process, like forest fire response, requires a high level of complex coordination, efficient communication and effective situation awareness within the team. Critical response decisions are based on a timely and effective collection and processing of large amounts of constantly changing information.

This research focuses on improving the data collection process during fire response operations. Efficient and comprehensive information input and accessibility can enhance the team's awareness about the fire situation.

Through a user-centered design approach, and the application of previously studied design approaches and principles, a design that facilitates the data input process is proposed. The design consists of an office and a mobile interface, which should be used in the headquarters and by the crew leaders on the field respectively to support information input, communication and distribution.

The user evaluation showed that the proposed design is effective for improving the data collection process and supporting the operators' required situation awareness during an incident response.

Keywords: Emergency response; Information collection; User interface design; User-centered design; Situation awareness

Acknowledgements

My sincere gratitude goes to Dr. Avi Parush and Dr. Anthony Whitehead for their support throughout the development of the research. Their guidance towards a successful completion of this thesis is greatly appreciated.

Many thanks to all team members from the Ministry of Natural Resources, their time and valuable and continuous feedback greatly assisted the full development of the study.

I would also like to thank my family for their continuous love and support. Last but not least I'd like to thank my loving husband Maged for his patience and encouragement throughout the entire process.

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1. Introduction

Forest fire management is the process of planning, preventing and fighting forest fires to protect people, property and the forest resource. It also involves fire to attain forestry, wildlife and land-use objectives [1]. The primary goal of the Ontario wildfire management program is the protection of public safety and values, as well as managing the ecological role of fire for resource management.

This can only be achieved through quick and efficient information communication and response operations. However, the wildfire response process includes the processing of large amounts of information collected from a complex and constantly changing situation. In addition, the response operation is often conducted by distributed teams, which can result in challenges and breakdowns in communication.

Through understanding the requirements and procedure of the wildfire response process this research aims to develop a design proposal that would improve the response process and enhance the team's situation awareness during response operations. The research focuses on the information flow between the field and the headquarters offices. The information flow includes the collection, communication and distribution of fire information required to maintain an accurate presentation of the situation and awareness about its dynamic factors. This continuously changing presentation of the situation is crucial for the

[1] Ministry of natural resources of Canada website

response decisions of managing individual fires as well as resource management in the entire region and province.

The proposed design solution, which was developed through a user-centered approach, offers a user-friendly interface that should enhance information collection and communication as a foundation for maintaining up-to-date awareness about a fire situation.

1.1 Thesis Framework

The problem addressed in the scope of this research lies in the complexity and dynamic nature of emergency response situations. Response decisions and actions are based on the processing and interpretation of the situation and the environment. In most cases however the situation is continuously changing and the information is constantly updated based on the progress of the operation as well as environmental factors (Figure 1).

Continuous, accurate and timely collection and update of information about the situation can be challenging, especially when some of the information needs to be remotely communicated from the field, like in the case of forest fire response. This research focuses therefore on the information collection process and the tools that are used for it.

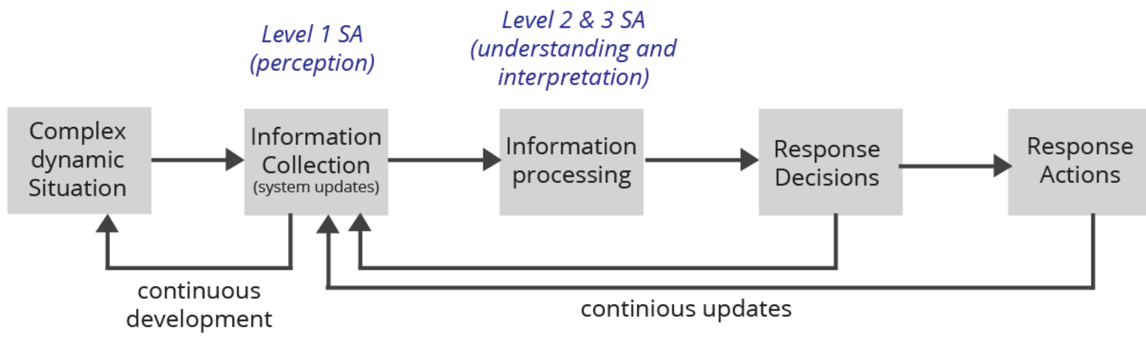

Figure 1: Emergency response process

The question of *how the information collection process can be enhanced to improve the team's situation awareness during a forest fire response operation* is addressed. The objective of the research is hence to identify design and structural principles that would facilitate the data gathering procedure and ultimately provide an improved overall situation awareness during forest fire response. The proposed solution was developed based on literature about designing for situation awareness and HCI principles as well as studies about supporting mobile emergency teams.

The design solution proposed focuses on creating an integrated and efficient system that would support the complex information collection process and ultimately leading to more accurate and timely situation awareness. The proposed design solution combines an integrated data input system and a mobile data input interface, tailored for the Ontario forest fire response process, to facilitate information collection and enhance situation awareness.

1.2 Reseach Contributions

The objective of this study was to develop a system enhancement proposal that would improve the forest fire response process as well as enhance the situation awareness of the team during response operations. The research was conducted through several iterations that were centered around understanding the users' and environment requirements, leading to the development of the final proposed design. This section outlines the contributions of the research.

Ontario wilfire management process analysis

The pre-design study as well as the continuous involvement of the forest fire management team provided detailed insight about their response process and requirements. The process and information required for maintaining situation awareness and completing wildfire management tasks were analyzed and verified and could therefore be beneficial for further forest fire management research. In addition the study highlights pain points in the current process that can be explored in future research. These pain points are current obstacles or problems that slow the process down. Moreover the methodology and procedure used can be applied in further emergency response studies.

Fire information collection interface

This research presents a unique attempt for the Ontario forest fire management offices to integrate the data collection software with the ministry's databases, through a user-centered design approach. The effectiveness and the usability of the design were validated in an empirical evaluation.

Extension into the mobile domain

Additionally, this research offers the first proposal for extending the fire response software into the mobile domain. This extension was evaluated by the operators, to potentially have a great value to the information gathering process as well the team's situation awareness.

1.3 Thesis Organization

In the introduction, the framework, background and contribution of the study are presented. The emergency response process is briefly introduced and the contribution of this research to it is explained.

The second chapter is the review of literature and previous studies related to the research. The review has an in depths introduction of the emergency response and the importance of situation awareness for its process. Previously developed and evaluated approaches and solutions for enhancing the emergency response process as well as maintaining situation awareness are discussed. The various approaches are analyzed to guide this research from understanding the forest fire response process to addressing its challenges. Design approaches and principles are also presented as guidelines for the design of the interface proposed in this study.

The third chapter presents the methodology followed in this study. It provides an overview of the methods used and how they contribute to the overall purpose of the study. The methods include a pre-design study and three different iterations for continuous evaluation of the development and progress. The specific procedures of each method and tool used are described as well as how they contributed to the development of the proposed design.

In the fourth chapter the results of the pre-design study are presented. It explains how the ecological design approach was applied for understanding the environment and process of the forest fire response, as well as to gain insight about the team's situation awareness and its current pain points and challenges. Based on the results, the enhancement proposals of this study are generated and presented.

The fifth chapter presents the results of the first iteration, where the results of the informative study were verified. The first iteration led to the focus on the data collection process as the priority of this study. In this chapter the design proposal and interfaces are presented in detail, linking the proposed features to the literature as well as the observed process challenges.

The sixth chapter presents the results of the second iteration, which was a GOMS-model evaluation that aimed to test the efficiency of the proposed interfaces and system. The development of the prototype, which is used for the user evaluation, based on the model evaluation is also presented in the sixth chapter.

The seventh chapter shows the results of the user evaluation, which was the third and final iteration. The results include the participants' overall acceptance and perceptions of the proposal and the system's usability evaluation.

Additionally the chapter presents the evaluation of the system’s performance for data collection and input as well as situation awareness and information accessibility. The development of the final design based on the participants’ feedback is presented at the end of the chapter.

The eighth and final chapter is the discussion of this study. It includes a summary of all the key results of the research concerning process improvement and situation awareness. It also includes an evaluation of the design approaches that were applied and an evaluation of the research and limitation of the study. Furthermore, more process improvement and research opportunities for the forest fire response process are suggested.

2. Literature Review

This research focuses on the communication and flow of information that is required to maintain situation awareness and to conduct response operations in emergency management. This section is a review of previous research that has studied emergency response domains as well as approaches and design solutions that aimed to enhance it. The aim of the review is to provide insight about the analysis methods and requirements for designing for emergency response. This insight guided the research methods as well as the design approaches applied in the development of the design solution.

2.1 The Forest Fire Management Domain

Forest fires are considered emergency incidents that require a special emergency response process to manage[2]. The teams involved need to respond as quickly as possible to fire that are considered an immediate threat to communities or infrastructure as well as limit the negative impact and costs when the environment could benefit from the fire. This section includes a short review of literature that has studied the team dynamics in emergency response operations.

2.1.1 Emergency response

The management of an emergency response process requires a high level of complex coordination between different operators and locations, in addition to

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[2] Emergency Management Ontario

efficient and timely communication. One of the many challenges of the domain is the necessity for rapid decision-making in situations of uncertainty and under time and resource constraints (Chen, Sharman, Rao, & Upadhyaya, 2008). Additionally the unpredictability and dynamic nature of emergency situations presents further complexity to the needed response strategies and actions. The establishment and maintenance of situational awareness (SA) is an essential requirement for successful crisis and emergency management (MacEachren et al., 2011). The maintenance of SA requires the proper collection of complete and accurate information about the situation in an accessible and timely manner as well as the proper analysis and interpretation of the different factors and overall situation (Hueston, 2012).

2.1.2 Command and Control Teams

Forest Fire management teams operate as command and control teams (C2); these are a form of decision-making teams where team members perform interdependent tasks towards a shared goal (Salas, Burke, & Samman, 2001). They are structured to support situation assessment, the development of action plans and the implementations of the selected plans as well as the management of the various resources (Salas et al., 2001).

Their performance depends on each member being able to anticipate the needs of others, adjust to it and keep a shared understanding of the process (Baker, Day, & Salas, 2006). The specialization and autonomy of each team member within the coordinated activity of the whole team is central to the goal of emergency management (Ma, 2012). Effective communication and information flow is identified as one of the key components of an effective incident command system (Neill, 2008) & (Salas et al., 2001). C2 teams often have to function in fast-paced, large-scale and stressful events where members are required to deal with and process large amounts of ambiguous information that must be processed in a limited time (Brandigampola, 2011).

The teams are also usually – as in the case of forest fire management – distributed over several locations with crews and operators in remote field areas. This geographical distribution can result in the lack of visual cues and restricted information flow between the managers and the field crew (Ma, 2012). The distributed C2 team must therefore have clear and precise communication strategies and its members must be able to dynamically and efficiently exchange information as well as resources (Salas et al., 2001). It is very important that all team members are able to hold a common picture of the emergency and situation at hand.

Forest Fire management operators are therefore constantly seeking more efficient communication tools, models and organizational structures to facilitate and support their decision-making process and overall performance.

2.2 Situation awareness

As described, the process of emergency response requires all members of the response team to be on the same level of awareness about the factors affecting their strategy and decisions. Their awareness of the situation must go beyond the perception of the elements in their environment to the prediction of their status in the near future.

Research about situation awareness (SA) is relevant and crucial for several emergency response domains. Studies from healthcare emergencies (Jalote-Parmar & Badke-Schaub, 2010), community and urban emergencies (Nadya Rustandjaja, 2013) as well as military teams (Smets, Streefkerk, & Neerincx, 2010) have explored the dimensions and factors affecting a teams' situation awareness in stressful and time-sensitive operations. The complexity of the process of maintaining SA is increased by the great amount of information and factors that are usually involved in emergency response. Technological advances have allowed for richer and more detailed information collection. However in many cases this information is spread among different sources and requires proper collection and interpretation from operators (Hueston, 2012). Many researchers, from fields of cognitive psychology to information engineering, are therefore interested in understanding and enhancing the SA process.

One of the most popular theoretical models of SA and its role in the dynamics of human decision making is the one developed by Mica Endsley (M. R. Endsley, 1995). Endsley defines SA as the "perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (M. R. Endsley, 1995). This definition has been adopted by the ESSAI (Enhanced Safety through Situation Awareness Integration in training) (ESSAI, 2000). Endsley's definition also summarizes the 3 levels of SA; perception, comprehension and projection. In the first level the operator should accurately perceive the necessary information elements and factors. At the comprehension level, the interpretation and significance of the perceived elements is affected by the person’s goals (M. Endsley & Jones, 2011). Through knowledge about the status and situation, obtained in the first stages, the ability to project the development of the situation at least in the near future is the highest level of SA. Endsley explains that, in addition to the goals and objective, this three-step process is affected by several other factors (M. R. Endsley, 1995); these include a person’s knowledge and experiences, their working environment as well as the interface and system that they are working with. The process of SA should not be confused with the decision making process nor with the person’s knowledge, previous experience or training.

Mica Endsley’s SA model is most widely used in the reviewed literature and was therefore also followed in the development of this research. However other definitions and models of SA include having a “common operational picture” (Kurapati & Kolfschoten, 2012) and a “moment to moment knowledge about, and understanding of the […] environment” (Andre & Cutler, 1998). Other research (Fracker, 1991) also considers the combination of new information with existing knowledge in working memory in the SA model.

2.2.1 Team situation awareness

As previously explained, emergency response is almost always conducted by teams of at least 2 members. This can add even more complexity to the required SA; in addition to the awareness about the environment, the operators are required to be updated with other team members’ activities, status as well as contribution to the cooperative task (Furuta & Shu, 2004). This process of awareness is referred to as team situation awareness (TSA).

Research focusing on optimizing this process has identified the need for shared mental models (Carpenter et al., 2008) and a common operational picture (Kurapati & Kolfschoten, 2012). Through training and experience, operators develop these mental models to understand the behavior of particular systems (M. R. Endsley, 1995); these models help in looking for critical cues, direct expectations and even serve as a link between recognition and action.

It is therefore logical that the presentation and processing of the information should be designed to support these existing mental models as well as their development.

In some studies, analyzing the team interaction and TSA is based on studying activity theory (Macredie & Sandom, 2003). In human computer interaction research, activity theory is used for understanding the context, purpose and meaning of user activities to be incorporated in interactive technologies (Kuutti, 1995). Their model for SA focuses on the interaction and relationship between the actors and their environment. The understanding of the activities of others provides context for the individual's activity (Dourish & Bellotti, 1992) and their role in achieving the team's objective.

In the dynamic nature of a team's activity, the information is "continuously being extracted from the real-world situation and integrated into the individual's awareness to form a mental representation upon which decisions are based and

[…] actions are undertaken" (Macredie & Sandom, 2003). The research confirms the importance of continuous acquisition and update of information for the maintenance of TSA.

2.2.2 Challenges of SA

In understanding an emergency response process, it becomes obvious that operators spend the majority of their time trying to ensure that their mental picture of the situation is up to date, complete and accurate (M. Endsley & Jones, 2011). Several challenges are encountered when trying to maintain SA, they are caused by both the complexity of the situation as well as the features of human information processing.

These challenges are important to understand before attempting to facilitate or support SA through the development of a response process, system or interface, as they should be considered and addressed directly. One of the most significant problems for SA in emergency response is data overload (Brandigampola, 2011). Although the technological advances in systems makes them able to produce huge amounts of data very quickly, unless the processing, organization and presentation of this data is properly structured and systematized, it would not lead to better SA.

Another potential problem related to the system design is the "complexity creep" (M. Endsley & Jones, 2011); when systems offer operators too many features, the users' ability to perceive and process the information is slowed down. Furthermore, while automation in systems can help eliminate some of the workload, there is the risk of it bringing the operators "out of the loop" (M.

Endsley & Jones, 2011) resulting in SA loss concerning the elements that are part of the automated process. The design of the automation should therefore keep the operators engaged enough in the process to avoid this risk.

Other challenges that are related to the human cognitive processing are for example stress, anxiety or fatigue, as well as reliance on short-term memory. Problems can also occur through operators' attention control. The operator might become too focused on their specific task that they lose track and awareness of other events or elements of their environment, this is also referred to as attention tunneling (Bolstad & Endsley, 2000).

Focus on a specific element can be caused through the operators' attention on their individual goal or the element's salience. Visual cues and elements' presentation have therefore a huge impact on guiding the operators' attention as well as supporting their cognitive process of maintaining their SA.

In the next section more guidelines and principles for designing systems and interfaces that can improve the response process, consider these challenges as well as support SA in general are presented.

2.3 Designing to improve the emergency response process

Understanding the process of emergency response, situation awareness and the challenges that are encountered within it, shows that the presentation of the information and the design of the interaction of the operators with this information play a crucial role in the maintenance of SA. A presentation and design that support the team's mental model and consider their needs and requirements should facilitate the accessibility to information as well as the continuous update and therefore improve the overall process.

Bill Buxton, one of the principal researchers at Microsoft research, explains: “The best [interaction] design is transparent, almost invisible” [3]. It means that a successful design can let the users smoothly accomplish their goals and complete their tasks without the need to consciously understand and study the interface they use to do this. This can be achieved through several design and usability principles that have been established by researchers. These include the alignment and consistency of the design with the real world and process and to support intuitiveness and recognition (Nielsen, 1994). Other principles include providing the users with appropriate feedback for their actions and avoiding unnecessary complexities in navigation and interactions.

The next paragraphs summarize the most relevant design principles for emergency response and situation awareness, which have been considered in the design development of the proposed system. Several of the reviewed design approaches were studied in different emergency domains like military and healthcare. The experience is translated to forest fire management domain in a way that considers the requirements of it (Parush, Kramer, Sohmer, Mastorias, & Calder, 2015).

In their book “Designing for Situation Awareness”, Endsley and Jones list close to 50 design principles that would support situation awareness and the response

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[3] http://www.rslnmag.fr/post/2011/06/15/Bill-Buxton-%E2%80%9CThe-best-interaction-design-is-transparent-almost-invisible%E2%80%9D.aspx

process in general (M. Endsley & Jones, 2011). The first, and probably the most important principle, is: “organizing the information around user goals”. Designers can be tempted to implement the most recent technology or focus on aesthetically pleasing or minimal design, however with emergency response and SA in mind the designer’s aim should be to provide efficient information accessibility required for achieving user goals. This automatically means that designing for different domains would require different priorities and in some cases even following different concepts. It is therefore extremely important to understand the users’ working process, their requirements and working conditions through a user-centered design (UCD) process. A user centered design process for emergency response would also help address essential usability needs that are specific to the users stressful work process. Design principles that specifically address operators’ stress have also been explored (Hancock & Szalma, 2003). Their developed guidelines focus around avoiding information dispersal between different sources and the integration of data presentation into a single display that does not require too much interpretation by the operators.

Other conceptual design approaches specific for emergency response systems include the integration of the human roles into the system and allowing for an appropriate degree of tailoring and filtering to fit the specific user roles (Turoff & Chumer, 2004).

2.3.1 Information visualization and cues and notifications

How the information is presented and visualized is another vital factor that affects the success of the design. Information visualization is “the use of computer-supported, interactive, visual representations of data to amplify cognition” (S. Card, Mackinlay, & Scheiderman, 2009). With the advancement of graphical displays and computers, the possibilities for dynamic and interactive information presentations and visualization seem endless. However as the stated definition suggests, information visualization should be used to support and elaborate cognitive processing of the perceived data. It is also widely agreed upon that visual representation, like diagrams and visual or color cues, offer better support for cognitive processing than textual or even voice communication of information (Chittaro, Zuliani, & Carchietti, 2007) and (Few, 2007).

One of the simplest principles for information visualization is grouping related information visually. This decreases the cognitive load as well as the time needed to search for information (S. Card et al., 2009). Information visualization is especially important for organizing and displaying huge amounts of complex information like in the case of forest fire response. The process of information design and visualization should above all keep the priorities and the needs of the users in the center. It becomes challenging to accommodate the priorities of different users working as a team with the same system; it is therefore recommended to base information design and visualization on the communication patterns of the team (Parush et al., 2011).

Information visualization also includes the integration of appropriate notifications and alerts. Alerts are most commonly used to notify users of important or risk information. They can also be employed to avoid attention tunneling by alerting users of other developments and updates in the situation (M. Endsley & Jones, 2011). These alerts are especially important in collaborative and teamwork contexts (Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003). They should be used to alert about the actions of other team members, typically referred to as “activity awareness”, and especially important for processes of planning and cooperation.

2.3.2 Intelligent Database and Decision Support

When it comes to emergency response and SA, it is recommended that representations should not only show raw data, but should support the interpretation as well as the future projections of the information – level two and three of SA (M. Endsley & Jones, 2011).

The comprehension and interpretation of information can be supported by systems, however systems can also be designed to aid in projecting the development of the situation and thus aid the decision making process. User interfaces can function as an intelligent agent to aid the search, query and operation on data (Tsou & Buttenfield, 1996). This can be through an intelligent database system that provides the users with additional or related information (Agrawal et al., 2004) and through the automatization of parts of the processes (Vieweg, Hughes, Starbird, & Palen, 2010). This, of course, requires a thorough understanding of the required information, the methods of communication as well as the process overall. In addition, the automatization of any process should be carefully integrated to keep operators “in the loop” and engaged in the process (M. Endsley & Jones, 2011).

2.3.3 Popular Design Approaches

Centering the design around the goals of the users means that design concepts are best domain-specific. This means that each field and each working process requires thorough understanding and analysis to be appropriately supported through the design. Nevertheless, reviewing research shows that there are a number of general design approaches that have been proven valuable for supporting emergency response.

Ecological Interface Design (EID)

One of the general approaches is ecological interface design (EID). EID a specific approach in interface design that was introduced specifically for complex and dynamic systems (Burns, Jamieson, Skraaning, Lau, & Kwok, 2007). The design concept is based on the relationship between the individual and the environment (Gibson, 1977); Individuals are able to pick up on certain information and use it effectively to guide their action within the current context.

Interpreted for system design, EID means that the interface is designed to reflect the components and constraints of the work environment in a way that is perceptually available to the users (Burns et al., 2007). This approach therefore requires a close examination of the environment prior in addition to the users and their needs. This includes understanding the problems and tasks to be performed by the users, as well as all the information they require control over (Hueston, 2012). Moreover representing the connection between operators and the environment can facilitate situation awareness and reduce the possibility for errors in a complex emergency response environment. The analysis of the environment of the forest fire response domain, as recommended by this approach, was applied into the proposed designs through the direct and clear presentation of the environment factors (see section 4).

Team Displays

One of the most popular design solutions for situation awareness is a team display. In the emergency response domain, they can be defined as “a display designed to provide integrated information required by teams performing command and control tasks in complex situations” (Parush & Ma, 2012). Studies that investigated and evaluated the benefits of team displays for the forest fire management domain, (Ma, 2012) and (Brandigampola, 2011), have confirmed that they can enhance team communication and significantly facilitate situation awareness.

Other researchers have also focused on the benefit of a large team display for the team and examined its effect on team collaboration and communication (Scott, Wan, Rico, Furusho, & Cummings, 2007), (Collective & Gouin, 2010) and (Jiang & Hong, 2004). In one study (Collective & Gouin, 2010), three challenges for designing efficient large team displays were identified; The information content, the display management and the interaction. These challenges are also best addressed through the understanding of the process and the environment as well as an analysis of the information required to achieve teams' objectives (M. Endsley & Jones, 2011) & (Scott et al., 2007). The studies offer insights about specific operator needs and priorities. For example when testing a large display for firefighters (Jiang & Hong, 2004), the researchers reported that in some cases the location of a firefighter was not as important to the commander as the task they are assigned or their role in the operation. In addition, the same researchers also concluded that redundancy is not necessarily unwelcome in high reliability organizations (HROs) and emergency response as it can improve communication and safety. These insights confirm the value of understanding the team dynamics and roles prior as part of the design process.

Shareable interfaces and information

Other studies have been concerned with emergency operators' need for multitasking and following up on different incidents or tasks (Mcnab, 2009) & (Pousman & Stasko, 2006). Process analysis has also identified the need for operators to perform their individual duties while maintaining awareness about the development of the general situation and other relevant updates (J. R. Wallace, Scott, Stutz, Enns, & Inkpen, 2009).

For an effective and efficient process support the system design must support both the overall team situation awareness as well as the individual roles and tasks of the team members (Gutwin & Greenberg, 1998). Large team displays could be designated for the general situation that everyone should be aware of even if not necessarily focused on (Pousman & Stasko, 2006), while other components of the system – for example operator displays - would facilitate the focus on individual responsibilities.

The possible risk for situation awareness associated with this arrangement is attention tunneling (M. Endsley & Jones, 2011). However the integration of notification systems that alert the operator of important changes and updates in the overall situation can be integrated to eliminate this risk (Carroll et al., 2003).

Dashboards

Another popular solution for integrating all information that operators needs to keep track of from different sources are dashboards (Few, 2007). A Dashboard is defined as "a visual display of the most important information needed to achieve one or more objectives consolidated and arranged on a single screen so the information can be monitored as a glance" (Few, 2006). If designed according to the users' requirements and process, they can be a powerful tool to encounter data overload. In addition to the previously discussed design principles, the prioritizing and relative importance of information and data are a key factor for successful dashboard design. They are commonly designed to support effective decision making through the presentation of key factors (Resnick, 2003). The advantage of summarizing key information on a single display for a common situation overview for the whole team has been considered in the design process of this research.

2.3.4 Supporting Mobile teams

Dashboards have also been recognized to be especially useful for mobile emergency response teams (Smets et al., 2010). Although at emergency response services the use of IT is often limited to the stationary headquarters dispatch system (Meissner & Eck, 2007), there have been a few studies about the extension of the system into the mobile domain.

A study concerned with distributed teams in disaster management (Baber, Cross, Smith, & Robinson, 2007) emphasizes the need for data collection directly from the field, for reliable information communication. Another study that proposes a PDA-based interface to replace paper sheets for ambulance run reporting (Chittaro et al., 2007), reports an enhanced timeliness and efficiency in recording and communication.

Another advantage for the extension to the mobile that has been highlighted by the above-mentioned studies is the connection of mobile teams to the headquarters system. This means that mobile and distributed teams get access to the headquarters databases for information they might need during emergency response directly and without having to rely on verbal or radio communication. This would, in addition to time efficiency, also help teams in avoiding misunderstandings and communication noise, which is considered a significant disadvantage of verbal communication exchange (Baber et al.).

Additionally the access to headquarters databases and information has the potential for improving the situation awareness of distributed teams (Chittaro et al., 2007); instead of a “passive information container”, like the fire diary, they are provided with an interactive system that can support information processing and interpretation as well, and thus support more efficient decision making.

Because of the significant recognized potential for the extension of the system into the field response, it is an important component of the design proposal of this research.

Geo-collaboration

One study expands the potential of the widely used GIS systems for emergency response to enhance geographic situation awareness between dispatched and headquarter teams (Resch, Schmidt, & Blaschke, 2007). In their methodology, they introduce the concept of geo-collaboration as a tool for interaction and collaboration within crisis management teams. The tool is based on a layered GIS system that allows for the team on the field to add “geo-notes” that can be accessed by the command teams. These notes can be compromised of texts, images or sketches that are directly posted on a map layer.

Although the scope of this research did not permit the testing of a similar functionality in the proposed system, it is highly recommended that such form of collaboration be integrated in the forest fire response process.

Data collection

The extension of the system to mobile teams, addresses, in addition to improved situational awareness, the issue of data collection. As presented in the thesis framework section (1.1), achieving any level of SA requires accurate and complete data. In the book “Designing for Situation Awareness” (M. Endsley & Jones, 2011), one of the main problems that affect SA and decision making is data uncertainty. This can happen through missing or incomplete information, ambiguous or noisy data or through non-credible information.

Another issue with data uncertainty is timeliness of it. A primary system objectives for situation awareness is real-time monitoring (Giri & Parashar, 2012). In order to achieve this, not only is accurate and continuously updated presentation needed, but the system should also allow and facilitate the continuous input and update of information by the team members. With the current technologies like GPS and radar trackers, information like resource and team members’ locations can be automatically updated, however a lot of data still requires manual input from users (Chittaro et al., 2007).

The recognition of the data collection and input process as the foundation of the team’s SA and the overall process is the focus of this research. The process of data collection addresses primarily level one of situation awareness (M. R. Endsley, 1995); It is concerned with the availability of relevant and timely data in appropriate detail. Especially in high workload situations or rapidly changing and dynamic situations, there is a high risk that information will be missed or not appropriately entered into the system (NOAA National Weather Service, n.d.). The main contribution of this research is therefore to facilitate fire and situation information input.

Most emergency response processes however require operators to already understand the information that they are inputting. This is because of the time limitation of the processes as well as the operators' experience in comprehending and processing situation variables. For the system and interface design, this means that the inputted information has to be appropriately presented and prioritized to facilitate its comprehension and level two SA. The principles and guidelines discussed in the previous sections should therefore also be considered and integrated in interfaces designed for collecting information. In addition to quick and efficient information collection, the input process and interface should be designed around how the information will be communicated and presented to the rest of the team, to support efficient information accessibility and situation awareness as well.

2.4 Application of design principles to enhance situation awareness

As presented in the framework (section 1.1), this research focuses on information collection and data input as the first step for maintaining situation awareness in a forest fire response operation. The previous chapter aimed to collect insights and design approaches that can be integrated in the design proposed in this research. From the review, the following are the primary principles to support situation awareness through the design:

(1) User centered design

(2) Intelligent databases

(3) Dashboard design principles

(4) Information visualization principles

The discussed approaches and design process confirmed the need for thorough understanding of the response process and the team's working environment, through a user centered design (M. Endsley & Jones, 2011) and ecological design process (Hueston, 2012). These processes are a successful tool for understanding the requirements and the challenges often encountered during the emergency response and the maintenance of situation awareness within it. The most important challenges discussed are data overload (M. Endsley & Jones, 2011) the dynamic and complex nature of emergency situations (Lindell, Perry, & Prater, 2005), the distribution of teams (Salas et al., 2001) and the need for multitasking (Mcnab, 2009).

Previous studies and approaches that address these challenges and to overall improve the emergency response process are discussed. The discussed design approaches provided insight about principles for information visualization (S. Card et al., 2009), the use of intelligent agents and databases for decision support (Tsou & Buttenfield, 1996), dashboards (Few, 2007) and team displays (Ma, 2012) to encounter data overload as well as the extension of the systems to support mobile teams (Meissner & Eck, 2007).

The data collection process (section 5.1), which is the focus of this research, is considered the first step in the response operation (Figure 1). Accurate and timely updates about the situation development is required to guarantee appropriate response decisions (M. R. Endsley, 1995). The discussed approaches and design principles were therefore applied for more efficient and accessible information input. However the communication and distribution of the inputted information is equally important for the response process. The communication and presentation of the information should be as timely and accurate as the documentation of it (Borth, 2013) and therefore should also be considered in the design.

This dynamic input and output flow of information is also crucial for maintaining the team’s situation awareness. Only through facilitating constant updates of accessible, easy to process and accurate information can a system meet the requirements of the emergency response process. This design presented in this research is hence an attempt to facilitate the information flow and updates, through more efficient data collection and distribution. The proposed design should accordingly improve the first phase of the response process as well as the team’s situation awareness.

3. Methodology

In addition to reviewing previous studies of design approaches applied for emergency response, this research was conducted using an empirical approach. The empirical approach was the primary tool for following a user-centered approach. It provided first-hand insight about the Ontario wildfire management process as well as continuous user evaluation of the research process.

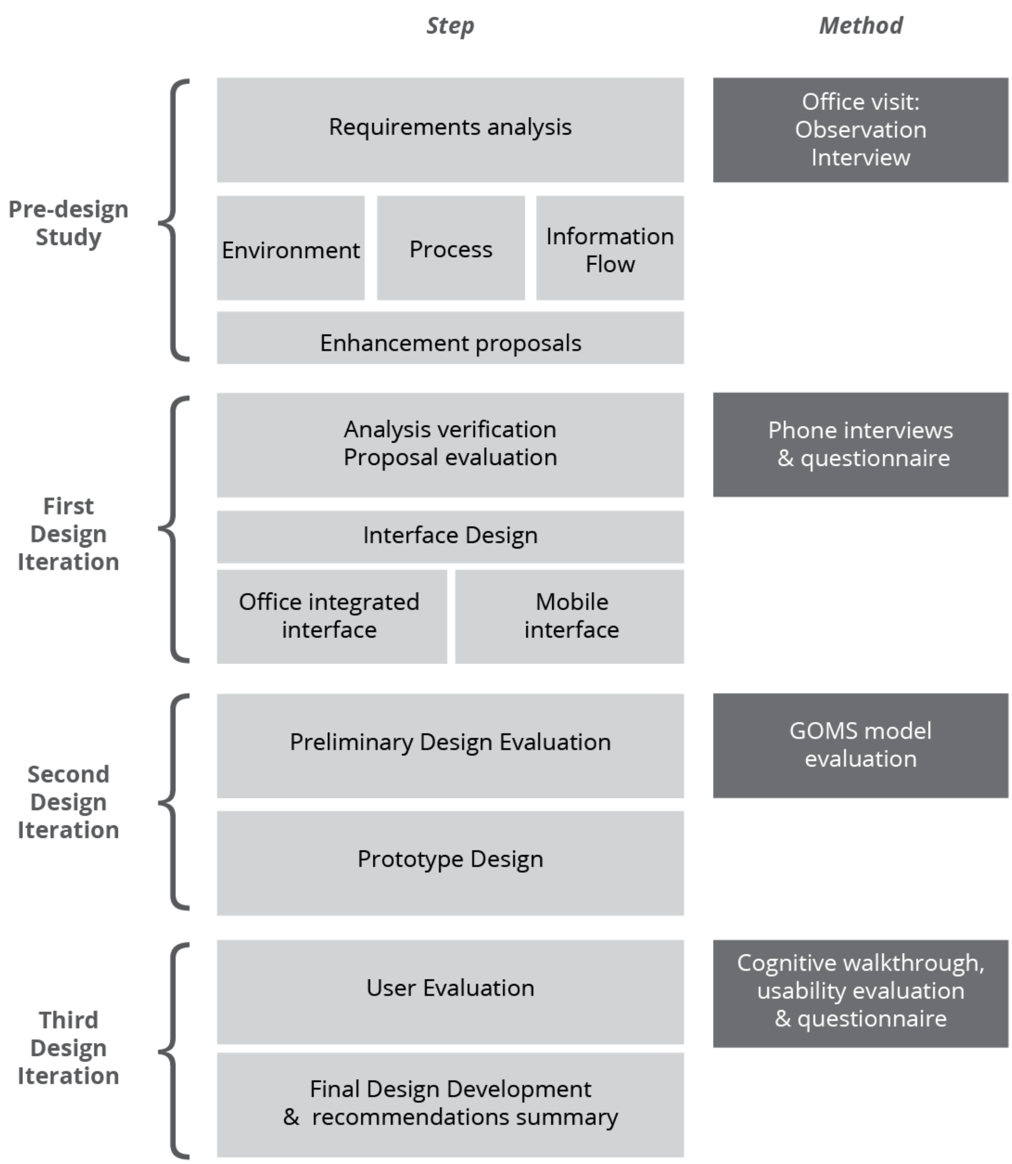

Figure 2: Research procedure and methodology

The user centered design approach was followed for addressing the requirements of the forest fire response team and the evaluation of the proposed enhancement (M. Endsley & Jones, 2011).

The users were therefore involved in every step of the design development process, starting from the early stages of understanding the response process and environment, to the evaluation of the proposed interface.

The steps of the study are broken down to a pre-design study and three evaluation iterations (Figure 2). The procedure and methods of each step are described in detail in the following sections. In summary, the first iteration aimed to verify the process analysis and evaluate the possible enhancement ideas that were generated based on the findings of the pre-design study. The second iteration (section 3.4) was a preliminary testing of the proposed interface design. The testing applied a “goals, operators, methods and selection rules” (GOMS) model evaluation (John & Kieras, 1996), focusing on the efficiency of the process. The third and last iteration (section 3.5) was the user evaluation. This was the main user evaluation about the overall acceptance and perceived value to the response process and its usability and value to the team’s situation awareness. Within every iteration, the results and the feedback were applied as guidelines for the development of the interface and system design. The time between the iterations varied from one to three months.

The design process also followed an ecological interface design approach (Burns et al., 2007), in that it also focused on the environment, the information flow and the process analysis for the development of the proposed system. The details of how this process was applied are discussed in section 3.2.

3.1 Participants

All the participants within all the iterations of this study were employees of the Ministry of Natural Resources (MNR) in Ontario, Canada. The number of participants in each iteration and their roles within the team is listed in its corresponding section (Numbers and roles are presented in Table 1, 2 and 3).

All the participants have worked at the response offices during fire seasons, with their experience at the ministry ranging from 6 to 33 years. It was important that the participants be familiar and experienced with the current system and process and be able to communicate its requirements and priorities accurately. Furthermore, it was necessary for them to provide insightful comparison between the current system versus the proposed system.

It was also essential that the study include participants of various roles within the response team. The participants' roles therefore included office operators, like the duty office (DO), the aircraft management office (AMO), the fire intelligent office and the sector response office (SRO) (the roles are described in section 4.1.1), as well as radio operators, crew leaders and technical employees. This variation provided a comprehensive overview of how the different elements and parts of the process fit together as well as the different requirements of the team members. Throughout the study, participants were encouraged to share their ideas and techniques with regards to how they cope with the dynamic and challenging nature of their job and responsibilities.

Based on their roles in the response team, eight operators participated in all the iterations of the research. The remaining participants were recruited according to availability.

3.2 Pre-design Study

This pre-design analysis presents the research phase (Parush, 2014) of the study. The main goal of it was to understand the forest fire management and response process. In addition, the researcher aimed to understand the tools and software used for communication and maintaining situational awareness in fire response operations as well as gain insight about pain points, challenges or gaps within the process. These pain points would be the guiding keys to the process enhancement proposals that were generated as part of this research. The pre-design study did not only focus on understanding the operators' requirements as the users of the proposed design but to also understand the context of their use and the nature of the information that they are required to deal with as guided by the ecological design approach (Burns et al., 2007). This meant that a thorough understanding of the forest fire response process was essential.

The study was conducted during a weeklong visit to the forest fire response and management offices in Dryden, Sault Ste Marie and Sudbury, Ontario. In Dryden and Sudbury, the visit included the regional and sector headquarters and in Sault Ste Marie, the provincial office.

The qualitative research methods that were used in this study included the observation of the daily work flow including preparedness and response processes, interviewing team members and the attendance of a fire response simulation training. In addition, several MNR report documents and training handbooks were collected in order to understand the requirements of the process.

Observations

The researcher spent a total of five working days in the previously mentioned response offices. The researcher was permitted to take pictures of the response rooms and the tools used, however video-recording was not permitted in the response office. The professional experience of the participating operators as well as the rapport that was established during the visit were considered to have reduced the observer or Hawthorne effect on the operators' performances and work routines. The researcher attended the daily briefings that were held twice at the response offices, as well as one crew-leaders' briefing at each of the sector headquarters visited.

Interviews

The researcher conducted interviews with a total of 24 operators at the offices visited. Table 1 shows the roles and the locations of the interviewed operators.

These interviews were semi-structured (see appendix 1), however the conversations were flexible to allow the operators to share information or experience that they find important for understanding the response process.

The interviews focused on understanding the individual responsibilities, needs and priorities of the different team members, as well as understanding their perceived and actual role within the overall response process. In addition, the researcher aimed to gain insight about their subjective situation awareness and the tools and methods they use to maintain it.

Provincial Office Sault Ste Marie		• Duty Office (DO) • Intelligence Officer	• Fire Technology program leader • Office clerk	4
Regional Office	Sudbury	• Duty Office (DO) • Intelligence O. • Response Coordinator.	• (AMO) Aircraft Management O. • Detection Officer • Radio Operator	6
	Dryden	• Duty Office (DO) • Intel. 1 & 2 • Intel. Assistant • Logistics officer	• AMO • Aerial Operations Technician • Information Systems Coordinator	8
Sector head-quarters	Sudbury	• Sector response officer • Air Attack officer	• Pilot	3
	Dryden	• Sector response officer • Crew leader 1& 2		3

Table 1: Roles and locations of interviewed operators (pre-design study)

Fire response simulation training

In order to gain insight about the process and the communication required for a fire response operation, a crew leader training simulation was arranged at the Dryden Sector office. The training simulation is usually used to train crew leaders for leading fire-fighting operations, through proper radio communication as well as appropriate response decisions. The researcher attended and video recorded the simulation, which was attended by one crew leader, one air attack officer, one pilot and one radio operator and facilitated by the sector office operator responsible for the training. The researcher received the script of the simulation as well as a fire diary to follow the procedure.

Ministry Handbooks

In addition, the researcher was required to complete the IMS 100 training[4] prior to the office visit, in order to understand the structure and command hierarchy of emergency response.

An SRO handbook and the AFFES response system presentation document were also provided for reference about the regulations and further understanding of the response operations process and requirements. And the AFFES Mapper software documentation was also provided upon request.

The findings of the pre-study were categorized into information about the environment, which includes the operators, tools and the physical environment and information about the process and about the team's situation awareness. The analysis of this information as well as the pain points determined and enhancements proposed are presented in chapter Four.

3.3 First Design Iteration: Verification and proposal evaluation

The aim of the first iteration was to verify the process analysis that was done in the informative study. This iteration focused specifically on understanding the information and display requirements for the response process and for the different response decisions, as well as confirming the data collection process. In the second phase, the enhancement proposals that were generated based on

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[4] Emergency Management Ontario: www.emergencymanagementontario.ca/english/emcommunity/ProvincialPrograms/IMS/Training/IMS_Training.html

the challenges and pain points observed and interpreted in the process were discussed with the operators in order to select one specific issue to address in the next steps of the study.

Analysis verification

Following the user centered design approach, the study aimed to involve the team operators as much as possible in the research and development steps of the design. Therefore it was important to have the operators verify the process analysis that was done after the informative study. A document that summarized the most important process analysis insights was created and sent to ten operators from the three locations (Table 2). The document used for the verification included a description of the purpose of the study and of the analysis, three diagrams about task analysis, one diagram about the team communication, two tables about the required information categories and four decision ladder scenarios for the four main operators in the response team (appendix 2a).

The decision ladders are diagrams that summarize the information processing and cognitive steps as well as the information required for completing the step (M. Endsley & Jones, 2011).

Dryden	Sudbury	Sault Ste Marie (provincial)
• Duty Officer • Intelligence officer 1 • Intelligent Officer 2 • Sector Response officer	• Intelligence officer • Duty Officer • Aircraft management of. • Sector response officer	• Duty officer 1 • Duty officer 2

Table 2: Operators participating in the first iteration of the study

The contacted operators were asked to check the document and the information presented in it. Phone interviews were set with each operator to discuss the analysis. The interviews ranged from 30 to 50 minutes and were guided by a set of feedback guidelines and questions to make sure all the diagrams and relevant points were covered (appendix 2b, 2c) Based on the feedback of the ten operators the analysis and the enhancement proposals were updated, the results are presented in section 4.2.

Proposals Evaluation

When the ten phone interviews were complete and the analysis and proposals were updated, another document presenting the six process enhancement ideas was prepared and sent to the same ten operators as a follow-up. However in this phase the operators were also sent a feedback questionnaire document (appendix 3) where they were asked to rank the proposals as well as provide feedback about them. The proposal ranking was based on selecting a system enhancement goal that they operators rank as the most important or urgent issue in their current process and tools. This selection aimed to fine-tune the purpose of the study and to serve as a guide to the development of the system and interface. In addition, it was an additional verification for the study's insights about the challenges in the response process. The results are presented in chapter 5.

Data Input process and design development

The ranking exercise revealed the facilitation of the data input process as the enhancement goal with the highest priority. Addressing this goal required further and deeper analysis of the information categories involved in the response process. This was done primary through an affinity diagram. An affinity diagram is a tool for organizing ideas and data. All the information categories were noted from the informative study and the process analysis and then categorized into information categories based on the operators' feedback as well as previous studies (Hueston, 2012). The information categories were attributed to the response process stages and additionally the sources of the information were noted in the diagram. The process and the diagram are presented in section 5.1.

The affinity diagram was used for the layout organization of the interface design of the proposed system. The review of design principles that have previously been studied for designing for emergency response and situation awareness (review in section 2.3), has also inspired many of the design features and solutions that were used in the development of the proposed design. These applications are presented in section 5.3.

3.4 Second Design Iteration: Preliminary model evaluation

The second iteration was intended as a preliminary evaluation of the proposed system. It focused on testing whether the proposed interface would improve the efficiency of the response process through a model evaluation. The model evaluation also provided a general insight for comparing the required working memory load with the proposed system to the current system. This insight helped in defining the stress points in the current response process. In addition, the evaluation served in detecting functionality and interaction style issues in the proposed interfaces as well as guided the design of the user evaluation (the third iteration).

The GOMS model evaluation

To address all the goals of the evaluation, a GOMS model evaluation was conducted. GOMS stands for Goals, Operators, Methods and Selection rules. The GOMS model, which was originally introduced in the 1980s (S. K. Card, Moran, & Newell, 1980), is a widely accepted analysis model in HCI research (Kieras & Arbor, 1994). It represents the procedural knowledge and action required to operate a system and considers physical, perceptual and cognitive actions (John, 1995). The GOMS model can be used at early stages in the design process quantitatively to predict system efficiency and performance time, as well as qualitatively to evaluate the design concepts (S. K. Card et al., 1980).

To conduct the evaluation, the open source software "Cogulator" [5] was used. "Cogulator" works through a basic text editor where linear or goal-specific operator syntax can be entered. It has 21 pre-installed operators with modifiable task times.

For the evaluation, 18 common response operation scenarios were created – for example updating a fire status report or adding a detected threatened value to

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[5] http://cogulator.io

the system. The scenarios were adapted from the response training simulation attended as well as the response process analysis within the pre-design study.

To compare the current system, which uses the radio and the DFOSS software, and the proposed system, a model was created for each use combination. This resulted in four models for each of the 18 scenarios:

(1) DFOSS and radio *(3) DFOSS and mobile interface and*

(2) Office interface and radio (4) Complete system (Office and Mobile Interface)

Using "Cogulator", the total time required for each model was calculated, and a graph depicting the switch between cognitive, perceptual and physical operators as well as the working memory load was produced. It is important to note that possibilities for human or technical errors, like mistypes, radio noise or misunderstandings, were not considered for any of the scenarios. The results of the model evaluation served as a guide for the development of the interface prototype as well as the user evaluation procedure presented in the next section.

3.5 Third Iteration: User evaluation

The third and last iteration of the research was the user evaluation, and it included the main interaction of the operators with the proposed design. The user evaluation was conducted at the Dryden and Sudbury offices. Over four days the system was evaluated by a total of 17 operators. Table 3 shows the roles and the locations of the participants. The sessions with each participant ranged between 25-40 minutes and were video-recorded with their consent (appendix 4a, 4b).

The user evaluation procedure aimed to assess the effectiveness of the interfaces for collecting all the required information for the response operations and its alignment with the response process. Furthermore it also aimed to evaluate the system's presentation of information and the situation awareness it provides about an incident. Moreover, the testing also aimed to provide feedback about the usability of the system through evaluation of the efficiency and understandability of the user interactions.

Tested interface	Dryden	Sudbury	Total
Office interface	2 Intelligence officers 1 Duty officer 1 Sector response officer 1 Radio operator	2 Intelligence officers 1 Duty officer 1 Sector response officer	9
Mobile Interface	4 crew leaders	4 crew leaders	8
Total	9	8	17

Table 3: Operators participating in the third iteration (user evaluation)

The user evaluation procedure was inspired from the guidelines for a heuristic walkthrough, a method that "combines the benefits of a heuristic evaluation, cognitive walkthrough and usability walkthroughs" (Sears, 1997). It is usually done in two phases; the first phase guides the participant through specific tasks, while in the second phase the participant is free to explore the interface in order to evaluate specific aspects of it (Mahatody, Sagar, & Kolski, 2010). The participants in this iteration have all been working at the ministry for a minimum of five years and were therefore considered experts of the domain. In order to asses the intuitiveness of the interface, the participants did not get any training with the prototype prior to the evaluation.

Afterwards the participants completed a questionnaire about their experience and perception of the proposed system. Table 4 summarizes the user evaluation procedure, which is discussed in detail in the following sections.

<table>
<tr><th colspan="2">Method</th><th>Tool</th><th>Purpose</th></tr>
<tr><td rowspan="2">Heuristic Walkthrough</td><td>Cognitive walkthrough</td><td>Interactive HTML prototype</td><td>- Assessing effectiveness
- Evaluating situation awareness</td></tr>
<tr><td>Heuristic evaluation</td><td>Usability evaluation sheet, guided by oral question; Interface prototype</td><td>- Evaluating system usability</td></tr>
<tr><td colspan="2">Questionnaire</td><td>Printed questionnaire; Printed interface screenshots</td><td>- User satisfaction assessment
- Users’ perceived value</td></tr>
</table>

Table 4: User evaluation methods, tools and purpose

Cognitive Walkthrough

The cognitive walkthrough was the first part of the user evaluation. It was designed to let the participants explore the interface through ten tasks (appendix 5 - ten tasks for office interface and ten for mobile), and to evaluate the effectiveness of the interface for the completion of those tasks. The tasks were inspired from the response process; they included tasks about inputting information about a fire or incident, and tasks to find information about an incident in order evaluate situation awareness. The cognitive walkthrough was completed using the interactive prototype, which is described in section 6.2.

The participants were asked to think-aloud while they interacted with the interface, while the procedure was video-recorded. Given that all participants were experts in their domain, their feedback and performance provided insight about the usefulness of system as well as the potential user experience. The evaluation of the cognitive walkthrough was guided by the four thought-focusing questions (Sears, 1997), described in table 5.

Label	Question	Interpretation
Understand	*Can users figure out what they need to do?*	Does the participant understand the task and how it relates to the interface?
Controls	*Can they find the controls?*	Was the participant able to find the information or buttons on the interface?
Complete	*Can they use the controls to complete the task?*	Did they participant successfully complete the task?
Feedback	*Does the system provide feedback that task/goal is achieved?*	Did the participant realize that he/she has completed the task?

Table 5: Thought-focusing questions for the cognitive walkthrough

The researcher used a nominal scale to evaluate the participants' performance for each of the above-described question for each task, resulting in 40 performance recordings for each participant. The evaluations recorded whether the participants were successful on their own (1), required longer time relative to other participants or the required completion time (2), needed assistance from the researcher (4) or were not successful (4). These recordings, in addition to the video-footage, were the main tool for analyzing the performance of the interface.

Verification of the evaluation

To verify the cognitive walkthrough evaluation, a different evaluator verified the evaluation scale of the researcher after the study was complete. The evaluator used the same nominal scale to describe the performance of 5 out of the 17 participants using the video-recordings of the study. The comparison showed a 76% agreement between the researchers and the evaluator's evaluation, resulting in a kappa value of 0.42, which is considered moderate agreement (Landis & Koch, 1977). The differences could be attributed to the evaluator's unfamiliarity with the process and the system or as an effect of observing through the recording versus real-time interaction. The evaluator's scale therefore did not affect the recorded performance of the researcher and served only as a validation for the method and scale.

Heuristic evaluation

After the participants completed the ten tasks, they were asked to rate usability aspects of the interface they were interacting with, as the heuristic evaluation. The prototype was available for reviewing during the rating. The usability aspects were explained in form of rating questions (appendix 6).

The questions were designed to address the following heuristics:

(1) Usefulness;	(2) Consistency;	(3) Simplicity;
(4) User control;	(5) Flexibility and	(6) Communication

The design the usability evaluation aimed to encourage a discussion. The researcher The rating scale for each aspect ranged from very bad, bad, neutral, good and very good.

Questionnaire

The last part of the user evaluation was a questionnaire for an overall evaluation of the participants' experience with the system (appendix 7). It also aimed to shed insight on the users' perceived value of the proposal to the response process. In addition to collecting information about the participants' experience at the MNR, the first part of the questionnaire included comparing the proposed system to the current system. Participants were also asked to rate aspects of the system that were not addressed in the usability evaluation.

In the second part of the questionnaire, participants were asked to mark on printed screenshots of the interface, the elements that they liked, disliked or would like to change. This part of the questionnaire served as confirmation for the usability evaluation as well as helped in the development of the specific elements of the interface in the final design.

4. Results of the Pre-design Study

4.1 Observations and Interview results

The observations and the interviews of the informative study were conducted in the operators' work environment and during the usual daily workflow. The observations focused on understanding the physical environment and the work dynamics of the team members. In the interviews the operators described the daily work process from the perspective of their role within the team.

Guided by the interview questions (appendix 1) they also described and presented the tools and software that they use to complete their tasks. They were also encouraged express any challenges that they experience in their process and describe their ideas and wishes for improvements or changes. Through the informative study at the sector, regional and provincial response levels, the researcher was able to gather an overall outline of the information and communication flow during the forest fire response operation and the preparation for them. In addition, the researcher attended an incident commander training simulation provided insight about the communication dynamics and the information exchange process between the field and the headquarters.

Overall the forest fire management centers are responsible for planning as well as executing the appropriate response to forest fire incidents in the province. This is done by following the standardized approach for emergency management; the Incident Management System (IMS)[6]. In addition, the province is divided into an east and west region, with each divided into 6-7 sectors, for more convenient resource management and response. Each region is operated by a regional response office (ROEC), which reports to the provincial response office (MOEC). And each sector is operated by its own headquarters to manage its resources and bases.

The following section presents the general overview of the response process as well as communication and information exchange tools in the forest fire management offices of Ontario. The outline focuses on the most important pain points and challenges in the process that offer space for improvement. This space for improvement was the subject of the enhancements proposals that were evaluated in the first iteration of the research.

4.1.1 Environment

Operators

Team members work in 3-4 days shifts, usually alternating between two people for every position. Crewmembers have a maximum working period of 19 days including travel days. Figure 3 presents the organizational structure of the team members on the regional level. And the following is a short description of the roles of the main response operators:

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[6] www.emergencymanagementontario.ca

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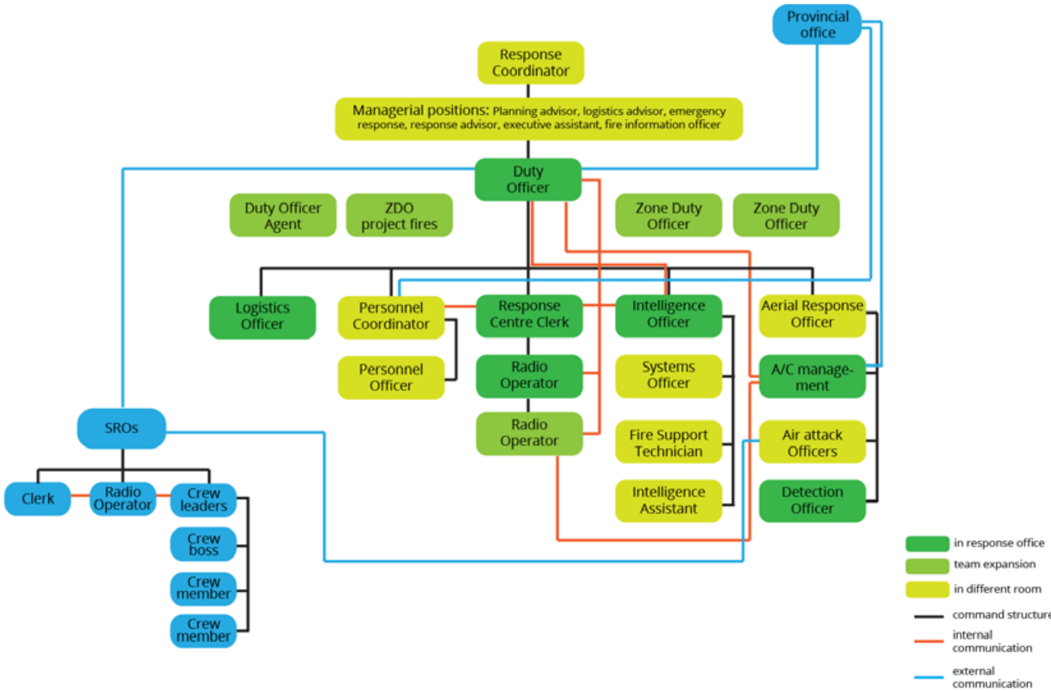

Figure 3: Regional organizational structure

a. Duty Officer (DO):

Duty officers are the leaders of the response operations on the regional level. They are responsible for the final decision making for resource availability and preparedness as well as communication with other regions.

b. Intelligence/ Planning Officer (Intel.):

They propose the daily preparedness level of the team and prepare the fire intelligence worksheet, weather briefing and daily Strategic Operation Plan (SOP). They are responsible for monitoring the weather and fire weather behavior as well as track prediction performance of the season.

c. Aircraft/Aviation Management Officer (AMO):

They are responsible for Aircraft preparedness and dispatch for fire attack and detection operations. They provide dispatch information and follow up to pilots.

d. Radio Operator:

Radio operators are responsible for all communication with MNR aircraft; dispatch information, scouting reports, fire updates and fire attack plans. They facilitate communication between incident commanders and the SRO or between the pilots and the duty officers.

e. Sector Response Officer (SRO):

They are the leaders on the sector level; they plan for and coordinate response operations in their respective sectors. They provide crew leaders with daily briefing and are responsible for crew and helicopter dispatch and approve the attack action plans.

f. Incident Commander:

The first crew leader arriving to the fire location is appointed the incident commander, and is only replaced if a leader of a higher rank is required for the operation. They are responsible for creating the response action plan and communicating scouting and fire reports, resource requirements and time objectives to the sector office.

Tools

The response office has a variety of tools of different technological levels to allow the team members to get a comprehensive overview of the situation in the region or sector. These tools include displays showing weather forecasts and regional maps showing resource locations. All offices also include a room-wide magnet map of the region response zones. The operators update the map to ensure it shows the latest the locations and alert levels of resources as well as burning fires. In addition, operators have access to the database through their own desktop computer. Most operators also have two displays to follow-up on several issues or events.

Information and database required is accessed through the Fire Management Information System (FMIS). FMIS gives access to fire reports, area information database and aircraft and personnel information. The specific applications are discussed below.

a. AFFES (aviation, forest fire and emergency services) Mapper:

Mapper is a web and GIS-based mapping tool that supports daily planning and response operations in Ontario. It serves as a hub for different services and region information. The software has been used in the offices since March 2014. The software is used for resource tracking (Figure 4) as well as accessing environment, weather and area information. Mapper is used in the response office as the main tool for maintaining the general situation awareness of the region.

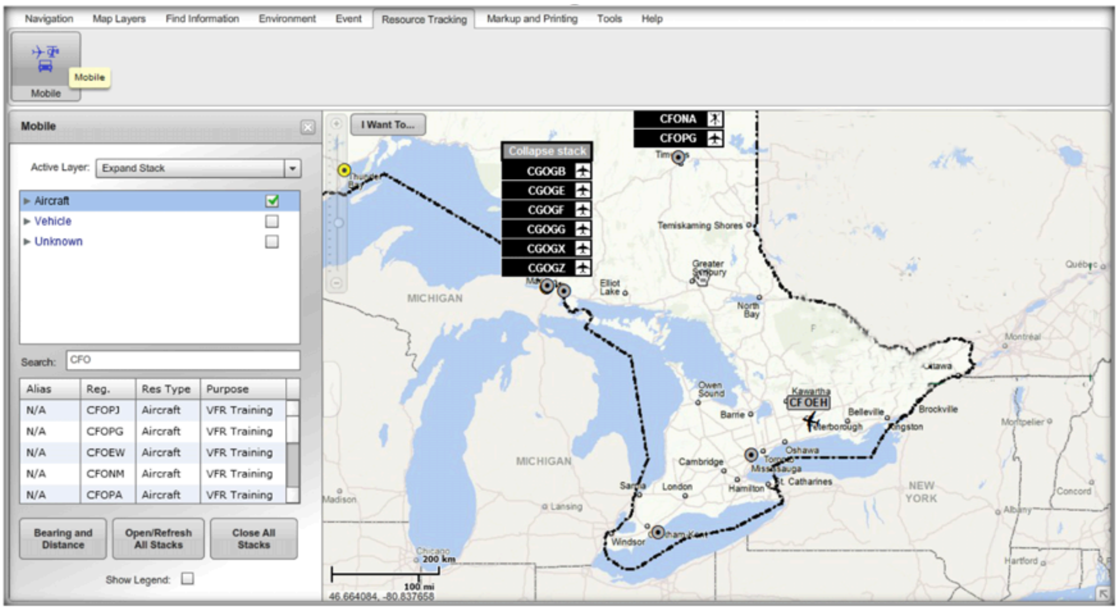

Figure 4: Mapper resource-tracking display

b. Daily Fire Operating Support System (DFOSS):

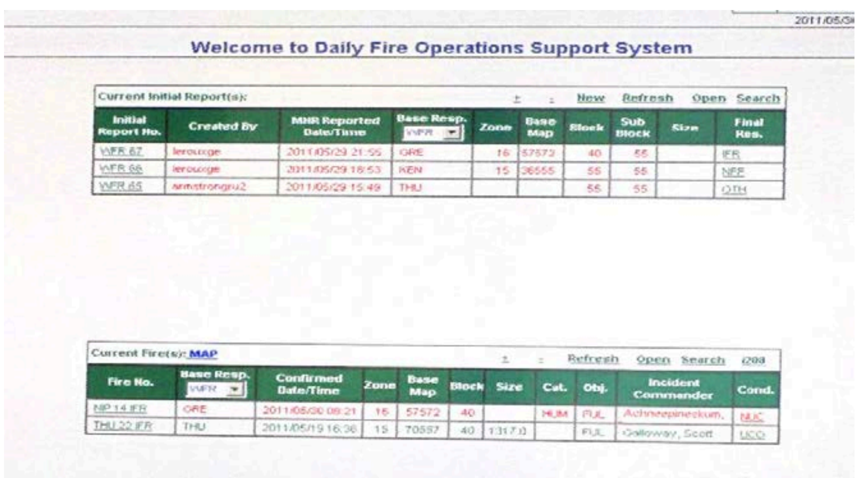

Figure 5: DFOSS initial report and burning fire lists

Through displaying list of incidents reports and confirmed fires (Figure 5), DFOSS gives access to updating information about suspected fires as well as burning fires in the region. Until a fire is confirmed by an MNR crewmember, it is considered an incident. Once a fire is confirmed and has been burning for a day it is moved to the current fire list.

DFOSS is the main tool for documenting fire information. It is used to create initial reports about suspected fires as well as update fire information about burning fires (Figure 5 & 6). Detailed fire and response information are updated on DFOSS for documentation and is the main tool for communicating updates to the rest of the team and the regional teams if necessary. Fire information and updates are communicated by the crew on the fire through the radio operator and entered by office operators into the system.

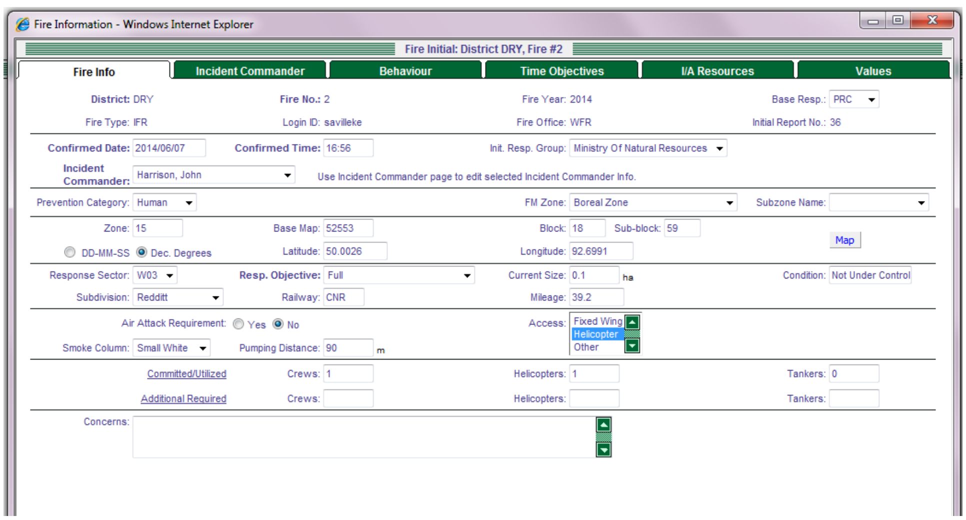

Figure 6: DFOSS initial report form

During a fire response operation, information about the development of the fire and its status need to be entered in a timely manner for appropriate decision making as well as documents for cost calculation in after-action reviews. Additionally, resource and crew getaway times need to be recorded for managing suitable working times for each.

c. Fire diary

The incident commander uses the fire diary (Figure 7) for gathering information about the fire. It includes some instructions on the necessary steps for fire assessment and communication as well as the essential elements to look out for in an attack operation. Most of the information documented in the fire diary is also communicated to the SRO through the radio operator, and in addition the fire diary is used for reviewing in after-action reviews.

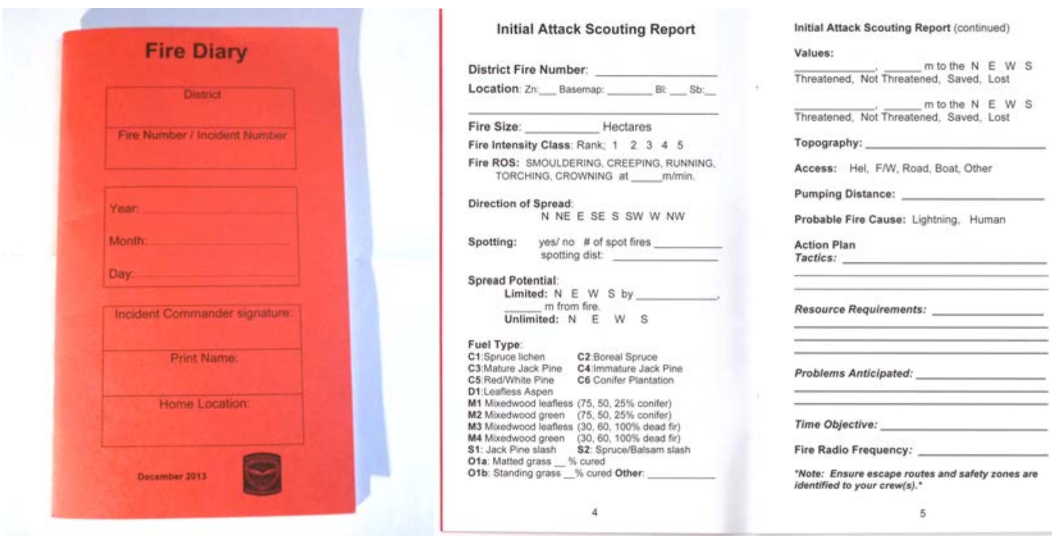

Figure 7: Fire diary, scouting report pages

Additionally, several briefing documents are exchanged throughout the day between regional and sector offices for team preparedness measures and potential response strategies. These documents include weather briefings, the strategic operation plan (SOP) and information about crew and resource availability and alerts in the sectors' TIPs (Tactical input plan).

Physical Environment

Each of the response offices visited had a different arrangement (Figure 8). Team members agree on their most preferred arrangement to facilitate communication and working together. All the desks and screens are arranged in a way that allows all team members too see all the common screens as well as all other team members in the room. Most commonly the desks were arranged in a circular way in the center of the room. Radio operators are situated in close adjacent rooms with glass separation.

Figure 8: West regional response office (top); East regional response office (left) Sudbury sector office (right)

4.1.2 Process

Like other emergency response processes, forest fire management follows a plan-based approach that relies on pre-incident preparedness (Chen et al., 2008). Daily preparedness measures are based on the number of fires and weather predictions. Accordingly, resource alerts throughout the region are planned. Figure 9 shows the dynamics between preparedness and attack operation as well as the operators and teams responsible.

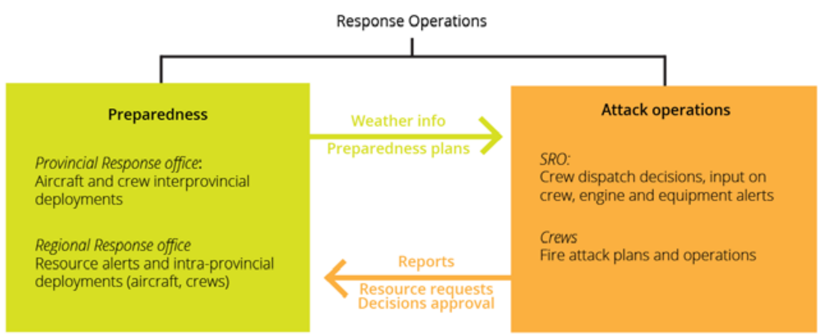

Figure 9: Division of Response Operations

Figure 10 shows the process during a fire response operation that begins with the reporting of an incident or a suspected fire. The report can come through a public call or through the MNR detection pilots. Information is constantly updated manually into the system while dispatch and fire attack operations are managed and monitored by different operators. The diagram also shows the different tasks and responsibilities of the operators during a fire response operation. The task analysis shows the importance of continuous updates and communication between the team members for successful response.

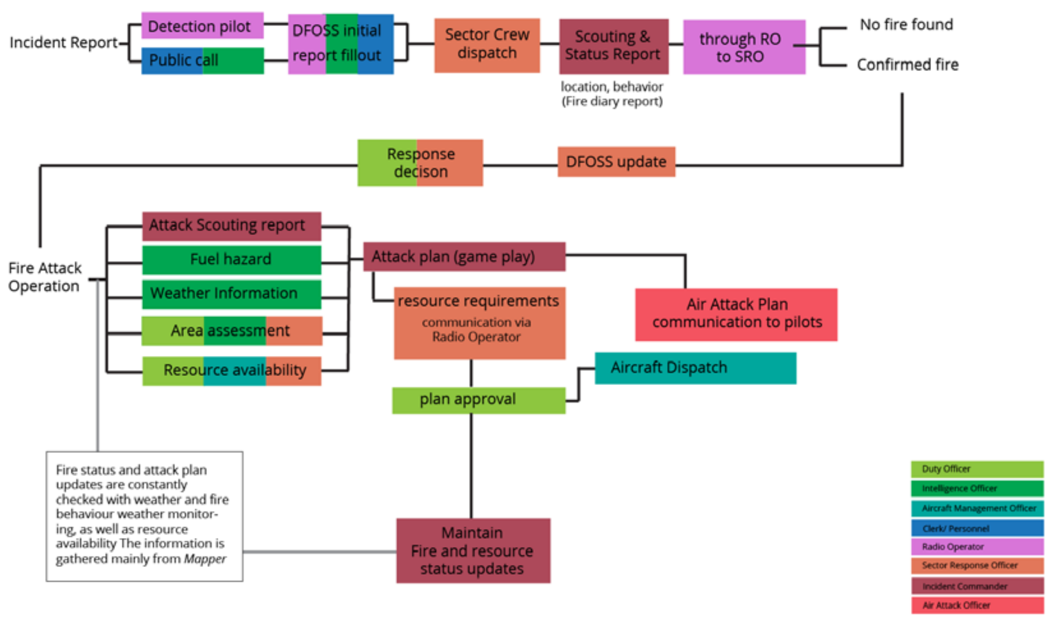

Figure 10: Task analysis during a fire response operation

4.1.3 Information Flow and Communication

All team members reported that the most important tool of communication is verbal. Depending on the location of the operators, the verbal communication is either face to face, over the phone in a conference call or through the Radio Operator -if during a fire attack operation. The offices are therefore arranged to facilitate verbal communication within the room. For less urgent requests or updates, emails are used between operators in different offices or locations. Emails are also used to communicate important documents like the SOP and the TIPs.

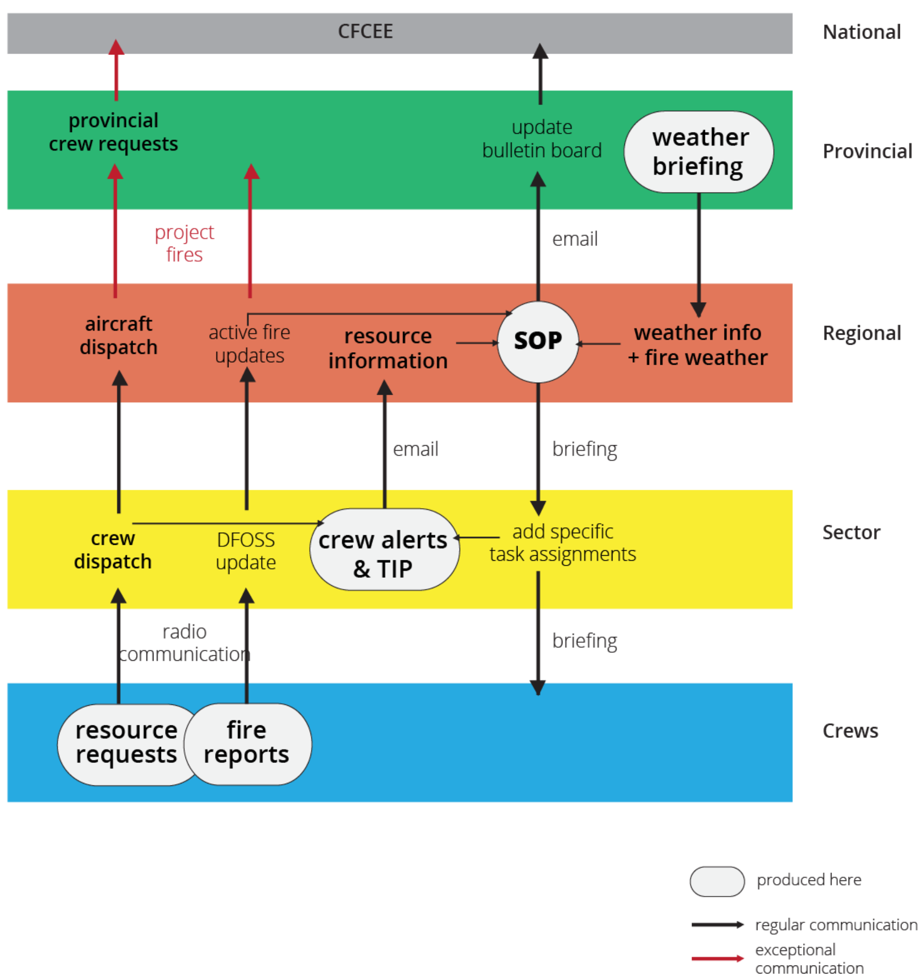

Figure 11: Vertical communication between response teams

A weather briefing is conducted by the weather specialists from the provincial office twice everyday. This briefing is the main tool for keeping all response operators up to date and informed of weather forecast and developments.

During fire operations, DFOSS and MAPPER are updated to communicate information about fire updates and resource commitments or locations. Figure 11 summarizes the information distribution and communication channels between all levels of response. In addition, several individual operator scenarios and decision ladders were analyzed (appendix 2). The analysis focused on understanding the information required for each step and each decision and the source of this information. Figure 12 presents a summary of the analyzed scenarios.

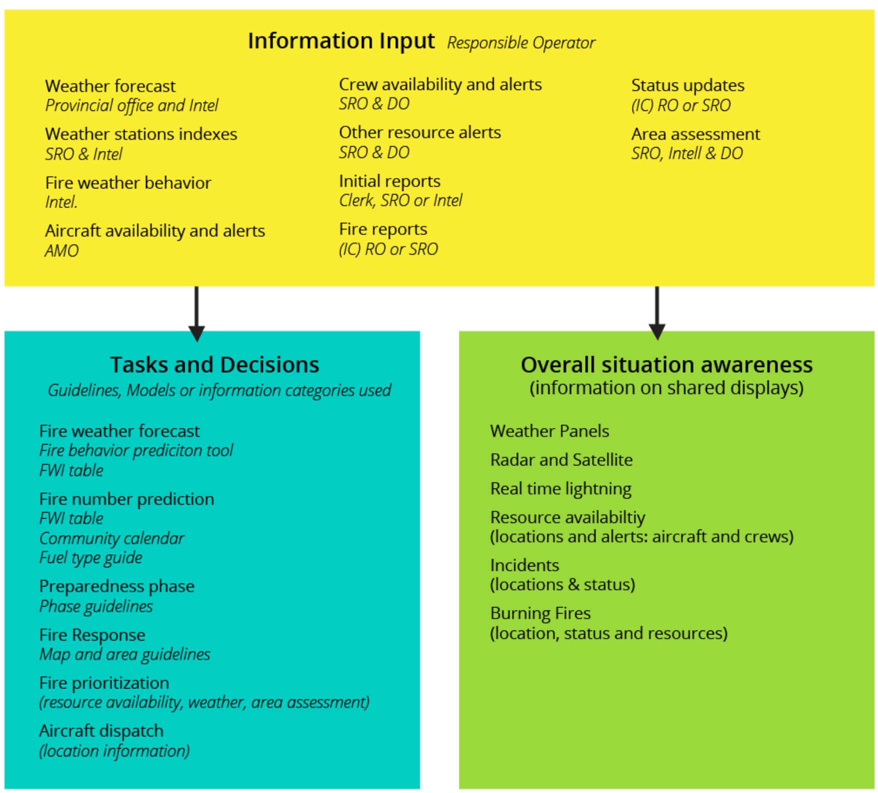

Figure 12: Overview of information flow

The information categories are divided into required input and the operator responsible for providing it, and the required information presentations that are produced. This analysis was the base of the researcher's understanding of the communication and information flow in the response office.

4.2 Summary and Conclusions

Given the described dynamics of the response team, it was concluded that within the response office and during the response operations, each team member is responsible for a specific decision and task and requires specific information for timely and accurate completion of those tasks. Each operator needs to maintain an overall awareness of the general situation while focusing on his or her individual responsibility. In most processes, the operators' tasks and decisions are interdependent and heavily rely on timely and accurate input, communication and distribution of information. The following pain points were concluded from the observations as well as reported by the operators.

4.2.1 Pain points and challenges

Several operators explained that although there are a lot of available tools to keep a good level of SA within the team, there is reluctance by team members to use the tools and the system regularly. Furthermore, there is a major reliance on verbal communication. This can be attributed to the complexity of some of the tools and the level of training required to use them. Moreover, the tools don't seem to be properly integrated and linked for quick and efficient updates. In situations of stress and high risk, verbal communication is found to be faster.

Another challenge faced by the operators (Table 6), especially in an emergency situation is the collection of valid and accurate information. More specifically, the issue lies in the fact that information from crewmembers regarding the fire is communicated through the radio operator to the SRO. This does not only cost time, but the reliance on notes and verbal interaction makes the communication vulnerable to errors, misunderstandings and delays.

As previously explained each team member requires specific information, input or guidelines for completing their role-specific tasks. With the current tools and process the operators have to search for the information needed among all sources (DFOSS, MAPPER, weather websites, handbooks, maps, etc.). This also can sometimes cause delays in critical situation. Additionally, most of the processes require a lot of training and experience, and although guidelines, models and handbooks are available and well prepared, they are not integrated into the tools used for quick and easy access.

Process Challenge	Enhancement proposal
Reliance on verbal and Radio Communication	(1) and (3)
Retrieval of information from different sources	(2) and (4)
Shift changes	(5)

Table 6: List of process challenges showing corresponding enhancement proposal from section 4.2.2

Other challenges include the 3-4 days shifts of operators; in order to have 7-day emergency response, a system of staggered shifts is implemented. This requires team members to manage systems for smooth shift changes and updates. One of the tools used for that are the operators' logs where they have to keep written notes of all events of the day. This shift change however could interrupt the process, especially in times where a lot of follow up on several fires is necessary.

4.2.2 Enhancement proposals

The above-described analysis concluded that the existing challenges could be addressed through facilitating the interaction with existing tools and databases rather than radical changes in the process. Based on this analysis, the following high-level system enhancements were proposed:

(1) Facilitate Data Input

A lot of the information needed to maintain situation awareness is highly reliant on the operators' manual input of data (Figure 10). Therefore the system interface should facilitate information input of incident and fire reports as well as resource information.

An efficient interaction with the system can help in decreasing reluctance and delay of operators to update required information. This should improve the overall team situation awareness (TSA) through enhancing the speed and quality of information collection.

(2) Accommodate operator specific tasks and process

Customizable dashboards to accommodate operators' specific needs (M. Endsley & Jones, 2011) could serve as operator-specific hubs for collecting information. They could include shortcuts to frequently used software, databases or models.

(3) Facilitate team activity awareness and communication

The system could accommodate team communication through document sharing, messaging or conference call tools. It could also provide information about team members' activities (J. Wallace, Ha, Ziola, & Inkpen, 2006), like location and task completion, according to process needs.

(4) Accommodate interaction between operator and team displays

The interface should allow operators to maintain the overall situational awareness through the team displays without interrupting their specific tasks and processes (Röcker & Magerkurth, 2007). Notifications or alert systems can be integrated to make sure operators are aware of important updates and situation developments and to avoid attention tunneling (M. Endsley & Jones, 2011).

(5) Facilitate operator shift changes

Team members coming into an emergency situation need extremely quick and efficient updates on the most important developments and incidents. This is especially important because these updates are usually provided by the operators working the previous shift. Thus, to smoothen the transition between shifts, the system should provide an organized notes tool that facilitates prioritization and links notes to information sources and reports.

(6) Accommodate operators' activity and updates log

Operators are required to record all updates and activity in a logbook, that could be later used for situation and decision assessment. Operators also use it to keep track of situation developments. The system could provide operators with a secured log that facilitates search within as well as offer cross-referencing if necessary.

Given the scope of the research, the proposed interface focused on only the proposed enhancements number 1. The above listed concepts were presented to the operators for them to prioritize. The results are presented in the next chapter.

5. Verification and proposal evaluation (First iteration)

In the first part of this iteration, the process analysis that was presented in the previous chapter was verified by operators who have been part of the pre-design study. A document summarizing the analysis was sent via email one day prior to the scheduled phone call.

In the phone interviews, the operators were asked to verify whether the analysis captures the process appropriately. And they were required to report any modifications or additions they think are necessary.

Overall the feedback from the interviewed operators about the accuracy of the presentation and analysis was positive. All operators agreed division between preparedness and response operations that was presented as well as the general flow and sequence of the tasks (Figure 9 & 10). The modifications that were suggested by some were related to the specific roles of the operators and team members and the software or information source used for completing some of the tasks or responsibilities. It is important to note that some of these comments were due to the slight differences in the process between the different regions and offices.

After all ten operators were interviewed; another document with the modified analysis was sent. This document included the summary of the challenges as well as the enhancement possibilities proposed by the researcher (see chapter 4.2) and a questionnaire. Nine out of the ten operators sent the feedback sheet back with comments about the detected challenges and with their subjective ranking of the high level system goals.

The comments included their perceived explanations for the challenges. For example one operator describes that “as soon as we get busy we revert back to our old ways and circumvent the system by taking short cuts”. Another explains that one of the reasons for the tendency to rely on verbal communication “is the need not only for valid and accurate information but to get that information in a timely manner”. One of the provincial operators also reports that the challenge is not just “collecting the information but in distributing the information”. These comments confirm the results of the high level ranking which are presented in Table 7.

Facilitate Data Input	1. 78	1
Facilitate Team Communication	2.67	2
Accommodate Operator Specific Tasks	3.22	3
Interaction between operator and team display	4	4
Operators activity and update logs	4.56	5
Facilitate shift changes	4.78	6

Table 7: High level goals ranking

Table 7 shows that the operators ranked “facilitating data input” as the most important enhancement goal for the system. “Facilitating team communication” was ranked in second place, referring to previously mentioned comment about the distribution of the information. This ranking exercise was the guiding tool for confirming the focus of the research and developing the design solution. As the issue with the highest priority, the study focused on enhancing the data collection and input process. Its importance also stems from it being the base step for the response operations and the foundation for the team's situation awareness (Figure 1, section 1.1)

5.1 The Data Input Process

Although the current tools offer the required functionalities for updating information and maintaining situation awareness, the comments and feedback from the operators shows that there are several problems with these tools.

For example the preference of verbal communication could be due the usability of the current tools. Quick and easy input interactions are not well supported. In addition some of the operators reported mistrust in the timely distribution of the information to other team members. One of the reasons is that operators don't receive any alerts when information has been updated and have to make sure to check regularly. In several cases, like with the personnel database and DFOSS, different information categories need to be updated on different tools that are not automatically linked together.

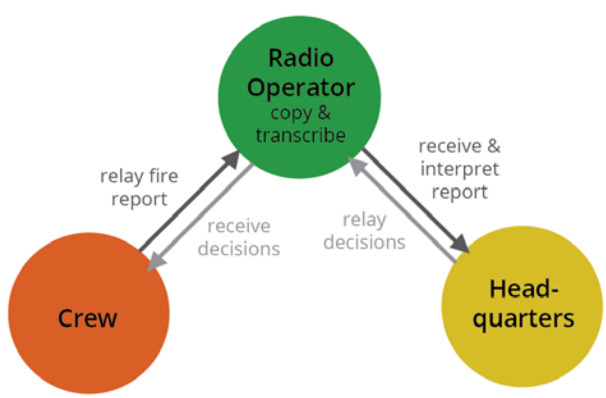

Figure 13: Radio Communication channel

This means that operators need to update the information several times, which is redundant and time-costly in emergency situations. Additionally, the tools don't offer interactive or intelligent data input, but rather passive fill-in interfaces.

Another major issue with the current tools, which was discussed in the previous section, is the crewmembers' disconnection from the databases and system. All information is communicated from and to the crew through the radio operator; this lengthens the crews' link to the headquarters, as shown in Figure 13.

In addition, the crews don't have a medium for any visual information or cues about the area, surroundings or the response operation. Information about values near the fires and approaching resources also has to be communicated via the radio. These results and comments served as the guide of the research direction towards attempting to facilitate the data collection, documentation and distribution process. This facilitation would be valuable specifically during fire response operations when operators are busier and more stressed.

The input of information is a critical issue for maintaining situation awareness. In many emergency response scenarios, timely information availability is critical for response decisions and action plans. This means that the input process should also be designed to facilitate the presentation and distribution of the information simultaneously (Borth, 2013). Even though the input of information is usually an ongoing process for continuous preparedness of the team, the more critical part of the process is the information flow between the field and the headquarters during an emergency. Therefore, this research aims to propose an interface that supports quick and efficient data input. This will serve as a first and crucial step for maintaining the required level of situation awareness.

Further analysis of the sources of the information as well as their communication and distribution was therefore conducted for establishing the interface design requirements.

Table 8 summarizes the main information categories that are required during a fire response operation. It shows components of each category as well as whether the information is usually inputted from the office operators or the crewmembers on the field.

	Information from the Response office	Information from the Field
Weather	Weather warnings (Forecast from preparedness phase)	Wind
Resources	IC assignment Radio frequency	Aircraft, crew, engines: Arrival, attack and getaway times, types
Area Assessment	Values	Fuel type Distance (access) Values
Fire Information	Location reported information	Fire Behavior: Spread, intensity, depths Scouting reports (fire diary) Area sketched (mapping) Fire cause
Response information	Recommendation for required response	Time objective Status reports

Table 8: Sources of Information categories during a fire response operation

In the next steps, more detailed information types were explored. These were collected from DFOSS fire information displays, the fire diary as well as the

Canadian Wildland Fire Information system[7]. According to the observations, interviews, feedback and previous research (Hueston, 2012), this information was classified into categories through an affinity diagram. An affinity diagram is a useful tool for sorting large amounts of data into logical groups. The tool also helped in prioritizing the information and served as a guide for the interface organization and structure.

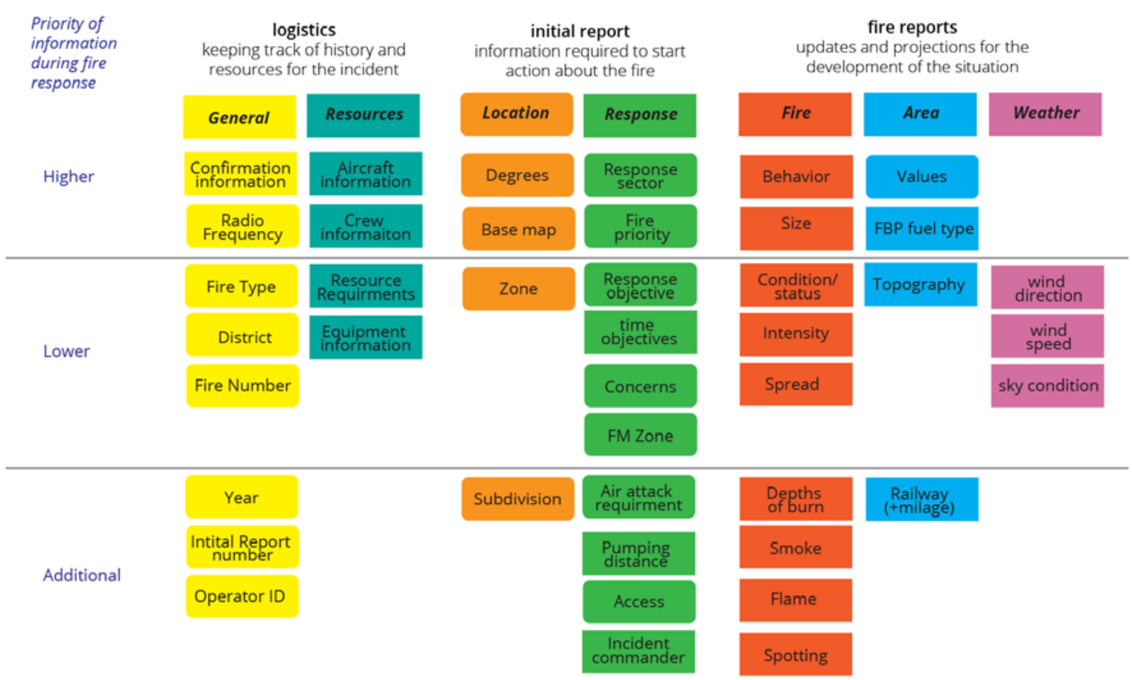

Figure 14: Final affinity diagram showing categories and prioritization

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[7] http://cwfis.cfs.nrcan.gc.ca/background/summary/fbp

The information categories were further investigated for understanding their function within the fire response process:

General: The majority of information within this category is generated automatically by the system when a new report is saved.

Location: When a call about a suspected fire is received the response office operator gathers as much information about the location as possible to search for and locate the fire. The exact location of the fire is only determined when the first crew reaches the actual location.

Response*:* This category is about the type of response recommended by the response office based on the information collected about the fire. The information within it is decision-related rather than observation-related and therefore are dependent on other information. The decisions are usually based on the location of the fire as well as resource availability.

Fire: This information is updated from the crew on field. The elements within this category are also updated frequently (changing parameters) especially with every new status report.

Resources*:* This information is needed to keep track of the hours of resources at the fire. It is used to maintain awareness about resource availability throughout the development of the incident as well as track working hours of crews.

Area*:* Contains a variety of information about the area around the fire, some of it can be determined through the location.

Weather*:* In addition to the weather forecast, specific weather conditions in the exact location are used to make decisions about the response and resource needs.

As a result, some relations (Figure 15) between the information categories were established. Even though there are more complex links that can be determined, for the design of the interface only ones are not situation - or variable specific should be taken in consideration, for the interface to be as adaptable and compatible as possible.

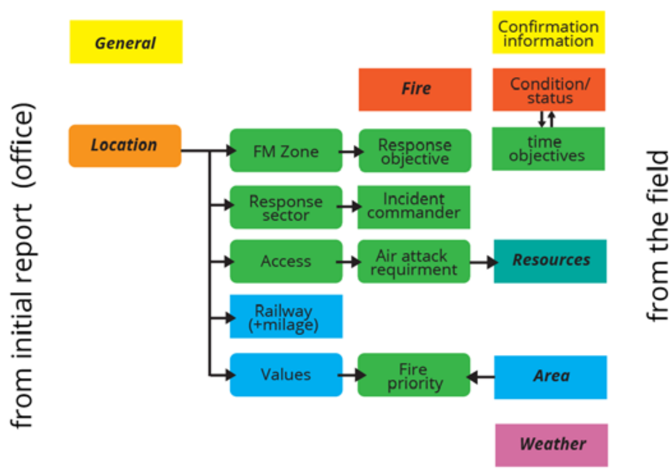

Figure 15: Relation between some of the information categories

These relations were used to generate auto-fill possibilities in the proposed interface, in order to facilitate and speed up the input process. Such auto-fills can be especially useful for location information and the response information related to it. The affinity diagrams, along with the information flow and categories analysis were the basis for the design proposal presented in the next section.

5.2 Design Proposal

The analysis of the sources of fire information shows two distinguished sources of information; the crews' notes and observations on the fire and information retrieved from databases and maps at the headquarters. This organization follows the previously discussed structure of command and control teams (Salas et al., 2001). Hence, the system should accommodate the possibility for data input from both locations and sources. This can ensure the continuous updating of the development of the situation and allow for the different teams to complement each other's tasks and decisions. Therefore, two different interfaces for the two environments are therefore proposed. The two interfaces are complementary and both should feed inputted information into the same system used by the response operators.

The design concept is to create an interactive integrated system that facilitates communication between headquarters and crew through real-time updates and notifications (Carroll et al., 2003). Although radio communication should still be used for unusual updates, the proposed interface should function as the main channel for updating, distributing and documenting fire response information, including fire, area and resource information. Although the main goal of the proposed interfaces is to facilitate the data collection process, through a usability- and process-oriented design, it also aims to support situation awareness through a clear and organized data presentation.

In addition, the design proposal supports the multitasking requirement in emergency response (Mcnab, 2009) & (Pousman & Stasko, 2006). As observed in the study, all operators use at least two different personal screens in addition to the large team displays around the response office. The proposed interface would allow operators to monitor one single fire or incident through one window only. This will facilitate following up on different incidents or events at the same time. This also means that the proposed interface would likely fit smoothly into the existing office arrangements and hardware requirements.

5.2.1 Response Office Interface

This interface will be used at the headquarters (sector office) and the regional office. It should be linked to the databases and other software currently used (MAPPER, PIMS), but will focus on summarizing the situation around one single incident or fire instead of an overview of a sector or region. It aims to give the operators access to all information related to the chosen incident, including:

- fire information
- resource information area information
- overview of the updates and history since the initial incident call

To minimize the navigation required for updating information, the same interface is used to view and update information. The office interface should also facilitate quick creation of new incidents from public calls with enhanced location search functions.

Following the dashboard design approach, the office interface summarizes all the information about one fire on one screen (Few, 2006). As opposed to the currently used DFOSS software where resource, fire and area information are found on different screens and where operators need MAPPER for visual presentation, the incident or fire can be monitored at a glance.

5.2.2 Mobile Interface

As discussed in section 2.3.4, direct data collection from the field has several advantages (Baber et al., 2007). This proposed interface would be used by the crew leaders on the field for updating information and also as a tool of visual communication and awareness about the fire situation. It should therefore be designed for mobility and used on a tablet device suitable for the environment. In order to be suitable for stressful and fast-paced environment, a touch interaction style was chosen.

The interface is directly linked to the headquarters' system for real-time updates. The connectivity will also link the crew to the headquarters' databases and other information, such as the weather briefings and recorded values, which has the potential to improve the crews' SA (Chittaro et al., 2007). Further developments should also link the crew with MAPPER databases and integrate geo-collaboration functions (Resch et al., 2007) for visual and map-based communication.

The specific design approaches and functionalities, presented in the following section, have been integrated into the proposed design to improve the process as well as situation awareness.

5.3 Interface design

The structure of the interface was based on the information categorization presented in the affinity diagram (section 5.1). The wireframes presented below follow the same color-coding as the previously presented diagram. For the full interface see appendix 8.

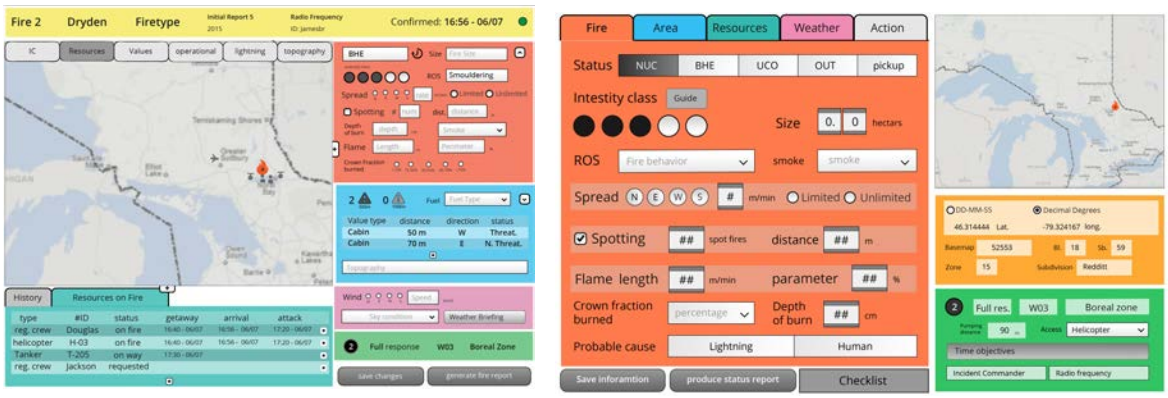

Figure 16: Color-coded wireframe for the fire monitor from the office interface (left); and the Fire information tab from the mobile interface (Full design in appendix 8)

The interface design follows the principle of team displays; it provides the required information about the often-complex situation as well as the team members in an integrated and accessible way for completing the emergency response and command and control tasks (Parush & Ma, 2012). In addition several design principles have been applied and are described below:

Information Prioritization

Based on the pre-design study (section 4) that was conducted to understand the operators' working process, needs and priorities, the information was organized and prioritized to follow the fire response process (M. Endsley & Jones, 2011) and (Burns et al., 2007). For example the mobile interface shows the fire information as the main tab, as it is the most frequently updated and important information (Figure 16 left). In addition the fire and area information panels in the response office interface were designed to display only the most important information, with the possibility for expanding the panel to view more detailed information (Figure 17). This helps in reducing the clutter and the data overload as well as supporting both “quick overviews” and detailed inspection (Parush et al., 2015).

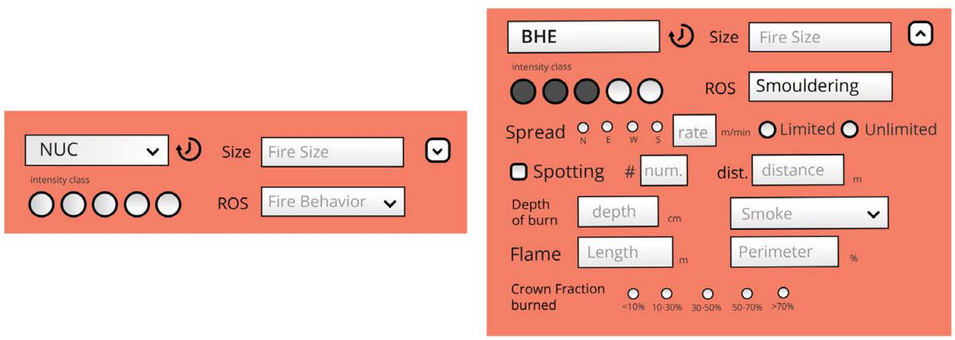

Figure 17 (left) Basic fire panel with expansion button in the top right corner; (right) expanded fire panel showing more detailed information

Furthermore information with high priority for headquarters’ operators are visualized and presented in different ways to ensure universal usability. For example, although the resources’ location, and status are shown on the map, the interface also shows a list view (Figure 18) of the resources committed to the fire, as each representation has a different value to the operators’ perception (Jiang & Hong, 2004).

Figure 18: Panel showing list of resources committed to the monitored fire

5.3.1 Intelligent database and decision support

The response interface could also function as an intelligent agent to aid in optimizing information processing (Tsou & Buttenfield, 1996). This approach is applied in a number of aspects of the proposed design.

Initial report location and response information

One of the aspects applying the intelligent database feature is the location and response information for an initial report. An initial report is entered into the system when an operator receives a call about a possible incident from the public or any pilot. The operator tries to gather as much information about the fire and its location from the caller as possible. Getting an accurate location for the incident is usually the biggest challenge but also most important part of the report. Based on the location as well as some area information, retrieved from both the caller or from the database, some response decisions are made. The interface is proposed (Figure 19) to fill in the information based on history and database information automatically when the location is determined.

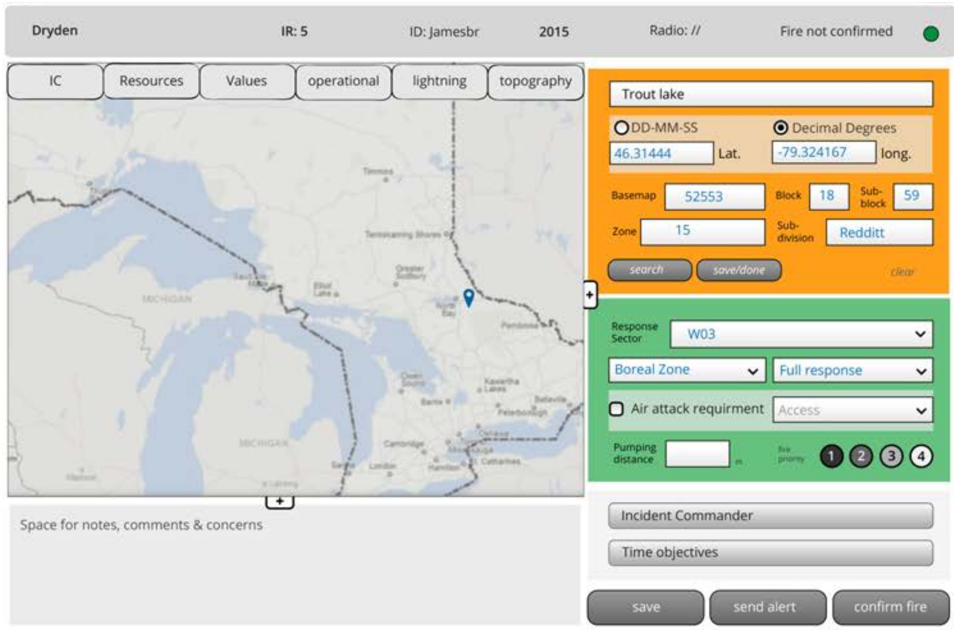

Figure 19: Initial report, location and response information are automatically filled based on location pin

The operator, whether the SRO or a detection officer can modify the suggested response information as they see fit. When enough information is collected about the location and the response requirements an alert is produced with dispatch information to send out a crew. This automation has the potential to save a lot of search time for operators. However, none of the response decisions should be finalized without the operators' confirmation. A similar feature is also proposed for the value detection around the fire. Based on the value database available in Mapper and from the ministry's resources, distance information should be automatically updated. In further development of the interface, the status of the value should also be computable through the fire information provided (Feature is discussed further in section 8.2).

Recordkeeping

Another feature proposed in the system is the automatic recording of events. Whether they are updated from the crew or from office operators, the device network time settings should be used to document the updates for record keeping of the fire and resource information (Figure 23). Through this feature, the history of the incident development is saved, to be clearly recorded, presented and accessed (Figure 22).

5.3.2 Information visualization and dashboard design principles

The proposed interface aims to support operators information perception and processing. Several design principles of information visualization have been applied (section 2.3.1).

Information grouping

The wireframes of the information (Figure 16) show related information visually grouped in order to ease navigation and searching for information (S. Card et al., 2009).

Visual Cues

Additionally, the visual presentation of most information on the map through interactive icons (Figure 20), offers a compact and accessible summary of the fire (Chittaro et al., 2007).

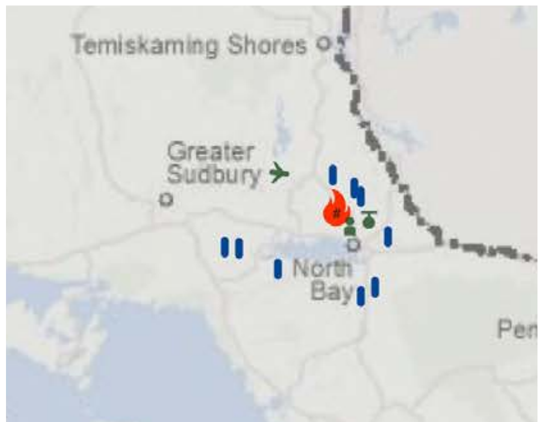

Figure 20: Resource and values icons showing on map

Visual cues have been subtly applied to guide the operators' attention. Examples of such applications are the fire intensity class and the threatened values icons (Figure 21)

Figure 21: Fire intensity class controls (left); Threatened values icons (right)

The history panel, where incident-update-history is recorded, shows an interactive timeline (Figure 22). This timeline helps in recognizing the time gaps between the updates and offers a summary of the development of the fire.

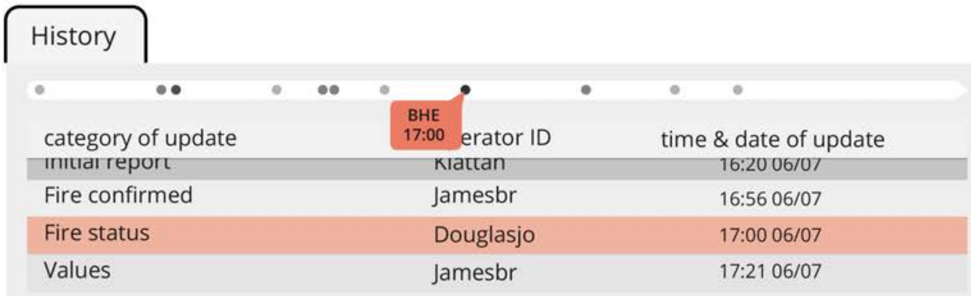

Figure 22: History Panel with interactive fire updates timeline

5.3.3 Features of the Mobile Domain

As previously discussed, the purpose of extending into the mobile domain is primarily to allow direct information input from the field and to avoid the communication loop or radio communication (Figure 13).

When a crew is dispatched in response to an incident report, they are provided with a device that has the mobile software ready. As a first step, the crew leader, who is usually responsible for communicating and recording scouting reports and fire updates, should login and select the incident that his or her crew is dispatched in response to. This leads to the dispatch screen, which shows the location and response information of the incident.

Once the crew arrives at the location, they can either confirm the fire or declare that there is no fire found. If the crew leader confirms a fire, the updated location is detected by the device and automatically recorded as part of the fire report.

GPS, time and network settings of the device are generally used for more accurate recording of information, like resource tracking and time recording (Figure 23) .

Figure 23: Mobile resource record keeping tab

In general, the fire update screen of the mobile interface works as a hub for all the information about one specific fire (Figure 24). The crew leader can update fire, resource, values and weather information as well as easily view the updates recorded by operators at the headquarters. This way noise and risks of verbal communication can be avoided (Baber et al., 2007)

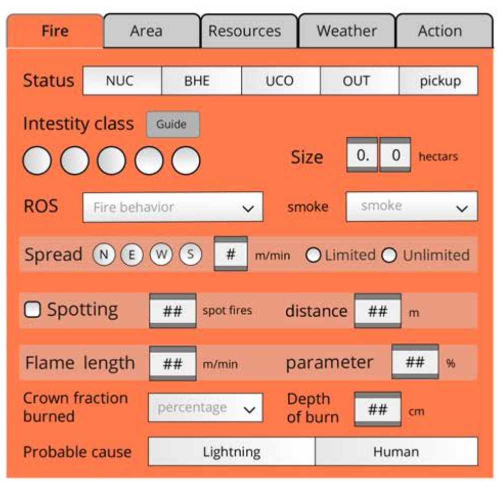

Figure 24: Mobile Fire information tab

In addition, the connectivity of the device gives the crew access to information required for the response operation (Chittaro et al., 2007), such as the most recently updated weather briefing (Figure 25).

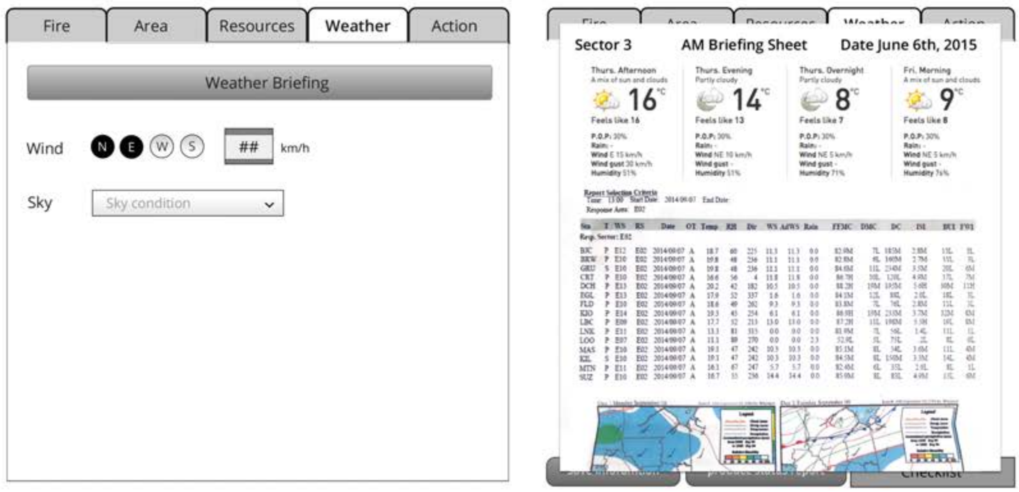

Figure 25: Mobile weather briefing access through weather tab

6. Preliminary model evaluation (Second iteration)

The aim of this iteration was to test the efficiency of the proposed system and interfaces through a comparison with the currently used system (DFOSS & Radio). This evaluation also helped in defining stress and critical points in the current process that should guide the design of the user study. Such stress points include tasks and processes that result in higher working memory load or are time consuming. In addition, the model evaluation served as a preliminary test for the functionalities and interaction styles of the interface and highlighted controls and elements that were added or improved in the development of the interface prototype (section 6.2)

6.1 Efficiency evaluation

As previously explained (in section 3.4), a GOMS (John & Kieras, 1996) model was used for this stage of the design evaluation. GOMS stands for "Goals, Operators, Methods and Selection rules", it is based on reducing the user interactions with a sys). Using the GOMS model, 18 tasks or scenarios were tested on Cogulator[8].

Table 9 presents the results for the 18 scenarios for four different possibilities. "DFOSS + radio" represents the current system as it is. "Integrated + radio" is the possibility for using the proposed office interface only. "DFOSS + mobile" represents the possibility for using the proposed mobile interface with the

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[8] http://cogulator.io/index.html

currently used DFOSS. And “Integrated + mobile” presents the results for using the complete proposed system with the two complementary interfaces.

	Scenario	DFOSS + radio	Integrated+ radio	DFOSS + mobile	Integrated + mobile
1	Initial report (public call)	71.4	19.7	NA	NA
2	Scouting report (confirm)	127.8	113.7	47	34.4
3	Scouting report (no fire found)	12.9	10.3	9.6	4.1
4	Status report (BHE)	72.6	66.1	27	20.5
5	Status report (UCO)	72.4	64.3	26.7	16.7
6	Status report (OUT)	59.7	57.8	22.8	21.7
7	Updating complete fire info	59.5	56.1	29	24.5
8	Add threatened value (f-o)	30.5	22.4	14.4	10.1
9	Add threatened value (o-f)	33.5	22.7	20.9	9.6
10	Add non threatened value	32.2	23.3	14.2	10.1
11	Resource request (crew)	16.7	13.6	8.9	5.8
12	Resource request (tanker)	17.9	15.6	10.5	5.8
13	Resource dispatch (crew)	18.8	15.2	14.2	10.6
14	Resource record keeping (crew on fire)	16.2	11.3	9.7	5.6
15	Resource record keeping (A on fire)	16.6	11.7	9.7	5.6
16	Resource record keeping (A attack)	16.2	11.3	9.3	5.6
17	Check time objectives of response	13.6	13.6	7.8	4.6
18	Edit time objectives (all 4)	38.8	27.1	14.2	11.8

Table 9: GOMS model results in seconds

Table 9 shows the total time (in seconds) needed to complete each tasks with each system combination. It is important to note that possibilities for human or technical errors, like mistypes, radio noise or misunderstandings, were not considered for any of the scenarios.

In addition, the software produced graphs showing the switch between physical, cognitive and perceptual action indicating the possible working memory load for each action (appendix 9).

The model evaluation indicated a high potential for making the process more efficient. The tested scenarios were mostly about communicating information between the field and the office. The tasks were selected to represent some important steps in the everyday process of forest fire operations. The wording and components of the tasks were guided by the observations and data collection of the informative study (Chapter 4).

The results show that the more information exchange is required the more efficient the proposed system becomes. For example, a status report is a case where a lot of details and information about the situation has to be communicated through the radio operator. The model shows that the proposed system can decrease the required time for the process by up to 76% (Task 5: Status report UCO). Overall the tested scenarios showed a potential for an average of 66% decrease in required time. The decrease is, as previously explained, mainly due to the elimination of the radio communication and transcription time.

This is also confirmed in the model using the proposed mobile vs. office interface only; comparing the current system with the proposed office interface only (Integrated + radio column), indicated the potential for an average of 18.7%[9] decrease in required time, while the proposed mobile interface only (DFOSS +

[9] This result excludes the initial report input task which tests the proposed location search functionality

mobile column) indicated the potential for 48% decrease. Eliminating the radio transcription step also showed a possible potential for the reduction of working memory load.

However the results produced by “Cogulator” were not precise enough for specific calculations or conclusions about the potential of the proposed system. Nonetheless the reduction in the time required for completing tasks possible with the proposed system, indicates a potential for making the data collection process more efficient. With reference to the research hypothesis (see section 1.1), a more efficient data collection and information exchange process should result in improved situation awareness.

Moreover the model evaluation focused only on tasks with information exchange and did not test finding information on the interface, as this would depend mostly on the operators’ experience and interaction with the test. The GOMS model, although it calculates for estimated processing and perception times, focuses mostly on point, click and typing operators required to complete a task (John, 1995). Nevertheless, the model evaluation provided validation for the potential of the proposed system and interfaces in order to process with design development and user evaluation. The scenarios used in the model testing were also used as guidance for designing the user evaluation tasks and procedure.

6.2. Prototype design

The prototype was designed to follow the same interaction styles and order that were followed the model evaluation. The interaction with the office interface is through point and click and typing, and with the mobile interface through touch interactions. The prototypes were created to support the user evaluation tasks of the cognitive walkthrough (see section 3.5) as well as some user errors and exploration. The prototypes were the main tools for user evaluation. They were meant to allow the operators to explore and interact with the proposed system in order to give feedback about the perceived value and further development requirements.

An HTML click-through prototype was prepared based on the wireframes presented in the previous chapter. The design was kept basic, with minimal colors to avoid unintentional attention grabbers and to allow for maximum participants' input about requirements and ideas (see appendix 8 for overview). Figures 26 and 27 show the flow diagram of the prototypes' screens and possible use scenarios. The flow diagrams present the high-level interactions that were part of the user evaluation procedure.

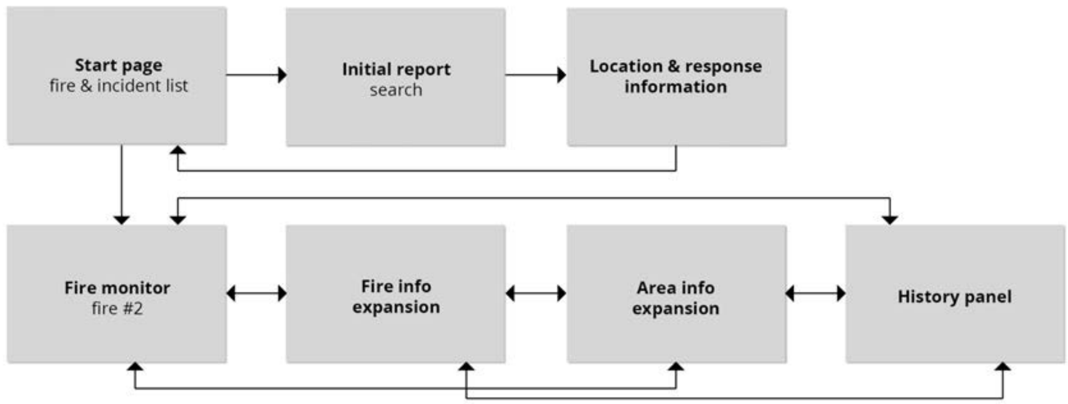

Figure 26: Office interface prototype flow diagram

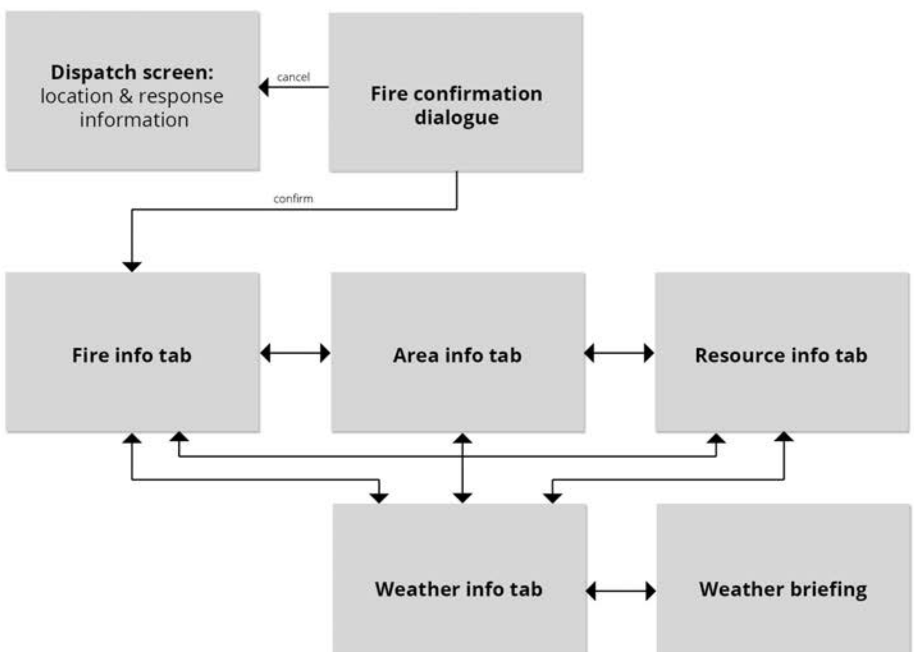

Figure 27: Mobile interface prototype flow diagram

7. User evaluation (Third iteration)

7.1 Evaluation results

The proposed interface aims to improve the operators' situation awareness by insuring that all required information is properly and efficiently inputted in the system and is easily accessible. This iteration aimed to assess the effectiveness of the interface for collecting all the required information as well as evaluate the situation awareness that the interface offers to the team members. Moreover, the user evaluation procedure also provided feedback about the usability of the system, to ensure that the interface can provide efficient and satisfactory interactions as required in the emergency response environment (Mcnab, 2009). The feedback of the response operators also guided the development of the interface design (see section 7.2).

Overall the participating operators expressed enthusiasm about the concept of linking crew leaders on the fire with the system and databases. "Giving the incident commander the ability to input information that I [the intelligence officer] and the sector officer can access is very useful" one of the participants explained. In addition, the office operators and the crew leaders seemed to be in agreement that with the advancement of available technology, making use of mobile connectivity is just a matter of time.

However during the testing sessions one of the surprising observations was that crew leaders, although on average younger than office operators, were less flexible and open to change concerning their response process. Their comments and feedback were mostly about adjusting the interface to follow the exact same sequence and formats of the fire diary, which they are currently using. In addition they expressed concerns about the connectivity, encryption and hardware of the proposed system. And although most of them expressed positive feedback about access to databases, maps, and visual updates in general, they were more reluctant to accept the proposed change to their process than the office operators. This could be due to the fact that the current process does not include any computer interface and that the proposed system presents a relatively extreme change in the nature of their process. As opposed to headquarters' tools and software, which undergo yearly updates and changes, the crews' tools have had minimum updates over the years. They have successfully depended on the fire diary, written reports and radio communication, possibly resulting in hesitancy to integrate more advanced technology. In addition their operation regulations and process is very strict to ensure maximum safety and efficiency, so they need the system to support all the requirements and conditions of their process, since any glitch or error presents an extreme risk. Nonetheless the evaluation was successful in gathering productive feedback about how the interface can be developed to address the requirements and concerns of the crew leaders.

7.1.1 Users' acceptance and rating

After interacting with the interfaces, the 17 participants were asked to complete a questionnaire to capture their perceived value and experience. The first part let the participants compare the proposed system with the system that is currently used in the Ontario forest fire management process. The second part of the questionnaire was an evaluation of the system's features and elements as well as the overall perceived value of the proposed system.

System comparison

When comparing the current *office system* and the proposed one (Figure 28), a few aspects stood out. 89% of the participants (8 out of 9 who evaluated the office interface) said that the proposed system is more efficient than the current (7 said it is somewhat better and 1 better) while one said it is somewhat worse. Additionally 78% (7 out of 9) operators preferred the proposed visual design while 22% said it's somewhat worse.

Many operators were neutral about the support of collaboration (56%) and whether the interface supports the process requirements (44%). Nonetheless 22% said that the proposed system is better in supporting collaboration and 11% said it is somewhat better while 11% said it is somewhat worse. Concerning ease of use, 44% of participants said it's somewhat better, 22% said it better, 11% neutral, 11% said somewhat worse and 11% said it worse.

When comparing the proposed *mobile interface* with the current system, many crew leaders were neutral, as they didn't compare to another interface but either verbal communication or the fire diary, which follows a different approach.

37.5% of participating crew leaders found the visual design of the interface better and 12.5% found it somehow better, while 25% were neutral and 25% found it somewhat worse.

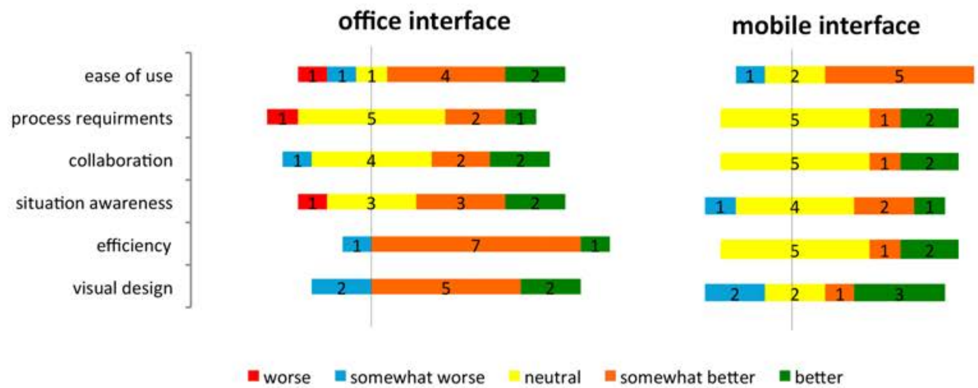

Figure 28: Current and proposed comparison results - diverging stacked bars showing positive(to the right) and negative (to the left) spread

62.5% (5 out of 8) said it is somewhat easier to use, while 25% were neutral and 12.5% found it somewhat more difficult. 62% were neutral about its efficiency, 12.5% found it somewhat more efficient and 25% said it's better than the current system. The interface's support of collaboration and coordination and the support of process requirements received the exact same ratings; 65% were neutral, 12.5% somewhat better and 25% better (Figure 28).

System Rating

When rating the office interface 78% (7 out of 9 participants) agreed that the interface supports all the features required, while 11% were neutral and 11% disagreed (Figure 29). 33% were neutral about the difficulty to understand the interface, while 67% disagreed that it is difficult to understand. 22% strongly disagreed that it's unnecessarily cluttered, 56% disagreed and 22% were neutral. When asked about the potential to save time 22% were neutral, 44% agreed and 33% strongly agreed that the system has the potential to save time during a response operation. 78% agreed that the functions are well integrated, 11% was neutral and 11% disagreed.

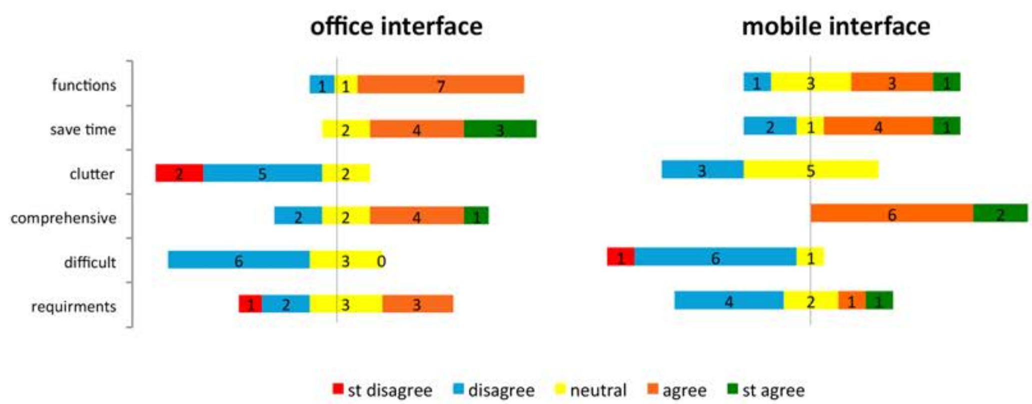

Figure 29: Proposed system rating results

The ratings of the mobile interface (Figure 29), showed that 50% of the participating crew leaders did not find that the interface supports all the features required for the process, 25% were neutral, and 25% said that it doesn't support all the feature requirements. Nonetheless only 12.5% were neutral about the difficulty of use while the majority (75% disagreed and 12.5% strongly disagreed) disagreed that it's difficult. 87.5 % of the participants didn't find the interface cluttered and 12.5% were neutral. When asked if the system has the potential to save time, 25% participants disagreed, 12.5% were neutral, 50% agreed and 12.5% strongly agreed. 12.5% did not think that the functions of the system are well integrated 37.5% were neutral, 37.5% agreed that they were well integrated and 12.5% strongly agreed.

Perceived value

In the questionnaire, participants were asked to rate the value of the proposed mobile interface. Two office operators were neutral, while nine said it's somehow valuable (six crew leaders and three office operators) and 6 said it's very valuable (two crew leaders and four office operators). The value of the proposed office interface was rated only by office operators (9 total); one operator was neutral, six said it's somewhat valuable and 2 said it's very valuable. These results confirm that inspire of the variation, the majority agreed about a certain value of the proposed system and interface to the forest fire response process. More specific aspects of the interface and the evaluation are discussed in the following section.

7.1.2 System Usability

Users rated some of the usability aspects listed below (Table 10) on a provided rating sheet, while they expressed comments or ideas concerning each aspect. The comments listed are also summarized from qualitative data collected while participants completed the tasks (cognitive walkthrough).

The rating shown is the average of the participants' ratings, with 1 indicating "very bad" and 5 "very good".

Usability Aspect	Average rating			Comments	
	Office	Mobile	Total	Office	Mobile
Intuitiveness and learnability	3.8	3.9	3.8	▪ Training needed to have the process as fast as required ▪ Clarification required for time objective icon and extension buttons ▪ Color coding	▪ More interaction with the map required ▪ Color coding statuses and critical information
Familiarity, recognition, (terminology) & memorability	4.1	4.0	4.1	▪ On route instead of on way ▪ Adding status for dispatch and reroute ▪ Crew type	▪ Resource statuses need to be more detailed and informative ▪ "Area" tab not clear ▪ Anticipated status
Consistency with the process	3.8	3.9	3.8	▪ Unit changes for some information (feet ins. Meters)	▪ Information input needs to follow the process more closely: initial report, scouting, investigation
Usefulness and efficiency (time saving potential)	4.2	4.1	4.2	▪ Search option very efficient if it works ▪ Adding more options for "closing" an initial report	▪ Map addition and visual feedback very useful ▪ Addition of investigation information required ▪ Some controls need to be bigger for more accuracy
Effectiveness of functionalities	4.1	4	4.1	▪ Fire priority field not required ▪ Addition of value entering feature (to update database)	▪ Resource requirements problematic through network only ▪ Weather briefing access very helpful, could be more enhance (weather widget)
Organization, layout and navigation	4.3	4	4.2	▪ Switching history and resource tab ▪ Color coding for statuses and history for easier navigation ▪ Resources layer as part of operational layer	▪ Adding fuel type to scouting report information (instead of fire) ▪ Time objectives to action instead of response ▪ Initial report information instead of response

Prioritization of information	3.8	3.8	3.7	▪ Mostly positive feedback about the expansion, only one preferred to see everything→ possibility for personalization according to preference	▪ Response information not very important, initial report information would be more useful
Flexibility of interaction	3.4	4	3.7	▪ More direct interaction through the map (resources + values) ▪ Allow shortcuts ▪ Different log-in privileges (some info can be changed by only specific operators)	▪ More interaction with the map ▪ Less flexibility and more strict order was encouraged, but also possibility to skip
Control for the user	3.7	3.9	3.8	▪ Status update dialogue	
Feedback and error handling	3.9	3.3	3.6	▪ Highlighting the information that has just been updated ▪ Highlighting the information that still needs to be updated	▪ Dialogue window for fire status change. Feedback and confirmation not enough ▪ Highlighting missing information, overview of report
Satisfaction	/	/	/	▪ Combining map database with initial report and fire information highly praised	▪ Just for scouting report ▪ Connection and encryption obstacles ▪ Concerns about hardware

Table 10: Usability ratings and comments for mobile and office interface

To get a deeper understanding of the how the participants perceived the usability and features of the interfaces, they were asked to mark elements they liked, disliked or would like to change on the printed screenshots of the interface; the results are presented below. Figure 30 shows the mobile interface with all participants' marks added (complete evaluation in appendix 10).

Most of the marks and comments were about the information categorization and the location of some controls. For example (as seen in Figure 30) the area and the action tab were elements that some participants did not like. However the map was highlighted by 4 participants as an element that they liked. Participants also liked the resources overview list, but marked dislike and concerns about the resource requirements controls.

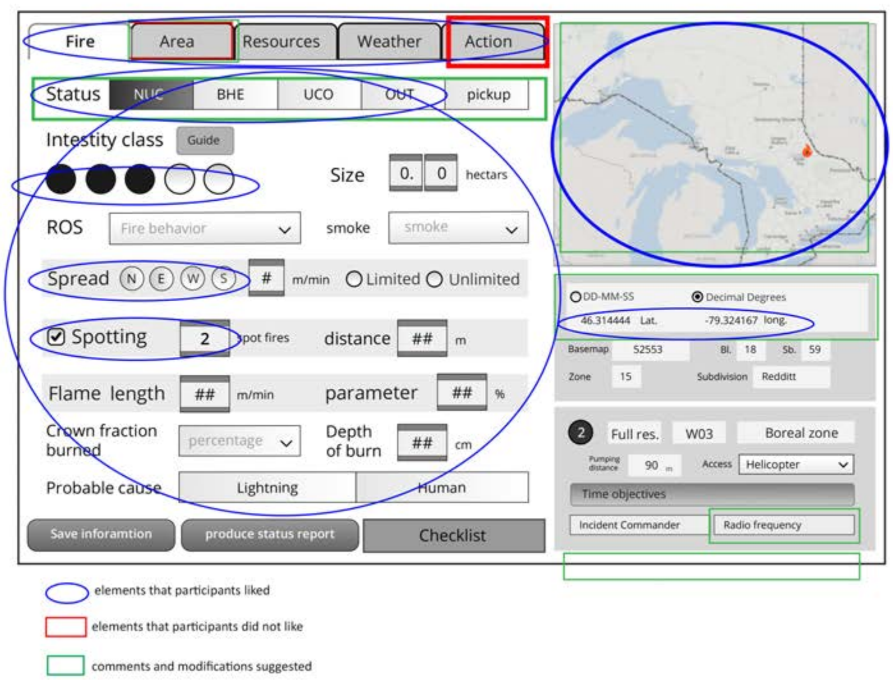

Figure 30: Mobile interface screenshot showing participants' markings

The marks on the office interface screenshots also showed high likability for the interactive map and the map icons. However the time objectives icon, the fire priority controls and the threatened values icons were the elements that received most criticism. Other markings included the terminology for the resource statuses and the placement of the history tab.

7.1.3 Data collection process

The proposed interface aims to facilitate the information gathering process. The purpose is to ensure that all the important factors, fire and environment information is up to date and accessible to all team members in order to ensure complete situation awareness during emergency response.

Participants were therefore asked whether they think the interface allows for comprehensive information collection. When asked about the office interface 11% strongly agreed that it allows for comprehensive information collection, 44% agreed, 22% were neutral and 22% disagreed (Figure 28). This indicates that even though most of the features and requirements of the process are included (as presented in previous section), some specific information categories still need to be added. However 75% of the participants rating the mobile interface agreed that the interface allows for comprehensive information collection and 25% strongly agreed, while none of the participants disagreed or were neutral.

In addition, some of the cognitive walkthrough task, required the participants to input information. Figure 31 shows the results of those tasks for the office interface. Overall participants were relatively successful with data input tasks.

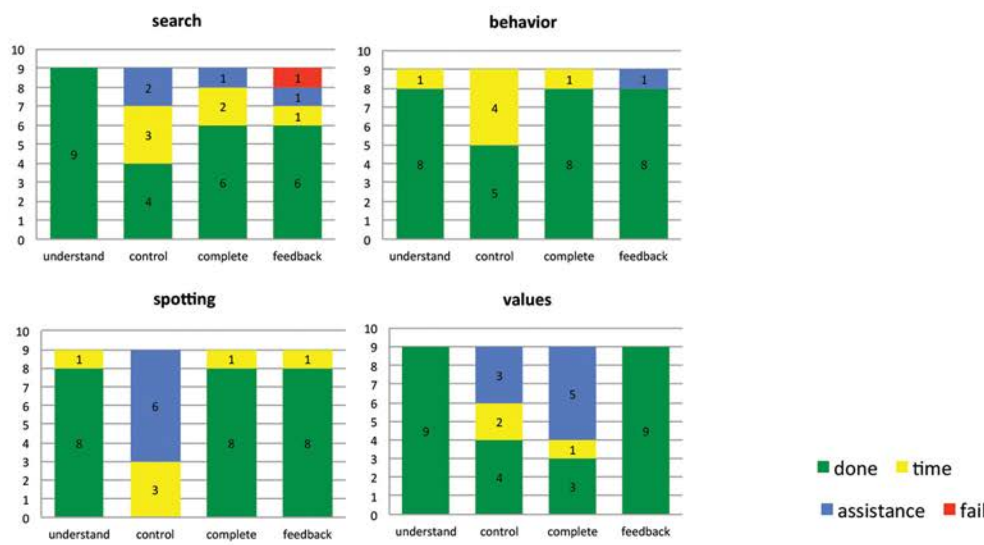

Figure 31: Cognitive walkthrough results for data input tasks with the office interface (9 participants)

Office Interface

Some of the struggle with the first task (the search task) was due to the participants' unfamiliarity with the prototype. 56% required longer time or assistance to find the search control and update the incident location, however 67% completed the tasks afterwards without any problems, 22% required some time and only 11% required assistance. Updating the fire behavior was one of the most successful tasks, 89% were able to complete the task without any problems. However one major issue that was observed for updating the spotting information, was in finding the expansion button to view more detailed fire information. None of the participants were able to find the control right away, 33% required time and 67% only found with the researchers assistance.

However once the controls were found, 8 out of 9 (89%) participants completed the task right away and only one required some time to update the information.

Additionally the majority participants struggled with adding a value. The main confusion was in understanding how the selected value can be added to the list. Despite the confusion all of the participants were able to complete the task eventually. 56% required assistance, 11% needed some time and 33% completed it on their own.

The cognitive walkthrough evaluation also recorded the participants’ reaction to the feedback provided by the system about their interaction. The researcher observed whether participants were aware of their success or failure about completing the task. Overall with the office interface the feedback recordings showed few problems. Only 11% failed to perceive the system feedback in the search task and 22% in the task of finding when the information was last updated. However participants provided feedback and ideas about how the system feedback can be improved (see section 7.1.2).

Mobile Interface

Participants evaluating the mobile interface completed five information input tasks (Figure 32). Similar to the office interface, many (62.5%) had problems with finding the controls of the first task, 12.5% were not able to complete the task.

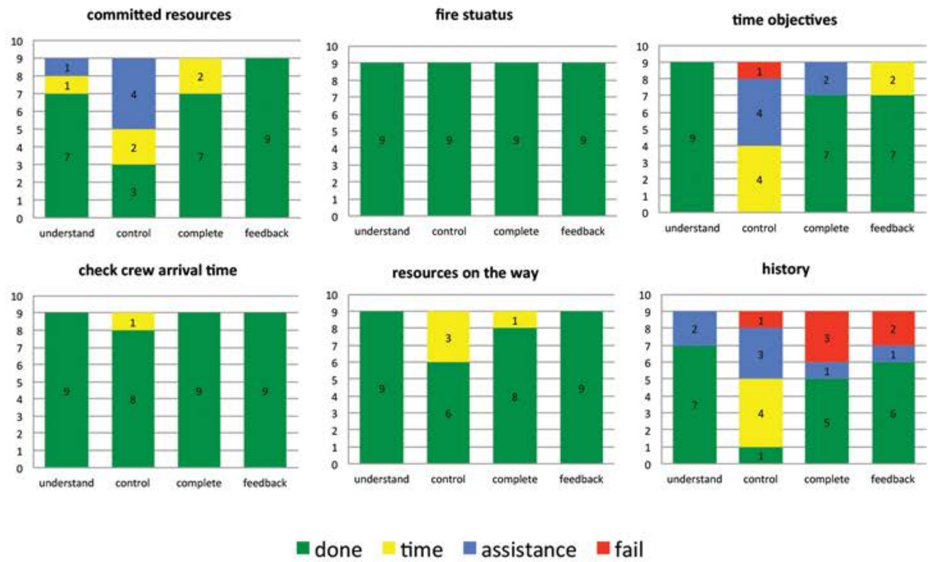

Figure 32: Cognitive walkthrough results for data input tasks with the mobile interface (8 participants)

However updating fire information (status, intensity and spotting) was completed successfully by all participants. Few participants however (25%) had problems with the system feedback for updating information. The issue was mainly due to their confusion about whether the information has been saved, many of the participants expressed concerns and ideas about how the system feedback can and should be improved.

A major issue for all participants was finding the controls for updating the fuel type around the fire. 37% needed time to find the control on their own, while the remaining 63% only found it with the researcher's assistance. One task that participants completed successfully was recording the arrival time of a crew. Only 25% needed some time to find the controls, but all were able to complete the task without any problems.

7.1.4 Information Accessibility and Situation Awareness

In addition, the affordance of the proposed system to support situation awareness was also tested. Six of the tasks of the cognitive walkthrough were designed to let the participants look for information about the incident that could be required for making response decisions. The results did not indicate an obvious difference between the performance on situation awareness tasks and information updating tasks.

Office Interface

Checking the fire status was the only task that all participants were able to successfully complete on their own. Tasks that were related to finding information about resources were also relatively successful. Participants searched for the information on the map and tried clicking resource icons shown on it; 44% required assistance in finding the resource tab and 22% required longer time to find it, but 78% were able to successfully complete the task on their own afterwards. By the second resource related task- crew arrival time- only one participant (11%) required some time to find the information while all others were successful in quickly finding the information and completing the task. Similar success rates were also reported for the third resource related task (resources on the way to the fire).

With the office interface, participants had most trouble in finding out when the information was last updated through the history tab. Although 79% (7 out of 9) of the participants had no problems in understanding what they were looking for, only one participant was able to successfully find the information on their own.

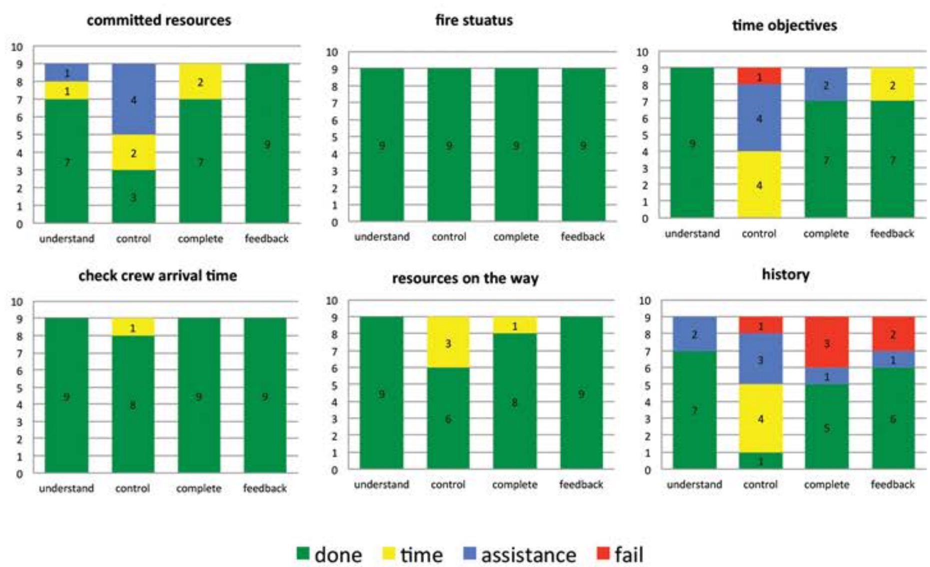

Figure 33: Cognitive walkthrough results for SA tasks using the office interface (9 participants)

44% of the participants needed time and tried several tabs before finding the right one, 33% only found it through the researcher’s assistance, and one was unable to find the tab. After they found the controls 56% were able to find the information successfully but 33% were still unable to find the information and complete the task (Figure 33).

Another control that participants couldn’t find right away was the icon for the time objectives; only 11% found it on their one, 33% required time, 44% found it with assistance and 11% were not able to complete the task at all.

Mobile Interface

With the mobile interface (Figure 34), the task where most issues were observed was also checking the time objectives of the response operation. 50% of the participants were unable to find the button for it. Participants looked for the information among the different tabs and did not look in the right part of the screen. Two participants (25%) were unable to complete the task at all and overall expressed confusion about the need for the tab (more in section 7.1.2).

Also finding information about values that have been updated by the sector office revealed some issues. The confusion was in understanding the abbreviations of the status of the values as well as recognizing the list. While only 37% were able to successfully find the controls, 75% found the information and completed the task successfully on their own. One participant (12.5%) required assistance and another was not able to complete the task.

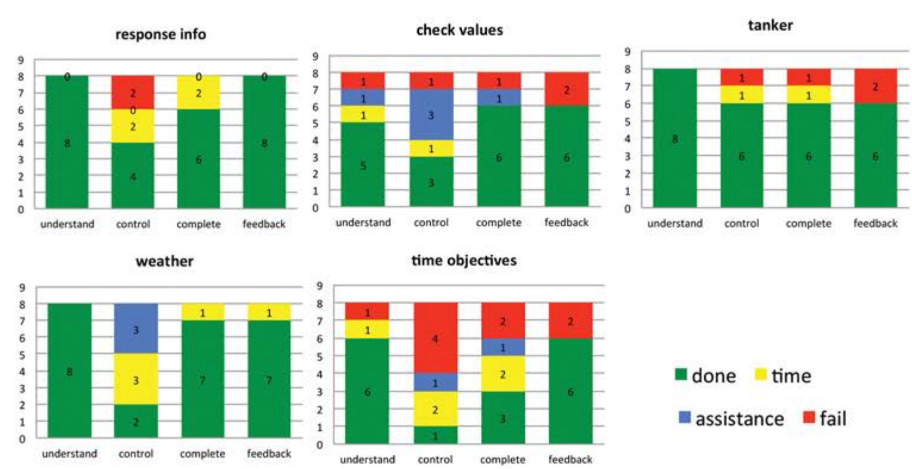

Figure 34: Cognitive walkthrough results for SA tasks using the mobile interface (8 participants)

However after understanding the presentation of the values, participants were able to add another value successfully; only one participant (12.5%) required assistance to find the control and longer time to complete the task.

The situation awareness tasks were designed to address both level one SA (perception) and level two SA (comprehension). However the participants' performance did not vary between the two SA levels.

In addition, participants also rated their perceived situation awareness with the proposed system in comparison to the current system as part of the questionnaire. One (11%) office operator said that it's worse, while 3 (33%) were neutral, 3 said it is somewhat better and 2 said it is better. From the participants who rated the mobile interface, 1 participant said that the situation awareness is somewhat worse, while 4 (50%) were neutral, 2 said it is somewhat better and 1 said it is better (Figure 28).

7.2 Final design development

The office and mobile interface were developed based on the feedback and the results of the user evaluation. Specific usability issues that the results showed need improvement, like the system's consistency with the process, were the priority of the development stage. The qualitative feedback and ideas of the participants for features and improvements were considered (section 7.1.2). In addition the design was enhanced to be more visually appealing and to incorporate colors for clarifying and coding information categories and statuses. The use of colors was based on the participants' feedback and recommendations during the evaluation. The specific elements that were changed are presented in the following pages, and the complete final design is shown in appendix 11.

7.2.1 Consistency with the process

Despite the predesign research about the response process, the user evaluation showed some inconsistencies in the interface with the requirements especially for the mobile interface. The participating crew leaders' feedback emphasized their preference to following their strict response procedure to minimize the risk of missing information.

The crew is usually dispatched in response to an initial report or burning fire, the interface should therefore let the crew leader login upon dispatch and allow them to select the incident that they are heading to as well as update dispatch information (Figure 35).

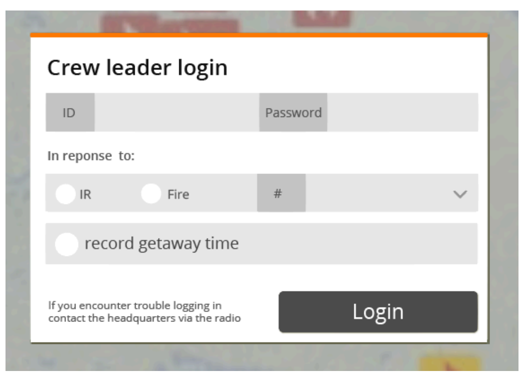

Figure 35: Crew leader login dialogue

Once a fire or incident is selected, the location and response information of the incident are shown to the crew leader; in addition, they can input their observations on the way to the fire (Figure 36) as it is sometimes necessary to notify specific information before the confirmation of the fire or the crew's arrival.

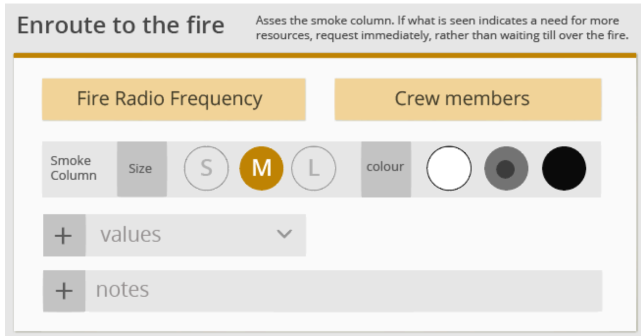

Figure 36: Panel for updating enroute observations and response information

When a fire is confirmed, the user (crew member responsible for updating the information), is led to the fire information tab. The information was reorganized so that the tab would include all the information required for a scouting report (Figure 37).

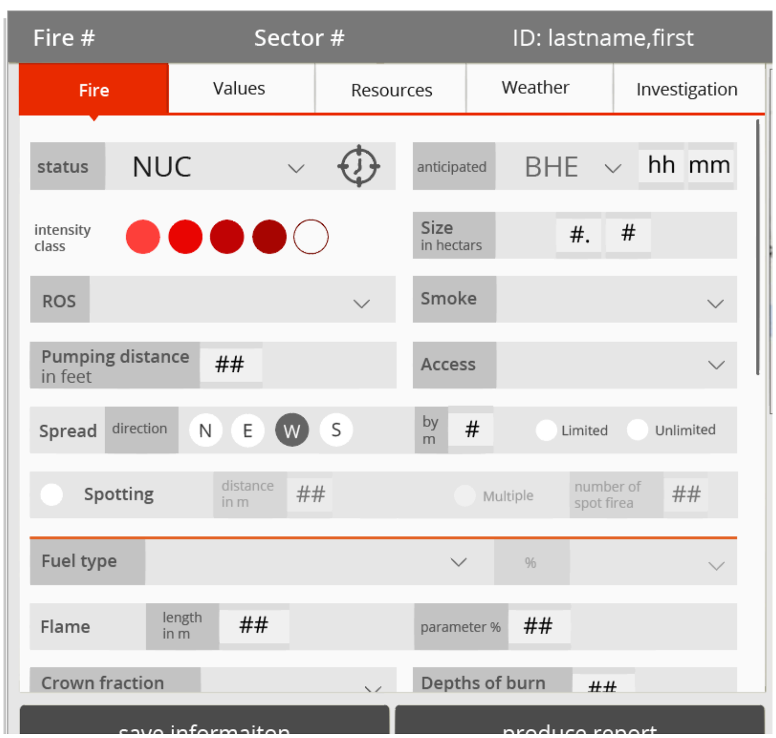

Figure 37: Fire information or scouting report tab

The majority of crew leaders explained that they would prefer to have the scouting report information on one screen rather than in two different tabs, even if it would require scrolling. The fuel type controls were therefore moved to the fire tab and the area tab, which was problematic in the testing, was changed to a values tab (Figure 37). Other changes in organization included adding the response information, like the anticipated status objectives and the pumping distance, to the fire information instead of an extra panel for response information, as it was reported to be unnecessary.

In general the design of the office interface did not show any major inconsistencies with the process. However specific requirements had to be added. The first one was the need for operator specific control level, which would depend on the users' login information. For example only the DO or the SRO have the authority to determine the requirements for air attack or the response objective for an incident. The option for greyed out controls that would be visible but locked for editing (Figure 38) for some operators was added.

Figure 38: Locked response objective controls

The need for different controls levels between the different operators has been established by some previous studies about designing for the emergency response process (Gutwin & Greenberg, 1998). This differentiation however requires a very deep understanding of the exact responsibilities of the operators as well as all the possible scenarios and can therefore only be perfected through repeated testing and development.

Another process requirement was the possibility to dismiss initial reports (Figure 39). As every reported incident has to be documented, it often occurs that the same incident is reported repeatedly from different sources or that the reported incident is already being attended to. The feature for dismissing initial reports was therefore added.

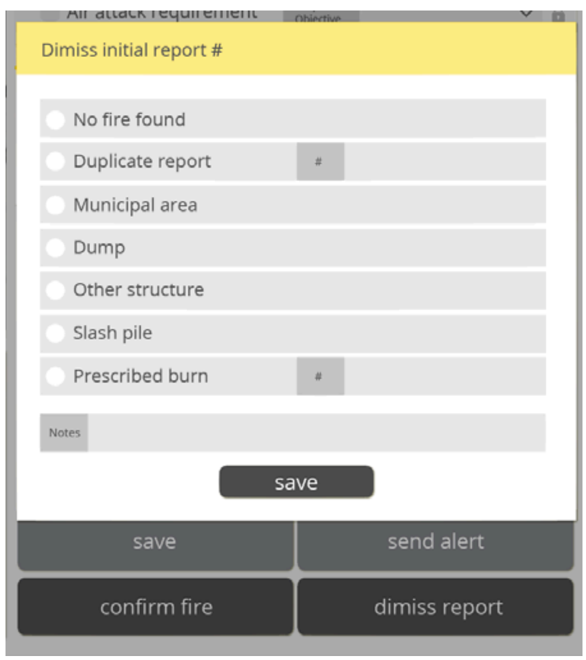

Figure 39: Initial report dismissal dialogue

7.2.2 Usefulness and Efficiency

In addition to features and design elements that were proposed and tested in previous studies, like geo-collaboration (Resch et al., 2007) and notifications (Röcker & Magerkurth, 2007), the participating operators also provided some design ideas that they believe would support and improve their process. The following paragraphs show how some of those features were integrated into the final design.

As previously mentioned the network settings of the mobile device would be used for more efficient time recording, however the GPS tracking of the mobile device should also be used for location recording as well as crew tracking at the headquarters. The automatic recording of update times coupled with the device's connectivity should also feed the notification system of the interface (Figure 40).

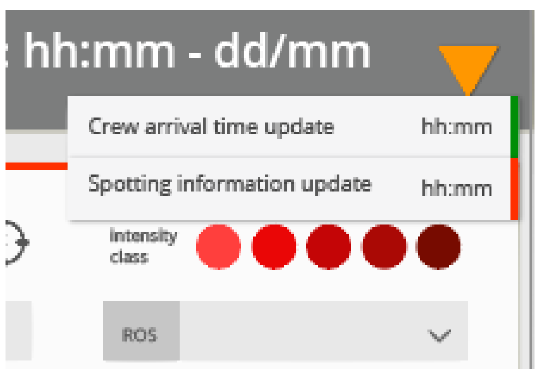

Figure 40: Color-coded update notifications

Whenever information is updated by the crew, the office operators receive a color-coded notification (Carroll et al., 2003).

These should alert the operators about the development of the incident or situation in a timely manner as well as help in avoiding attention tunneling (M. R.

Endsley, 1995) when headquarters' operators are busy with other tasks or incidents.

Participating operators also expressed enthusiasm about the geo-notes feature (Resch et al., 2007) when asked about it during the user evaluation. And although the testing of the feature was not possible in the scope of this research, the controls required for it were incorporated in the final design development.

A button for adding geo-notes is added on the mobile interface map (see map on figure 41), and the notes can be visible to the office operators through the "IC" (incident commander) map layer.

In addition, the possibility for taking pictures as well as reviewing the pictures taken of the fire or location was added to the mobile interface. The pictures taken should be incorporated into scouting or fire reports that are sent to the headquarters (figure 41).

Crew leaders who participated in the user evaluation showed very positive reactions to having access to the weather briefing and real-time weather information (section 7.1). Many of them also offered their ideas about how the information can be presented. Two crew leaders suggested having the interface detect the closest weather station closest to its location and presenting the weather information captured by it. Although the technical development of such a feature would still need to be developed and tested, it was also integrated in the development of the final design (Figure 41).

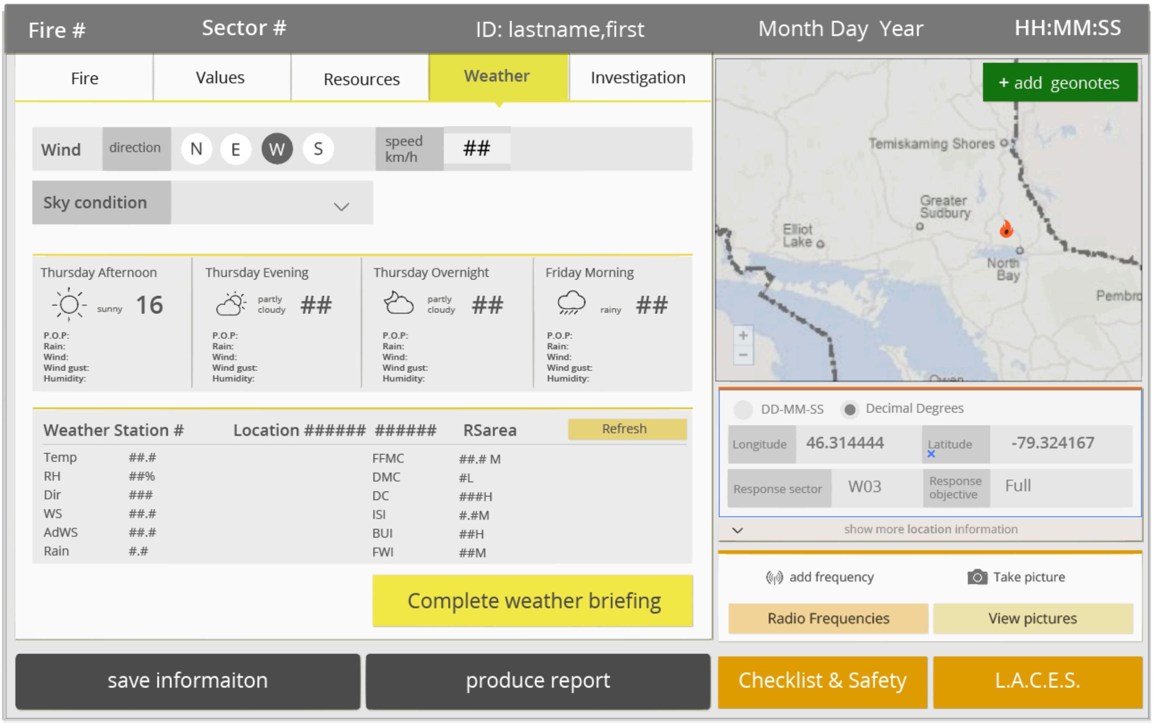

Figure 41: Mobile Interface showing the weather tab (full design in appendix 11)

7.2.3 Interface usability

The user evaluation revealed that some controls were not intuitive and recognizable enough (see section 7.1.3). Some of the control issues were solved through different tab or button labeling, like values instead of area. One major issue however was the expansion of the fire and values panels in the office interface. Although basic software training would increase the recognition rate, an intuitive and clear solution was required. The control was moved to the bottom of the panel, where the panel would be expanded making it more logical and intuitiveness. Additionally, with the space availability, a description of what the expansion shows was added to make sure the users know what to expect when they click it, giving them more control (Figure 42).

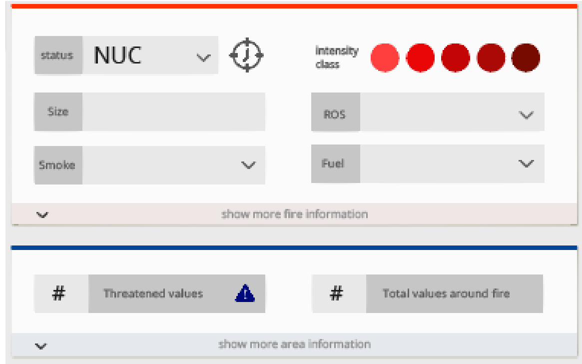

Figure 42: Fire and area panels showing expansion controls at the bottom of each

Moreover, some participants reported that they required more feedback and confirmation for fire status changes. The fire status is considered the primary information about an incident as it guides the response actions and the objectives of the operators and thus cannot afford any misunderstandings or confusions in communication.

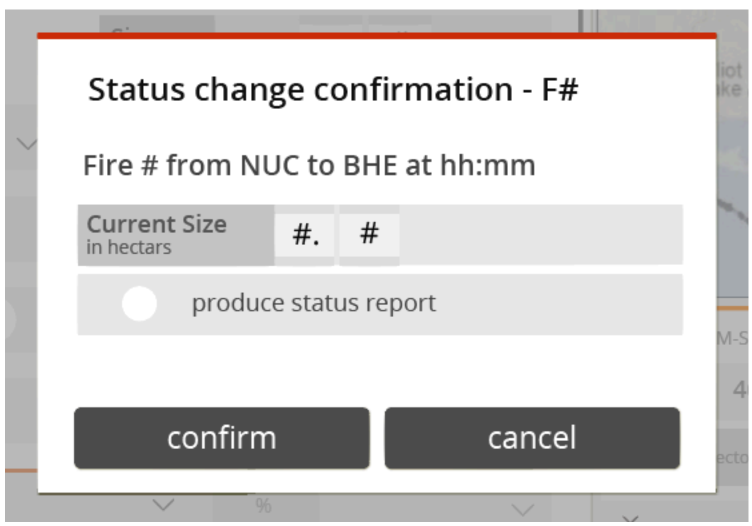

Figure 43: Status change confirmation dialogue

A dialogue box for confirming a status change was added to both the mobile and the office interface (Figure 43). The dialogue box allows the operators or crew members to actively engage in confirming all the fire information related to the status change, and produce a mini report or a full status report.

The fire history panel, which operators were also enthusiastic about, was also developed for more intuitiveness and consistency with other elements of the interface. The timeline events were color-coded to match the colors of the information categories (e.g. orange is fire information, green is resource information) (Figure 44). The distances between the events should reflect the actual relative time gaps between the updates and the timeline presentation is interactive for users to select specific events or updates to view more details.

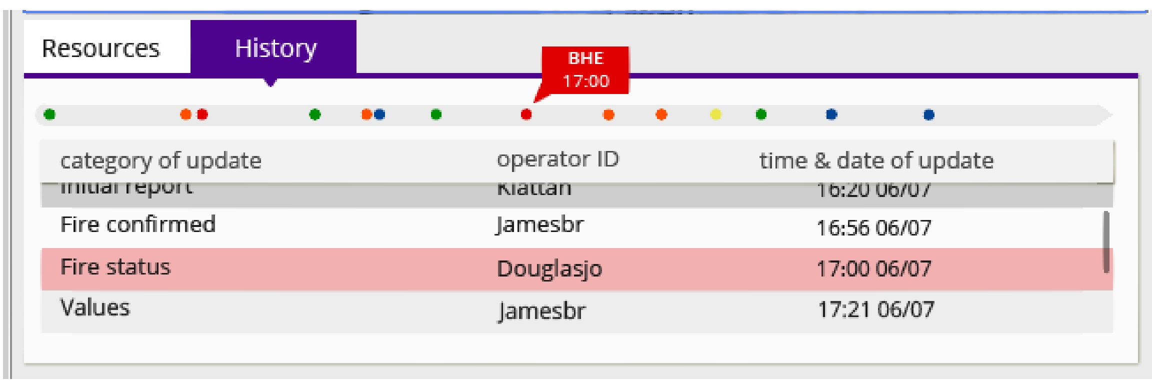

Figure 44: History panel, with color-coded timeline and selected status update

The changes and developments done for the final stage of this research (appendix 11) were based on the user feedback and testing of the third iteration. Further testing, especially in the response teams actual environment would reveal more insight about how the interface can be improved further; a few possibilities are discussed in section 8.2.

8. Discussion

8.1 Conclusions

The objective of this study was to develop a design proposal that would improve the forest fire response process as well as enhance the situation awareness of the team during response operations. The pre-design study conducted at the beginning of the research led to the focus on the data collection and input process, which is the first and fundamental step for the response operations and for maintaining team situation awareness (Figure 1; Section 1.1).

The collection of accurate and complete information in a timely manner is crucial to the response process, since decisions and actions are taken based on the development and factors of the fire situation. And especially in a complex and dynamic environment like wildfire management, the efficiency and effectiveness of the data collection process is fundamental.

A design composed of an office interface and a mobile interface is proposed and tested. By applying previously studied design principles and approaches, the proposed interface facilitates data collection, information accessibility and in turn situational awareness.

Overall the feedback about the value of the proposed system to the response process was majorly positive. The proposed solution to the research problem provided a process and user-friendly interface for fire information collection and communication. Participating operators and crew leaders expressed enthusiasm about the direct link between field crew and the headquarters system and databases that the proposed system provided, with 88% of participants agreeing that the system would be a valuable addition to the response process.

8.1.1 Process improvement and SA conclusions

The user evaluation procedure was designed to assess whether the interface facilitates the input of data and team situation awareness required during an incident response operation. The testing confirmed the potential for the proposed interface to improve the data collection process as well as provide reliable access for incident information and thus facilitating information processing (Figure 45). The tasks of the user evaluation were also designed to test level-one, by inputting and viewing information, as well as level-two situation awareness, through understanding what the information means for the response process (see appendix 5). The participants showed equal performance in both types of tasks.

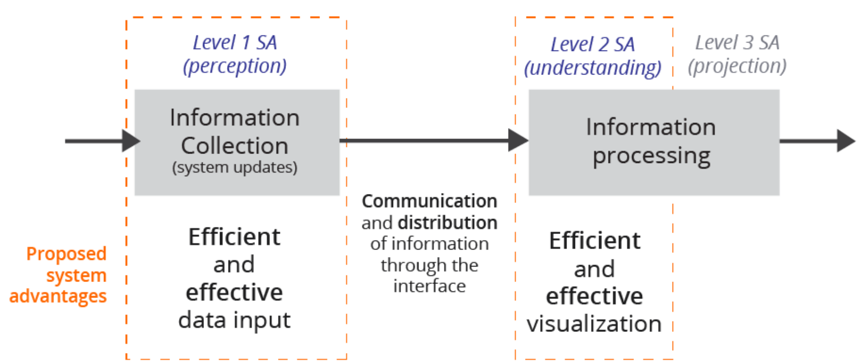

Figure 45: Proposed system advantages in relation to the emergency response process

The proposed interface thus enhances both the information collection process as well as part of the information processing process, which affect level one and level two of situation awareness respectively (Figure 45).

Information collection

The advantages to the data collection process include making it more efficient and more effective. The efficiency of data collection was tested through the model evaluation (discussed in section 6.1). It is achieved mainly through the collection of data directly from the field as well as the integration of the intelligent database. In addition, the user-friendly design results in more efficient user interactions.

The effectiveness of data input, which was confirmed in the user evaluation, is accomplished through ensuring that the system offers comprehensive data collection and supports all the process requirements.

Information visualization

The proposed system is the main tool for communicating and distributing the inputted data by making it directly accessible to the whole team. The efficiency and effectiveness of the information visualization to the team members was evaluated in third iteration of the study (user evaluation). The efficiency of the visualization is achieved through the use of screen space, grouping and prioritization of the information. The user evaluation also showed that the comprehensive presentation of the incident information as well as the use of icons and visual cues offers an effective visualization. The effective visualization can enhance the processing of the incident information.

The interface is also flexible for the addition of further features, that could support level-three situation awareness by helping the operators predict the development of the fire situation (section 8.2.1).

8.1.2 Evaluation of Design Approaches applied

Ecological design approach

A review of previous studies that addressed designing for emergency response, guided the design principles and approaches that were applied in the design development of this research solution. One approach is ecological interface design (EID). EID was applied in the development of the design solution through enhancing the connection between the operators and the environment. This was achieved through the in-depth analysis of the response process and its requirements conducted in the pre-study. The design proposed in this research considers the complexity and dynamic nature of wildfire management and is designed to support the information requirements for response operations. The in-depth analysis of the response process also ensured the interface covers all the information communicated and required as well as reflected the priorities of the users during a response operation.

The extension into the mobile domain

The extension of the response system into the mobile domain was also favored by most of the response operators. However although almost all participants agreed that applying mobile connectivity technologies offers several advantages and is "just a matter of time", many of the crew leaders were skeptical about this relatively extreme change in the nature of their response process. The researcher attributed this reaction to the absence of any computer interfaces in the crews' current process and to the rareness of updates or changes in their process as opposed to the continuously updated headquarters software and tools. Moreover, their concerns were also related to the connectivity and security issues that need to be studied before the proposal can be implemented.

Interface design principles

Several of the design principles that were applied in the development of the interface were related to information organization and visualization. One of them is the presentation of all information on the same screen, which some studies show to be preferred for emergency response and situation awareness (Hueston, 2012) and (Few, 2007). Through this research, this was confirmed only for the headquarters' interface, where operators require more of an overall overview of an incident as well as the general situation. However the crew leaders preferred a mobile interface that lets them follow their relatively strict response and information collection process through different screens, rather than one that provides an overview of the incident. The grouping of all incident information on one screen for the headquarters' operators however showed a high potential for improving their situation awareness, even without the use of the proposed mobile interface. The proposed interface, which gathers all information about one incident on one screen, would allow them to quickly and efficiently monitor its development. This would also help in monitoring several incidents effectively as it is often required at the headquarters.

The interface organization and information grouping was reported to be successful for updating and finding information. During the user evaluation, crew leaders proposed modifications to align the organization more with their response process. These modifications were considered in the development of the final design. The notifications alerting operators about fire information updates were also reported to be important. Their integration and need for the mobile interface, to alert crew leaders about updates should however still be further explored.

8.1.3 Research Process evaluation and study limitations

User centered design

The research followed a user-centered design approach. The approach was effective in understanding the critical and multifaceted response process; through letting the users guide and inspire the progress of understanding the problems and developing solutions to address them. The involvement of the users at every step insured that the research stayed focused on their needs and their everyday process requirements. The study also included users from a diverse range of team members, which ensured that the design solution would accommodate the whole team and the complete process.

Through the different iterations, the researcher was able to discuss all aspects of the process and to gain deep insight about wildfire emergency response. Due to the high complexity and high risk involved in emergency response, any tools or process development needs to be done closely to the operators and through analytical understanding of the process. The sensitive work environment of the response team however did not permit the organization of a moderated group discussion or focus group, since a minimum number of operators are required to be in the response office throughout the whole day. A group discussion might have shed interesting insights to the study, by letting different team members discuss and debate their perspectives and ideas between each other.

Testing environment

Another limitation that was caused by the nature of the response process was the circumstances of the user evaluation. The evaluation was conducted with operators individually using sample tasks and scenarios. Testing in the real environment where the interface are intended to be used was not possible especially for the mobile interface, where the environment is usually remote, intense and involves high risk operations.

8.2 Future research

8.2.1 Further process improvement possibilities

The process of this research contributed in an in-depth understanding of the forest fire response process, leading to insight about possible enhancements. This research focused on enhancing the data collection process as the starting step for the response process and the foundation for situation awareness.

The design developed in this research presents the starting and base step for a more integrated system that would accommodate efficient data input and collection as well as information communication, thus improving the team's situation awareness.

System integration

Further developments of the proposed interface could include its integration with the other current software and tools used by the response team, like MAPPER and PIMS. Additionally the development of the interface features to exploit the technologies used, like the interactive team displays, could possibly enhance its performance even more. Exploring how the operator would apply and interact with the interface within their office arrangement and multiple screen use as well as testing it in real response operations could provide insight about how the interfaces should be developed further.

Supporting the complete response process

Further development should also be in the direction of supporting more advanced response processes, like the fire investigation process, cost and after action reviews. Furthermore, the interface can be further developed to support the projection of the situation development (level-three SA) through integrating the interface with fire behavior prediction models. Such models are regularly developed by ministry operators, and are not integrated with other response software and are therefore often unused.

8.2.2 Research opportunities

Wildfire management process enhancement

In attempting to improve the response process and the team situation awareness, this research focused on data collection. The analysis of the response process conducted in the first phase of the research, led however to several proposals for enhancements, like the accommodation of the interaction between operator displays used for individual tasks and team displays for overall situation awareness, or digitalizing the operators' updates log. These proposals are discussed in detail in section 4.2.2 and represent future research opportunities for improving the process of forest fire management.

Crew and mobile connectivity

The extension of the dispatch system into the mobile domain also presents a major research opportunity. This research focused on the design of an interface that would support complete data collection and offered design concepts for improving the crew's connectivity and situation awareness. However solutions for the network connectivity of the devices still need to be researched. The response teams are often operating in remote areas with no mobile or Internet connectivity. In addition, given the nature of the operations and the process, encryption and security measures need to be considered for the information that is communicated between the crew and the headquarters. Research about aircraft Wi-Fi possibilities is already in process for the fire detection processes in Dryden (McFayden, 2015).

Research methodology

The methodology used for this research can be applied to other areas of emergency response. These areas could include municipal fire response, medical processes, police or military operations, or any complex response environment that requires awareness about dynamic situations and response team management.

The design principles applied and evaluated could also be effective in other information collection and presentation processes, including team management or status management tasks.

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Appendix 1

Glossary of Terms and Acronyms

Information Systems and Tools

A/CIMS – Aircraft Information Management Systems
DFOSS – Daily Fire Operations Support System
FMIS – Fire Management Infomration System
IMIS - Inventory Management Infromation System
PIMS – Personnel Information Management System
SOP – Strategic Operations Plan
TIP – Tactical Input Plan

Incident Command Functions

AMO – Aircraft Management Officer
DO – Duty Officer
IC – Incident Commander
RO – Radio Operator
SRO – Sector Response Officer

Operations

BHE – Being Held
BOB – Being Observed
DMC – Duff Moisture Code
FFMC – Fine Fuel Moisture Code
ISI – Initial Spread Index
NUC – Not Under Control
ROS – Rate of Spread
UCO – Under Control

Organization

AFFES – Aviation, Forest Fire and Emergency services
FFMC – Forest Fire Management Centre
MEOC – Ministry Emergency Operations Centre
REOC – Regional Emeregency Operations Centre

Appendix 2

Pre-design Study Interview questions

1. The environment:
   - *General understanding of the forest fire-fighting domain:*
     what needs to be done? What are the possible responses and decisions taken? What are the daily tasks? What are urgent incidents? What are urgent actions and when are they needed?
     → Scenarios:
     - Collecting daily scenarios and emergency scenarios
     - How are responses decided for the different scenarios?
   - Operators:
     - Who are the team member and what are their tasks, position within the team and responsibilities?
     - What is the organizational structure of the team?
   - Tools:
     - What are available tools and displays and what information do they show?
     - Which team members use which tools, for what and when?
   - Physical Environment:
     - Understand the working conditions and how they affect the different team members
     - Space and layout of the center/office
     - Location of operators and info sources and links between them?

     → *Comparison between the 3 offices*

2. The process:
   - Task analysis:
     - What are physical/motoric actions and which are cognitive actions? When are which necessary and what tools, or information are necessary for them? What team members are included?
     - How are decisions taken, who takes them and what information is needed to take them? How far are decisions based on experience or "subjective" factors?
   - Work flow:
     - What are daily or routine tasks? What information do they need?
     - What defines and emergency response? What tasks are included in it? What information is priority for an emergency response?
     - What are the key phases and stages of the process?
     - How does responsibility shift between operators in relation to stages and status?

- Information Flow
  - What are the main information categories and what are their sources?
  - The relation between space and process: relation between the team members and the tools, how does information flow within the room and between team members?
  - How is the information flow linked to the physical environment and space layout?
  - Information Collection, Input and Integration: Which team member needs which information and how to they collect it.
  - Mapping the information flow for the different scenarios and for the different phases and stages of the process
  - What phases or stages of the process are considered most critical and what are the key functionalities within the system?

3. Team situational awareness:
   - Communication Flow:
     - Team communication and network: how is the information shared and communicated? Who needs what information, when, how do they access it?
     - Who has access to which information; do they share it, how and why and with whom?
     - How is the information flow related to the communication network?
     - How are working shifts handled? What are the tools that should ensure the smooth transition?
   - Pain points/Challenges/Gaps:
     - What situations create higher workload? How is this high workload handled and what strategies for preparedness are there?
     - What are the escalation and team expansion plans?
     - What kinds of communication breakdowns occur and what are possible reasons for them?
     - What are the main challenges that each team member faces within the system and how do they currently handle them?
     - Are there gaps in the current system that are worked around or issues that are sometimes handled?
     - What phases or stages are most risky?

Appendix 3

a) Analysis verification document

Forest Fire Management and Response
1st iteration: Process Analysis

Content

I. Goals
II. Process analysis
  a. Task Analysis
  b. Communication
III. Team Situation awareness analysis
  a. Information categories
  b. Decision ladders and scenarios
  c. Display requirements

I. Goals

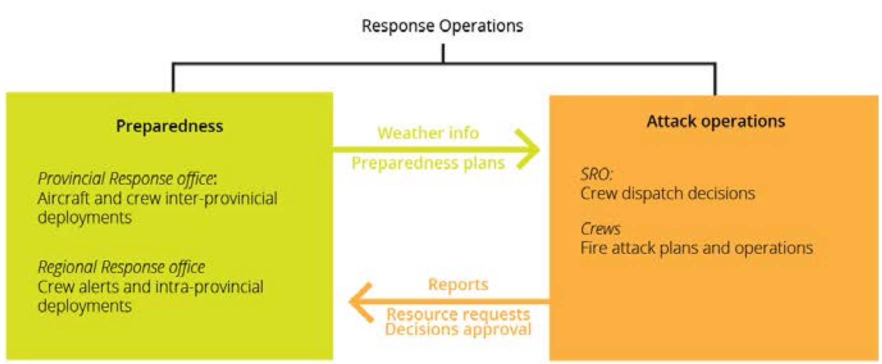
Overall aim of research:
Enhance the speed and quality of the team situation awareness in the forest fire management response centers.

Goals of this iteration:
- Verification of the process analysis and description
- Verification and additional input from operators about display requirements

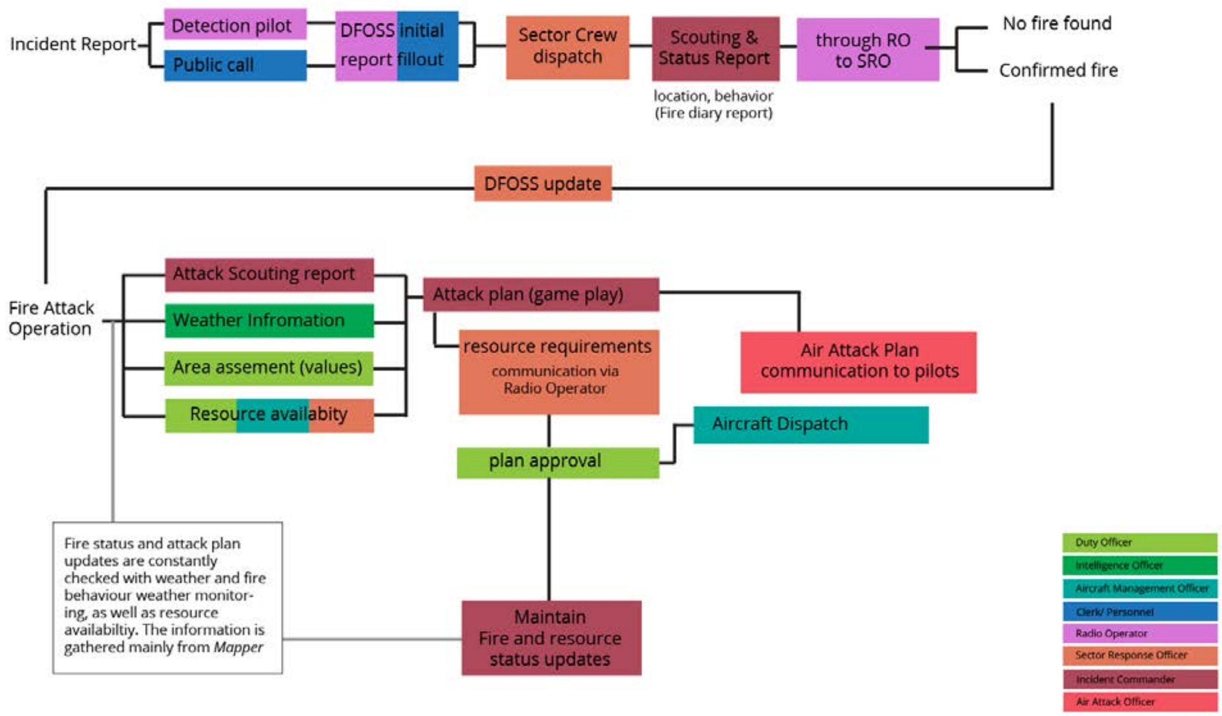
II. Process analysis

a. Task Analysis

The observations and analysis of the process showed a division in the response operations between preparedness measures and fire attack operations with specific channels of interaction in between:



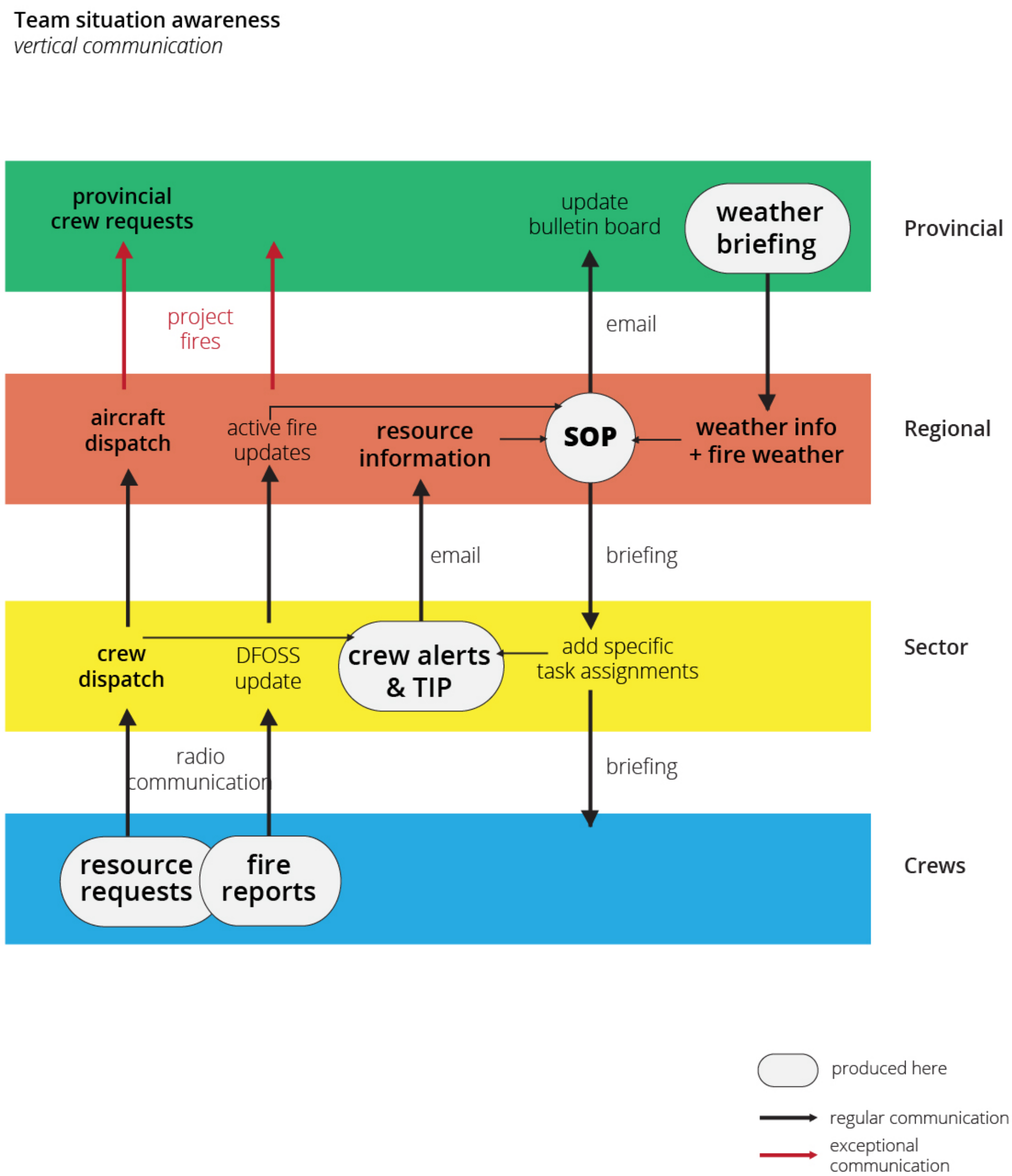
Task Analysis
Fire Response



Task Analysis
Strategic Operation Plan

The SOP is the main preparedness document/tool that is used among all levels of command

b. Communication



III. Team Situational Awareness analysis

a. Information Categories

From the observations and interviews 3 types of information that are used for maintaining TSA were identified:
(1) Backbone information (SOP and brieifing)
(2) Ambient information (3) Task specific information

Shared versus Operator Specific information
Team and Operators displays & other sources

Duty Officer
(most use of shared displays)
Fire prioritization Information
Mapper & physical maps
Fire reports (details)
DFOSS & Mapper
IC messages and reports
Radio e-log

Intelligence Officer
Weather stations and forecast
Multiple Sources
Fire weather maps
Mapper
Fire history documentation
Excel Sheet
Preparedness phase guide
Printed document
Briefing and SOP
Microsoft PP and word

AMO
Dispatch Information (detailed)
Mapper
Dispatch Ticket
(?)
IC messages and reports
Radio e-log

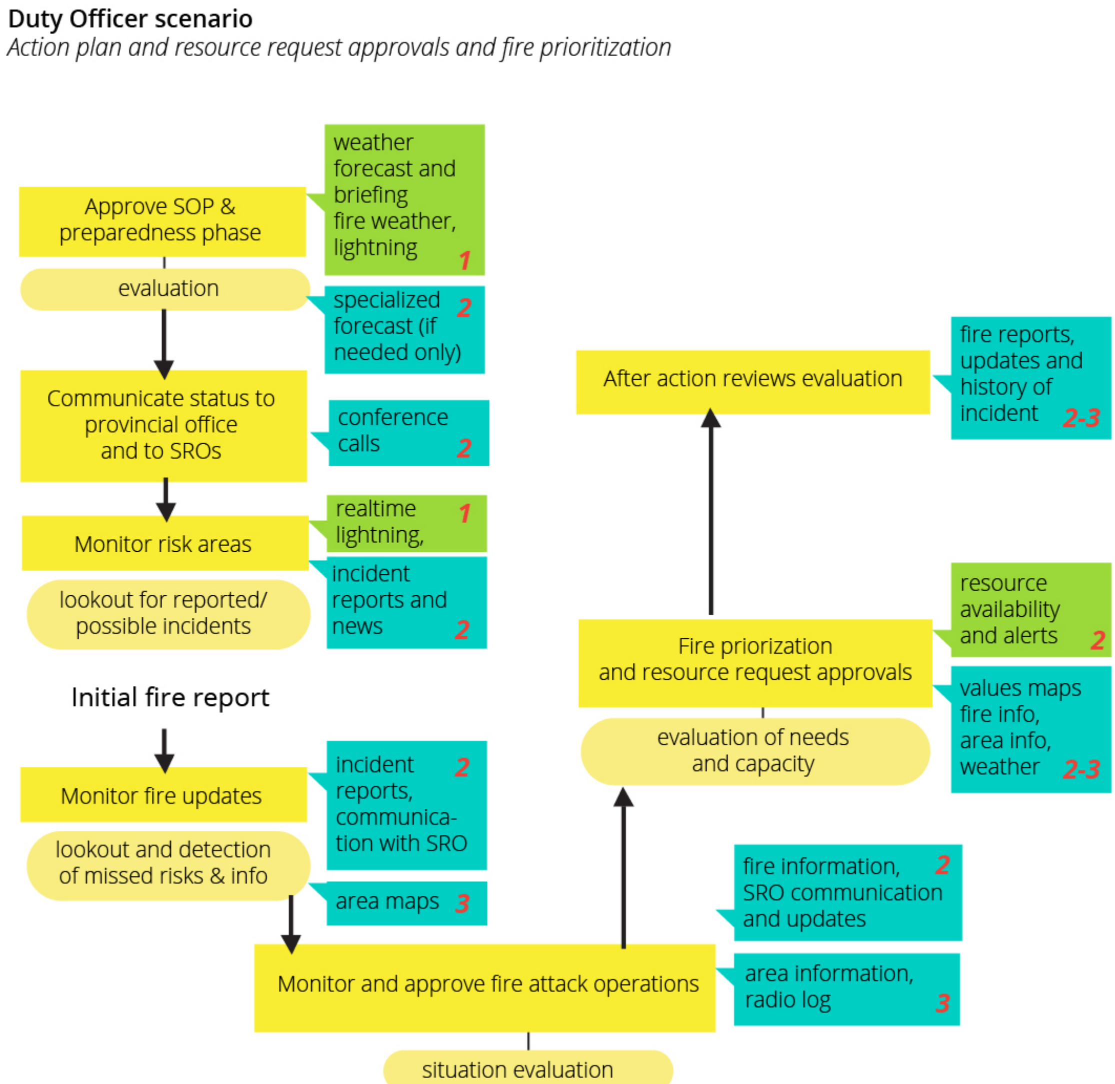
Ambient Information
shared displays showing:
Weather forecast and information
weather network
Real-time lightning map
Mapper
Intitial reports and burning fires
DFOSS (FMIS)
Dispatch Information (aircraft)
Mapper
Fire weather forecast
Mapper
Fire weather guide
Printed Table

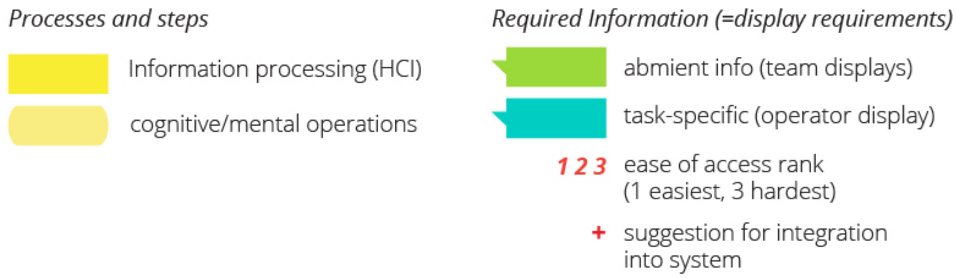
Sector office
Weather forecast *weather network*
Manpower + alerts *whiteboard*
Active Fires *whiteboard*

SRO
(focus on sector only)
Fire prioritization Information
Mapper
Fire reports (details)
DFOSS & Mapper
Crew Information
Excel sheets & word documents
Weather forecast
Multiple Sources

b. Decision ladders and Scenarios

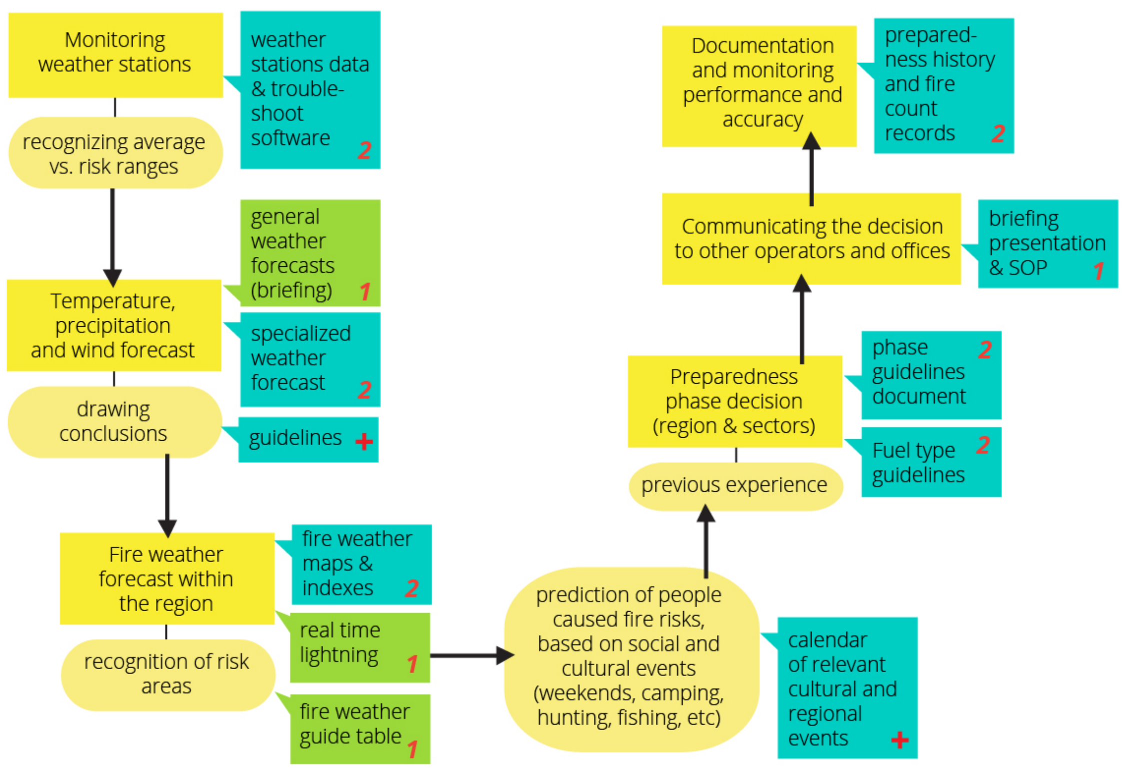
The following diagrams summarize selected scenarios of the most common and major tasks of the operators. The diagrams also show the display requirements and information needed for each step in the process.





Intelligence Officer scenario and decision ladder

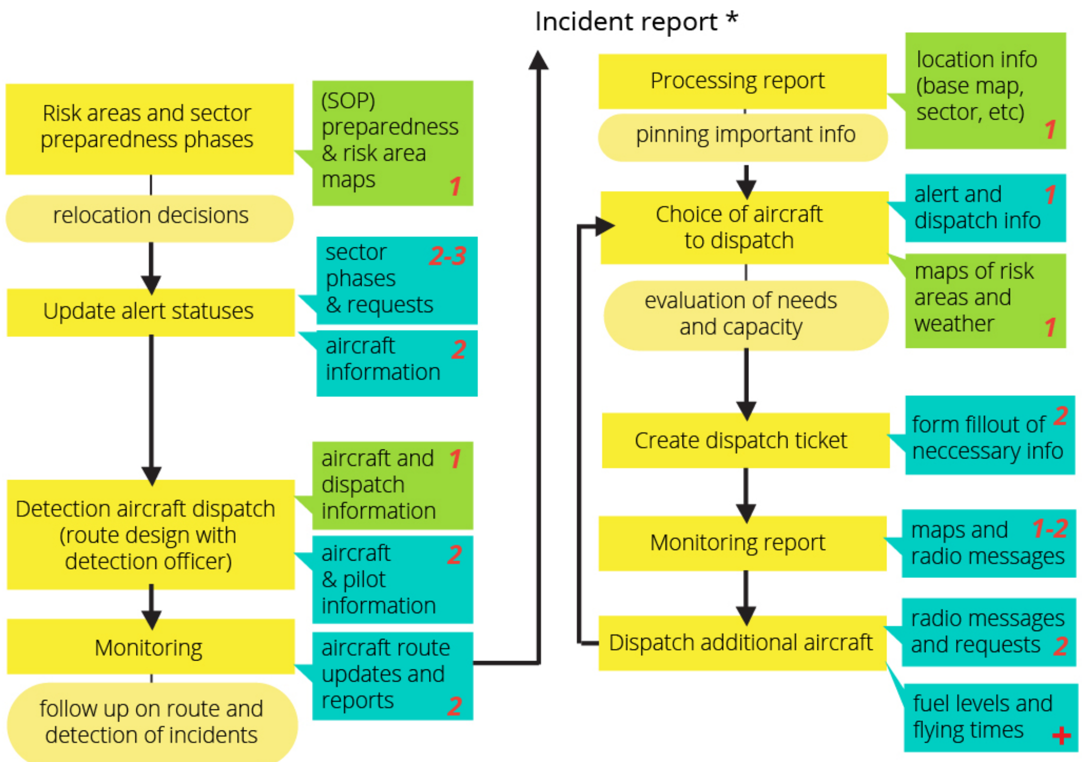
Decision: Preparedness phase for region & sectors



The AMO is only responsible for dispatching water bombers and detection aircraft. Helicopter dispatch is on the sector level (see SRO diagram).

AMO scenario and decision ladder

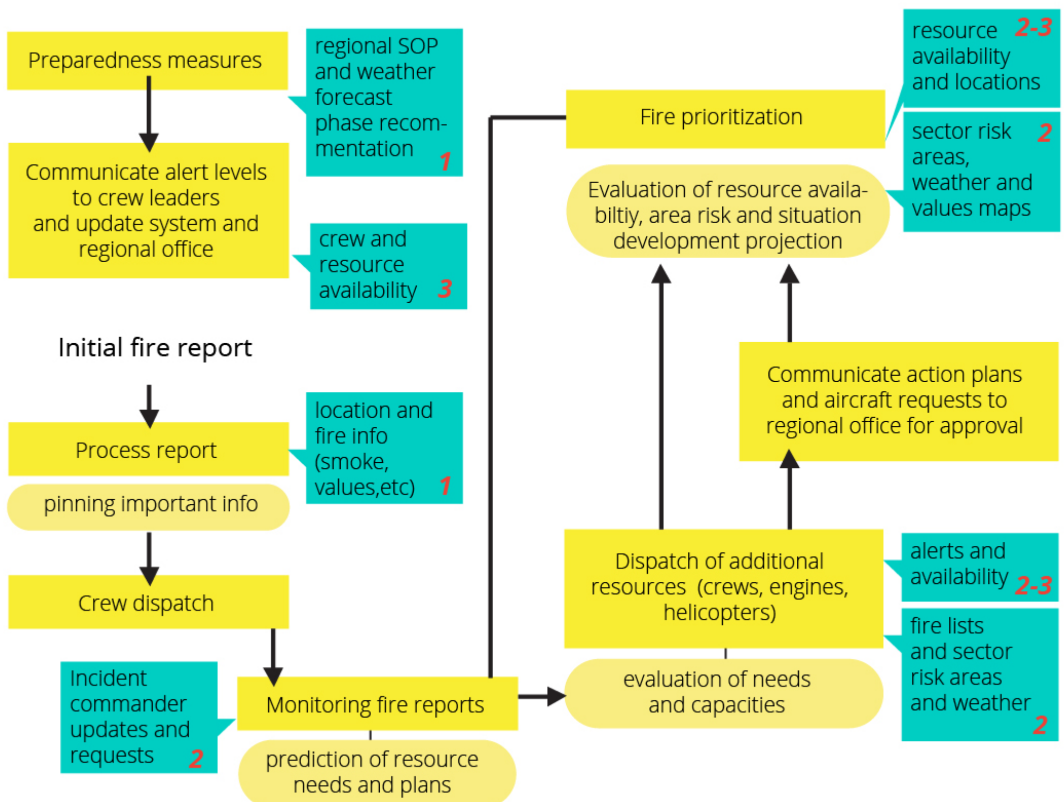
Decision: Aircraft Dispatch



*Process sometimes starts here if report comes from public and not the detection aircraft

The SRO is located in the sector office and not in the regional response office, only the SRO, maybe an assistant, the radio operator and an office clerk are located in the office, therefore the differentiation between ambient and task-specific information and displays is not clearly defined.

SRO scenario and decision ladder
Fire response operation



c. Display requirements

Information Category	Current Source	Ease of Access	Operators
Weather forecast	Weather network; weather briefing	1 team briefing twice daily/weather channel screen	all
Specialized weather forecast	External sources	2 requires some search	Intelligence Officer
Weather stations information	Special access	2 intelligence officer access and software	Intelligence Officer
Fire weather maps and indexes	Mapper	2 through appropriate layers and imports	Intelligence officer
Fire weather briefing maps	Mapper	1 maps created by intelligence officer	all
Real-time lighting	Mapper	1 mapper layer	all
Fire weather indexes guide	Printed table	2 easy access but needs information from weather stations to draw conclusions	Intelligence officer; sometimes DO
Fire and Initial reports	DFOSS	1list only	all
Detailed fire reports (locations & information)	DFOSS	2 access through fire number on the system	DO, AMO, SRO
Fire updates	DFOSS radio log	2 need manual input 2 limited access	DO, AMO, SRO
IC messages and updates	Verbal communication	1-2 varying reliability (through radio op.)	DO, AMO, SRO
Aircraft dispatch information	Mapper	1 showing locations and alerts, needs input from AMO	DO, AMO, (SRO)
Resource requests	Verbal com. +FMIS	2 through radio op. or through SRO, supposedly should be through FMIS	AMO, DO
Resource (crew & engines) availability	TIP documents, verbal com. + whiteboard (SRO only)	2 for SRO easier through direct communication 3 for DO (not always needed though)	SRO, DO

Information Category	Current Source	Ease of Access	Operators
Response zone maps	Physical map + Mapper	1 -2 depending on detail level needed	DO, SRO, (Intel.)
Value maps	Mapper	2-3 depending on area database and information	DO, SRO
Fire history and updates	DFOSS	2-3	DO
Fire number documentation	Word document	2 manual input needed from intelligence officer	Intelligence officer
Preparedness phase guide	Printed document	2 available with intelligence officer, passive guidelines for decision	Intelligence officer
Fuel type guide	Printed booklet	3 search within booklet requires prior understanding and experience	Intelligence officer, (DO)
Strategic operation plan (daily preparedness and plans)	Digital and printed document	1-2 available to all operators, presented twice daily, but document not interactive	all
Cultural and regional events	Experience & news	2-3 depending on popularity	Intel. + DO
Fire permits	Printed and digital permits	3 available only for SRO	SRO

Ambient information (team)

task specific information (operator)

Appendix 3

b) Analysis verification guiding questions (phone interview)

- Process analysis:
  - Are there major steps missing from the task analysis diagram?
  - Is your role properly included in the process?
  - Does the communication diagram capture the dynamics of the vertical communication properly?
  - Is there other information that needs to be included?

- TSA analysis:
  - Do you agree with this information categorization?
  - What other information categories should be included?
  - Can you relate to the distinction between operator and ambient information?
  - Is there information that you think is misplaced?
  - Do the diagrams capture all important aspects of the process?
  - Are there important issues or processes missing?
  - Can you relate your responsibilities and task to the ladders/scenarios?
  - Are there any cognitive or mental processing steps that you think should be added?
  - Are the information requirements integrated into the process properly? Where would you have a different interaction?

- Display requirements
  - What changes would you make in the ease of access rankings? Is the access of information described properly?
  - Are the other requirements that need to be included?
  - How differently would you distinguish between task-specific and ambient information?
  - Are there important information sources missing from the list?

Appendix 3

c) First Iteration Participation Email

Dear Mr. / Ms.,
Hope this email finds you well.

Since my visit to the forest fire response offices last September I have been working on analyzing the team process and situation awareness as well as come up with a proposal on how to enhance it.

At this point I am looking to verify the analysis I have so far with each operator. Therefore I would highly appreciate if you let me know when you are available for such a discussion by phone in the next week.

The phone call should not take longer than 20-25 minutes; I have prepared a document that includes a summary of the analysis that I will send to you before the scheduled call.

Thanks a lot, really appreciate your time.

Best Regards,

Appendix 4

Enhancement proposals ranking questionnaire

(Enhancement proposals in section 4.2.2 of thesis)

1. What additional conclusions or challenges do you think should be added to the list (page 1)?

2. From these conclusions (page1), including any you think should be added, which one would you rank as the most important or pressing challenge?
    a. Facilitate the use of current tools
    b. Facilitate input of updates
    c. Integrate guidelines and models for decision making
    d. Flexibility of information prioritizing
    e. …
    f. …

3. What additions or modifications would you suggest to the information flow diagram (page2)?

4. What other goals do you think the system should accommodate to facilitate the process (pages 3,4)?

5. How would you rank of the high-level goals listed (pages3,4) for the system according to their importance? (1 being the most important)

Goals	Your ranking
Facilitate data input	
Accommodate operator specific tasks and processes	
Facilitate team activity awareness and communication	
Accommodate interaction between operator and team displays	
Facilitate operator shift changes	
Accommodate operators’ activity and updates log	

Appendix 5

a) User Evaluation Recruitment Email

Title: FFMS research continuation | Carleton University

Hello Mr. (operator name)

Hope this email finds you well.
My name is Laila Goubran, I am a master's student at the Human Computer Interaction program at Carleton University in Ottawa.
In continuation with the research, I have started in September; I have been working on an interface proposal that is supposed to facilitate fire information collection and input during fire response operations. The proposal is based on the observations and discussions I have done during my visit in September as well as the process validation that I have conducted with a number of operators end of November.

At this point I will be looking for an evaluation and preliminary testing of the system proposal by a number of expert operators from your office. Ideally operators, who are responsible for inputting information to the system during response operations.

According to my timeline my prototype should be ready for evaluation starting May 2015. I understand that the fire season would've already started, so I would therefore appreciate your help in coordinating the best time to conduct this evaluation with operators who can be available and willing to participate.

The evaluation sessions should take maximum 60 minutes. The operators would interact with a prototype of the proposed interface to complete 10 potential fire response tasks, and then complete a questionnaire about their experience with the interface.

The testing session does not propose any social or economic harm higher than that encountered by the participants in their everyday professional environment, and working the proposed interface does not reflect or affect the participants' professional competence in any way.

The ethics protocol for this project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact the Research Ethics Board (REB) at Carleton University through: ethics@carleton.ca.

I really appreciate your time and help.

Best Regards,
Laila Goubran

Appendix 5

b) User Evaluation Consent Form

Carleton UNIVERSITY
Canada's Capital University

Consent Form

Title: **Facilitating Information Collection as the Foundation of situation awareness in forest fire response**

Funding Source: MNRF, Ministry of National Resources and Forestry, Province of Ontario, Forest Fire and Emergency Services Branch

Date of ethics clearance: To be determined by the REB (as indicated on the clearance form)

Ethics Clearance for the Collection of Data Expires: To be determined by the REB (as indicated on the clearance form)

I ____, choose to participate in a study testing a proposed fire information input system. This study aims to evaluate a proposed interface to facilitate information gathering and distribution in forest fire response operations. **The researcher for this study is Laila Goubran in the Human Computer Interaction program at Carleton University.**
She is working under the supervision of Dr. Anthony Whitehead in the School of Information Technology at Carleton University.

This is a 60-minute study. That includes two parts. In the first part you will interact with an interface prototype to complete 10 tasks. The researcher will read out the tasks one by one and you have unlimited time to complete them. You will be asked to try to describe your thoughts and actions while interacting with the interface as well as to answer some questions about the interface in between the tasks. With your consent, the session will be video recorded.
In the second part of the study you will be asked to complete a questionnaire about your experience with the interface.

You have the right to end your participation in the study at any time, for any reason, up until (July 15th 2015). You can withdraw by phoning or emailing the researcher or the research supervisor. If you withdraw from the study, all information you have provided will not be used.

Your data will only be linked to your role within the response team and all your information will be confidential during the whole project. The video recordings will be erased once they are transcribed. All research data will only be accessible by the researcher and the research supervisor. The testing session does not propose any social or economic harm higher than that encountered by the participants in their everyday professional environment, and working the proposed interface does not reflect or affect the participants professional competence in any way.

If you would like a copy of the finished research project, you are invited to contact the researcher to request an electronic copy, which will be provided to you.

The ethics protocol for this project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

REB contact information:
Professor Louise Heslop, Chair
Professor Andy Adler, Vice-Chair
Research Ethics Board
Carleton University
511 Tory
1125 Colonel By Drive
Ottawa, ON K1S 5B6
Tel: 613-520-2517
ethics@carleton.ca

Researcher contact information:
Name :Laila Goubran
Department:
Human Computer Interaction
Carleton University
Tel: 613 619 1868
Email: Laila.goubran@carleton.ca

Supervisor contact information:
Name: Anthony Whitehead
Department
School of Information Technology
Carleton University
Tel:
Email:Anthony.whitehead@carleton.ca

Do you agree to be video-recorded: ___Yes ___No

_________________________ _______________
Signature of participant Date

_________________________ _______________
Signature of researcher Date

Appendix 5

c) Debriefing sheet

What are we trying to learn in this research?

We want to research how the information collection process can be improved to accommodate better team communication and thus better team situation awareness. In this study we aim to evaluate the operators' interaction with the proposed interfaces as well as the awareness level that the interfaces provide during a fire response operation

What are our hypotheses and predictions?

This study aimed to test the two assumptions that (1) an integrated data input interface and a (2) mobile data input interface would be suitable enhancements for the information collection process.
We predict that an intelligent interactive system that directly links response office operators and field crew can enhance the information collection process to support the team's general situation awareness during a fire response operation.

Why is this important to scientists or the general public?

In emergency response domains, such as forest fighting, the timely collection and distribution of the information is crucial for maintaining the team's awareness of the situation and taking the required response decisions and actions. Therefore a system and interface that can support and facilitate the information flow is of great value to the whole overall process.

Where can I learn more?

There have been many studies about designing for emergency response.
Here are a few examples:

* Designing for Situation Awareness
  Endsley, Mica, and Debra Jones. 2011. *Designing for Situation Awareness, An Approach to User-Centered Design*. Second edi. CRC Press.

* Extending the Fire Dispatch System into the Mobile Domain
  A Meissner, Andreas, and Ralf Eck. 2007. "Extending the Fire Dispatch System into the Mobile Domain." In *Mobile Response*, Springer Berlin Heidelberg, 143–52.

What if I have questions later?

If you have any further concerns, questions or comments about the research, please feel free to contact Laila Goubran (Principal Investigator), at laila.goubran@carleton.ca;

Appendix 6

Cognitive Walkthrough Script (User Evaluation)

Hello. My name is Laila and I'm a master's student at Carleton University in Ottawa, at the Human Computer Interaction program.
First of all I would like to thank you for taking the time to participate in this study. The purpose of the study is to evaluate the interface proposed for my thesis.
Based on the research, I have started in September about the fire response process and through the feedback given to me by several fire response operators I have focused my thesis on attempting to facilitate data collection and documentation during fire response operations. So I have developed both an interface to be used in the response office and a mobile interface that can be used by the crewmembers on the fire.

Given your role in the response team you will be testing the response office interface/ mobile interface. For the purposes of this test I should mention that this is just a prototype for the interface, so not all icons and functions are active.
I will be reading out small tasks for you to complete using the prototype. I would appreciate if you can try to express you thoughts and actions while your interacting with the prototype.

After you have completed all 10 tasks, you will be asked to rate a few aspects of the interface. At the end you will complete a short questionnaire to further evaluate your experience.
Before we start please take a moment to read the consent form and sign it at the bottom whenever you are ready.

Thank you. Now the interface is ready for the test.

Response office interface: […] You can interact with the interface with the mouse through point and click
Mobile interface: [...] As you can see this is a touch interface.

Just a few things to help you interact, when you enter new information you will see that they're in blue and only when you click save will they turn black indicating that they have been inputted.

In addition to find or add some information you will need to expand specific windows sometimes.

Whenever you are ready I will start reading out task by task for you to complete. It is important to keep in mind that this process is intended to test the design, not you. You are not being timed so please take your time. And as much as you can try to express your thought process or any comments you have about the interface while we proceed. If you are ready we can start with the first task:

Tasks for the response office interface

	Task	Type
1	You have received a public call about a fire near Trout Lake. You need to create a new initial report on the system. How do you do that?	Input
2	You have received an update on the fire behavior from the crew on fire number 2. You need to update it to shouldering. How do you do this?	Input
3	The crew has reported 4 spot fires. How do you update this information on the system?	Input
4	The duty officer asks you to check for values around fire number 2. You find one threated value close to the fire and need to add it to the list. How would you do that?	Input
5	What types resources that are committed to fire number 2?	SA Level 1
6	Fire number 2 has been burning for a day now, you want to check when the crew first arrived there? How can you do this?	SA Level 2
7	What is the current status of the fire?	SA Level 1
8	When does the incident commander aim to have the fire OUT?	SA Level 2
9	The crew on fire number 2 requested assistance. Are there any resources on the way to them? If yes, can you name them?	SA Level 2
10	You need to make sure that the information shown in up to date. When was information last updated	SA Level 2

Tasks for the mobile interface

	Task	Type
1	You’re on the way a reported incident and you check the response information. In what zone is the fire? And what is the response objective?	SA level 1
2	Your crew has been dispatched in response to an initial report. You arrive at the location and find a fire. You need to confirm the fire and update the status and the intensity class (3) on the system. How would you do that?	Input
3	The fire has 2 spot fires. How can you update this information on the system?	Input
4	As part of the scouting report of the fire you need to update the fuel type in the area to M2 (mixedwood green)	Input
5	The values around the fire have been updated from the sector office on the system. How many threatened values are currently on the list for fire number 2?	SA level 2
6	You see a cabin 50 m to the north of the fire? How do you update this information on the system?	Input
7	An additional crew has been dispatched for controlling the fire. They have just arrived at the fire and you need to record their arrival time. (Jones)	Input
8	You have requested an aircraft for your response operation. You would like to check the status of this request. Has the aircraft been dispatched already?\	SA Level 2
9	While you’re thinking of the action plan to attack the fire you’d like to check the fire weather forecast for the area. What is the forecasted temperature for today?	SA Level 1
10	What time does the team aim to have the fire OUT.	SA Level 2

Appendix 7

Heuristic Evaluation Questions (user testing)

Before we proceed to the questionnaire I would like you to rate a few aspects of the interface. The prototype you've been using is available to you if you'd like to reassess a specific interaction. I will be reading out question by question and you can express any comments or ideas about each aspect and then record your rating on the sheet :

" How would you rate […]" / "How do you find […]"

1. The intuitiveness of the interface for finding the information you were looking for?

2. The familiarity with the language and abbreviations used?

3. The usefulness the interface?

4. The flexibility of the interface for inputting information?

5. The consistency of this function with your usual response process?

6. The control that the interface offers you for completing the tasks?

7. The organization of the information?

8. The effectiveness of the functionalities in terms of process requirements?

9. The feedback that the interface provides about your progress or the task?

10. The prioritization of the information presentation (e.g. hidden vs. main info)?

Appendix 8

Questionnaire

b) Questionnaire (including the prototype interface)

You have almost completed the evaluation. The following questions should enhance the understanding of your overall experience with the proposed system. Please answer as honestly as you can, these answers will assist in the development of a reliable, efficient design.

1. General information
   a. How long have you been working at the MNR: _______________

   b. What is your role in the MNR fire response team: __________________________________

   c. Which interface have you tested
      ☐ mobile interface ☐ office interface

2. How would you rate the interaction with the proposed design in comparison to the current system in terms of:

		Worse	Somewhat worse	Same	Somewhat better	Better
a.	Ease of Use	☐	☐	☐	☐	☐
b.	Support of process requirements	☐	☐	☐	☐	☐
c.	Support of coordination, and collaboration	☐	☐	☐	☐	☐
d.	Support of situation awareness	☐	☐	☐	☐	☐
e.	Efficiency (effort and time required)	☐	☐	☐	☐	☐
f.	Visual design and organization	☐	☐	☐	☐	☐

3. Do you agree or disagree with the following statements:

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a.	The functions of the system are well integrated	☐	☐	☐	☐	☐
b.	The system has the potential to save time during a response operation	☐	☐	☐	☐	☐
c.	The interface is unnecessarily cluttered	☐	☐	☐	☐	☐
d.	The system allows for comprehensive information collection	☐	☐	☐	☐	☐
e.	The interface is difficult to understand	☐	☐	☐	☐	☐
f.	The system supports all features and controls required for a fire response process	☐	☐	☐	☐	☐

4. Do you feel that the proposed system would be a valuable addition to your process?
   - ☐ very valuable
   - ☐ somewhat valuable
   - ☐ neutral
   - ☐ not valuable

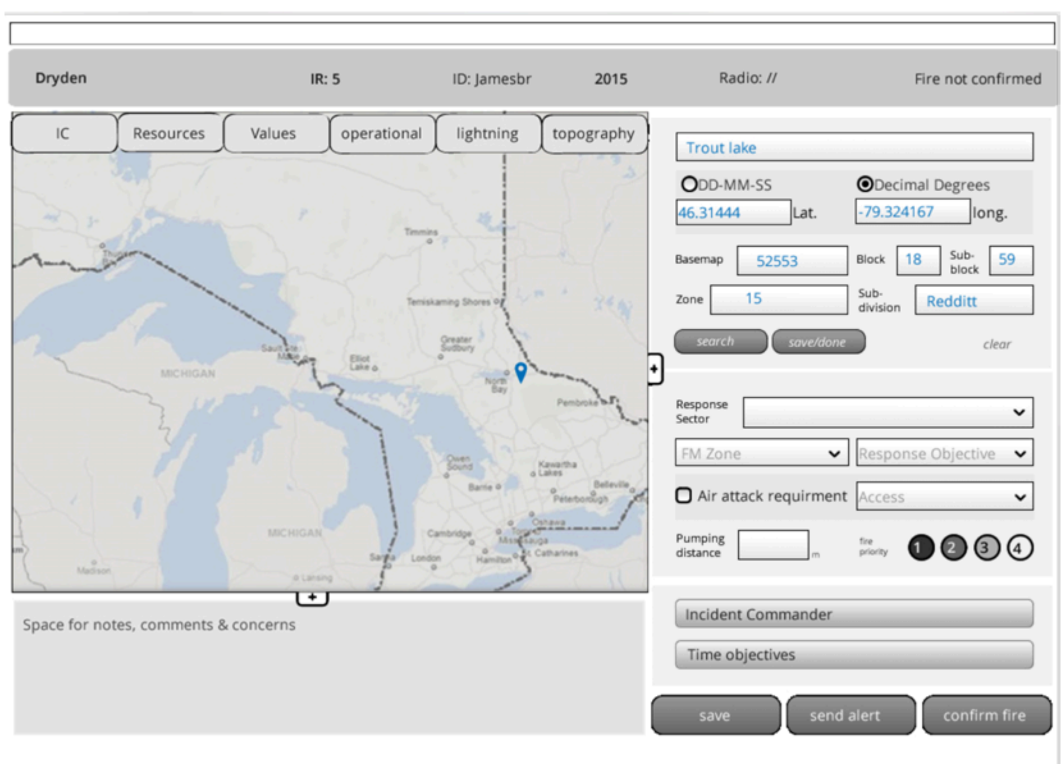
5. (For office operators only) Do you feel that a mobile information input interface for the crew would be a valuable addition to your process?
   - ☐ very valuable
   - ☐ somewhat valuable
   - ☐ neutral
   - ☐ not valuable

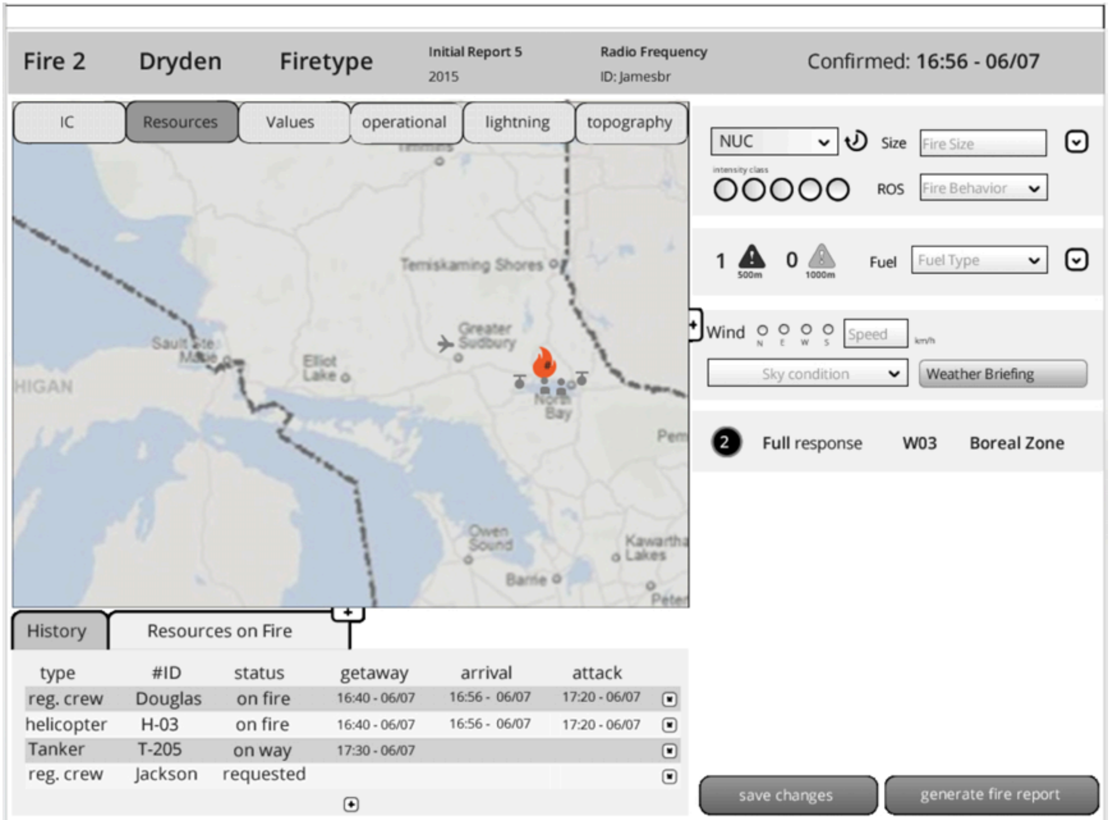
6. On the printed interface provided (on following pages) , would you please:
   a. Circle features or components you liked
   b. Draw a square around features or components that you did not like
   c. Add any comments that you would like to express about the interface

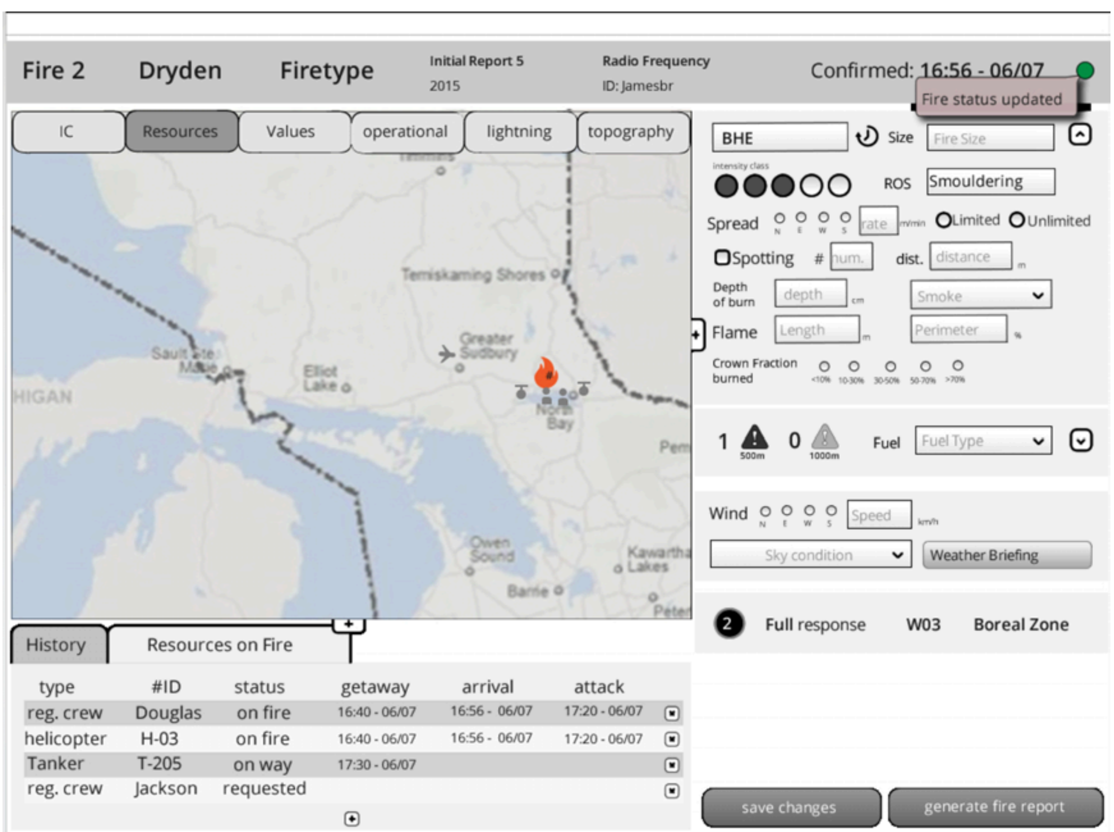
Thank you so much for your time

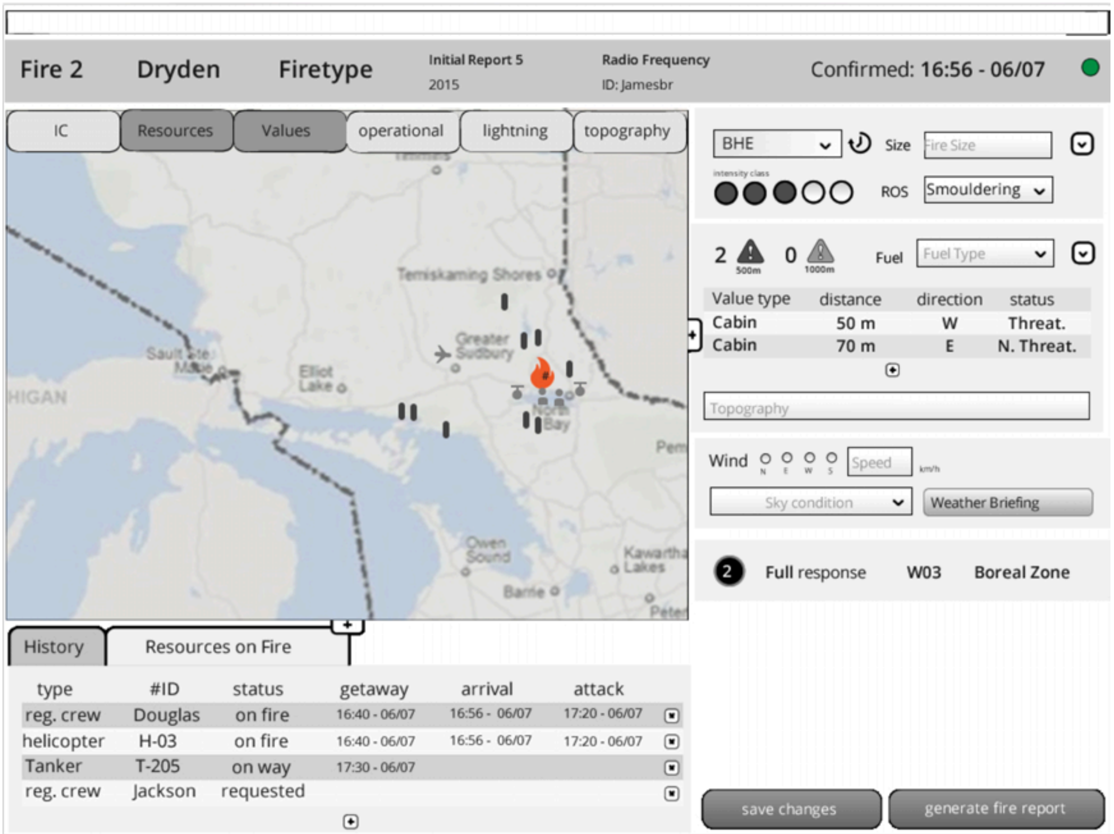
Appendix 9

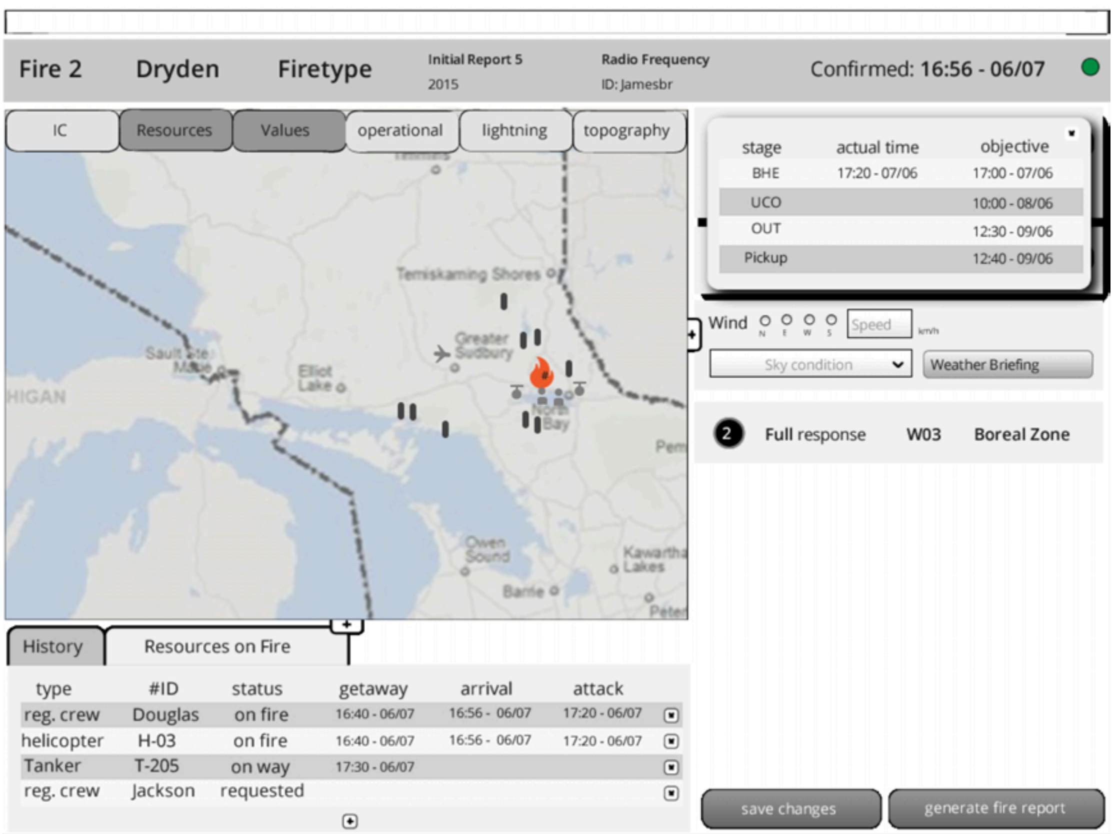
a) Prototype: Office interface

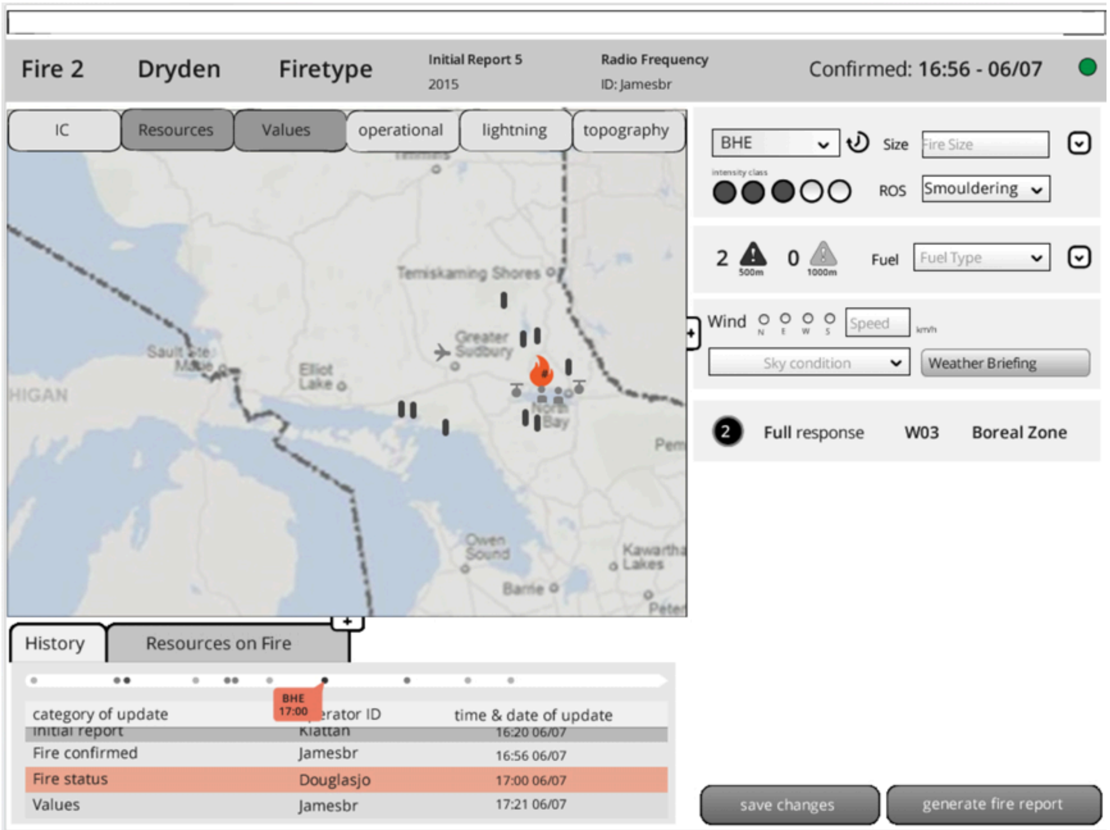



Fire 2
Dryden
Firetype
Initial Report 5
2015
Radio Frequency
ID: Jamesbr
Confirmed: 16:56 - 06/07
IC
Resources
Values
operational
lightning
topography
NUC
Size
Fire Size
intensity class
ROS
Fire Behavior
1
500m
0
1000m
Fuel
Fuel Type
Wind
N E W S
Speed
km/h
Sky condition
Weather Briefing
2
Full response
W03
Boreal Zone
Temiskaming Shores
Greater Sudbury
Sault Ste Marie
Elliot Lake
HIGAN
North Bay
Owen Sound
Kawartha Lakes
Barrie
History
Resources on Fire
type
#ID
status
getaway
arrival
attack
reg. crew
Douglas
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
helicopter
H-03
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
Tanker
T-205
on way
17:30 - 06/07
reg. crew
Jackson
requested
save changes
generate fire report


Fire 2
Dryden
Firetype
Initial Report 5
2015
Radio Frequency
ID: Jamesbr
Confirmed: 16:56 - 06/07
Fire status updated
IC
Resources
Values
operational
lightning
topography
BHE
Size
Fire Size
intensity class
ROS
Smouldering
Spread
N E W S
rate
m/min
Limited
Unlimited
Spotting
#
num.
dist.
distance
m
Depth of burn
depth
cm
Smoke
Flame
Length
m
Perimeter
%
Crown Fraction burned
<10%
10-30%
30-50%
50-70%
>70%
1
500m
0
1000m
Fuel
Fuel Type
Wind
N E W S
Speed
km/h
Sky condition
Weather Briefing
2
Full response
W03
Boreal Zone
Temiskaming Shores
Greater Sudbury
Sault Ste Marie
Elliot Lake
HIGAN
North Bay
Owen Sound
Kawartha Lakes
Barrie
History
Resources on Fire
type
#ID
status
getaway
arrival
attack
reg. crew
Douglas
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
helicopter
H-03
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
Tanker
T-205
on way
17:30 - 06/07
reg. crew
Jackson
requested
save changes
generate fire report

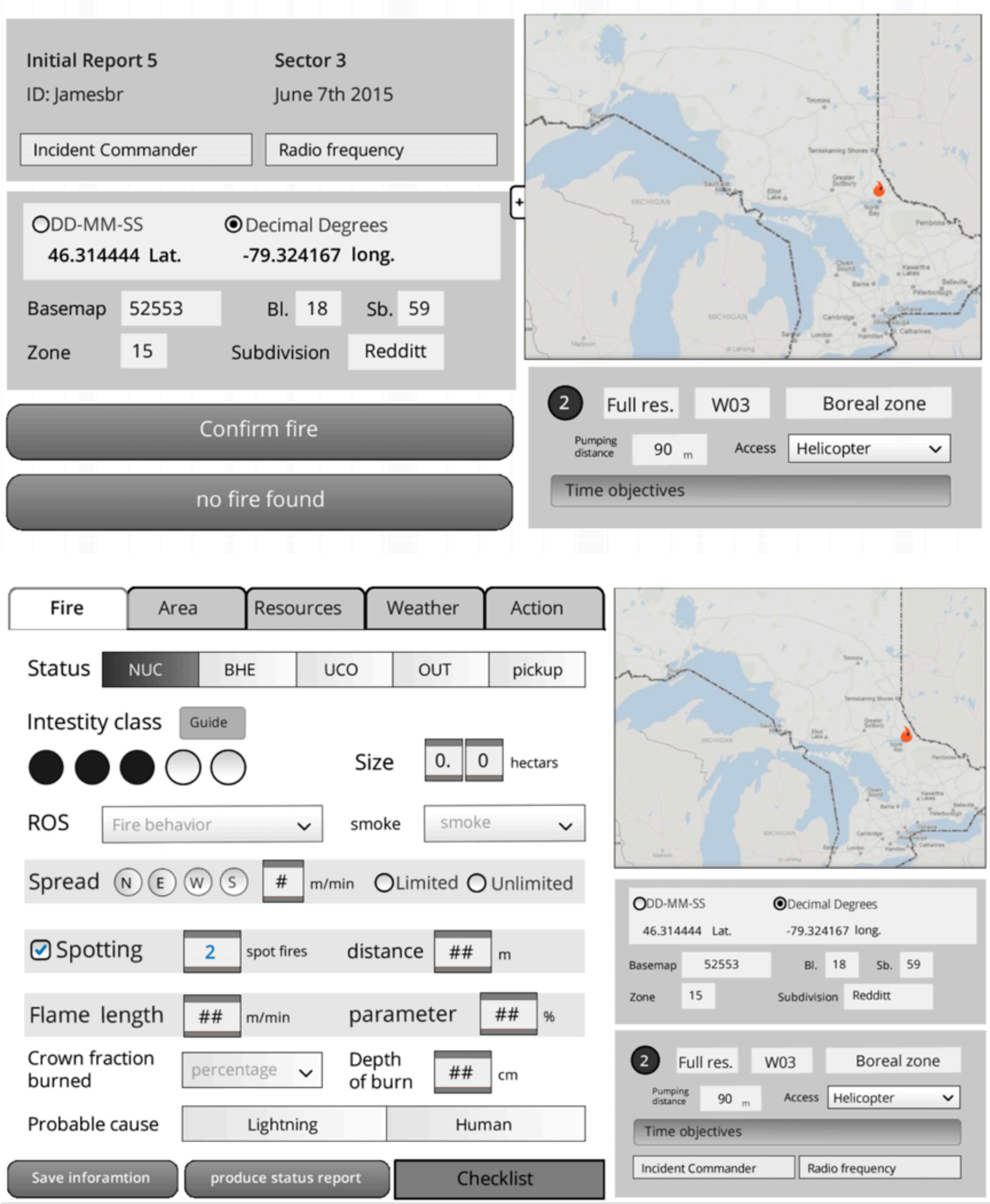

Fire 2
Dryden
Firetype
Initial Report 5
2015
Radio Frequency
ID: Jamesbr
Confirmed: 16:56 - 06/07
IC
Resources
Values
operational
lightning
topography
BHE
Size
Fire Size
intensity class
ROS
Smouldering
2
500m
0
1000m
Fuel
Fuel Type
Value type
distance
direction
status
Cabin
50 m
W
Threat.
Cabin
70 m
E
N. Threat.
Topography
Wind
N E W S
Speed
km/h
Sky condition
Weather Briefing
2
Full response
W03
Boreal Zone
History
Resources on Fire
type
#ID
status
getaway
arrival
attack
reg. crew
Douglas
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
helicopter
H-03
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
Tanker
T-205
on way
17:30 - 06/07
reg. crew
Jackson
requested
save changes
generate fire report

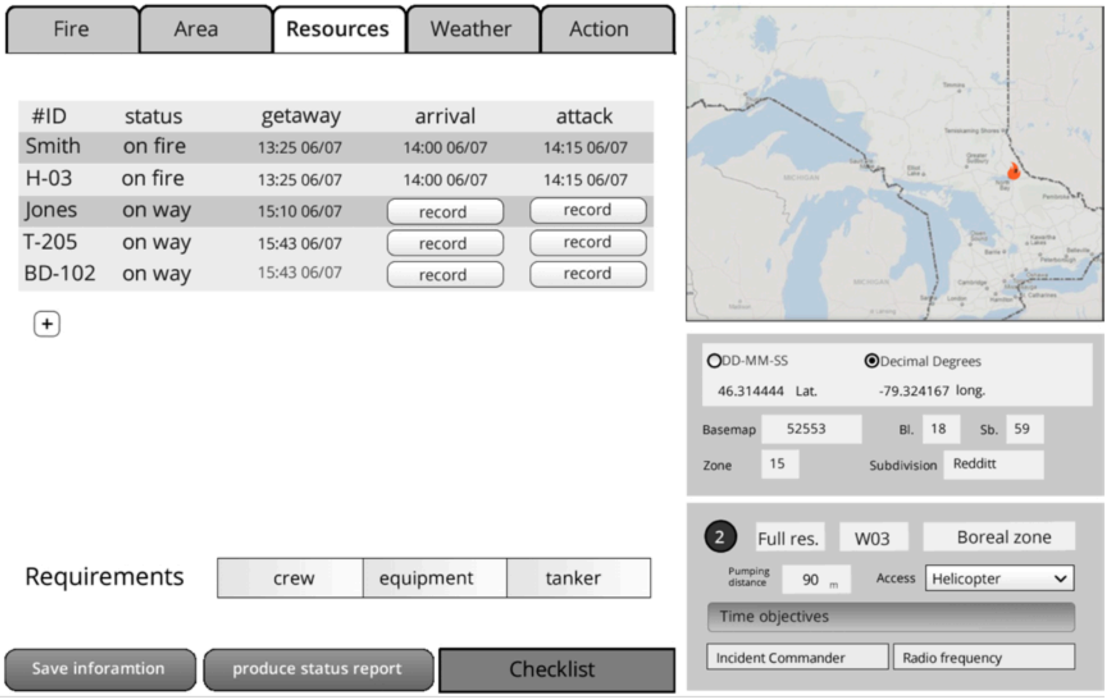

Fire 2
Dryden
Firetype
Initial Report 5
2015
Radio Frequency
ID: Jamesbr
Confirmed: 16:56 - 06/07
IC
Resources
Values
operational
lightning
topography
stage
actual time
objective
BHE
17:20 - 07/06
17:00 - 07/06
UCO
10:00 - 08/06
OUT
12:30 - 09/06
Pickup
12:40 - 09/06
Wind
N E W S
Speed
km/h
Sky condition
Weather Briefing
2
Full response
W03
Boreal Zone
History
Resources on Fire
type
#ID
status
getaway
arrival
attack
reg. crew
Douglas
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
helicopter
H-03
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
Tanker
T-205
on way
17:30 - 06/07
reg. crew
Jackson
requested
save changes
generate fire report

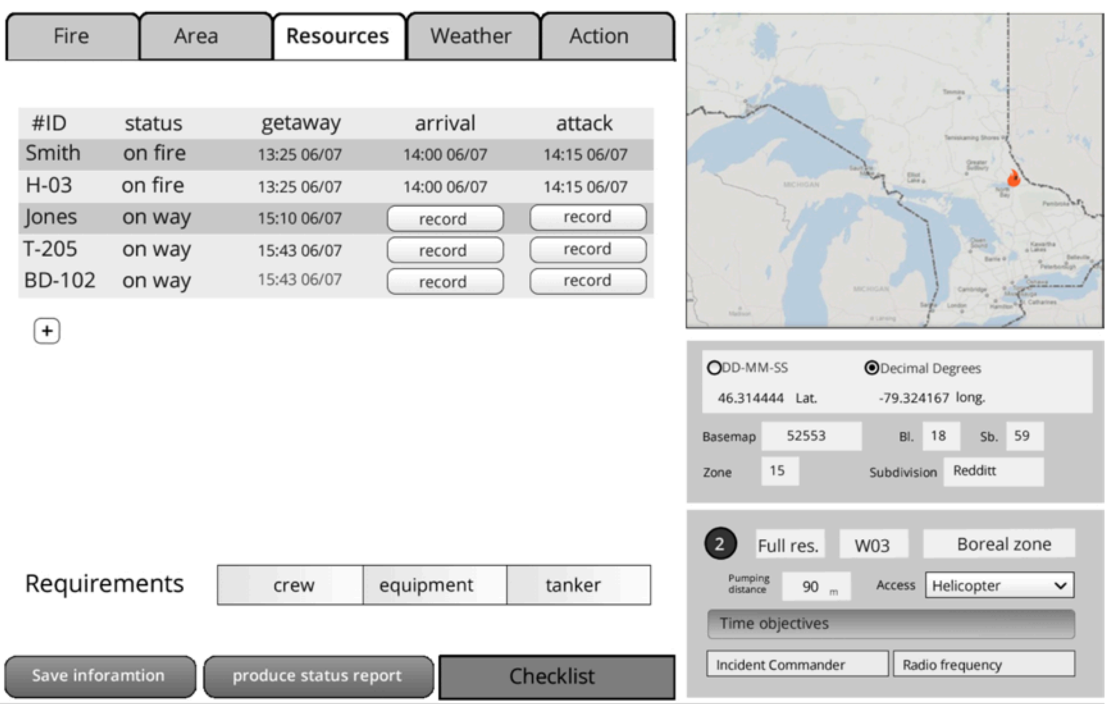

Fire 2
Dryden
Firetype
Initial Report 5
2015
Radio Frequency
ID: Jamesbr
Confirmed: 16:56 - 06/07
IC
Resources
Values
operational
lightning
topography
BHE
Size
Fire Size
intensity class
ROS
Smouldering
2
500m
0
1000m
Fuel
Fuel Type
Wind
N E W S
Speed
km/h
Sky condition
Weather Briefing
2
Full response
W03
Boreal Zone
Temiskaming Shores
Greater Sudbury
Sault Ste. Marie
Elliot Lake
North Bay
Owen Sound
Kawartha Lakes
Barrie
History
Resources on Fire
BHE
17:00
category of update
operator ID
time & date of update
Initial report
Klattan
16:20 06/07
Fire confirmed
Jamesbr
16:56 06/07
Fire status
Douglasjo
17:00 06/07
Values
Jamesbr
17:21 06/07
save changes
generate fire report

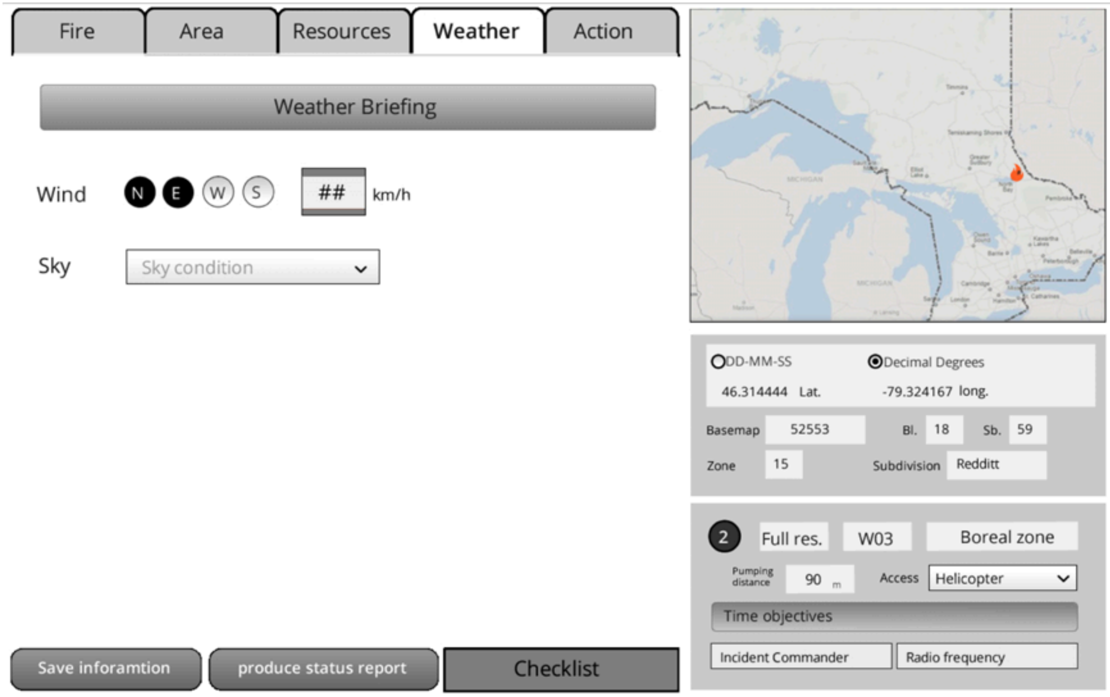
Appendix 9

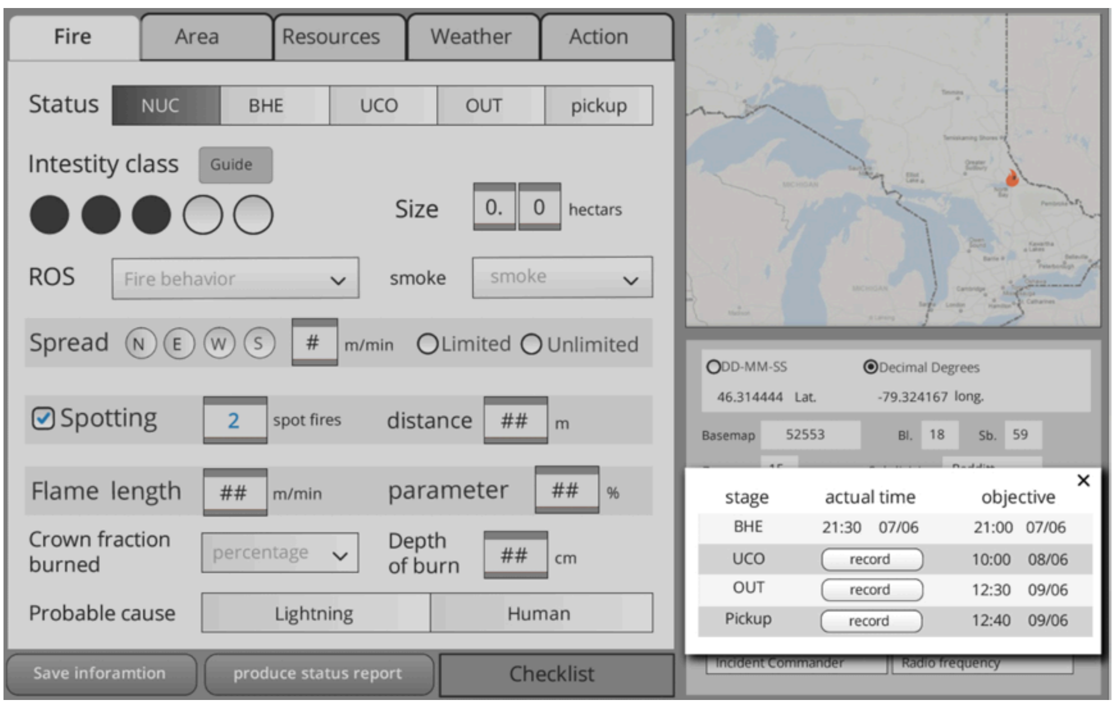
b) Prototype: Mobile interface




Fire
Area
Resources
Weather
Action
#ID status getaway arrival attack
Smith on fire 13:25 06/07 14:00 06/07 14:15 06/07
H-03 on fire 13:25 06/07 14:00 06/07 14:15 06/07
Jones on way 15:10 06/07 record record
T-205 on way 15:43 06/07 record record
BD-102 on way 15:43 06/07 record record
+
Requirements
crew
equipment
tanker
Save inforamtion
produce status report
Checklist
DD-MM-SS
Decimal Degrees
46.314444 Lat.
-79.324167 long.
Basemap 52553
Bl. 18
Sb. 59
Zone 15
Subdivision Redditt
2
Full res.
W03
Boreal zone
Pumping distance 90 m
Access Helicopter
Time objectives
Incident Commander
Radio frequency


Fire
Area
Resources
Weather
Action
#ID status getaway arrival attack
Smith on fire 13:25 06/07 14:00 06/07 14:15 06/07
H-03 on fire 13:25 06/07 14:00 06/07 14:15 06/07
Jones on way 15:10 06/07 record record
T-205 on way 15:43 06/07 record record
BD-102 on way 15:43 06/07 record record
+
Requirements
crew
equipment
tanker
Save inforamtion
produce status report
Checklist
DD-MM-SS
Decimal Degrees
46.314444 Lat.
-79.324167 long.
Basemap 52553
Bl. 18
Sb. 59
Zone 15
Subdivision Redditt
2
Full res.
W03
Boreal zone
Pumping distance 90 m
Access Helicopter
Time objectives
Incident Commander
Radio frequency

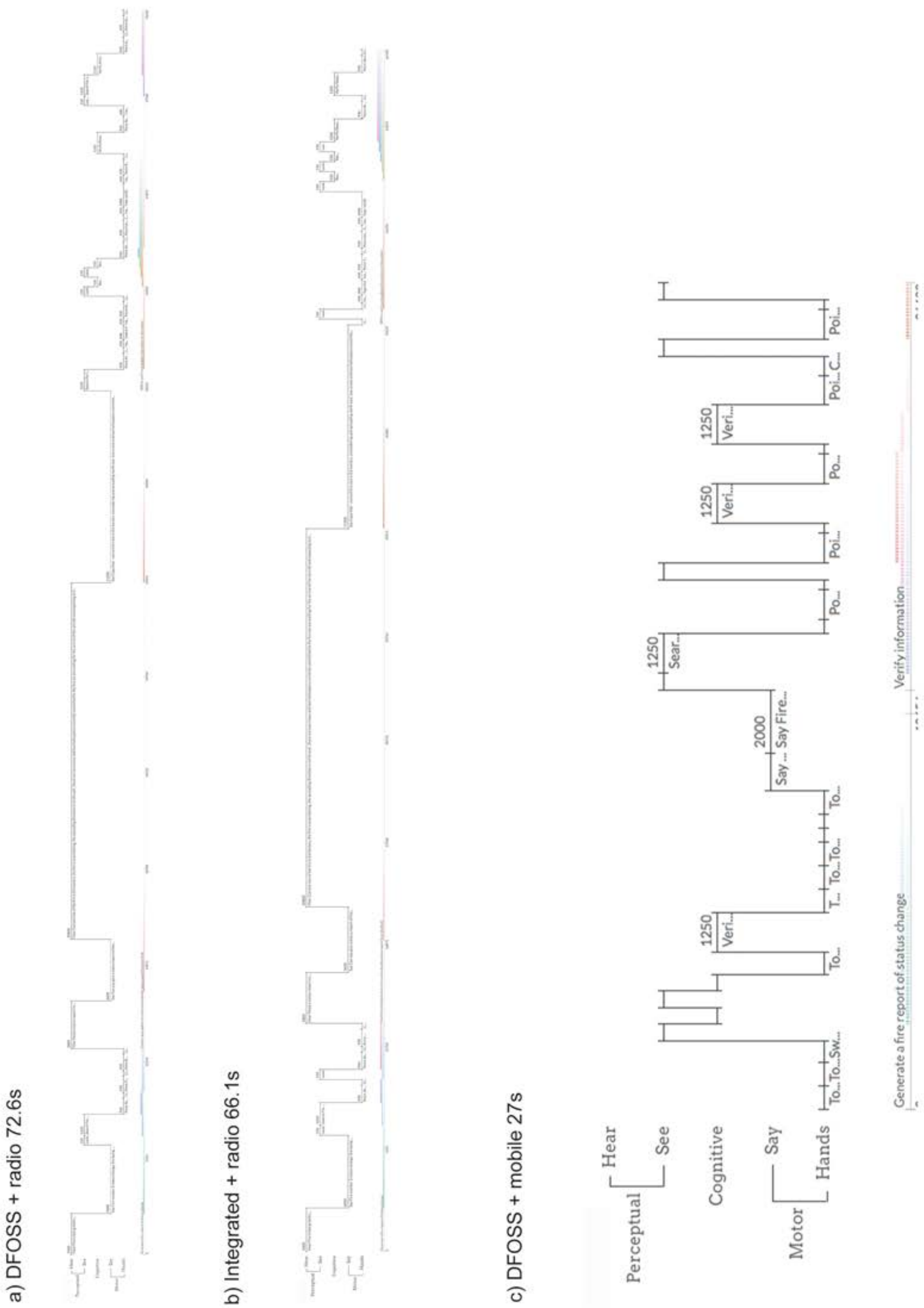

Fire
Area
Resources
Weather
Action
Weather Briefing
Wind
N E W S
##
km/h
Sky
Sky condition
Save inforamtion
produce status report
Checklist
DD-MM-SS
Decimal Degrees
46.314444 Lat.
-79.324167 long.
Basemap 52553
Bl. 18
Sb. 59
Zone 15
Subdivision Redditt
2
Full res.
W03
Boreal zone
Pumping distance 90 m
Access Helicopter
Time objectives
Incident Commander
Radio frequency


Fire
Area
Resources
Weather
Action
Status
NUC
BHE
UCO
OUT
pickup
Intestity class
Guide
Size
0.
0
hectars
ROS
Fire behavior
smoke
smoke
Spread
N E W S
#
m/min
Limited
Unlimited
Spotting
2
spot fires
distance
##
m
Flame length
##
m/min
parameter
##
%
Crown fraction burned
percentage
Depth of burn
##
cm
Probable cause
Lightning
Human
Save inforamtion
produce status report
Checklist
DD-MM-SS
Decimal Degrees
46.314444 Lat.
-79.324167 long.
Basemap 52553
Bl. 18
Sb. 59
stage
actual time
objective
BHE 21:30 07/06 21:00 07/06
UCO record 10:00 08/06
OUT record 12:30 09/06
Pickup record 12:40 09/06
Incident Commander
Radio frequency

Appendix 10

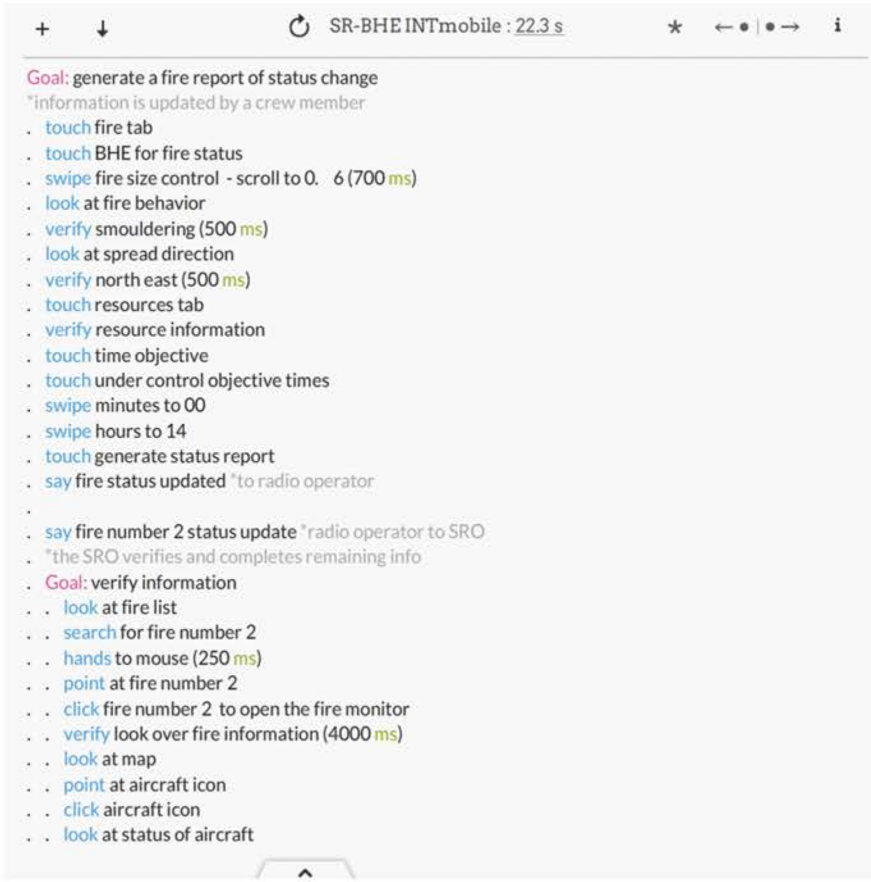
Model Evaluation Results (sample of 3 scenarios)

Scenario 4: Status Report (BHE)



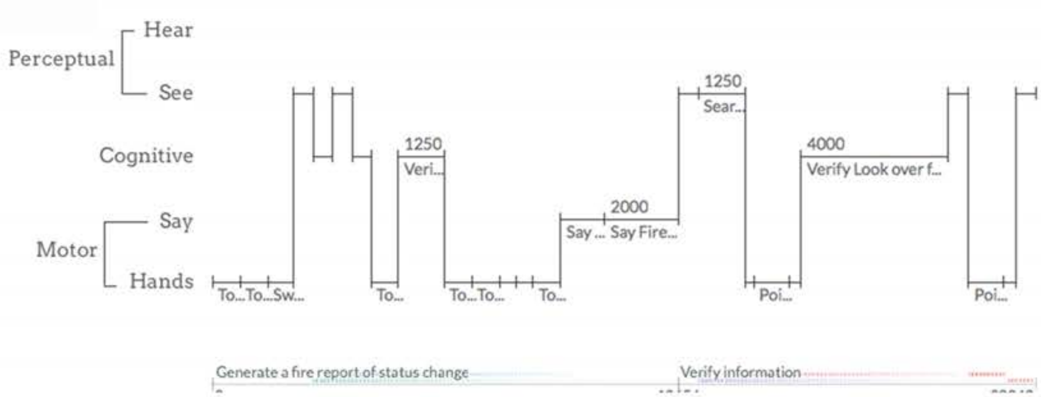
Scenario 4: Status Report (BHE) - continued

d) Integrated + mobile 20.5s (Cogulator syntax)



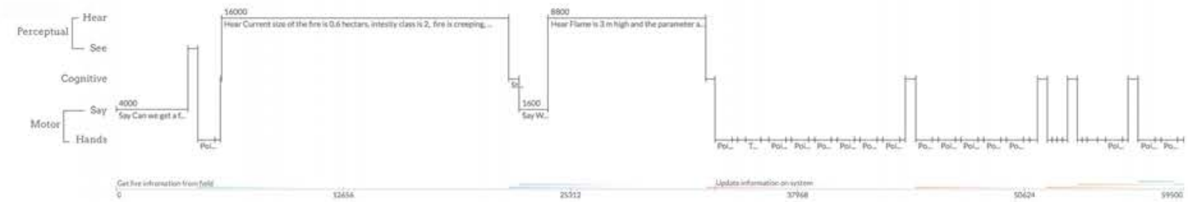
SR-BHE INTmobile : 22.3 s

Goal: generate a fire report of status change
*information is updated by a crew member
. touch fire tab
. touch BHE for fire status
. swipe fire size control - scroll to 0. 6 (700 ms)
. look at fire behavior
. verify smouldering (500 ms)
. look at spread direction
. verify north east (500 ms)
. touch resources tab
. verify resource information
. touch time objective
. touch under control objective times
. swipe minutes to 00
. swipe hours to 14
. touch generate status report
. say fire status updated *to radio operator
.
. say fire number 2 status update *radio operator to SRO
. *the SRO verifies and completes remaining info
. Goal: verify information
. . look at fire list
. . search for fire number 2
. . hands to mouse (250 ms)
. . point at fire number 2
. . click fire number 2 to open the fire monitor
. . verify look over fire information (4000 ms)
. . look at map
. . point at aircraft icon
. . click aircraft icon
. . look at status of aircraft

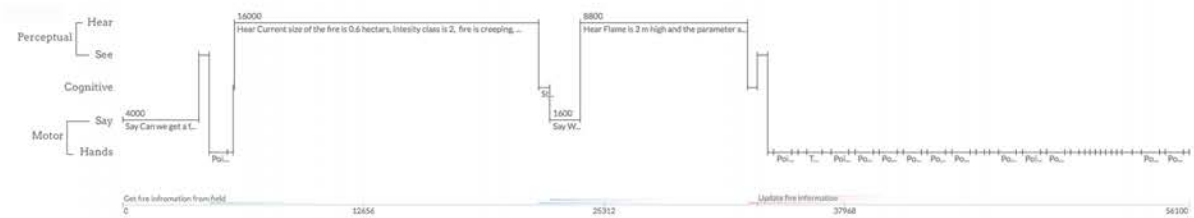


Scenario 7: Updating complete Fire info

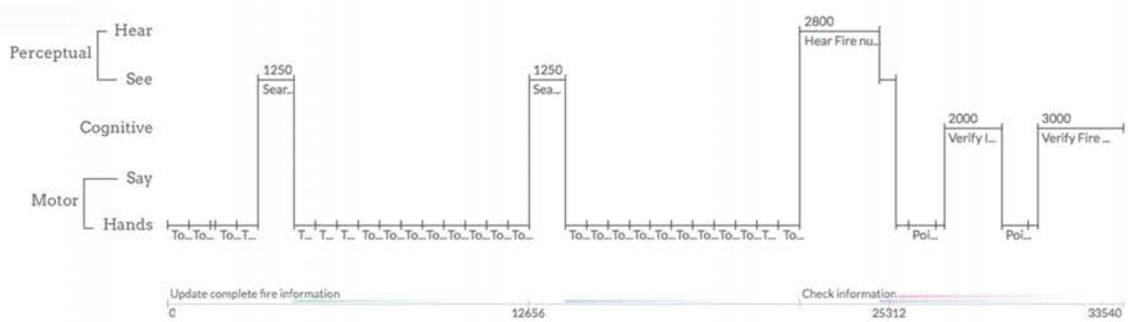
a) DFOSS + radio 59.5s



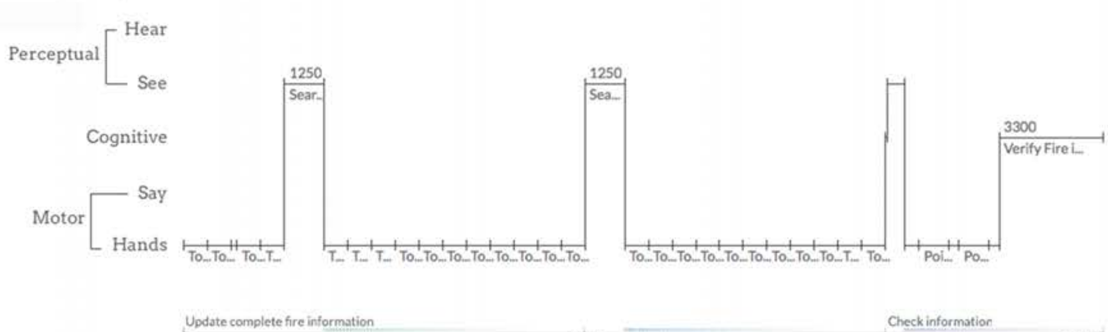
b) Integrated+ radio 57.8s



c) DFOSS+ mobile 29s

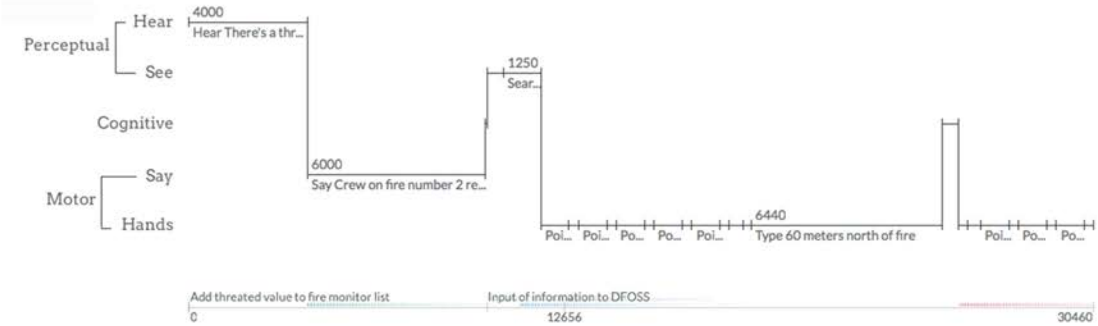


c) Integrated+ mobile 24.5

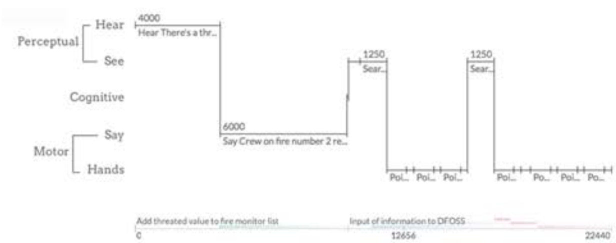


Scenario 8: Add threatened value (field to office)

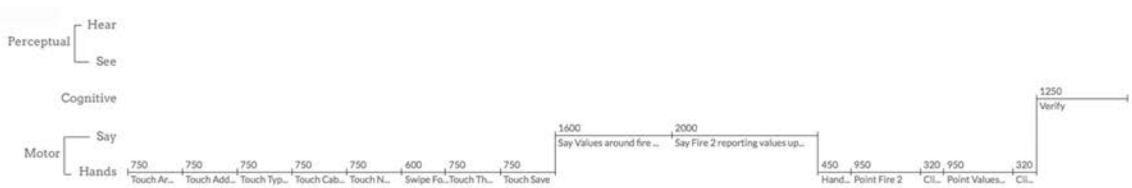
a) DFOSS + radio 30.5s



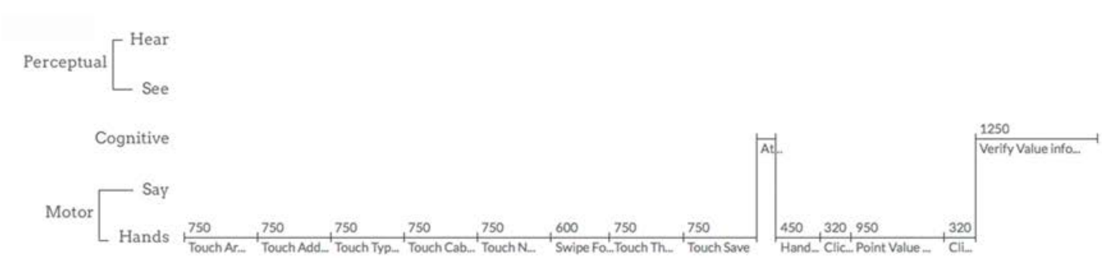
b) Integrated + radio 22.4s



c) DFOSS+ mobile 14.4s

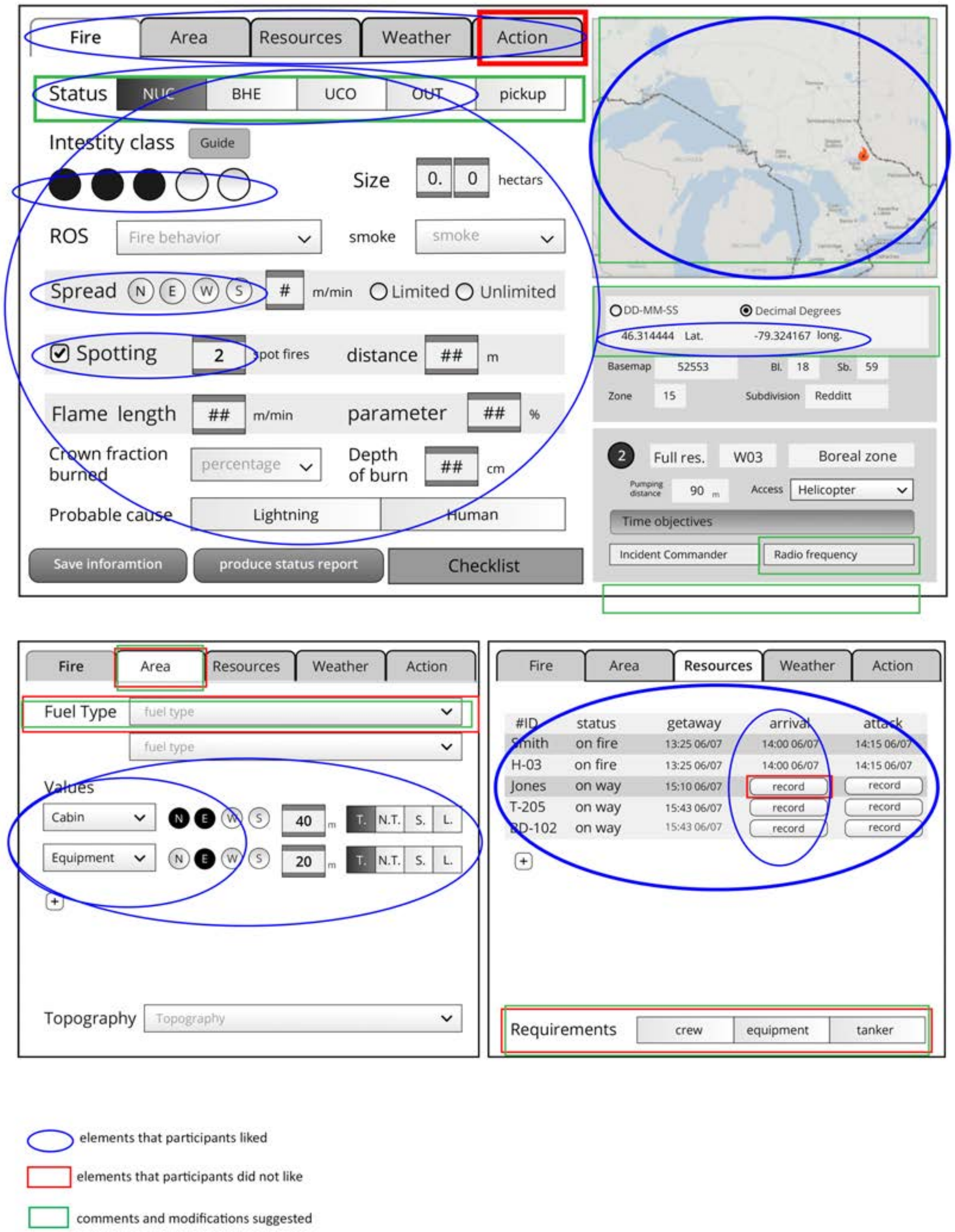


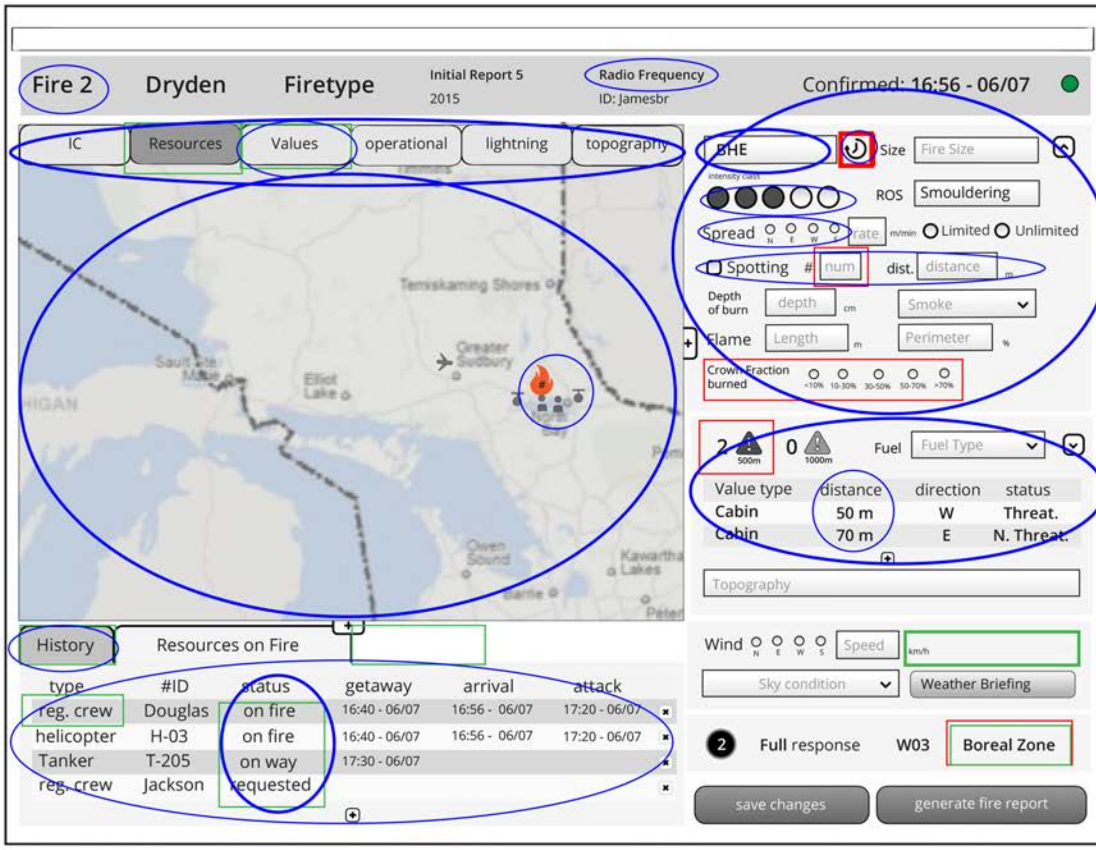
d) Integrated+ mobile 10.1s

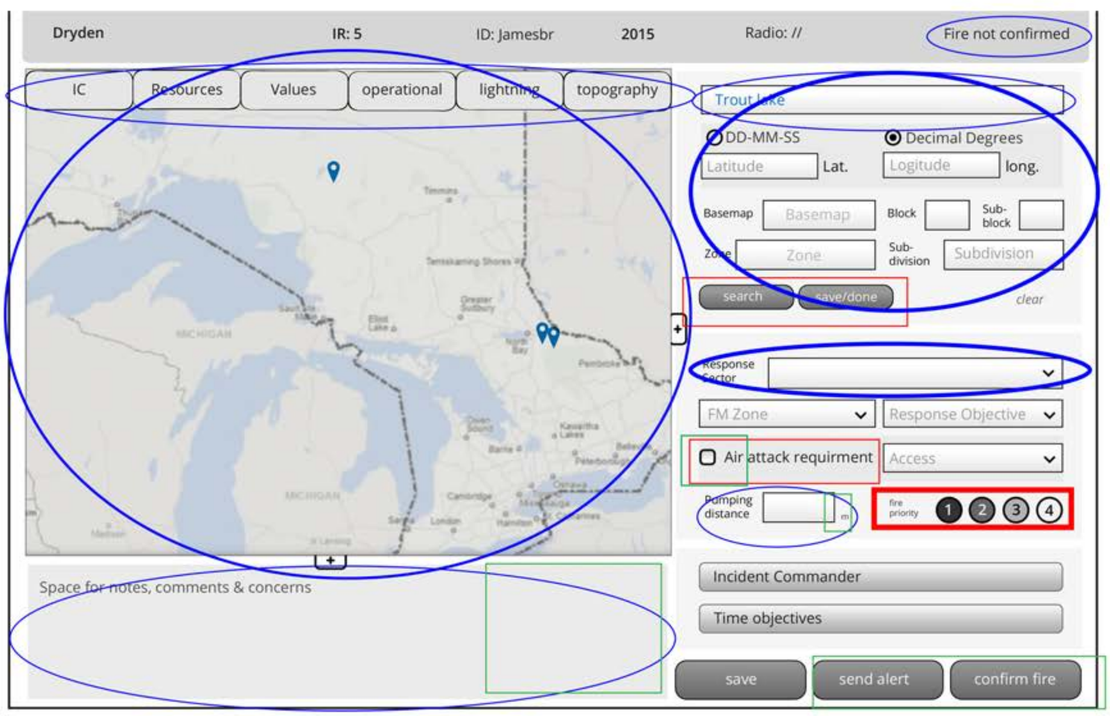


Appendix 11

Interface Screenshot- markings (from user evaluation)

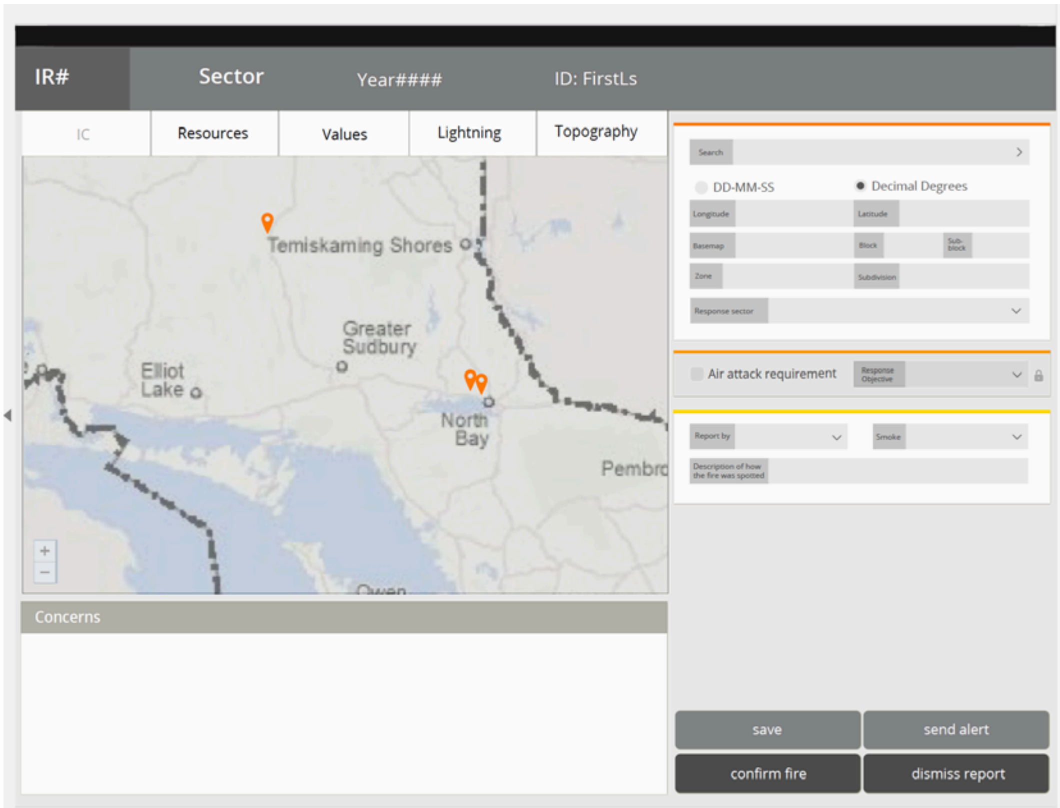


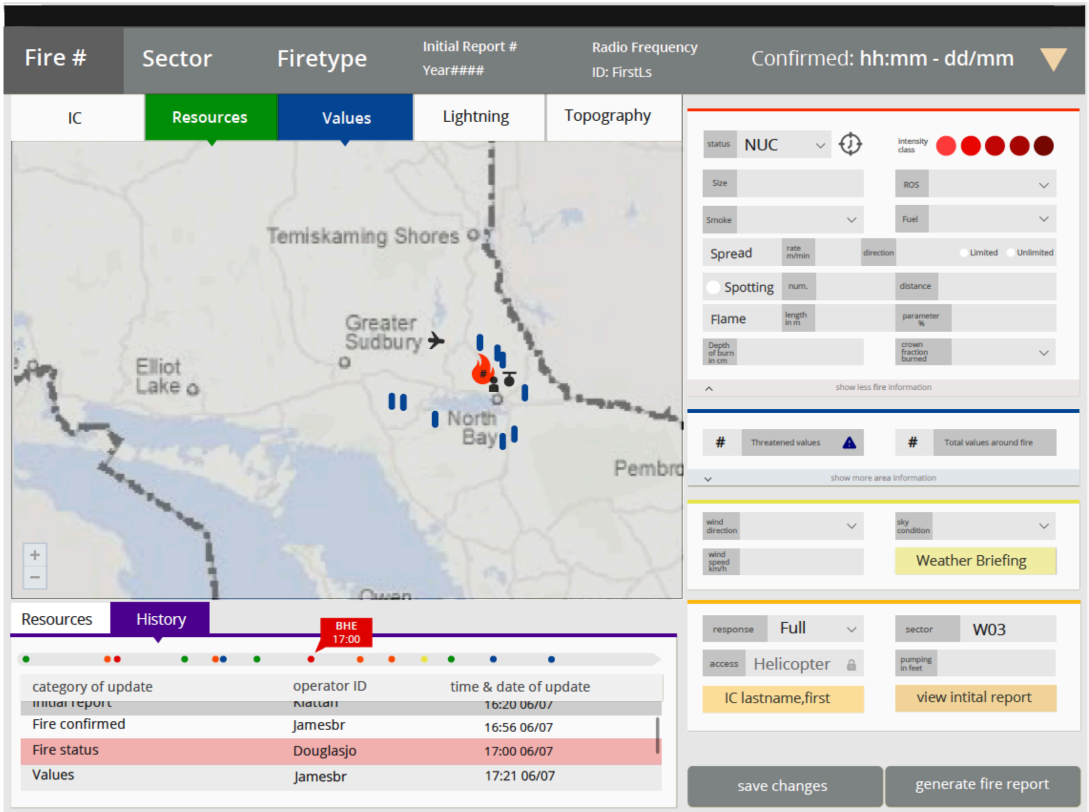

Fire 2
Dryden
Firetype
Initial Report 5
2015
Radio Frequency
ID: Jamesbr
Confirmed: 16:56 - 06/07
IC
Resources
Values
operational
lightning
topography
BHE
Size
Fire Size
ROS
Smouldering
Spread
rate
Limited
Unlimited
Spotting
num
dist.
distance
Depth of burn
depth
Smoke
Flame
Length
Perimeter
Crown Fraction burned
2
0
Fuel
Fuel Type
Value type
distance
direction
status
Cabin
50 m
W
Threat.
Cabin
70 m
E
N. Threat.
Topography
History
Resources on Fire
type
#ID
status
getaway
arrival
attack
reg. crew
Douglas
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
helicopter
H-03
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
Tanker
T-205
on way
17:30 - 06/07
reg. crew
Jackson
requested
Wind
Speed
Sky condition
Weather Briefing
2
Full response
W03
Boreal Zone
save changes
generate fire report

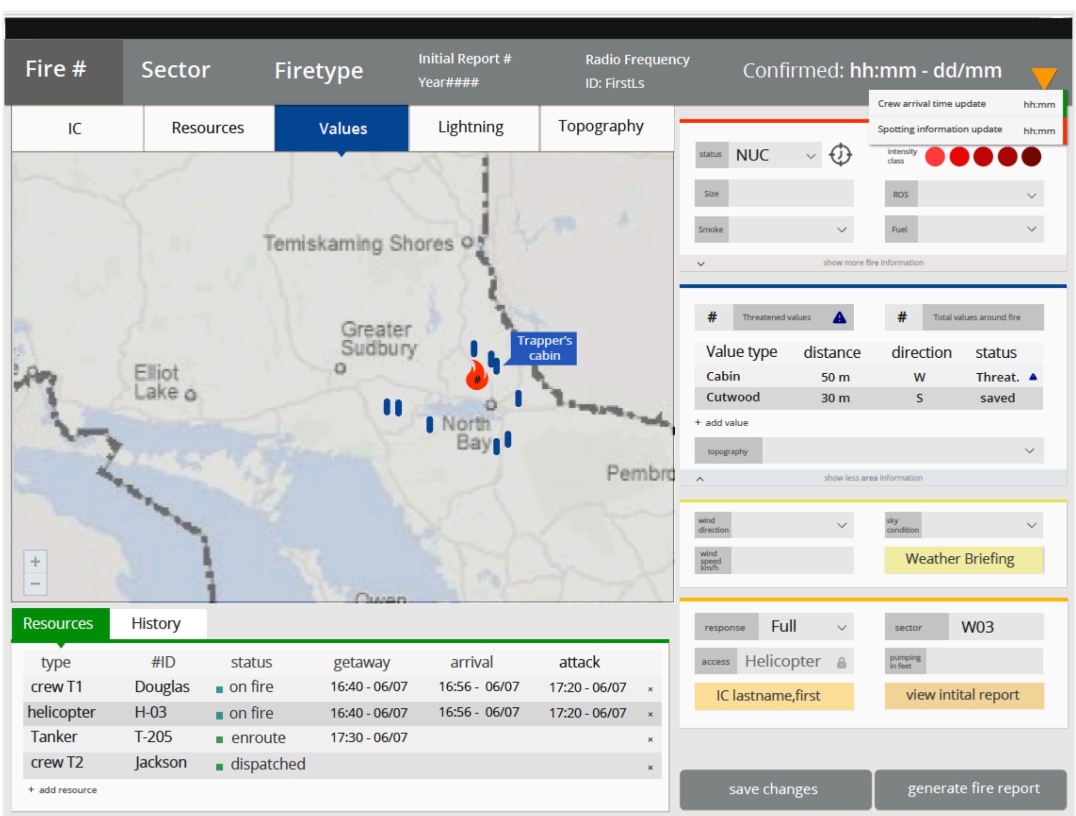

Dryden
IR: 5
ID: Jamesbr
2015
Radio: //
Fire not confirmed
IC
Resources
Values
operational
lightning
topography
Trout lake
DD-MM-SS
Decimal Degrees
Latitude
Lat.
Logitude
long.
Basemap
Basemap
Block
Sub-block
Zone
Zone
Sub-division
Subdivision
search
save/done
clear
Response Sector
FM Zone
Response Objective
Air attack requirment
Access
Pumping distance
fire priority
1
2
3
4
Space for notes, comments & concerns
Incident Commander
Time objectives
save
send alert
confirm fire

Appendix 12

a) Final Interface Design: Office interface

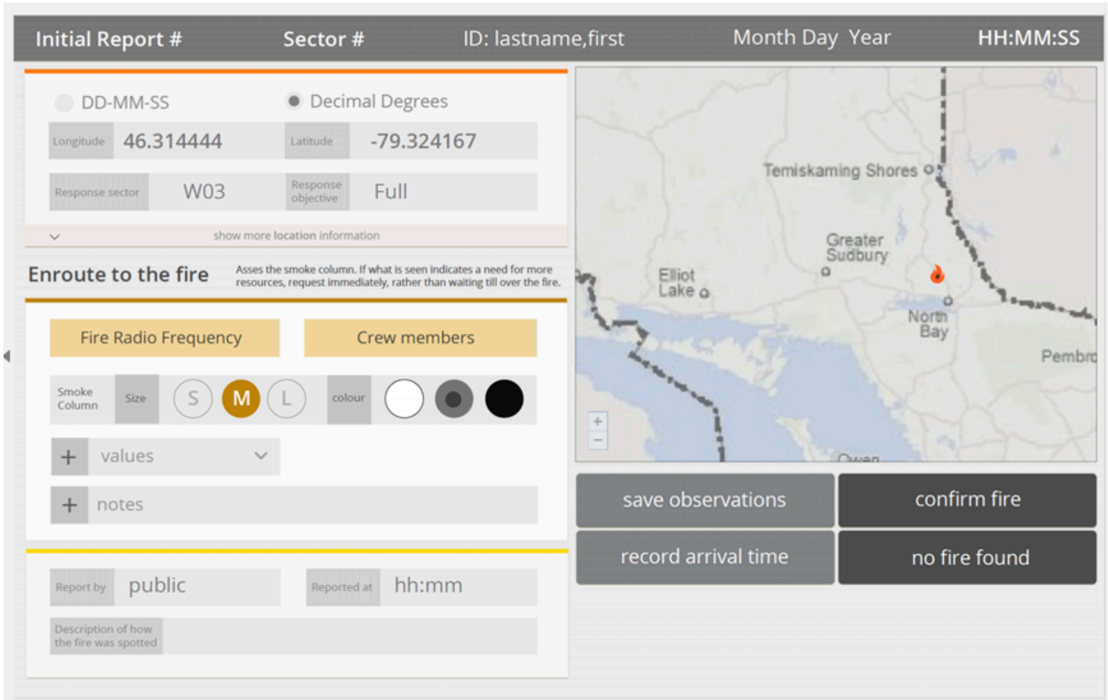


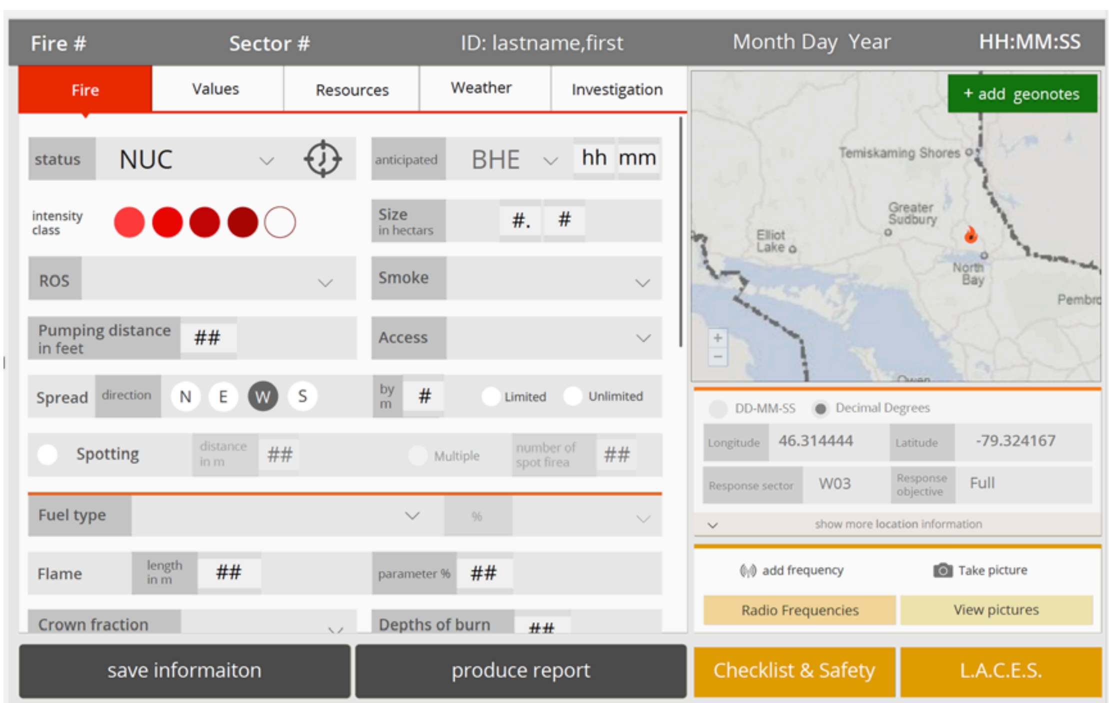

Fire #
Sector
Firetype
Initial Report #
Year####
Radio Frequency
ID: FirstLs
Confirmed: hh:mm - dd/mm
IC
Resources
Values
Lightning
Topography
Temiskaming Shores
Greater Sudbury
Elliot Lake
North Bay
Pembro
status
NUC
intensity class
Size
ROS
Smoke
Fuel
Spread
direction
Limited
Unlimited
Spotting
distance
Flame
parameter
show less fire information
#
Threatened values
Total values around fire
show more area information
wind direction
sky condition
Weather Briefing
response
Full
sector
W03
access
Helicopter
IC lastname,first
view intital report
Resources
History
BHE
17:00
category of update
operator ID
time & date of update
Fire confirmed
Jamesbr
16:56 06/07
Fire status
Douglasjo
17:00 06/07
Values
Jamesbr
17:21 06/07
save changes
generate fire report

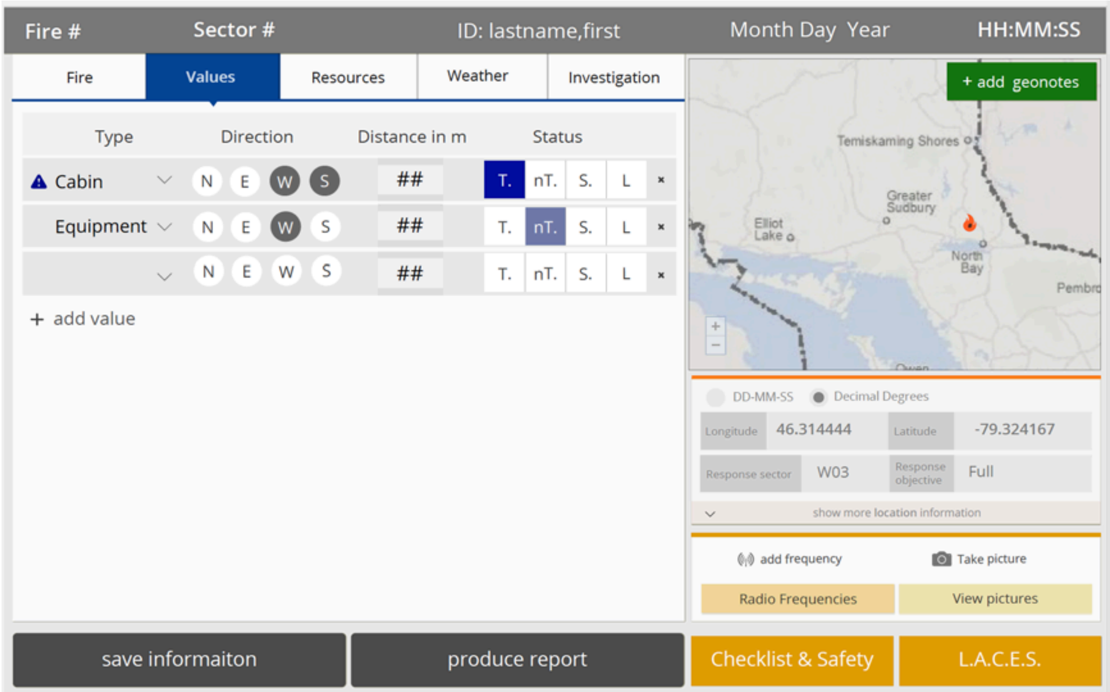

Fire #
Sector
Firetype
Initial Report #
Year####
Radio Frequency
ID: FirstLs
Confirmed: hh:mm - dd/mm
Crew arrival time update
hh:mm
Spotting information update
hh:mm
IC
Resources
Values
Lightning
Topography
Temiskaming Shores
Greater Sudbury
Trapper's cabin
Elliot Lake
North Bay
Pembro
status
NUC
intensity class
Size
ROS
Smoke
Fuel
show more fire information
#
Threatened values
Total values around fire
Value type
distance
direction
status
Cabin
50 m
W
Threat.
Cutwood
30 m
S
saved
+ add value
topography
show less area information
wind direction
sky condition
Weather Briefing
response
Full
sector
W03
access
Helicopter
IC lastname,first
view intital report
Resources
History
type
#ID
status
getaway
arrival
attack
crew T1
Douglas
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
helicopter
H-03
on fire
16:40 - 06/07
16:56 - 06/07
17:20 - 06/07
Tanker
T-205
enroute
17:30 - 06/07
crew T2
Jackson
dispatched
+ add resource
save changes
generate fire report

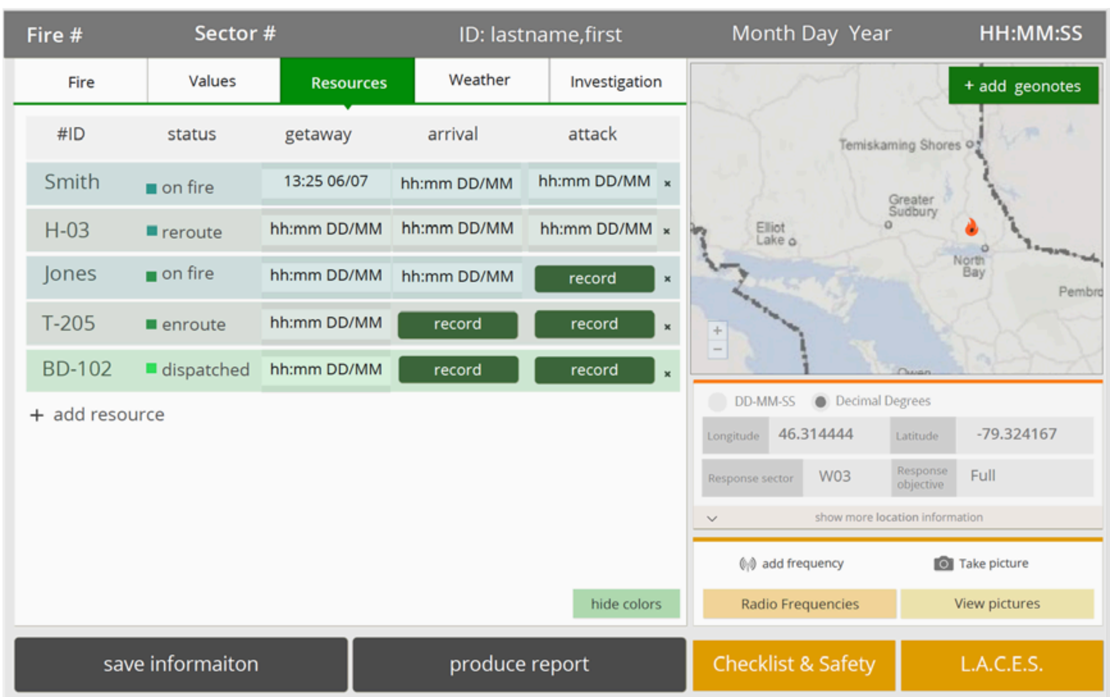
Appendix 12

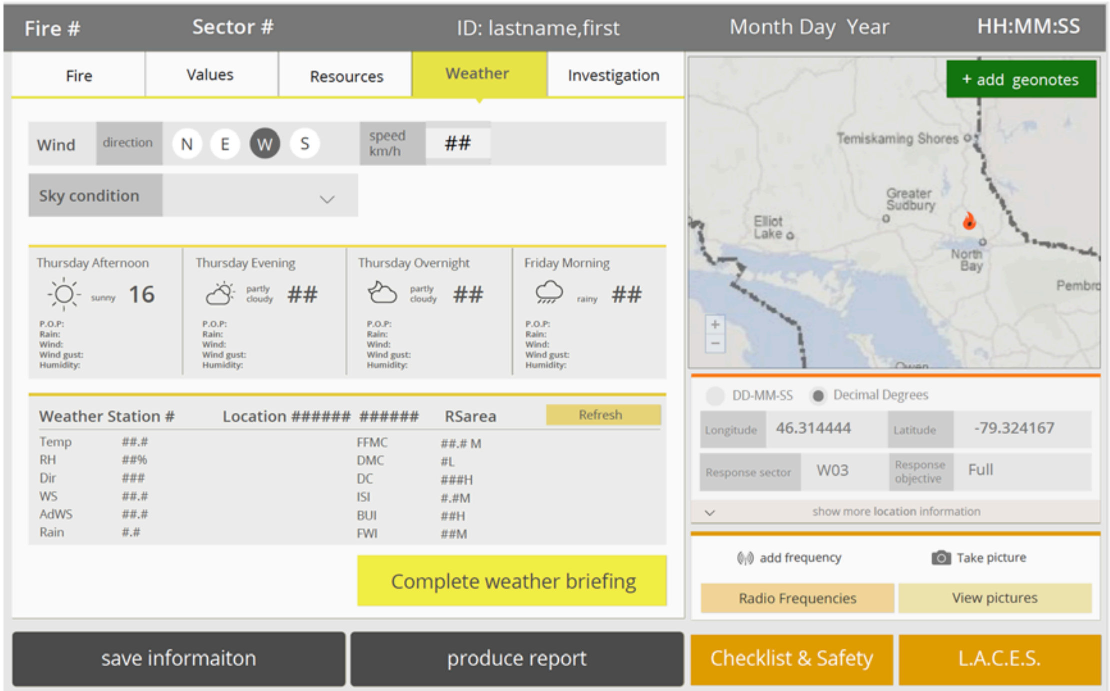
b) Final interface design: Mobile interface






Fire #
Sector #
ID: lastname,first
Month Day Year
HH:MM:SS
Fire
Values
Resources
Weather
Investigation
+ add geonotes
Type
Direction
Distance in m
Status
Cabin
N E W S
##
T. nT. S. L
Equipment
+ add value
DD-MM-SS
Decimal Degrees
Longitude
46.314444
Latitude
-79.324167
Response sector
W03
Response objective
Full
show more location information
add frequency
Take picture
Radio Frequencies
View pictures
save informaiton
produce report
Checklist & Safety
L.A.C.E.S.


Fire #
Sector #
ID: lastname,first
Month Day Year
HH:MM:SS
Fire
Values
Resources
Weather
Investigation
+ add geonotes
#ID
status
getaway
arrival
attack
Smith
on fire
13:25 06/07
hh:mm DD/MM
H-03
reroute
Jones
record
T-205
enroute
BD-102
dispatched
+ add resource
hide colors
DD-MM-SS
Decimal Degrees
Longitude
46.314444
Latitude
-79.324167
Response sector
W03
Response objective
Full
show more location information
add frequency
Take picture
Radio Frequencies
View pictures
save informaiton
produce report
Checklist & Safety
L.A.C.E.S.


Fire #
Sector #
ID: lastname,first
Month Day Year
HH:MM:SS
Fire
Values
Resources
Weather
Investigation
Wind
direction
N
E
W
S
speed km/h
##
Sky condition
Thursday Afternoon
sunny
16
Thursday Evening
partly cloudy
##
Thursday Overnight
partly cloudy
##
Friday Morning
rainy
##
P.O.P:
Rain:
Wind:
Wind gust:
Humidity:
Weather Station #
Location ###### ######
RSarea
Refresh
Temp ##.#
RH ##%
Dir ###
WS ##.#
AdWS ##.#
Rain #.#
FFMC ##.# M
DMC #L
DC ###H
ISI #.#M
BUI ##H
FWI ##M
Complete weather briefing
+ add geonotes
Temiskaming Shores
Greater Sudbury
Elliot Lake
North Bay
DD-MM-SS
Decimal Degrees
Longitude 46.314444
Latitude -79.324167
Response sector W03
Response objective Full
show more location information
add frequency
Take picture
Radio Frequencies
View pictures
save informaiton
produce report
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